DIRECT SEEDING BLACK SPRUCE AND JACK PINE:
A Field Guide for Northern Ontario

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About the Guide

This guide was developed to provide in a convenient form the information needed by forest managers to successfully plan and carry out direct seeding of black spruce (*Picea mariana* [Mill.] B.S.P.) and jack pine (*Pinus banksiana* Lamb.) in northern Ontario. It is based on information gained from seeding research, operational trials and practical experience.

The guide is organized in a step-by-step fashion to follow the sequence of events that typically occur when carrying out a direct seeding project. The guide includes software, entitled PC-SEED, which can be used to help develop direct seeding prescriptions.

This guide will provide the first time practitioner with much of the information and methods needed to initiate a successful direct seeding program. For the experienced practitioner, the guide reinforces basic principles and can be used as a reference to fine tune existing direct seeding programs.

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1.0 ORIENTATION

1.1 Introduction

Black spruce and jack pine are the two most important conifers used by Ontario's forest industry, with an annual harvest totalling over 14 million cubic metres (OMNR 2001). Successful re-establishment following harvesting is essential to sustain forests of these species and the broad range of benefits they provide. Because of the potential cost savings and other advantages associated with direct seeding, this technique has been used for years in Ontario, especially to regenerate jack pine. However, the likelihood of success is increased by careful planning, knowledge of the site, and skilled execution of necessary operational procedures.

Although jack pine is the main species seeded, this guide nevertheless places a considerable emphasis on the development of prescriptions for black spruce; which is inherently more difficult to establish through direct seeding and occupies a wider range of sites.

1.2 Background and Historical Perspective Of Direct Seeding

In northern Ontario, direct seeding was strictly a research activity until the late 1940s. During the 1950s and 60s it was practised operationally with various types of hand-operated spot seeding devices on manually or mechanically prepared seedbeds (Brown 1973). The invention and development in 1962 of an airborne tree seed broadcaster, by Howard Brohm of the Research Branch of the Ontario Ministry of Natural Resources (OMNR) in Maple (Brown 1973), dramatically increased the area of forest lands that were direct seeded. Until 1968, the Brohm seeder was used in combination with a helicopter, but since that time it has been used almost exclusively with fixed-wing aircraft. In the late 1960s, the development of a motorized tree seed broadcaster, designed for use on snowmobiles, prompted a slight increase in winter sowing for about a decade (Brown 1969). Spot seeding experienced a renaissance in the late 1970s and early 1980s with the advent of the plastic cone seed shelter. Developed in Scandinavia, this photodegradable device proved effective in ameliorating germination conditions and enabled greater control over spacing and density, but extensive use was limited by operational costs. Several row seeders were introduced in the late 1980s and early 1990s. Row seeders have traditionally been plagued by mechanical seed application problems, but improvements to the seed metering systems have greatly enhanced the accuracy of seed deposition.

Direct seeding is sometimes considered risky because of the substantial number of failures that have occurred in the past. However, many of these failures were the inevitable outcome of faulty procedures such as inappropriate site selection, inadequate site preparation, and poor seed distribution. This haphazard approach to direct seeding may be rooted in the misconception that if enough seeds are applied, a successful outcome is ensured. In fact, the biological requirements of direct seeding are more rigorous than for planting, because both successful seed germination and seedling establishment are needed. Therefore, direct seeding demands greater care both with site selection and site preparation.

In addition to insufficient preparation for seeding, assessments following operational direct seeding have often been inadequate. Because of a lack of follow-up, seeding personnel often have not had an opportunity to learn from their mistakes.

Recent advances in site classification, seed application, site preparation equipment, and prescribed burning know-how, combined with on-going research into direct seeding, have improved our ability to get good results from direct seeding. Ecologically appropriate harvesting, site selection, and site preparation, coupled with adequate and timely seeding, can reliably lead to well-stocked stands of desirable species.

In Ontario, the annual area direct seeded since 1975 averages about 27,000 hectares (Figure 1), which represents approximately 25 percent of Ontario's total artificial regeneration program. Jack pine accounts for 80% of the area seeded, while the remainder is largely black spruce.

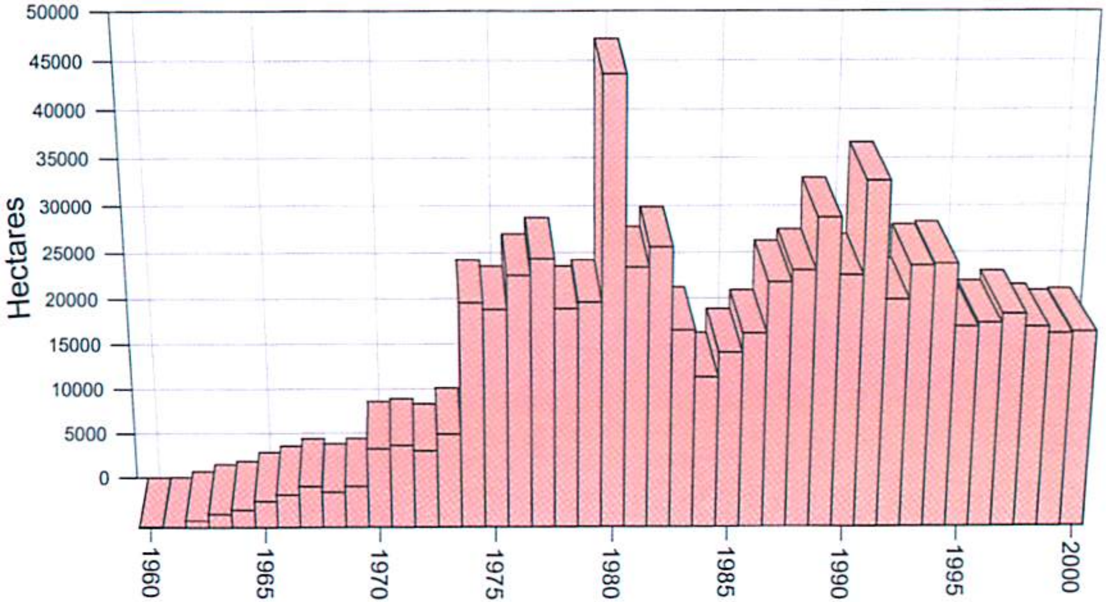

Figure 1.1 Area direct seeded in Ontario from 1960 to 2001 *(Brown 1973; CCFM: National Forestry Database 1997; OMNR: Annual Report on Forest Management 2001)*. The large area seeded in 1980/81 is attributed to a major fire season the previous year which resulted in the availability of large amounts of burned over area.

1.3 How to Use the Guide

The guide can be used in a step-by-step fashion to help establish an effective direct seeding program. It is organized to follow the same sequence of events used to plan and carry out a direct seeding operation. It provides considerable detail for most of the steps, which may be particularly helpful for foresters with little experience in direct seeding.

The steps to be followed for a successful direct seeding program are:

1. Review the effectiveness of past direct seeding projects in your region and the reasons for their success or failure. Review the background of direct seeding and learn how the guide is used. [Section 1]
2. Become acquainted with the prerequisites, advantages and disadvantages, and the economic considerations involved in direct seeding. [Section 2]
3. Determine which sites are candidates for direct seeding. [Section 3]
4. Determine the amount of seed required and initiate seed procurement. [Section 4]
5. Use a harvesting method that is compatible with direct seeding, while taking complementary natural regeneration into account. [Section 5]
6. Review the factors that influence seedbed suitability and seedling establishment. Learn how to identify and classify seedbed types. [Section 6]
7. Select the method of site preparation. [Section 7]
8. Carry out a seedbed survey prior to seeding. [Section 8]
9. Develop the direct seeding prescription. [Section 9]
10. Choose an appropriate seed application method. [Section 10]
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12. Forecast expected early stand development and tending needs. [Section 12]

2.0 SEEDING AS A REGENERATION OPTION

If a site requires artificial regeneration, the choice between planting and seeding must be made as early as possible. The prerequisites for and the advantages and disadvantages of direct seeding will influence this choice.

2.1 What Are the Prerequisites for Direct Seeding?

Successful direct seeding requires:

- Careful site selection;
- An adequate supply of viable seeds from a source well adapted to the site;
- Sufficient quantities of well-distributed, receptive seedbeds;
- Development of an appropriate seeding prescription;
- Proper seed application;
- Subsequent control of density and competition where necessary.

2.2 What Are the Principal Advantages and Disadvantages of Direct Seeding?

Like any regeneration method, direct seeding has its particular strengths and weaknesses.

Advantages of direct seeding:

1. It is less expensive to carry out than planting, because it requires fewer personnel and much less supervision, and there is no cost for planting stock. Cost comparisons are reviewed in Section 2.3.
2. Treatment time is much shorter, with large areas rapidly seeded.
3. The work can be scheduled in the winter and early spring when personnel are readily available.
4. The season is longer than for planting; it can begin in late winter on the snow.
5. The natural development of the root system of seeded trees promotes faster growth and makes them less susceptible to root diseases and windfall than planted trees.

6. Seeded stands often have a more natural appearance than planted stands due to the random distribution of seedling establishment.
7. In row seeding, the number of seeds required to produce an established seedling is similar to the number required in container seedling production, and less than the number required in producing bare root stock. This may make it practicable in the future to use genetically improved seeds for direct seeding.
8. Direct seeding is more flexible than planting, because seeds held in inventory can be used on short notice.

Disadvantages of direct seeding:

1. Aerial seeding requires large quantities of seed (the seed required for broadcast seeding is approximately 8 to 20 times greater than for container stock).
2. Achieving specific results can be less certain than planting because of uncontrollable factors such as rainfall.
3. Density may vary considerably within seeded stands and clumping of seedlings, particularly with spot seeding, can be problematic.
4. Seeded black spruce trees have slow initial growth, and it usually takes them longer to reach free-to-grow status than planted trees.
5. A variety of competing species, especially hardwoods, become established following direct seeding. This competition may conflict with stand composition objectives and slow the growth of the seeded species, thus necessitating earlier release than would be the case for planted stock.
6. Foresters and technicians need to have a more detailed knowledge of ecosystems and their successional development as well as seed and plant biology.

2.3 How Much Does Direct Seeding Cost?

This subsection compares the costs of establishing a stand using direct seeding with those of planting container stock. Bare root stock was not included in this analysis because it is designed for higher productivity sites, where regeneration by direct seeding would be inappropriate. Some of the more widely used methods of direct seeding included here are: aerial seeding, mechanical seeding during site preparation and hand seeding using seed shelters. Section 10 provides more detailed information regarding the application of these methods.

2.3.1 Assumptions used in cost calculations

Certain assumptions are made to create a common basis for a comparative analysis:

1) Sites are adequately site prepared.
2) The most appropriate method of seeding or planting is used to promote a good distribution of seeds or seedlings on the target sites.
3) Site-specific regeneration treatments are applied at an optimum time.

The planting stock costs include all costs involved in stock production, including the cost of seed.

Sources of cost data can be found in Appendix A. A plantation density of 2,100 seedlings per hectare for both jack pine and black spruce is used for cost calculation. On-site storage reflects the cost of delivery and cold storage of seedlings.

Mechanical site preparation costs are the same for all treatments with the exception of mechanical ground application. This method involves seeding during site preparation with the aid of a mechanical seeding device attached to the prime mover. The higher site preparation cost takes into account both the additional costs of the seeder and reduced productivity of the system. Prescribed burning is included as a site preparation method for broadcast seeding jack pine.

Costs for jack pine seeding are based on a typical seeding rate of 50,000 seeds per hectare (Riley 1980; Brown 1984). Higher seeding rates are normally required for black spruce; a rate of 100,000 seeds per hectare was used in this analysis. In both cases the cost of the seed far outweighs the cost of aerial application.

Although the cost of seed shelters is considerable, it is less than the cost of producing container stock. Because not all seed shelters will produce an established seedling, the analysis uses 2,500 seed shelters per hectare. It takes at least as long to install a seed shelter as to plant a tree (Dominy 1991). The analysis assumes that it takes longer, because proper anchoring of the shelter takes more time. Installation costs could be reduced if better anchoring systems were adopted and self seeding seed shelters were used. Hand seeding without seed shelters is also an option on some lowland black spruce sites (Adams 1994). The cost of application would increase slightly but the cost of shelters would be eliminated.

Table 2.1 Comparative cost analysis of jack pine regeneration by planting and direct seeding on a per hectare basis.

Cost items	Planting Container Stock	Direct Seeding			
		Aerial (mechanical site preparation)	Aerial (prescribed burn)	Ground (mechanical site preparation)	Seed Shelters
Stocking Material	$315.00[a]	$53.50[b]	$53.50	$21.40[c]	$158.00[d]
Site Preparation	$148.12	$148.12	$59.00	$188.97	$148.12
On-site Storage	$20.66	$0.00	$0.00	$0.00	$0.00
Application[e]	$234.00	$19.77	$19.77	$0.00	$337.70
Total Establishment Costs/ha	**$717.78**	**$221.39**	**$132.27**	**$210.37**	**$643.82**

[a] Based on 2100 seedlings/ha at $0.15/seedling

[b] Based on 50,000 seeds/ha at $1.07/1 000

[c] Based on 20,000 seeds/ha at $1.07/1 000

[d] Based on 2500 shelters @ $0.06/cone and 3 seeds/cone

[e] Seeding or planting costs

2.3.2 Results of cost comparison

For jack pine, the cost of aerial seeding on mechanically site prepared ground is about $221.00 per hectare (Table 2.1), whereas the cost of planting is more than 3 times greater. The cost of seedling production (stocking material) and the cost of planting represent the major differences. Aerial seeding on prescribed burns is the least expensive method due to reduced site preparation costs. Ground mechanical seeding offers another cost effective alternative. Unlike aerial broadcast seeding, seeds are deposited direct only onto a prepared furrow or scalp which increases efficiency and reduces the amount of seed required.

Although shelter seeding is only slightly less expensive than planting, it does offer some flexibility in that no planting stock is required. Seeding onto ground that has not been site-prepared, using a boot screefing technique, is also an option. The savings made by foregoing site preparation would likely exceed the increased costs resulting from reduced planter productivity.

For black spruce, aerial seeding on a prepared site is about 1/3 the cost of planting with container stock (Table 2.2). On lowland sites with abundant *Sphagnum* cover, full tree logging can disturb the surface of peat soils sufficiently to eliminate the need for mechanical site preparation, which results in a very low cost alternative to site preparation.

If a double-pass aerial application is prescribed to improve the uniformity of seed distribution, the establishment cost can easily be recalculated by doubling the per hectare application cost.

Table 2.2 Comparative cost analysis of black spruce regeneration by direct seeding and planting on a per hectare basis.

Cost items	Planting Container Stock	Direct Seeding			
		Aerial (mechanical site preparation)	Aerial (no site preparation	Ground (mechanical site preparation)	Seed Shelters
Stocking Material	$378.00[a]	$69.00[b]	$69.00	$27.60[c]	$155.18[d]
Site Preparation	$148.12	$148.12	$0.00	$188.97	$148.12
On-site Storage	$20.66	$0.00	$0.00	$0.00	$0.00
Application[e]	$234.00	$19.77	$19.77	$0.00	$337.70
Total Establishment Costs/ha	**$780.78**	**$236.89**	**$88.77**	**$216.57**	**$641.00**

[a] Based on 2100 seedlings/ha at $0.18/seedling

[b] Based on 100,000 seeds/ha at $0.69/1 000

[c] Based on 40,000 seeds/ha at $0.69/1 000

[d] Based on 2500 shelters @ $0.06/cone and 3 seeds/cone

[e] Seeding or planting costs

2.3.3 Future costs

2.3.3.1. Fill-in planting or re-seeding

One common problem with direct seeding is the occurrence of understocked and overstocked areas on the treated site. This is due to the uneven distribution of seeds and seedbeds, and the variation in site conditions. Fill-in seeding or planting is costly, and can be almost as expensive as the initial operation (Riley 1973). There is also a risk that the more recently seeded or planted trees may not develop at a similar rate to the initially established trees because of competition. Aerial re-seeding is less expensive than ground re-seeding, but may increase disparities in density while not greatly improving stocking in understocked areas.

Re-seeding, if it is to be carried out, should be done as soon as a failure has been detected, while seedbeds are still receptive. Decreases in seedbed receptivity with time (see Section 6), and the growth of competing vegetation, will eventually make fill-in seeding or planting infeasible. Fill-in planting can be used successfully in understocked seeded areas, and has the advantage of more easily matching the height of the introduced trees with those already growing.

The decision to conduct fill-in planting or seeding should be based on a regeneration survey involving a small companion seed spot trial (see Section 11.1). This survey will show if the initial treatment was not successful enough to ensure a sufficiently stocked stand, yet successful enough that retreating the entire site is not warranted.

For black spruce, if a failure is detected within 1-2 years after the initial treatment, then immediate fill-in or re-treatment should be considered. Conversely, high black spruce stocking in the first several years does not necessarily indicate success because of possible high initial mortality.

For jack pine, low stocking in the first years does not necessarily indicate regeneration failure. Anecdotal reports suggest that some sites with apparent stocking failures at the end of the first growing season are adequately stocked after the second or third growing season. This can be attributed to delayed germination, residual natural seed and seedling ingress from other means (Section 11.2.2). Thus, the decision to re-seed should be made with caution and should be delayed until the third year after sowing (Riley 1980).

There is no general threshold stocking value below which re-treatment or fill-in is required. This depends on site characteristics, management objectives, availability of resources, and logistics.

RECOMMENDATIONS

- Re-seeding or fill-in planting may be worth doing on sites where the potential growth and value of the stand is high.
- Select treatments that will target understocked areas while not contributing to additional overstocking.

2.3.3.2 Spacing

Excessive stand density may occur following direct seeding. Because of the clumping of seedlings, spacing (pre-commercial thinning) of overly dense parts of the stand may be carried out (see Section 12). Pre-commercial thinning increases the diameter increment of residual trees, resulting in larger diameter trees at rotation, which in turn increases product value and harvest efficiency. Spacing may, however, decrease total volume yields, particularly for black spruce.

The cost of spacing can be quite variable and depends on several factors: target spacing, method used, stand density, terrain conditions, and average tree diameter. Generally, costs range between $300 and $550 per hectare. Even with these costs included, however, direct seeding followed by pre-commercial thinning is more cost effective than using planting to achieve the same result. The timing of the expenditures accounts for part of the cost advantage (e.g., investing $300 at age 10 is equivalent to spending $184.17 at age 0, assuming an interest rate of 5%).

Improved methods of ground-based seeding may significantly reduce the cost of subsequent thinning operations. Methods of precision row seeding that permit systematic seed singularisation, or spot seeding techniques that deliver an exact number of seeds per spot (e.g., pre-seeded shelters) will decrease both stand density and the incidence of clumping.

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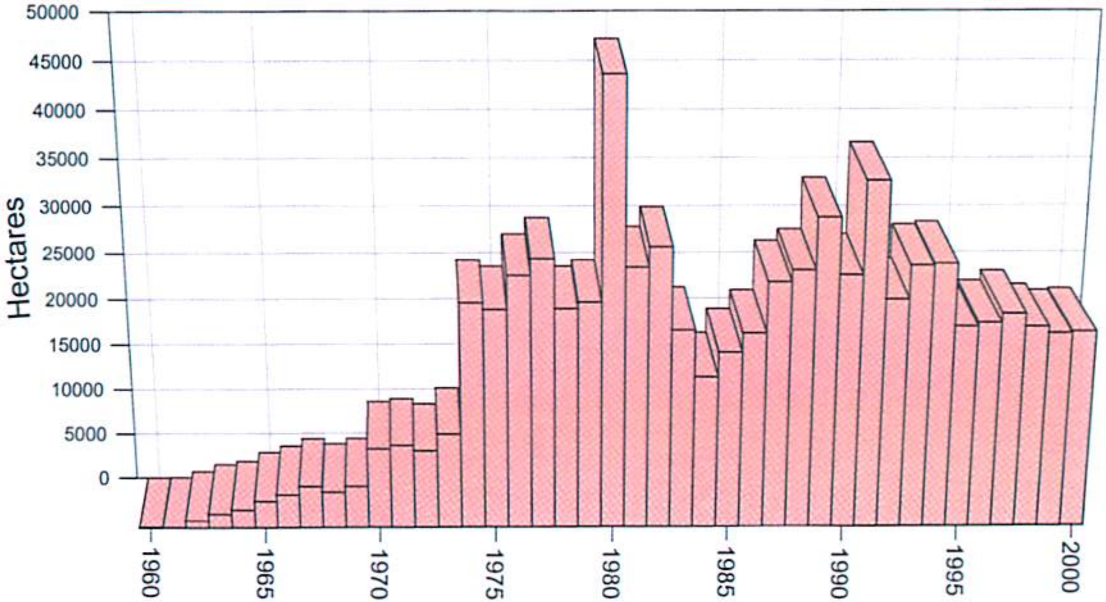

Figure 1.1 Area direct seeded in Ontario from 1960 to 2001 *(Brown 1973; CCFM: National Forestry Database 1997; OMNR: Annual Report on Forest Management 2001)*. The large area seeded in 1980/81 is attributed to a major fire season the previous year which resulted in the availability of large amounts of burned over area.

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8. Direct seeding is more flexible than planting, because seeds held in inventory can be used on short notice.

Disadvantages of direct seeding:

1. Aerial seeding requires large quantities of seed (the seed required for broadcast seeding is approximately 8 to 20 times greater than for container stock).
2. Achieving specific results can be less certain than planting because of uncontrollable factors such as rainfall.
3. Density may vary considerably within seeded stands and clumping of seedlings, particularly with spot seeding, can be problematic.
4. Seeded black spruce trees have slow initial growth, and it usually takes them longer to reach free-to-grow status than planted trees.
5. A variety of competing species, especially hardwoods, become established following direct seeding. This competition may conflict with stand composition objectives and slow the growth of the seeded species, thus necessitating earlier release than would be the case for planted stock.
6. Foresters and technicians need to have a more detailed knowledge of ecosystems and their successional development as well as seed and plant biology.

2.3 How Much Does Direct Seeding Cost?

This subsection compares the costs of establishing a stand using direct seeding with those of planting container stock. Bare root stock was not included in this analysis because it is designed for higher productivity sites, where regeneration by direct seeding would be inappropriate. Some of the more widely used methods of direct seeding included here are: aerial seeding, mechanical seeding during site preparation and hand seeding using seed shelters. Section 10 provides more detailed information regarding the application of these methods.

2.3.1 Assumptions used in cost calculations

Certain assumptions are made to create a common basis for a comparative analysis:

1) Sites are adequately site prepared.
2) The most appropriate method of seeding or planting is used to promote a good distribution of seeds or seedlings on the target sites.
3) Site-specific regeneration treatments are applied at an optimum time.

The planting stock costs include all costs involved in stock production, including the cost of seed.

Sources of cost data can be found in Appendix A. A plantation density of 2,100 seedlings per hectare for both jack pine and black spruce is used for cost calculation. On-site storage reflects the cost of delivery and cold storage of seedlings.

Mechanical site preparation costs are the same for all treatments with the exception of mechanical ground application. This method involves seeding during site preparation with the aid of a mechanical seeding device attached to the prime mover. The higher site preparation cost takes into account both the additional costs of the seeder and reduced productivity of the system. Prescribed burning is included as a site preparation method for broadcast seeding jack pine.

Costs for jack pine seeding are based on a typical seeding rate of 50,000 seeds per hectare (Riley 1980; Brown 1984). Higher seeding rates are normally required for black spruce; a rate of 100,000 seeds per hectare was used in this analysis. In both cases the cost of the seed far outweighs the cost of aerial application.

Although the cost of seed shelters is considerable, it is less than the cost of producing container stock. Because not all seed shelters will produce an established seedling, the analysis uses 2,500 seed shelters per hectare. It takes at least as long to install a seed shelter as to plant a tree (Dominy 1991). The analysis assumes that it takes longer, because proper anchoring of the shelter takes more time. Installation costs could be reduced if better anchoring systems were adopted and self seeding seed shelters were used. Hand seeding without seed shelters is also an option on some lowland black spruce sites (Adams 1994). The cost of application would increase slightly but the cost of shelters would be eliminated.

Table 2.1 Comparative cost analysis of jack pine regeneration by planting and direct seeding on a per hectare basis.

Cost items	Planting Container Stock	Direct Seeding			
		Aerial (mechanical site preparation)	Aerial (prescribed burn)	Ground (mechanical site preparation)	Seed Shelters
Stocking Material	$315.00[a]	$53.50[b]	$53.50	$21.40[c]	$158.00[d]
Site Preparation	$148.12	$148.12	$59.00	$188.97	$148.12
On-site Storage	$20.66	$0.00	$0.00	$0.00	$0.00
Application[e]	$234.00	$19.77	$19.77	$0.00	$337.70
Total Establishment Costs/ha	**$717.78**	**$221.39**	**$132.27**	**$210.37**	**$643.82**

[a] Based on 2100 seedlings/ha at $0.15/seedling

[b] Based on 50,000 seeds/ha at $1.07/1 000

[c] Based on 20,000 seeds/ha at $1.07/1 000

[d] Based on 2500 shelters @ $0.06/cone and 3 seeds/cone

[e] Seeding or planting costs

2.3.2 Results of cost comparison

For jack pine, the cost of aerial seeding on mechanically site prepared ground is about $221.00 per hectare (Table 2.1), whereas the cost of planting is more than 3 times greater. The cost of seedling production (stocking material) and the cost of planting represent the major differences. Aerial seeding on prescribed burns is the least expensive method due to reduced site preparation costs. Ground mechanical seeding offers another cost effective alternative. Unlike aerial broadcast seeding, seeds are deposited direct only onto a prepared furrow or scalp which increases efficiency and reduces the amount of seed required.

Although shelter seeding is only slightly less expensive than planting, it does offer some flexibility in that no planting stock is required. Seeding onto ground that has not been site-prepared, using a boot screefing technique, is also an option. The savings made by foregoing site preparation would likely exceed the increased costs resulting from reduced planter productivity.

For black spruce, aerial seeding on a prepared site is about 1/3 the cost of planting with container stock (Table 2.2). On lowland sites with abundant *Sphagnum* cover, full tree logging can disturb the surface of peat soils sufficiently to eliminate the need for mechanical site preparation, which results in a very low cost alternative to site preparation.

If a double-pass aerial application is prescribed to improve the uniformity of seed distribution, the establishment cost can easily be recalculated by doubling the per hectare application cost.

Table 2.2 Comparative cost analysis of black spruce regeneration by direct seeding and planting on a per hectare basis.

Cost items	Planting Container Stock	Direct Seeding			
		Aerial (mechanical site preparation)	Aerial (no site preparation	Ground (mechanical site preparation)	Seed Shelters
Stocking Material	$378.00[a]	$69.00[b]	$69.00	$27.60[c]	$155.18[d]
Site Preparation	$148.12	$148.12	$0.00	$188.97	$148.12
On-site Storage	$20.66	$0.00	$0.00	$0.00	$0.00
Application[e]	$234.00	$19.77	$19.77	$0.00	$337.70
Total Establishment Costs/ha	**$780.78**	**$236.89**	**$88.77**	**$216.57**	**$641.00**

[a] Based on 2100 seedlings/ha at $0.18/seedling

[b] Based on 100,000 seeds/ha at $0.69/1 000

[c] Based on 40,000 seeds/ha at $0.69/1 000

[d] Based on 2500 shelters @ $0.06/cone and 3 seeds/cone

[e] Seeding or planting costs

2.3.3 Future costs

2.3.3.1. Fill-in planting or re-seeding

One common problem with direct seeding is the occurrence of understocked and overstocked areas on the treated site. This is due to the uneven distribution of seeds and seedbeds, and the variation in site conditions. Fill-in seeding or planting is costly, and can be almost as expensive as the initial operation (Riley 1973). There is also a risk that the more recently seeded or planted trees may not develop at a similar rate to the initially established trees because of competition. Aerial re-seeding is less expensive than ground re-seeding, but may increase disparities in density while not greatly improving stocking in understocked areas.

Re-seeding, if it is to be carried out, should be done as soon as a failure has been detected, while seedbeds are still receptive. Decreases in seedbed receptivity with time (see Section 6), and the growth of competing vegetation, will eventually make fill-in seeding or planting infeasible. Fill-in planting can be used successfully in understocked seeded areas, and has the advantage of more easily matching the height of the introduced trees with those already growing.

The decision to conduct fill-in planting or seeding should be based on a regeneration survey involving a small companion seed spot trial (see Section 11.1). This survey will show if the initial treatment was not successful enough to ensure a sufficiently stocked stand, yet successful enough that retreating the entire site is not warranted.

For black spruce, if a failure is detected within 1-2 years after the initial treatment, then immediate fill-in or re-treatment should be considered. Conversely, high black spruce stocking in the first several years does not necessarily indicate success because of possible high initial mortality.

For jack pine, low stocking in the first years does not necessarily indicate regeneration failure. Anecdotal reports suggest that some sites with apparent stocking failures at the end of the first growing season are adequately stocked after the second or third growing season. This can be attributed to delayed germination, residual natural seed and seedling ingress from other means (Section 11.2.2). Thus, the decision to re-seed should be made with caution and should be delayed until the third year after sowing (Riley 1980).

There is no general threshold stocking value below which re-treatment or fill-in is required. This depends on site characteristics, management objectives, availability of resources, and logistics.

RECOMMENDATIONS

- Re-seeding or fill-in planting may be worth doing on sites where the potential growth and value of the stand is high.
- Select treatments that will target understocked areas while not contributing to additional overstocking.

2.3.3.2 Spacing

Excessive stand density may occur following direct seeding. Because of the clumping of seedlings, spacing (pre-commercial thinning) of overly dense parts of the stand may be carried out (see Section 12). Pre-commercial thinning increases the diameter increment of residual trees, resulting in larger diameter trees at rotation, which in turn increases product value and harvest efficiency. Spacing may, however, decrease total volume yields, particularly for black spruce.

The cost of spacing can be quite variable and depends on several factors: target spacing, method used, stand density, terrain conditions, and average tree diameter. Generally, costs range between \$300 and \$550 per hectare. Even with these costs included, however, direct seeding followed by pre-commercial thinning is more cost effective than using planting to achieve the same result. The timing of the expenditures accounts for part of the cost advantage (e.g., investing \$300 at age 10 is equivalent to spending \$184.17 at age 0, assuming an interest rate of 5%).

Improved methods of ground-based seeding may significantly reduce the cost of subsequent thinning operations. Methods of precision row seeding that permit systematic seed singularisation, or spot seeding techniques that deliver an exact number of seeds per spot (e.g., pre-seeded shelters) will decrease both stand density and the incidence of clumping.

3.0 THE SITE

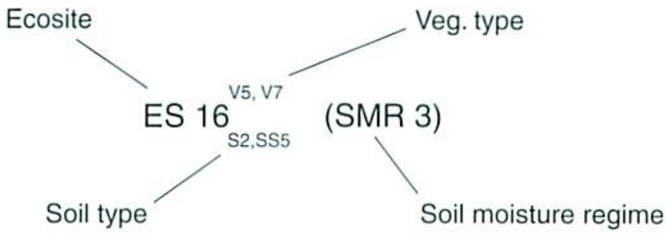
Not all sites can be successfully direct seeded. For this reason, the decision about whether or not to seed must be based on detailed information about the site. Furthermore, on sites where direct seeding is feasible, the seeding prescription must take site conditions into account.

Because direct seeding results are strongly influenced by vegetation and soil conditions, Forest Ecosystem Classifications (FECs) are highly applicable in planning direct seeding. Ideally, pre-harvest FEC information will be used to determine the suitability of a site for seeding.

3.1 What are the Roles of FEC and PHSPs in Site Selection?

Both general and very site-specific classification tools have been developed for northern Ontario to assist users in developing ecosystem-based management strategies. FECs have been completed for both northeastern and northwestern Ontario. These classifications overlap somewhat in northcentral Ontario. The northeastern Ontario (NEO) FEC, originally published in 1983, has been expanded and a new nomenclature has been introduced. Although much of the information in this guide for NEO derives from research reported using the 1983 Clay Belt FEC nomenclature, all Clay Belt Operational Groups (OGs) have been converted to the Site Types (STs) used in the more recent NEO FEC (McCarthy et al. 1994). For northwestern Ontario, recently developed ecosites (ESs) have largely replaced treatment units (TUs) (Racey et al. 1989), and represent an intermediate level of ecological organization. The general relationship between generic treatment units and forested ecosites can be found in Appendix B. Both northwestern Ontario (NWO) ecosites and northeastern Ontario (NEO) site types are management-oriented aggregations of defined soil and vegetation conditions, which provide a coarser division of the land base. They are appropriate for describing and mapping forest ecosystems at a scale compatible with the Ontario Forest Resource Inventory, while the soil types (S-types) and vegetation (V-types) provide the finer detail required to develop direct seeding prescriptions.

The classification nomenclature involving ecosites (site types), ecoelements (V-types and S-types) and first order observations (soil texture and moisture class) can be cumbersome to deal with. However, this information can be integrated and simplified by combining the numbering systems: e.g.:



Collection of information in such a format will allow candidate sites to be quickly assessed for their direct seeding potential (Section 3.2.1).

Other information collected during the classification process, such as frost heave hazard and soil erosion hazard, can also be helpful in developing prescriptions.

We recommend that a site-specific pre-harvest silvicultural prescription (PHSP) be developed prior to laying out areas for harvesting. It should include: a description of the current structure and condition of the forest; a plan for harvesting, renewal and maintenance activities; a description of the expected future structure and condition of the forest; and a record of the guidelines used to develop the prescription (Bidwell et al. 1996). Incorporating an FEC survey (section 3.1.1) into the PHSP will provide much of the information needed to develop a direct seeding prescription (section 9).

3.1.1 Pre-harvest FEC survey

The FEC survey is part of the PHSP and can be integrated into an operational timber cruise.

The first step of the survey is to assemble relevant information such as Forest Resource Inventory (FRI) maps, aerial photographs, soil surveys or other background material.

Next, mark cut block boundaries on the FRI map and then stratify the cut block based on FRI stand boundaries and vegetation or landform differences apparent from aerial photographs. The strata should represent areas that might require different treatments.

Next, lay out cruise lines in each of the strata. Bidwell et al. (1996) suggest a minimum of three to five plots per stratum. Alternatively, Racey et al. (1989) recommend one sample plot every 10 ha, or 1 plot every 300 m for a pre-harvest survey of sample intensity level 2. If there are inclusions within a stratum, these should be sampled because they may change the prescription.

Avoid placing plots on roads, landings or trails.

At each sample plot, record the FEC soil type, vegetation type, soil texture and soil moisture regime. Also record additional information relevant to direct seeding such as: occurrence of extensive rock outcrops, cover of *Sphagnum* mosses, abundance of advance growth, thickness of LFH layers, potential for competition development, and anticipated slash loadings.

Most of this information can also be collected in a post-harvest survey. Information collected about advance growth, slash amounts, cone loading in slash, seedbed cover and surface disturbance will be more reliable after the harvest is completed.

3.2 What Sites are Most Suitable for Direct Seeding?

Ordination diagrams (Figures 3.1, 3.2, 3.3 and 3.4), developed for both northwestern ecosites and northeastern site types, are based on the spatial distribution of vegetation and soil types across the landscape and provide a convenient format for plotting potential direct seeding opportunities. Sites are rated as having either high or moderate potential for direct seeding. Direct seeding has a good probability of success on high potential sites; on moderate potential sites, direct seeding is feasible but the risk of failure is greater. Periods of unfavourable weather, competing vegetation, and inadequate site preparation are more likely to cause failure on moderate potential sites than on high potential sites. More detailed information regarding characteristic V-type, S-type and moisture regimes associated with these sites along with site-specific considerations and recommendations can be found in Tables 3.1, 3.2, 3.3 and 3.4 which follow these diagrams. These interpretations are intended to be used as general guidelines for developing your own rating structure and can be further modified based on local knowledge and experience.

3.2.1 Potential Sites for direct seeding jack pine in northwestern Ontario.

Generally, ES 13, 14, 15, 20, 25, 26 and 31 have good potential for jack pine direct seeding. However, the landforms associated with these ecosites can be quite variable and characteristic soil types range from shallow sandy to deep fresh clayey soils. Deep to moderately shallow, sandy to coarse loamy soils that are moderately fresh to very fresh provide the best seeding chances for jack pine.

ES 11 and 12 will benefit from well distributed mineral soil seedbeds. However, these sites are generally prone to seasonal drought, which reduces the likelihood of successful direct seeding.

Precision seeding with seed shelters is recommended for ES16, 19 and 21.

When planning harvesting method and site prep prescriptions, take into account the ingress potential of the site. Augmenting direct seeding with cone scattering or preservation of residuals can significantly enhance stocking. Consider vegetation control, timing of seed application and both timing and method of harvest for those ecosites that are prone to moderate or high levels of competition.

Jack pine can establish over a range of soil moisture regimes (Ø to 6). However, unless favourable weather conditions occur in both the seeding and the following year, seeding on sites that have a SMR of Ø or 0 is likely to fail. Jack pine stands that become established on SMR >4 may be subject to early stand breakup because of increased occurrence of butt and heart rot on these moist soils.

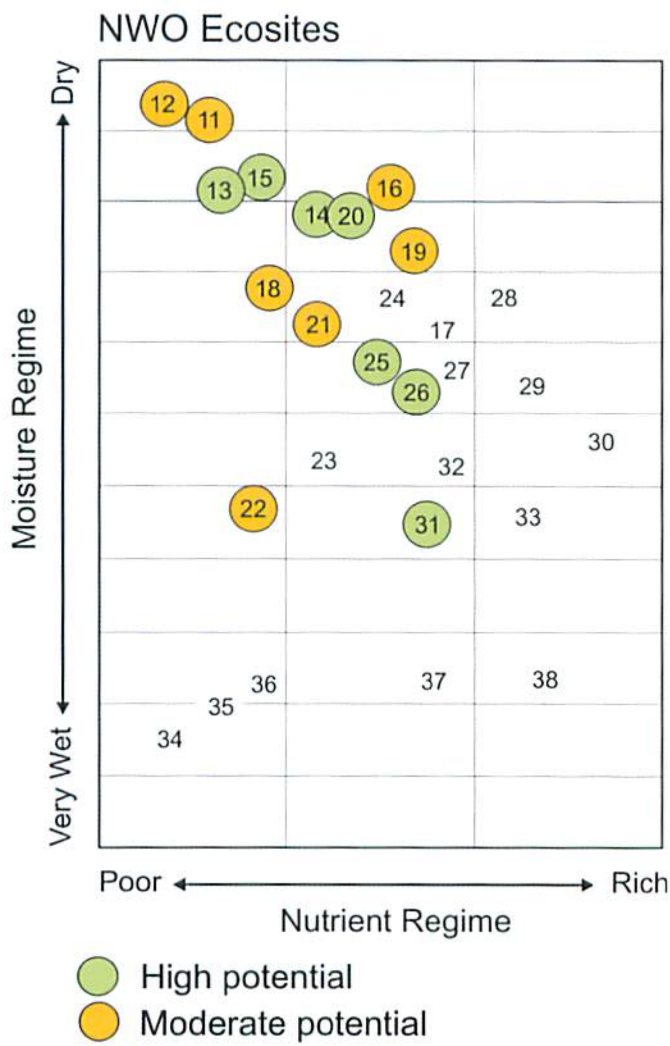


Figure 3.1 Potential for direct seeding jack pine in northwestern Ontario *(adapted from Racey et al. 1996)*.

Table 3.1 Site-specific considerations and recommendations associated with the potential for direct seeding jack pine in northwestern Ontario *(adapted from OMNR 1997).*

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 11	Red Pine–White Pine–Jack Pine: Very Shallow Soils	V12, 13, 26, 27, 29, 30	SS1-4, (SS5, 6&9)	TU–H	SMR 0-2

General Comments:
- V types 12, 13 and 29 have a moderate potential for direct seeding while V26 and V27 are considered moderate-to-poor.
- Soil types SS1- 3 are highly susceptible to seasonal drought and pose an increased risk to nutrient loss and erosion.
- This ecosite has a low mortality potential from competition, frost heaving or flooding.
- Expect moderate-to-low levels of jack pine seed dispersion from sun-opened cones on juvenile jack pine.

Recommendations:
- Broadcast seeding jack pine may be one of the few cost effective alternatives to regenerate this rock-controlled ecosite.
- Consider cone scattering to augment direct seeding on fresher phases of this ecosite.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 12	Black Spruce–Jack Pine: Very Shallow Soils	V30, (35-38)	SS1-SS4, (SS5)	TU–I1	SMR 0-2

General Comments:
- Prone to seasonal drought, which will influence the success of direct seeding efforts.
- Moderate to low levels of jack pine seed ingress.
- Moisture regimes greater than 1 are uncommon on this ecosite.

Recommendations:
- V 30 has a moderate potential for direct seeding.
- This ecosite provides an opportunity for boot-screefing and shelter seeding.
- V types 35 - 38 occur in small patches on this ecosite and are generally wet and / or organic peaty phase seedbeds and are considered as having low potential. These V types also pose a moderate-to-high flooding potential and higher incidence of root rot.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 13	Jack Pine–Conifer: Dry–Moderately Fresh, Sandy Soil	V28-30, (32-33)	S1, S2, (SS5)	TU–I2	SMR 0-1

General Comments:
- Prone to moderate-to-high levels of seasonal drought. However, adequate rainfall may yield high stocking with excessive densities.
- Ingress of naturals after harvesting and site preparation is high.

Recommendations:
- This ecosite has a moderate-to-high potential for direct seeding.
- Scarification to scatter and align jack pine slash will enhance regeneration success.

ES 14	Pine–Spruce Mixedwood: Sandy Soil	V17-20, (10, 31-33)	S1, S2, (SS5)	TU–E1, E2, F	SMR 0-3

General Comments:
- Drier phases of this ecosite are prone to seasonal drought.
- Coarser soils are nutrient poor.
- Potential for competition ranges from low to high.
- Ingress of naturals after harvesting and site preparation is generally high.

Recommendations:
- This ecosite has a moderate-to-high potential for direct seeding.
- Precision sowing is recommended. Boot-screefing can be effective.
- Augmenting cone/slash scattering with direct seeding will produce good results.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 15	Red Pine–White Pine: Sandy Soil	V1, 42, 13, (26, 27)	S1, S2, (SS5)	TU–H	SMR 0-2

General Comments:

- Exposed mineral soil seedbeds will be prone to seasonal drought.
- Adequate rainfall during the germination-establishment period is required to assure success on these generally rapidly drained soils.

Recommendations:

- This ecosite has a moderate-to-high potential for jack pine direct seeding.
- Use light intensity mechanical site preparation or boot-screefing.
- Success of cone scattering to augment artificial seeding will be highly variable on this site.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 16	Hardwood–Fir–Spruce Mixedwood: Sandy Soil	V4-11, (17, 18, 20)	S1, S2, (SS5)	TU–B1	SMR 0-3

General Comments:

- Moderate-to-high levels of competition. Rapid ingress and vigorous development of competitors on this relatively fertile and generally fresh to moist site may preclude high jack pine stocking from direct seeding.
- Dry moisture regimes prone to seasonal drought.
- Smothering of seedbeds with hardwood litter may limit broadcast seeding.

Recommendations:

- V types 4 to 9 have low potential, however V10,V11,17, 18 and 20 have moderate-to-high potential for direct seeding.
- Encourage prompt establishment.
- Shelter seeding is recommended. Vegetation control will be required.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 18	Red Pine–White Pine: Fresh, Coarse Loamy Soil	V26, 27, (12, 13)	S3, SS6	TU–H	SMR 0-2

General Comments: • Shallow soils (20 to 50 cm) are susceptible to erosion, seasonal drought/desiccation and low nutrient levels.
• Moderate-to-high levels of competition. Competition must be controlled to ensure success of seeding treatments.
• Moderate potential for frost heaving.

Recommendations: • Use a light site preparation technique and ensure even distribution of mineral soil. However, a high proportion of boulders and cobbles may limit mechanical site preparation.
• Boot-screefing on sites with shallower organic matter depths and spot seeding is an option.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 19	Hardwood–Fir–Spruce Mixedwood: Fresh, Sandy–Coarse Loamy Soil	V4-11, (14, 15, 17)	S2, S3, (S1, S2, SS5)	TU–B1	SMR 0-3

General Comments: • High levels of competition.
• Potential for high surface stone content may limit equipment operability.
• Low-to-moderate potential for frost heaving and flooding.
• Smothering of seedbeds with hardwood litter may limit broadcast seeding.

Recommendations: • This ecosite has a low potential for jack pine direct seeding on V types 4-9 and a moderate-to-high potential for V 10, 11, 14, 15 and 17.
• Shelter seeding is recommended. Vegetation control will be required.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 20	Spruce–Pine / Feather-moss: Fresh, Coarse Loamy Soil	V28-33, (17, 18, 20)	S2, S3, SS6, (S1, SS5)	TU–E2, F	SMR 2-3

General Comments:
- Moderate competition may be expected from green alder, willow and aspen.
- Expect high levels of jack pine ingress.

Recommendations:
- Good distribution of mineral soil seedbeds will contribute to successful direct seeding of jack pine on this ecosite.
- Augment direct seeding with passive cone scattering.

ES 21	Fir–Spruce Mixedwood: Fresh, Coarse Loamy Soil	V14-16, 19, (24, 25)	S3, SS6	TU–D1	SMR 0-3

General Comments:
- Moderate levels of competition.
- Low levels of jack pine ingress.
- Moderate potential for frost heaving.
- Potential for high surface stone content may limit equipment operability.
- Consider prescribed burning to reduce heavy slash loading associated with this ecosite.
- Smothering of seedbeds with hardwood litter may limit success.

Recommendations:
- This ecosite has a moderate potential for jack pine direct seeding.
- Seed shelters are recommended.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 22	Spruce–Pine / *Ledum* / Feathermoss: Moist, Sandy–Coarse Loamy Soil	V33, 34, (19, 20, 35, 37)	S7, S8, (SS8)	TU–E3	SMR 4-6

General Comments:
- A moderate level of ingress can be expected on this ecosite.
- Excessive disturbance on moist soils on this site will promote non-crop vegetation.
- moderate-to-high incidence of flooding on V-Types 34, 35 and 37.
- While jack pine may be easily established by seeding on well distributed mineral soil seedbed, thrifty development and growth may only occur on the better drained portions of this ecosite.

Recommendations:
- On sandy phases of this ecosite, broadcast or precision seeding of jack pine on mineral soil seedbeds is highly successful.
- Cone scattering of jack pine slash with light site preparation is another option if site conditions permit.

ES 25	Pine–Spruce / Feathermoss: Fresh, Silty soil.	V31, 32, (11)	S4, (SS7)	TU–E2	SMR 1-3

General Comments:
- Fine textured soils are susceptible to compaction and rutting during the frost free season.
- Excessive disturbance on this site will promote non-crop vegetation and increase the potential for erosion and frost heaving.
- Small seedlings on exposed finer textured mineral soils are prone to frost heaving - this may be mitigated by maintaining a thin (5–20 mm) H/FH horizon over the mineral soil).

Recommendations:
- This ecosite has a high potential for direct seeding jack pine.
- Expect moderate-to-high levels of jack pine ingress on this ecosite.
- Low intensity scarification to scatter and align jack pine slash will enhance regeneration success.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 26	Spruce – Pine / Feather-moss: Fresh, Fine Loamy–Clay Soil	V31, 33, (20, 32)	S5, S6 (SS7)	TU–E3	SMR 1-3
ES 31	Spruce – Pine / Feather-Moss: Moist, Silty–Clayey Soil	V33, 34, (31, 32)	S9, S10 (SS7, SS8)	TU–E2	SMR 1-3

General Comments:
- Both are low-to-moderate competition sites.
- These ecosites have moderate-to-high levels of frost heaving on finer textured soils; mitigate by maintaining a thin (5–20 mm) H/FH horizon over the mineral soil.
- Moderate-to-high levels of flooding may occur on moister phases of these ecosites.

Recommendations:
- Creating receptive seedbed through fire or mechanical site preparation is necessary for direct seeding these ecosites.
- Select phases of these ecosites with lower silt contents to minimize competition for direct seeding treatments.
- High levels of jack pine ingress will augment artificial seeding.

3.2.2 Potential sites for direct seeding jack pine in northeastern Ontario.

ST 1, ST 5a and ST 5b should be considered as having good potential for direct seeding. On ST 2a and 2b, seed only when moisture regimes are greater than or equal to one. Seeding itself will not bring back a jack pine-dominated stand on ST 3a and 6c and should only be used when augmented with other regeneration methods. Distribution, abundance and vigour of competitive woody and herbaceous species on sites such as ST 3b may preclude germination, survival and growth of jack pine, unless controlled. Ensure adequate seedbed (i.e., a minimum 10 to 25% receptive seedbed) on ST 4.

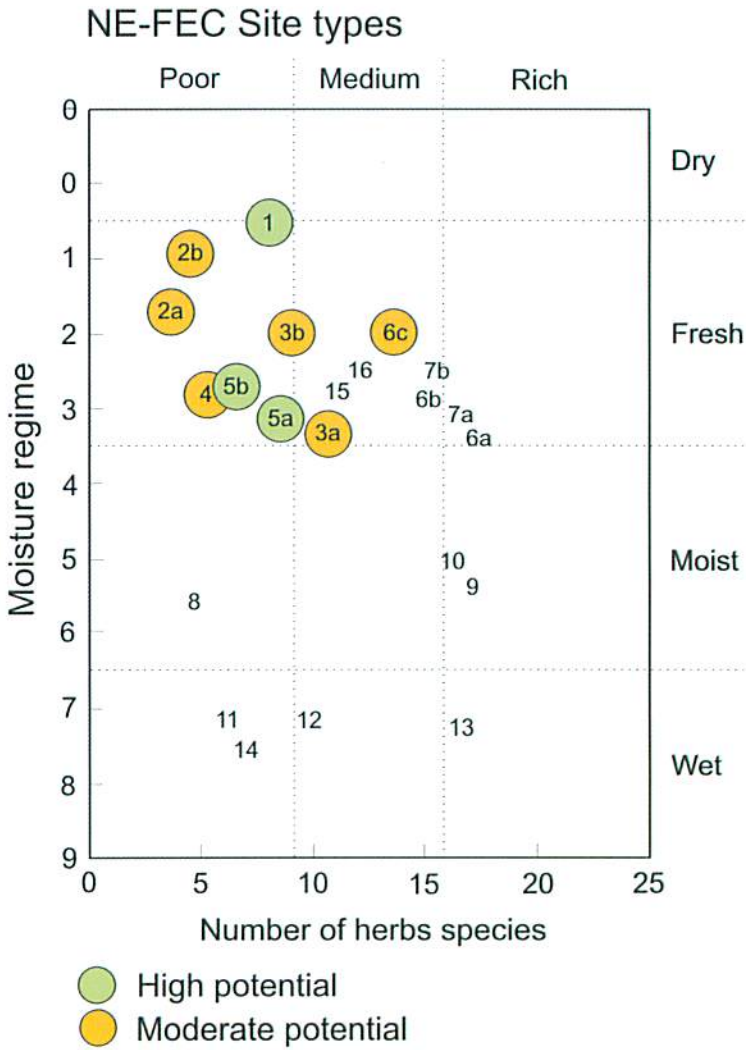


Figure 3.2 Potential for direct seeding jack pine in northeastern Ontario *(adapted from McCarthy et al. 1994)*

Table 3.2 Site-specific considerations and recommendations associated with the potential for direct seeding jack pine in northeastern Ontario *(adapted from OMNR 1997).*

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 1	Very Shallow Soil	V16[2], 13[2], 14[1], 22[1], other[4]	(SS1-4)[10]	SMR Ø-2

General Comments:
- These sites have ≤30 cm of mineral soil over bedrock, with the greatest percentage of them having a moisture regime ranging from Ø to1.
- Seed and/or seedlings could experience desiccation.
- Very sensitive to site damage from harvesting.
- High probability of augmenting direct seeding with natural ingress.

Recommendations:
- Good candidate for direct seeding to jack pine.
- Rule out extensive portions of this site that have SMR <1.
- Use a light site preparation technique due to a thin organic layer or consider boot-screefing and spot seeding.
- Good candidate for cone scattering.

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 2a	Jack Pine: Coarse Soil	V16[6], 15[3], 18[1]	S1[4], (S2, S5)[3], S6[2], S7[1]	SMR 1-3

General Comments:
- Extremely high level of jack pine ingress (>5,000 stems/ha.(sph))
- Low competition site.
- Moderate-to-high risk of nutrient loss.
- New germinants susceptible to extended droughts on SMR ≤1.

Recommendations:
- Direct seeding is recommended on sites predominantly SMR 2–3.
- Use a light site preparation technique due to a thin organic layer or consider boot-screefing and spot seeding.
- Medium potential for cone scattering.

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 2b	Jack Pine: Very Coarse Soil	V16$^{(4)}$, 15$^{(3)}$, 17$^{(1)}$, 18$^{(1)}$, 5$^{(1)}$	S1$^{(7)}$, S2$^{(1)}$, S3$^{(1)}$, (S5, S6)$^{(1)}$	SMR Ø-3

General Comments:
- Extremely high level of jack pine ingress (>5,000 sph)
- Low competition site.
- Desiccation of seed and/or seedlings may take place during very dry seasons.

Recommendations:
- Direct seeding is recommended on sites with SMR ≤1.
- Direct seeding may yield low stocking on portions of site with SMR: Ø–0, excepting germination and post germination seasons with adequate rainfall. Obtaining consistent, uniform stocking may depend on the distribution of the SMR mosaic.
- Use a light site preparation technique due to a thin organic layer or consider boot-screefing and spot seeding.
- Medium potential for cone scattering.

ST 3a	Mixedwood: Medium Soil	V13$^{(5)}$, 14$^{(2)}$, (V10, 12, 17, 23)$^{(3)}$	S11$^{(4)}$, S9$^{(2)}$, S12$^{(2)}$, S10$^{(1)}$ S15$^{(1)}$	SMR 1, 3, (2,4)

General Comments:
- On finer textured soils frost heaving may occur if the entire LFH layers are removed.
- Moderate competition site.

Recommendations:
- This site has a moderate potential for direct seeding; it should only be used to augment other regeneration methods.
- Prompt post harvest site preparation may permit seeded jack pine to better cope with developing competition.

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 3b	Mixedwood: Coarse Soil	V13(5), 14(2), 12(1), 17(1), (5, 15, 23)(1)	S1(3), S2(2), S5(2), S7(2), S3(1)	SMR Ø-5

General Comments:
- On finer textured soils frost heaving may occur if the entire organic layer is removed.
- Moderate competition site.

Recommendations:
- This site has a moderate potential for direct seeding
- Avoid dry moisture regimes (SMR Ø to 0).
- Competition may preclude success of direct seeding efforts unless controlled.
- Prompt post harvest site preparation is recommended.

ST 4	Jack Pine–Black Spruce: Coarse Soil	V18(4), 23(4), 17(1), (13, 14, 22)(1)	S3(3), S1(3), S7(2), S4(1), S5(1)	SMR Ø-5

General Comments:
- High probability of jack pine ingress (5,000 sph)
- Moderate competition site.

Recommendations:
- This site has a moderate potential for direct seeding
- Requires a minimum 10 to 15% receptive seedbed exposure.
- Avoid extensive areas with uniformly dry (Ø–0) moisture regimes.
- Good candidate site for cone scattering.
- Potential site for seed tree underburning.

ST 5a	Black Spruce: Fine Soil	V23(4), 18(2), (8, 13, 14, 16, 21, 22)(4)	S13(6), S14(4)	SMR 2-5

General Comments:
- High probability of jack pine ingress (1,000 to 5,000 sph)
- Avoid damaging saturated fine textured soils during harvesting.
- On finer textured soils frost heaving may occur if the entire organic layer is removed.
- Moderate competition, however avoid heavy site preparation.

Recommendations:
- This site has a high potential for direct seeding jack pine.
- Avoid seeding jack pine on extensive areas with SMR >4.

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 5b	Black Spruce: Medium Soil	V16[3], 18[3], 23[2], 22[1], 15[1]	S12[4], S10[3], S11[2], S9[1]	SMR: 1-4

General Comments:
- On finer textured soils frost heaving may occur if the entire organic layer is removed.
- Very high probability of jack pine ingress (>5,000 sph) when jack pine is present in the overstory prior to harvest.
- Moderate competition, however avoid heavy site preparation.

Recommendations:
- This site has a high potential for direct seeding jack pine.
- High potential for cone scattering when organic matter depth is less than 10 cm.

ST 6c	Hardwood Mixedwood: Coarse Soil	V12[5], 9[1], 11[1], 14[1], (5, 7, 8, 13)[2]	S1[2], S2[2], S7[2], S3[1], S4[1], S5[1], S6[1]	SMR Ø-4

General Comments:
- Potential abundant suckering and sprouting of shrubs following harvest.

Recommendations:
- This site has a moderate potential for direct seeding jack pine.
- Consider prompt post harvest site preparation to permit seeded jack pine to better cope with developing competition.
- Seeding must be augmented with other regeneration methods to successfully regenerate this site.
- Potential for cone scattering on drier phases of this site.

3.2.3. Potential sites for direct seeding black spruce in northwestern Ontario.

3.2.3.1 Upland black spruce

On uplands, ecosites 20 and 25 offer the best potential for direct seeding. Proper site preparation is critical to regeneration success on both these ecosites. Avoid sites that are predisposed to heavy competition.

The most favourable soil types are moderately shallow to deep silty very fine sands and sandy loams. It is more difficult to establish black spruce by direct seeding on soil classifications S2 and S3 (deep, moderately dry to fresh, loamy and silty sands) and on types SS2 and SS3 (very shallow, silty sands and sandy loams).

Even with above average rainfall during the first and second growing seasons, SMR Ø and 0 offer little chance of success for direct seeding and should be avoided. Coarse textured soils with a SMR of 1 are also likely to result in seeding failures. On shallow soils however, a SMR of 1 can produce acceptable stocking in a year with adequate rainfall and moderate-to-high stocking in a year of above normal precipitation. Best results are obtained on very fresh to very moist soils (SMR 3-6).

3.2.3.2 Lowland black spruce

Lowland black spruce sites in the northwest are characterized by deep, very moist to wet organic soils. Substantial accumulations of organic matter provide good water storage capacity. Those sites dominated by *Sphagnum* moss (ES 34, 35 and 36) have good potential for direct seeding. The hygroscopic nature of living *Sphagnum* and *Sphagnum* peat allows the seedbeds associated with these sites to retain large quantities of available water, regardless of the underlying substrate (Fleming and Mossa 1994).

Generally, these ecosites have high levels of advance growth. Preservation of this advance growth through the use of careful logging techniques can supplement regeneration establishment by direct seeding.

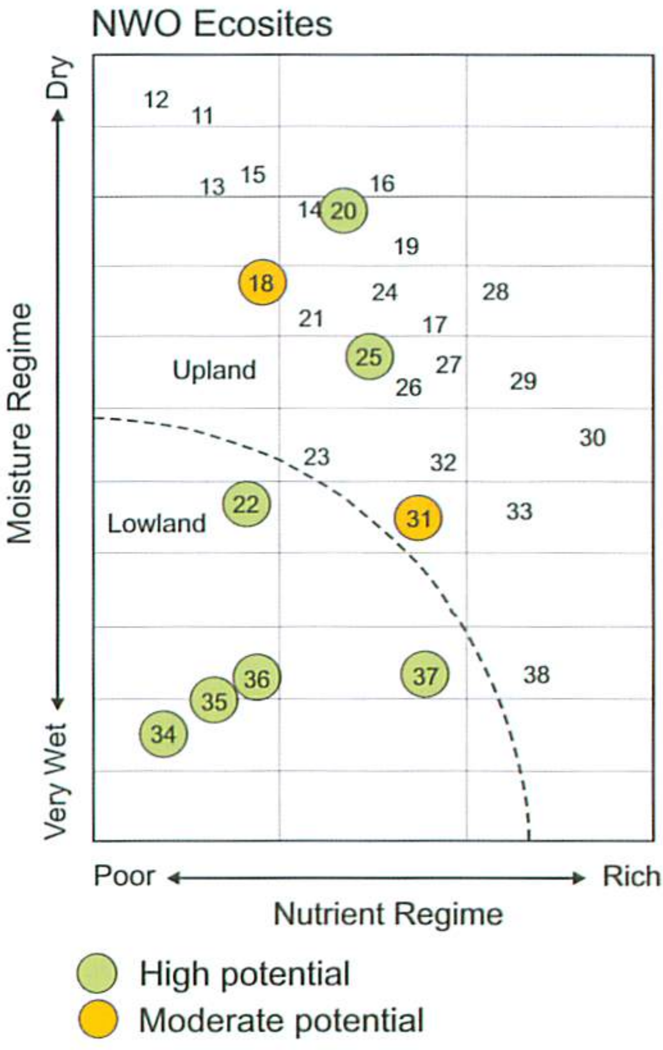


Figure 3.3 Potential for direct seeding black spruce in northwestern Ontario *(adapted from Racey et al. 1996).*

Table 3.3 Site-specific considerations and recommendations associated with the potential for direct seeding black spruce in northwestern Ontario *(adapted from OMNR 1997).*

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 18	Red Pine–White Pine: Fresh, Coarse Loamy Soil	V26, 27, (12,13)	S3, SS6	TU–H	SMR 0-2

General Comments:
- Shallow soils (20 to 50 cm) are susceptible to erosion, seasonal drought/desiccation and low nutrient levels.
- Moderate-to-high levels of competition. Competition must be controlled to ensure success of seeding treatment.

Recommendations:
- Shelter seeding only. Boot-screefing, where site conditions permit, will moderate both moisture and temperature extremes and minimize competition.
- Broadcast seeding is not recommended.

ES 20	Spruce – Pine / Feathermoss: Fresh, Coarse Loamy Soil	V28-33, (17,18, 20)	S2, S3, SS6 (S1,SS5)	TU–E2, F	SMR 2-3

General Comments:
- Moderate competition may be expected from green alder, willow and aspen.
- This ecosite supports an abundance of advance growth.
- Careful logging to preserve advance growth should be considered.

Recommendations:
- This ecosite has a moderate-to-high potential for aerial seeding.
- Site preparation is required to expose sufficient suitable seedbed.
- A combination of black spruce seed trees and prescribed burning may be an option.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 25	Pine–Spruce / Feather-moss: Fresh, Silty Soil	V31, 32, (11)	S4, (SS7)	TU– E2	SMR 1-3

General Comments:
- Fine textured soils are susceptible to compaction and rutting during the frost free season.
- Excessive disturbance on this site will promote non-crop vegetation and increase the potential for erosion and frost heaving.

Recommendations:
- This ecosite has a moderate-to-high potential for aerial seeding.
- Light site preparation is required to expose sufficient suitable seedbed.
- A combination of black spruce seed trees and prescribed burning may be an option (target the less competitive V-types for this treatment).

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 31	Spruce – Fine – Feathermoss: Moist, Silty–Clayey Soil	V33, 34, (31, 32)	S9, S10, S11 (SS7, SS8)	TU–E3	SMR 4-6

General Comments:
- This ecosite has high levels of black spruce ingress after disturbance and moderate levels of advance growth.
- Excessive disturbance on this site will promote non-crop vegetation and increase the potential for erosion and frost heaving.
- Fine textured soils are susceptible to compaction and frost heaving.

Recommendations:
- This ecosite has a moderate potential for aerial seeding.
- Light site preparation is required to expose sufficient suitable seedbed.
- A high degree of ingress is required to supplement aerial seeding.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 22	Spruce–Pine / *Ledum* / Feathermoss: Moist, Sandy–Coarse Loamy Soil	V33, 34, (19, 20)	S7, S8 (SS8)	TU–E3	SMR 4-6

General Comments:
- Moderate-to-high level of advance growth with a moderate level of ingress.
- Excessive disturbance on moist soils on this site will promote non-crop vegetation.

Recommendations:
- This ecosite has a moderate-to-high potential for aerial seeding.
- Light site preparation is required to expose sufficient suitable seedbed.
- A high degree of ingress is required to supplement aerial seeding.
- Employ careful logging to augment stocking.
- A combination of black spruce seed trees and prescribed burning may be an option.

ES 34	Black Spruce / *Sphagnum*: Organic Soils	V37, 38	S12S, S12	TU–J2	SMR 6-8

General Comments:
- High level of advance growth.
- High potential for rutting and disturbance of surface water.
- Low productivity site.

Recommendations:
- This ecosite has high potential for direct seeding.
- Good opportunity for protection of advance growth to complement seeding.
- Employ careful logging.

ES 35	Black Spruce: Organic Soils	V37, 38	S12S, S12 (S11, SS9)	TU–J1	SMR 6-8

General Comments:
- High level of advance growth.
- High potential for rutting and disturbance of surface water.
- Prone to seasonal flooding.

Recommendations:
- Aerial seeding is a recommended option on phases of this ecosite with abundant *Sphagnum* cover and low levels of advance growth.
- Use careful logging to protect the site and conserve advance growth.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 36	Black Spruce (Tamarack): Organic Soils	V23, 35, (36)	S12S, S12F, (S11, SS9)	TU–J1	SMR 6-8

General Comments:
- High level of advance growth.
- High potential for rutting of organic soils.
- Prone to seasonal flooding, which may limit access.

Recommendations:
- Aerial seeding is a recommended option on phases of this ecosite with abundant *Sphagnum* cover and low levels of advance growth.
- Use careful logging to minimize ground disturbance and conserve advance growth.

ES 37	Cedar (Other Conifer): Organic Soils	V21, 22	S11 (S12F, S12S, SS9)	TU–J1, D2	SMR 4-8

General Comments:
- High level of advance growth.
- High potential for rutting of organic soils.
- Prone to seasonal flooding, which may limit access.
- Potentially high levels of alder competition following harvesting.

Recommendations:
- Aerial seeding is a recommended option on phases of this ecosite with abundant *Sphagnum* cover and low levels of advance growth.
- Use careful logging to protect the site and conserve advance growth.
- Minimizing ground disturbance will limit competition development, although tending may be required.

3.2.4. Potential Sites for direct seeding black spruce in northeastern Ontario.

On upland sites, ST 5a and 5b offer the best chance of success. Ensure that there is sufficient receptive seedbed available before seed application. All other identified sites have only moderate potential and in many cases the treatment by itself will not result in a black spruce dominated site and should only be used when augmented with other regeneration methods.

On lowland sites, as in northwestern Ontario, the greatest likelihood of seeding success occurs on those site types which support a high cover of *Sphagnum* moss. *Sphagnum* cover is consistently high in the black spruce *Labrador-Tea* and *Speckled Alder* site types (ST 11 & 12), and can be high in the black spruce feather moss/*Sphagnum* and Conifer Speckled Alder site types (ST 8 & 13) (Groot and Adams 1984).

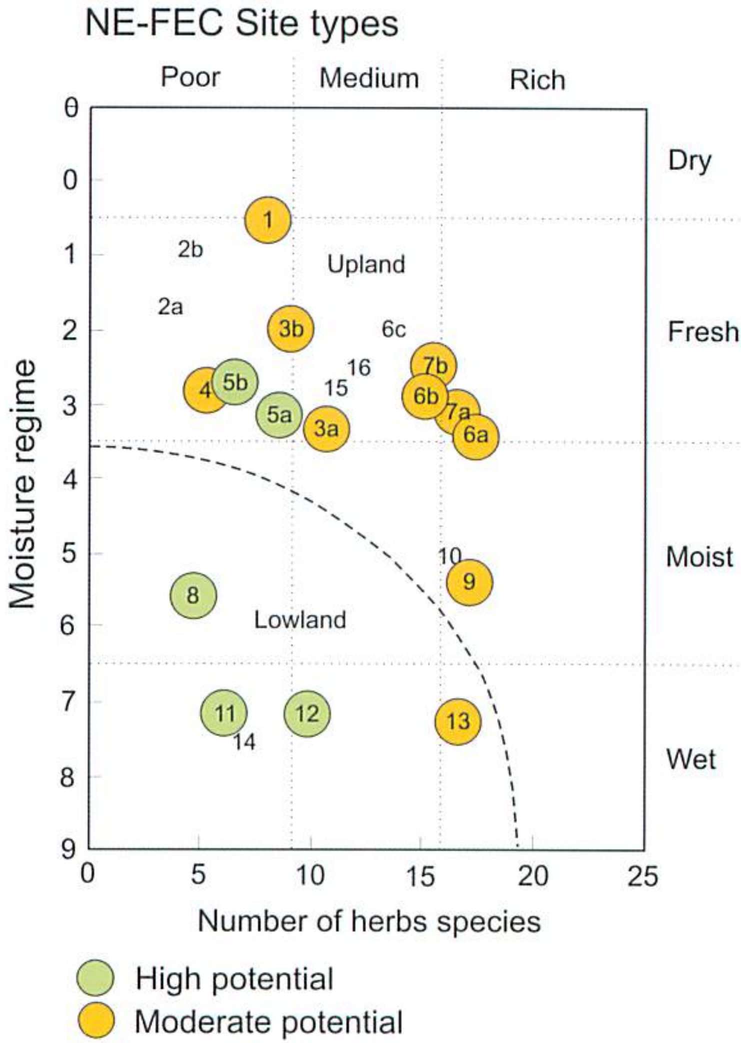


Figure 3.4 Potential for direct seeding black spruce in northeastern Ontario *(adapted from McCarthy et al. 1994)*

Table 3.4 Site-specific considerations and recommendations associated with the potential for direct seeding black spruce in northeastern Ontario *(adapted from OMNR 1997).*

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 1	Very Shallow Soil	V16, 13, 14, 22	SS1–4	SMR Ø-2

General Comments: • These sites have ≤30 cm of mineral soil over bedrock; the greatest percentage of them have a moisture regime ranging from Ø to 1.
• Seed and/or seedlings could experience desiccation.
• Very sensitive to site damage from harvesting.

Recommendations: • Good candidate for seeding to black spruce.
• Rule out any sites having a SMR <1.
• Use a light site preparation technique due to the thin organic layer or consider boot-screefing and spot seeding.

ST 3a	Mixedwood: Medium Soil	V13, 14, (10, 12, 17, 23)	S11, S9, S12, S10, S15	SMR 1,3, (2, 4)

General Comments: • Frost heaving may occur if the entire organic layer is removed.
• Moderate competition site.

Recommendations: • This site has a moderate potential for direct seeding.
• Seeding should only be used to augment other regeneration methods.

ST 3b	Mixedwood: Coarse Soil	V13, 14, 12, 17, (5, 15, 23)	S1, S2, S5, S7, S3	SMR1-2, (Ø-0, 3, 4, 5)

General Comments: • Frost heaving may occur if the entire organic layer is removed.
• Moderate competition site.

Recommendations: • This site has a moderate potential for direct seeding black spruce.
• Avoid dry moisture regimes (Ø to1).
• Competition may preclude success of direct seeding efforts unless controlled.

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 4	Jack Pine–Black Spruce: Coarse Soil	V18, 23, 17, (13, 14, 22)	S3, S1, S7, S4, S5	SMR 3-4, (Ø-0, 1, 2, 5)

General Comments: • If jack pine occupied a significant component of the original stand then there will be a high probability of jack pine ingress.
• Moderate competition site.

Recommendations: • This site has a moderate potential for direct seeding black spruce.
• On moisture phases (SMR 4 and 5) of this site, augment stocking by careful logging to protect advance growth.
• Avoid dry moisture regimes (Ø to1).

ST 5a	Black Spruce: Fine Soil	V23, 18, (8, 13, 14, 16, 21, 22)	S13, S14	SMR 2-4, (5)

General Comments: • Avoid damaging saturated fine textured soils during harvesting.
• Black spruce advance growth may be of sufficient quantity to form a major part of the new stand.
• Moderate competition, however avoid heavy site preparation.

Recommendations: • This site has a high potential for direct seeding black spruce.
• Use careful logging to protect advance growth.

ST 5b	Black Spruce: Medium Soil	V16,18, 23, 22,15	S13, S14	SMR 1-4

General Comments: • Very high probability of jack pine ingress (>5,000 sph) on dryer phases of this site when jack pine is present in the overstory prior to harvest.
• Moderate competition, however avoid heavy site preparation.

Recommendations: • This site has a high potential for direct seeding black spruce.
• Moister phases of this site offer good opportunity to augment seeding by using careful harvesting to protect advance growth.

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 6a	Mixedwood: Fine Soil	V8, 7, (9,13), 10, (14, 18, 22)	S13, S14	SMR 2, 3, 5, (4)
ST 6b	Conifer Mixedwood: Medium Soil	V8,12,13, (4, 7, 9, 17)	S12, S9, S10, S11	SMR 2, 3, 4, (1, 5)
ST 7a	Hardwood: Fine Soil	V9, 7, 10, 8, 11, (12, 14)	S13, S14	SMR 2, 3, (4, 5, 6)
ST 7b	Hardwood: Medium Soil	V9, 11, 12, (8, 10, 13)	S9, S11, S10, S12, S15	SMR 2 ,3, (1, 4, 5)

General Comments: • All of these sites are highly competitive, which can make renewal by direct seeding difficult.

Recommendations: • Abundance of competition will require vegetation control.
• Consider precision seeding with seed shelters.

ST 9	Conifer: Moist Soil	V7, 6, 22,1 9, 14, 23	S16, S15, S12, S7, S11	SMR 4, 5, (6)

General Comments: • Minimize disturbance of peat layer to avoid site damage.
• Site can have moderate amounts of advance growth.

Recommendations: • This site has a moderate potential for direct seeding black spruce.
• Augment seeding by using careful harvesting to protect advance growth.

ST 8	Black Spruce / Feathermoss / *Sphagnum*	V23, 24, 22, (25, 18)	S16, S7, S14 (S3, S4, S8, S15)	SMR 6, 5, (4)

General Comments: • Minimize disturbance of peat layer to avoid site damage
• Site can have moderate-to-high amounts of advance growth.

Recommendations: • This site has a high potential for direct seeding black spruce.
• Protect advance growth.
• Vegetation control will be required for those sites with high alder components.

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 11	Black Spruce / Labrador-tea	V25, 24, 22, 21	S17, S19, S18	SMR 7, (6, 8)

General Comments:
- Minimize disturbance of peat layer to avoid site damage.
- Site has a high amount of advance growth.

Recommendations:
- This site has an excellent potential for direct seeding black spruce.
- Protect advance growth with careful harvesting.

ST 12	Black Spruce / Speckled Alder	V21, 24, 20, 19	S17, S18, S19	SMR 7, (6, 8)

General Comments:
- Minimize disturbance of peat layer to avoid site damage.
- Site has a high amount of advance growth.

Recommendations:
- This site has an excellent potential for direct seeding black spruce.
- Protect advance growth with careful harvesting.
- Control alder competition.

ST 13	Conifer / Speckled Alder	V19, 21, 6, 20, 7, 22	S19, S18, S17	SMR 7, (6, 8)

General Comments:
- Minimize disturbance of peat layer to avoid site damage.
- High potential for site disturbance and elevated water table following harvest.
- Site has a moderate amount of advance growth.

Recommendations:
- This site has a moderate-to-high potential for direct seeding black spruce.
- Protect advance growth with careful harvesting.
- Vegetation control will be required.

4.0 THE SEED

Good quality seed is a prerequisite for direct seeding. An efficient and flexible seed procurement system should be in place to take advantage of good cone years when they occur – a cycle that averages three years for jack pine and four years for black spruce. Seeds from a particular locality within a seed zone should be used in areas as close as possible to their place of origin to ensure that the future stand is adapted to local ecological conditions

Aerial seeding requires large quantities of seed, dictating that bulk cone collections will remain the main source of seeds for the foreseeable future. However, surplus seeds from orchards and other improved sources may be available in the future for direct seeding, especially for methods such as row or spot seeding.

The majority of both black spruce and jack pine seed shipped from seed extraction plants in the province is slated for use in direct seeding programs (Figure 4.1).

For information regarding cone and seed characteristics refer to Appendix C.

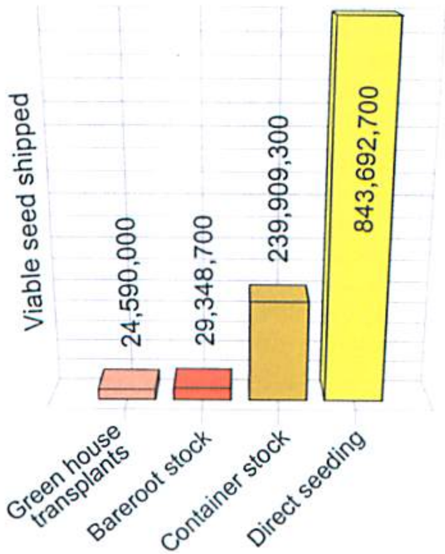


Figure 4.1 Typical amounts of viable seed shipped per year by the Ontario Tree Seed Plant for artificial regeneration programs *(Source: OTSP)*.

4.1 How Are Cones Collected, Stored, and Shipped?

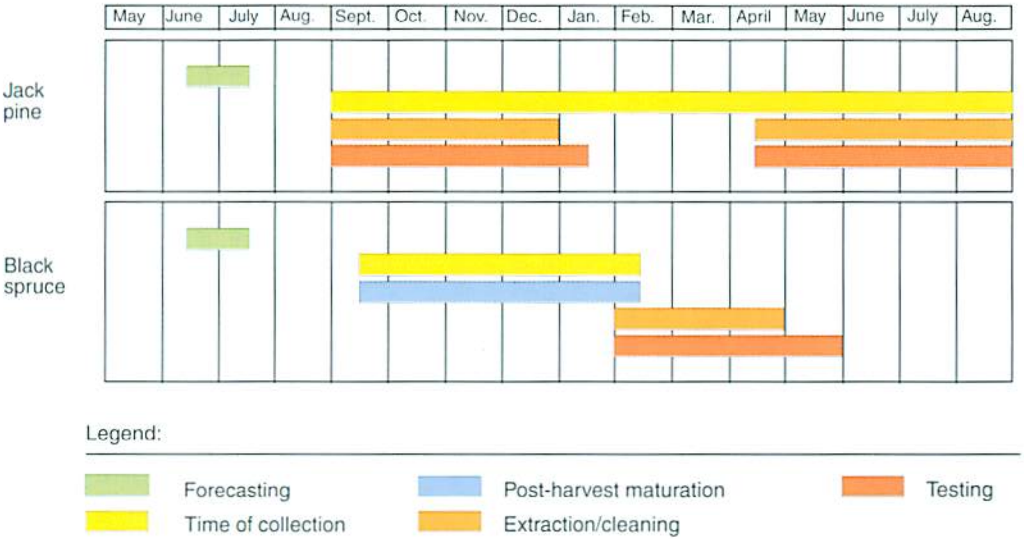
In preparation for cone collecting, the annual cone crop of the target species should be assessed for its volume and quality. By assessing the cone crop in advance, budgeting can be adjusted to allow for extra cone harvesting to take advantage of a good crop year. Forecasting the size of the cone crop can be done several weeks after flowering, when immature cones have formed in the crowns (Ontario Ministry of Natural Resources 1986a). For both jack pine and spruce, this occurs in the two week period from the last week in June to the first week in July (Figure 4.2). Early forecasting will provide ample time to organize for cone collecting in the fall and winter. Jack pine cones take two years to develop, so forecasts should be based on second year conelets.

We recommend that cones be collected only during good or bumper crop years, for both biological and economic reasons. The high volume of pollen ensures ample cross pollination and therefore a high degree of heterogeneity (genetic diversity) in the seeds. Seeds originating from bumper crop years generally have higher viability, vigour, and storage capacity.

Pest damage is proportionately reduced in above average cone crop years because of the high volume of cones, whereas during poorer cone crop years insects can destroy much of the crop. The cost per litre of collecting cones during good crop years is reduced because of the high cone concentrations.

For serotinous and semiserotinous species like jack pine and black spruce, respectively, cones may retain their seeds for several years, which allows for more flexible collection dates. Older cones (i.e., cones that are entirely grey) should be avoided because of reduced seed yields and seed viability. When collecting jack pine cones, look for large, straight cones with no evidence of insect damage (Figure 4.3). Current season cones should not be collected before the cones are mature, usually the first week of September.

General cone collections can be coordinated with black spruce and jack pine harvesting operations. By doing so, cone-laden tops are easily assembled and can be hand picked on site or moved to a central location for cone removal. Mechanical cone processing units can be a very cost-effective method of collecting large quantities of both black spruce and jack pine cones. Recent improvements to this technology have greatly reduced the amount of foreign material that is mixed in with cone shipments, but more development is needed to increase the safety and efficiency of mechanical cone processing.



Note: Collection period for jack pine refers to the current year's cones. Previous year's cones can be collected at any time.

Jack pine can be processed on a year round basis, however, the late winter months are usually set aside for the extraction and testing of other species.

Black spruce cones may retain seed for several years, which allows for more flexibility in collection dates.

Figure 4.2 Tree seed crop forecasting, collection, and processing summary for jack pine and black spruce *(Source: OMNR 1994).*

Figure 4.3 A tray of both current year (brown) and recently mature (partially grey) jack pine cones ready for kiln drying *(photo courtesy Millson Forestry Ltd.).*

All cone collections must be labelled with the seed source number (Appendix D), U.T.M. (universal transverse mercator) grid, elevation (m), date collected, number of hectolitres, and crop year. An example of how U.T.M. grids are used in seed collection records is given in Ontario Ministry of Natural Resources (1991). Proper identification ensures that seeds will be applied in the same seed zone that they were collected in.

The seed source number includes a field for site region or seed zone. Prior to 1996 seed sources were identified by site region. In 1996 a new seed zone system was adopted. Because seed that has been in storage prior to 1996 may be identified with the older version, both identification systems have been included in Appendix D. More recently, focal point seed zones have been developed for northwestern Ontario (Parker and van Neijenhuis 1996). If seed collections are properly tracked, focal point seed zones provide a good basis for managing seed deployment.

Black spruce cones collected up to the end of November should be shipped to a seed extraction plant on trays; if bagged, their high moisture content can cause overheating and moulding. Jack pine cones can be shipped to a processing centre on a year-round basis. Postharvest maturation is not required for either species, and cones can be processed without a waiting period. If cones must be stored before shipping they should be placed in a thin layer (<10 cm thick) under dry, cool, well-ventilated conditions to prevent overheating or moulding. This guideline especially applies to black spruce.

4.2 What Aspects of Seed Quality are Important in Direct Seeding?

4.2.1 Seed testing

Every seed lot should be tested to evaluate its quality and determine its field sowing values. The quality of a seed lot is a function of seed source, genetic make-up, flowering conditions, seed set, cone collection time, handling, and storage conditions. The principal characteristics for which seed lots are tested include: purity, weight, moisture content, viability, germinability, and vigour. Each of these characteristics influences how the seed will be used.

Seed testing is normally carried out by the seed extraction facility.

4.2.2 Seed storage

Seeds must be properly stored so that they remain viable until required for direct seeding. To store seeds properly:

- Ensure that the seeds are mature (fully ripe) prior to storage.
  Immature seeds have low initial viability and are liable to sustain further damage during seed processing resulting in shorter storage life.

- Reduce seed moisture content.
  Moisture contents of 4-6 percent for black spruce and 6-10 percent for jack pine are recommended. This will decrease the rate of seed respiration and reduce the utilization of food reserves.

- Store at constant low temperature.
  Store at temperatures of 1-3°C for black spruce and 1-5°C for jack pine. Avoid fluctuations outside this temperature range.

- Store in sealed containers
  Use glass or plastic bottles with screw tops, polyethylene bags or fiberboard drums. Avoid opening cold containers in warm atmosphere or leaving the containers unsealed for an extended period (Wang 1974).

Seeds of black spruce and jack pine can be stored for up to 20 years or longer if proper conditions for safe storage are used.

4.3 Do Methods Exist to Improve Seed Germination and Establishment?

4.3.1 Seed treatments

Currently, no form of seed treatment is used operationally in Ontario. However, seed treatments undertaken to enhance seed germination and seedling establishment have been successfully employed in agriculture for decades. Adaptation of these techniques for forestry application has met with some experimental success (e.g., natural and synthetic hormone pre-treatments designed to accelerate or delay the germination process, osmotic priming and micro nutrient pre-soaking as methods of embryo stimulation, inoculation with growth promoting rhizobacteria, and gel seeding with pre-germinated seed), but most have been either too difficult or too costly to apply operationally. Further development may allow seed treatments that have shown potential on an experimental scale to be used operationally (Figure 4.4).

Figure 4.4 Osmotic priming is an example of seed preconditioning that produces significantly faster and more uniform germination. This technique involves the soaking of seeds in an aqueous solution of polyethylene glycol (PEG) and distilled water.

4.3.2 Seed pelleting and encapsulation

Pelleting is the application of solid, inert materials to a single seed in sufficient quantity to embed the seed in a relatively uniform spherical shape. The objective is to improve handling and the accuracy of seed delivery (Figure 4.5). The ability to customize size and improve the seed's uniformity increases the potential for mechanical application, as well as providing a potential vehicle for the incorporation of additives designed to protect or enhance early seedling establishment. Laboratory trials have demonstrated that germination delays due to the coating process are directly related to the thickness of the coating and the type of coating medium used. Two common types of coating material used for conifer seeds are fine grain silica (<200 mesh) and diatomaceous earth. Silica coatings will break down readily when moistened, but may not be appropriate for some pneumatic seeders because of the tendency of the loosely held fine particles to become detached and cause excessive "dusting". This can lead to mechanical metering problems. Pellets made from diatomaceous earth hold together well even when vigorously handled. To prevent excessive germination delay, the diameter of pelleted seeds should be no greater than 3 mm for black spruce and 4 mm for jack pine.

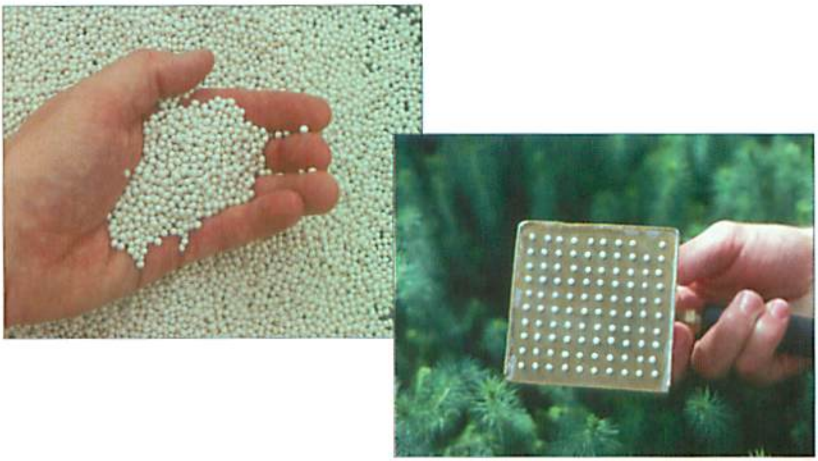


Figure 4.5 Pelleting or coating small conifer seeds can improve handling, metering and accuracy of seed delivery; as shown here with the aid of a vacuum plate seeder.

Encapsulation is the technique of enveloping single or multiple seeds in a composite mixture that is compressed or bonded into a wafer, plug or pill-like form (Figure 4.6). Both laboratory and field trials have shown that the compressed medium can act as a barrier to the emergence of embedded seeds, and can consequently cause a significant germination delay (Adams 1995; Buse 1992a). However, attaching seeds to the outside of compressed peat wafers using a water-soluble adhesive improves germination. Wafers or plugs can provide their own micro-site for initial seedling development, and can provide a carrier for additives.

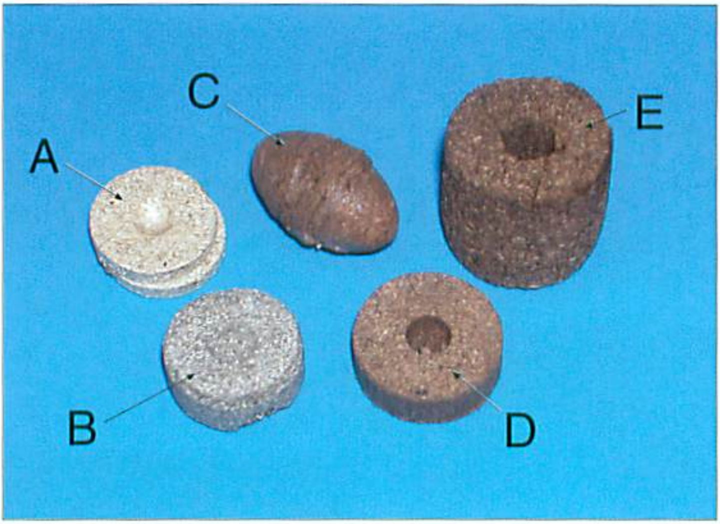


Figure 4.6 Examples of experimental seed encapsulation techniques used over the last decade: (A) the FMC wafer (a single seed in a semispherical cavity of a flat, round disk formed by cementing together two identical halves of compressed vermiculite), (B) University of Idaho seed tablet (multiple seeds embedded in a tablet composed of fine grade vermiculite and activated charcoal, bound by methylcellulose) (C) the Dupont "tree egg" (a blend of hydrophilic polymers, dried and pressed into a two gram, egg shaped pellet into which the desired number of seeds are embedded), (D) A Jiffy Products (N.B) Ltd., J-9 wafer (compressed peat that has been bitumized to hold the wafer together following saturation and expansion) and (E) a full imbibed J-9 wafer.

4.3.3 Protective coatings

As recently as the early 1970s, practically all seeds used for direct seeding in Ontario were coated with chemical repellents, ostensibly to minimize losses to insects, diseases, birds, and rodents. It was presumed that the absence of repellents would result in extensive seed predation. Concerns over the phytotoxicity of various repellents, tighter restrictions over the use of certain chemical formulations, and questions about the actual need and effectiveness of such measures lead to studies to elucidate the impact of small mammals (Figure 4.7) on direct seeding programs (Martell et al. 1995). It was determined that both black spruce and jack pine seeds were virtually absent from the summer diets of small mammals in northern Ontario, and losses due to predation are not considered to significantly affect the success of direct seeding operations. Currently, no protective treatments are used in direct seeding programs in Ontario.

Figure 4.7 Deer mouse (*Peromyscus*). Studies have shown that seed predation by rodents is not considered a significant threat to direct seeding programs.

5.0 HARVESTING CONSIDERATIONS

Forest harvesting practices can affect the success of subsequent direct seeding operations in several ways. On sensitive sites (peatlands and shallow-soiled sites), excessive disturbance by harvesting equipment reduces the area of receptive seedbed. Also, excessive slash can make it difficult to expose or create sufficient seedbed. Seed input from cones in slash, residual trees, and stand edges is strongly influenced by harvesting methods. Similarly, harvesting methods, to a large extent, will determine post-harvest advance growth quantities and will have a great impact on the composition and amount of vegetative competition.

5.1 Site Damage on Peatlands

The amount of receptive seedbed is reduced when harvesting machinery creates deep, water-filled ruts (Figure 5.1). Rutting also promotes the invasion of sedges, grasses, rushes, and cattails, all serious competitors to newly established seedlings. Rutting can also cause localized ponding by disrupting and blocking natural surface drainage patterns. This may temporarily or permanently reduce site productivity by raising the water level and reducing the rooting zone depth. The risk of frost heaving increases on black, humified peats and on fine-textured mineral soils that have been exposed during harvesting, usually as a result of skidding. Susceptibility to rutting is greatest on NEO FEC ST12 and ST13, moderate on ST9 and ST11, and least on ST8.

Figure 5.1 Site damage from harvesting machinery on a sensitive peatland site.

Prevent rutting damage by harvesting in the winter, after the frost has penetrated deeply into the ground, particularly on NEO FEC ST13 and ST12. If summer operations must be carried out on these sites, reduce damage by selecting appropriate harvesting equipment (e.g., high flotation tires, wide tracked fellers and clambunk skidders) (Figure 5.2) and operating techniques (e.g., a minimum number of skid trails), and by carefully planning road and skid trail layout. In northwestern Ontario FEC ecosites 34, 35, 36 and 37 (V-types 21-23 and 35-38) should be winter harvested to prevent severe degradation and to protect advance growth that is often abundant.

Brad Sutherland (FERIC)

Figure 5.2 The clambunk skidder; its articulated boom eliminates damage caused by lateral sweeping and larger load capacity results in fewer passes over the site.

RECOMMENDATIONS

- Unless harvesting is done in the frozen season, use low ground pressure (high flotation) equipment, which generally exerts <10 psi when loaded;
- Lay out logging roads so that *Alnus*-herb poor (ST12) and *Alnus*-herb rich (ST13) types are at the rear of the logging chance where they will sustain a minimum of machinery traffic.
- When STs 12 and 13 occur as drainage ways, orient skidways parallel to the drainage ways so that machinery does not have to cross them.
- NW-FEC ecosites 34, 35, 36 and 37 (V-types 21-23 and 35-38) should be winter harvested.
- Provide adequate training to equipment operators so they are able to recognize sensitive sites and take precautionary measures.

5.2 Site Damage on Uplands

On uplands, compaction, rutting and erosion can reduce the quantity and quality of seedbeds available for direct seeding. FEC information on soil depth and texture can be used to reduce logging damage by scheduling the harvest when impacts will be minimized, and by matching the equipment to the site.

On soils such as fine loams and clays (NWO FEC soil types S2, S3, S6, SS6, S4), which are susceptible to compaction, harvesting should be done in the dry season or in winter. More moist, poorly drained sites (S7, S8, S9, S10, SS8), are prone to compaction or rutting, and if possible should be harvested in winter. If harvested in summer, high flotation equipment should be used.

Thin soils overlying bedrock (SS1, SS2, SS3) (Figure 5.3), are quite fragile and highly sensitive to erosion. Dry, nutrient poor sites are also easily disturbed by summer logging and may be susceptible to humus destruction and nutrient losses.

Additional information on site damage can be found in: Forest Management Guidelines for the Physical Environment (Archibald et al. 1998), Silvicultural Guide to Managing for Black Spruce, Jack Pine and Aspen on Boreal Forest Ecosites *in* Ontario (OMNR 1997) and Forestry Practices Aimed at Maintaining Site Productivity *in* Long-Term Productivity of Boreal Forest Ecosystems (Kershaw et al. 1996).

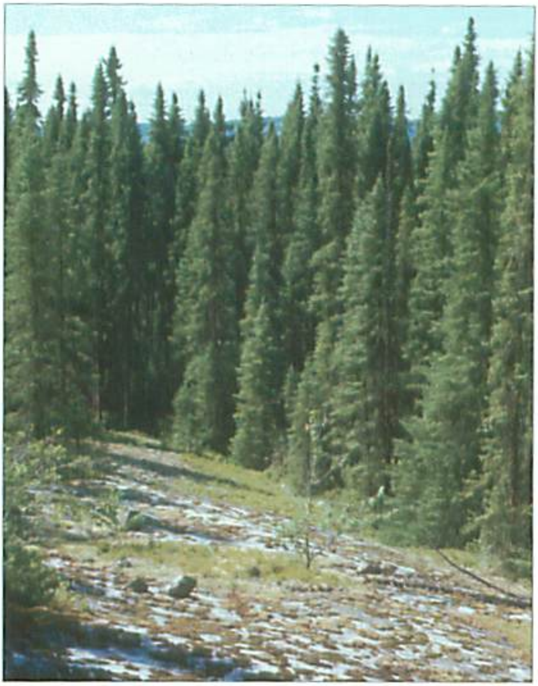


Figure 5.3 Very shallow soils over bedrock.

5.3 How Does Slash Affect Direct Seeding?

Heavy slash reduces the probability of success in direct seeding because it eliminates potential seedbeds. Dense accumulations of fine slash <5 cm in diameter pose the greatest impediment to direct seeding by covering receptive seedbed on lowland sites and preventing effective site preparation on upland sites. Tree-length or shortwood harvesting operations result in fine slash being distributed across the cutover at average volumes of 10.7 to 12.7 m^3/ha (Smith et al. 1985). Full-tree operations reduce fine slash cover on cutovers by about 40 percent. However, delimbing in full-tree operations usually concentrates slash along landings, and direct seeding will not be feasible on that part of the harvest area.

RECOMMENDATIONS

- Reduce the volume of slash by prescribing full-tree harvesting and slash disposal at roadside.
- Alternatively, prescribe tree-length or shortwood harvesting, followed by broadcast burning.

5.4 What Role Does Natural Regeneration Play in Combination With Direct Seeding?

Natural regeneration will often occur on harvest areas where direct seeding is being considered. Levels of natural regeneration should be anticipated and taken into account when developing direct seeding prescriptions. Direct seeding may be a particularly effective complement to planned natural regeneration methods if it can be used to increase regeneration on otherwise understocked portions of the harvest area. If the potential for natural regeneration is high, then it may be preferable to use planned natural regeneration instead of direct seeding to regenerate the area.

5.4.1 Natural regeneration of jack pine

Natural regeneration of jack pine commonly arises from cones in the logging slash, (Figure 5.4) and probably contributes to the regeneration of many direct seeded areas. Tree-length and shortwood systems leave greater post-harvest cone densities than full-tree systems (Figure 5.5). If the post-harvest cone distribution is patchy, then direct seeding may be used to increase stocking of areas that would otherwise be understocked. The recommendations for using the jack pine cone scattering method of regeneration should be followed to maximize the contribution of regeneration from cones (Boisvenue et al. 1994; Bowling and Goble 1994). Note that most seeds are released from cones during the first summer after harvest, so site preparation for direct seeding after this period may destroy some of the naturally regenerated seedlings.

For further information regarding factors which affect cone and seed supply and ingress of natural regeneration refer to Bowling and Niznowski (1991) and Bowling et al (1997).

Figure 5.4 Natural jack pine regeneration from cones in logging slash.

5.4.2 Natural regeneration of black spruce

Black spruce natural regeneration can arise from cones in the logging slash, from seeding-in by residual trees within or adjacent to the harvest area, or from advance regeneration.

5.4.2.1 Natural regeneration of black spruce from cones in logging slash

As with jack pine, large numbers of viable seeds are released from black spruce cone-bearing logging slash (Figure 5.6). If properly distributed throughout the cutover and elevated off the ground to prevent decomposition, these cones can make a substantial contribution to subsequent stocking levels. Most of the viable seed is released within the first year following harvesting (Fleming and Mossa 1996). The most rapid seed release originates from elevated cones above upland humus substrates. A reduction in the number of seeds released and a decline in the number of filled seeds from cones lying on or adjacent to the ground surface can be attributed to a higher cone moisture content and damage caused by pathogens and insects. The total viable seed release after harvest can range from 1–2 million viable seeds/ha.

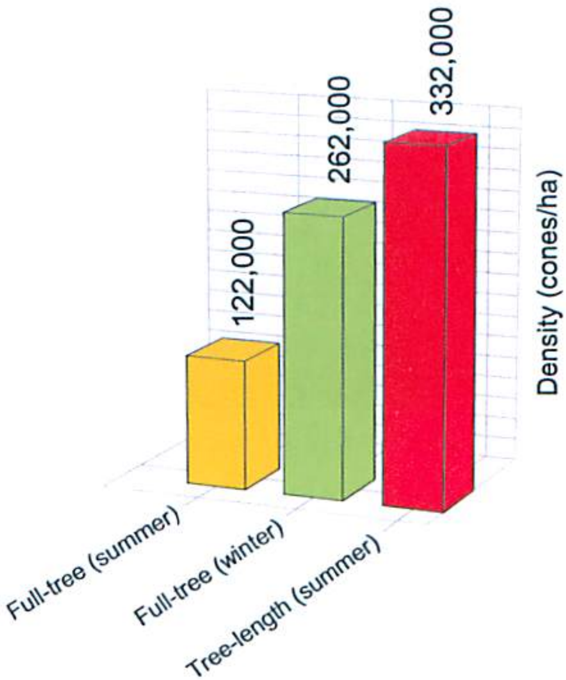


Figure 5.5 Post-harvest jack pine density *(adapted from Bowling and Goble 1994).*

Harvesting systems that leave cone-bearing tops on the cutover are best able to take advantage of this potential seed supply. Scarification should be conducted soon after harvest – delay will result in premature seed dispersal on unreceptive seedbeds. Unlike jack pine, black spruce cone scattering alone will not produce adequately stocked stands on upland sites and should only be used to augment artificial regeneration efforts.

Figure 5.6 Natural black spruce regeneration from cone-bearing logging slash.

5.4.2.2 Natural Regeneration of Black Spruce from Residual Trees

Portions of harvest areas that are within 60 m of residual black spruce stands will receive a substantial amount of seed. Any residual black spruce stems within the harvest area may also provide seed.

5.4.2.3 Natural Regeneration of Black Spruce from Advance Regeneration

Black spruce advance regeneration is common in many black spruce stands, especially in lower density stands on nutrient-poor peatlands (Figure 5.7). The recommendations for harvest methods to preserve advance regeneration should be followed to maximize the contribution of this source of regeneration (Archibald and Arnup 1993). If the distribution of advance regeneration after harvest is patchy then direct seeding can be used to improve stocking.

Stocking of advance growth declines as site conditions become richer or drier (Figure 5.8 and 5.9). Black spruce advance growth stocking levels greater than 40 percent are associated with STs/V-types that have high soil moisture and poor stand nutrient conditions. However, there is great variability in stocking values within these groupings.

Most advance growth mortality occurs within one growing season after harvest (Groot 1995) (Figure 5.10); assessments made after this time will provide a good indication of whether supplementary regeneration efforts will be required.

Figure 5.7 Typical post-harvest advance growth found on Site Type 11.

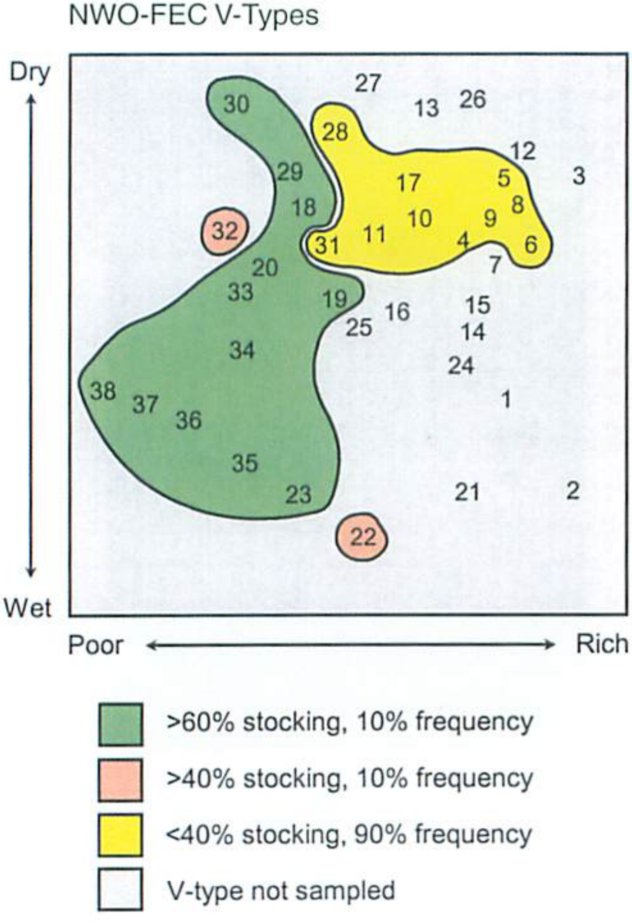


Figure 5.8 An FEC ordination diagram depicting the frequency occurrence of sampled V-types in various black spruce advance growth stocking classes in northwestern Ontario *(Sims and Walsh 1995)*.

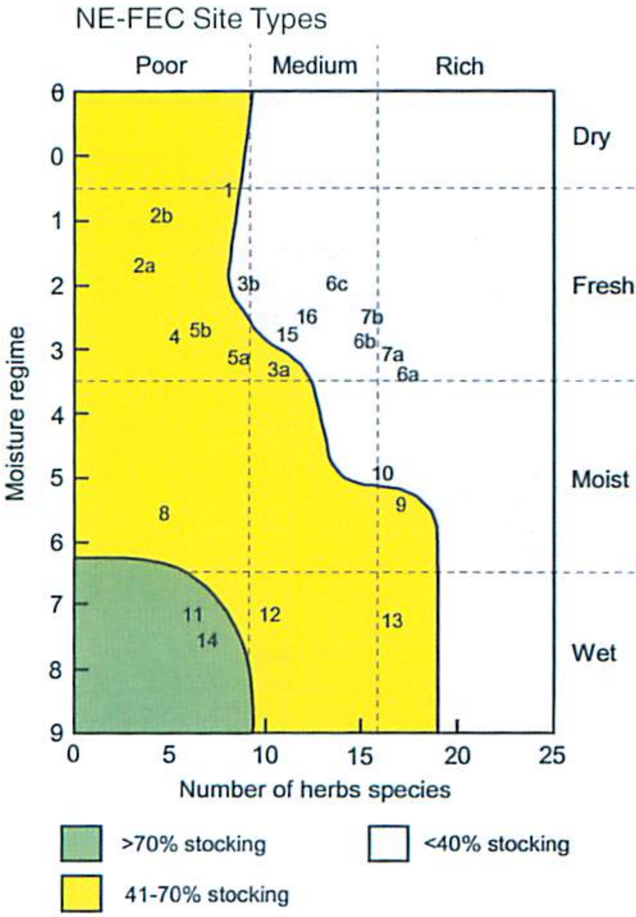


Figure 5.9 An FEC ordination diagram depicting the relationship between site type and abundance of black spruce advance growth by stocking class in northeastern Ontario *(Arnup 1996)*.

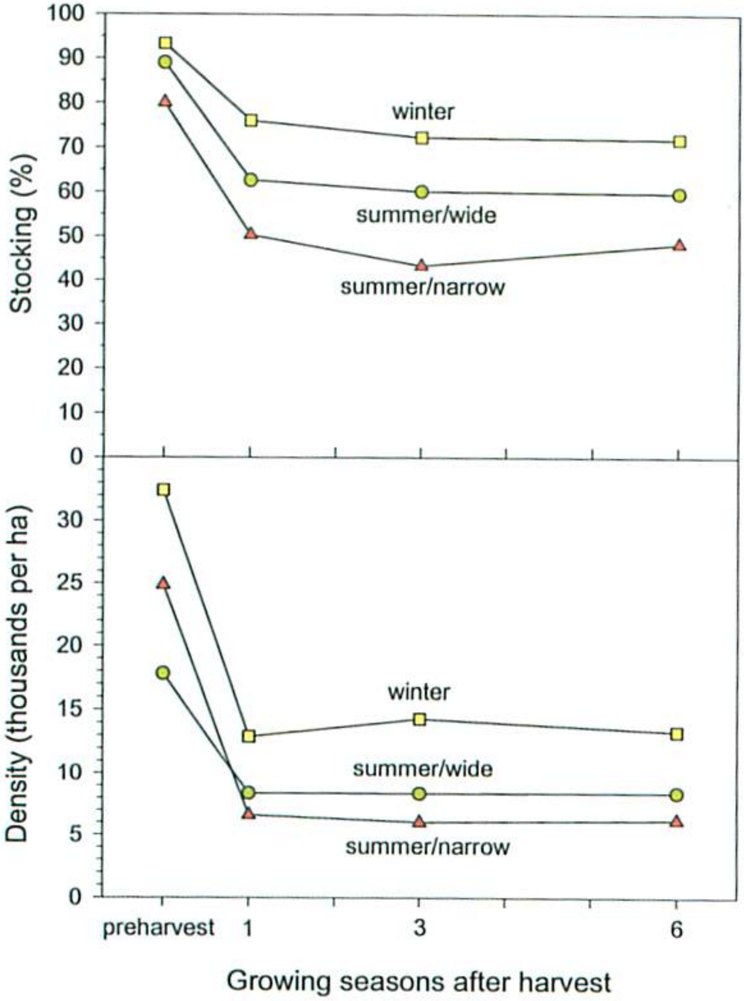


Figure 5.10 Stocking and density of black spruce advance growth before and after harvesting, using three methods *(Groot 1995)*.

6.0 SEEDBED SUITABILITY

6.1 What Makes a Seedbed Receptive?

A receptive seedbed provides conditions suitable for the germination of seeds and the early growth of seedlings. The receptivity of a seedbed depends on many factors, including seedbed type, soil texture, soil moisture regime (SMR), position within the soil horizon and weather conditions. A fundamental requirement for a receptive seedbed is that it provides sustained adequate moisture during the period of seedling establishment.

On uplands, exposed coarse loamy, and to a lesser extent, exposed fine sandy mineral soils are generally excellent seedbeds for spruce and pine because of the following characteristics:

- good capacity for aeration and water infiltration.
- good soil-seed contact for the transfer of moisture to the seed.
- good heat conducting capacity – therefore they warm faster than organic soils.
- they harbour fewer harmful micro-organisms than do organic soils.
- they have substantial water storage capacities and allow good capillary movement of water from the underlying soil matrix.

Seedbeds generally become less receptive as the thickness of organic matter of soil increases, and as the decomposition status of organic matter decreases, because thicker, less decomposed organic material is prone to surface drying. Black spruce is more sensitive than jack pine to these organic matter characteristics.

Although peatlands usually have a shallow water table, seed germination still requires a relatively moist surface. The following conditions provide appropriate moisture levels:

- a predominance of *Sphagnum* moss species, *Sphagnum* peat, sheared *Sphagnum*, or decayed wood.
- an un-disrupted seedbed, whereby the underlying water level can provide continuous moisture to the surface.

Frost heaving can be a serious problem on fine textured mineral soils, such as clays, silts, silty loams, on rotten wood, and deep humic materials. The danger of frost heaving may be reduced, however, if mineral soil is covered by a layer of organic matter (e.g., dead leaves or grasses), because of its insulating effect on the soil. On peatland sites, well decomposed organic peats (black muck) exposed by disturbances are particularly prone to frost heaving because of their colloidal nature and water holding capacity.

6.2 How is Receptivity Determined?

Seedbed receptivity can be measured by the establishment ratio (ER) – the number of established seedlings per viable seeds sown (e.g., two established seedlings out of five viable seeds sown gives an ER of 40%).

Establishment ratios for a given seedbed type are most reliably obtained by monitoring seed spots (See Section 11). ER values for the most common seedbed types are given in the seedbed data sheets (SDS) presented in this chapter.

6.3 How do Seedbeds Change with Time?

The quality of seedbeds changes with time because of soil movement, weathering, litter accumulation and the ingress of vegetation. Changes in seedbed quality begin within a year of site preparation, but are most noticeable three-to-five-years afterwards, especially on the drier upland sites.

On uplands, heavy rainfall can wash mineral soil into depressions and bury seeds. Large seeds, such as the pines, can germinate at depths of up to 7.5 cm, but smaller seeds such as black spruce can tolerate little more than 1 cm of soil coverage (Arnott 1973). Mechanical erosion of recently scarified seedbeds following heavy rains, independent of the degree of slope, may account for 20% of seed losses due to the smothering of seeds by debris. This may be mitigated by delaying seed application until after initial weathering of the site preparation has occurred.

Weathering refers to physical or chemical changes induced by environmental conditions. For example, crusts, which are sometimes observed to develop on exposed soil surfaces, are thought to decrease receptivity. Another example of weathering is the breakdown of surface organic layers. Thinner, more decomposed layers (e.g., H horizon) are most susceptible to this breakdown.

The cover of shrubs, herbs and grasses often increases rapidly following forest harvesting. This vegetation cover, and the litter that it produces, commonly decreases the cover of receptive seedbed types. The development of lichen mats (*Cladonia* and *Cladina* spp.) also reduces seedbed receptivity.

Pioneer mosses (e.g., *Polytrichum* spp. and *Dicranum* spp.) invade seedbeds about 2 years after site preparation, and are most prevalent on moister sites that lack heavy grass competition. These mosses make good seedbeds initially, because of their slow growth and minimal competition for light and moisture. Three or four years after their establishment, however, the height growth of some species can prevent further black spruce ingress.

On peatland sites, the tendency is to increasing cover of living *Sphagnum* mosses. This can be positive if this seedbed replaces a poor seedbed, but often the more receptive *Sphagnum* peat is also covered over.

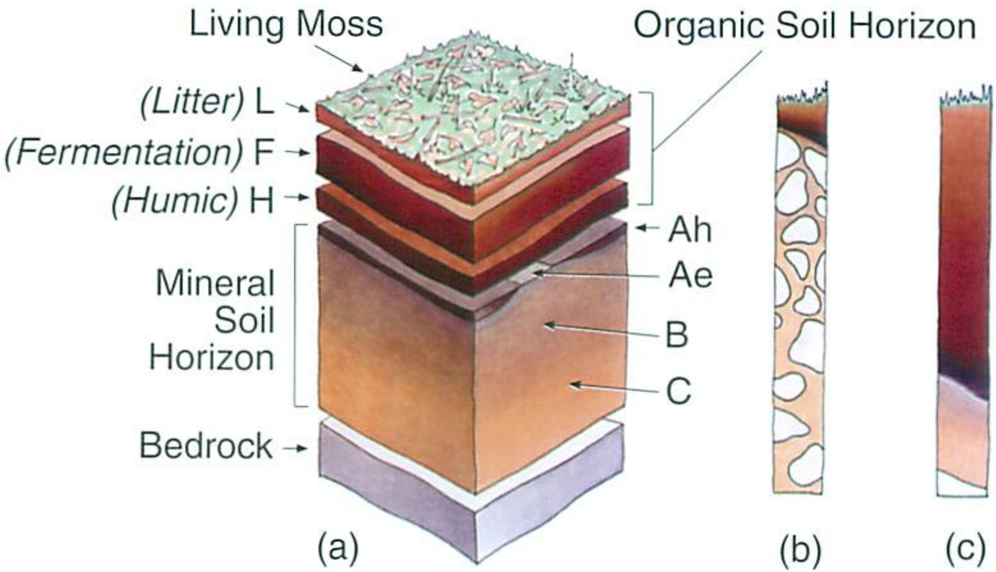


Figure 6.1 (a) A typical undisturbed upland forest soil profile common to northern Ontario. (b) very shallow soil on boulder pavement (c) peaty phase (mineral) soil profile.

6.4 What Establishment Ratios can be Expected?

6.4.1 Black spruce uplands

Black spruce establishment ratios are strongly affected by the position of the seedbed in the original soil profile. A typical undisturbed deep upland soil profile (Figure 6.1a) comprises the following layers, going from the organic matter surface downwards to the mineral soil: the litter layer (L), the fermentation layer (F), the humus layer (H), the upper mineral soil horizons (Ah, Ae and B) and the lower mineral soil horizon (C). The depth and structure of minerals soils can be highly variable ranging from very shallow to peaty phase (mineral) soils (Figure 6.1b & c). A certain amount of variability can exist even within a seeding block. Site specific site preparation equipment and operator awareness and flexibility will assist in achieving the prescribed seedbed exposure.

On coarse-textured tills, spruce seedlings establish mainly on thin F, thin H, and upper mineral soil horizons (<10 cm below the mineral soil/humus interface). On all sites, ERs are significantly greater on seedbeds near the mineral soil/ humus interface than on seedbeds located at or just below the forest floor surface (Fleming and Mossa 1995a). Some types of site preparation equipment produce inverted surface horizons with a mineral soil cap; if this cap is thin, these mounds are little better than litter or thick F (>5 cm thick) seedbeds. On drier soils, results are best on upper mineral soil horizon seedbeds (<10 cm mineral soil removed), but on moist to very moist soils, thin F seedbeds have the best results. Lower mineral soil horizon seedbeds (>10 cm mineral soil removed) give poorer results than do seedbeds located just above or below the mineral soil/humus interface.

Differences between establishment ratios at the mineral soil/humus interface and on undisturbed ground surfaces are smallest on moist to very moist soils, and greatest on very fresh to moderately moist soils. Thus, good quality site preparation that exposes much receptive seedbed area will be most advantageous on very fresh to moderately moist soils.

Establishment ratios are poorer for all seedbed types on the more coarse-textured soils (sands and loamy sands) and very shallow soils (SS3) where soil moisture is the limiting factor. Because of slow initial root development, black spruce establishment on these site types is generally unsuccessful.

The highest ERs on coarse-textured soils are often found on thin H or upper mineral soil horizon seedbeds with very fresh to moderately moist soils. Near-

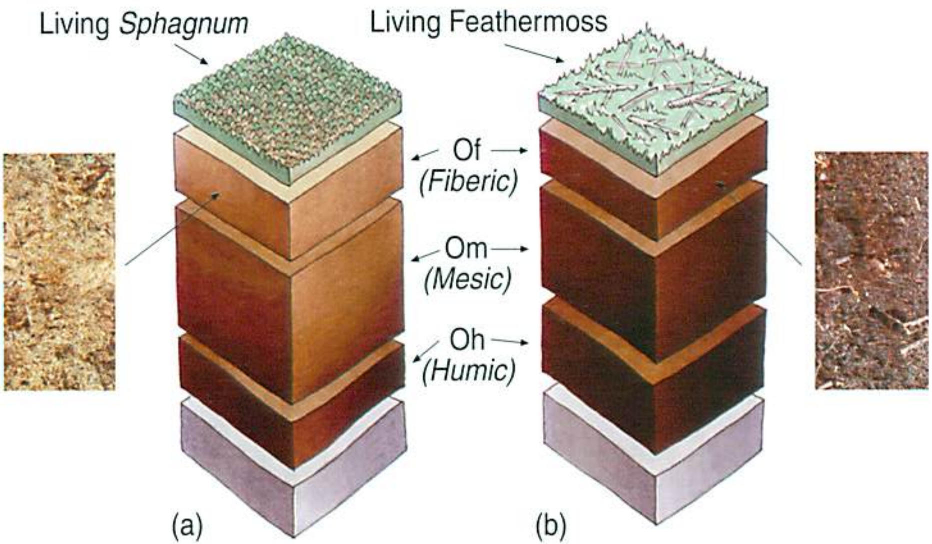


Figure 6.2 Two typical undisturbed peatland soil profiles showing the various humus types and their relative position within the soil horizon; a) represents a soil profile that has developed from *Sphagnum* while b) has developed from feathermoss. Note the humus layers that originate from *Sphagnum* are lighter in colour.

surface moisture levels are adequate, but spring and fall soil moisture content is not so high that it causes extensive frost heaving. On finer textured soils, high soil moisture content reduces soil aeration and can result in flooding, which is why the best seedbeds are found closer to the soil surface, usually on the thin H and F layer.

For many seedbeds ERs vary considerably among seeding years, probably a reflection of variation in weather. However, the relative rankings of different seedbeds on a particular site are usually similar from year to year.

6.4.2 Black spruce lowlands

Establishment ratios on lowland sites are generally greatest on poorly decomposed *Sphagnum* peat seedbeds exposed during the harvesting operation or following site preparation. The average 5th year ER for this seedbed is about 40%. Black spruce establishment ratios diminish throughout the first 5 year period on almost all lowland seedbed types, but declines are most marked on well-decomposed organic matter and pioneer mosses, followed by rotten wood and living *Sphagnum* seedbeds (Groot and Adams 1994). Frost heaving, erosion, and aggressive *Sphagnum* encroachment are the main causes for these declines.

Figure 6.2 illustrates two typical undisturbed peatland soil profiles depicting the various humus types and their relative position within the soil horizon. Of *(fibric)*, Om *(mesic)* and Oh *(humic)* are organic horizons developed mainly from mosses, rushes and woody material and are generally defined by their degree of decomposition. For field testing procedures refer to the Von Post Scale of Decomposition *in* Field Manual for Describing Soils (Ontario Institute of Pedology 1985).

6.4.3 Jack pine sites

Establishment ratios for jack pine are strongly related to the availability of sufficient moisture to support both germination and growth until the new germinant has produced root growth adequate to access permanent soil moisture. Substrates that maintain available near surface moisture between rainfall events tend to be better substrates for establishing jack pine. On ecosites suitable for seeding jack pine, exposed mineral soil generally meets this requirement: surfaces dry rapidly providing a thin mineral soil mulch that delays drying of the underlying substrate. Similarly, thin H and/or FH horizons tend to mitigate the drying of underlying mineral soil. On organic layers of increasing thickness jack pine can establish as soil moisture regime increases from moderately fresh to moderately moist. Both length and frequency of droughts during germination and the 40 to 60 day period following germination increases mortality on any substrate. Growth of the established seedling must also be considered; maximum seedling heights following three growing seasons generally occurs on or adjacent (within a few cm) to organic substrates over mineral soil. Conversely, while establishment may be consistently high on exposed lower mineral soil horizons, 3-year height growth tends to be relatively suppressed.

6.4.4 Prescribed burns

6.4.4.1 Black spruce

Prescribed fire plays a minor role in regenerating black spruce, although it can be effective (Archibald and Baker 1989). Desirable seedbed is exposed through the consumption of slash and reduction of the organic mat, which directly relates to the intensity of the burn. Site type, available fuels and ignition pattern have an effect not only on the amount of seedbed exposure but also on competition response.

Expect ER values to be very low on feathermoss-dominated sites[1] if the burn is not sufficiently intense to eliminate both L and F horizons and to expose the underlying well-decomposed humus layer. In contrast, a light intensity burn with little duff removal on *Sphagnum*-rich sites[2] will temporarily retard *Sphagnum* growth and provide excellent conditions for black spruce establishment. Alder-dominated sites[3] can be problematic: too deep a burn can lead to an increase in shrub and graminoid competition, while a low depth-of-burn may promote vegetative suckering (Aksamit 1982). Application of herbicide prior to ignition can help to dry the vegetation and allows a moderate-to-deep burn to be conducted under lower indices (Elliott 1988). This type of burn will result in the creation of receptive seedbeds with little initial competition response.

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1 NWO FEC V-types 20, 31, 33 and 34; NE FEC V-types 18, 22 and 23.

2 NWO FEC V-types 37 and 38; NE FEC V-types 25 and 26.

3 NWO FEC V-type 35; NE FEC V-types 21 and 24

Establishment ratios on burned upland spruce sites are highly variable. Avoid seeding on coarse textured soils where the usually thin organic layers are completely consumed (Viro 1974); drought and lethal temperatures will limit survival. A mosaic of exposed mineral soil and thin (< 5 cm) of humus over mineral soil offers the best seeding chance.

6.4.4.2 Jack pine

At first glance, a fresh burn appears as a uniform blackened surface of ash and char over organic matter and/or mineral soil and/or rock. Despite this apparent uniformity, there is considerable variation in the type and depth of the organic layer, in the depth and texture of mineral soil and in moisture regime and drainage. These characteristics all affect jack pine seedling establishment ratios.

For shallow to deep mineral soils (>15 cm depth to bedrock), establishment ratios are greater than 10% on thin (<1 cm) organic layers. On very shallow mineral soils (<15 cm depth to bedrock), however, establishment ratios are low on thin organic layers. Establishment ratios are generally greater on moderately fresh to moderately moist moisture regimes than on drier conditions. Establishment ratios are near 0 on bedrock or boulder surfaces and on wetland inclusions; these substrates should be considered non-receptive.

6.5 How are Seedbed Types Identified and Defined?

A series of seedbed data sheets (SDS) has been developed to identify, describe, and characterize seedbed types. The SDSs are divided into three main categories; black spruce lowland seedbeds, black spruce upland seedbeds and jack pine seedbeds. These are further subdivided by type of site preparation used to create the seedbed – by either mechanical means or by prescribed fire (refer to the SDS Index on page 76). The SDSs represent the more commons seedbed types found in these categories and will also include associated undisturbed seedbeds. A similar presentation format is used for spruce upland and lowland categories, based on fifth year seed spot data collected over several years from a variety of site types (Groot and Adams 1994; Fleming and Mossa 1994, 1995b).

Because there have been no comprehensive studies examining the range of jack pine seedbeds, the jack pine SDSs are based on operational trials and some research studies (Sims 1970; Winston and Schneider 1977; Winston 1980). Experience-based estimates of ERs are provided for jack pine seedbeds that have not been examined in trials or studies.

Establishment ratios for black spruce on prescribed burns are based on fifth year seed spot data collected from three prescribed burn seeding trials located in northeastern Ontario (Adams 1993).

SDSs for jack pine seedbeds on prescribed burns were developed using third year data from three experimental trials conducted in northeastern Ontario (Foreman 1997). Substrate material, substrate thickness and local soil moisture regime were all used to characterize seedbeds in these trials. Two of the three establishment years experienced lower than normal rainfall over the critical germination-establishment season, which may help to explain the range in standard deviation.

These data sheets can be used at various stages of decision making:

- Pre-site preparation stage: to assist in determining the target seedbed types to be created by site preparation.
- Post-site preparation stage: used by the assessment crews to accurately identify the type and quantity of available seedbeds.
- Seeding prescription stage: the SDSs provide the mean receptivity value for input into PC-SEED (Section 9).

6.5.1 Description of the seedbed data sheets

Figure 6.3 describes the layout of the seedbed data sheets. The banner at the top of the page identifies the seedbed type and assigns it a number [1]. This banner is colour coded for mechanically site prepared (MSP) black spruce lowland sites (pink), MSP black spruce upland sites (blue), prescribed burned black spruce upland and transitional sites (yellow), MSP jack pine sites (green) and prescribed burned jack pine sites (brown). The layout for individual (MSP) black spruce and jack pine seedbed types have a similar format which includes: single or multiple photographs depicting the physical attributes of the seedbed [2]; a brief description of the seedbed [3]; an illustration representing the relative location of the seedbed within a soil profile [4]; graphs indicating the change in establishment ratios with time and the relationship between stocking and the number of seeds sown [5]. ER values [6] are placed on a modified Soil Moisture Regime scale [7]. Lines extending above and below the circle [8] represent the standard deviation of the mean. The grey-shaded area [9], which extends to the left and right of the circle, represents the range of soil moisture regimes covered by that particular data set.

The SDS layout for prescribed burn seedbeds may vary somewhat from this format. However, all SDSs share the same purpose; to help identify seedbed types and to supply an estimated receptivity value and standard deviation.

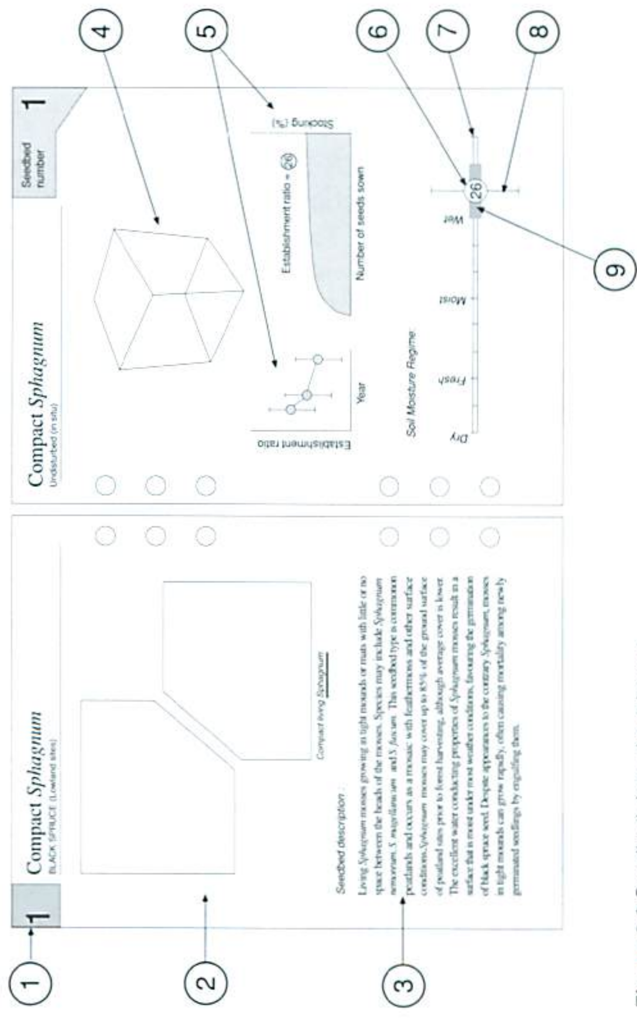

Figure 6.3 Seedbed data sheet layout.

6.5.2 Seedbed Data Sheet (SDS) Index

Seedbed Numbers 1 to 8	BLACK SPRUCE on lowland site types • *mechanical site preparation*
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Seedbed Numbers 17 to 22	BLACK SPRUCE on upland and transitional site types • *site prepared by prescribed burning*
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Black Spruce Seedbeds

Lowland Seedbed Types

Upland Seedbed Types

Prescribed Burn Seedbeds

Compact Sphagnum
BLACK SPRUCE (Lowland Sites)

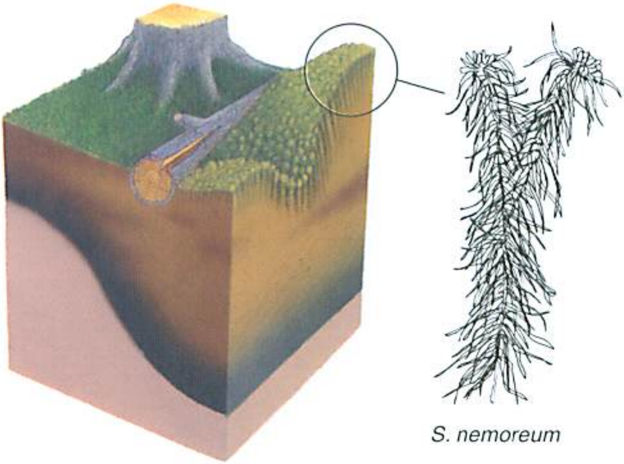
Compact living Sphagnum

Seedbed Description:

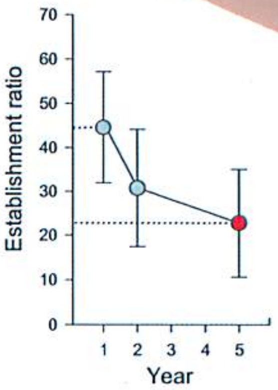
Living *Sphagnum* mosses growing in tight mounds or mats with little or no space between the heads of the mosses. Species may include *Sphagnum nemoreum, S. magellanicum* and *S. fuscum*. This seedbed type is common on peatlands and occurs as a mosaic with feather-mosses and other surface conditions. *Sphagnum* mosses may cover up to 85% of the ground surface of peatland sites prior to forest harvesting, although average cover is lower. The excellent water conducting properties of *Sphagnum* mosses result in a surface that is moist under most weather conditions, favouring the germination of black spruce seed. Despite appearances to the contrary, *Sphagnum* mosses in tight mounds can grow rapidly, often causing mortality among newly germinated seedlings by engulfing them.

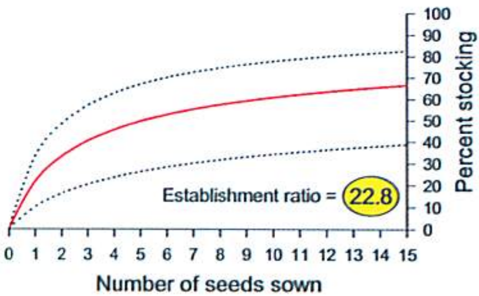
Compact Sphagnum
Undisturbed (in situ)

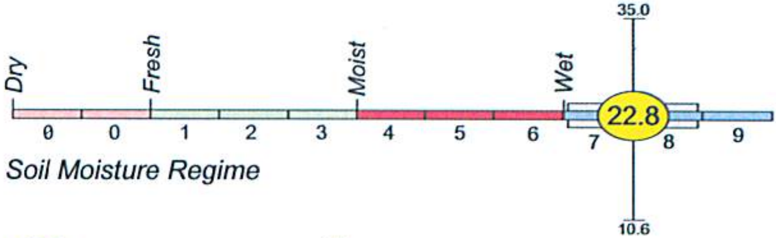
Seedbed Number 1



S. nemoreum







Establishment ratio — Standard deviation — Range

Loose Sphagnum

BLACK SPRUCE (Lowland Sites)

Loose Sphagnum (under shade)

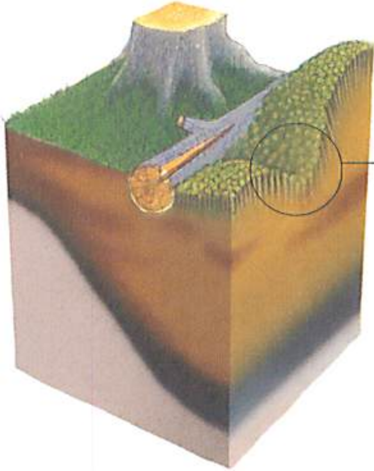
Loose Sphagnum (under full sun)

Seedbed Description:

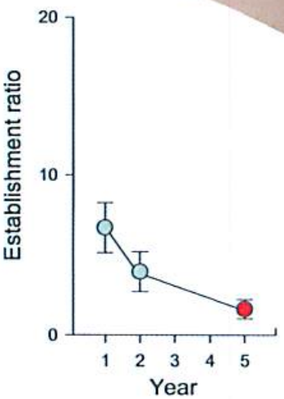
Living *Sphagnum* mosses growing in loose mounds or mats with large gaps between the heads of the mosses. Species may include *Sphagnum girgensohnii* and *S. angustifolium*. The loose growth habit is less common than the compact habit, particularly in the open after harvesting. This seedbed is not favourable for seedling establishment because of the likelihood of seeds falling into the gaps between the heads of the mosses. Even if seeds germinate further down among the moss stems, they have little chance of growing above the surface of the mosses.

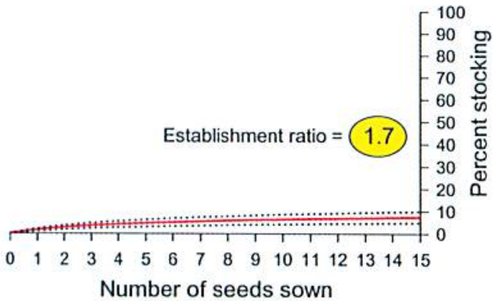
Loose Sphagnum
Undisturbed (in situ)

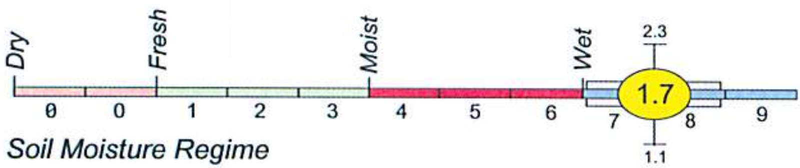
Seedbed Number 2



S. girgensohnii







Establishment ratio — Standard deviation — Range

Living feathermoss
BLACK SPRUCE (Lowland Sites)

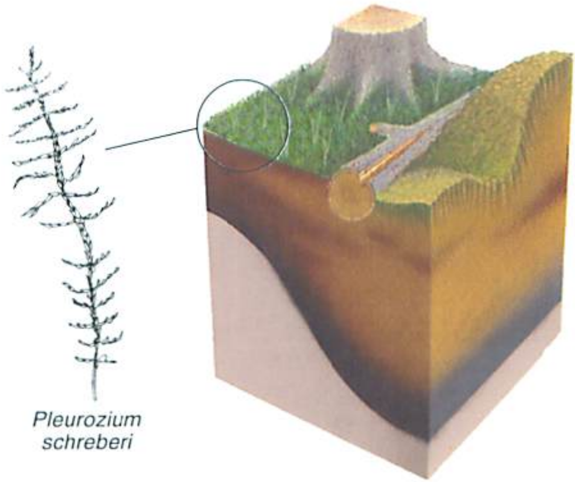
Pleurozium schreberi (under shade)

Pleurozium schreberi (under full sun)

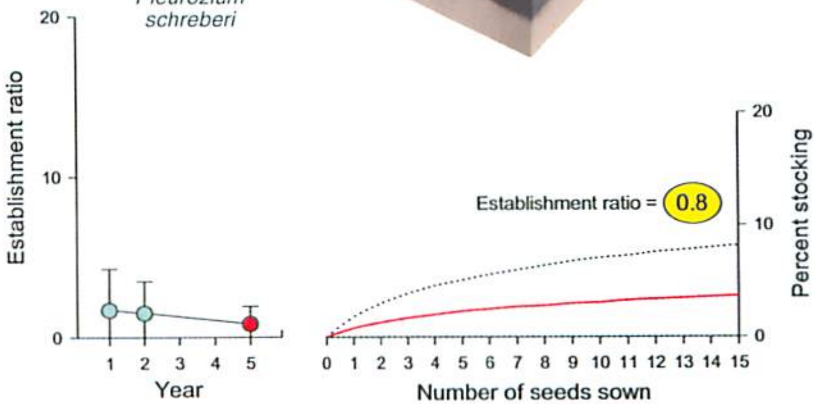
Seedbed Description:

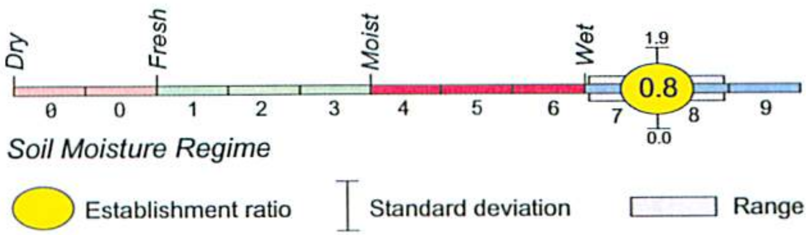
Living feathermosses (*Pleurozium schreberi, Ptilium crista-castrensis, Hylocomium splendens and Dicranum spp.)* growing in mats. This seedbed type is common on a wide range of jack pine and black spruce site types. Cover values can exceed 50% on upland sites, and can be as high as 70% on peatlands. Because feathermosses dry very rapidly after rainfall, they are highly unfavourable for seedling establishment. High mortality of feathermosses is common on removal of the overstory.

Living feathermoss
Undisturbed (in situ)



Pleurozium schreberi





Poorly decomposed Sphagnum peat

BLACK SPRUCE (Lowland Sites)

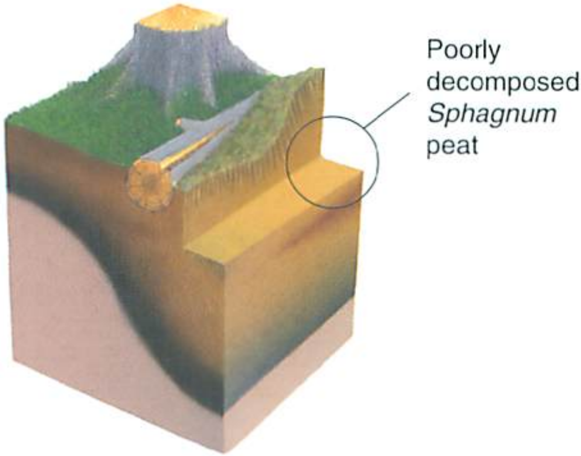
Poorly decomposed Sphagnum peat

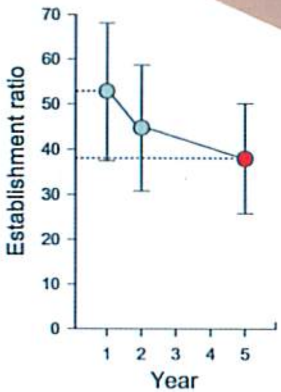
Seedbed Description:

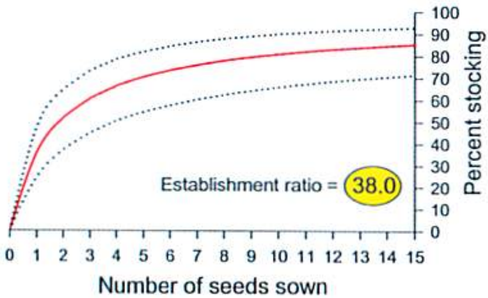
Stems and foliage of *Sphagnum* mosses in the initial stages of decomposition. Much of the original structure of the mosses is still evident in this seedbed, and colour ranges from a pale straw colour to yellowish-brown. This seedbed can be produced by removing the living portions of *Sphagnum* mosses by winter shearblading, prescribed fire or by the scraping action of harvesting equipment and skidded trees. Black spruce establishes very well on this seedbed, because the water-supplying characteristics of *Sphagnum* cells maintain a moist surface and competition by living mosses has been eliminated. *Sphagnum* peat is a nutrient-poor medium, however, and seedling growth can be slow on this material.

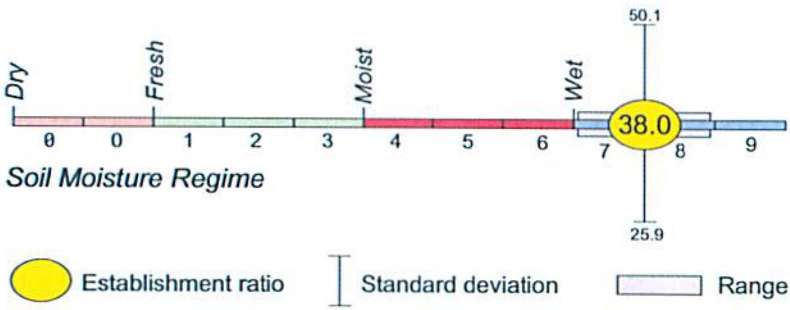
Poorly decomposed Sphagnum peat
Exposed following mechanical site preparation

Seedbed Number 4









5 *Poorly decomposed feathermoss peat*

BLACK SPRUCE (Lowland Sites)

A thin layer of poorly decomposed feathermoss peat over a well-decomposed feather-moss layer.

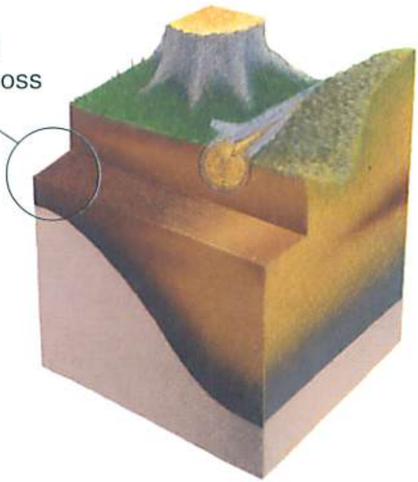
Seedbed Description:

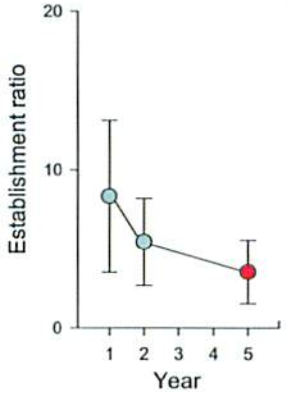
Stems and foliage of feathermosses in the initial stages of decomposition. Some of the original structure of the mosses is still evident in this seedbed, and colour ranges from a light brown to brownish-black. This seedbed can be produced by removing the surface layer of feathermosses by mechanical site preparation, prescribed fire or harvesting disturbance. Seedling establishment is poor on this seedbed, because the surface layer dries very rapidly after rainfall. Establishment improves if only thin layers of this seedbed occur over mineral soil, better decomposed organic matter or *Sphagnum* peat.

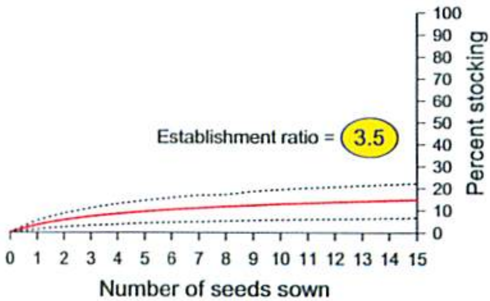
Poorly decomposed feathermoss peat

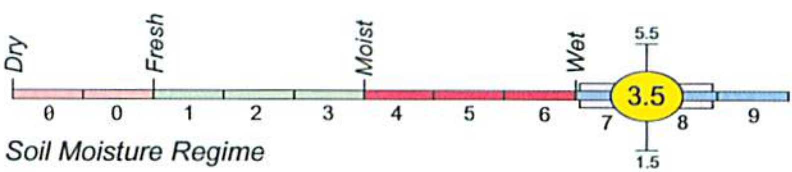
Exposed following mechanical site preparation

Seedbed Number 5









Displaced Sphagnum peat

BLACK SPRUCE (Lowland Sites)

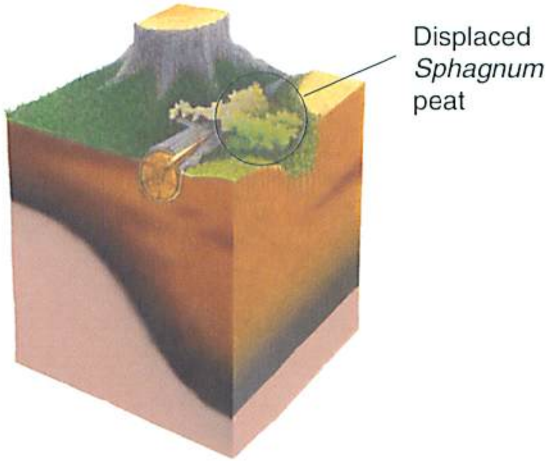
Displaced Sphagnum peat

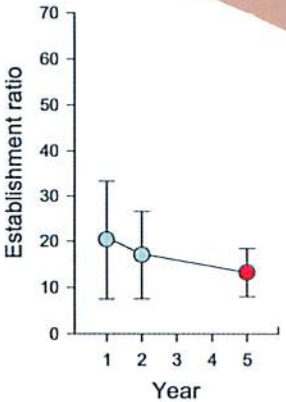
Seedbed Description:

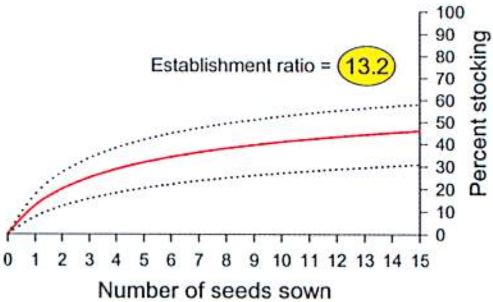
On peatland types, winter shearblading, or more rarely, harvesting disturbance, can detach chunks of *Sphagnum* peat and deposit them on the soil surface. The suitability of this material for seedling establishment depends upon the size of the chunk and the degree of contact with the underlying peat soil. Larger chunks have greater moisture reserves and dry less quickly. If the chunk rests on slash, it will dry because moisture cannot be absorbed from the soil. In general, seedling establishment is poorer on this material than on *Sphagnum* peat in situ.

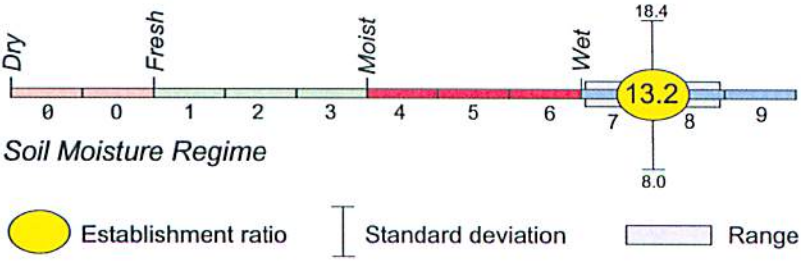
Displaced Sphagnum peat

Exposed following mechanical site preparation





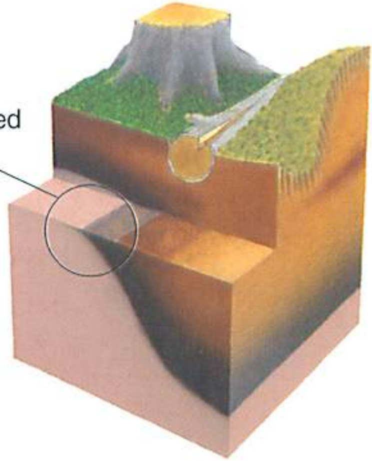


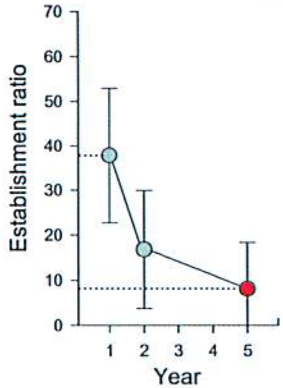


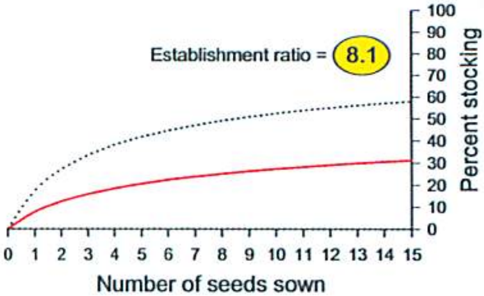
Moderately to well-decomposed organic matter

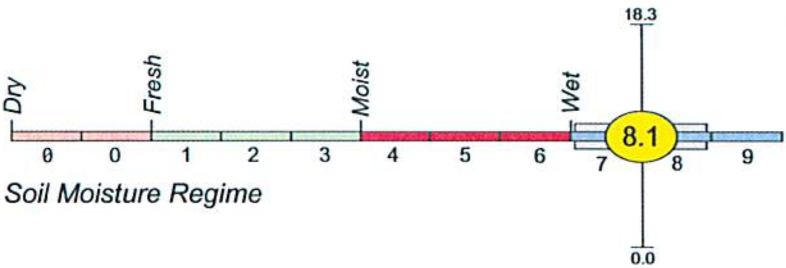
Seedbed Description:

On peatland types, disturbance by harvesting or site preparation equipment can expose better-decomposed layers of peat. This substrate is dark brown or black in colour when wet, and originates from the Oh or Om layers. Proximity to the water table and fine texture maintain a constant supply of moisture at the surface of this seedbed, promoting seed germination. High mortality is usual, however, because of flooding, frost-heaving, erosion and competition from other vegetation, especially grasses and sedges, which often establish aggressively on this material.









Establishment ratio | Standard deviation | Range

Moderately to well-decomposed wood fiber

BLACK SPRUCE (Lowland Sites)

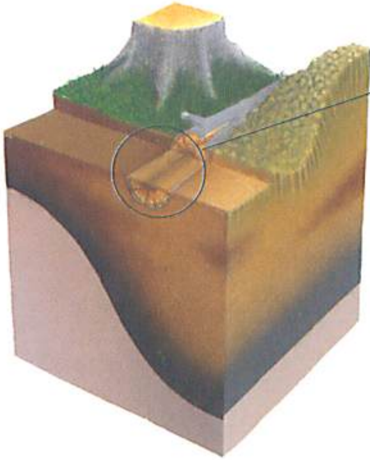
Moderately to well-decomposed wood fibre

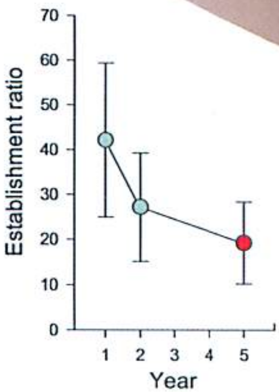
Seedbed Description:

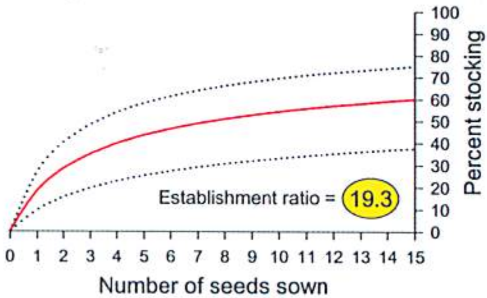
Partially decomposed stumps and fallen logs are present on most forest floors. In the initial stages of decay, the wood becomes somewhat spongy and it is possible to rub off some fibres. With more advanced decay, wood develops a buttery consistency. Rotten wood has good moisture-retaining characteristics and permits good seed germination. Significant mortality usually occurs, however, because of frost-heaving, and, on well-decomposed wood, erosion.

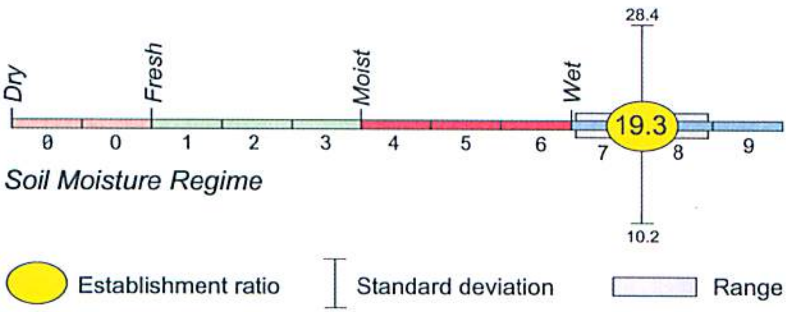
Moderately to well-decomposed wood fiber

Exposed following mechanical site preparation









Litter: Undecomposed organic matter
BLACK SPRUCE (Upland Sites)

Surface litter

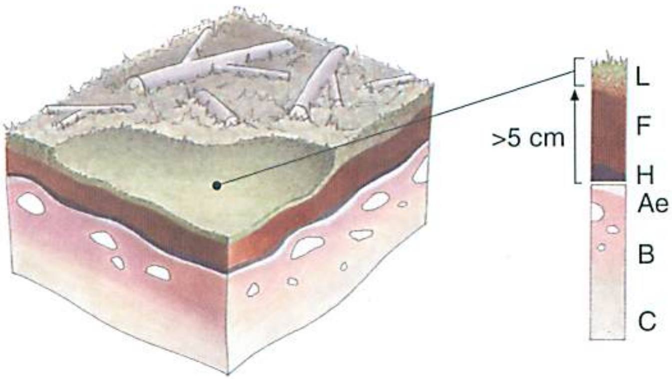
Sub-surface L horizon

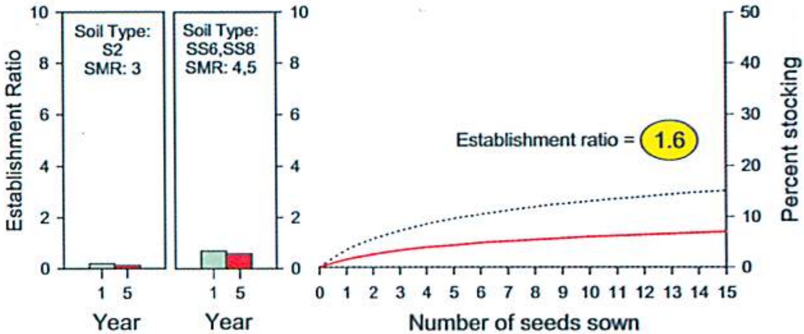
Seedbed Description:

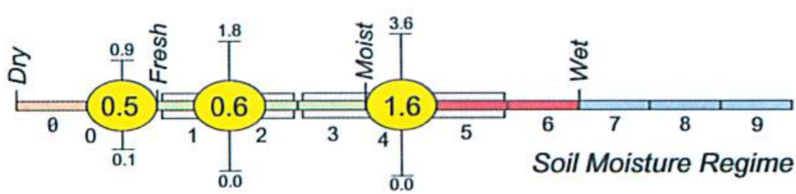
This material forms the L horizon of upland forest soils, the uppermost layer of the forest floor. There are many varieties of litter seedbeds, depending on vegetation and soil characteristics, but all are characterized by an accumulation of leaves, needles, twigs and woody materials. Most of the original structures are easily discernible. It forms the substrate for feathermoss growth in the understory of developing stands. Following clearcutting, these seedbeds are characterized by extreme temperatures and lack of available water.

Litter

>5 cm above the mineral soil/humus interface







10 *Thin-F: Partially decomposed organic matter*
BLACK SPRUCE (Upland Sites)

Thin F horizon

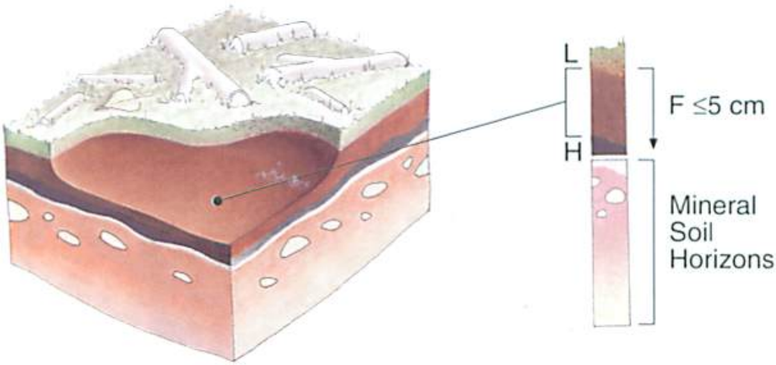
Seedbed Description:

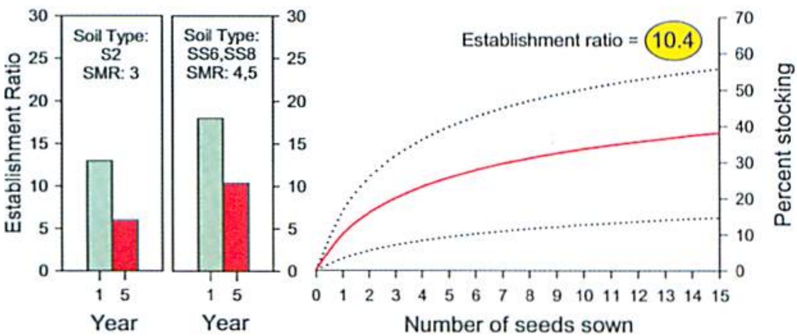
This material forms the F horizon of upland forest soils. It is characterized by an accumulation of partly decomposed organic matter derived largely from leaves and woody material. Some of the original structures are difficult to recognize and may be altered by soil fauna (moder) or permeated by fungal hyphae (mor). This seedbed type is found just above thin-H and/or shallow mineral seedbeds and is commonly exposed by light disturbance.

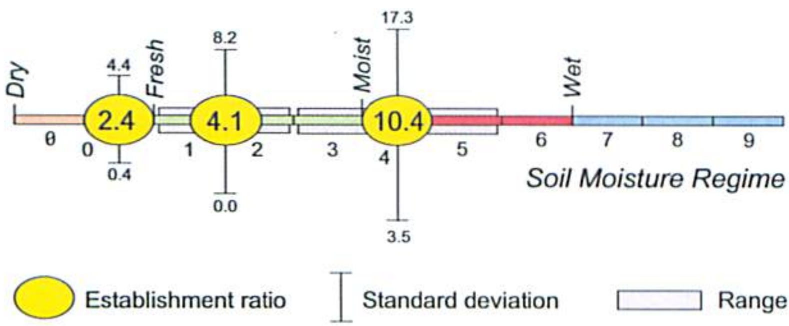
This seedbed type changes less with time than other types. Most changes occur between years three and five, generally developing into litter seedbeds on drier sites, dense graminoids on productive sites and pioneer mosses on the more moist sites.

Thin-F

≤5 cm above the mineral soil/humus interface







Thick-F: Partially decomposed organic matter

BLACK SPRUCE (Upland Sites)

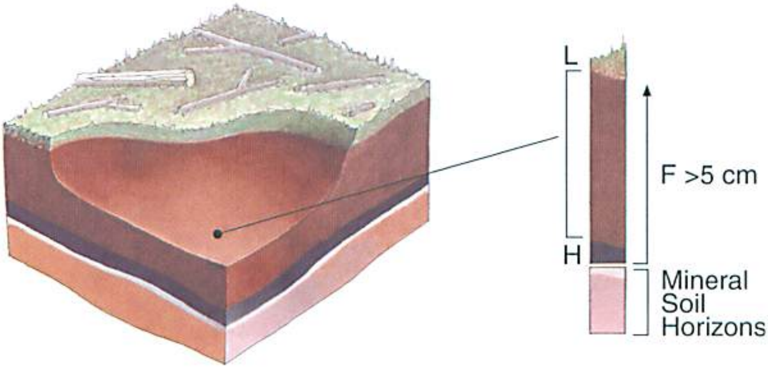
Thick F horizon

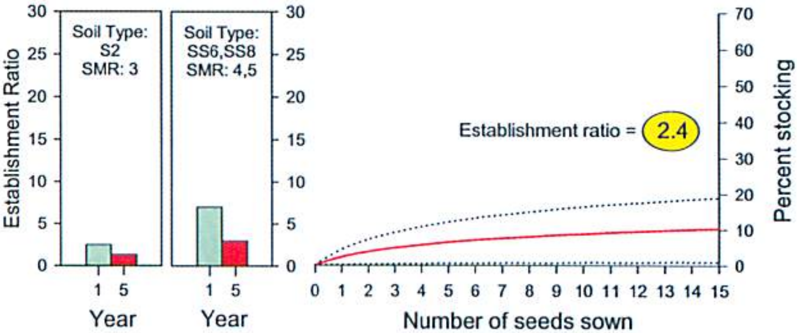
Seedbed Description:

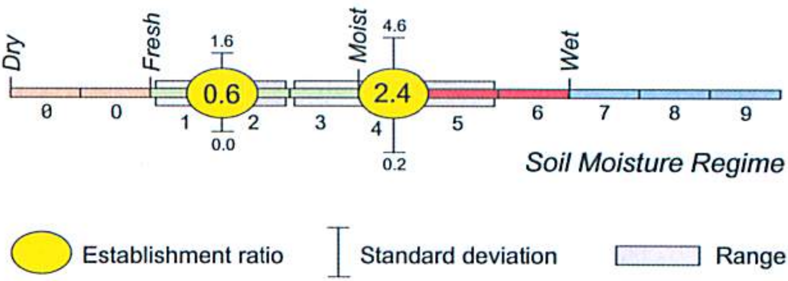
This seedbed is same as seedbed 10 but is thicker and thus further away from the soil/humus interface. Because this seedbed is in the initial stages of decomposition its texture predisposes it to desiccation following exposure. It also lacks the nutrients required for early seedling development. Generally the thicker the layer the poorer the establishment ratio. The only condition where this substrate would have some potential is if it was allowed to settle onto a firm base and was situated on deep soils with higher water contents (SMR >4).

Thick-F

>5 cm above the mineral soil/humus interface







12 *Thin-H: Well decomposed organic matter*
BLACK SPRUCE (Upland Sites)

Thin H horizon

Seedbed Description:

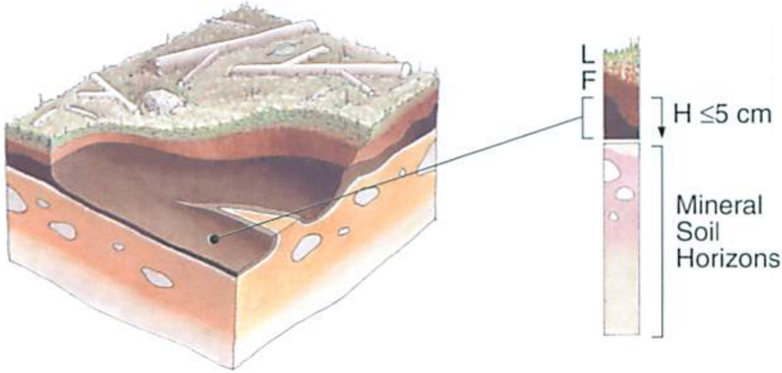
This material is composed of the H and Hi horizons of upland boreal forest soils (<40 cm of organic matter over mineral soil) under coniferous stands. It is characterized by an accumulation of decomposed organic matter in which the original structures are indiscernible. These horizons are found just above, and may be sharply delineated from (mor) or partially incorporated into the mineral soil (moder, mull). Although uncommon in boreal conifer forests, Ah horizons, mineral soils enriched with organic matter, are also included in this category.

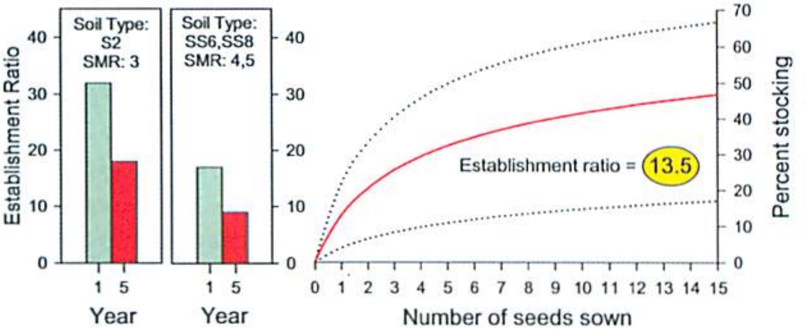
This seedbed type weathers rapidly; the frequency of occurrence can be reduced by 50% within a year of site preparation. By year five less than 10% of this type may still be present.

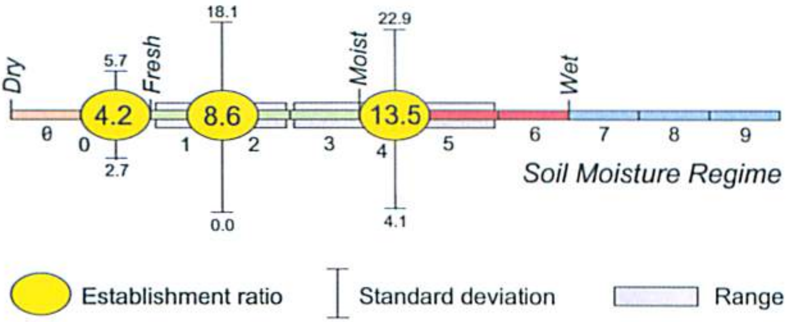
Thin-H

≤5 cm above the mineral soil/humus interface

Seedbed Number 12







Upper mineral soil horizon

BLACK SPRUCE (Upland Sites)

Upper mineral soil exposure

Seedbed Description:

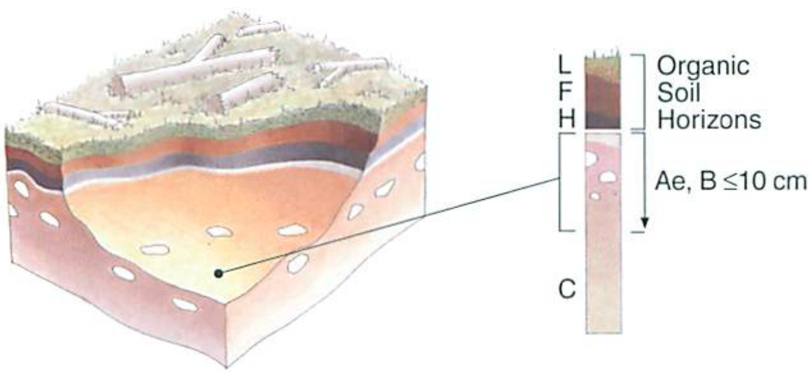
This material consists of Ae and B mineral soil horizons. Ae horizons are light-coloured surface horizons characterized by the loss (eluviation) of clay, iron, aluminum and/or organic matter. B horizons are characterized by enrichment in clay organic matter, iron, aluminum or clay; by soil structure development; or by a colour change denoting reduction or oxidation. These include Bt horizons, which are greyish-brown subsurface horizons enriched with clay; Bf horizons, which are reddish-brown subsurface horizons with accumulations of iron, aluminum and organic matter; Bm horizons, which are brownish subsurface horizons with only a slight addition of iron, aluminum and/or clay; and Bg horizons, which are mottled or greenish to bluish grey subsurface horizons characterized by periodic or permanent saturation. The quality of these seedbeds is greatly affected by soil texture, and to a lesser degree, Soil Moisture Regime. Coarse sandy mineral soils are often too dry to support good establishment, whereas fine loamy-clayey mineral soils often suffer excessive frost heaving. Best results are often obtained on fine sandy to silt loamy textures.

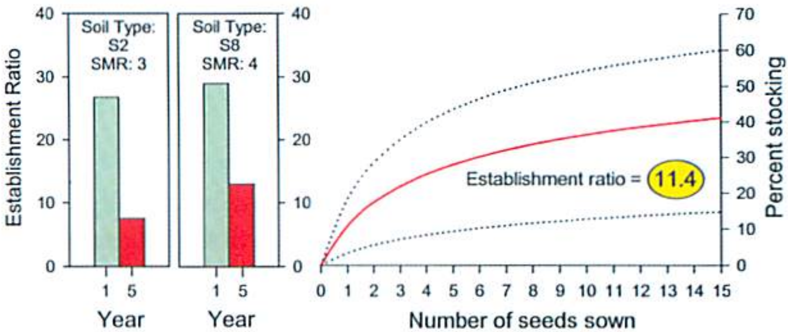
This seedbed type can retain over 50% of the original cover up to year three; cover declines markedly thereafter as a result of invasion by pioneer mosses.

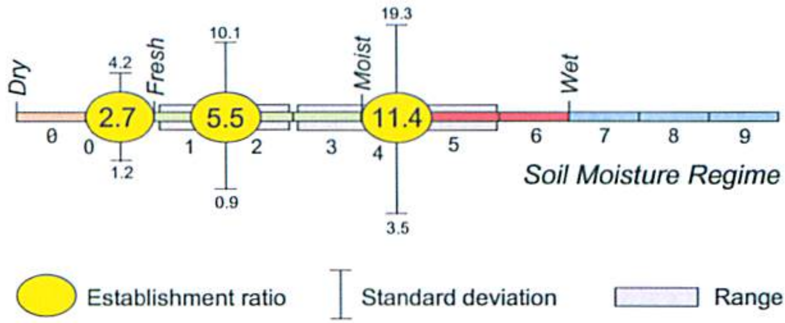
Upper mineral soil horizon

Mineral Soil ≤10 cm below the mineral soil/humus interface

Seedbed Number 13







Lower mineral soil horizon
BLACK SPRUCE (Upland Sites)


Photo by D. Cormier (FERIC)

Lower mineral soil exposure

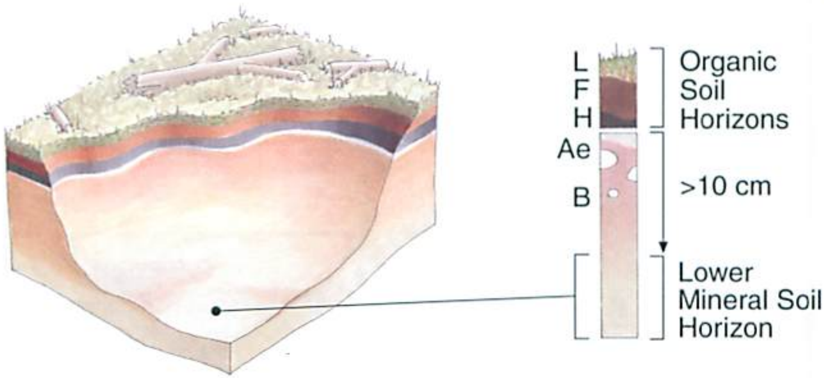
Seedbed Description:

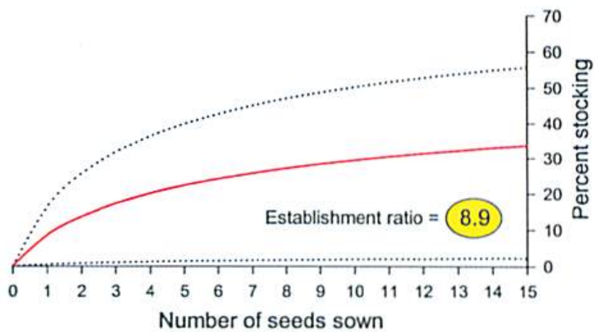
This material consists of the lower B and C horizons, usually exposed by excessively deep scarification or rutting. C horizons are subsurface mineral soil horizons, below the A and B horizons, which are relatively unweathered and represent the soil parent material. The quality of these seedbeds is greatly affected by the micro-site created (e.g., deep ruts or depressions vs broad expanses) as well as soil texture and Soil Moisture Regime.

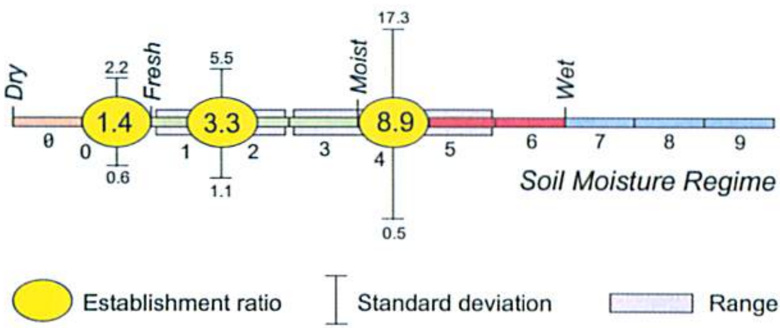
Lower mineral soil horizon

Mineral soil >10 cm below the mineral soil/humus interface

Seedbed Number 14







Pioneer moss
BLACK SPRUCE (Upland Sites)

Pioneer moss

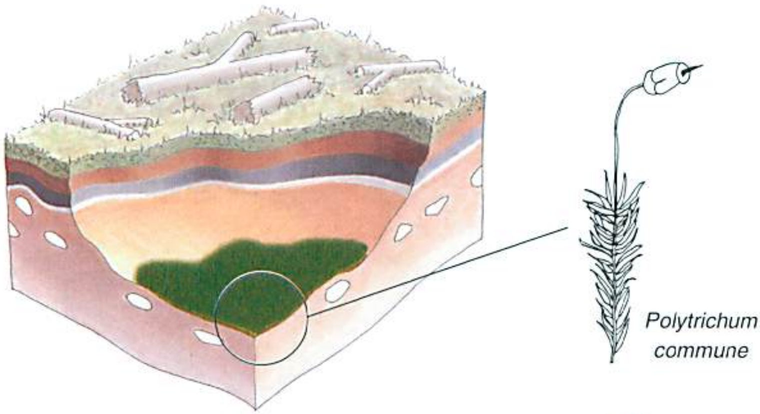
Seedbed Description:

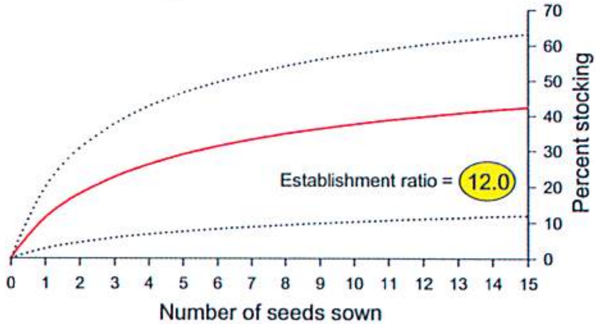
Pioneer mosses such as *Polytichum commune* and *Polytichum juniperinum* colonize recently disturbed organic and mineral soil surfaces and are particularly common on soils near the mineral soil/humus interface. They are found on a broad range of Soil Moisture Regimes and are seldom suppressed by heavy leaf fall. On moist, favourable locations, annual height growth may vary from 3-6 cm. Low, open growth of these mosses is favourable for germination, but rank growth is not. Other short, mat-like pioneering mosses, such as *Ceratadon purpureus, Pohlia nutans* and *Funaria hygrometrica,* which commonly invade freshly disturbed upland sites can also provide good seedbed media.

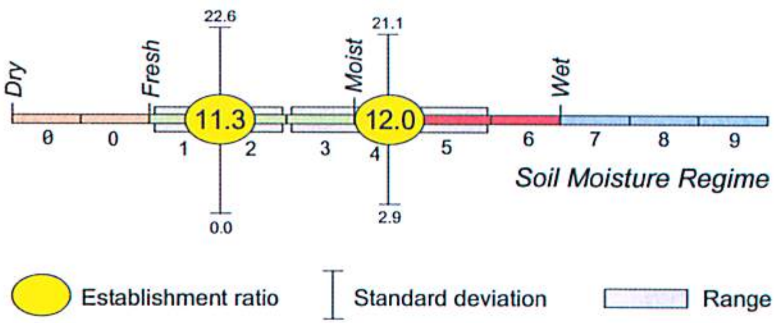
Pioneer moss

Polytrichum commune and Polytrichum juniperinum

Seedbed Number 15







Upturn

BLACK SPRUCE (Upland Sites)

Upturn

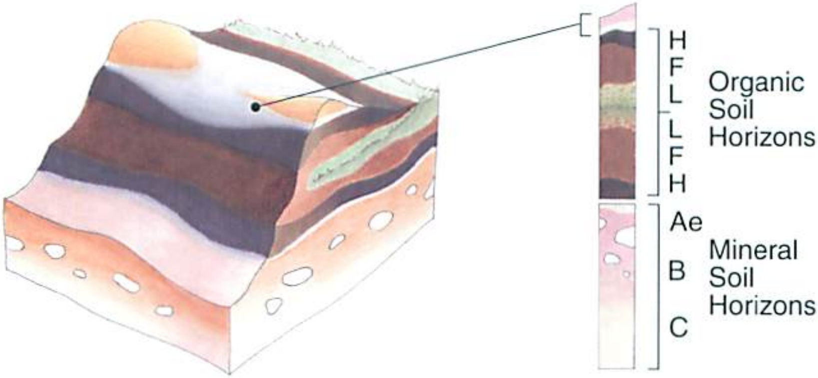
Seedbed Description:

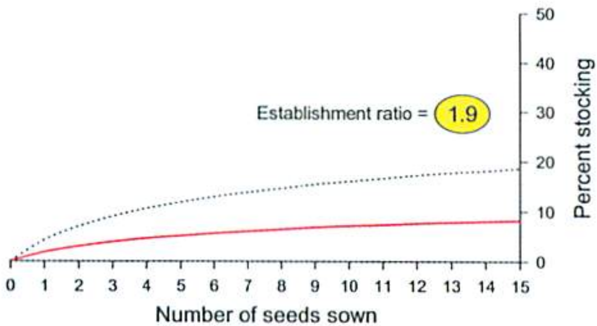
This material is formed from inverted mineral soil and lower organic horizons (F, H and Hi) separated from the underlying mineral soil by a layer of undecomposed or poorly decomposed organic matter. It also includes loose mixtures of mineral and organic material. It is commonly found in spoil banks, mounds or berms created by scarification or during harvesting. These seedbeds are prone to desiccation because of lack of capillary contact with the underlying mineral soil, and are often too dry during many growing seasons for dependable seedling establishment.

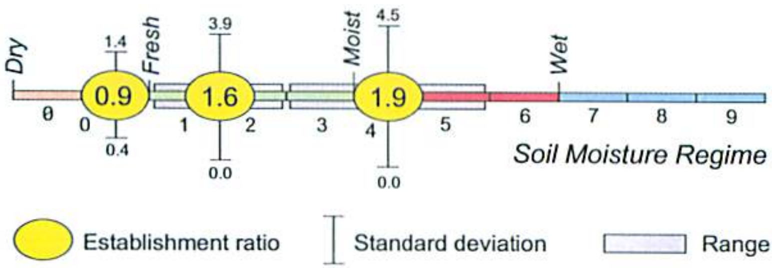
Upturn

Inverted mineral/organic horizons over undecomposed organic

Seedbed Number 16







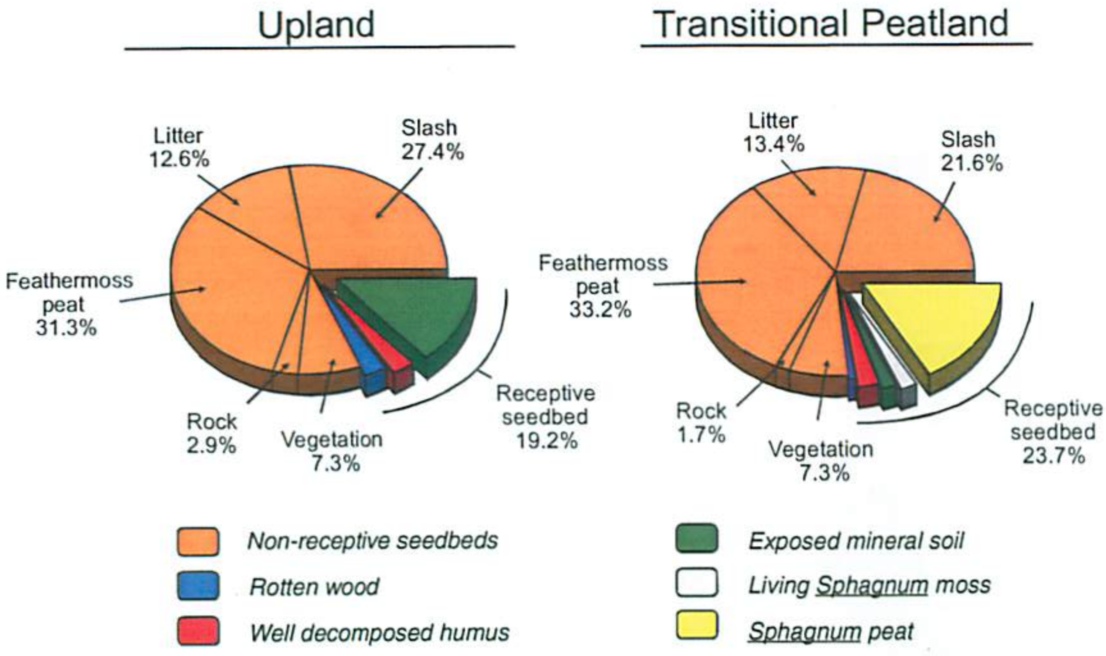


Figure 6.4 Proportions of receptive and non-receptive seedbed types following prescribed burning on three upland and three transitional peatland black spruce sites in northern Ontario *(Adams 1993)*.

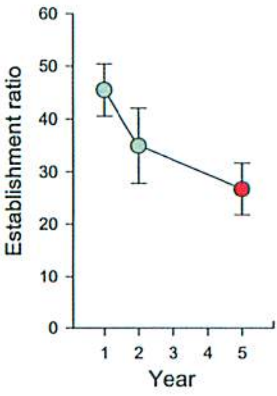
Living compact Sphagnum
BLACK SPRUCE (Prescribed Burns)

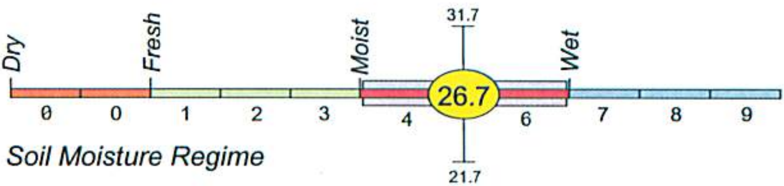
Seedbed Number 17

Living compact Sphagnum

Seedbed Description:

Wet living *Sphagnum* mosses can inhibit the rate of spread and depth of burn of prescribed fire. In low lying areas where *Sphagnum* mosses proliferate, fire may merely scorch the mounds of *Sphagnum* and burn off slash and litter accumulation. This results in a patchwork of burned, scorched and unburned seedbeds. Residual pockets of unburned *Sphagnum* may account for an average of only 2 percent of the area burned but will provide an excellent seedbed for black spruce germination. In some cases *Sphagnum* growth can be temporarily put into check by fire; more often however, competition from living *Sphagnum* will cause significant mortality during the early establishment years.

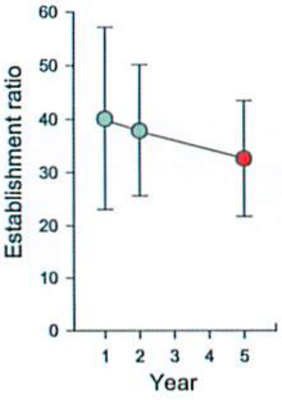




Sphagnum peat

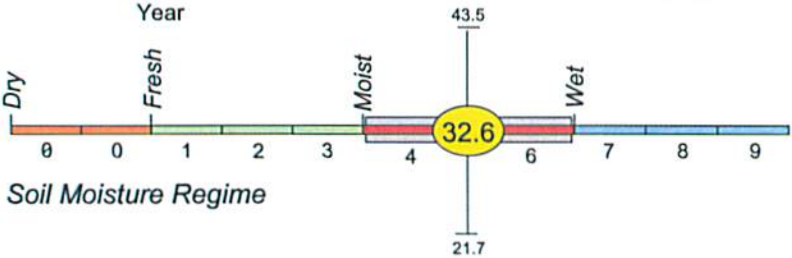
BLACK SPRUCE (Prescribed Burns)

Sphagnum peat

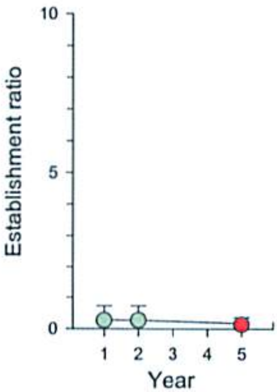


Seedbed Description:

This seedbed comprises dead, scorched or moderately decomposed *Sphagnum* moss. The living layer has either been removed by mechanical means during the harvest or pre-burn tramping or consumed by the fire. Because of its excellent moisture retention this substrate usually does not burn appreciably. Colour may vary from dark brown when scorched by fire to straw colored to yellowish-brown when exposed mechanically. The original *Sphagnum* stems should be readily identifiable and the seedbed will feel moist to the touch. Recorded cover values on transitional and lowland sites range from 3 to 35 % of the area burned. This seedbed provides the best opportunity for germination and seedling establishment.



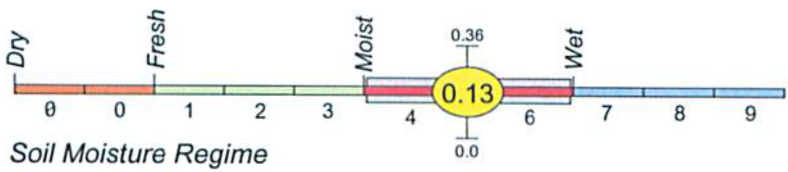
Burned feathermoss peat



Seedbed Description:

Even though feathermosses and *Sphagnum* can grow in close proximity, they have quite different physical properties. Feathermosses, unlike *Sphagnum*, do not have a well established capillary connection to moist underlying layers and do not sustain a high moisture content once the protective canopy is removed. Feathermosses are shade dependent and die quickly following harvesting. The resulting surface layer of dry dead moss is readily consumed by fire, leaving a black fibric substrate. The underlying feathermoss mat can be quite thick and requires a fairly intense burn to expose the moist, compact and better decomposed humus layers below. If a deep burn is not achieved the resulting burned, poorly-decomposed feathermoss peat will provide a hostile environment for germination. Due to its colour and texture this substrate is subject to extreme surface temperatures and desiccation. This non-receptive seedbed can make up a considerable portion of the blackened area of an upland black spruce burn (Figure 6.4).

Because of the large difference in receptivity between burned feathermoss peat and scorched *Sphagnum* peat, it is important that survey crews be able to distinguish these two seedbed types.

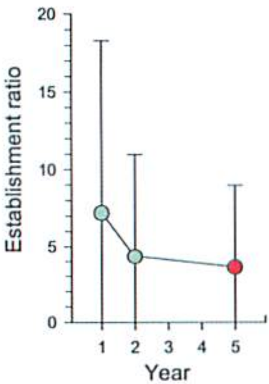


20 **Seedbed Number**

Exposed mineral soil

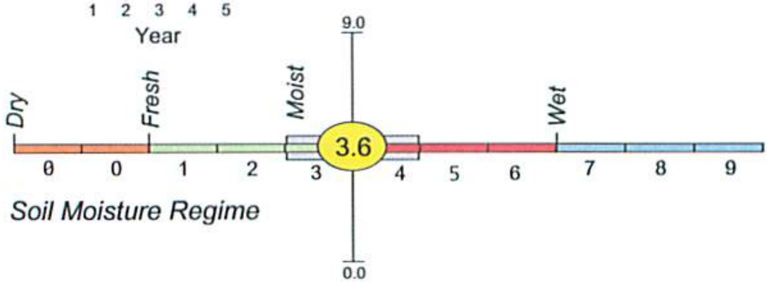
BLACK SPRUCE (Prescribed Burns)

Exposed mineral soil



Seedbed Description:

Large expanses of exposed mineral soil, where fire has completely removed the surface organic layer, provide unfavorable conditions for black spruce establishment. Better results can be achieved on smaller patches of exposed mineral soil that are in close proximity to residual organic substrates. Conditions are slightly more favorable on sites with wetter soil moisture regimes or when some shade is available. Some mineral soils that have been exposed to intense heat can appear fluffy or powder-like and require time (e.g., overwintering) to settle and maintain good contact with moist underlying layers. The quality of this seedbed is also greatly affected by the surface soil texture (the coarser the material the less water retention capability). This seedbed will benefit from higher than normal rainfall, but is generally not recommended as target seedbed.

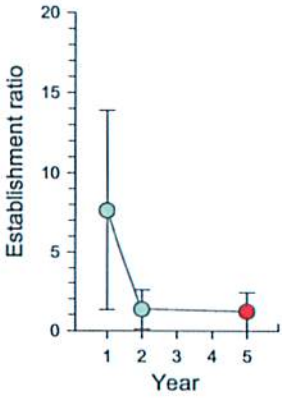


Partially decomposed rotten wood

BLACK SPRUCE (Prescribed Burns)

Seedbed Number 21

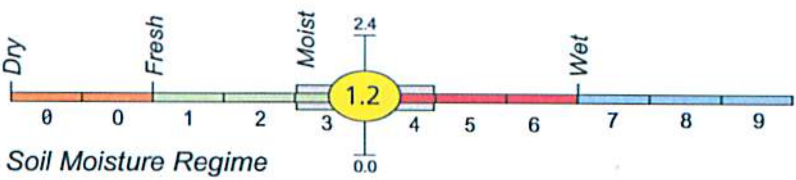
Partially decomposed rotten wood



Seedbed Description:

Rotten wood occurs in fallen trees and stumps and is exposed by harvesting, tramping or prescribed fire. This substrate can be in various stages of decomposition ranging from fibrous, to spongy, to buttery. It appears that much of the finer well decomposed material gets eroded by rain or volatilized by the heat of the fire leaving less decomposed material which is less likely to maintain adequate moisture reserves. This could account for the significant drop in establishment ratio between the first and second year. The average cover value for this seedbed is quite variable and is related to the condition of the original stand, method and timing of harvest and depth of burn, but usually represents less than 3 percent of the area burned.

This seedbed, like many of the marginally receptive substrates, will benefit from frequent rainfall throughout the growing season.

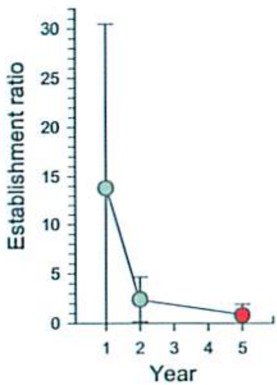


22 Seedbed Number

Exposed well-decomposed humus

BLACK SPRUCE (Prescribed Burns)

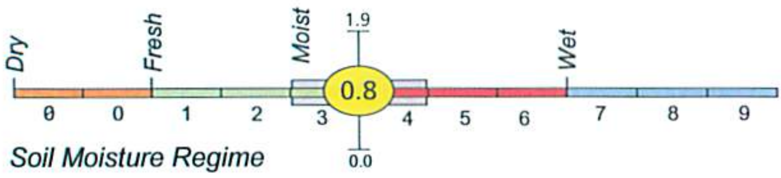
Exposed well-decomposed humus



Seedbed Description:

This seedbed is created when fire is intense enough to consume the fibric portions of the organic layer exposing the better decomposed underlying layers. This material originates in the Oh (humic) organic horizon and is the most well decomposed substrate, containing only small amounts of well preserved fiber. Its colour is dark brown or black when wet and feels greasy to the touch. Expect to find this seedbed at the base of stumps where fire has had a chance to burn deep into the duff or in close proximity to exposed mineral soil.

Initially this seedbed is reasonably receptive, however it is prone to flooding, frost heaving, erosion and competition from other vegetation resulting in high mortality. It accounts for a relatively low cover value (<3%).



Mechanically Site Prepared Seedbeds

Prescribed Burn Seedbeds

Jack pine seedbeds

Exposed following mechanical site preparation

Figures 6.5 (a), (b) and (c) represent some of the more common micro-sites that may be present following various methods of mechanical site preparation. Specific seedbed types are identified with numbered circles. The colour of the circle provides an indication of their relative receptivity to seeding. Each seedbed is further described in more detail in the following seedbed data sheets.

Differences in depth of organic, soil texture and moisture regime within micro-sites is reflected in a sometimes highly variable establishment ratio [ER]. The standard deviation associated with each ER, to a large degree, reflects year to year climatic variation. All of these aspects should be taken into consideration when estimating the seeding potential of individual seedbeds.

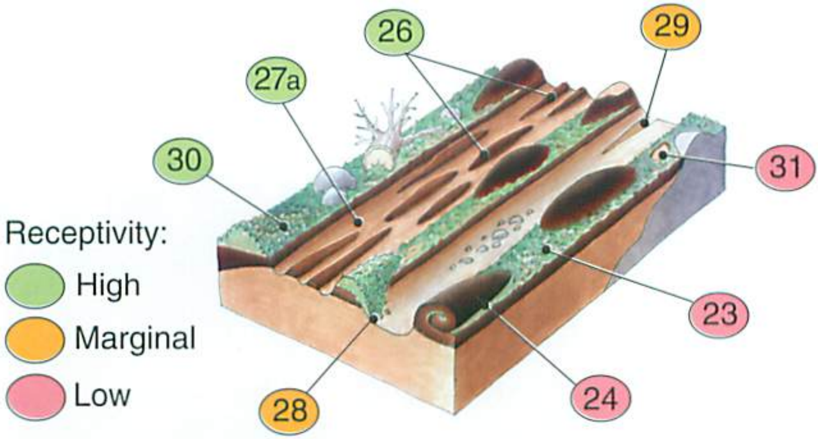


Figure 6.5(a) A conceptual illustration of seedbeds created by screefing which removes or displaces the organic layer to expose and/or lightly disturb the underlying mineral soil. Drag units consisting of light to heavy barrels, anchor chains/tractor pads, blade attachments and disk trenchers are some of the pieces of equipment commonly used to create this condition *(adapted from Sutherland and Foreman 1995)*.

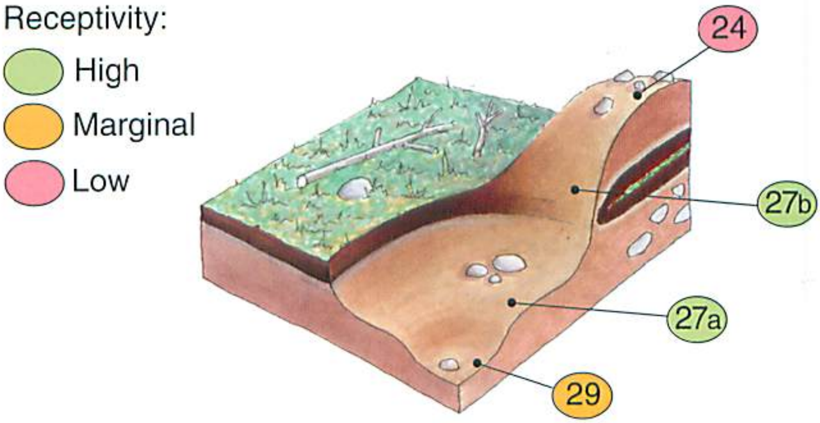


Figure 6.5(b) An illustration of the scalp produced when the organic and upper mineral soil horizons are excavated and inverted over the adjacent undisturbed LFH layer. This condition is commonly created by spot inverting (e.g. Bracke) and continuous inverting (e.g. mold-board plows) (*adapted from Sutherland and Foreman 1995*).

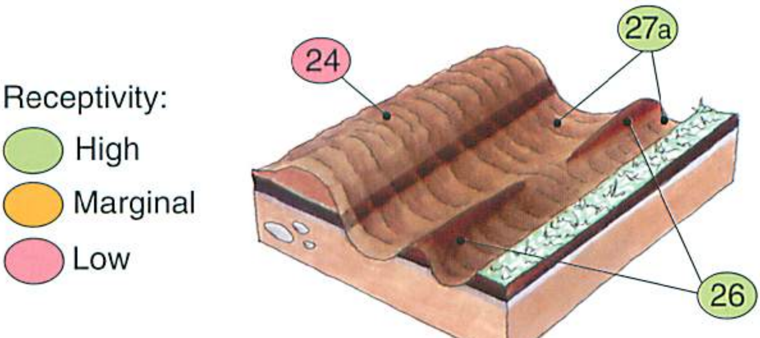


Figure 6.5(c) An illustration of the trench produced when organic and upper mineral soil horizons are removed and subsequently deposited in berms beside the trench. Disk trenchers, cone trenchers and heavy barrel drags are commonly used to create this condition *(adapted from Sutherland and Foreman 1995).*

23 Litter: Undecomposed organic matter

JACK PINE (Mechanical Site Preparation)

Litter

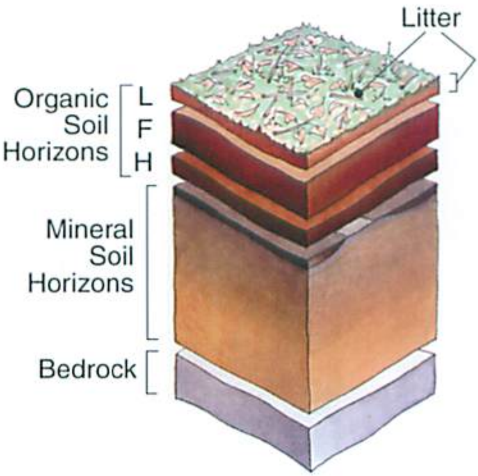
Seedbed Description:

This undisturbed seedbed is characterized by accumulations of needles, leaves, twigs and woody materials in which the original structures are easily discernible.

Following harvesting and removal of the protective canopy this seedbed is exposed to extreme temperatures and moisture deficits. This seedbed may include a minor component of mosses. Most of these mosses are shade tolerant and quickly die off following exposure which in turn contributes to the amounts of litter present.

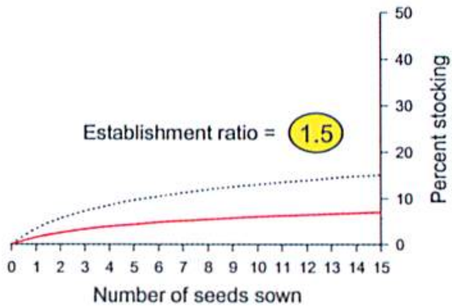
Litter

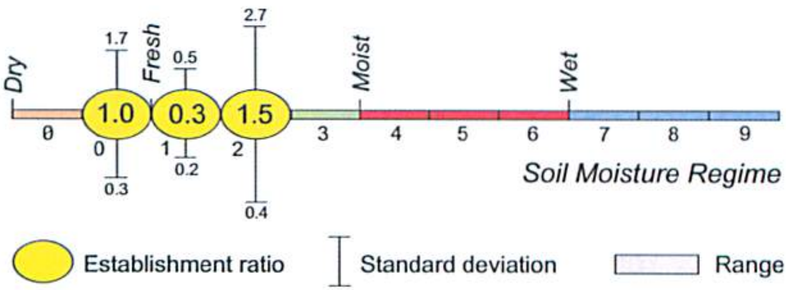
Depending on site conditions and the type of site preparation used, undisturbed litter can represent a considerable portion of the seeding chance. Because of its low potential for seedling establishment it is not normally considered a target seedbed, however, it does have a receptivity value and as such should be separated from truly unreceptive conditions such as deep slash, rock and stumps when conducting a post site prep assessment survey. A seedbed with a seemingly insignificant ER has the potential to affect seeding prescription if it represents a significant amount of the surface area.



This seedbed can produce large seedlings if establishment is successful because of the undisturbed nature of the underlying substrates and the retention of below surface moisture.

A thinner LFH and wetter SMR may help to improve establishment.





24 *Upturn*

JACK PINE (Mechanical Site Preparation)

Side berm with logging slash

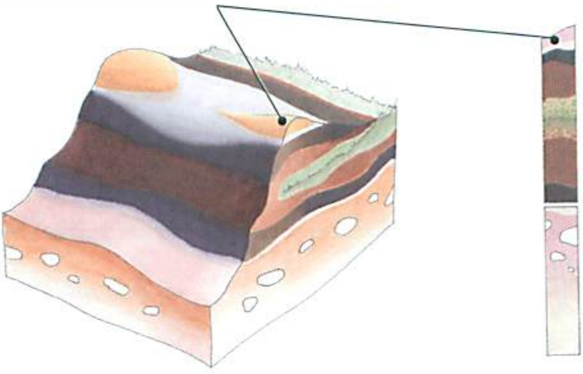
Seedbed Description:

These seedbeds are a product of site preparation or harvesting operations.

They can be characterized by:

a) side berms, spoil banks and loose mixtures of mineral soil, organic material and logging debris.

b) mineral soil/humus upturns where displaced mineral and upper organic horizons have been removed and heaped onto an undisturbed substrate.



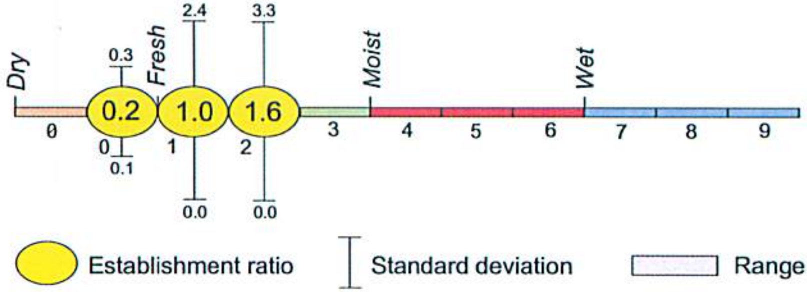
Upturn – displaced mineral/organic inverted over undisturbed substrate

c) inverted scalps (mineral soil cap over organic). This inclusion refers to the top portion of the inverted scalp only; not the lower slope or hinge area of the mound.

In all of the above cases the extracted mineral soil and upper organic horizons (L, F, and H) are separated from the underlying mineral soil by a layer of undecomposed or poorly decomposed organic matter. Considerable variation exists in the capillary contact with underlying layers which predisposes these substrates to periodic desiccation. Consequently these seedbeds are often too dry during many growing seasons to support seedling establishment with any dependability.

As in the case of litter, these seedbeds have an associated ER value and as such, the area taken up by these seedbeds should be recorded in the post site preparation assessment (Appendix F) and included in the predictive model's work sheet so that an accurate prescription can be developed.

Soil Moisture Regime



F horizon: Partially decomposed organic matter

JACK PINE (Mechanical Site Preparation)

F horizon (fermentation layer)

Seedbed Description:

This substrate is characterized by an accumulation of partly decomposed organic matter derived mainly from leaves, twigs and woody materials; some of the original structures are still recognizable and fungal hyphae may be present. Exposure of this substrate is usually associated with light disturbance.

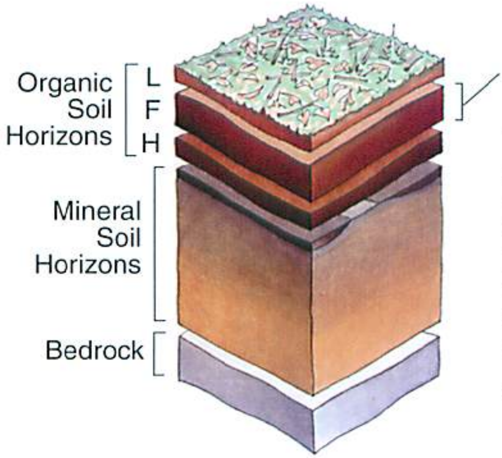
When subjected to excessive sun exposure the usually dark surface layer of this seedbed will often take on an ash grey colour and have a crusty texture. At this stage moisture availability for newly established seedlings is negligible and desiccation soon follows. Because of this, seedling establishment is generally considered to be poor. However, this substrate may be considered marginally receptive on sites with a high water table.

F horizon (fermentation layer)

F horizon

Exposed fermentation layer

Seedbed Number 25



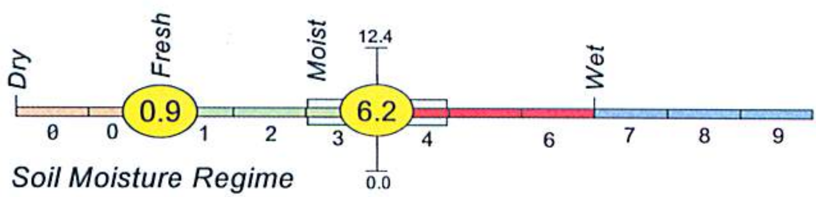
Fermentation layer

There is little formal receptivity data available for this seedbed type. However, it has been observed that both moisture regime and thickness of the substrate play a significant role in its performance.

RECOMMENDATIONS

The following recommendations should be considered:

- Thick F can *only* be considered a target seedbed on deep soils with a high water content (SMR >4).
- Seeding onto a thin F plus H (<1.5 cm) layer which readily forms a firm base can be considered as recommended for deep sands and coarse or fine loams with SMRs greater than 3 only.
- On shallow soils this substrate is subject to desiccation and should be avoided.



H and Ah horizons: Well-decomposed organic matter

JACK PINE (Mechanical Site Preparation)

H horizon (humus layer)

Seedbed Description:

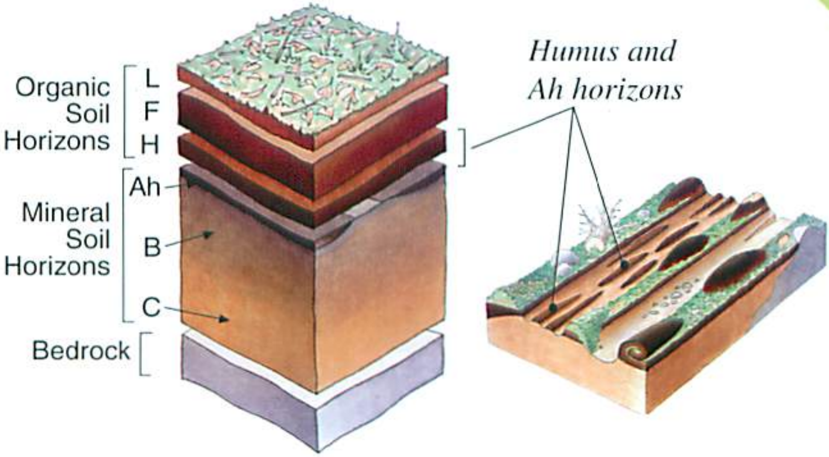
The H horizon is characterized by an accumulation of well decomposed organic matter in which the original structures are indiscernible. It differs from the F horizon by having greater humification chiefly due to the action of micro-organisms.

Ah is a mineral horizon enriched with organic matter (<17% organic by weight). This material is very dark in colour and feels greasy to the touch. Unfortunately, H and Ah horizons are often not well delineated and for the purposes of this manual have been lumped together to simplify field identification.

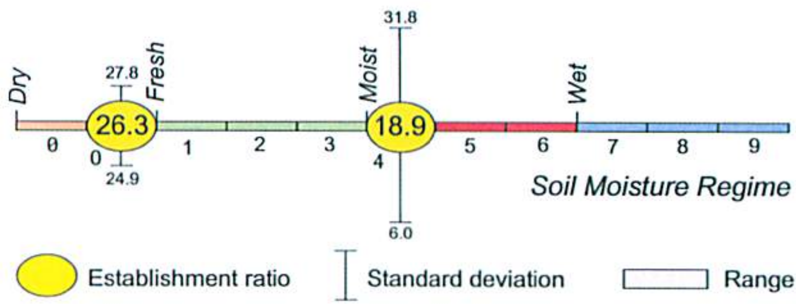
Ah horizon (organic enriched mineral soil)

H and Ah horizons

Exposed humus layer



The combination of moisture retention and nutrient availability makes this seedbed the ideal micro-site for seedling establishment and early growth. Because of the variable nature in thickness of the H/Ah horizon (in some cases only a few millimeters thick), exposure is often more by happenstance than design. However, site preparation operators should be made aware of the potential of this seedbed and strive to expose as much of it as possible. The H and Ah horizons are the most susceptible to deterioration, where the frequency of occurrence can be reduced by over 50 percent within a year of site preparation; by year five less than 10 percent of this seedbed type may still be present.



27a *Upper mineral soil horizon (furrow)*

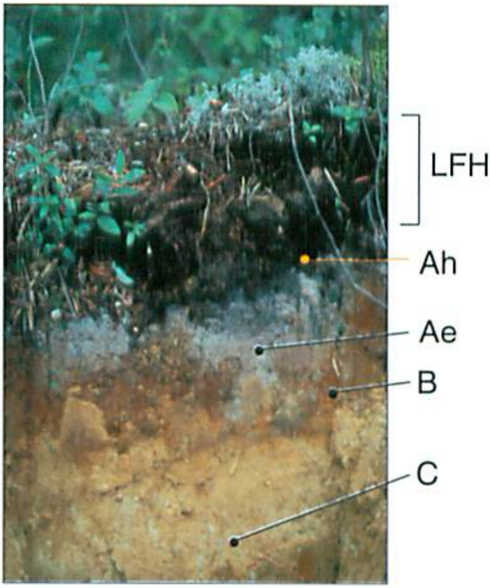
JACK PINE (Mechanical Site Preparation)

Exposed upper mineral soil horizons

Seedbed Description:

This seedbed can be found in the bottom of shallow troughs, scrapes and furrows. It usually consists of Ae and B mineral soil horizons. Ae horizons are light-coloured surface horizons characterized by the loss (eluviation) of clay, iron, aluminum and/or organic matter.

B horizons are characterized by enrichment in clay organic matter, iron, aluminum or clay; by soil structure development; or by a colour change denoting reduction or oxidation. These include Bt horizons which are greyish-brown subsurface horizons enriched with clay; Bf horizons which are reddish-brown subsurface horizons with accumulations of iron, aluminum and organic matter; Bm horizons which are brownish subsurface horizons with only a slight addition of iron, aluminum and/or clay; and Bg horizons which are mottled or greenish to bluish grey subsurface horizons characterized by periodic or permanent saturation.



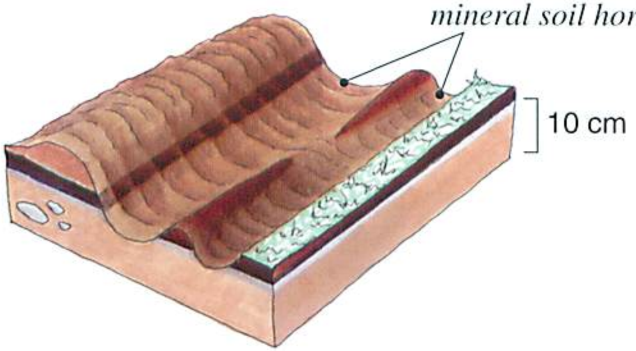
Mineral soil horizons

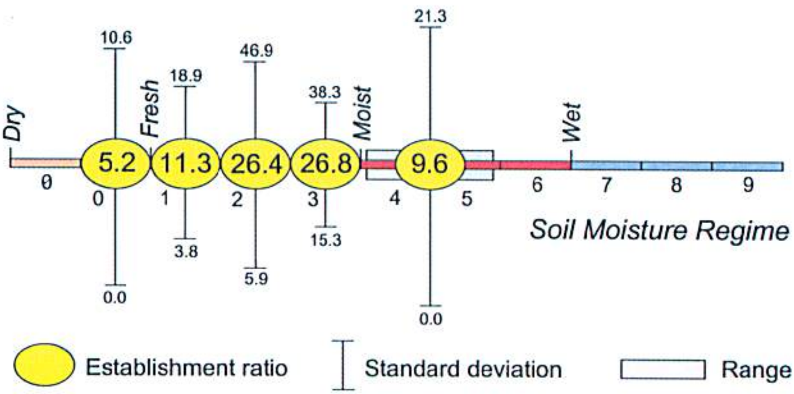
Upper mineral soil horizon (furrow)

Mineral Soil <10 cm below the mineral soil/humus interface

Seedbed Number 27a

Shallow mineral soil exposure with a firm base on deep sands with SMR 1-3 is considered to be a good micro-site for jack pine establishment. Any position within the trench is acceptable as long as the seed lands no higher than the original mineral/organic interface. Avoid depressions on moist deep sands and coarse or fine loams that are not well drained or if excessive sedimentation is anticipated.





27b *Upper mineral soil horizon (scalp)*

JACK PINE (Mechanical Site Preparation)

Mid-slope position in a Bräcke scalp

Seedbed Description:

The mid-slope of the scalp is considered to be a target micro-site.

Ideally this micro-site should be allowed to settle to a firm base prior to seeding. Compaction of this micro-site through manual or mechanical means will stabilize the slope, reduce erosion and significantly improve stocking potential.

Base of the berm

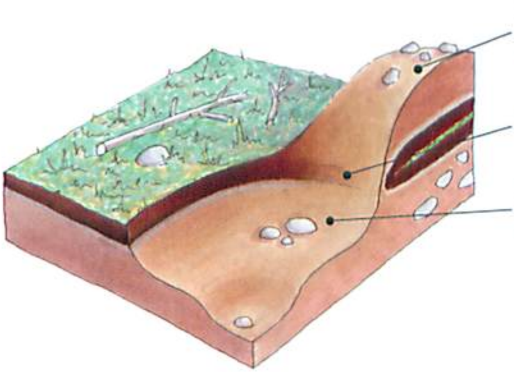
The base and lower slope of the berm on furrowed sites have very similar properties to the mid-slope position within the scalp. On dry sites there is a certain amount of protection afforded by the berm. In the case of east-west scarification, the base of the north-facing slope benefits from the berm's shade, which tends to mitigate temperature extremes and provides some soil moisture conservation.

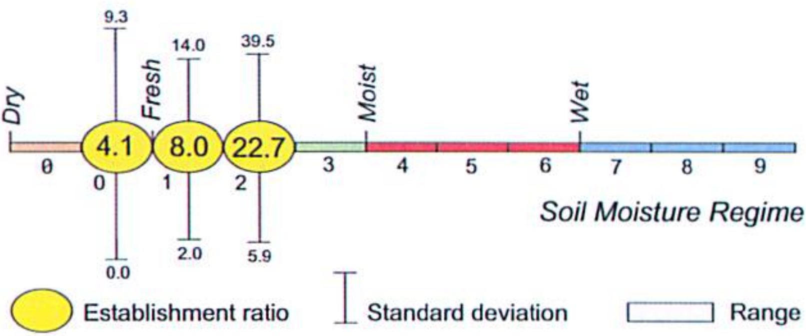
Upper mineral soil horizon (scalp)

Mid-slope of a scalp or base of a berm

Seedbed Number 27b

The upper slope or hinge area of an inverted scalp is considered as conditionally recommended as target seedbed on moist sites only, because of its predisposition to desiccation. If establishment is successful, seedlings will benefit from their proximity to the mineral/ humus interface. On richer sites, incursion of competing vegetation from the sides may also favor seeding the hinge area.





Incidental FH/mineral mixes

JACK PINE (Mechanical Site Preparation)

Thin FH/mineral mix on a firm mineral soil base

Seedbed Description:

This seedbed is created by the disking or dragging action of some scarification equipment (e.g., barrels and chains and power trenchers). While these mixes are not overly common occurrences on most site prepared blocks they may, under some moisture conditions, be considered a target seedbed. Incorporation of humus layers with mineral soil by mixing has been found to increase the soil's water-holding capacity in the rooting zone and can improve soil moisture by reducing the density of competing vegetation, particularly in coarser-textured soils. On fine-textured soils, mixing can increase the infiltration of moisture and can avoid capillary discontinuity in raised beds (Sutherland and Foreman 1995).

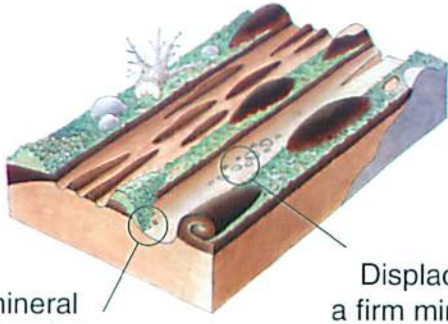
The same scarification action that produces a FH/mineral mix can result in displaced mineral soil on a mineral soil base. The receptivity of this seedbed is directly related to its proximity to the mineral/humus interface, the degree of settling that has occurred and the moisture regime of the site. Generally, if it is not in good contact with the underlying mineral layer or is perched too far above (10 cm) the mineral/humus interface it should be considered as having poor potential.

Displaced mineral on a firm mineral soil base

Incidental FH/mineral mixes

and displaced mineral on a firm mineral soil base

Seedbed Number 28



No formal establishment ratio data exists for these seedbed types, however the following recommendations will give an indication of potential success relative to soil moisture regime.

RECOMMENDATIONS

- A thin (<1.5cm) FH/mineral mix that readily forms a firm base is recommended as a target seedbed for deep sands and coarse or fine loams with dry to fresh SMRs and is considered the micro-site of choice for shallow soils <100 cm.
- Moderately thick (1.5-3 cm) FH/mineral soil mixes may result in only marginal success on moist substrates. FH/mineral soil mixes thicker than 3 cm are not recommended under any site conditions.
- Seeding on displaced mineral soil on a firm mineral soil base is recommended on moist deep sands and course or fine loams.

Lower mineral soil horizon

JACK PINE (Mechanical Site Preparation)

Lower mineral soil exposure

Seedbed Description:

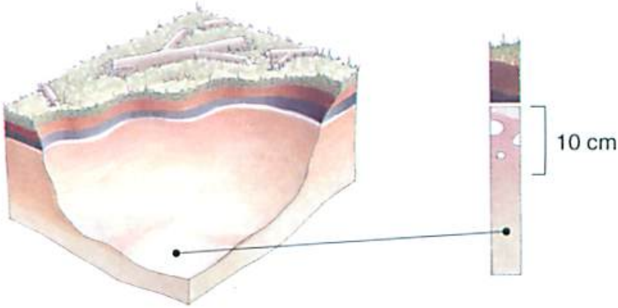
This material consists of the lower B and C horizons, usually exposed by excessively deep scarification or rutting. C horizons are subsurface mineral soil horizons, below the A and B horizons, which are relatively unweathered and represent the soil parent material. The quality of these seedbeds is greatly affected by the micro-site created (e.g., deep ruts or depressions vs broad expanses) as well as soil texture and Soil Moisture Regime.

Limit the amount of this type of exposure. On many site preparation operations however, a certain amount of deep mineral soil exposure is generally unavoidable and is a function of site type, operator experience, ground bearing capacity and equipment suitability. Regardless of how it is created it will be a substrate that will be encountered and as such should be identified and quantified.

Water-filled furrow

Lower mineral soil horizon

>10 cm below the mineral soil/humus interface



The lack of nutrient availability, especially on coarse textured soils, will have a negative impact on seedling performance. If a stand is established primarily on deeply screefed micro-sites, experience suggests site index class (index height at age 50) may be reduced by as much as two site classes.

Cold air and water often pond in these depressions; subjecting germinants to low soil temperatures, frost or frost heaving and flooding.

Unfortunately, no formal establishment data exists for this substrate. Consider the following recommendations.

RECOMMENDATIONS

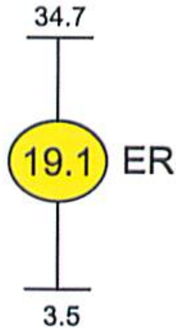
- Rarely are deeply screefed micro-sites desirable. However, small (<1 m^2), deeply screefed seedbeds with good air drainage may provide acceptable jack pine establishment on some dry (SMR Ø) to moderately dry (SMR 0) sites.
- Avoid seeding into deep furrows or scrapes on sites with SMRs >3. Water ponding in these depressions is anticipated.
- Avoid seeding on slopes prone to erosion. Deep screefs tend to act as channels for runoff.

30 *Living Sphagnum and Sphagnum peat*

JACK PINE (Mechanical Site Preparation)

Seedbed Description:

Living *Sphagnum* or *Sphagnum* peat may occur on moist portions of the seeding chance (SMRs >4) or on imperfectly drained very shallow soils. Expect good initial establishment on this seedbed but the lack of available nutrients and overly moist growing conditions may reduce seedling performance.



31 *Very shallow soil: (5-30 cm) over bedrock*

JACK PINE (Mechanical Site Preparation)

Seedbed Description:

Direct seeding may be the only available regeneration option on very shallow soils with extensive bedrock outcrops, boulder pavements or excessive surface boulders. Soil moisture regimes on these sites can be highly variable. Drainage classes can range from rapid to imperfect. This can result in a range of conditions, from water ponding in depressions to moisture deficits on perched seedbeds. Recommending specific target micro-sites may be inappropriate. Thus, as a rule of thumb, seed as close to the mineral soil/humus interface as possible.

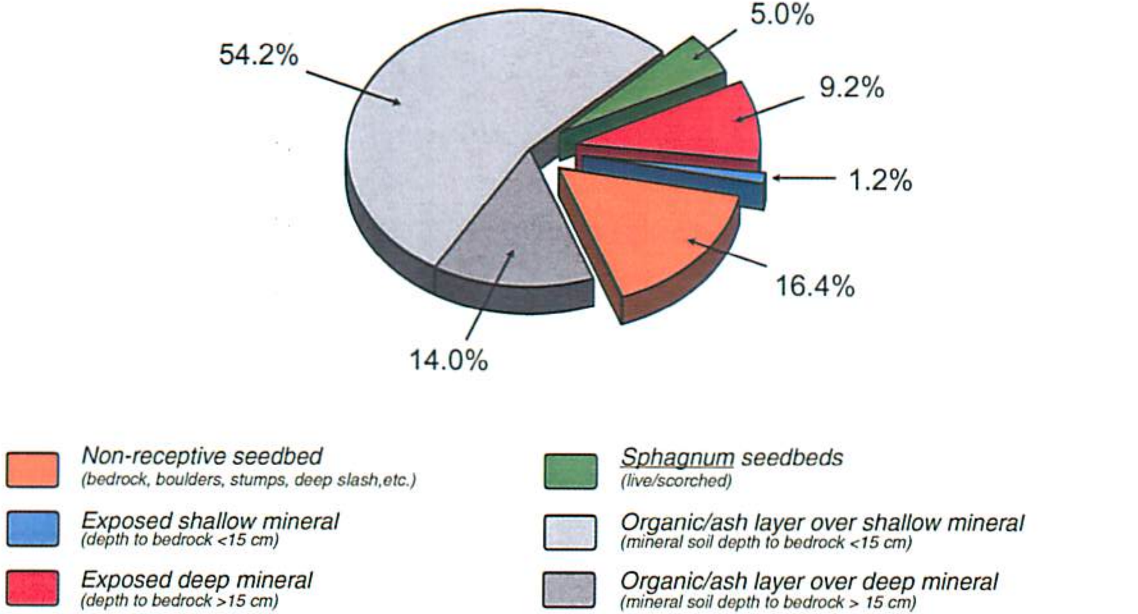


Figure 6.6 Proportion of receptive and non-receptive seedbed types following prescribed burning on three jack pine sites in northern Ontario *(Foreman 1997)*.

Sphagnum/Sphagnum peat

JACK PINE (Prescribed Burns)

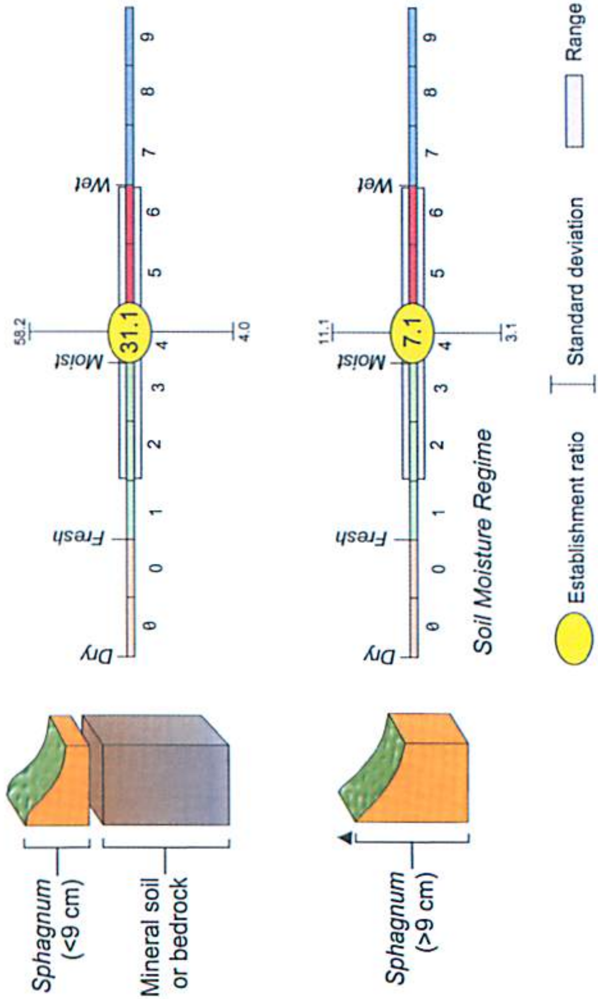
Seedbed Description:

Sphagnum mosses are not abundant on jack pine sites, but small pockets (1-10m diameter) of *Sphagnum* occur in association with water holding bedrock depressions on very shallow soils. Establishment ratios are highest on the periphery of these pockets. Recorded cover values average 5 percent (Fig 6.6).

This seedbed category includes living undisturbed, scorched, dead and partially charcoal covered *Sphagnum.* In dry years *Sphagnum* seedbeds provide the sustained moisture required for jack pine germination; in years with regular plentiful rainfall establishment may be poor. Chlorotic seedlings have been observed on *Sphagnum* substrates, suggesting that this medium is not well suited for jack pine growth.

Sphagnum/Sphagnum peat

JACK PINE (Prescribed Burns)



33 *Organic material and ash over very shallow mineral soil*

Seedbed Description:

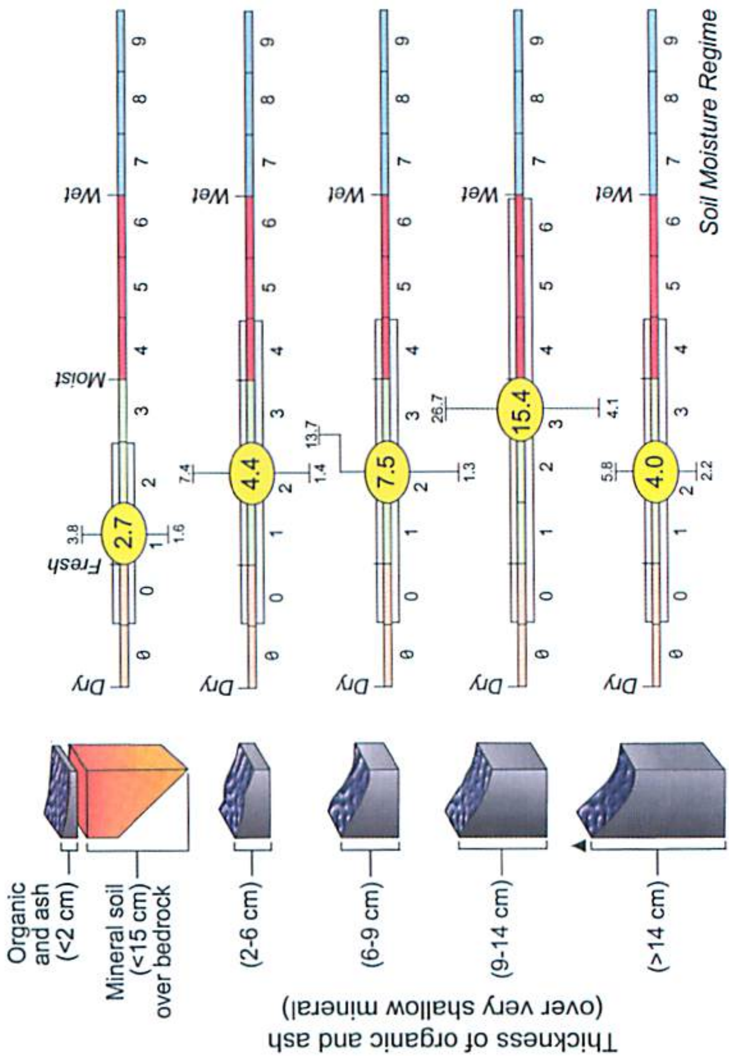
This group of substrates includes the burned and unburned soil organic horizons (LFH layers) as well as ash, charcoal, rotten wood, and dead moss. These materials can occur separately or in mixture with each other. The depth of the underlying mineral soil is less than 15 cm over bedrock.

The thickness of ash and organic material after prescribed fire depends largely on the intensity of the burn, but also upon the moisture content of the organic layer. Organic layer moisture content shows considerable spatial variation on shallow soil sites because the undulating bedrock and boulder sub-surface topography causes variation in the soil moisture regime. Most of the organic material on dry moisture regimes is burned, while thicker layers of organic material remain after fire on wetter moisture regimes. Jack pine establishment ratios on ash and organic material seedbeds vary with the thickness of this layer and with soil moisture regime.

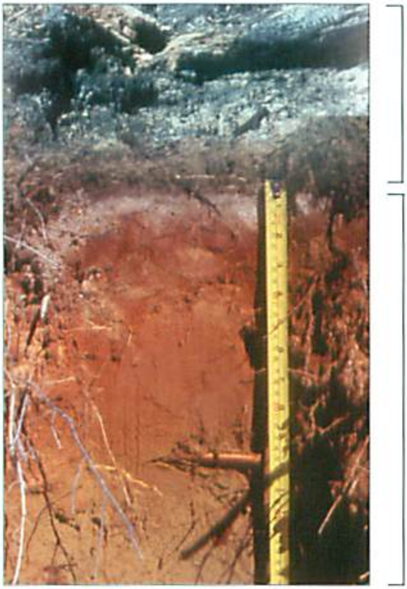
Organic material and ash *(<15 cm of mineral)*

JACK PINE (Prescribed Burns)

Seedbed Number 33



34 *Organic material and ash over shallow-to-deep mineral soil*



Seedbed Description:

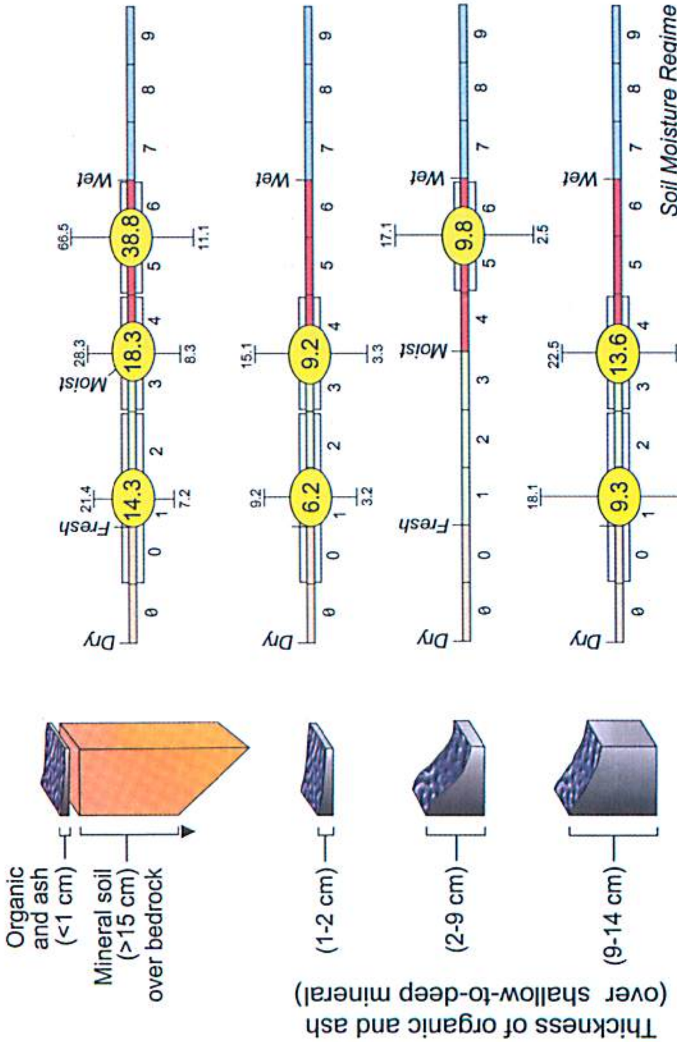
Similar to the previous group, this group of substrates includes the burned and unburned soil organic horizons (LFH layers) as well as ash, charcoal, rotten wood, and dead moss. These materials can occur separately, in mixture with each other, or in mixture with mineral soil. In this instance the underlying mineral soil depth to bedrock is greater than 15 cm.

Establishment ratios on this material generally decrease as the thickness of the organic layer increases or as soil moisture regimes become drier. On sites typically occupied by jack pine, soil moisture regimes are commonly dry to moderately moist. Moist and very moist moisture regimes may occur as smaller inclusions.

Seedbed Number 34

Organic material and ash (>15 cm of mineral)

JACK PINE (Prescribed Burns)



35 *Exposed mineral soil*

JACK PINE (Prescribed Burns)

Seedbed Description:

This substrate is exposed mainly by removal of the organic layer by fire, but also by timber harvesting and transportation activities.

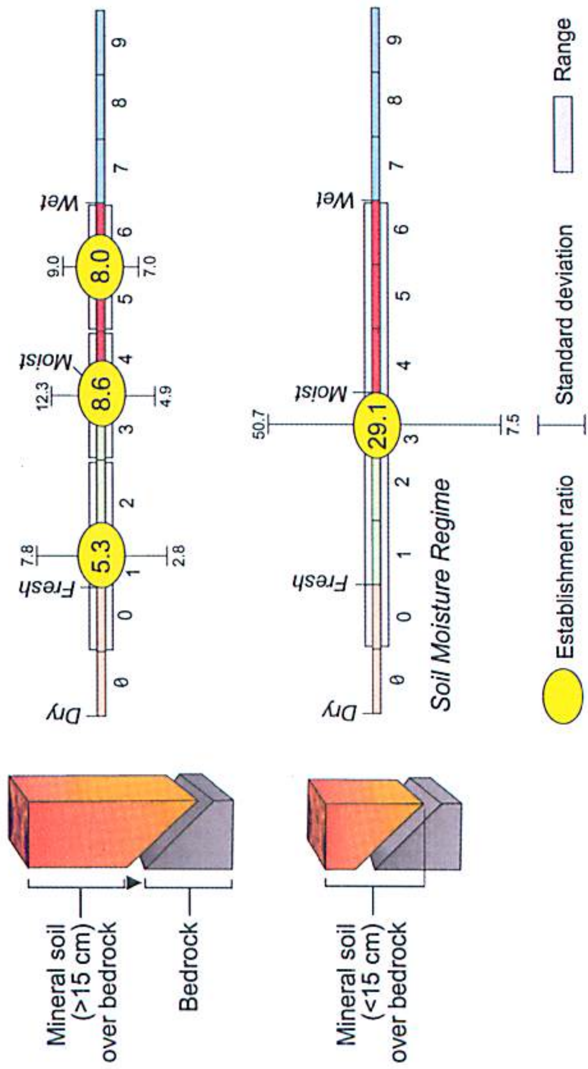
Jack pine establishment ratios are lowest on the driest (SMR 0-2) and most frequently occurring conditions, and are moderately low on more moist (SMR 3-6) shallow to deep (depth to bedrock >15 cm) mineral soils. The cover of moist to very moist conditions (SMR 4-6) is small; these conditions occur as occasional inclusions.

The moisture regimes of very shallow soils (depth to bedrock <15 cm), and consequently the establishment ratios, vary considerably because of undulating subsurface bedrock and boulder topography. Water seepage into and retention within local bedrock depressions coupled with the removal of excessive moisture by rapid to very rapid drainage result in very favourable establishment conditions, resulting in high average establishment ratios for this condition.

Exposed mineral soil

JACK PINE (Prescribed Burns)

Seedbed Number 35



7.0 SITE PREPARATION

Receptive seedbed is essential for direct seeding. The objectives of site preparation are: to expose or create seedbed in the amount and distribution specified in the seeding prescription (Section 9); to create microsites with favourable temperature and moisture conditions; and, to reduce as much as possible vegetative competition to seedlings. In the case of hand spot seeding, an additional objective is to allow unimpeded movement of workers over the site by aligning and /or redistributing slash and other obstacles.

On upland sites, site preparation is normally required because the disturbance caused by harvesting equipment alone seldom produces enough well-distributed, receptive seedbeds for direct seeding to be successful. On peatlands, however, the harvesting disturbance can sometimes expose enough seedbed to eliminate the need for subsequent site preparation.

7.1 General Principles

On uplands, site preparation must remove slash and soil layers with poor moisture-supplying capability (typically the L and F layers of the forest floor) and expose seedbeds located just above, at or just below the mineral soil-humus interface (thin F, thin H, and upper mineral soil horizons). Establishment ratios on these seedbeds are usually many times greater than on relatively undisturbed soils (litter and deep F), or on inverted mounds (spoil banks) (Figure 7.1); see also Section 6). As the Soil Moisture Regime (SMR) increases, the optimum seedbed is found higher in the soil profile, from shallow mineral horizons for drier SMRs to the H or F horizon for wetter SMRs.

The main benefit of removing a large portion of the forest floor layer on uplands is an improvement in the surface moisture conditions for seedling germination and establishment, but other benefits include soil warming, less extreme surface temperatures, and frequently a reduction in vegetative competition.

Inappropriate site preparation on uplands can have negative consequences for seedling establishment. The incidence of frost-heaving increases when fine-textured soils are exposed, the risk of moisture deficits increases when coarse-textured soils are mounded; nutrient supply to seedlings is reduced when lower mineral soil horizons (B and C) are exposed. These consequences can be avoided by careful planning and proper execution of the site preparation prescription.

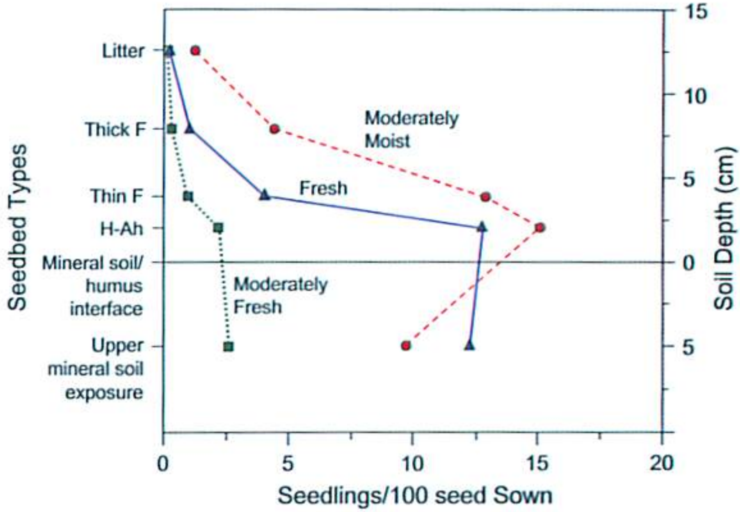


Figure 7.1 Mean fifth-year seedling establishment ratios by Soil Moisture Regime category and seedbed type for black spruce on upland coarse-textured soils. (*Fleming et al. 1995*)

On uplands, site preparation implemented in a regular pattern can potentially result in minimal quadrat-to-quadrat variability in seedbed areas, although typical operations result in considerable variability.

On peatlands, site preparation should aim to remove the living portions of *Sphagnum* moss and remove layers of living feathermoss and feathermoss peat. The soil surface of lowlands is a mosaic, typically dominated by patches of *Sphagnum* and feathermosses. In addition to this horizontal variation, the vertical profile of the peat may exhibit a layer of peat formed by one of these moss types above a layer of peat formed by another moss type. Living feathermosses and feathermoss peat are not acceptable seedbeds because they dry rapidly even on peatlands. Poorly decomposed *Sphagnum* peat is superior to living *Sphagnum* moss, because the living moss can engulf newly established seedlings. On peatlands, the combined vertical and horizontal variability in substrates preclude low quadrat to quadrat variability in seedbed areas. Consequently, the distribution of receptive seedbed on peatlands resulting from both harvesting and site preparation is often more variable than on uplands.

Site preparation should be carried out as soon as possible after harvesting so that seeded species become established before competitive species can dominate the site. Site prepare prior to the release of seeds from supplementary seed sources, such as slash and seed trees, so these seed sources can contribute to stocking.

7.2 What Are Some Points to Consider When Planning for Site Preparation?

The prescription for site preparation must specify an amount and distribution of receptive seedbeds: (i) that will result in regeneration success; and (ii) that is operationally achievable. The prescription must take into account the site preparation methods that are available, and their capabilities and limitations. Proper execution of the site preparation prescription is a prerequisite for direct seeding success, but may sometimes be difficult, particularly on shallow-soil sites (e.g., NWO SS1, SS2, SS3).

Prescription development and execution may be complicated by the fact that many seeding blocks are made up of a patchwork of associated but distinct site types; optimum treatment requires site adapted site preparation.

Considerations for choosing a site preparation method fall into three main categories:

- biological: How well does the method prepare receptive seedbed on a given site?
- economic: Is it cost effective, given the site and its location?
- technical: Can the selected method be applied effectively on the site?

7.3 What Site Preparation Methods Are Available?

Site preparation methods include manual (boot-screefing, hand tools, etc.), motor manual (commonly, an end tool adapted to either a brush saw or chainsaw), mechanical site preparation (MSP), prescribed fire, chemical site preparation and combinations of two or more of the foregoing.

Both manual and motor manual methods of site preparation are labour intensive. Generally, they are suitable for either small scale regeneration efforts or supplementary in-filling of localized failures in otherwise successfully regenerated large scale sites. Manual and motor-manual methods may be associated with either spot seeding including shelter cones or planting.

Both mechanical site preparation methods and prescribed burning are options on a range of sites; disturbance by full-tree harvesting may be an additional option on lowland sites (Figure 7.2).

MSP is commonly used to prepare large industrial scale sites for aerial broadcast seeding. However, on some sites seed application may be integrated with MSP as in row seeding (e.g., Bart seeder with disc trenchers or the Bräcke patch-scarifier-seeder), or manual spot seeding may be used. The time window for combined seeding and site preparation is relatively narrow. However, if a range of upland site conditions are available, MSP may be carried out throughout the frost free period. Similarly, on both peatlands and transitional-to-upland sites, MSP may be carried out when the soil is either frozen or partially thawed – when the surface is sufficiently thawed to be tilled / relocated and the subsurface frozen substrates will support the heavy machinery (Sutherland and Foreman 1995).

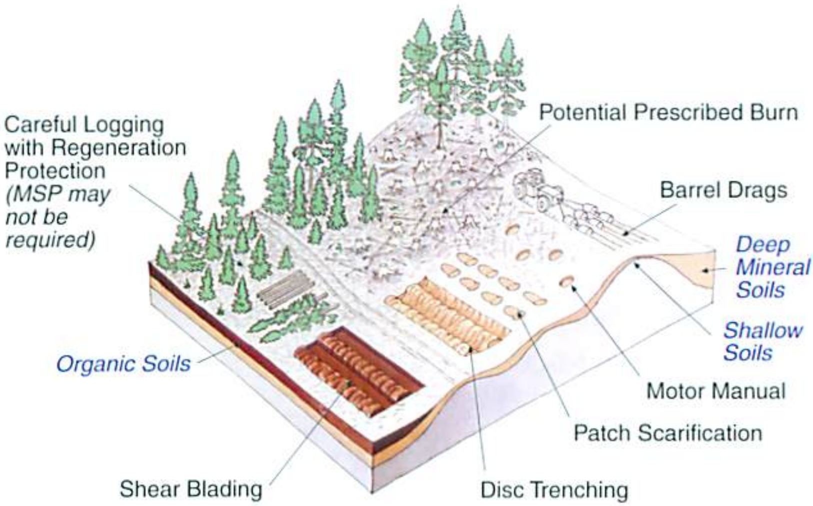


Figure 7.2 An illustrated example of how to match the site preparation method to the site. *(adapted from von der Gönna 1992)*

7.3.1 Mechanical site preparation methods on uplands

The method selected should match the slash and soil conditions and the species to be seeded. Because site conditions (SMR, soil type, slash loading, humus depth) often vary within a cutover, ensure that the equipment operator understands the objectives of the site preparation prescription and how to adjust the implement to achieve consistent results as conditions change across the site.

Of the eight classes of MSP methods described by Ryans and Sutherland (2001), only screefing, trenching, occasionally inverting and mounding, and, rarely, mixing are suitable for preparing receptive seedbeds for direct seeding. However, other described methods including clearing and shearing, raking and chopping may be used in conjunction with chemical site preparation and/or prescribed fire. The effectiveness of such equipment in creating specific seedbed conditions suitable for direct seeding is presented in Table 7.1.

There are many impediments to mechanical site preparation that can significantly inhibit the ability of the equipment to carry out the desired effect. These difficulties may be directly related to the site: excessive slope, poor trafficability due to interrupted drainage patterns and variable plasticity within the soil profile, which influence bearing strength and traction capacity of the prime mover. These site related difficulties may be overcome by allowing some flexibility in the timing of the operation and ensuring that a site appropriate scarifier/prime mover combination is used.

Impediments may also come in the form of physical obstructions such as surficial erratic boulders, overly stony or cobbled soils, dense stump fields and high slash loading following harvesting. It may be possible to overcome some of these impediments by increasing the power of the prime mover, installing a slash-parting blade or increasing the weight of drag units or downward pressure of discing units. If these adjustments are not effective in achieving the required exposure with a single pass, a second pass may be required.

If slash or stony conditions are too harsh for effective mechanical site preparation, consider motor manual or manual screefing of individual seed spots. On shallow or extremely coarse-textured soils, maintain nutrient availability by prescribing shallow site preparation in small patches or narrow furrows.

Black spruce has more exacting seedbed requirements than jack pine. Monitor the site preparation operation carefully to ensure that the prescription for seedbed quantity and quality is fulfilled.

Type of Treatment	Operational Impediments	Generic Equipment Type								
		Drags		Disc Trenchers		Patch Scarifiers or Mounders	Blades or Plows	Choppers or Masticators	Rakes	Mixers or Tillers
		Light	Heavy	Mechanical (trailing)	Powered (mounted)					
L & part of **F** layer removed or displaced (e.g., shallow screef)	Heavy	Slightly effective	Moderately effective	Slightly effective	Slightly effective / Moderately effective	Slightly effective	Slightly effective	Treatment to avoid	Very effective	Not applicable
	Light	Moderately effective / Very effective	Treatment to avoid	Slightly effective / Moderately effective	Moderately effective / Very effective	Very effective	Slightly effective	Treatment to avoid	Very effective	Not applicable
LFH removed, mineral soil intact (e.g. deep screef)	Heavy	Slightly effective	Slightly effective / Very effective	Slightly effective / Moderately effective	Moderately effective / Very effective	Slightly effective	Very effective	Not applicable	Very effective	Not applicable
	Light	Very effective	Very effective	Slightly effective / Very effective	Very effective	Very effective	Very effective	Not applicable	Very effective	Not applicable
LFH removed, some mineral soil removed (e.g., deep screef)	Heavy	Slightly effective	Slightly effective / Moderately effective	Slightly effective	Very effective	Slightly effective	Very effective	Not applicable	Slightly effective	Not applicable
	Light	Slightly effective / Moderately effective	Slightly effective / Very effective	Slightly effective / Very effective	Very effective	Very effective	Very effective	Not applicable	Slightly effective	Not applicable
LFH removed, mineral mound on mineral soil	Heavy	Not applicable	Not applicable	Not applicable	Treatment to avoid	Treatment to avoid	Treatment to avoid	Not applicable	Not applicable	Not applicable
	Light	Not applicable	Not applicable	Not applicable	Treatment to avoid	Treatment to avoid	Treatment to avoid	Not applicable	Not applicable	Not applicable
LFH and mineral Layers inverted (mineral over organic)	Heavy	Not applicable	Not applicable	Not applicable	Not applicable	Treatment to avoid	Not applicable	Not applicable	Not applicable	Not applicable
	Light	Not applicable	Not applicable	Not applicable	Not applicable	Treatment to avoid	Not applicable	Not applicable	Not applicable	Not applicable
LFH and mineral Mixed(e.g., tilling)	Heavy	Slightly effective	Slightly effective	Slightly effective	Slightly effective	Not applicable	Treatment to avoid	Slightly effective	Slightly effective	Slightly effective
	Light	Slightly effective / Moderately effective	Slightly effective / Moderately effective	Slightly effective	Slightly effective	Not applicable	Treatment to avoid	Slightly effective	Slightly effective	Very effective
Part of **OF** removed (e.g., shearblading)	Heavy	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Very effective	Not applicable	Not applicable	Not applicable
	Light	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Very effective	Not applicable	Not applicable	Not applicable

Very effective · Moderately effective · Slightly effective · Treatment to avoid · Not applicable

Table 7.1 Effectiveness of site preparation equipment in creating specific soil microsites suitable for direct seeding *(adapted from Ryans and Sutherland 2001).*

7.3.2 Mechanical site preparation methods on lowlands

Tractor-mounted shearblades (e.g., Rome, Fleco, and Superior V-blade) have been used to prepare lowland seedbeds for black spruce. The peat soil must be thoroughly frozen so that the tractor pads do not create ruts. Blading can move slash into windrows, and depending on the microtopography, remove a thin layer of surface moss and peat, or remove the tops from moss hummocks. Deep blading is not desirable on peatlands because of shallow water tables. Clumps of *Sphagnum* peat detached by deep blading are not good seedbeds because they are not well connected to the underlying water supply.

7.3.3 Prescribed burning

When considering prescribed burning for site preparation, take into account the following factors: fuel loading, soil substrate, SMR, landforms, stage of green-up, and boundary controls (Racey et al. 1989; Archibald et al. 1994). Choose a harvesting method that will provide the fuel load required to carry combustion. Do not use prescribed burning when preservation of advance growth is an objective.

The degree of burn achieved is dependent on weather conditions and the ignition technique. Fairly intensive burn conditions are needed to sufficiently reduce slash and organic matter and create receptive microsites for seeding. Refer to Duff Moisture Codes and the Prescribed Burn Manual (Ontario Ministry Natural Resources 1987) to assist in carrying out the burn.

7.3.3.1 Prescribed burning on upland sites

The fire must be intense enough to burn sufficient duff and raw humus to achieve some degree of mineral soil exposure (Chrosciewicz 1990a). In general, burn to reduce the thickness of the LFH horizon to just above the mineral soil/humus interface. If the burn is too severe, and the humus layer is completely removed, an inhospitable environment for seedling establishment can result. In northern Ontario, summer prescribed burning programs traditionally began July 15, but extending the burning window into early summer can significantly increase the availability of suitable burning days in a season (Archibald et al. 1994).

For some NWO FEC V-types (20, 31, 33, and 34), burning can be effective on fresh to moist, fine textured, deep to moderately deep S-types (S5CS10, SS7, and SS8). Fire should produce about 50 percent mineral soil exposure in a patchwork of residual, partially burned humus. However, on these types of sites there is a higher risk of seeding failure due to drought.

Jack pine V-types (17, 18, 28-30, and 32) that are tree-length harvested may be well suited to burning because of their slash loading. However, if V-types 18, 29, and 32 (jack pine/feathermoss) are full-tree logged, it is not likely they will burn well unless a continuous cover of feathermoss is present to carry the fire. Though prescribed fire will open jack pine cones in the slash, most of the seeds are destroyed.

Do not burn on poor quality, coarser-textured sandy uplands (V30). These soils are nutritionally poor and have thin organic layers. Deep burning destroys this organic layer resulting in decreased soil water holding capacity, soil moisture content, soil nutrients and increased potential for erosion resulting in lower long-term site productivity.

7.3.3.2 Prescribed burning on lowland sites

This site preparation method may be effective on lowland sites in reducing slash coverage and in slowing *Sphagnum* moss growth. The use of heavy equipment may be too costly or unwarranted on these sites because of the potential for site degradation (e.g., sites where the permanent water table is less than 1 m below the surface).

Because *Sphagnum* is an excellent black spruce seedbed, burning is not considered essential to regenerate *Sphagnum*-rich sites, unless there is a heavy cover of slash (i.e., NWO FEC S11, S12S, and SS9, and NEO FEC STs 11, 12 and 8). However, moderate-to-severe burning can improve the success of black spruce seeding. It scorches living *Sphagnum* and subsequently slows its growth, burns feathermosses and feathermoss peat down to wetter layers, eliminates slash that often covers significant portions of the seedbed, improves seedbed fertility and, sets back competition from shrubs and grasses for a time.

On sites with a high speckled alder cover, mild burns can favour black spruce regeneration by reducing alder densities without totally removing it. If too much alder is removed, other competitors are favoured, which negates the advantage for black spruce. In NW Ontario, speckled alder is an important competitor in V-types 22, 23, and 35; and may be so in V-types 34 and 36; in NE Ontario, in ecosites 12 and 13.

7.3.4 Disturbance by harvesting equipment on lowland sites

Full-tree harvesting on lowland sites (NEO FEC STs 11 and 12; NWO FEC V-types 35,36 and 37) can be an effective and economical method of exposing *Sphagnum* peat seedbeds. Full-tree harvesting reduces the amount of slash coverage of seedbeds, and the dragging of tree crowns along skidways prunes away the living portions of the *Sphagnum* and exposes the poorly decomposed peat below. Sufficient coverage of receptive seedbeds is likely to occur mainly with summer harvesting, and will be concentrated along equipment trails.

Direct seeding of the equipment trails will complement preservation of black spruce advance growth between the skid trails.

This technique is not appropriate for site types that are susceptible to rutting (e.g., NEO STs 12 and 13).

RECOMMENDATIONS

- Identify fragile sites (e.g., very shallow-soiled uplands and rich organic sites) and minimize their disturbance.
- Prior to treatment, determine slash loadings, stocking, and density of advance growth, topographic uniformity, competition potential, soil depth, and Soil Moisture Regime.
- Ensure that seedbeds are well distributed over the site.
- Avoid prescribing any form of site preparation treatment on sites that have high levels of post-harvest advance growth.
- Ensure that the site preparation equipment operator is well aware of the objectives and adjusts the machinery to achieve consistent results as conditions change over the site.

8.0 SEEDBED ASSESSMENT

8.1 Why Do a Seedbed Assessment?

A seedbed survey should be carried out after site preparation and before seeding to assess the area and distribution of available seedbeds, and to identify portions of the seeding block where site preparation is inadequate. The survey will determine whether the site preparation prescription has been satisfied, and to some extent, allows for adjusting the seeding rate prescription.

8.2 Seedbed Survey for Broadcast Seeding

Most seedbed surveys are plot-based. The size of the sample plot (quadrat) should be the same as the size of the stocking unit used to assess regeneration (typically 4 m^2).

The number of plots needed to adequately describe the seedbeds in the proposed seeding chance can be determined statistically. However, this requires pre-sampling the area to ascertain seedbed variability and then calculating the total number of quadrats necessary. In an operational setting, this approach may be impractical; therefore, it is recommended that a minimum of 100 quadrats per seeding chance be used, 200 being preferable. This approach will normally provide an accurate estimate of the area of most seedbed types.

Ideally, the quadrats should be randomly located: overlay a map of the seeding block with a numbered mylar grid (similar to those used to calculate stand areas), and use a table of random numbers to choose the quadrat locations. Systematic location of quadrats can simplify positioning and navigation within the cutover, but invalidates the statistical basis for determining accuracy. Clustering quadrats reduces the amount of walking time required, but clustered quadrats are then not independent, and individual quadrats cannot count fully to the required sample size (Figure 8.1). For example, the accuracy provided by 20 randomly located clusters of 10 quadrats is less than that provided by 200 randomly located quadrats. Thus, more quadrats must be sampled when using clusters.

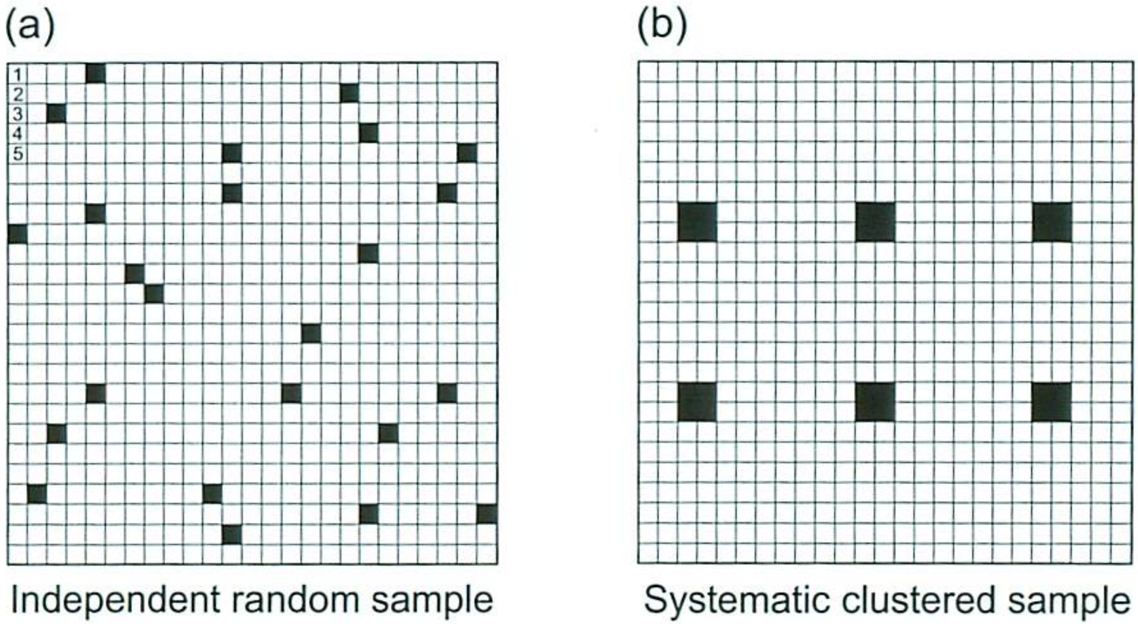


Figure 8.1 An illustration of two sampling techniques: (a) an independent random sample, and (b) a systematic clustered sample.

The following combinations provide roughly equivalent accuracy:

- 200 individual quadrats
- 102 clusters of 2 quadrats
- 54 clusters of 4 quadrats
- 30 clusters of 8 quadrats
- 25 clusters of 10 quadrats

If a random clustered design is selected (e.g., a 20-m line segment containing 10 quadrats), ensure that the site preparation and sampling patterns do not coincide and result in bias. Survey lines should cross the mechanical site preparation furrows at a 90° angle (perpendicular to the direction of site preparation). Close attention should be paid to the variable direction of the site preparation, and the angle of the sampling pattern should be adjusted as required.

Areas with wide variation in site type or in uniformity of site preparation should be stratified before sampling is carried out to provide greater accuracy. This work may be done in the office if maps or aerial photographs are available.

Appendix E gives a step-by-step guide to establishing baselines, transects, and quadrats to achieve a random clustered sampling pattern.

8.2.1 Quadrat assessment

Determine seedbed types and their percent coverage for each 4-m^2 quadrat. Use Section 6 to identify common seedbed types, to determine their relative position within the soil horizon, and their potential receptivity. Note that the term seedbed not only refers to those surfaces that have been exposed by site disturbance (mechanical site preparation, prescribed burning, or the logging operation) but may also include surfaces that are in an undisturbed state (e.g., living *Sphagnum* and litter).

The seedbed classification used in the survey must provide enough detail to allow the development of a sound prescription, but should not be so detailed that it makes the survey and subsequent analysis inefficient. Generally, all seedbeds with high receptivity should be identified, unless they are very rare. Identify seedbeds with high area coverage even if they have low receptivity, since they may significantly augment stocking. Seedbed types with similar characteristics (especially similar ERs) can be lumped together. Do not identify non-receptive substrates (rock, water, thick slash, stumps etc.)

For lowland black spruce sites the main seedbed types are typically:

- compact living *Sphagnum* moss
- loose living *Sphagnum* moss
- exposed *Sphagnum* peat
- living or dead feathermoss
- exposed feathermoss peat
- rotten wood
- moderately to well-decomposed organic matter

For upland black spruce and jack pine sites the main seedbed types are typically:

- upturn
- litter
- thick - F
- thin - F
- thin - H
- upper mineral soil horizon [<10 cm below mineral/humus interface]
- lower mineral soil horizon [>10 cm below the mineral/humus interface]

Appendix F provides step-by-step methods for assessing quadrats.

Besides the above, information on advance growth, cone quantities, and site conditions can also be gathered for silvicultural planning purposes. An example of a quadrat survey tally sheet (Figure F.1) is provided in appendix F. Electronic data recorders can also be used to facilitate the entire operation.

The time required to carry out a seedbed assessment entailing 150-4 m^2 sample plots (not including block layout) would take a trained two person crew approximately 12 to 14 working hours.

8.3 Seedbed Assessments for Spot Seeding or Row Seeding

The objective of a spot seeding survey is to determine the number of seedable spots per ha (e.g., for use in conjunction with a seed shelter operation). The criteria for the selection of a seedable spot must be established prior to the assessment. Section 6 of this Guide can help identify the most suitable seedbeds for a particular species and site type. The minimum acceptable distance between seed spots must also be determined, because it strongly influences the number of seedable spots per ha. It is undesirable to place seed spots too close together; this could lead to overcrowding. However, for many seedbed types, the percentage of stocked seedbeds will be much lower than 100 percent: to establish a given number of stocked spots per ha, it is necessary to set out a substantially higher number of seed spots. The distance between spots must decrease as the percentage of stocked spots decreases.

Base the survey on a minimum acceptable distance between seed spots; about 1 m is appropriate for most circumstances. Confine sampling to the site-prepared sections of the seeding chance, since this is where seeds will be applied.

Unlike a plantability assessment, it is not necessary to define the spots as receptive, marginal or non-receptive. Simply identify the seedbed type.

Appendix G provides details on carrying out a seed spot survey.

CONSIDERATIONS

- The results of the assessment for spot seeding can be entered into PC SEED to provide an estimate of stocking.
- If the stocking is less than desired, consider:
  - (i) decreasing spacing between spots.
  - (ii) carrying out manual spot screefing at the time of seeding to increase spot density.
  - (iii) increasing the number of seeds per spot.

For row seeding carried out simultaneously with site preparation, a seedbed assessment is not necessary. However, to ensure that the prescribed seeding rate is followed, regularly monitor seed deposition on the prescribed microsite and ensure proper inter row spacing during the operation.

9.0 DEVELOPING DIRECT SEEDING PRESCRIPTIONS

Three factors that have an important bearing on stocking and that can be influenced by the forest manager are described in the "seeding success triangle" (Figure 9.1):

- seedbed receptivity (percent);
- seeding rate (e.g., 50,000 seeds/ha);
- seedbed area (amount and distribution) (e.g., 20 percent of the gross area, uniformly distributed).

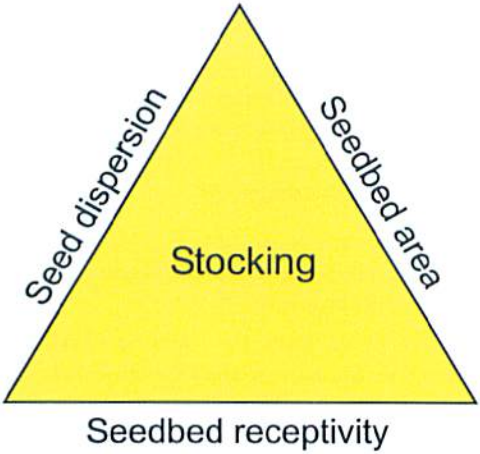


Figure 9.1 The three elements that determine stocking in broadcast seeding *(Groot 1994).*

The prescription for direct seeding should specify the area and distribution of receptive seedbeds and the seeding rate. Prescriptions that make use of information about site types and seedbed receptivity have the greatest likelihood of success, but often prescriptions are developed with less than complete information. Depending on the information available, several approaches to the development of prescriptions are possible.

9.1 What Information Sources Exist?

Information on seedbed availability

- The typical seedbed availability associated with a particular site preparation technique on a certain site may be known from local experience or published reports. Using such information does not require a visit to the site, but prescriptions based on such information may be invalidated if the particulars of the situation produce markedly different seedbed availability. A site inspection is highly recommended.

- An inspection of the site can provide a subjective estimate of seedbed availability. The quality of this information is dependent on the ability of the inspector to estimate seedbed amounts.

- A thorough survey can be carried out to determine seedbed availability (see Section 8). This approach provides the most accurate seedbed information.

Information on seedbed receptivity

Because of variable weather and site conditions, it is not possible to have exact knowledge of seedbed receptivity prior to the seeding operation. Probable or typical values can be determined, however.

- Local experience can be the basis for a relative ranking of receptivity for different seedbeds, but does not provide absolute values for establishment ratios.

- The seedbed data sheets (Section 6.5) provide establishment ratios for a number of common seedbed types. This information was obtained from a number of direct seeding experiments, and has greatest applicability to areas that have similar site types and weather patterns.

- Locally collected information on seedbed receptivity (seed spots or less direct techniques) is the best source of receptivity information. (see Section 11)

Information on site type

- Site type can be interpreted from aerial photographs, maps and general knowledge of the region.

- Site types can be identified during an inspection of the site. The intensity of this inspection can vary from a cursory examination to a detailed survey (Section 3).

9.2 What Approaches Can be Used to Develop Prescriptions?

Use a standard prescription based on local experience.

The combination of site preparation and seeding rate that will result in successful stocking and density for a given site type may be known. Local experience can provide good prescriptions, but it also involves risks. If conditions (e.g., site type, quality of site preparation) change, local experience may offer little immediate guidance for changes to prescriptions. If regeneration fails, it may be difficult to identify the cause of failure.

The main requirement when using a standard prescription is that the site is similar to sites where the prescription has succeeded previously. Because site type can be interpreted from maps and aerial photographs, a visit to the site, although highly desirable, is not strictly necessary.

The availability of more detailed information on seedbed receptivity, site conditions or seedbed availability (e.g., from a survey conducted after site preparation) may prompt modification to a standard prescription. This modification could include changing the seeding rate, or, in cases of grossly inadequate site preparation, to prescribe site preparation re-treatment or planting of the site.

Develop a prescription based on published statistical relationships.

Broadcast seeding experiments have provided statistical relationships between seeding rates, seedbed amounts and stocking for jack pine in northeastern Ontario and black spruce on peatlands in the Ontario clay belt. In both cases, the relationships provide a basis for prescribing combinations of seedbed amounts and seeding rates.

Riley (1980) developed curves relating stocking to receptive seedbed availability for several seeding rates of jack pine in northeastern Ontario (Figure 9.2). Based on these curves, Riley (1980) considered the optimum receptive seedbed[1] area to

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1 Receptive seedbed was defined as: a) exposed mineral soil with a firm base, or b) a thin (<13 mm) duff/mineral soil mix which should readily settle to a firm base, or c) firm mineral soil with a very thin duff cover, generally not more than 7 mm thick.

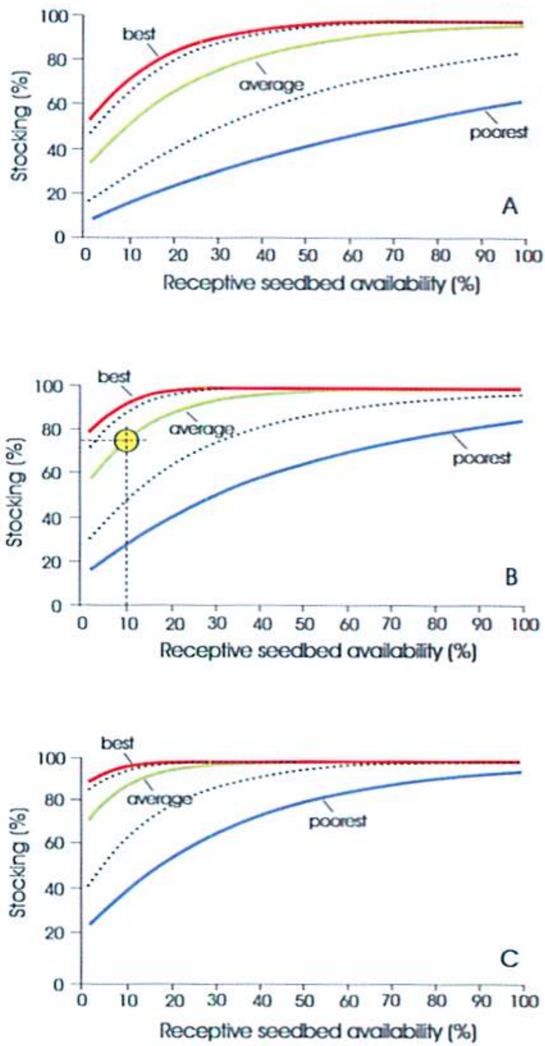

Figure 9.2 Jack pine stocking probability curves for a range of growing conditions by seedbed availability class for deposition rates of (A) 25,000, (B) 50,000 and (C) 75,000 seeds/ha three years after seeding *(Riley 1980)*.

be 15 to 25% with a seeding rate of 50,000 seeds per ha. The effects of altering seedbed availability or seeding rate can be examined using these curves. For example, a mean 3rd year stocking value of 76 to 77% can be achieved with 10% receptive seedbed area and a seeding rate of 50,000 seeds per ha, or with 30% receptive seedbed and a seeding rate of 25,000 seeds per ha.

Groot and Adams (1994) developed a relationship between stocking and effective seeding rate (actual seeding rate x receptive seedbed[2] area) for broadcast seeding black spruce on peatlands in northeastern Ontario (Figure 9.3). From this relationship, an effective seeding rate of 6 or 7 seeds per quadrat[3] (4 m^2) was recommended to achieve 80% stocking. The following combinations of seeding rate and seedbed area all result in an effective seeding rate of 6 seeds per quadrat: 50,000 seeds per ha and 30% receptive seedbed area; 100,000 and 15%; and, 200,000 and 7.5%. If lower stocking is acceptable, the relationship in Figure 9.3 can be used to determine the appropriate effective seeding rate, leading again to varying combinations of actual seeding rate and receptive seedbed area.

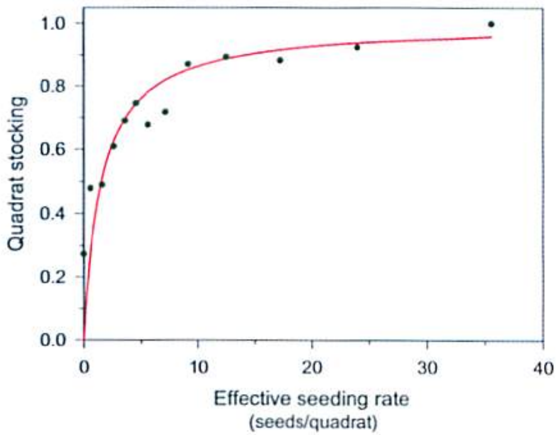

Figure 9.3 Relationship between quadrat stocking and effective seeding rate (number of seeds per quadrat x area of receptive seedbed per quadrat) *(Groot and Adams 1994).*

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[2] Receptive seedbed was defined as: compact *Sphagnum*, poorly decomposed *Sphagnum* peat (in situ) or, sheared *Sphagnum*.

[3] [Effective seeds per quadrat = viable seeds per ha. / 2,500 quadrats per ha. x receptive seedbed area]

Both the jack pine and black spruce relationships give the stocking probability for quadrats with a given amount of seedbed and seeding rate. The relationships would be immediately applicable to the whole seeding block, if each quadrat had the same seedbed area. Seedbed areas typically vary from quadrat to quadrat, however, and Riley (1980) outlined a procedure to take this variation into account. Essentially, the procedure involves the following steps: (i) conduct a seedbed survey; (ii) determine the percentage of quadrats falling into receptive seedbed area classes; (iii) for a selected seeding rate, determine the probability of stocking for each receptive seedbed area class; and (iv) sum the products of the values determined in (ii) and (iii). The same procedure can be used with the peatland black spruce relationships.

It should be recognized that these statistical relationships may not be valid in different regions, on different site types, or when the relative proportions of different seedbed types change.

Develop a prescription based on probabilistic models.

Probabilistic models use information on seedbed availability, seedbed receptivity and seeding rate to estimate stocking. Such models are more complex and have not previously been used operationally. The PC-SEED program included with this manual is designed to simplify the use of probabilistic models.

PC-SEED is a spreadsheet-like DOS-based program that can be used to explore the relationship of stocking and density to seedbed characteristics and seeding rate. The PC-SEED manual provides details on the commands used to operate the program.

PC-SEED requires information on seedbed area and receptivity for each seedbed type. The name of the seedbed type ("Seedbed Type") is entered into the first column, and seedbed receptivity is entered into the second column ("Recept"). Sources of information for receptivity data are outlined in section 9.1. Ideally, seedbed areas are determined from a seedbed survey, and are entered into the "Q1" ... columns in PC-SEED. If only an estimate of the average area of a seedbed is available, it is also possible to enter this value in the "Area" column (select **|Calculate|Areas|Generate** from the menu). To incorporate the effect of variability in seedbed areas, PC-SEED generates quadrat areas with a selected value of variance.

When the required information has been entered, the probability of each quadrat being stocked can be displayed along the bottom line of the screen (**|Setup|Bottom Line|Stocking**). These probabilities are based on a seeding rate that can be set in **|Calculate|Broadcast|Seeding Rate**. The effect of varying seeding rate can be examined by selecting **|Graph|Stocking** and a graph scale.

9.3 Considerations in developing broadcast seeding prescriptions

Diminishing returns

It is evident from Figures 9.2 and 9.3 that stocking does not increase with seedbed area and seeding rate in a linear manner. Instead, the law of diminishing returns applies and increases in seedbed area or seeding rate eventually produce smaller and smaller increases in stocking. As a result, it is often not feasible to compensate for insufficient seedbed area or low seedbed receptivity with higher seeding rates.

Natural seed sources

Natural sources will often make a substantial contribution of seed in direct seeding operations. This seed can originate from residual trees on or adjacent to the harvested area, or from cones in the logging debris. If the natural seed input is expected to be significant, it must be considered when developing prescriptions.

In PC-SEED the effect of natural seed input can be taken into account by adding it to the planned seeding rate in **|Calculate|Broadcast|Seeding Rate**. For example, if the planned seeding rate is 100,000 seeds per ha, and the estimated natural input is 20,000 seeds per ha, then a value of 120,000 should be entered in this area.

Estimating natural seed inputs can be problematic. One method is to compare seedling densities on areas that have been seeded at a known rate with areas that have not been seeded. If the density on the area seeded at known rate A is D_{n+a}, and the density on unseeded area is D_n, then the estimated natural seeding rate is

$$\frac{AD_n}{D_{n+a} - D_n} .$$

This equation is valid only if the site conditions and the arrangement of seed sources is similar on both the seeded and unseeded areas.

Stratifying seeding blocks

If the seeding block contains areas that differ significantly in seedbed receptivity, type or amount, then the block should be stratified into more uniform sub-blocks (see Section 8.2). Potential stocking should be evaluated separately for each sub-block using local experience, statistical relationships or PC-SEED. This will provide an indication of how regeneration success will vary among the sub-blocks if a single prescription is used over the whole seeding block, or it can provide guidance for tailoring prescriptions to best suit each seeding block.

Confidence limits

Accurate prediction of the outcome of a direct seeding operation is not possible because of the many sources of variability involved. These include weather, natural seed input, seed application, site conditions, and site preparation. As a result, stocking results can show wide variation (Figure 9.2). Information about standard deviation of seedbed receptivity can help a forest manager assess the range of potential results of a seedling operation.

The seedbed data sheets (Section 6.5) provide the standard deviation in receptivity for a number of seedbeds. If the mean receptivity of a seedbed is 25% and the standard deviation is 10%, then a lower confidence limit one standard deviation from the mean would be 25% - (1 x 10%) = 15%. Assuming a normal distribution, receptivity values greater than this lower confidence limit would occur on 84% of all seeding blocks (see Table 9.1 for other values).

Table 9.1 Lower confidence limits and probability of greater values.

Lower confidence limit for receptivity	Probability of a greater receptivity value
mean - 0.5 x standard deviation	69%
mean - 1.0 x standard deviation	84%
mean - 1.5 x standard deviation	93%
mean - 2.0 x standard deviation	98%

These lower confidence limits for receptivity can be used to assess the likelihood of a successful direct seeding operation. In Figure 9.2, the lower dashed line is the stocking result that occurs when receptivity is one standard deviation less than the mean. Stocking will be above this line in 84% of all cases. Similar analyses can be carried with PC-SEED by entering lower confidence limits into the "Recept" column.

Traditional seeding rates

The seeding rate traditionally used for jack pine is 50,000 viable seeds/ha, and 100,000 for black spruce. However, a single seeding rate is not applicable to all situations. A "one size fits all" approach cannot bring about consistent results, because it addresses only one side of the seeding triangle.

Developing spot seeding prescriptions

In planning spot seeding operations (see Section 10.4.4), it is necessary to identify the desired seedbed types, and to prescribe the number of spots per hectare and the number of seeds per spot. It should be noted that the determination of spacing in spot seeding differs from that in tree planting. In planting, the survival of planted seedlings is often sufficiently high that the spacing of surviving trees is similar to the initial spacing. In spot seeding, however, the percentage of stocked spots will be substantially less than 100 percent for most seedbeds. To establish a given number of stocked spots per ha, it is necessary to set out a considerably higher number of seed spots. For example, to obtain 2,000 stocked seed spots/ha when the percentage of stocked spots is 40% requires setting out 5,000 spots/ha.

If the spot seeding is done in combination with mechanical site preparation, the closer initial spacing can be achieved by decreasing the distance between rows of site preparation, or by decreasing the distance between seed spots along a row, or both.

The **Calculate | Seed spot and Graph | Seed spot** options in PC-SEED can be used to explore how seedbed receptivity, number of seeds per spot and seed viability influence stocking in spot seeding.

It is evident that increasing the number of seeds per spot generally cannot compensate for low seedbed receptivity (Figure 9.4). It is possible to compensate for low seed spot stocking by increasing the number of seed spots initially set out, but there is a point at which this becomes impractical. Regeneration using seed spots is most feasible when high receptivity seedbeds are available, or whenseedbed receptivity can be improved using treatments such as seed shelters (see 10.4.4). When seedbeds have high receptivity, a low number of seeds per spot can be used and the proportion of stocked spots is high.

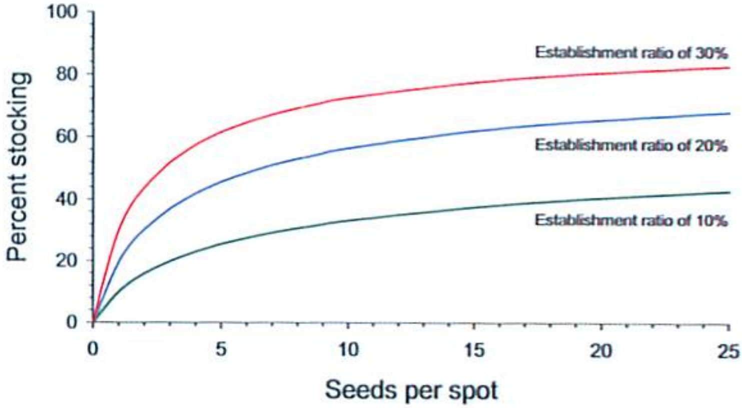


Figure 9.4 Relationship between seeds per spot, establishment ratio and stocking.

Developing row seeding prescriptions

If the row seeding operation deposits single seeds, then the seeding density can be estimated from:

$$\text{density} = \sum_{I=1}^{n} \text{proportion of seeds deposited on seedbed I} \times \text{ER for seedbed I} \times \text{seeding rate.}$$

For example, suppose that a seeder is used to deposit seeds onto mineral soil (ER = 20%) in trenches. The trenches are 2 m apart and seeds are deposited every 50 cm (i.e., 10,000 seeds/ha.). About 90% of the seeds land on the target seedbed and 10% fall on litter seedbeds (ER = 2%) beside the trench.

The density = 90% x 20% x 10,000 seeds/ha
+ 10% x 2% x 10,000 seeds/ha
= 1,820 seedlings/ ha

If the row seeding operation deposits more that one seed per spot, then the procedures used for developing spot seeding prescriptions should be used.

10.0 SEED APPLICATION

The likelihood of regeneration success is increased if the seed is applied at the appropriate time with suitable equipment and methods.

10.1 What Season Is Best?

Generally, black spruce and jack pine should be seeded onto the snow in late winter or in the spring soon after the snow melts. Seeding on the snow is preferable because seeds are able to take advantage of the available soil moisture as the snow melts in the spring. Another advantage of sowing early is that the germinants also benefit from the rainfall occurring in April and May.

Sowing either species later than mid-June is not recommended – stocking will be typically much lower than in spring sowing. Both black spruce and jack pine can be fall-seeded, but there is increased risk that seeds will be lost due to predation, burial, or other causes. Fall seeding should be done as late as possible to prevent premature germination.

10. 2 How Soon After Site Preparation Should Seeding Occur?

Seeding should be carried out after newly prepared seedbeds have stabilized, but before seedbed receptivity begins to decline with age.

After mechanical site preparation, seedbeds may be unfirm because of high porosity and unstable microtopography. Some experienced foresters advise that seeding be delayed for 1 to 6 months after site preparation to allow some soil settling to occur, thus reducing the number of seeds and germinants lost by burying. This is of particular concern for black spruce because of its small seed size. A significant rainfall will achieve much of the weathering required to stabilize mechanically site prepared seedbeds.

Seedbed chemical conditions may be unfavourable for seedling establishment immediately after prescribed burning. Allowing prescribed burns to overwinter will permit burned seedbeds to undergo weathering and leaching resulting in a lower pH, reduced toxicity and improved hydraulic conductivity. Overwintering may not be required for prescribed burns carried out from early July-to-late August and seeded in mid-to-late November.

Seedbed receptivity often declines as seedbeds age, because of re-colonization by vegetation and physical changes in soil structure. Consequently, seeding should be carried out within a year of site preparation. Establishment can be significantly reduced if seeding is delayed on sites that are predisposed to invasion by herbaceous or graminoid competition (Section 3).

When seeded within a year, stocking of jack pine is often in the 68-78 percent range. When seeding is delayed for 1 to 2 years, stocking rates of 18-32 percent are not uncommon.

For black spruce, the greatest establishment ratios on preferred upland seedbeds usually occur in the first year following scarification. However, factors such as near-surface soil moisture, soil and air temperature, frost heaving, and insect and disease conditions vary greatly from one year to the next, and can have a profound effect on seedling establishment ratios. Because of this, seeding black spruce within the first year of site preparation and repeating the seeding one year later may increase the probability of success.

On lowlands, prompt seed application is less critical because of the predominance of seedbeds such as living *Sphagnum* or *Sphagnum* peat; seeding on these types may be successful even if delayed for several years.

10.3 What Seeding Methods Are Used?

Four sowing methods are commonly used operationally with associated site preparation methods:

1. Aerial seeding:
   - in furrows;
   - on intermittent scalps;
   - on burned areas;
   - on surfaces disturbed by harvesting (e.g., peatlands).
2. Mechanical ground seeding:
   - in rows;
   - on patches.
3. Spot seeding with or without seed shelters
4. Ground broadcast seeding

Aerial seeding is the method most used in Ontario. It is well-suited to jack pine, which represents approximately 80% of all seeding done in the province. Research and development are ongoing to improve mechanical ground seeders that sow at the time of scarification. Hand seeding has been carried out on relatively small areas, usually in conjunction with seed shelters. Ground broadcast seeding using the Brohm seeder was practised in the early 1970s using snowmobiles, and worked well for relatively small areas.

Row seeding and hand seeding methods require less seed than aerial seeding where over 75% of the seeds applied fall on non-receptive seedbed.

10.3.1 Aerial seeding

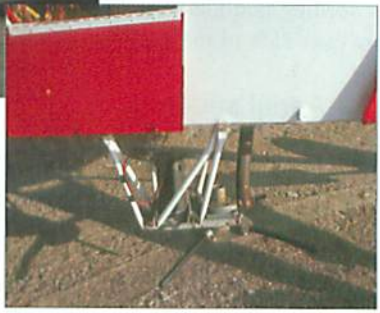
The Brohm aerial seeder is the most commonly used seeder in Ontario. It was developed in the late 1950s and early 1960s by the MNR, and is of slinger design. It is now used in combination with fixed-wing aircraft, most notably the Piper Super Cub (Table 10.1).[1] The Brohm seeder consists of a hopper from which the seed is metered by a variable-speed auger via a flexible duct to a constant-speed slinger beneath the aircraft (Figure 10.1). The rate of seed application can be controlled in flight by adjusting the auger speed (Foreman 1995). Several aerial seeder/helicopter combinations have been developed and used operationally in both northwestern and northeastern Ontario (Figure 10.2). All seeders have unique seed-metering mechanisms. Both the Alberta Forest Seeder, developed by the Alberta Forest Service for turbine-powered helicopters and the Tembec Aerial Seeder, developed by Tembec Inc. (Spruce Falls) use rotating, large-diameter cylinders or wheels, with seed pick-up on the outer surface of the cylinder, to transfer seed from the hopper to the slinger. The Isolair Broadcaster, developed by Isolair, uses a pneumatic seed delivery system (Reynolds 1997).

Table 10.1 Capacity of the Piper Super Cub (PA-18A) Brohm Seeder Combination

Flying Time	5 hours
Area coverage rate	50 to 75 ha per hour
Seed Hopper Capacity	55 kg (approx. 15 million jack pine seed)

1 In Ontario only one contractor (General Airspray, Lucan) has the PA-18A Aircraft Brohm seeder equipment. They first operationally sowed in 1967. As of 2005 they had four aircraft dedicated to aerial seeding. Over time this firm has acquired proprietary knowledge and skills.

Piper PA-18A Aircraft



Brohm Seeder

Figure 10.1 The Brohm seeder has traditionally been used in combination with the Piper PA-18A aircraft.

Alberta Forest Seeder

Jeff Leach (Tembec Inc.)

Tembec Inc. Seeder

Figure 10.2 Examples of two aerial seeder/helicopter combinations

10.3.1.1 Calibration and seed distribution

If possible, the seeder should be calibrated on the ground to determine an output rate that will provide the prescribed application rate for the proposed aircraft ground speed and inter-pass spacing (see Appendix H for the Brohm seeder calibration procedure).

Variation in seedling stocking and density would be least if the seed could be deposited uniformly over the site, but uniform distribution of seeds at the quadrat scale cannot be achieved with broadcast seeding. Random distribution is potentially achievable by broadcast seeding devices, but in practice uneven distribution occurs. Even with completely random distribution, low seeding rates will result in a significant proportion of quadrats receiving far fewer than the average number of seeds per quadrat (Figure 10.3).

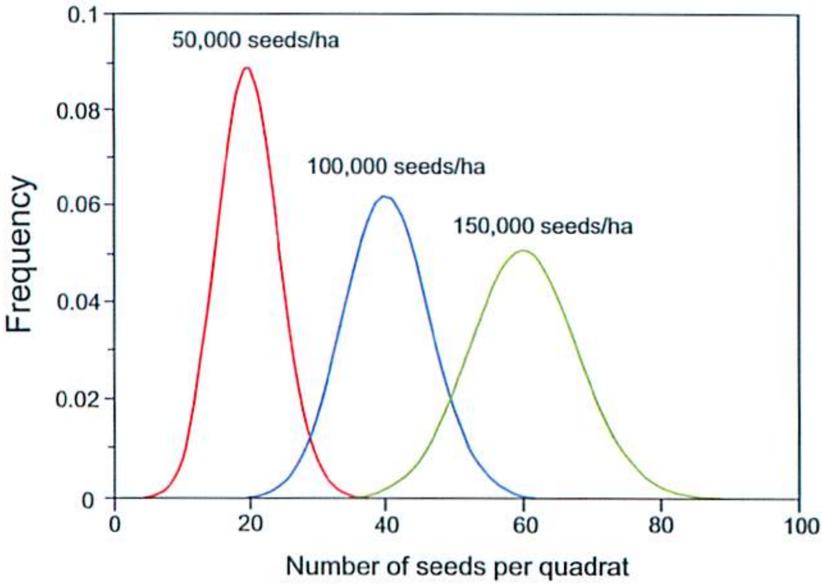


Figure 10.3 Frequency distribution of number of seeds per 4-m^2 quadrat, for three broadcast seeding rates with random seed distribution *(Groot 1994)*.

In aerial seeding, seed is broadcast in long, parallel swaths; variation in distribution occurs both across and along the swath (Figure 10.4). Based on knowledge of the seed deposition characteristics for particular equipment and operating conditions, the forest manager and the aerial seeding applicator should try to reduce these variations. The following standard has been suggested as a measure of adequate seed distribution: minimum seed deposition on a 4-m² quadrat basis should be ≥50% of the mean deposit rate over >90% of the seeding chance (Fleming et al. 1985).

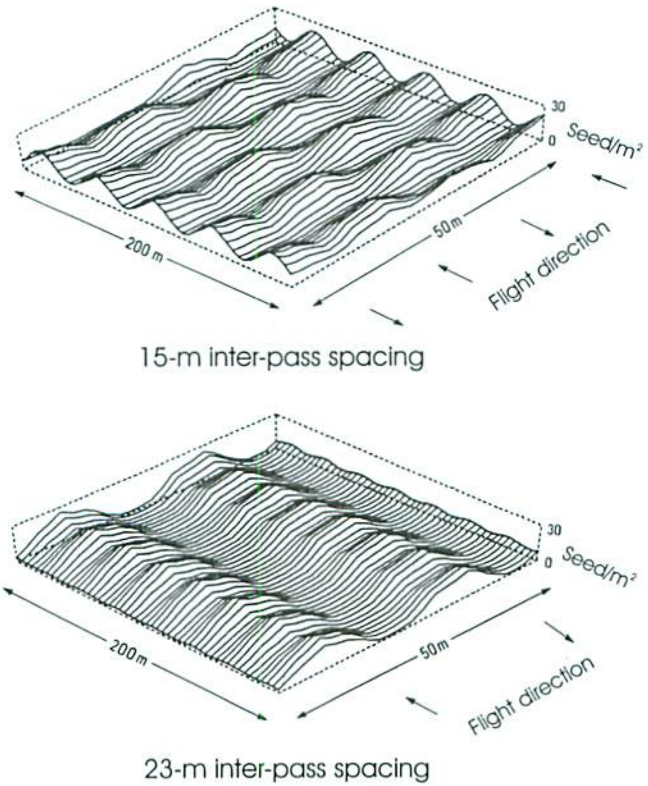


Figure 10.4 Expected black spruce seed distribution across and along the flight path at 15 and 23-m inter-pass spacing, 100,000 seeds/ha. *(Fleming et al. 1985).*

The distribution of seed across and along the swath is influenced by several factors. A primary factor is the pattern of turbulent airflow about and in the wake of the aircraft, which in turn is affected by the particular aircraft-seeder combination in use, crosswind, headwind, aircraft speed and flying height. Seed distribution is also influenced by the flight characteristics of the seed and by the rate of seed discharge.

Seed distribution across the swath determines the inter-pass flight spacing in aerial seeding operations. For example, if most of the seed is deposited within a swath of 20 m, then the spacing of flight passes should not exceed this distance. The Brohm Seeder/Piper PA-18A distributes jack pine and black spruce differently across the swath, likely because of differences in the aerodynamic characteristics of seeds of the two species. Black spruce seed distribution is more symmetrical than that of jack pine seed (Figure 10.5 and 10.6), but requires a narrower inter-pass spacing. The most effective inter-pass spacing for both black spruce and jack pine is 15 m; however, a swath width of 18 m is acceptable for jack pine if flight paths can be maintained within 2 m.

Because the seed output of seeders is not completely steady, but varies in a cyclical pattern, the distribution of seed along a swath can show a wave-like repeating pattern (Figure 10.7). With the Brohm seeder, the surging output of single land augers produced an especially pronounced pattern. Increasing both the number of lands on the auger and its pitch has reduced the variation of distribution along the swath.

To maintain consistent uniform site coverage, gyroscopes are used to maintain parallel flight lines over the site. In the past, ground flag persons were used to improve precision of coverage over (free-flying). Now navigation can be carried out with GPS units (Figure 10.8) (Reynolds 1999a). Correction signals can be obtained from satellites in stationary geo-synchronous orbit (e.g., Landstar).

Jeff Leach (Tembec Inc.)

Figure 10.8 GPS-based AGNAV navigational system

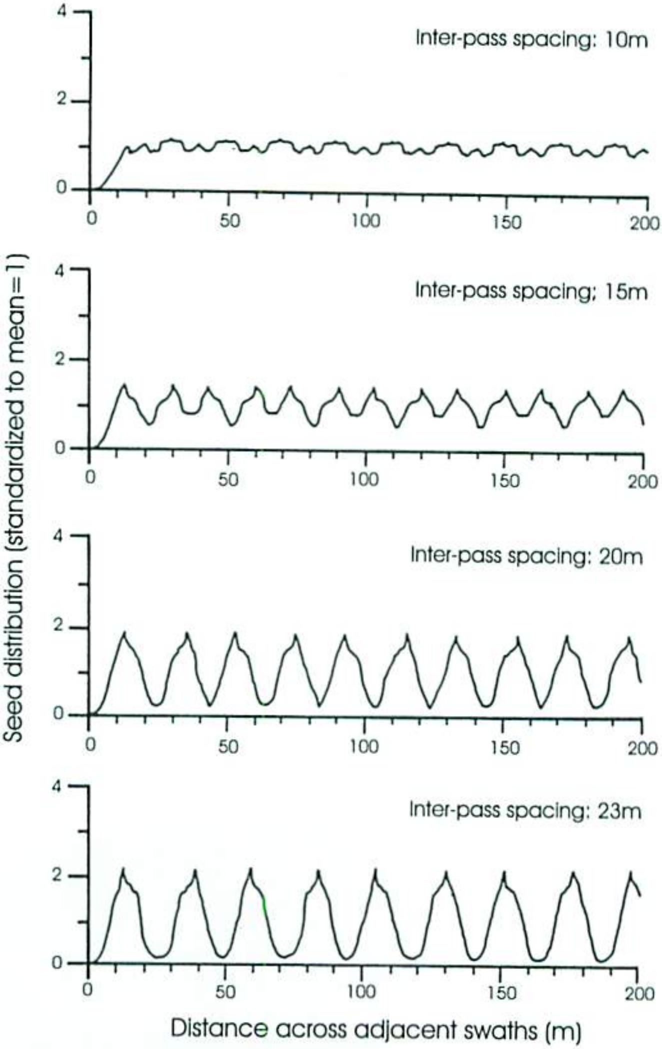


Figure 10.5 Black spruce seed distribution across adjacent swaths at four inter-pass spacings *(Fleming et al. 1985)*.

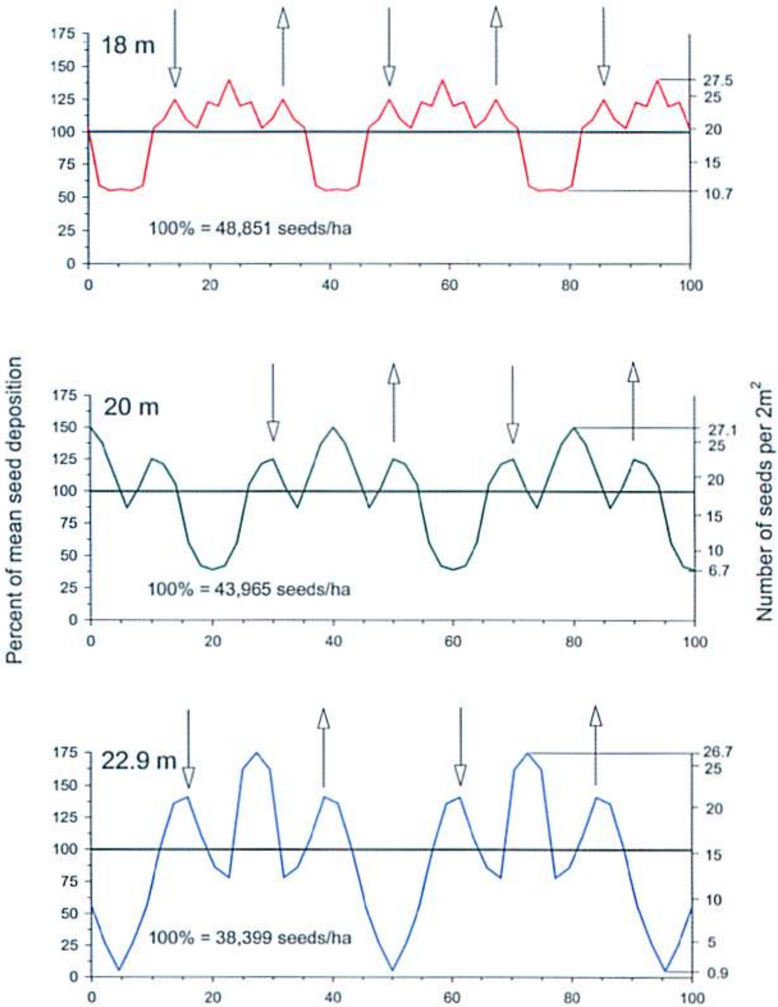


Figure 10.6 Jack pine seed distribution across adjacent swaths at three inter-pass spacings. Arrows indicate location and direction of aircraft track in relation to seed swath *(Riley 1980)*.

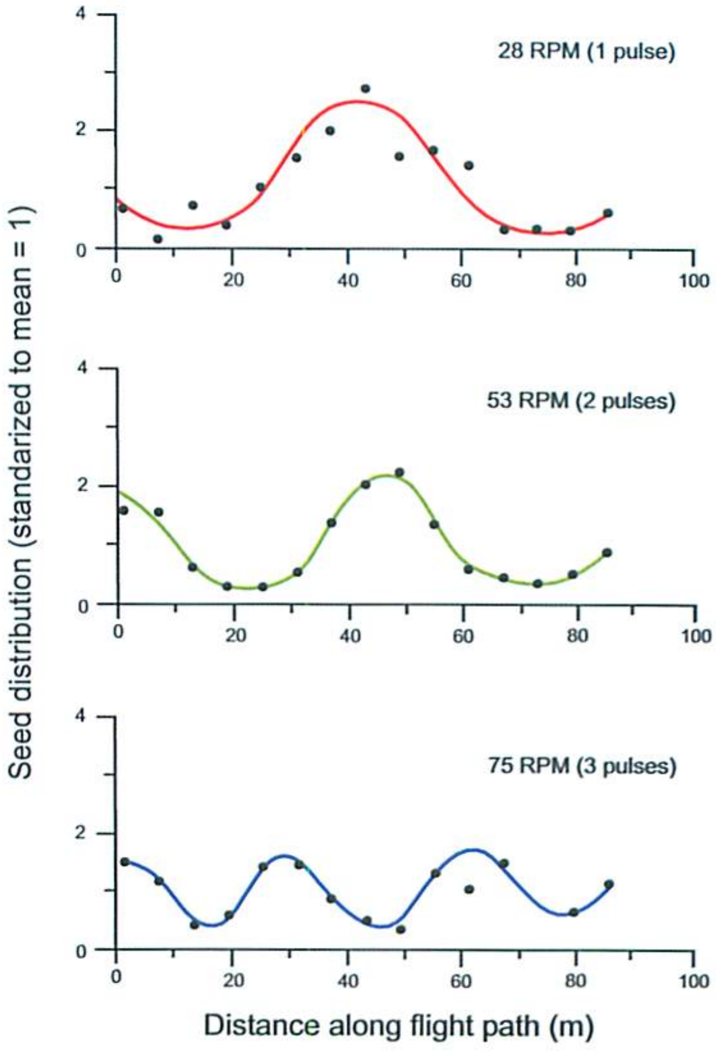


Figure 10.7 Black spruce seed deposition along the flight path *(Fleming et al. 1985)*.

RECOMMENDATIONS

For all aerial seeding equipment combinations careful and consistent calibration and flying procedures are necessary to ensure satisfactory seed deposition and distribution.

For the Brohm Seeder/Piper PA-18A aircraft configuration, the following steps should be taken:

1. Calibrate the seeder carefully using the instructions in Appendix H.
2. Sow at 15-m inter-pass spacing for black spruce and 18-m for jack pine using an accurate guidance system.
3. To avoid large variations in distribution along the flight path, do not sow at auger speeds of less than 70-75 rpm.
4. Seed only when wind speeds at 1.5 m above the ground are less than 10km/hr, and avoid seeding when winds are variable or shifting, regardless of average wind speed.
5. Select a reasonable flying height (25-35 m) and aircraft ground speed (130-150 km/hr), and maintain these throughout the seeding operation. This is of much greater benefit than attempting to fly as low or as slowly as possible (Fleming et al. 1985).

10.3.1.2 How is the seeding deposition rate monitored?

Seeding operations that are accessible should be monitored to quantify the seeding rate and provide the forester with information needed to analyze seeding results. Seed traps are useful for this purpose, and can consist of a wooden frame and a base made of aluminum mesh screening covered with finely woven fabric, such as cotton sheet material or curtain sheers (Figure 10.9). A trap size of 0.25 m^2 (0.5 m on a side) has often been used in experimental seeding projects, but other sizes may be equally or more effective.

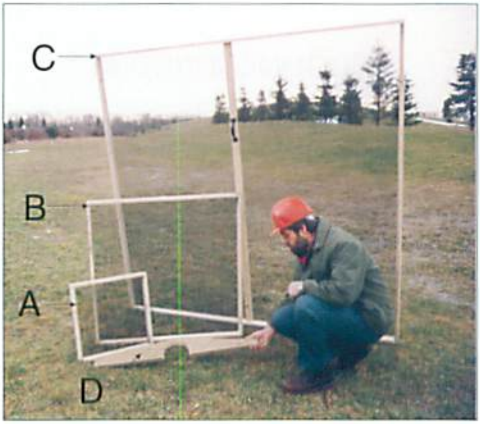


Figure 10.9 Three trap sizes displayed: (A) 0.25 m^2, (B) 1 m^2, and (C) 4 m^2. The 4 m^2 trap, is equipped with a handle and centre-mounted screw eye to facilitate carrying when using the (D) yoke *(Cameron and Foreman 1995).*

Trap sizes of 4 m^2 (2 m x 2 m) are suitable to monitor seeding rates of 50,000 to 100,000 seeds/ha; with this size only 25 traps are needed to achieve an estimate that is within 10 percent of the actual rate, 19 times out of 20. For seeding rates of 150,000 or more, use smaller traps (e.g., 1 m^2). With 1 m^2 traps, only 30 traps are required at a seeding rate of 150,000 seeds per hectare, and 25 traps at 200,000 seeds per hectare or more.

To reduce the total number of trap locations in the sample area, clusters are recommended for the 0.25 m^2 trap size. If trap clusters are used, determine the number required by using the TRAPS program provided with this manual or using the table provided in Appendix I. Enter the prescribed seeding rate (seeds/ha), the acceptable error in the estimate of the mean seeding rate (seeds/ha), the surface area of a single seed trap (m^2) and the number of seed traps that will be positioned at each cluster location. TRAPS will determine the appropriate number of clusters.

Alternatively, enter the number of clusters to be established and TRAPS will determine the associated error limits. Because the number of seed traps required increases rapidly as error limits become smaller, narrow error limits are impractical. Appendix I provides an estimate of the number of traps required to sample an aerial application of seed at various seeding rates and confidence intervals.

Set traps out randomly, so that all traps have an equal chance to sample the various seed distribution patterns. An all-terrain vehicle may facilitate trap delivery and gathering. As nearly as possible, arrange trap clusters in a square pattern. Enough space should be left between traps to allow access between them on foot.

A simple method to randomly choose the cluster or individual trap locations is to establish a numbered grid of points on a map of the seeding block. The number of points should be at least several times greater than the number of individual traps or clusters to be established. Points can then be selected using a table of random numbers.

Transport the traps to the site before the seeding operation and distribute them on the day of seeding. If the traps are placed in the final position several days ahead of time, accumulated seeds and foreign materials will introduce errors, or at least make the task of counting seeds more difficult. Count the captured seed and retrieve the traps immediately after the seeding operation.

To determine the actual seeding rate, summarize the trapped seed counts by cluster as follows:

$$\text{Seeding rate/ha} = \frac{\text{average total number of seeds in the cluster} \times 10{,}000}{\text{trap area } (m^2) \times \text{number of traps per cluster}}$$

Average the seeding rate values for each cluster to obtain the actual seeding rate.

When individual traps are used rather than clusters, follow the same procedures as outlined above, substituting the number of traps for the number of clusters.

10.3.2 Mechanical row and patch seeding

This method has most frequently been used for seeding jack pine while site preparing with the Bräcke patch cultivator, or more recently, row seeding with a disk trencher in combination with the Bartt Mark IV and the TTS Sigma precision seeders. Both mechanical row and patch seeding are less expensive than mechanical site preparation with aerial seeding, reduce the amount of seeds required and may give better control over seedling density and spacing (van Damme 1988; Reynolds 1999b).

The sowing season for row and patch seeding is limited to two seeding windows, a 7–8 week period in early spring, and about 4 weeks in the late fall. Because of poor road conditions, especially during the spring thaw period, some areas may not be accessible.

The Bräcke patch scarifier is capable of a wide range of between row and within row scalp spacings, and can site prepare and seed 2,500 scalps per hectare at the rate of 0.8-1.2 ha per hour. The main problems with patch seeders are seed clumping due to imprecise seed metering, clogging of seeds in the seeder, and inaccurate targeting of seeds to the most receptive microsites. Mechanical problems and weather-related limitations may result in significant losses of production time.

With spring seeding using the Bräcke, 60 percent or greater stocking can be obtained at a seeding rate of 15 seeds per seed spot. However, Sidders (1993) found fall seeding at seeding rates as low as five viable seeds per scalp to be the optimum treatment, with little or no clumping. Seeding rates generally range from 12,400 to 25,000 seeds/ha. Seedbed compaction done at the time of scalping can significantly improve jack pine establishment (Van Damme et al. 1992), but does not improve black spruce establishment.

Unlike the patch type scarifiers, skidder-mounted row seeders are designed to singulate seed and deliver it at prescribed intervals during site preparation by a furrow type scarifier (Davidson 1992). Singulation is done using a vacuum pressure, revolving orifice or screw auger system and the seed is pneumatically delivered through seed delivery hoses to the target microsite. Computerized monitor systems or infrared sensors are used to ensure the prescribed sowing rates are being met. Disc trenchers set at a two metre spacing and an in-row application spacing of 30 cm, would yield 16,666 seeds/ha.

On uplands in general, ground seeding combined with scarification is more difficult for black spruce than for jack pine. This is due in part to the more narrow spectrum of receptive seedbeds available and the difficulty in accurately targeting specific microsites.

10.3.3 Spot seeding with and without seed shelters

Spot seeding involves the application of seeds to a prescribed microsite using hand-held seeding devices. This technique provides the most reliable method of seed placement and allows manual microsite manipulation at the time of seed application. It is, however, the most labour intensive method of seed application.

Early methods used seed-filled jars with perforated lids to shake seeds onto exposed seedbeds. However, this technique offered little control over seedling density. Over the years, numerous mechanical hand seeding devices have been developed for dispensing conifer seeds, i.e., the German-made R and S seeder, the Cerbo seeding tool, the Panama direct seeder, and the Accuseeder. Precision metering for black spruce, however, has always been problematic because of the small seed size. More recently, to overcome the inaccuracies of metering devices, methods of seed encapsulation or pre-attaching seed to peat wafers have been used to deliver an exact number of seeds to a specific microsite, while at the same time providing a medium for early seedling establishment.

On uplands, site preparation is necessary before spot seeding to prepare receptive seedbeds. Continuous furrow scarification is the preferred method because it promotes the ingress of naturals, facilitates microsite selection, and contributes to higher worker productivity. Patch scarifiers create a narrower range of microsites than do continuous scarification methods, and unless soil conditions are uniform, the seeding operation is more difficult than that for row scarification.

Similar to other methods, the best season to spot seed is in early spring when soil moisture and weather conditions are conducive to seed germination and seedling growth.

Seed shelters

Seed shelters improve seedling establishment by ameliorating the microenvironment for both germination and early seedling development. Shelters come in a variety of shapes and sizes and can be fabricated from a host of biodegradable materials, including plastic, paper, peat, or polypropylene cloth.

The most common types are open-ended translucent plastic cones that are anchored to the seedbed surface and seeded through the top, either manually or by a variety of hand operated mechanical seeders (Figure 10.10).They are constructed of photodegradable polypropylene or polyethylene and break down into carbon dioxide and water when exposed to ultraviolet radiation. Above-surface decomposition usually occurs after 2 to 5 years, but the shelter's base may persist under the soil surface for as long as ten years.

These semi-translucent plastic shelters acts as a "mini-greenhouse" that both enhances microclimate and protects against frost, burial, and predation. Shelters increase air humidity and both soil and air temperatures to levels that favour germination and early development. The use of such shelters has often resulted in substantial increases in seedling establishment of both black spruce and jack pine, and in some cases height growth can match or exceed that of planted container stock by year five.

Figure 10.10 A successfully stocked polyethylene seed shelter following two growing seasons.

The best results with shelter seeding have been obtained on well-drained upland sites with little competition. Conversely, poor results are common on more productive uplands and on rich organic sites because of vegetative competition. Peatland sites with an abundance of *Sphagnum* seedbeds may not require seed shelters because of their naturally receptive qualities (Figure 10.11).

The inherent inaccuracy of metering devices designed for use with seed shelters has prompted the development of pre-seeded shelter cones. This technique involves attaching a predetermined number of seeds to a small flap or flange located at the apex of the shelter. The seeds are held in place by a water-soluble adhesive and are released during the first rainfall. Experimental trials have shown promising results (Adams 1994).

Non-transparent seed shelter designs, or "shade" shelters made from peat, paper, or mesh have also been effective in improving direct seeding performance. They protect soil surfaces from rapid changes in temperature and moisture, thus reducing evaporative stress and providing a stabilizing effect on the seedbed. They also protect against excessive microsite erosion and dislocation during periods of excessive rainfall. Adams and Henderson (1994) found that peat shelters significantly moderated soil surface temperature, had comparable stocking results to plastic shelters in jack pine seed spot experiments, and were considerably less expensive.

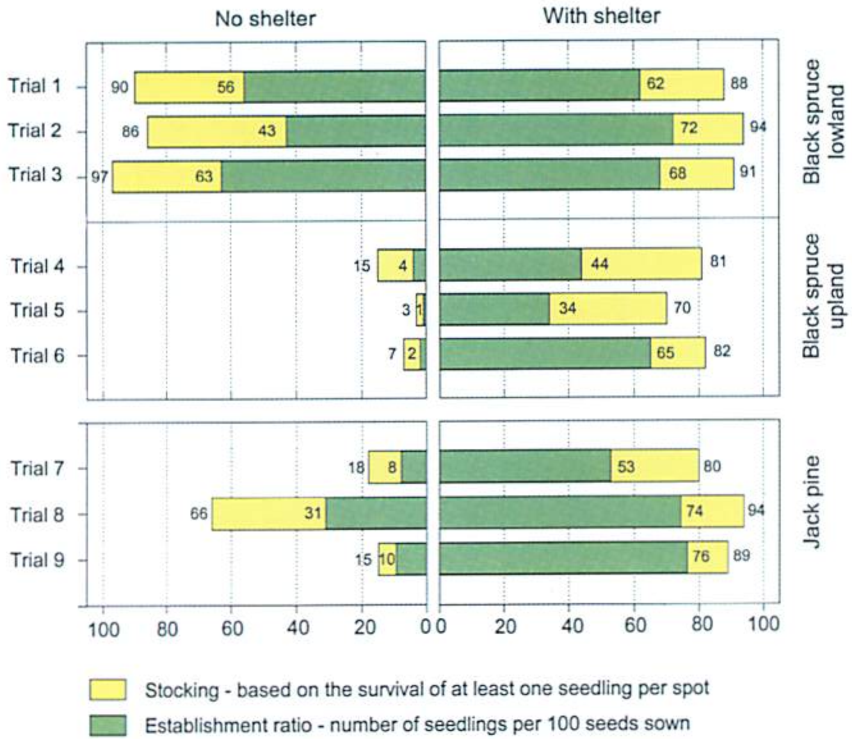


Figure 10.11 Fifth-year stocking and establishment ratio of sheltered and non-sheltered black spruce and jack pine seed spots *(Adams 1994)*.

Production rates for seed shelter installation are approximately the same as for container stock planting.

Regeneration crews must be trained in microsite and seedbed selection and in shelter placement, anchoring, and seed dispensing techniques. Refer to the following recommendations box for tips on seed shelter installation.

RECOMMENDATIONS

How to properly install shelter cones:

1. Choose the best micro-site within the spacing requirements.
2. Select a mid-slope location within the furrow or scalp.
3. Scuff the micro-site with the toe of the boot.
4. Lightly compress the soil under the boot to provide a firm base for shelter placement.
5. Place the shelter onto the prepared microsite and completely cover the bottom lip of the shelter with loose soil.
6. If the shelter is not pre-seeded, dispense seeds through the top of the shelter. When using a mechanical seed dispenser, wait long enough for the seed to fall the length of the delivery shaft prior to disengaging it from the shelter.
7. Make sure the seeding device has been properly calibrated for the desired seeding rate prior to use. Periodically check the seeder's calibration during the seeding process.

(Adapted from Campbell and Baker 1989)

Some of the advantages and disadvantages of seed shelters are listed below:

Advantages:

1. Provides a good micro environment for germination and early seedling establishment.

2. Stabilizes the immediate seedbed and reduces the effect of soil washing and incidents of seed burial.

3. Higher establishment ratios within seed shelters allow fewer seeds to be used and subsequently reduces the incidence of excessive numbers of seedlings in clumps.

4. Enables greater control over spacing across the treated area, and a more conservative use of seeds, when compared to broadcast seeding.

5. Eliminates the cost of production, transport, and on-site storage of nursery stock.

6. Results in the development of a natural, undisturbed root system.

Disadvantages:

1. Is the most expensive method of seed application.

2. Is labour intensive, with productivity similar to that of container stock planting.

3. Is limited to sites with lower productivity.

4. During the critical establishment stages, seedlings originating from shelter cones lag behind nursery stock by at least one year.

5. It may result in clumping of seedlings.

6. Planters require a greater knowledge of microsites than for tree planting.

10.3.4 Ground broadcast seeding

10.3.4.1 Cyclone hand seeder

This seeder has sometimes been used operationally to seed scarified cutovers, but has been employed most often in experimental or pilot-scale applications to simulate operational broadcast seeding. The seeder is carried on a harness and seeds are broadcast across a 5 m swath as the operator turns a hand crank (Figure 10.12).

The seeder should be calibrated using seed traps before being used operationally. The operator calibrates the walking and cranking speeds needed to distribute the correct seed volume. Because of the small size of black spruce seed it must be mixed with a carrier. Vermiculite and sand (Arnott 1970) have been used as carriers in cyclone seeders in the past, while Groot and Adams (1994) found mixing black spruce seed with single-cut red clover provided a good distribution pattern. If seed such as clover is used as a carrier, it should be killed by heating in an oven or microwave prior to mixing with the conifer seed.

The productivity of the cyclone seeder is approximately 1.5 ha/hour, based on the following assumptions:

- Walking speed: 3 km (3,000 m) per hour
- Seeding swath: 5 m
- Production rate: 15,000 m^2/hr = 1.5 ha/hr

or 2 km of walking to seed one hectare.

Figure 10.12 Broadcast seeding with the cyclone hand seeder.

10.3.4.2 Snowmobile-mounted Brohm seeder

In the late 1960s and early 1970s, the Brohm seeder was adapted for use on snowmobiles. Reportedly, this application worked well in cutovers that were too small to seed from the air. Seeding was done in the late winter and in some cases productivity was reported as approximately 25 hectares per hour with a 15 m treatment swath.

Though the method has not been used for many years, it may be applicable in areas with good winter access where clearcut blocks are relatively small, such as in strip cuts after the leave strips have been harvested.

RECOMMENDATIONS

- For aerial applications, seed both jack pine and black spruce in late winter (mid-to-late March) or in early spring.
- Do not seed for at least 1 month after mechanical site preparation to permit the soil to settle.
- Seed within 1 year of site preparation, before significant vegetative competition has occurred. This period may be extended on *Sphagnum* sites.

11.0 ASSESSING SEEDLING ESTABLISHMENT

The results of direct seeding projects should be assessed to: (i) determine if the project was successful, (ii) determine the need for subsequent treatments (spacing, cleaning etc.), and (iii) provide data that can be used to forecast stand development. The type and timing of seedling assessment depends on which of these goals is being addressed.

Conventional seeding assessment procedures in Ontario recommend that a quadrat-based regeneration survey be carried out following the first and second growing seasons, while a survey following the third growing season is considered optional (Chaudhry 1981). This may be an acceptable practice for row seeding, Bräcke seeding, or shelter cone seeding because seed deposition occurs on prepared seedbeds that have readily discernible boundaries. It is very difficult, however, to carry out an effective regeneration assessment the first growing season following aerial seeding due to the random nature of seed dispersal and the small size of first year seedlings (especially black spruce) (Figure 11.1). Thus, we recommend that a complementary seed spot trial be established at the time of aerial seeding to provide an indication of the success of the operational seeding.

Figure 11.1 The small size and random distribution of first year black spruce seedlings makes it difficult to carry out an effective quadrat-based regeneration assessment.

11.1 How Can Seed Spots Be Used to Forecast Seeding Results?

The establishment and monitoring of seed spots on the most frequently occurring seedbeds in the seeding block will provide an early indication of seedling establishment. Observation of seed spots also helps to develop local knowledge of seedbed receptivity.

A seed spot trial will not however, provide information about the contribution of advance growth and ingress of naturals.

11.1.1. Procedures for seed spot trial establishment

The recommended procedure for establishing seed spots is as follows:

1. Place seed spots on only the two or three most common receptive seedbed types in the seeding block:

Upland spruce sites:

- Upper mineral soil horizon (<10 cm below the mineral soil/humus interface).
- Thin F (<5 cm above the mineral soil/humus interface).

Lowland spruce sites:

- Living compact *Sphagnum*.
- Sheared *Sphagnum* or exposed (compacted) *Sphagnum* peat.

Jack pine sites:

- Exposed mineral soil with a firm base.
- Thin F/H horizon (<5 cm)

2. Use a specific number of seeds per seed spot (usually 5). Ensure that the same number of seeds are dispensed at each seed spot. This can be done by pre-counting the exact number of seeds per spot and placing them into individual containers prior to application or by closely monitoring seed deposition at the time of seeding using a suitable spot seeding device such as the R&S hand seeder. Use seeds from the same seed lot used in the direct seeding project.

3. Establish seed spots in clusters along a transect. The more seed spots established, the greater the reliability of the results. However, it would likely be sufficient and cost effective if 50 to 100 seed spots were placed on each of the principal seedbeds throughout the seeding block in clusters of 4 to 5 spots.

4. Identify seed spot locations with flagged and numbered wire pins (Figure 11.2).

Figure 11.2 A successfully stocked seed spot identified by a numbered wire pin. Each seedling is marked by a plastic swizzle stick.

5. Establish the seed spots at the time of aerial seeding or shortly afterward, so that the same environmental conditions are experienced.

6. During the first year assessment, mark each germinant with a swizzle stick (placed on the north side of the seedling at a distance of approximately 5 cm) for easy relocation on subsequent visits.

To gain some perspective on the effectiveness of the artificial seeding, compare the germination data collected during the first year seed spot assessment with establishment ratios for specific seedbed types found in Section 6. PC SEED can be used at this stage to explore the consequences of these initial results.

11.2 When Should Seeding Assessments Take Place?

11.2.1 Black spruce

Over 90% of winter or early spring seeded black spruce germinants emerge by mid-to-late July of the first growing season, and nearly all seedling emergence takes place in the first growing season following seeding. Thus the number of seeded trees is at a maximum during the first growing season; seedling mortality will cause a decline in numbers in subsequent years.

If a seed spot trial has been established, seed spots should be assessed at the end of the first or second (or both) growing season, usually from late August onwards. Poor establishment at the end of the first growing season indicates failure, but good establishment does not necessarily indicate success, because of the possibility of subsequent mortality. Good establishment at the end of the second growing season is a better, though not certain, indication of success.

Quadrat-based assessments of black spruce seeding are not recommended during the first two growing seasons. The small size of the seedlings during this period makes detection difficult, and unless very careful and time-consuming assessments are undertaken, seedling establishment will be underestimated. Quadrat-based assessments are feasible in the third-to-fifth year following seeding. Results become increasingly reliable with increasing time since seeding, because of improved seedling detection, and because mortality rates decrease with time.

The quadrat-based survey will determine the combined stocking and density of direct seeded and naturally seeded trees, and can also provide information about advance growth.

11.2.2 Jack pine

First year jack pine seedlings are larger and better developed than are black spruce, and can usually be detected on patches of receptive seedbed. Thus, the establishment of an on-site seed spot trial may not be essential; however, it is recommended as a means of isolating the performance of artificially applied seeds, independent of the presence of seedling ingress from natural seed sources and to improve local knowledge of seedling establishment. If a seed spot trial is undertaken, assessment of the seed spot trial should be carried out at the end of the first growing season. An assessment at this time may underestimate establishment, since there is evidence that the germination of some jack pine seed may be delayed until the second or third season after seeding.

Seed spots will not reflect the ingress of seedlings from natural seed sources. Natural ingress varies depending on site, stand age, method and season of harvest, site preparation technique, slash density and microclimatic exposure, but it is usually substantial. The seed source for natural ingress is primarily cone-bearing slash, but residual trees on or adjacent to the site may also contribute some seed. There is even evidence that old cones buried in the forest floor can release small amounts of viable seed when exposed by fire or site preparation.

Figure 11.3 A quadrat-based regeneration assessment at year three will reflect establishment from both artificial and natural seed sources.

Because of ingress from natural sources, and, possibly, delayed germination of sown seed, stocking and density in jack pine seeding trials has been observed to increase from the first to the third growing season. Thus a quadrat-based regeneration assessment (Figure 11.3) should be conducted after three growing seasons. An assessment at this time will provide a good indication of regeneration resulting from both artificially applied and natural seed sources.

In some cases, further increases in stocking and density may occur when jack pine seedlings established in the seeding operation begin to produce cones and contribute seed. This may occur as early as the sixth year after establishment.

RECOMMENDATIONS

- Use seed spots to check on performance and to develop local knowledge of seedbed receptivity.
- In the case of black spruce, if stocking levels are not acceptable following the first assessment, remedial action should be taken as soon as possible.
- Quadrat-based regeneration assessments should be conducted between 3 and 5 years following seeding, depending on site quality and expected growth rates, to capture both artificially seeded trees and those resulting from ingress.

11.3 What Kind of Survival Can Be Expected From Seeded Trees?

11.3.1 Black spruce on uplands

On upland coarse-textured soils, substantial mortality occurs until the end of the third growing season, with a steady decline in annual mortality rates thereafter; great variation in mortality occurs in different seeding years on the same site and seedbed types (Figure 11.4).

Insufficient moisture in the surface soil (possibly combined with high surface temperatures) and frost heaving appear to be the main causes of seedling mortality on upland sites. On thin F and upper mineral soil horizons, two of the most common types of upland seedbeds, more mortality may occur on the drier sites (S2, S3, and SS3) than for the same seedbeds on wetter sites (S8, S9, and SS8).

11.3.2 Black spruce on lowlands

The main causes of seedling mortality on lowland black spruce sites are competition from rapidly growing *Sphagnum*, frost heaving, and erosion of well-decomposed materials.

On seed spots, stocking and establishment ratios decline throughout the initial 5 years of growth on almost all seedbed types, but declines are most marked on pioneer mosses and well-decomposed organic matter, followed by rotten wood and living, slow growing *Sphagnum* seedbeds (Figure 11.5).

11.3.3 Jack pine

The combination of lethal surface temperature and drought are considered the greatest cause of jack pine seedling mortality during the initial stages of germination and establishment (Sims 1975). Heat injury may not kill a seedling but may weaken it and leave it more susceptible to drought. Early germinants have a slightly higher chance of survival. However, if germination is too early, mortality from spring frost may occur. In terms of survival, the last week of May and the first 2 weeks of June is the optimum time to obtain germination.

Total germination and mortality increase and decrease respectively from dry to fresh moisture regimes (Sims 1970). Unlike upland black spruce, jack pine seedlings surviving through the year of germination are essentially established; subsequent mortality is low and occurs mainly during the second year (Sims 1975).

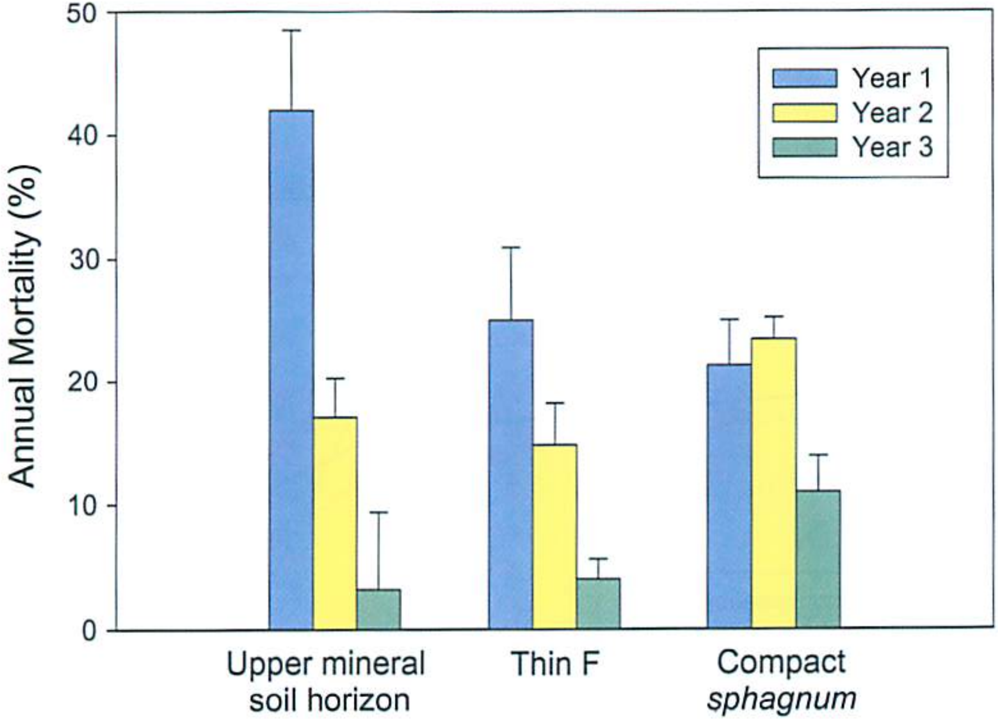


Figure 11.4 Annual mortality of Black spruce (mean and standard deviation) by seedbed type *(Fleming and Mossa 1994).*

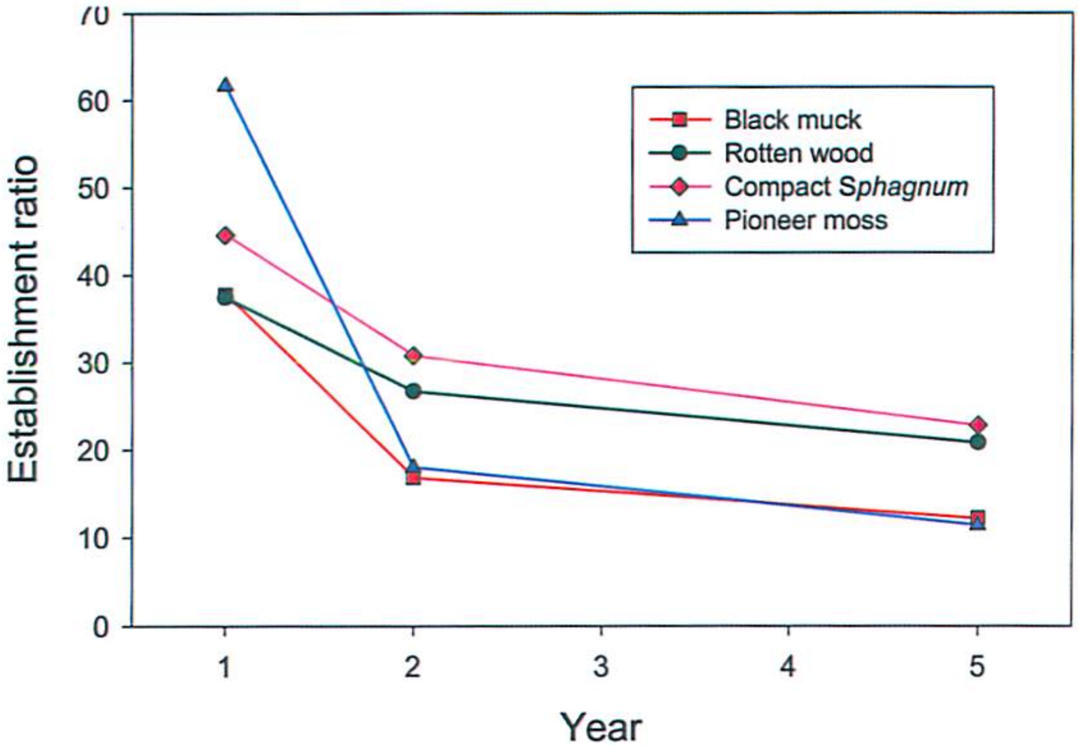
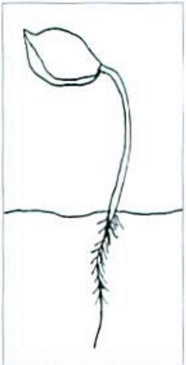


Figure 11.5 Mean black spruce establishment ratios (no. of established seedlings per viable seeds sown) on selected lowland seedbed types *(Groot and Adams 1994)*.

11.4 How Do Weather and Damaging Agents Affect Seeding Success?

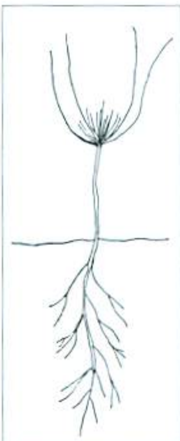
This section focuses on the risks to seedlings during the first growing season, when most mortality occurs.



Germination phase

Germination phase: radicle emerges and seed coat is lifted off the surface of the soil (1 to 7 days).

Technically, the germinative process begins when chemical changes are initiated within the seed, brought on with the imbibition of water, favourable temperatures and in the presence of oxygen. However in practical terms, germination begins with the extrusion of the radicle through the broken seed coat (Baker 1950). The greatest cause of mortality at this stage is an inadequate supply of surface moisture to allow the radicle to become established, and to supply the moisture required for cotyledon development (Arnott 1973) Also, damping-off fungi can cause serious losses at this stage; in warm, moist years on fresh sites damping-off may account for half of the mortality in newly established jack pine. Seedlings growing on mineral soils are less susceptible to this disease (LeBarron 1944; Sims 1975).

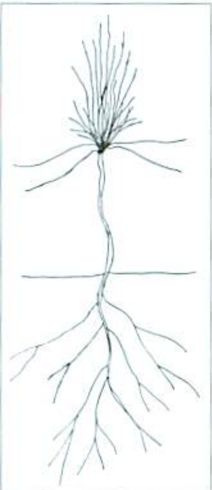


Succulent phase

Succulent phase: about 25 days from germination

For a few weeks following germination, the young seedling is frail, delicate, and watery, having no specialized strengthening tissues and only a very rudimentary vascular system (Baker 1950). At this stage, high air and soil temperatures are an important limiting factor for seedling survival. High solar irradiance can be a cause of seedling mortality because of a combination of high air temperature that causes transpirational stress, and high surface temperatures that desiccate the seedbed surface. Seedling mortality occurs if there is an insufficient supply of soil moisture to replenish its requirement for water. Heat injury and mortality occur when the seedling crown is exposed to air temperatures of approximately 50°C or greater. This is why soils with poor thermal conductivity, such as duff and litter, are poor seedbeds: they quickly heat up to lethal temperatures but do not supply moisture, as do mineral soils.

The total amount of rainfall in a given year is less important than its distribution throughout the growing season (Arnott 1973). Regular rainfall is needed immediately after germination and during the succulent phase to prevent seedbed drying and seedling desiccation. On lowland sites, moist *Sphagnum* and peat seedbeds do not present the same degree of risk as do uplands because of the generally plentiful supply of moisture.



Juvenile phase

Juvenile phase: hypocotyl (stem) becomes hardened

Seedling mortality at this stage of development is mostly due to drought, brought about indirectly by slow root development or by competition for limited water. For jack pine on dry to moderately fresh sites (SMR Ø-1), singular precipitation events producing more than 6-7 mm of rain every 5-7 days are required. Mortality will be noticeable after five days of drought and become significant by seven days and approaching total mortality after ten days of drought (Sims 1970, 1972, 1975). It is essential that a growing root system keep ahead of the deepening soil drying front as the season progresses (Arnott 1973). Black spruce is more vulnerable than jack pine in this respect, because of its slower early root growth and lateral root growth habit. High atmospheric demand (vapour pressure deficits) and low soil moisture reserves lead to moisture deficits in young seedlings, resulting in wilting and death.

Complete shading by competing species can also cause mortality at the juvenile stage. However, low to moderate shading may be beneficial, by moderating ambient air and soil temperatures. The degree of competition is dependent upon the effective life of prepared seedbeds. Competition is most severe on fertile sites. Where broad-leaved plants are abundant, smothering of first-year seedlings by litterfall may cause mortality.

Frost heaving can be an important cause of mortality on moist sites and those with fine textured soils. Spruce is more susceptible than pine because of its more shallow rooting habit. Severe rain or hailstorms may physically damage fragile seedlings, wash them out of the substrate, bury them with splashed soil or cause mortality by flooding. Frost damage to new foliage can be problematic for those seedlings, which have become established in low lying areas (Figure 11.6).

Flooding

Competition

Defoliating insects

Frost damage

Juvenile seedling predation

Figure 11.6 A variety of damaging agents can have a significant impact on seeding success.

High populations of defoliating insects can cause localized seedling mortality (e.g., spruce budworm (*Choristoneura fumiferana* (Clem.), European spruce sawfly (*Gilpinia hercyniae* (Htg.), Black army cutworm (*Actebia fennica* (Tausch.)) white grubs of the June beetles (*Scarabaeidae*), Cicadas (*Cicadidae*) and grasshoppers (*Camnula spp.*) (Rudolph and Laidly 1998).

Deer mice, meadow voles and hares have been reported to actively seek out and consume jack pine seedlings in the first few weeks after germination (Buckner 1972).

SUGGESTION

When conducting a seeding operation on sites in the dry-to-moderately fresh moisture regime range, it is suggested that an on-site recording rain gauge be used to monitor local rainfall events and the length of drought periods. These devises are relatively inexpensive and can be preprogrammed to operate maintenance free over the entire growing season. Early detection of potential failures can lead to swift remedial action.

12.0 EARLY GROWTH, TENDING AND SPACING

12.1 What Early Growth Can Be Expected?

12.1.1 Black spruce on uplands

Height growth of seedlings over the first three growing seasons is slow regardless of seedbed type, site, or seeding year. Mean total height of between 5 and 10 cm can be expected by the third year. Current annual height increment accelerates between years 3 and 5, and often reaches its highest rate by age 10. Thereafter, it decreases slowly with time largely due to the impact caused by intraspecific competition. Early seedling growth rates are difficult to predict on upland sites using standard site classification systems. Microclimate, local nutrient status, and rooting conditions of particular microsites are important factors in determining seedling growth within given site types.

The major difference in the growth of upland black spruce among different seeding years is likely a function of the degree of competition from surrounding vegetation (Figure 12.1). The superior height growth usually associated with trees that came from the first seeding year, compared with seedlings from subsequent seeding years, is attributed to the differences in the size and development of competitors (Fleming and Mossa 1995b).

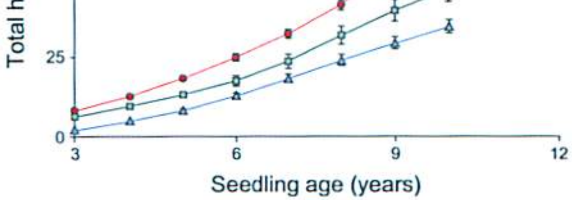


Figure 12.1 Mean black spruce seeding height as a function of seedling age, for three consecutive seeding years *(Fleming and Mossa 1995b).*

12.1.2 Black spruce on lowlands

On peatland sites, the height development of trees established from seed is slow, and foresters should expect lengthy regeneration periods. After two growing seasons seedling heights average 2 to 4 cm. Fifth-year height average 8 to 17 cm, and fifth-year height increments average 4 to 5 cm. Although *Sphagnum* peat and *Sphagnum* moss are good seedbeds from the point of view of establishment, they do not provide good conditions for seedling growth. Conversely, seedlings establish poorly on feathermoss peat, but once established grow much more rapidly than on *Sphagnum* peat, likely because of nutritional differences. Height growth can vary considerably from location to location (Figure12.2). Growth of seeded black spruce will be very slow on *Ledum* site types (NEO FEC ST11), especially those that grade into the unmerchantable Chamaedaphne site types (ST14). Extremely long regeneration periods should be expected when direct seeding such sites.

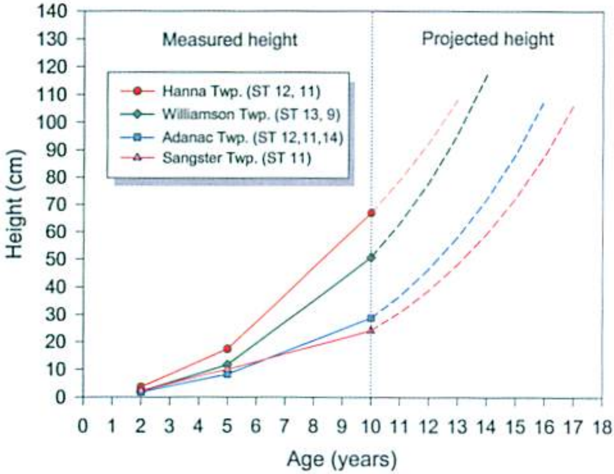


Figure 12.2 Average black spruce seedling height development at four experimental locations. Broken lines indicate projected height growth *(Groot 1996)*.

Height growth also varies considerably within a given location (Figure 12.3). Improved height growth on lowland sites may be obtained by applying seeding prescriptions that achieve high overall seedling densities, which will result in a greater number of taller seedlings. The risk of an eventual reduction in individual

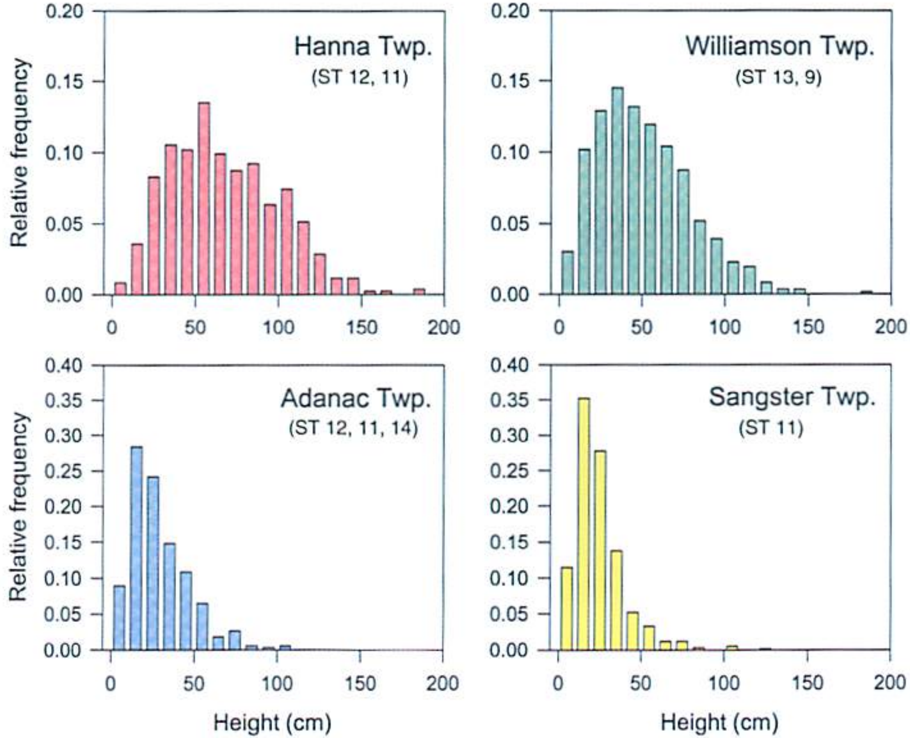


Figure 12.3 Black spruce seedling height frequency distribution at year ten at four experimental locations *(Groot 1996).*

tree growth due to high seedling densities is mitigated by the uneven size distribution of the stand. As the stand develops (Figure 12.4), the large number of smaller seedlings will become increasingly suppressed and will have little impact on the growth of larger trees (Groot 1996).

Figure 12.4 Twentieth year re-measurement of broadcast seeded black spruce at 100,000 seeds per ha. Williamson Twp., Kapuskasing Dist., Site Type 13 and 9.

12.1.3 Jack pine

Early height growth of jack pine can be quite variable – site, substrate, exposure, micro climate and competition all have a significant influence on early height growth (Figure 12.5).

Some reported 3rd year average heights include: 62.5 cm (maximum 80 cm) in full light and 17.6 cm in 43% light on a moderately fresh to fresh moisture regime (Lebarron 1944); 13.6 cm on a very fresh to moist moisture regime and 12.5 cm on a moderately dry to moderately fresh moisture regime (Winston 1973); 4.6-24.9 cm for five distinct substrates and three levels of exposure on a dry site (Sims 1975) and 16.8-23.4 cm on a wildfire (St. Pierre et al. 1992). Fleming

Figure 12.5 Results after five growing seasons following mechanical site preparation (CFS Fire Plow) and aerial seeding at 50,000 seeds per ha. Topham Twp., Chapleau District.

et al. (1995) (Figure12.6) found 12-year average height growth of naturally seeded jack pine established on fresh to moderately moist sites to average 3.7 m. Roe (1949), reported 10-year average heights of 3.6-4.3 m and dominant heights of 4.3-4.8 m from an operational spot seeding on rich soils in northeastern Minnesota; average height declined and maximum height increased with increasing numbers of trees per seed spot. Goble and Bowling (1993) reported 10 year average heights of 3.4-3.8 m following hand seeding on a Jack Pine Mixedwood/ Feathermoss site with a dry to fresh soil moisture regime.

12.2 When Should a Free-Growing Regeneration Assessment be Conducted?

The timing of the assessment should be based on site productivity, crop species, competitor species, and the chosen minimum crop tree height standard. These are all inter-related with the method of harvest, the renewal method, and management objectives. Field procedures for conducting the free-to-grow regeneration assessment are outlined in the Free-Growing Regeneration Assessment Manual for Ontario (OMMR 1995). The recommended window for the assessment is 7-11 growing seasons after harvest. This takes into consideration the time needed for ingress establishment. However, some measure of flexibility should be built into the timing of the assessment to compensate for the initial slow growth of black spruce on sites of low productivity.

12.3 What Kind of Competition Control is Required?

Vegetation management is an integral part of forest management. Non-crop vegetation often limits the survival and growth of young trees by reducing available light, moisture, and nutrients. The proper timing and choice of vegetation management treatments can mean the difference between success and failure of regeneration programs (Buse and Baker 1991).

12.3.1 Black spruce on uplands

On most upland sites, tending will be necessary if seeded black spruce are to attain free-to-grow status within 10 to 15 years (Fleming et al. 1995). Species such as jack pine, trembling aspen, white birch, pin cherry, alder, and willow quickly invade scarified sites, and after 12 years their mean height can be over 2 m more than the average height of seeded black spruce (Figure 12.6). Because competitive species cause the current annual height increment to decrease between age 7 and 9, tending should be done before this period to prevent a growth lapse.

12.3.2 Black spruce on lowlands

Competition control requirements will vary with site type and site preparation. On nutrient poor sites (e.g., NEO FEC ST-11) tending is often not necessary, whereas it will probably be required on rich sites (e.g., NEO FEC ST-13). Tending regimes for direct seeded lowland sites have received little attention to date.

12.3.3 Jack pine

On sites prone to competition, seeded jack pine stands should be treated within 2 to 5 years of establishment to prevent growth reduction or mortality caused by faster growing woody species, and to ensure that seedlings reach free-to-grow status as quickly as possible. Given an equal or head start, jack pine may cope with low-to-moderate levels of competition, and, depending on the complex of species, may also cope with rather high levels of competition. Once established, thrifty jack pine seedlings tend to gain height as rapidly as many competitors – however, the rate of increase in diameter may be limited until the jack pine either dominates or is released.

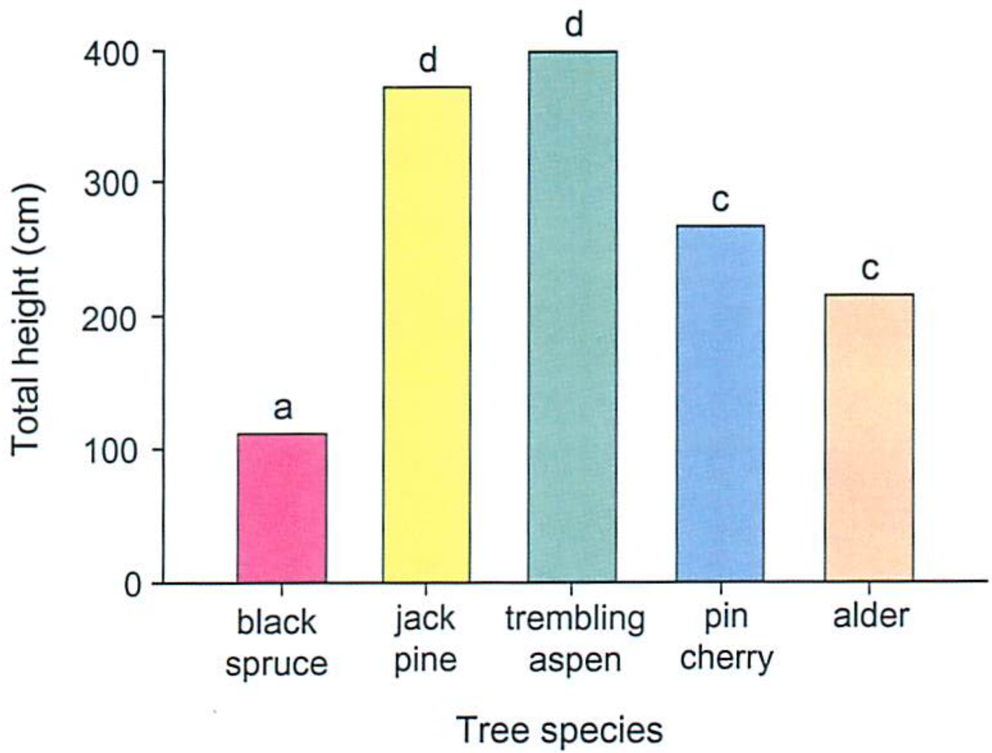


Figure 12.6 Mean heights of dominant competitors and black spruce, 12 years after seeding. Values (bars) with the same lower case letter above them are not significantly different (p>0.05) *(Fleming and Mossa 1995b).*

12.4 Is Juvenile Spacing Always Required?

Because of the excessive density that can occur when direct seeding, especially the clumping of seedlings following ground seeding, spacing (pre-commercial thinning) of overly dense parts of the stand will ensure that the full growth potential of the individual trees is captured.

As a general rule, maximum biological benefits accrue when proper spacing is achieved early in the life of the stand (Riley 1973). The target optimum density should be somewhat flexible, and should reflect the management objectives for the stand.

Spacing can be used to achieve a number of management objectives: release selected crop trees, control or adjust species composition, shorten the rotation period of a stand, increase product value, and increase the merchantable growth of the stand.

From both biological and operational standpoints, the ideal time for spacing is generally from age 7 to 25 years. This will vary depending on stand density, tree height, tree form, and bole diameter. There may be less of a requirement for pre-commercial thinning in black spruce because slower growth and more variable initial growth can allow larger trees to dominate the stand.

12.4.1 Black spruce

Though 5,000 to 20,000 seedlings per hectare can become established on uplands following direct seeding (Fleming and Mossa 1989), only a fraction of them will express dominance within a few years. The height distribution shows substantial size inequality among individual seedlings with a long tail into the larger height classes (Figure 12.7). This can be attributed to genotypic variation, microsite differences, or irregular competition indices. Dominant seedlings can attain heights of 1.5 m on fresh and moist seedbeds by age 10, significantly overtopping average seedlings, which have a median height of approximately 0.6 m. This condition is commonly observed in developing stands, and suggests that variation in growth prevents stagnation through intraspecific competition. Furthermore, spacing may reduce total net merchantable pulpwood yields at biological rotation ages (maximum mean annual increment) on better sites (Fleming et al. 1995). Because of this phenomenon, overstocking of black spruce after broadcast seeding seldom demands spacing. However, spacing is required after spot seeding on scalps because a number of seeds sown together invariably results in clumping.

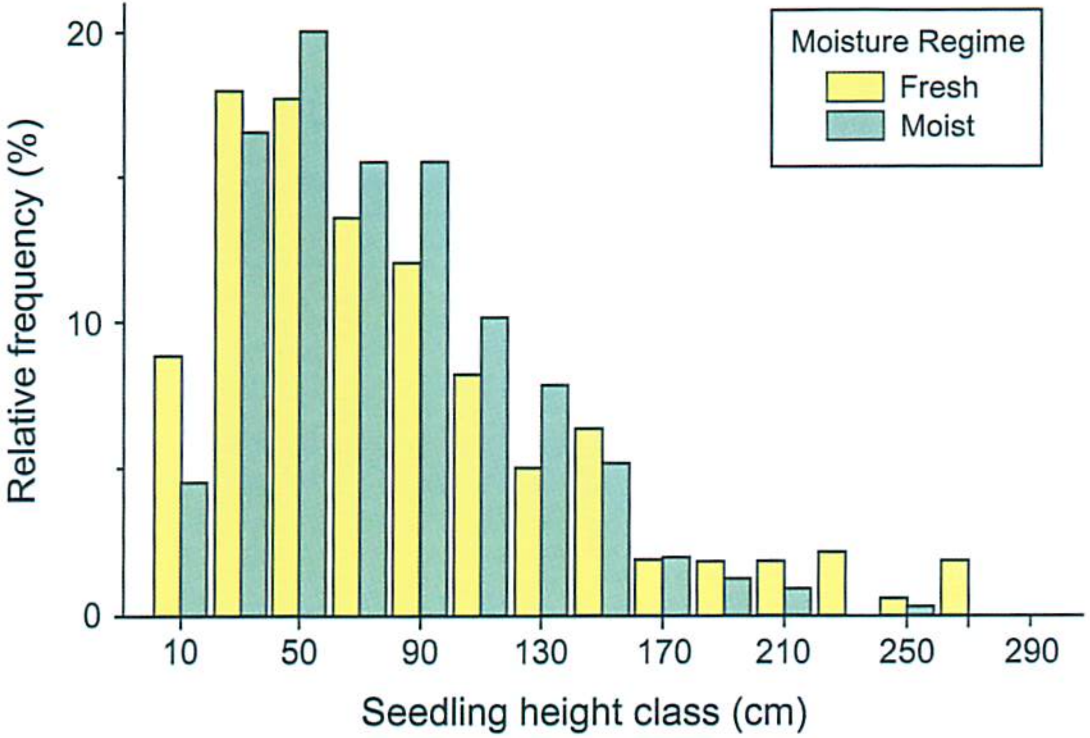


Figure 12.7 Relative frequency distribution of black spruce seedling heights by moisture regime, 12 years after seeding *(Fleming and Mossa 1989).*

12.4.2 Jack pine

Spacing is generally considered beneficial to jack pine stands that have originated from broadcast seeding. Several factors need to be considered when planning the intensity and timing of spacing. Early spacing often has the lowest cost, but spacing that is too early or too wide can lead to reduced wood quality (greater branchiness, larger knots, lower wood density, greater taper, and poorer strength and pulping characteristics), and greater risk for damage by snow and ice (Barbour 1991). Insect pests of jack pine shoots (white pine weevil and eastern pine shoot borer) may damage a portion of jack pine stems, especially those in full sunlight. It may be prudent to maintain higher densities to reduce the incidence of damage by these pests, and to ensure that sufficient numbers of undamaged trees are present when the stand is no longer susceptible to attack. Susceptibility decreases when crowns close or stands reach about 7 m in height, and becomes negligible when stands exceed 9 m in height.

RECOMMENDATIONS

- For black spruce the key to encouraging vigorous, healthy stands that optimize site productivity and best serve diverse uses is to quickly obtain complete site utilization and canopy closure. Dense, well-stocked seeded stands in which vigorous competition is controlled should meet these objectives.
- There is a distinct lack of long-term, site-specific, growth and yield data in relation to spacing and thinning jack pine in Ontario. However, Density Management Diagrams (Archibald and Bowling 1995) that graphically portray relationships between average tree volume, tree height, stand diameter, and stand density can be used to make stand-level silviculture decisions to help optimize stand structure and product yields.

Appendix A: Sources for cost data

Seed costs were calculated from information supplied by the Ontario Tree Seed Plant at Angus. These included costs of cone crop forecasting, cone collection and shipment, cone and seed processing, seed germination tests, and seed storage. The costs of capital investment, energy, employee salaries, and operation and management of the seed plant are also included (Sarker et al. 1995).

The cost of container stock was obtained by averaging the cost of production from several nursery operations located in Northern Ontario. Aerial seeding costs were obtained from Reynolds (1999b) and verified by General Airspray Limited. Site preparation costs were also obtained from Reynolds (1999b). Many of the costs obtained from Reynolds (1999b) were derived with FERIC's *Interface* software, which summarizes individual project costs by analysing the range of cost components. Cost estimates for prescribed burning were supplied by the Forest Industries Section, Provincial Operations Branch of the OMNR.

Delivery and on-site storage costs for planting stock are based on FMA subsidy rates, and have been adjusted by the Consumer Price Index (CPI) to obtain present day cost estimates. To avoid year-specific random variations in cost estimates, a three year cost average was used. Shelter cone seeding costs were derived from time studies conducted by the Forest Engineering Research Institute of Canada (Dominy 1991a).

Mechanical site preparation for seeding may be more costly than for planting, because more seedbed area and better receptivity are required for successful stand establishment. In the absence of method-specific cost information, however, we have applied the same site preparation costs for both planting and seeding.

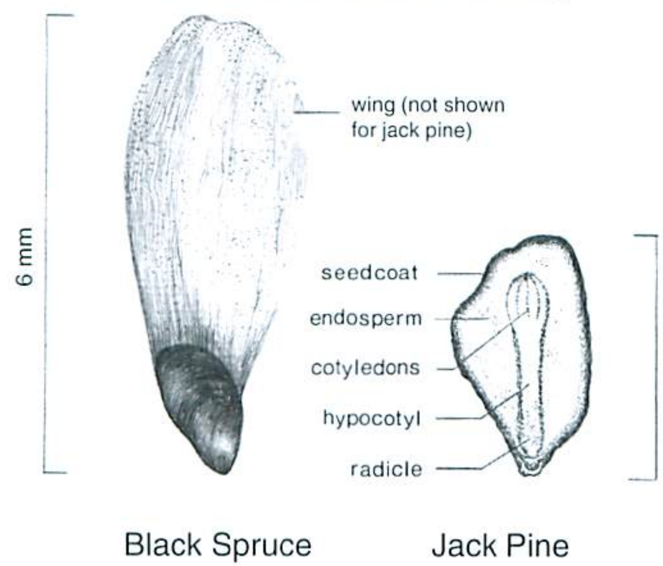
Appendix B: General relationship between generic treatment units and forested ecosites *(Racey et al. 1989)*

Generic Treatment Units	V-types and S-types	Ecosites
A	V1-V3, S6, S8-S10,S12F	ES30, ES36
B1	V5-V11, V19, S1-S4, S6	ES16, ES19, ES28, ES29
B2	V5-V11, V19, S7-S10	ES23, ES33
C	V4, S1-S3, S7, SS6, SS8	too specific for direct interpretation to ecosites
D1	V14-V16, V21, V24, V25, S1-S3, S6, SS6	ES17, ES27
D2	V14-V16, V21, V24, V25, S7-S10	ES17
E1	V19, V20, V31-V33, S1, SS6, SS3	ES14, ES22
E2	V19, V20, V31-V33, S2-S4, S6,SS6	ES14, ES20, ES25, ES26
E3	V19, V20, V31-V33, S7-S10, SS8	ES22, ES31, ES32
F	V18, V29, V31, V32, S1-S3, SS6	ES14, ES20
G	V11, V17, V28, S1-S3, SS6	ES20
H	V12, V13, V26, V27, S1-S3, SS6	ES11, ES15, ES18, ES24
I1	V30, SS1-SS3	ES12
I2	V30, S1, S2, SS5, SS6	ES13
J1	V22, V23, V35, S12S, S12F	ES35, ES36
J2	V34-37, S8, S11, S12S, S12F	ES34
K	V38, S12S	non-forested

Appendix C: Cone and seed characeristics of black spruce and jack pine *(OMNR 1986a)*

	Black spruce	Jack pine
Average viable seed per gram	873	270
Average viable seed per hectolitre of cones	352,555	162,226
Average number of cones per litre	192 - 440	68 - 82
Average number of viable seeds per cone	8 - 18	20 - 24
Average number of new cones per tree	580 - 1140	300 - 500

Seed Dimensions and Anatomy



Appendix D: Seed source identification *(OMNR 1986)*

All seed collections must be identified by a Seed Source Number (SSN).

The (SSN) consists of a string of five numeric codes representing the species, site region, geographic location, collection agency and type of collection (OMNR 1986a):

000-00-00-0-00

1) species
2) site region
3) geographic location
4) agency
5) collection type

1) Species Codes

013 Black spruce
003 Jack pine

2) Site Region Codes

12 .... 1E
22 .... 2E
24 .... 2W
32 .... 3E
33 .... 3S
34 .... 3W
42 .... 4E
43 .... 4S
44 .... 4W
52 .... 5E
53 .... 5S
62 .... 6E
72 .... 7E

3) Geographic Location Codes (Northern Ontario)

10	**Northwestern Region**
11	Dryden
12	Fort Frances
13	Ignace
14	Kenora
15	Red Lake
16	Sioux Lookout
17	Wabigoon Nursery
20	**North Central Region**
21	Atikokan
22	Geraldton
23	Nipigon
24	Terrace Bay
25	Thunder Bay
27	Thunder Bay Nursery
30	**Northern Region**
31	Chapleau
32	Cochrane
33	Gogama
34	Hearst
35	Kapuskasing
36	Kirkland Lake
37	Moosonee
38	Timmins
39	Swastika Nursery
40	**Northeastern Region**
41	Blind River
42	Espanola
43	North Bay
44	Sault Ste. Marie
45	Sudbury
46	Temagami
47	Wawa

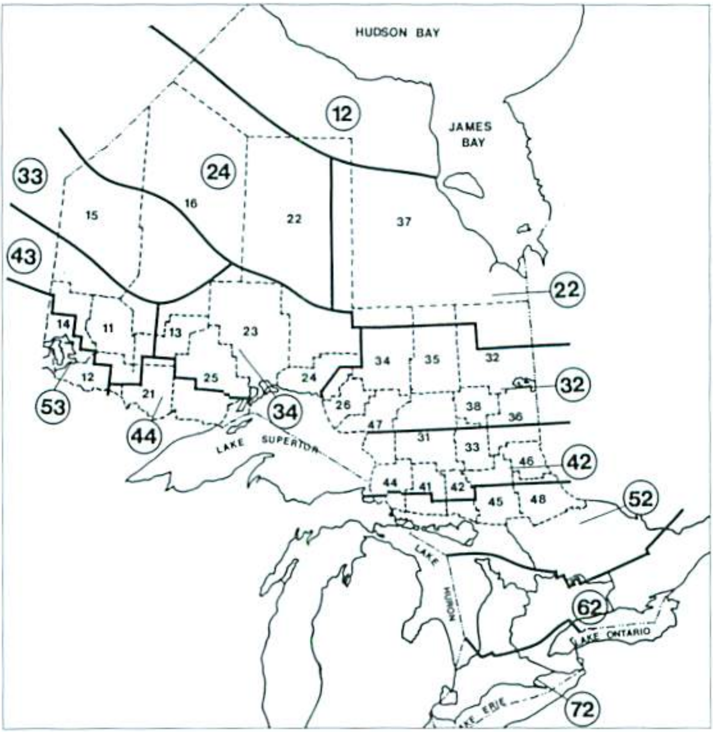
4) Agency Codes

0	Ministry of Natural Resources
1-9	Others

5) Collection Type Codes

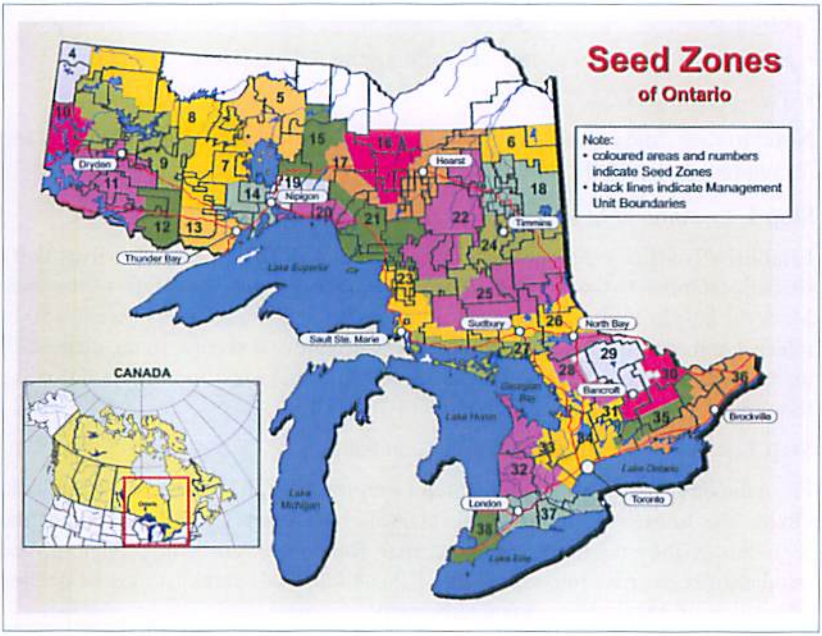
00	General Collection
01-19	Gene Pool Reserve
21-39	Seed Collection Area
41-59	Seed Production Area
61-79	Seed Orchard
81-99	Special Collection

Map of Site Region and Geographic Location



New Seed Zone Delineations for Ontario:

These new boundaries were defined using the Ontario Climate Model (OCM) by coupling climatic variables with a Digital Elevation Model (DEM) to generate homogeneous climate zones and made operational by delineating boundaries to coincide with geographic or administrative regions. The coloured areas and numbers indicate Seed Zones while the black lines indicate Management Unit Boundaries.



(Source: Ontario Tree Seed Plant [on-line]http://www.ontariotreeseed.com/).

Appendix E: A methodology for establishing base lines, transects and quadrats following site preparation

Equipment and Crew:

- Two 2-m rods (2-cm diameter marked off at 20-cm intervals);
- 50-m tape;
- Painted or flagged 1.5-m stakes;
- Compass;
- Shovel or soil auger capable of sampling the "C" horizon;
- Two-person crew.

Note: to save time in the field steps 1 and 2 can be done in the office if maps and /or photos are available.

Step 1. Location of baseline and establishment of grid system.

Establish a baseline bisecting the long axis of each block. If the block is irregularly shaped, establish two or more baselines to ensure adequate coverage of the area. Mark the baseline with flagged or painted stakes at 50-m intervals. At each 50-m interval and at right angles to the baseline estimate and record, to the nearest 20 m, the width of the treated area to the block boundaries on either side of the baseline.

Step 2. Random selection of transect segments.

From the information collected in Step 1 prepare a rough grid map of each block. Divide the lines crossing at 50-m intervals into 20-m segments. Number the segments serially beginning in one corner. Randomly select the predetermined number of segments required (Figure E.1). Additional segments may be needed depending on local and regional variability.

Step 3. Establishment of quadrats on selected transect segments.

Using a metre tape locate the predetermined (randomly selected) position of the first segment to be sampled. At this point lay the tape out 20 m at right angles to the direction of equipment travel. This represents the centre line of the ten 2-m x 2-m quadrats (Figure E.2). Starting at the first quadrat lay both 2-m rods on the ground perpendicular to the direction of the tape so that the tape crosses the centre line or the 1-m point of each rod. The rods are situated at the zero and 2 m points of the tape. Following assessment of the first quadrat move the rodmarking the zero point to the 4 m position in a "leap frog" manner, thus establishing the second quadrat boundaries. Refer to Appendix F for an outline of quadrat sampling and recording procedures.

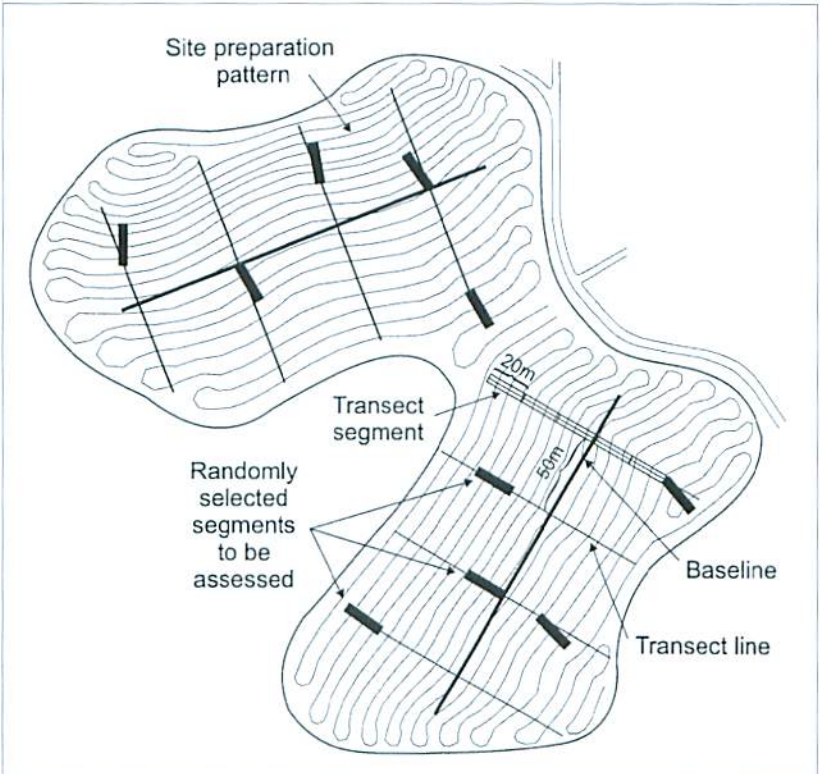


Figure E.1 Random selection of pre-numbered transect segments (*adapted from Sutherland 1986)*

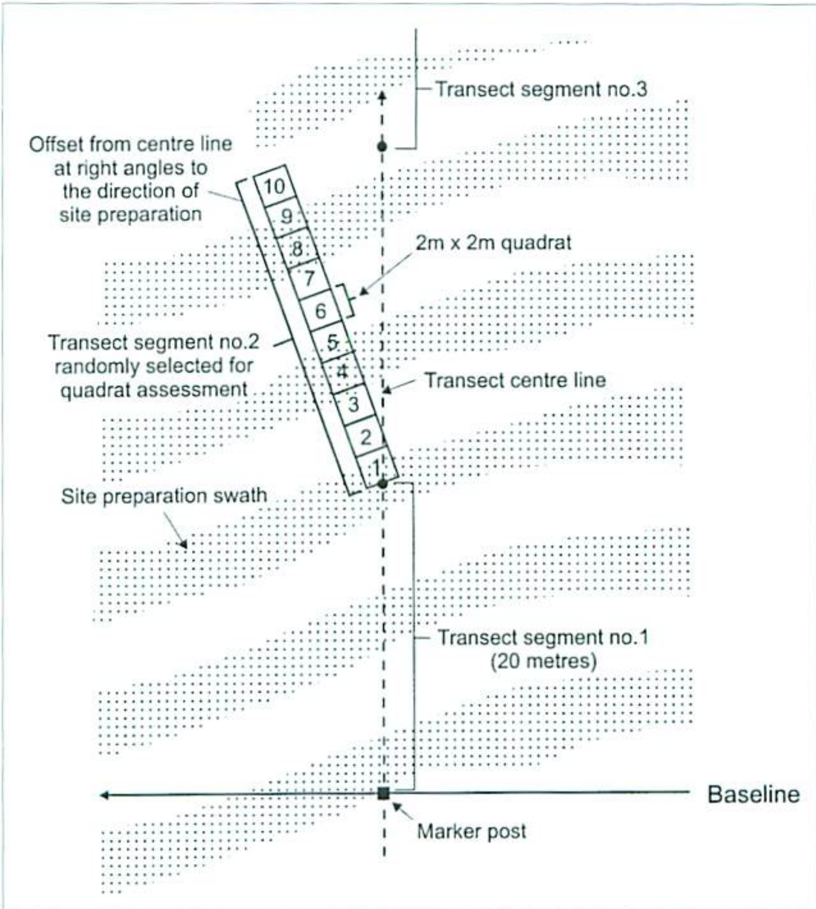


Figure E.2 Establishment of quadrats on selected transect segments *(adapted from Sutherland 1986)*

Appendix F: Quadrat assessment procedures

The following section outlines a method of assessing the amount and distribution of seedbeds on a given site. This information is used to develop the seeding prescription. The procedure works well with a two-person crew – one responsible for assessing the parameters of the quadrat and the other recording results.

Equipment and crew:

- Seedbed tally sheets, or a preprogrammed electronic data recorder;
- Two 2-m rods (2-cm diameter marked off at 20-cm intervals);
- 50-m tape;
- Compass;
- Shovel or soil auger capable of sampling the "C" horizon;
- A field manual for describing soils (Ontario Institute of Pedology 1985);
- Two-person crew (one assessor and one tally person)

Step 1. Locate the line segment previously selected during the baseline/transect establishment phase and position the 2m rods (as described in Appendix E) marking the boundaries of the first quadrat to be assessed.

Step 2. Identify all seedbed types that appear within the 2m x 2m area and estimate the coverage (percent of quadrat area) of each to the nearest 5%. The presence of trace amounts of distinct seedbed types less than 5% should also be recorded to the nearest 1%. Record all data on paper tally sheets or electronic data collection devices in a format similar to the example provided (Figure F.1). Make use of the cover percent charts (Figure F.2) to assist in defining area measurements. Note that a 20 cm x 20 cm patch represents 1 percent of the quadrat area (Figure F.3).

Record the cover of receptive seedbeds types (including low receptivity seedbeds with high area coverage), but do not record unreceptive substrates such as exposed rock, open water, stumps, slash, roots, dense vegetation, etc. Seedbeds must be free of overtopping obstacles (e.g., logging debris or residual vegetation) that may intercept seed deposition. Correctly identifying seedbed types and accurately estimating their respective cover is essential to the process of determining the prescribed seeding rate.

	Block	Baseline	Transect seg.	Seedbed type.	Quadrat no.1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Transect seg.	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
	1	1	1												2										
SEEDBED INFORMATION (percent cover)																									
ADDITIONAL SILVICULTURAL PLANNING INFORMATION				Number of advance growth stems (<2.5cm)																					
				Amount of Cone bearing slash?																					
				Micro relief / obstructions / others																					

Figure F.1 Sample tally sheet for quadrat seedbed assessment

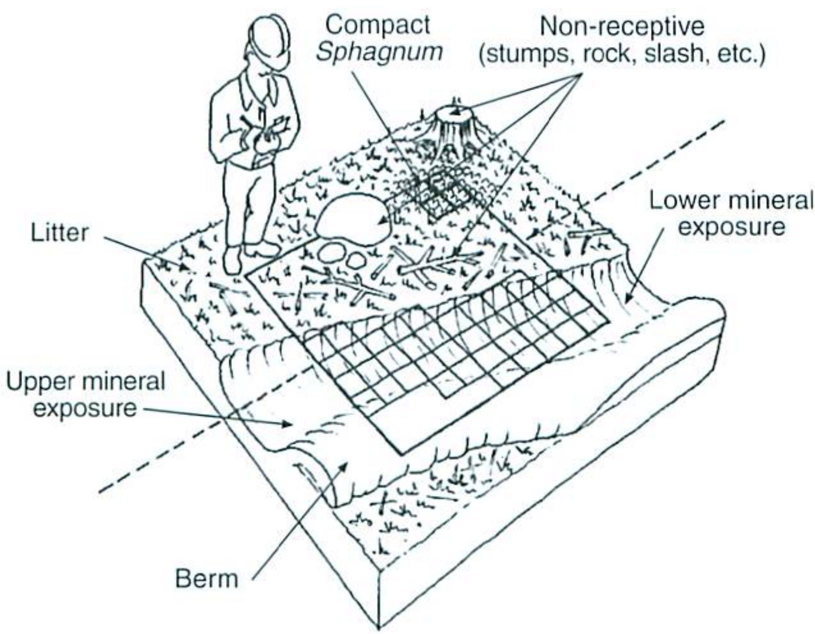


Figure F.2 Distribution of seedbed types within a 4 m² quadrat

Step 3. Record additional relevant information (e.g., number of stems of advance regeneration (must be rooted in the quadrat), the number of jack pine cones on receptive surfaces, the number of elevated cone laden black spruce tops, etc.)

Step 4. This step is for upland sites only. Once per line segment dig a soil pit to determine soil moisture regime by examining the soil's physical properties and profile characteristics. Locate the sampling point near the first quadrat of each selected line segment. Starting at the first quadrat of each selected line segment, offset approximately 2 m at a right angle from the centre line. From this point move in a parallel direction to the centre line until an undisturbed surface condition (not site-prepared) can be found. Using the techniques described in *A Field manual for describing soils* (Ontario Institute of Pedology 1985) determine and record soil moisture regime (SMR). An auger can be used to obtain this sample.

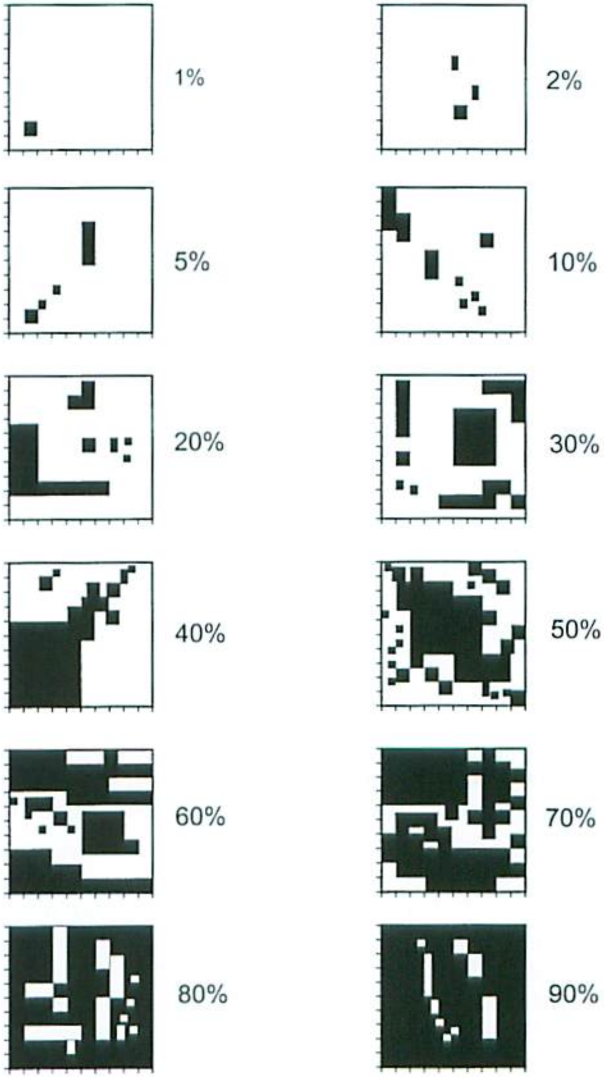


Figure F.3 Percentage cover charts

Appendix G: Procedures for carrying out a seedbed survey for spot seeding

The following information outlines a method of assessing the number of seedable spots per ha. The information collected can also be used by PC SEED to assist in determining the required number of seeds per spot.

Equipment needed:

- Spot seeding survey tally sheets (Figure F.1) or electronic data recorder;
- 50-m tape;
- Compass;
- Shovel or soil auger capable of sampling the "C" horizon;
- A Field manual for describing soils (Ontario Institute of Pedology 1985).

Step 1. Predetermine the spacing requirements and target seedbed types based on establishment ratios provided by the SDSs.

Step 2. In the case of disc trenching; walk at a right angle to the direction of site preparation and record the number of rows of site preparation per 100 m. Randomly select a bisecting trenched row. Walk up the trench for a distance of 40-m and record the best available seedbed type within the recommended target area of 1m ± 0.5 m from the starting point. A spot is not acceptable if it is closer than the minimum spacing. Record the best seedbed in the first 1-m segment. If there is no suitable seedbed, go to the next 1-m segment and repeat. Measure 1-m from the suitable seedbed and record the best seedbed in the next 1-m segment. When looking for an appropriate microsite it is acceptable to screef or compress the surface of the prepared area to improve its receptivity or create a suitable spot as would be done during an operational hand seeding exercise. If no suitable seedbed can found or created, record the spot as unseedable and go to the next 1-m segment.

In the case of spot scarification use the same type of procedure. Check the number of spot-making attempts over a 40 m length of row and record the number of attempts that resulted in acceptable spots for seeding.

For a bladed site several rows of spots may be established within a prepared swath. Prior to the survey, predetermine the minimum distance between rows within the swath [inter-swath spacing] and take this into account when calculating potential spot density.

Appendix H: Calibration of the Brohm Seeder in combination with the Piper PA-18A aircraft

Seeder description:

The output of the Brohm seeder is controlled by a variable speed auger that moves the seed from the seed tank to a duct leading to a revolving slinger attached to the belly of the aircraft. The pilot monitors the speed of the auger on a tachometer, and can adjust the auger speed in flight (Foreman 1995). The Brohm seeder can accept interchangeable augers with differing numbers of lands (flutes) and different pitches to accommodate different seed sizes and application rates. Using an auger with more lands and a finer pitch reduces the variation in deposition along the line of flight, but may cause more abrasion to the seed coat.

The seeder can apply seeds at a mean output within ± 10 percent of the desired application rate, except at low application rates (<40,000 seeds/ha for jack pine and <100,000 seeds/ha for black spruce).

Seeder calibration:

Calibrate the seeder on the ground over 30-second intervals using a stop watch and sensitive (± 0.1g accuracy) balance to meter seeds at the prescribed output rate for the proposed aircraft ground speed, inter-pass spacing, and application rate. The seeding unit should be warmed up prior to calibration, particularly if the ambient temperature is low (<10°C), and the electrical power supply to the unit should be supplemented if the aircraft battery is not being recharged during calibration. Adjust the speed of the auger for each successive test until the calculated weight of seeds equivalent to the prescribed output rate (viable seeds per second) is obtained consistently. These values can be plotted to identify the relationship between auger speed and output rate (e.g., Figure H.1, Fleming et al. 1985).

Accurate determination of the number of viable seeds per gram is critical for proper calibration of the seed-metering device. Information on seed viability and seed weight is provided by the seed plant for each seed lot number. However, this information reflects the state of the seed under cool storage and low relative humidity conditions. It is therefore advisable to condition the seed to the ambient field relative humidity and then determine the number of seeds/g, based on the weight of 0.1 gram samples (Foreman 1995).

Calculation example:

A prescribed seeding rate of 50,000 jack pine seeds/ha is desired. Assume an inter-pass spacing of 15 m and an aircraft ground speed of 130 km/h.

1. Calculate the area (ha) covered per minute of flight:

   [aircraft ground speed (m/min) x aircraft inter-pass spacing (m)/10,000]

   e.g., 130 km/h (2167 m/min) x 15 (m)/10,000 = 32,505 m^2 = 3.2 ha/min.

2. Determine the weight (g) of seeds required per ha:

   [application rate (viable seeds/ha)/number of viable seeds/g[1]]

   e.g., 50 000 seeds per ha/280 seeds/g = 179 g of seed/ha

3. Determine the output rate of seeds (g) required per 30-second interval to provide the prescribed seeding rate:

   [area covered per minute of flight x g of seeds required per ha/2]

   e.g., 3.2 ha/min. x 179 g/ha ÷ 2 = 286 g of seeds per 30 second test interval will meet the prescribed seeding rate of 50 000 seeds/ha.

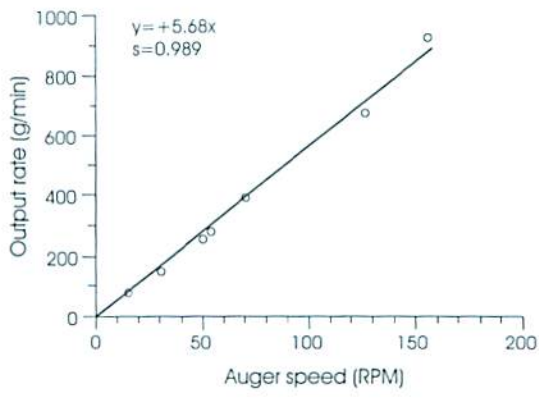


Figure H.1 A strong linear relationship exists between auger speed and output rate for black spruce seeds *(Fleming et al. 1985)*.

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1 Provided by the seed extraction plant, checked under field conditions

Appendix I: Number of traps required to sample aerial seeding at various seeding rates and confidence intervals *(Cameron and Foreman 1995)*

Seeding rate/ha	Level of confidence	Confidence interval	Trap size 0.25 m^2	1 m^2	4 m^2
50,000	19 times out of 20	+/- 10%	308	80	22
		+/- 5%	1230	308	80
	99 times out of 100	+/- 10%	531	133	37
		+/- 5%	2125	531	133
100,000	19 times out of 20	+/- 10%	154	41	12
		+/- 5%	615	154	42
	99 time out of 100	+/- 10%	236	71	21
		+/- 5%	1062	266	71
150,000	19 times out of 20	+/- 10%	106	28	9
		+/- 5%	410	107	29
	99 times out of 100	+/- 10%	177	48	15
		+/- 5%	708	177	48
200,000	19 times out of 20	+/- 10%	80	22	7
		+/- 5%	308	80	22
	99 times out of 100	+/- 10%	133	37	12
		+/- 5%	531	133	37
300,000	19 times out of 20	+/- 10%	54	16	6
		+/- 5%	205	54	16
	99 times out of 100	+/- 10%	93	26	10
		+/- 5%	354	93	26

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3.0 THE SITE

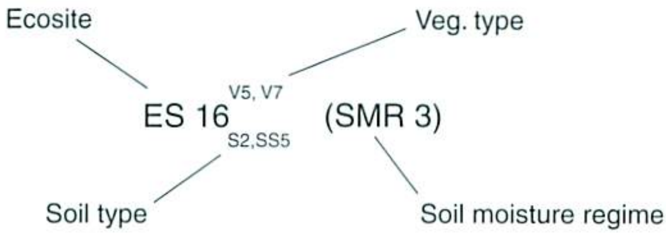
Not all sites can be successfully direct seeded. For this reason, the decision about whether or not to seed must be based on detailed information about the site. Furthermore, on sites where direct seeding is feasible, the seeding prescription must take site conditions into account.

Because direct seeding results are strongly influenced by vegetation and soil conditions, Forest Ecosystem Classifications (FECs) are highly applicable in planning direct seeding. Ideally, pre-harvest FEC information will be used to determine the suitability of a site for seeding.

3.1 What are the Roles of FEC and PHSPs in Site Selection?

Both general and very site-specific classification tools have been developed for northern Ontario to assist users in developing ecosystem-based management strategies. FECs have been completed for both northeastern and northwestern Ontario. These classifications overlap somewhat in northcentral Ontario. The northeastern Ontario (NEO) FEC, originally published in 1983, has been expanded and a new nomenclature has been introduced. Although much of the information in this guide for NEO derives from research reported using the 1983 Clay Belt FEC nomenclature, all Clay Belt Operational Groups (OGs) have been converted to the Site Types (STs) used in the more recent NEO FEC (McCarthy et al. 1994). For northwestern Ontario, recently developed ecosites (ESs) have largely replaced treatment units (TUs) (Racey et al. 1989), and represent an intermediate level of ecological organization. The general relationship between generic treatment units and forested ecosites can be found in Appendix B. Both northwestern Ontario (NWO) ecosites and northeastern Ontario (NEO) site types are management-oriented aggregations of defined soil and vegetation conditions, which provide a coarser division of the land base. They are appropriate for describing and mapping forest ecosystems at a scale compatible with the Ontario Forest Resource Inventory, while the soil types (S-types) and vegetation (V-types) provide the finer detail required to develop direct seeding prescriptions.

The classification nomenclature involving ecosites (site types), ecoelements (V-types and S-types) and first order observations (soil texture and moisture class) can be cumbersome to deal with. However, this information can be integrated and simplified by combining the numbering systems: e.g.:



Collection of information in such a format will allow candidate sites to be quickly assessed for their direct seeding potential (Section 3.2.1).

Other information collected during the classification process, such as frost heave hazard and soil erosion hazard, can also be helpful in developing prescriptions.

We recommend that a site-specific pre-harvest silvicultural prescription (PHSP) be developed prior to laying out areas for harvesting. It should include: a description of the current structure and condition of the forest; a plan for harvesting, renewal and maintenance activities; a description of the expected future structure and condition of the forest; and a record of the guidelines used to develop the prescription (Bidwell et al. 1996). Incorporating an FEC survey (section 3.1.1) into the PHSP will provide much of the information needed to develop a direct seeding prescription (section 9).

3.1.1 Pre-harvest FEC survey

The FEC survey is part of the PHSP and can be integrated into an operational timber cruise.

The first step of the survey is to assemble relevant information such as Forest Resource Inventory (FRI) maps, aerial photographs, soil surveys or other background material.

Next, mark cut block boundaries on the FRI map and then stratify the cut block based on FRI stand boundaries and vegetation or landform differences apparent from aerial photographs. The strata should represent areas that might require different treatments.

Next, lay out cruise lines in each of the strata. Bidwell et al. (1996) suggest a minimum of three to five plots per stratum. Alternatively, Racey et al. (1989) recommend one sample plot every 10 ha, or 1 plot every 300 m for a pre-harvest survey of sample intensity level 2. If there are inclusions within a stratum, these should be sampled because they may change the prescription.

Avoid placing plots on roads, landings or trails.

At each sample plot, record the FEC soil type, vegetation type, soil texture and soil moisture regime. Also record additional information relevant to direct seeding such as: occurrence of extensive rock outcrops, cover of *Sphagnum* mosses, abundance of advance growth, thickness of LFH layers, potential for competition development, and anticipated slash loadings.

Most of this information can also be collected in a post-harvest survey. Information collected about advance growth, slash amounts, cone loading in slash, seedbed cover and surface disturbance will be more reliable after the harvest is completed.

3.2 What Sites are Most Suitable for Direct Seeding?

Ordination diagrams (Figures 3.1, 3.2, 3.3 and 3.4), developed for both northwestern ecosites and northeastern site types, are based on the spatial distribution of vegetation and soil types across the landscape and provide a convenient format for plotting potential direct seeding opportunities. Sites are rated as having either high or moderate potential for direct seeding. Direct seeding has a good probability of success on high potential sites; on moderate potential sites, direct seeding is feasible but the risk of failure is greater. Periods of unfavourable weather, competing vegetation, and inadequate site preparation are more likely to cause failure on moderate potential sites than on high potential sites. More detailed information regarding characteristic V-type, S-type and moisture regimes associated with these sites along with site-specific considerations and recommendations can be found in Tables 3.1, 3.2, 3.3 and 3.4 which follow these diagrams. These interpretations are intended to be used as general guidelines for developing your own rating structure and can be further modified based on local knowledge and experience.

3.2.1 Potential Sites for direct seeding jack pine in northwestern Ontario.

Generally, ES 13, 14, 15, 20, 25, 26 and 31 have good potential for jack pine direct seeding. However, the landforms associated with these ecosites can be quite variable and characteristic soil types range from shallow sandy to deep fresh clayey soils. Deep to moderately shallow, sandy to coarse loamy soils that are moderately fresh to very fresh provide the best seeding chances for jack pine.

ES 11 and 12 will benefit from well distributed mineral soil seedbeds. However, these sites are generally prone to seasonal drought, which reduces the likelihood of successful direct seeding.

Precision seeding with seed shelters is recommended for ES16, 19 and 21.

When planning harvesting method and site prep prescriptions, take into account the ingress potential of the site. Augmenting direct seeding with cone scattering or preservation of residuals can significantly enhance stocking. Consider vegetation control, timing of seed application and both timing and method of harvest for those ecosites that are prone to moderate or high levels of competition.

Jack pine can establish over a range of soil moisture regimes (Ø to 6). However, unless favourable weather conditions occur in both the seeding and the following year, seeding on sites that have a SMR of Ø or 0 is likely to fail. Jack pine stands that become established on SMR >4 may be subject to early stand breakup because of increased occurrence of butt and heart rot on these moist soils.

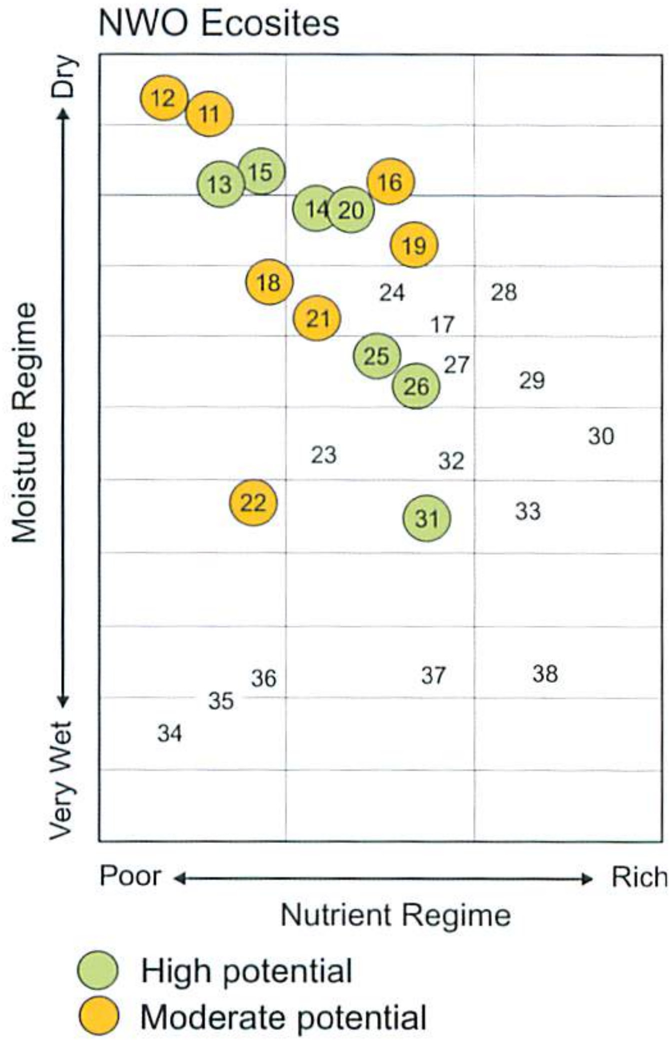


Figure 3.1 Potential for direct seeding jack pine in northwestern Ontario *(adapted from Racey et al. 1996)*.

Table 3.1 Site-specific considerations and recommendations associated with the potential for direct seeding jack pine in northwestern Ontario *(adapted from OMNR 1997)*.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 11	Red Pine–White Pine–Jack Pine: Very Shallow Soils	V12, 13, 26, 27, 29, 30	SS1-4, (SS5, 6&9)	TU–H	SMR 0-2

General Comments:
- V types 12, 13 and 29 have a moderate potential for direct seeding while V26 and V27 are considered moderate-to-poor.
- Soil types SS1- 3 are highly susceptible to seasonal drought and pose an increased risk to nutrient loss and erosion.
- This ecosite has a low mortality potential from competition, frost heaving or flooding.
- Expect moderate-to-low levels of jack pine seed dispersion from sun-opened cones on juvenile jack pine.

Recommendations:
- Broadcast seeding jack pine may be one of the few cost effective alternatives to regenerate this rock-controlled ecosite.
- Consider cone scattering to augment direct seeding on fresher phases of this ecosite.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 12	Black Spruce–Jack Pine: Very Shallow Soils	V30, (35-38)	SS1-SS4, (SS5)	TU–I1	SMR 0-2

General Comments:
- Prone to seasonal drought, which will influence the success of direct seeding efforts.
- Moderate to low levels of jack pine seed ingress.
- Moisture regimes greater than 1 are uncommon on this ecosite.

Recommendations:
- V 30 has a moderate potential for direct seeding.
- This ecosite provides an opportunity for boot-screefing and shelter seeding.
- V types 35 - 38 occur in small patches on this ecosite and are generally wet and / or organic peaty phase seedbeds and are considered as having low potential. These V types also pose a moderate-to-high flooding potential and higher incidence of root rot.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 13	Jack Pine–Conifer: Dry–Moderately Fresh, Sandy Soil	V28-30, (32-33)	S1, S2, (SS5)	TU–I2	SMR 0-1

General Comments:

- Prone to moderate-to-high levels of seasonal drought. However, adequate rainfall may yield high stocking with excessive densities.
- Ingress of naturals after harvesting and site preparation is high.

Recommendations:

- This ecosite has a moderate-to-high potential for direct seeding.
- Scarification to scatter and align jack pine slash will enhance regeneration success.

ES 14	Pine–Spruce Mixedwood: Sandy Soil	V17-20, (10, 31-33)	S1, S2, (SS5)	TU–E1, E2, F	SMR 0-3

General Comments:

- Drier phases of this ecosite are prone to seasonal drought.
- Coarser soils are nutrient poor.
- Potential for competition ranges from low to high.
- Ingress of naturals after harvesting and site preparation is generally high.

Recommendations:

- This ecosite has a moderate-to-high potential for direct seeding.
- Precision sowing is recommended. Boot-screefing can be effective.
- Augmenting cone/slash scattering with direct seeding will produce good results.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 15	Red Pine–White Pine: Sandy Soil	V1, 42, 13, (26, 27)	S1, S2, (SS5)	TU–H	SMR 0-2

General Comments:
- Exposed mineral soil seedbeds will be prone to seasonal drought.
- Adequate rainfall during the germination-establishment period is required to assure success on these generally rapidly drained soils.

Recommendations:
- This ecosite has a moderate-to-high potential for jack pine direct seeding.
- Use light intensity mechanical site preparation or boot-screefing.
- Success of cone scattering to augment artificial seeding will be highly variable on this site.

ES 16	Hardwood–Fir–Spruce Mixedwood: Sandy Soil	V4-11, (17, 18, 20)	S1, S2, (SS5)	TU–B1	SMR 0-3

General Comments:
- Moderate-to-high levels of competition. Rapid ingress and vigorous development of competitors on this relatively fertile and generally fresh to moist site may preclude high jack pine stocking from direct seeding.
- Dry moisture regimes prone to seasonal drought.
- Smothering of seedbeds with hardwood litter may limit broadcast seeding.

Recommendations:
- V types 4 to 9 have low potential, however V10,V11,17, 18 and 20 have moderate-to-high potential for direct seeding.
- Encourage prompt establishment.
- Shelter seeding is recommended. Vegetation control will be required.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 18	Red Pine–White Pine: Fresh, Coarse Loamy Soil	V26, 27, (12, 13)	S3, SS6	TU–H	SMR 0-2

General Comments:
- Shallow soils (20 to 50 cm) are susceptible to erosion, seasonal drought/desiccation and low nutrient levels.
- Moderate-to-high levels of competition. Competition must be controlled to ensure success of seeding treatments.
- Moderate potential for frost heaving.

Recommendations:
- Use a light site preparation technique and ensure even distribution of mineral soil. However, a high proportion of boulders and cobbles may limit mechanical site preparation.
- Boot-screefing on sites with shallower organic matter depths and spot seeding is an option.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 19	Hardwood–Fir–Spruce Mixedwood: Fresh, Sandy–Coarse Loamy Soil	V4-11, (14, 15, 17)	S2, S3, (S1, S2, SS5)	TU–B1	SMR 0-3

General Comments:
- High levels of competition.
- Potential for high surface stone content may limit equipment operability.
- Low-to-moderate potential for frost heaving and flooding.
- Smothering of seedbeds with hardwood litter may limit broadcast seeding.

Recommendations:
- This ecosite has a low potential for jack pine direct seeding on V types 4-9 and a moderate-to-high potential for V 10, 11, 14, 15 and 17.
- Shelter seeding is recommended. Vegetation control will be required.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 20	Spruce–Pine / Feather-moss: Fresh, Coarse Loamy Soil	V28-33, (17, 18, 20)	S2, S3, SS6, (S1, SS5)	TU–E2, F	SMR 2-3

General Comments:
- Moderate competition may be expected from green alder, willow and aspen.
- Expect high levels of jack pine ingress.

Recommendations:
- Good distribution of mineral soil seedbeds will contribute to successful direct seeding of jack pine on this ecosite.
- Augment direct seeding with passive cone scattering.

ES 21	Fir–Spruce Mixedwood: Fresh, Coarse Loamy Soil	V14-16, 19, (24, 25)	S3, SS6	TU–D1	SMR 0-3

General Comments:
- Moderate levels of competition.
- Low levels of jack pine ingress.
- Moderate potential for frost heaving.
- Potential for high surface stone content may limit equipment operability.
- Consider prescribed burning to reduce heavy slash loading associated with this ecosite.
- Smothering of seedbeds with hardwood litter may limit success.

Recommendations:
- This ecosite has a moderate potential for jack pine direct seeding.
- Seed shelters are recommended.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 22	Spruce–Pine / *Ledum* / Feathermoss: Moist, Sandy–Coarse Loamy Soil	V33, 34, (19, 20, 35, 37)	S7, S8, (SS8)	TU–E3	SMR 4-6

General Comments:
- A moderate level of ingress can be expected on this ecosite.
- Excessive disturbance on moist soils on this site will promote non-crop vegetation.
- moderate-to-high incidence of flooding on V-Types 34, 35 and 37.
- While jack pine may be easily established by seeding on well distributed mineral soil seedbed, thrifty development and growth may only occur on the better drained portions of this ecosite.

Recommendations:
- On sandy phases of this ecosite, broadcast or precision seeding of jack pine on mineral soil seedbeds is highly successful.
- Cone scattering of jack pine slash with light site preparation is another option if site conditions permit.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 25	Pine–Spruce / Feather-moss: Fresh, Silty soil.	V31, 32, (11)	S4, (SS7)	TU–E2	SMR 1-3

General Comments:
- Fine textured soils are susceptible to compaction and rutting during the frost free season.
- Excessive disturbance on this site will promote non-crop vegetation and increase the potential for erosion and frost heaving.
- Small seedlings on exposed finer textured mineral soils are prone to frost heaving - this may be mitigated by maintaining a thin (5–20 mm) H/FH horizon over the mineral soil).

Recommendations:
- This ecosite has a high potential for direct seeding jack pine.
- Expect moderate-to-high levels of jack pine ingress on this ecosite.
- Low intensity scarification to scatter and align jack pine slash will enhance regeneration success.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 26	Spruce – Pine / Feather-moss: Fresh, Fine Loamy–Clay Soil	V31, 33, (20, 32)	S5, S6 (SS7)	TU–E3	SMR 1-3
ES 31	Spruce – Pine / Feather-Moss: Moist, Silty–Clayey Soil	V33, 34, (31, 32)	S9, S10 (SS7, SS8)	TU–E2	SMR 1-3

General Comments:
- Both are low-to-moderate competition sites.
- These ecosites have moderate-to-high levels of frost heaving on finer textured soils; mitigate by maintaining a thin (5–20 mm) H/FH horizon over the mineral soil.
- Moderate-to-high levels of flooding may occur on moister phases of these ecosites.

Recommendations:
- Creating receptive seedbed through fire or mechanical site preparation is necessary for direct seeding these ecosites.
- Select phases of these ecosites with lower silt contents to minimize competition for direct seeding treatments.
- High levels of jack pine ingress will augment artificial seeding.

3.2.2 Potential sites for direct seeding jack pine in northeastern Ontario.

ST 1, ST 5a and ST 5b should be considered as having good potential for direct seeding. On ST 2a and 2b, seed only when moisture regimes are greater than or equal to one. Seeding itself will not bring back a jack pine-dominated stand on ST 3a and 6c and should only be used when augmented with other regeneration methods. Distribution, abundance and vigour of competitive woody and herbaceous species on sites such as ST 3b may preclude germination, survival and growth of jack pine, unless controlled. Ensure adequate seedbed (i.e., a minimum 10 to 25% receptive seedbed) on ST 4.

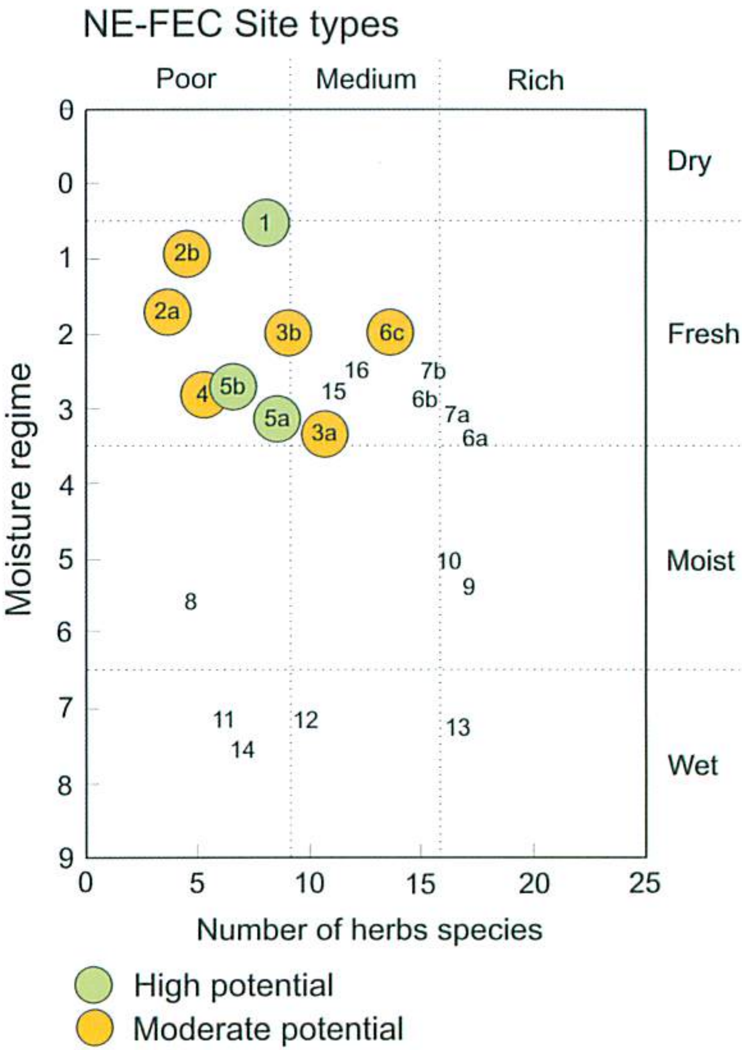


Figure 3.2 Potential for direct seeding jack pine in northeastern Ontario *(adapted from McCarthy et al. 1994)*

Table 3.2 Site-specific considerations and recommendations associated with the potential for direct seeding jack pine in northeastern Ontario *(adapted from OMNR 1997)*.

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 1	Very Shallow Soil	V16$^{(2)}$, 13$^{(2)}$, 14$^{(1)}$, 22$^{(1)}$, other$^{(4)}$	(SS1-4)^{10}	SMR Ø-2

General Comments:
- These sites have ≤30 cm of mineral soil over bedrock, with the greatest percentage of them having a moisture regime ranging from Ø to1.
- Seed and/or seedlings could experience desiccation.
- Very sensitive to site damage from harvesting.
- High probability of augmenting direct seeding with natural ingress.

Recommendations:
- Good candidate for direct seeding to jack pine.
- Rule out extensive portions of this site that have SMR <1.
- Use a light site preparation technique due to a thin organic layer or consider boot-screefing and spot seeding.
- Good candidate for cone scattering.

ST 2a	Jack Pine: Coarse Soil	V16$^{(6)}$, 15$^{(3)}$, 18$^{(1)}$	S1$^{(4)}$, (S2, S5)$^{(3)}$, S6$^{(2)}$, S7$^{(1)}$	SMR 1-3

General Comments:
- Extremely high level of jack pine ingress (>5,000 stems/ ha.(sph))
- Low competition site.
- Moderate-to-high risk of nutrient loss.
- New germinants susceptible to extended droughts on SMR ≤1.

Recommendations:
- Direct seeding is recommended on sites predominantly SMR 2–3.
- Use a light site preparation technique due to a thin organic layer or consider boot-screefing and spot seeding.
- Medium potential for cone scattering.

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 2b	Jack Pine: Very Coarse Soil	V16(4), 15(3), 17(1), 18(1), 5(1)	S1(7), S2(1), S3(1), (S5, S6)(1)	SMR Ø-3

General Comments:
- Extremely high level of jack pine ingress (>5,000 sph)
- Low competition site.
- Desiccation of seed and/or seedlings may take place during very dry seasons.

Recommendations:
- Direct seeding is recommended on sites with SMR ≤1.
- Direct seeding may yield low stocking on portions of site with SMR: Ø–0, excepting germination and post germination seasons with adequate rainfall. Obtaining consistent, uniform stocking may depend on the distribution of the SMR mosaic.
- Use a light site preparation technique due to a thin organic layer or consider boot-screefing and spot seeding.
- Medium potential for cone scattering.

ST 3a	Mixedwood: Medium Soil	V13(5), 14(2), (V10, 12, 17, 23)(3)	S11(4), S9(2), S12(2), S10(1) S15(1)	SMR 1, 3, (2,4)

General Comments:
- On finer textured soils frost heaving may occur if the entire LFH layers are removed.
- Moderate competition site.

Recommendations:
- This site has a moderate potential for direct seeding; it should only be used to augment other regeneration methods.
- Prompt post harvest site preparation may permit seeded jack pine to better cope with developing competition.

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 3b	Mixedwood: Coarse Soil	V13(5), 14(2), 12(1), 17(1), (5, 15, 23)(1)	S1(3), S2(2), S5(2), S7(2), S3(1)	SMR Ø-5

General Comments:
- On finer textured soils frost heaving may occur if the entire organic layer is removed.
- Moderate competition site.

Recommendations:
- This site has a moderate potential for direct seeding
- Avoid dry moisture regimes (SMR Ø to 0).
- Competition may preclude success of direct seeding efforts unless controlled.
- Prompt post harvest site preparation is recommended.

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 4	Jack Pine–Black Spruce: Coarse Soil	V18(4), 23(4), 17(1), (13, 14, 22)(1)	S3(3), S1(3), S7(2), S4(1), S5(1)	SMR Ø-5

General Comments:
- High probability of jack pine ingress (5,000 sph)
- Moderate competition site.

Recommendations:
- This site has a moderate potential for direct seeding
- Requires a minimum 10 to 15% receptive seedbed exposure.
- Avoid extensive areas with uniformly dry (Ø–0) moisture regimes.
- Good candidate site for cone scattering.
- Potential site for seed tree underburning.

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 5a	Black Spruce: Fine Soil	V23(4), 18(2), (8, 13, 14, 16, 21, 22)(4)	S13(6), S14(4)	SMR 2-5

General Comments:
- High probability of jack pine ingress (1,000 to 5,000 sph)
- Avoid damaging saturated fine textured soils during harvesting.
- On finer textured soils frost heaving may occur if the entire organic layer is removed.
- Moderate competition, however avoid heavy site preparation.

Recommendations:
- This site has a high potential for direct seeding jack pine.
- Avoid seeding jack pine on extensive areas with SMR >4.

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 5b	Black Spruce: Medium Soil	V16(3), 18(3), 23(2), 22(1), 15(1)	S12(4), S10(3), S11(2), S9(1)	SMR: 1-4

General Comments: • On finer textured soils frost heaving may occur if the entire organic layer is removed.
• Very high probability of jack pine ingress (>5,000 sph) when jack pine is present in the overstory prior to harvest.
• Moderate competition, however avoid heavy site preparation.

Recommendations: • This site has a high potential for direct seeding jack pine.
• High potential for cone scattering when organic matter depth is less than 10 cm.

ST 6c	Hardwood Mixedwood: Coarse Soil	V12(5), 9(1), 11(1), 14(1), (5, 7, 8, 13)(2)	S1(2), S2(2), S7(2), S3(1), S4(1), S5(1), S6(1)	SMR 0-4

General Comments: • Potential abundant suckering and sprouting of shrubs following harvest.

Recommendations: • This site has a moderate potential for direct seeding jack pine.
• Consider prompt post harvest site preparation to permit seeded jack pine to better cope with developing competition.
• Seeding must be augmented with other regeneration methods to successfully regenerate this site.
• Potential for cone scattering on drier phases of this site.

3.2.3. Potential sites for direct seeding black spruce in northwestern Ontario.

3.2.3.1 Upland black spruce

On uplands, ecosites 20 and 25 offer the best potential for direct seeding. Proper site preparation is critical to regeneration success on both these ecosites. Avoid sites that are predisposed to heavy competition.

The most favourable soil types are moderately shallow to deep silty very fine sands and sandy loams. It is more difficult to establish black spruce by direct seeding on soil classifications S2 and S3 (deep, moderately dry to fresh, loamy and silty sands) and on types SS2 and SS3 (very shallow, silty sands and sandy loams).

Even with above average rainfall during the first and second growing seasons, SMR Ø and 0 offer little chance of success for direct seeding and should be avoided. Coarse textured soils with a SMR of 1 are also likely to result in seeding failures. On shallow soils however, a SMR of 1 can produce acceptable stocking in a year with adequate rainfall and moderate-to-high stocking in a year of above normal precipitation. Best results are obtained on very fresh to very moist soils (SMR 3-6).

3.2.3.2 Lowland black spruce

Lowland black spruce sites in the northwest are characterized by deep, very moist to wet organic soils. Substantial accumulations of organic matter provide good water storage capacity. Those sites dominated by *Sphagnum* moss (ES 34, 35 and 36) have good potential for direct seeding. The hygroscopic nature of living *Sphagnum* and *Sphagnum* peat allows the seedbeds associated with these sites to retain large quantities of available water, regardless of the underlying substrate (Fleming and Mossa 1994).

Generally, these ecosites have high levels of advance growth. Preservation of this advance growth through the use of careful logging techniques can supplement regeneration establishment by direct seeding.

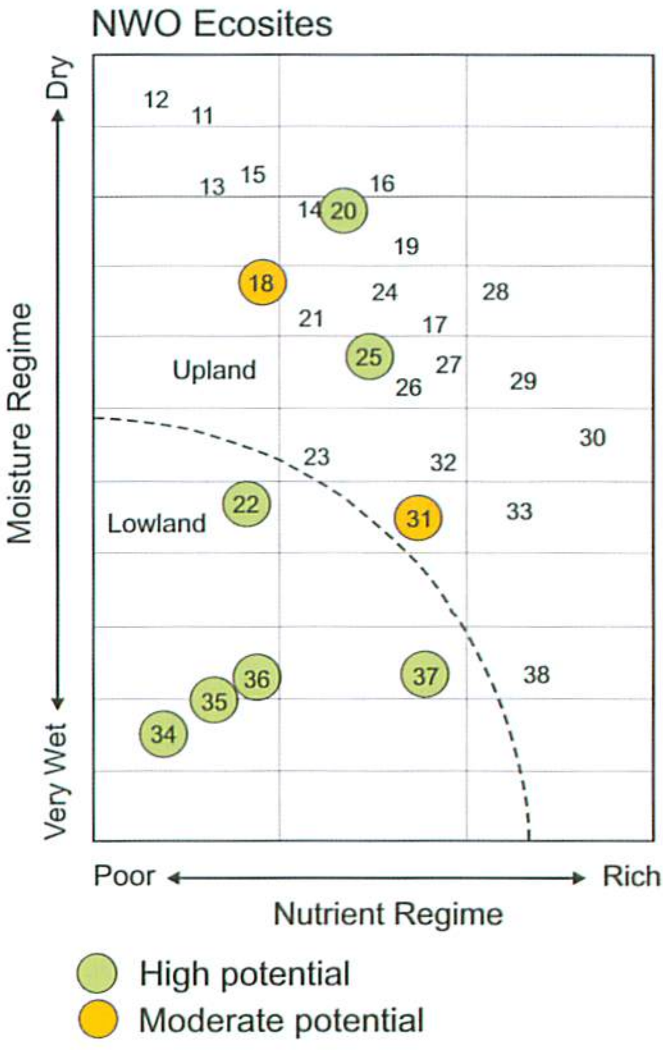


Figure 3.3 Potential for direct seeding black spruce in northwestern Ontario *(adapted from Racey et al. 1996).*

Table 3.3 Site-specific considerations and recommendations associated with the potential for direct seeding black spruce in northwestern Ontario *(adapted from OMNR 1997).*

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 18	Red Pine–White Pine: Fresh, Coarse Loamy Soil	V26, 27, (12,13)	S3, SS6	TU–H	SMR 0-2

General Comments:
- Shallow soils (20 to 50 cm) are susceptible to erosion, seasonal drought/desiccation and low nutrient levels.
- Moderate-to-high levels of competition. Competition must be controlled to ensure success of seeding treatment.

Recommendations:
- Shelter seeding only. Boot-screefing, where site conditions permit, will moderate both moisture and temperature extremes and minimize competition.
- Broadcast seeding is not recommended.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 20	Spruce – Pine / Feathermoss: Fresh, Coarse Loamy Soil	V28-33, (17,18, 20)	S2, S3, SS6 (S1,SS5)	TU–E2, F	SMR 2-3

General Comments:
- Moderate competition may be expected from green alder, willow and aspen.
- This ecosite supports an abundance of advance growth.
- Careful logging to preserve advance growth should be considered.

Recommendations:
- This ecosite has a moderate-to-high potential for aerial seeding.
- Site preparation is required to expose sufficient suitable seedbed.
- A combination of black spruce seed trees and prescribed burning may be an option.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 25	Pine–Spruce / Feather-moss: Fresh, Silty Soil	V31, 32, (11)	S4, (SS7)	TU– E2	SMR 1-3

General Comments:
- Fine textured soils are susceptible to compaction and rutting during the frost free season.
- Excessive disturbance on this site will promote non-crop vegetation and increase the potential for erosion and frost heaving.

Recommendations:
- This ecosite has a moderate-to-high potential for aerial seeding.
- Light site preparation is required to expose sufficient suitable seedbed.
- A combination of black spruce seed trees and prescribed burning may be an option (target the less competitive V-types for this treatment).

ES 31	Spruce – Fine – Feathermoss: Moist, Silty–Clayey Soil	V33, 34, (31, 32)	S9, S10, S11 (SS7, SS8)	TU–E3	SMR 4-6

General Comments:
- This ecosite has high levels of black spruce ingress after disturbance and moderate levels of advance growth.
- Excessive disturbance on this site will promote non-crop vegetation and increase the potential for erosion and frost heaving.
- Fine textured soils are susceptible to compaction and frost heaving.

Recommendations:
- This ecosite has a moderate potential for aerial seeding.
- Light site preparation is required to expose sufficient suitable seedbed.
- A high degree of ingress is required to supplement aerial seeding.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 22	Spruce–Pine / *Ledum* / Feathermoss: Moist, Sandy–Coarse Loamy Soil	V33, 34, (19, 20)	S7, S8 (SS8)	TU–E3	SMR 4-6

General Comments:
- Moderate-to-high level of advance growth with a moderate level of ingress.
- Excessive disturbance on moist soils on this site will promote non-crop vegetation.

Recommendations:
- This ecosite has a moderate-to-high potential for aerial seeding.
- Light site preparation is required to expose sufficient suitable seedbed.
- A high degree of ingress is required to supplement aerial seeding.
- Employ careful logging to augment stocking.
- A combination of black spruce seed trees and prescribed burning may be an option.

ES 34	Black Spruce / *Sphagnum*: Organic Soils	V37, 38	S12S, S12	TU–J2	SMR 6-8

General Comments:
- High level of advance growth.
- High potential for rutting and disturbance of surface water.
- Low productivity site.

Recommendations:
- This ecosite has high potential for direct seeding.
- Good opportunity for protection of advance growth to complement seeding.
- Employ careful logging.

ES 35	Black Spruce: Organic Soils	V37, 38	S12S, S12 (S11, SS9)	TU–J1	SMR 6-8

General Comments:
- High level of advance growth.
- High potential for rutting and disturbance of surface water.
- Prone to seasonal flooding.

Recommendations:
- Aerial seeding is a recommended option on phases of this ecosite with abundant *Sphagnum* cover and low levels of advance growth.
- Use careful logging to protect the site and conserve advance growth.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 36	Black Spruce (Tamarack): Organic Soils	V23, 35, (36)	S12S, S12F, (S11, SS9)	TU–J1	SMR 6-8

General Comments:
- High level of advance growth.
- High potential for rutting of organic soils.
- Prone to seasonal flooding, which may limit access.

Recommendations:
- Aerial seeding is a recommended option on phases of this ecosite with abundant *Sphagnum* cover and low levels of advance growth.
- Use careful logging to minimize ground disturbance and conserve advance growth.

Ecosite	Site Description	V-Type	S-Type	Treatment Unit	Soil Moisture Regime
ES 37	Cedar (Other Conifer): Organic Soils	V21, 22	S11 (S12F, S12S, SS9)	TU–J1, D2	SMR 4-8

General Comments:
- High level of advance growth.
- High potential for rutting of organic soils.
- Prone to seasonal flooding, which may limit access.
- Potentially high levels of alder competition following harvesting.

Recommendations:
- Aerial seeding is a recommended option on phases of this ecosite with abundant *Sphagnum* cover and low levels of advance growth.
- Use careful logging to protect the site and conserve advance growth.
- Minimizing ground disturbance will limit competition development, although tending may be required.

3.2.4. Potential Sites for direct seeding black spruce in northeastern Ontario.

On upland sites, ST 5a and 5b offer the best chance of success. Ensure that there is sufficient receptive seedbed available before seed application. All other identified sites have only moderate potential and in many cases the treatment by itself will not result in a black spruce dominated site and should only be used when augmented with other regeneration methods.

On lowland sites, as in northwestern Ontario, the greatest likelihood of seeding success occurs on those site types which support a high cover of *Sphagnum* moss. *Sphagnum* cover is consistently high in the black spruce *Labrador-Tea* and *Speckled Alder* site types (ST 11 & 12), and can be high in the black spruce feather moss/*Sphagnum* and Conifer Speckled Alder site types (ST 8 & 13) (Groot and Adams 1984).

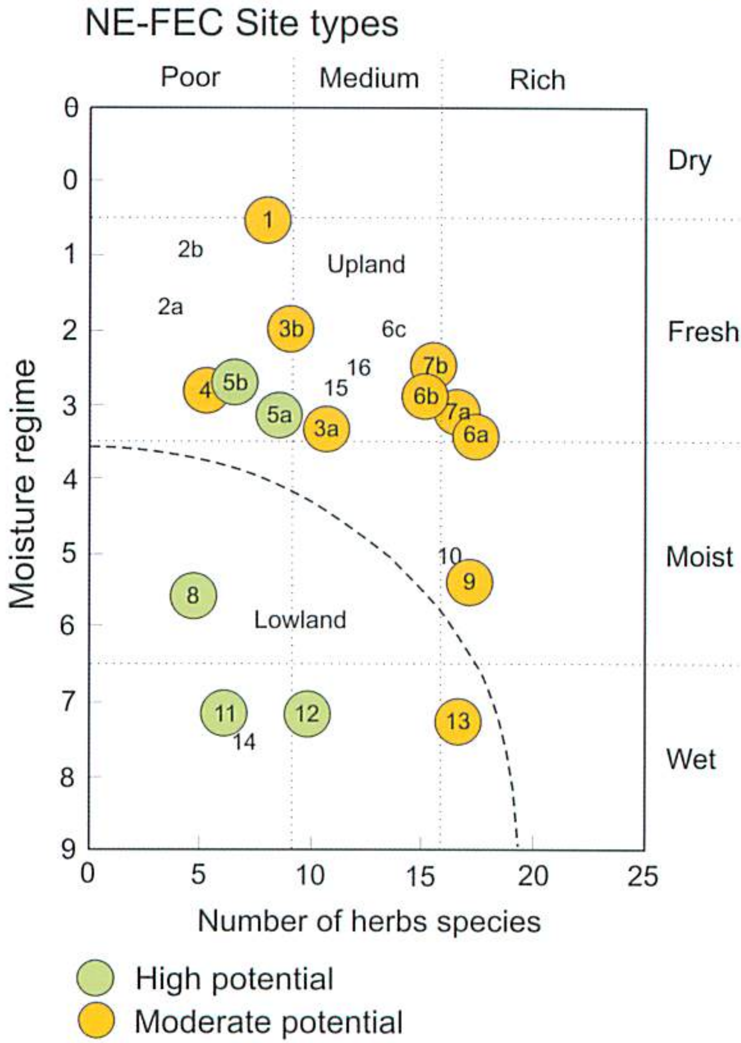


Figure 3.4 Potential for direct seeding black spruce in northeastern Ontario *(adapted from McCarthy et al. 1994)*

Table 3.4 Site-specific considerations and recommendations associated with the potential for direct seeding black spruce in northeastern Ontario *(adapted from OMNR 1997).*

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 1	Very Shallow Soil	V16, 13, 14, 22	SS1–4	SMR Ø-2

General Comments:
- These sites have ≤30 cm of mineral soil over bedrock; the greatest percentage of them have a moisture regime ranging from Ø to 1.
- Seed and/or seedlings could experience desiccation.
- Very sensitive to site damage from harvesting.

Recommendations:
- Good candidate for seeding to black spruce.
- Rule out any sites having a SMR <1.
- Use a light site preparation technique due to the thin organic layer or consider boot-screefing and spot seeding.

ST 3a	Mixedwood: Medium Soil	V13, 14, (10, 12, 17, 23)	S11, S9, S12, S10, S15	SMR 1,3, (2, 4)

General Comments:
- Frost heaving may occur if the entire organic layer is removed.
- Moderate competition site.

Recommendations:
- This site has a moderate potential for direct seeding.
- Seeding should only be used to augment other regeneration methods.

ST 3b	Mixedwood: Coarse Soil	V13, 14, 12, 17, (5, 15, 23)	S1, S2, S5, S7, S3	SMR1-2, (Ø-0, 3, 4, 5)

General Comments:
- Frost heaving may occur if the entire organic layer is removed.
- Moderate competition site.

Recommendations:
- This site has a moderate potential for direct seeding black spruce.
- Avoid dry moisture regimes (Ø to1).
- Competition may preclude success of direct seeding efforts unless controlled.

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 4	Jack Pine–Black Spruce: Coarse Soil	V18, 23, 17, (13, 14, 22)	S3, S1, S7, S4, S5	SMR 3-4, (Ø-0, 1, 2, 5)

General Comments: • If jack pine occupied a significant component of the original stand then there will be a high probability of jack pine ingress.
• Moderate competition site.

Recommendations: • This site has a moderate potential for direct seeding black spruce.
• On moisture phases (SMR 4 and 5) of this site, augment stocking by careful logging to protect advance growth.
• Avoid dry moisture regimes (Ø to1).

ST 5a	Black Spruce: Fine Soil	V23, 18, (8, 13, 14, 16, 21, 22)	S13, S14	SMR 2-4, (5)

General Comments: • Avoid damaging saturated fine textured soils during harvesting.
• Black spruce advance growth may be of sufficient quantity to form a major part of the new stand.
• Moderate competition, however avoid heavy site preparation.

Recommendations: • This site has a high potential for direct seeding black spruce.
• Use careful logging to protect advance growth.

ST 5b	Black Spruce: Medium Soil	V16,18, 23, 22,15	S13, S14	SMR 1-4

General Comments: • Very high probability of jack pine ingress (>5,000 sph) on dryer phases of this site when jack pine is present in the overstory prior to harvest.
• Moderate competition, however avoid heavy site preparation.

Recommendations: • This site has a high potential for direct seeding black spruce.
• Moister phases of this site offer good opportunity to augment seeding by using careful harvesting to protect advance growth.

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 6a	Mixedwood: Fine Soil	V8, 7, (9,13), 10, (14, 18, 22)	S13, S14	SMR 2, 3, 5, (4)
ST 6b	Conifer Mixedwood: Medium Soil	V8,12,13, (4, 7, 9, 17)	S12, S9, S10, S11	SMR 2, 3, 4, (1, 5)
ST 7a	Hardwood: Fine Soil	V9, 7, 10, 8, 11, (12, 14)	S13, S14	SMR 2, 3, (4, 5, 6)
ST 7b	Hardwood: Medium Soil	V9, 11, 12, (8, 10, 13)	S9, S11, S10, S12, S15	SMR 2 ,3, (1, 4, 5)

General Comments: • All of these sites are highly competitive, which can make renewal by direct seeding difficult.

Recommendations: • Abundance of competition will require vegetation control.
• Consider precision seeding with seed shelters.

ST 9	Conifer: Moist Soil	V7, 6, 22,1 9, 14, 23	S16, S15, S12, S7, S11	SMR 4, 5, (6)

General Comments: • Minimize disturbance of peat layer to avoid site damage.
• Site can have moderate amounts of advance growth.

Recommendations: • This site has a moderate potential for direct seeding black spruce.
• Augment seeding by using careful harvesting to protect advance growth.

ST 8	Black Spruce / Feathermoss / *Sphagnum*	V23, 24, 22, (25, 18)	S16, S7, S14 (S3, S4, S8, S15)	SMR 6, 5, (4)

General Comments: • Minimize disturbance of peat layer to avoid site damage
• Site can have moderate-to-high amounts of advance growth.

Recommendations: • This site has a high potential for direct seeding black spruce.
• Protect advance growth.
• Vegetation control will be required for those sites with high alder components.

Site Type	Site Description	V-Type	S-Type	Soil Moisture Regime
ST 11	Black Spruce / Labrador-tea	V25, 24, 22, 21	S17, S19, S18	SMR 7, (6, 8)

General Comments:
- Minimize disturbance of peat layer to avoid site damage.
- Site has a high amount of advance growth.

Recommendations:
- This site has an excellent potential for direct seeding black spruce.
- Protect advance growth with careful harvesting.

ST 12	Black Spruce / Speckled Alder	V21, 24, 20, 19	S17, S18, S19	SMR 7, (6, 8)

General Comments:
- Minimize disturbance of peat layer to avoid site damage.
- Site has a high amount of advance growth.

Recommendations:
- This site has an excellent potential for direct seeding black spruce.
- Protect advance growth with careful harvesting.
- Control alder competition.

ST 13	Conifer / Speckled Alder	V19, 21, 6, 20, 7, 22	S19, S18, S17	SMR 7, (6, 8)

General Comments:
- Minimize disturbance of peat layer to avoid site damage.
- High potential for site disturbance and elevated water table following harvest.
- Site has a moderate amount of advance growth.

Recommendations:
- This site has a moderate-to-high potential for direct seeding black spruce.
- Protect advance growth with careful harvesting.
- Vegetation control will be required.

4.0 THE SEED

Good quality seed is a prerequisite for direct seeding. An efficient and flexible seed procurement system should be in place to take advantage of good cone years when they occur – a cycle that averages three years for jack pine and four years for black spruce. Seeds from a particular locality within a seed zone should be used in areas as close as possible to their place of origin to ensure that the future stand is adapted to local ecological conditions

Aerial seeding requires large quantities of seed, dictating that bulk cone collections will remain the main source of seeds for the foreseeable future. However, surplus seeds from orchards and other improved sources may be available in the future for direct seeding, especially for methods such as row or spot seeding.

The majority of both black spruce and jack pine seed shipped from seed extraction plants in the province is slated for use in direct seeding programs (Figure 4.1).

For information regarding cone and seed characteristics refer to Appendix C.

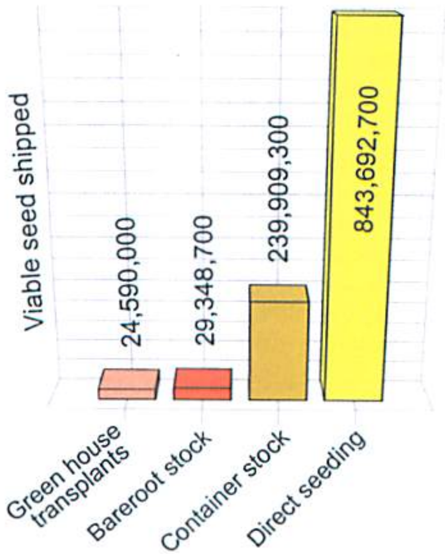


Figure 4.1 Typical amounts of viable seed shipped per year by the Ontario Tree Seed Plant for artificial regeneration programs *(Source: OTSP).*

4.1 How Are Cones Collected, Stored, and Shipped?

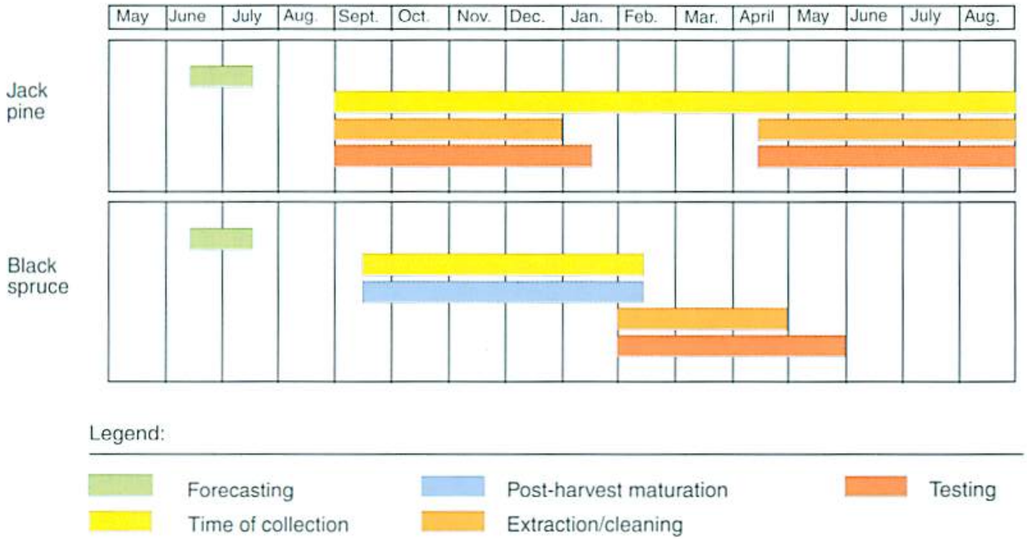
In preparation for cone collecting, the annual cone crop of the target species should be assessed for its volume and quality. By assessing the cone crop in advance, budgeting can be adjusted to allow for extra cone harvesting to take advantage of a good crop year. Forecasting the size of the cone crop can be done several weeks after flowering, when immature cones have formed in the crowns (Ontario Ministry of Natural Resources 1986a). For both jack pine and spruce, this occurs in the two week period from the last week in June to the first week in July (Figure 4.2). Early forecasting will provide ample time to organize for cone collecting in the fall and winter. Jack pine cones take two years to develop, so forecasts should be based on second year conelets.

We recommend that cones be collected only during good or bumper crop years, for both biological and economic reasons. The high volume of pollen ensures ample cross pollination and therefore a high degree of heterogeneity (genetic diversity) in the seeds. Seeds originating from bumper crop years generally have higher viability, vigour, and storage capacity.

Pest damage is proportionately reduced in above average cone crop years because of the high volume of cones, whereas during poorer cone crop years insects can destroy much of the crop. The cost per litre of collecting cones during good crop years is reduced because of the high cone concentrations.

For serotinous and semiserotinous species like jack pine and black spruce, respectively, cones may retain their seeds for several years, which allows for more flexible collection dates. Older cones (i.e., cones that are entirely grey) should be avoided because of reduced seed yields and seed viability. When collecting jack pine cones, look for large, straight cones with no evidence of insect damage (Figure 4.3). Current season cones should not be collected before the cones are mature, usually the first week of September.

General cone collections can be coordinated with black spruce and jack pine harvesting operations. By doing so, cone-laden tops are easily assembled and can be hand picked on site or moved to a central location for cone removal. Mechanical cone processing units can be a very cost-effective method of collecting large quantities of both black spruce and jack pine cones. Recent improvements to this technology have greatly reduced the amount of foreign material that is mixed in with cone shipments, but more development is needed to increase the safety and efficiency of mechanical cone processing.



Note: Collection period for jack pine refers to the current year's cones. Previous year's cones can be collected at any time.

Jack pine can be processed on a year round basis, however, the late winter months are usually set aside for the extraction and testing of other species.

Black spruce cones may retain seed for several years, which allows for more flexibility in collection dates.

Figure 4.2 Tree seed crop forecasting, collection, and processing summary for jack pine and black spruce *(Source: OMNR 1994)*.

Figure 4.3 A tray of both current year (brown) and recently mature (partially grey) jack pine cones ready for kiln drying *(photo courtesy Millson Forestry Ltd.)*.

All cone collections must be labelled with the seed source number (Appendix D), U.T.M. (universal transverse mercator) grid, elevation (m), date collected, number of hectolitres, and crop year. An example of how U.T.M. grids are used in seed collection records is given in Ontario Ministry of Natural Resources (1991). Proper identification ensures that seeds will be applied in the same seed zone that they were collected in.

The seed source number includes a field for site region or seed zone. Prior to 1996 seed sources were identified by site region. In 1996 a new seed zone system was adopted. Because seed that has been in storage prior to 1996 may be identified with the older version, both identification systems have been included in Appendix D. More recently, focal point seed zones have been developed for northwestern Ontario (Parker and van Neijenhuis 1996). If seed collections are properly tracked, focal point seed zones provide a good basis for managing seed deployment.

Black spruce cones collected up to the end of November should be shipped to a seed extraction plant on trays; if bagged, their high moisture content can cause overheating and moulding. Jack pine cones can be shipped to a processing centre on a year-round basis. Postharvest maturation is not required for either species, and cones can be processed without a waiting period. If cones must be stored before shipping they should be placed in a thin layer (<10 cm thick) under dry, cool, well-ventilated conditions to prevent overheating or moulding. This guideline especially applies to black spruce.

4.2 What Aspects of Seed Quality are Important in Direct Seeding?

4.2.1 Seed testing

Every seed lot should be tested to evaluate its quality and determine its field sowing values. The quality of a seed lot is a function of seed source, genetic make-up, flowering conditions, seed set, cone collection time, handling, and storage conditions. The principal characteristics for which seed lots are tested include: purity, weight, moisture content, viability, germinability, and vigour. Each of these characteristics influences how the seed will be used.

Seed testing is normally carried out by the seed extraction facility.

4.2.2 Seed storage

Seeds must be properly stored so that they remain viable until required for direct seeding. To store seeds properly:

- Ensure that the seeds are mature (fully ripe) prior to storage.
  Immature seeds have low initial viability and are liable to sustain further damage during seed processing resulting in shorter storage life.

- Reduce seed moisture content.
  Moisture contents of 4-6 percent for black spruce and 6-10 percent for jack pine are recommended. This will decrease the rate of seed respiration and reduce the utilization of food reserves.

- Store at constant low temperature.
  Store at temperatures of 1-3°C for black spruce and 1-5°C for jack pine. Avoid fluctuations outside this temperature range.

- Store in sealed containers
  Use glass or plastic bottles with screw tops, polyethylene bags or fiberboard drums. Avoid opening cold containers in warm atmosphere or leaving the containers unsealed for an extended period (Wang 1974).

Seeds of black spruce and jack pine can be stored for up to 20 years or longer if proper conditions for safe storage are used.

4.3 Do Methods Exist to Improve Seed Germination and Establishment?

4.3.1 Seed treatments

Currently, no form of seed treatment is used operationally in Ontario. However, seed treatments undertaken to enhance seed germination and seedling establishment have been successfully employed in agriculture for decades. Adaptation of these techniques for forestry application has met with some experimental success (e.g., natural and synthetic hormone pre-treatments designed to accelerate or delay the germination process, osmotic priming and micro nutrient pre-soaking as methods of embryo stimulation, inoculation with growth promoting rhizobacteria, and gel seeding with pre-germinated seed), but most have been either too difficult or too costly to apply operationally. Further development may allow seed treatments that have shown potential on an experimental scale to be used operationally (Figure 4.4).

Figure 4.4 Osmotic priming is an example of seed preconditioning that produces significantly faster and more uniform germination. This technique involves the soaking of seeds in an aqueous solution of polyethylene glycol (PEG) and distilled water.

4.3.2 Seed pelleting and encapsulation

Pelleting is the application of solid, inert materials to a single seed in sufficient quantity to embed the seed in a relatively uniform spherical shape. The objective is to improve handling and the accuracy of seed delivery (Figure 4.5). The ability to customize size and improve the seed's uniformity increases the potential for mechanical application, as well as providing a potential vehicle for the incorporation of additives designed to protect or enhance early seedling establishment. Laboratory trials have demonstrated that germination delays due to the coating process are directly related to the thickness of the coating and the type of coating medium used. Two common types of coating material used for conifer seeds are fine grain silica (<200 mesh) and diatomaceous earth. Silica coatings will break down readily when moistened, but may not be appropriate for some pneumatic seeders because of the tendency of the loosely held fine particles to become detached and cause excessive "dusting". This can lead to mechanical metering problems. Pellets made from diatomaceous earth hold together well even when vigorously handled. To prevent excessive germination delay, the diameter of pelleted seeds should be no greater than 3 mm for black spruce and 4 mm for jack pine.

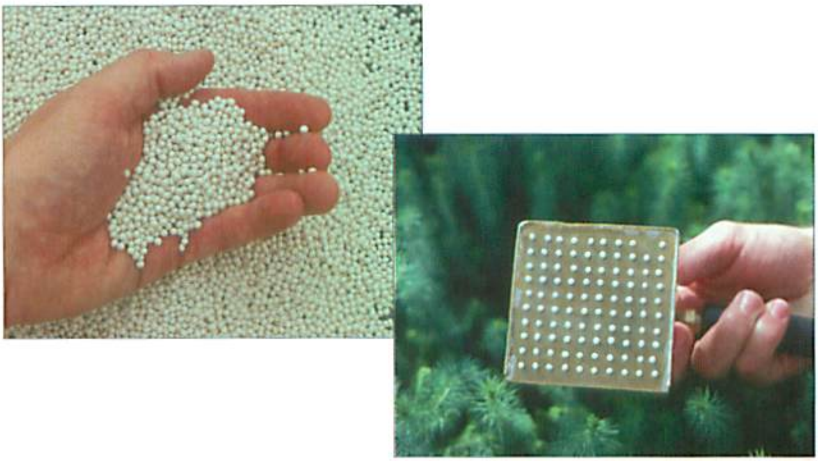


Figure 4.5 Pelleting or coating small conifer seeds can improve handling, metering and accuracy of seed delivery; as shown here with the aid of a vacuum plate seeder.

Encapsulation is the technique of enveloping single or multiple seeds in a composite mixture that is compressed or bonded into a wafer, plug or pill-like form (Figure 4.6). Both laboratory and field trials have shown that the compressed medium can act as a barrier to the emergence of embedded seeds, and can consequently cause a significant germination delay (Adams 1995; Buse 1992a). However, attaching seeds to the outside of compressed peat wafers using a water-soluble adhesive improves germination. Wafers or plugs can provide their own micro-site for initial seedling development, and can provide a carrier for additives.

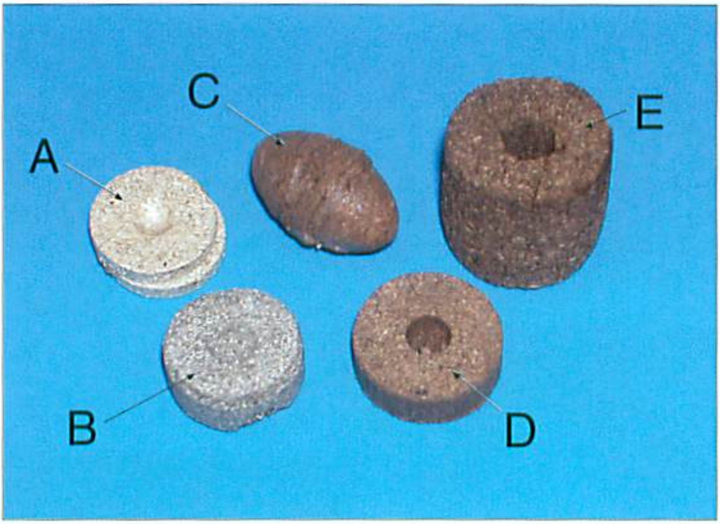


Figure 4.6 Examples of experimental seed encapsulation techniques used over the last decade: (A) the FMC wafer (a single seed in a semispherical cavity of a flat, round disk formed by cementing together two identical halves of compressed vermiculite), (B) University of Idaho seed tablet (multiple seeds embedded in a tablet composed of fine grade vermiculite and activated charcoal, bound by methylcellulose) (C) the Dupont "tree egg" (a blend of hydrophilic polymers, dried and pressed into a two gram, egg shaped pellet into which the desired number of seeds are embedded), (D) A Jiffy Products (N.B) Ltd., J-9 wafer (compressed peat that has been bitumized to hold the wafer together following saturation and expansion) and (E) a full imbibed J-9 wafer.

4.3.3 Protective coatings

As recently as the early 1970s, practically all seeds used for direct seeding in Ontario were coated with chemical repellents, ostensibly to minimize losses to insects, diseases, birds, and rodents. It was presumed that the absence of repellents would result in extensive seed predation. Concerns over the phytotoxicity of various repellents, tighter restrictions over the use of certain chemical formulations, and questions about the actual need and effectiveness of such measures lead to studies to elucidate the impact of small mammals (Figure 4.7) on direct seeding programs (Martell et al. 1995). It was determined that both black spruce and jack pine seeds were virtually absent from the summer diets of small mammals in northern Ontario, and losses due to predation are not considered to significantly affect the success of direct seeding operations. Currently, no protective treatments are used in direct seeding programs in Ontario.

Figure 4.7 Deer mouse (*Peromyscus*). Studies have shown that seed predation by rodents is not considered a significant threat to direct seeding programs.

5.0 HARVESTING CONSIDERATIONS

Forest harvesting practices can affect the success of subsequent direct seeding operations in several ways. On sensitive sites (peatlands and shallow-soiled sites), excessive disturbance by harvesting equipment reduces the area of receptive seedbed. Also, excessive slash can make it difficult to expose or create sufficient seedbed. Seed input from cones in slash, residual trees, and stand edges is strongly influenced by harvesting methods. Similarly, harvesting methods, to a large extent, will determine post-harvest advance growth quantities and will have a great impact on the composition and amount of vegetative competition.

5.1 Site Damage on Peatlands

The amount of receptive seedbed is reduced when harvesting machinery creates deep, water-filled ruts (Figure 5.1). Rutting also promotes the invasion of sedges, grasses, rushes, and cattails, all serious competitors to newly established seedlings. Rutting can also cause localized ponding by disrupting and blocking natural surface drainage patterns. This may temporarily or permanently reduce site productivity by raising the water level and reducing the rooting zone depth. The risk of frost heaving increases on black, humified peats and on fine-textured mineral soils that have been exposed during harvesting, usually as a result of skidding. Susceptibility to rutting is greatest on NEO FEC ST12 and ST13, moderate on ST9 and ST11, and least on ST8.

Figure 5.1 Site damage from harvesting machinery on a sensitive peatland site.

Prevent rutting damage by harvesting in the winter, after the frost has penetrated deeply into the ground, particularly on NEO FEC ST13 and ST12. If summer operations must be carried out on these sites, reduce damage by selecting appropriate harvesting equipment (e.g., high flotation tires, wide tracked fellers and clambunk skidders) (Figure 5.2) and operating techniques (e.g., a minimum number of skid trails), and by carefully planning road and skid trail layout. In northwestern Ontario FEC ecosites 34, 35, 36 and 37 (V-types 21-23 and 35-38) should be winter harvested to prevent severe degradation and to protect advance growth that is often abundant.

Brad Sutherland (FERIC)

Figure 5.2 The clambunk skidder; its articulated boom eliminates damage caused by lateral sweeping and larger load capacity results in fewer passes over the site.

RECOMMENDATIONS

- Unless harvesting is done in the frozen season, use low ground pressure (high flotation) equipment, which generally exerts <10 psi when loaded;
- Lay out logging roads so that *Alnus*-herb poor (ST12) and *Alnus*-herb rich (ST13) types are at the rear of the logging chance where they will sustain a minimum of machinery traffic.
- When STs 12 and 13 occur as drainage ways, orient skidways parallel to the drainage ways so that machinery does not have to cross them.
- NW-FEC ecosites 34, 35, 36 and 37 (V-types 21-23 and 35-38) should be winter harvested.
- Provide adequate training to equipment operators so they are able to recognize sensitive sites and take precautionary measures.

5.2 Site Damage on Uplands

On uplands, compaction, rutting and erosion can reduce the quantity and quality of seedbeds available for direct seeding. FEC information on soil depth and texture can be used to reduce logging damage by scheduling the harvest when impacts will be minimized, and by matching the equipment to the site.

On soils such as fine loams and clays (NWO FEC soil types S2, S3, S6, SS6, S4), which are susceptible to compaction, harvesting should be done in the dry season or in winter. More moist, poorly drained sites (S7, S8, S9, S10, SS8), are prone to compaction or rutting, and if possible should be harvested in winter. If harvested in summer, high flotation equipment should be used.

Thin soils overlying bedrock (SS1, SS2, SS3) (Figure 5.3), are quite fragile and highly sensitive to erosion. Dry, nutrient poor sites are also easily disturbed by summer logging and may be susceptible to humus destruction and nutrient losses.

Additional information on site damage can be found in: Forest Management Guidelines for the Physical Environment (Archibald et al. 1998), Silvicultural Guide to Managing for Black Spruce, Jack Pine and Aspen on Boreal Forest Ecosites *in* Ontario (OMNR 1997) and Forestry Practices Aimed at Maintaining Site Productivity *in* Long-Term Productivity of Boreal Forest Ecosystems (Kershaw et al. 1996).

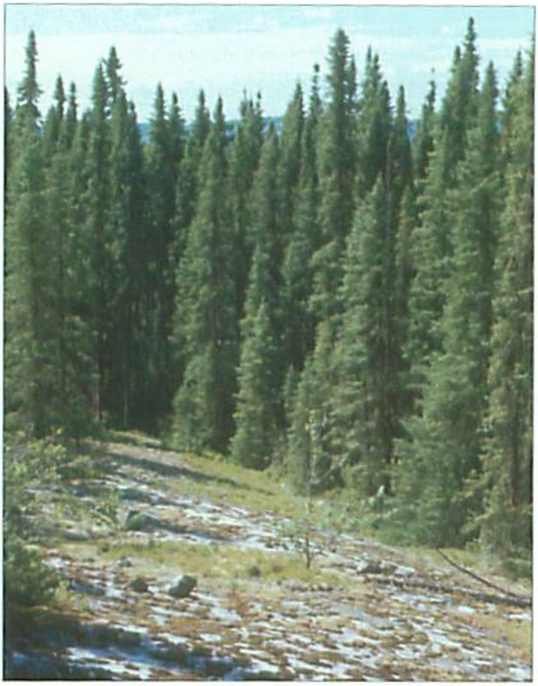


Figure 5.3 Very shallow soils over bedrock.

5.3 How Does Slash Affect Direct Seeding?

Heavy slash reduces the probability of success in direct seeding because it eliminates potential seedbeds. Dense accumulations of fine slash <5 cm in diameter pose the greatest impediment to direct seeding by covering receptive seedbed on lowland sites and preventing effective site preparation on upland sites. Tree-length or shortwood harvesting operations result in fine slash being distributed across the cutover at average volumes of 10.7 to 12.7 m^3/ha (Smith et al. 1985). Full-tree operations reduce fine slash cover on cutovers by about 40 percent. However, delimbing in full-tree operations usually concentrates slash along landings, and direct seeding will not be feasible on that part of the harvest area.

RECOMMENDATIONS

- Reduce the volume of slash by prescribing full-tree harvesting and slash disposal at roadside.
- Alternatively, prescribe tree-length or shortwood harvesting, followed by broadcast burning.

5.4 What Role Does Natural Regeneration Play in Combination With Direct Seeding?

Natural regeneration will often occur on harvest areas where direct seeding is being considered. Levels of natural regeneration should be anticipated and taken into account when developing direct seeding prescriptions. Direct seeding may be a particularly effective complement to planned natural regeneration methods if it can be used to increase regeneration on otherwise understocked portions of the harvest area. If the potential for natural regeneration is high, then it may be preferable to use planned natural regeneration instead of direct seeding to regenerate the area.

5.4.1 Natural regeneration of jack pine

Natural regeneration of jack pine commonly arises from cones in the logging slash, (Figure 5.4) and probably contributes to the regeneration of many direct seeded areas. Tree-length and shortwood systems leave greater post-harvest cone densities than full-tree systems (Figure 5.5). If the post-harvest cone distribution is patchy, then direct seeding may be used to increase stocking of areas that would otherwise be understocked. The recommendations for using the jack pine cone scattering method of regeneration should be followed to maximize the contribution of regeneration from cones (Boisvenue et al. 1994; Bowling and Goble 1994). Note that most seeds are released from cones during the first summer after harvest, so site preparation for direct seeding after this period may destroy some of the naturally regenerated seedlings.

For further information regarding factors which affect cone and seed supply and ingress of natural regeneration refer to Bowling and Niznowski (1991) and Bowling et al (1997).

Figure 5.4 Natural jack pine regeneration from cones in logging slash.

5.4.2 Natural regeneration of black spruce

Black spruce natural regeneration can arise from cones in the logging slash, from seeding-in by residual trees within or adjacent to the harvest area, or from advance regeneration.

5.4.2.1 Natural regeneration of black spruce from cones in logging slash

As with jack pine, large numbers of viable seeds are released from black spruce cone-bearing logging slash (Figure 5.6). If properly distributed throughout the cutover and elevated off the ground to prevent decomposition, these cones can make a substantial contribution to subsequent stocking levels. Most of the viable seed is released within the first year following harvesting (Fleming and Mossa 1996). The most rapid seed release originates from elevated cones above upland humus substrates. A reduction in the number of seeds released and a decline in the number of filled seeds from cones lying on or adjacent to the ground surface can be attributed to a higher cone moisture content and damage caused by pathogens and insects. The total viable seed release after harvest can range from 1–2 million viable seeds/ha.

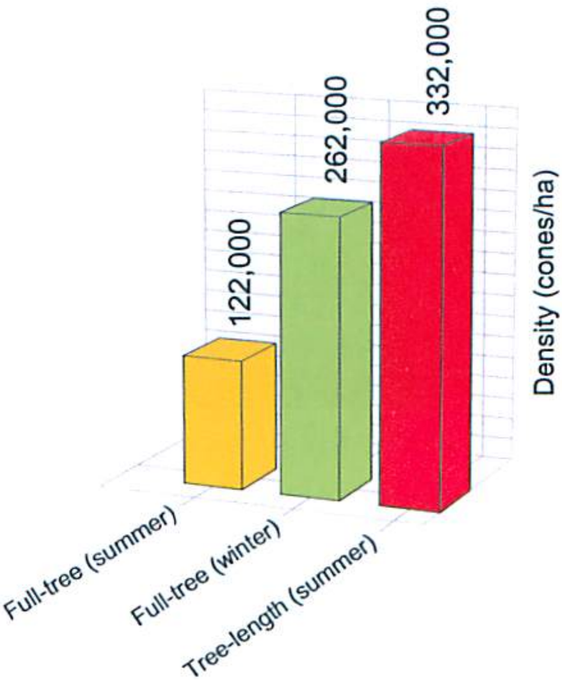


Figure 5.5 Post-harvest jack pine density *(adapted from Bowling and Goble 1994).*

Harvesting systems that leave cone-bearing tops on the cutover are best able to take advantage of this potential seed supply. Scarification should be conducted soon after harvest – delay will result in premature seed dispersal on unreceptive seedbeds. Unlike jack pine, black spruce cone scattering alone will not produce adequately stocked stands on upland sites and should only be used to augment artificial regeneration efforts.

Figure 5.6 Natural black spruce regeneration from cone-bearing logging slash.

5.4.2.2 Natural Regeneration of Black Spruce from Residual Trees

Portions of harvest areas that are within 60 m of residual black spruce stands will receive a substantial amount of seed. Any residual black spruce stems within the harvest area may also provide seed.

5.4.2.3 Natural Regeneration of Black Spruce from Advance Regeneration

Black spruce advance regeneration is common in many black spruce stands, especially in lower density stands on nutrient-poor peatlands (Figure 5.7). The recommendations for harvest methods to preserve advance regeneration should be followed to maximize the contribution of this source of regeneration (Archibald and Arnup 1993). If the distribution of advance regeneration after harvest is patchy then direct seeding can be used to improve stocking.

Stocking of advance growth declines as site conditions become richer or drier (Figure 5.8 and 5.9). Black spruce advance growth stocking levels greater than 40 percent are associated with STs/V-types that have high soil moisture and poor stand nutrient conditions. However, there is great variability in stocking values within these groupings.

Most advance growth mortality occurs within one growing season after harvest (Groot 1995) (Figure 5.10); assessments made after this time will provide a good indication of whether supplementary regeneration efforts will be required.

Figure 5.7 Typical post-harvest advance growth found on Site Type 11.

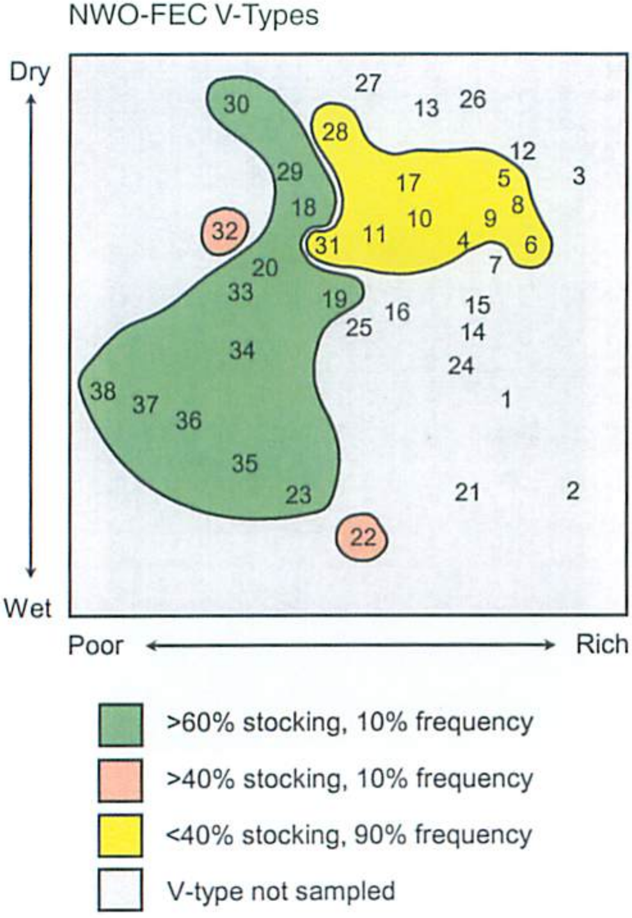


Figure 5.8 An FEC ordination diagram depicting the frequency occurrence of sampled V-types in various black spruce advance growth stocking classes in northwestern Ontario *(Sims and Walsh 1995).*

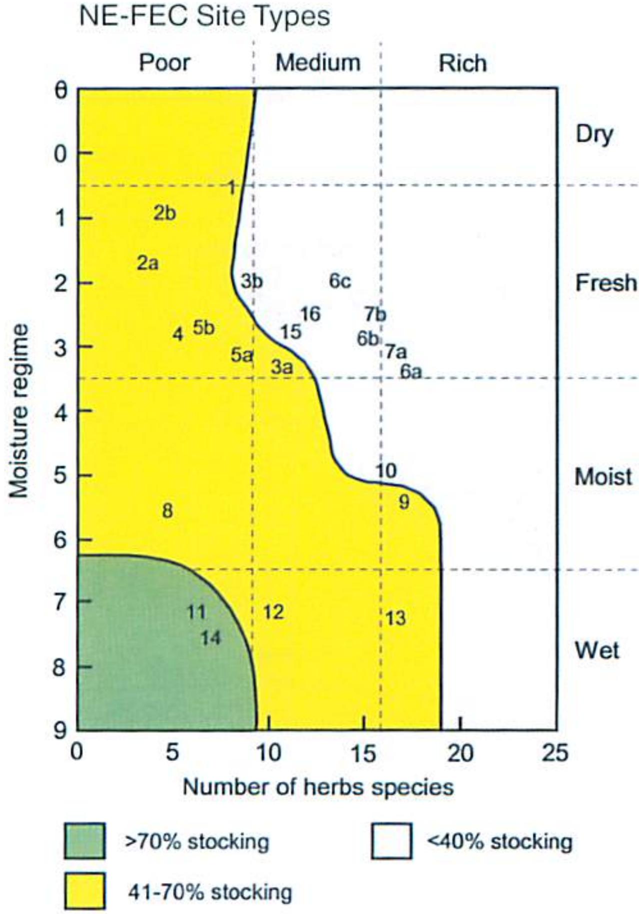


Figure 5.9 An FEC ordination diagram depicting the relationship between site type and abundance of black spruce advance growth by stocking class in northeastern Ontario *(Arnup 1996)*.

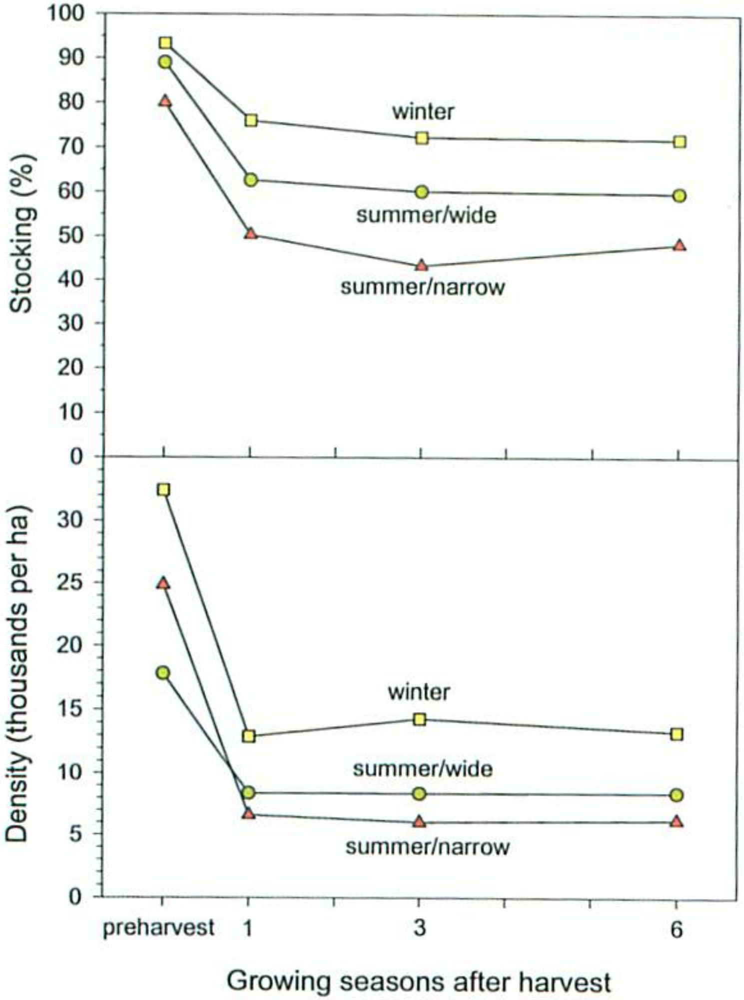


Figure 5.10 Stocking and density of black spruce advance growth before and after harvesting, using three methods *(Groot 1995)*.

6.0 SEEDBED SUITABILITY

6.1 What Makes a Seedbed Receptive?

A receptive seedbed provides conditions suitable for the germination of seeds and the early growth of seedlings. The receptivity of a seedbed depends on many factors, including seedbed type, soil texture, soil moisture regime (SMR), position within the soil horizon and weather conditions. A fundamental requirement for a receptive seedbed is that it provides sustained adequate moisture during the period of seedling establishment.

On uplands, exposed coarse loamy, and to a lesser extent, exposed fine sandy mineral soils are generally excellent seedbeds for spruce and pine because of the following characteristics:

- good capacity for aeration and water infiltration.
- good soil-seed contact for the transfer of moisture to the seed.
- good heat conducting capacity – therefore they warm faster than organic soils.
- they harbour fewer harmful micro-organisms than do organic soils.
- they have substantial water storage capacities and allow good capillary movement of water from the underlying soil matrix.

Seedbeds generally become less receptive as the thickness of organic matter of soil increases, and as the decomposition status of organic matter decreases, because thicker, less decomposed organic material is prone to surface drying. Black spruce is more sensitive than jack pine to these organic matter characteristics.

Although peatlands usually have a shallow water table, seed germination still requires a relatively moist surface. The following conditions provide appropriate moisture levels:

- a predominance of *Sphagnum* moss species, *Sphagnum* peat, sheared *Sphagnum*, or decayed wood.
- an un-disrupted seedbed, whereby the underlying water level can provide continuous moisture to the surface.

Frost heaving can be a serious problem on fine textured mineral soils, such as clays, silts, silty loams, on rotten wood, and deep humic materials. The danger of frost heaving may be reduced, however, if mineral soil is covered by a layer of organic matter (e.g., dead leaves or grasses), because of its insulating effect on the soil. On peatland sites, well decomposed organic peats (black muck) exposed by disturbances are particularly prone to frost heaving because of their colloidal nature and water holding capacity.

6.2 How is Receptivity Determined?

Seedbed receptivity can be measured by the establishment ratio (ER) – the number of established seedlings per viable seeds sown (e.g., two established seedlings out of five viable seeds sown gives an ER of 40%).

Establishment ratios for a given seedbed type are most reliably obtained by monitoring seed spots (See Section 11). ER values for the most common seedbed types are given in the seedbed data sheets (SDS) presented in this chapter.

6.3 How do Seedbeds Change with Time?

The quality of seedbeds changes with time because of soil movement, weathering, litter accumulation and the ingress of vegetation. Changes in seedbed quality begin within a year of site preparation, but are most noticeable three-to-five-years afterwards, especially on the drier upland sites.

On uplands, heavy rainfall can wash mineral soil into depressions and bury seeds. Large seeds, such as the pines, can germinate at depths of up to 7.5 cm, but smaller seeds such as black spruce can tolerate little more than 1 cm of soil coverage (Arnott 1973). Mechanical erosion of recently scarified seedbeds following heavy rains, independent of the degree of slope, may account for 20% of seed losses due to the smothering of seeds by debris. This may be mitigated by delaying seed application until after initial weathering of the site preparation has occurred.

Weathering refers to physical or chemical changes induced by environmental conditions. For example, crusts, which are sometimes observed to develop on exposed soil surfaces, are thought to decrease receptivity. Another example of weathering is the breakdown of surface organic layers. Thinner, more decomposed layers (e.g., H horizon) are most susceptible to this breakdown.

The cover of shrubs, herbs and grasses often increases rapidly following forest harvesting. This vegetation cover, and the litter that it produces, commonly decreases the cover of receptive seedbed types. The development of lichen mats (*Cladonia* and *Cladina* spp.) also reduces seedbed receptivity.

Pioneer mosses (e.g., *Polytrichum* spp. and *Dicranum* spp.) invade seedbeds about 2 years after site preparation, and are most prevalent on moister sites that lack heavy grass competition. These mosses make good seedbeds initially, because of their slow growth and minimal competition for light and moisture. Three or four years after their establishment, however, the height growth of some species can prevent further black spruce ingress.

On peatland sites, the tendency is to increasing cover of living *Sphagnum* mosses. This can be positive if this seedbed replaces a poor seedbed, but often the more receptive *Sphagnum* peat is also covered over.

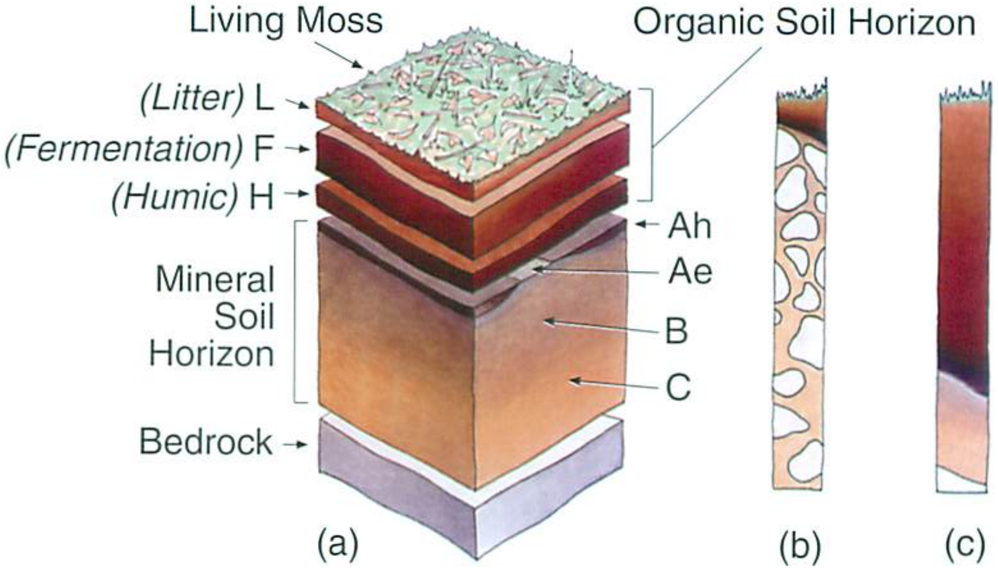


Figure 6.1 (a) A typical undisturbed upland forest soil profile common to northern Ontario. (b) very shallow soil on boulder pavement (c) peaty phase (mineral) soil profile.

6.4 What Establishment Ratios can be Expected?

6.4.1 Black spruce uplands

Black spruce establishment ratios are strongly affected by the position of the seedbed in the original soil profile. A typical undisturbed deep upland soil profile (Figure 6.1a) comprises the following layers, going from the organic matter surface downwards to the mineral soil: the litter layer (L), the fermentation layer (F), the humus layer (H), the upper mineral soil horizons (Ah, Ae and B) and the lower mineral soil horizon (C). The depth and structure of minerals soils can be highly variable ranging from very shallow to peaty phase (mineral) soils (Figure 6.1b & c). A certain amount of variability can exist even within a seeding block. Site specific site preparation equipment and operator awareness and flexibility will assist in achieving the prescribed seedbed exposure.

On coarse-textured tills, spruce seedlings establish mainly on thin F, thin H, and upper mineral soil horizons (<10 cm below the mineral soil/humus interface). On all sites, ERs are significantly greater on seedbeds near the mineral soil/humus interface than on seedbeds located at or just below the forest floor surface (Fleming and Mossa 1995a). Some types of site preparation equipment produce inverted surface horizons with a mineral soil cap; if this cap is thin, these mounds are little better than litter or thick F (>5 cm thick) seedbeds. On drier soils, results are best on upper mineral soil horizon seedbeds (<10 cm mineral soil removed), but on moist to very moist soils, thin F seedbeds have the best results. Lower mineral soil horizon seedbeds (>10 cm mineral soil removed) give poorer results than do seedbeds located just above or below the mineral soil/humus interface.

Differences between establishment ratios at the mineral soil/humus interface and on undisturbed ground surfaces are smallest on moist to very moist soils, and greatest on very fresh to moderately moist soils. Thus, good quality site preparation that exposes much receptive seedbed area will be most advantageous on very fresh to moderately moist soils.

Establishment ratios are poorer for all seedbed types on the more coarse-textured soils (sands and loamy sands) and very shallow soils (SS3) where soil moisture is the limiting factor. Because of slow initial root development, black spruce establishment on these site types is generally unsuccessful.

The highest ERs on coarse-textured soils are often found on thin H or upper mineral soil horizon seedbeds with very fresh to moderately moist soils. Near-

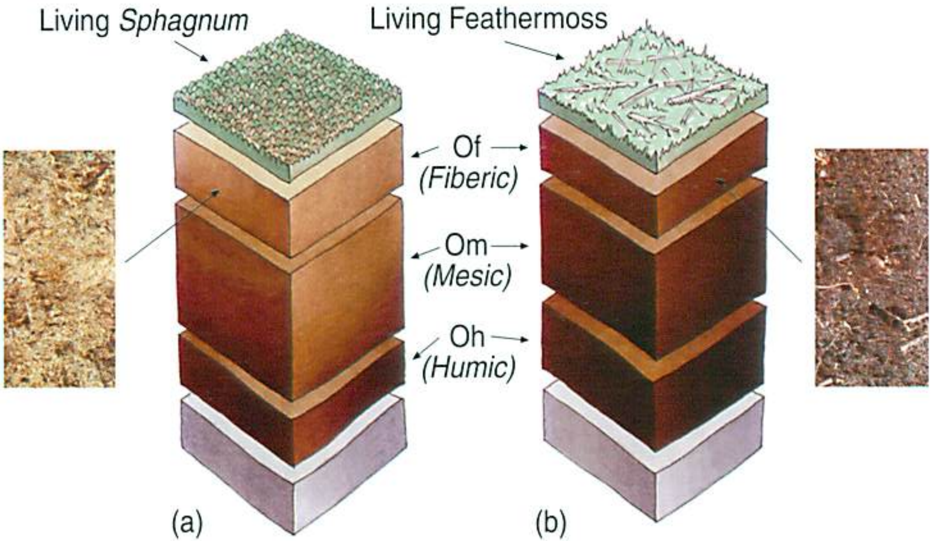


Figure 6.2 Two typical undisturbed peatland soil profiles showing the various humus types and their relative position within the soil horizon; a) represents a soil profile that has developed from *Sphagnum* while b) has developed from feathermoss. Note the humus layers that originate from *Sphagnum* are lighter in colour.

surface moisture levels are adequate, but spring and fall soil moisture content is not so high that it causes extensive frost heaving. On finer textured soils, high soil moisture content reduces soil aeration and can result in flooding, which is why the best seedbeds are found closer to the soil surface, usually on the thin H and F layer.

For many seedbeds ERs vary considerably among seeding years, probably a reflection of variation in weather. However, the relative rankings of different seedbeds on a particular site are usually similar from year to year.

6.4.2 Black spruce lowlands

Establishment ratios on lowland sites are generally greatest on poorly decomposed *Sphagnum* peat seedbeds exposed during the harvesting operation or following site preparation. The average 5th year ER for this seedbed is about 40%. Black spruce establishment ratios diminish throughout the first 5 year period on almost all lowland seedbed types, but declines are most marked on well-decomposed organic matter and pioneer mosses, followed by rotten wood and living *Sphagnum* seedbeds (Groot and Adams 1994). Frost heaving, erosion, and aggressive *Sphagnum* encroachment are the main causes for these declines.

Figure 6.2 illustrates two typical undisturbed peatland soil profiles depicting the various humus types and their relative position within the soil horizon. Of *(fibric)*, Om *(mesic)* and Oh *(humic)* are organic horizons developed mainly from mosses, rushes and woody material and are generally defined by their degree of decomposition. For field testing procedures refer to the Von Post Scale of Decomposition *in* Field Manual for Describing Soils (Ontario Institute of Pedology 1985).

6.4.3 Jack pine sites

Establishment ratios for jack pine are strongly related to the availability of sufficient moisture to support both germination and growth until the new germinant has produced root growth adequate to access permanent soil moisture. Substrates that maintain available near surface moisture between rainfall events tend to be better substrates for establishing jack pine. On ecosites suitable for seeding jack pine, exposed mineral soil generally meets this requirement: surfaces dry rapidly providing a thin mineral soil mulch that delays drying of the underlying substrate. Similarly, thin H and/or FH horizons tend to mitigate the drying of underlying mineral soil. On organic layers of increasing thickness jack pine can establish as soil moisture regime increases from moderately fresh to moderately moist. Both length and frequency of droughts during germination and the 40 to 60 day period following germination increases mortality on any substrate. Growth of the established seedling must also be considered; maximum seedling heights following three growing seasons generally occurs on or adjacent (within a few cm) to organic substrates over mineral soil. Conversely, while establishment may be consistently high on exposed lower mineral soil horizons, 3-year height growth tends to be relatively suppressed.

6.4.4 Prescribed burns

6.4.4.1 Black spruce

Prescribed fire plays a minor role in regenerating black spruce, although it can be effective (Archibald and Baker 1989). Desirable seedbed is exposed through the consumption of slash and reduction of the organic mat, which directly relates to the intensity of the burn. Site type, available fuels and ignition pattern have an effect not only on the amount of seedbed exposure but also on competition response.

Expect ER values to be very low on feathermoss-dominated sites[1] if the burn is not sufficiently intense to eliminate both L and F horizons and to expose the underlying well-decomposed humus layer. In contrast, a light intensity burn with little duff removal on *Sphagnum*-rich sites[2] will temporarily retard *Sphagnum* growth and provide excellent conditions for black spruce establishment. Alder-dominated sites[3] can be problematic: too deep a burn can lead to an increase in shrub and graminoid competition, while a low depth-of-burn may promote vegetative suckering (Aksamit 1982). Application of herbicide prior to ignition can help to dry the vegetation and allows a moderate-to-deep burn to be conducted under lower indices (Elliott 1988). This type of burn will result in the creation of receptive seedbeds with little initial competition response.

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1 NWO FEC V-types 20, 31, 33 and 34; NE FEC V-types 18, 22 and 23.

2 NWO FEC V-types 37 and 38; NE FEC V-types 25 and 26.

3 NWO FEC V-type 35; NE FEC V-types 21 and 24

Establishment ratios on burned upland spruce sites are highly variable. Avoid seeding on coarse textured soils where the usually thin organic layers are completely consumed (Viro 1974); drought and lethal temperatures will limit survival. A mosaic of exposed mineral soil and thin (< 5 cm) of humus over mineral soil offers the best seeding chance.

6.4.4.2 Jack pine

At first glance, a fresh burn appears as a uniform blackened surface of ash and char over organic matter and/or mineral soil and/or rock. Despite this apparent uniformity, there is considerable variation in the type and depth of the organic layer, in the depth and texture of mineral soil and in moisture regime and drainage. These characteristics all affect jack pine seedling establishment ratios.

For shallow to deep mineral soils (>15 cm depth to bedrock), establishment ratios are greater than 10% on thin (<1 cm) organic layers. On very shallow mineral soils (<15 cm depth to bedrock), however, establishment ratios are low on thin organic layers. Establishment ratios are generally greater on moderately fresh to moderately moist moisture regimes than on drier conditions. Establishment ratios are near 0 on bedrock or boulder surfaces and on wetland inclusions; these substrates should be considered non-receptive.

6.5 How are Seedbed Types Identified and Defined?

A series of seedbed data sheets (SDS) has been developed to identify, describe, and characterize seedbed types. The SDSs are divided into three main categories; black spruce lowland seedbeds, black spruce upland seedbeds and jack pine seedbeds. These are further subdivided by type of site preparation used to create the seedbed – by either mechanical means or by prescribed fire (refer to the SDS Index on page 76). The SDSs represent the more commons seedbed types found in these categories and will also include associated undisturbed seedbeds. A similar presentation format is used for spruce upland and lowland categories, based on fifth year seed spot data collected over several years from a variety of site types (Groot and Adams 1994; Fleming and Mossa 1994, 1995b).

Because there have been no comprehensive studies examining the range of jack pine seedbeds, the jack pine SDSs are based on operational trials and some research studies (Sims 1970; Winston and Schneider 1977; Winston 1980). Experience-based estimates of ERs are provided for jack pine seedbeds that have not been examined in trials or studies.

Establishment ratios for black spruce on prescribed burns are based on fifth year seed spot data collected from three prescribed burn seeding trials located in northeastern Ontario (Adams 1993).

SDSs for jack pine seedbeds on prescribed burns were developed using third year data from three experimental trials conducted in northeastern Ontario (Foreman 1997). Substrate material, substrate thickness and local soil moisture regime were all used to characterize seedbeds in these trials. Two of the three establishment years experienced lower than normal rainfall over the critical germination-establishment season, which may help to explain the range in standard deviation.

These data sheets can be used at various stages of decision making:

- Pre-site preparation stage: to assist in determining the target seedbed types to be created by site preparation.
- Post-site preparation stage: used by the assessment crews to accurately identify the type and quantity of available seedbeds.
- Seeding prescription stage: the SDSs provide the mean receptivity value for input into PC-SEED (Section 9).

6.5.1 Description of the seedbed data sheets

Figure 6.3 describes the layout of the seedbed data sheets. The banner at the top of the page identifies the seedbed type and assigns it a number [1]. This banner is colour coded for mechanically site prepared (MSP) black spruce lowland sites (pink), MSP black spruce upland sites (blue), prescribed burned black spruce upland and transitional sites (yellow), MSP jack pine sites (green) and prescribed burned jack pine sites (brown). The layout for individual (MSP) black spruce and jack pine seedbed types have a similar format which includes: single or multiple photographs depicting the physical attributes of the seedbed [2]; a brief description of the seedbed [3]; an illustration representing the relative location of the seedbed within a soil profile [4]; graphs indicating the change in establishment ratios with time and the relationship between stocking and the number of seeds sown [5]. ER values [6] are placed on a modified Soil Moisture Regime scale [7]. Lines extending above and below the circle [8] represent the standard deviation of the mean. The grey-shaded area [9], which extends to the left and right of the circle, represents the range of soil moisture regimes covered by that particular data set.

The SDS layout for prescribed burn seedbeds may vary somewhat from this format. However, all SDSs share the same purpose; to help identify seedbed types and to supply an estimated receptivity value and standard deviation.

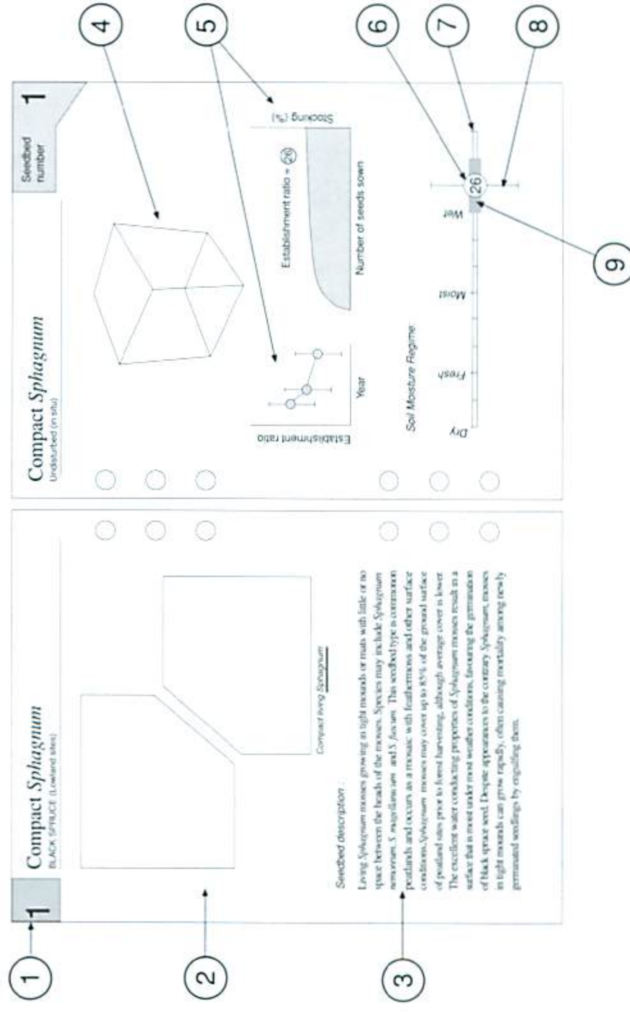


Figure 6.3 Seedbed data sheet layout.

6.5.2 Seedbed Data Sheet (SDS) Index

Seedbed Numbers 1 to 8	BLACK SPRUCE on lowland site types • *mechanical site preparation*
Seedbed Numbers 9 to 16	BLACK SPRUCE on upland site types • *mechanical site preparation*
Seedbed Numbers 17 to 22	BLACK SPRUCE on upland and transitional site types • *site prepared by prescribed burning*
Seedbed Numbers 23 to 31	JACK PINE on deep-to-shallow mineral soils • *mechanical site preparation*
Seedbed Numbers 32 to 35	JACK PINE on deep-to-shallow mineral soils • *site prepared by prescribed burning*

Black Spruce Seedbeds

Lowland Seedbed Types

Upland Seedbed Types

Prescribed Burn Seedbeds

1

Compact Sphagnum

BLACK SPRUCE (Lowland Sites)

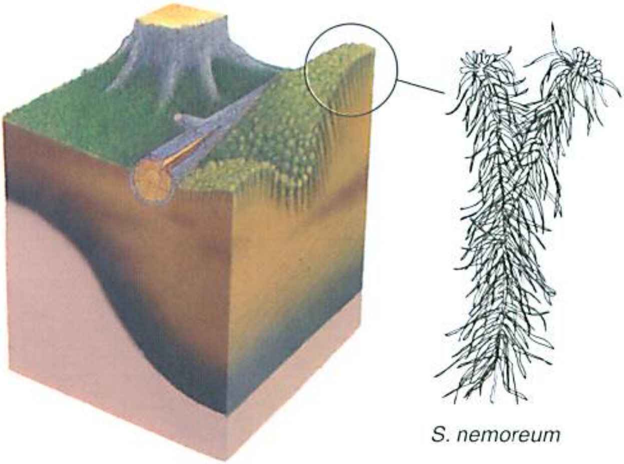
Compact living Sphagnum

Seedbed Description:

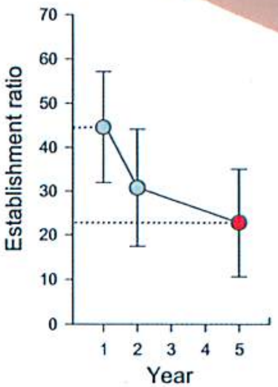
Living *Sphagnum* mosses growing in tight mounds or mats with little or no space between the heads of the mosses. Species may include *Sphagnum nemoreum, S. magellanicum* and *S. fuscum.* This seedbed type is common on peatlands and occurs as a mosaic with feather-mosses and other surface conditions. *Sphagnum* mosses may cover up to 85% of the ground surface of peatland sites prior to forest harvesting, although average cover is lower. The excellent water conducting properties of *Sphagnum* mosses result in a surface that is moist under most weather conditions, favouring the germination of black spruce seed. Despite appearances to the contrary, *Sphagnum* mosses in tight mounds can grow rapidly, often causing mortality among newly germinated seedlings by engulfing them.

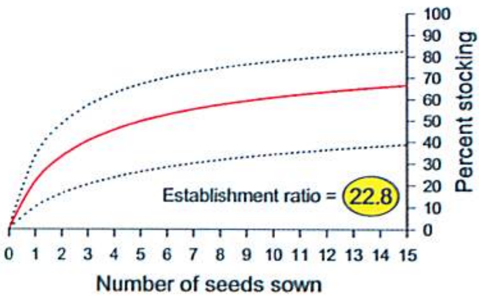
Compact Sphagnum
Undisturbed (in situ)

Seedbed Number 1



S. nemoreum





Soil Moisture Regime

Establishment ratio | Standard deviation | Range

Loose Sphagnum

BLACK SPRUCE (Lowland Sites)

Loose Sphagnum (under shade)

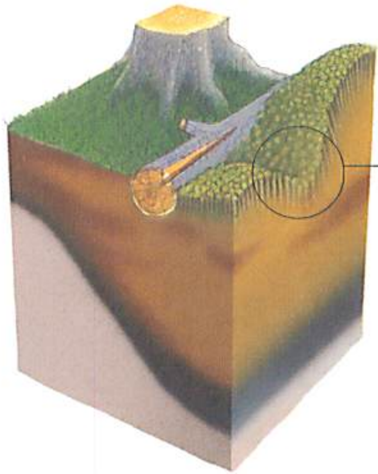
Loose Sphagnum (under full sun)

Seedbed Description:

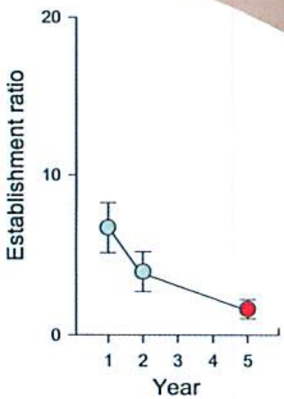
Living *Sphagnum* mosses growing in loose mounds or mats with large gaps between the heads of the mosses. Species may include *Sphagnum girgensohnii* and *S. angustifolium*. The loose growth habit is less common than the compact habit, particularly in the open after harvesting. This seedbed is not favourable for seedling establishment because of the likelihood of seeds falling into the gaps between the heads of the mosses. Even if seeds germinate further down among the moss stems, they have little chance of growing above the surface of the mosses.

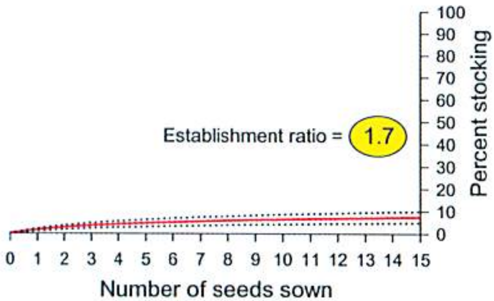
Loose Sphagnum
Undisturbed (in situ)

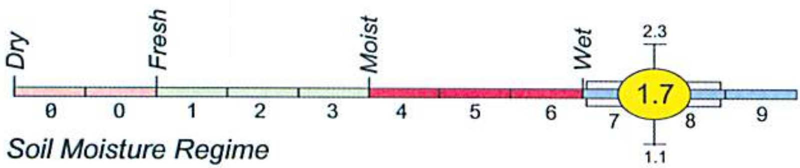
Seedbed Number **2**



S. girgensohnii







Living feathermoss

BLACK SPRUCE (Lowland Sites)

Pleurozium schreberi (under shade)

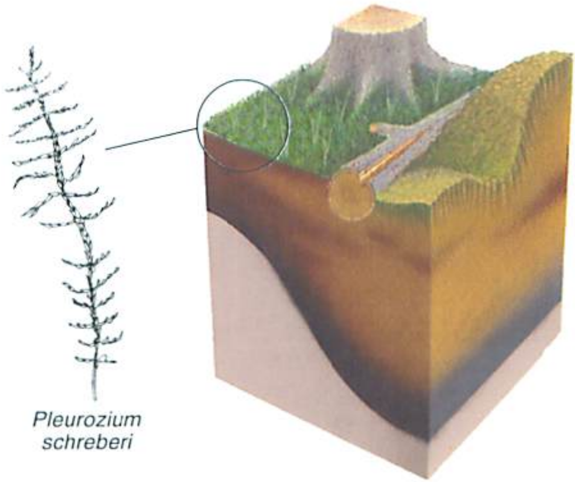
Pleurozium schreberi (under full sun)

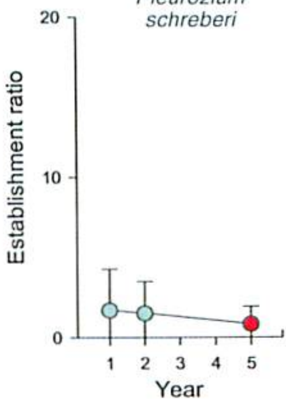
Seedbed Description:

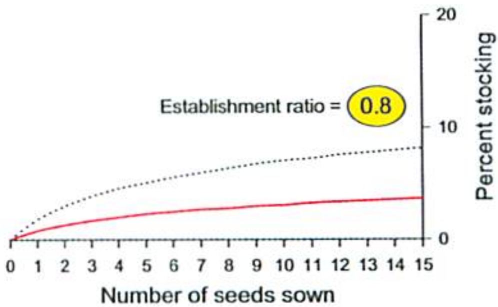
Living feathermosses (*Pleurozium schreberi, Ptilium crista-castrensis, Hylocomium splendens and Dicranum spp.)* growing in mats. This seedbed type is common on a wide range of jack pine and black spruce site types. Cover values can exceed 50% on upland sites, and can be as high as 70% on peatlands. Because feathermosses dry very rapidly after rainfall, they are highly unfavourable for seedling establishment. High mortality of feathermosses is common on removal of the overstory.

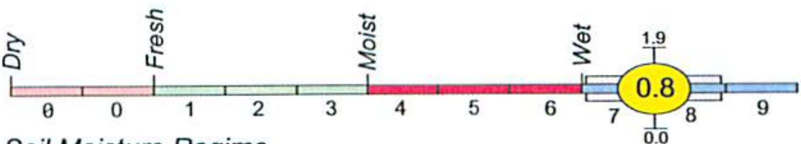
Living feathermoss

Undisturbed (in situ)









Soil Moisture Regime

Establishment ratio — Standard deviation — Range

4 *Poorly decomposed Sphagnum peat*

BLACK SPRUCE (Lowland Sites)

Poorly decomposed Sphagnum peat

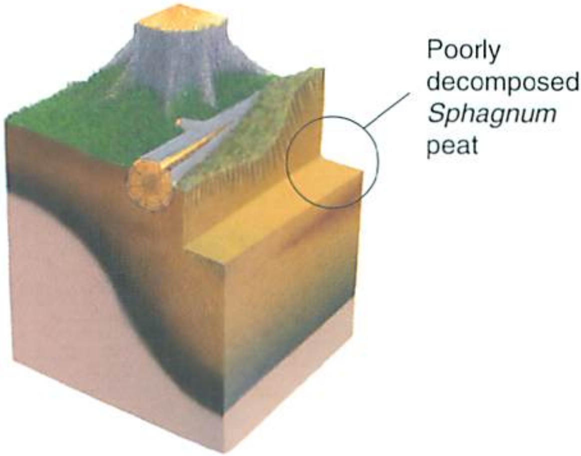
Seedbed Description:

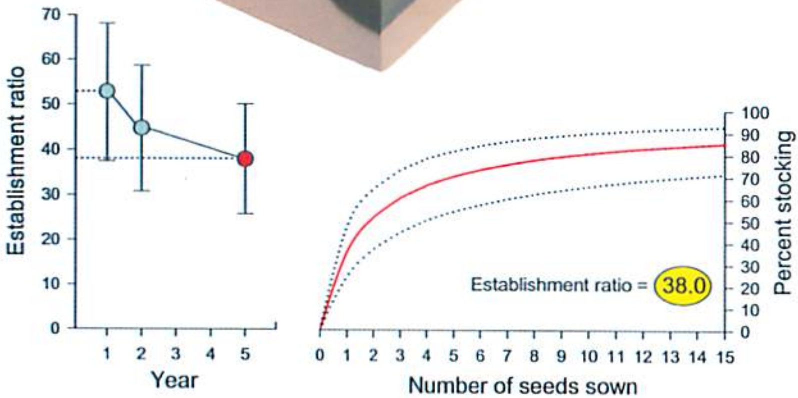
Stems and foliage of *Sphagnum* mosses in the initial stages of decomposition. Much of the original structure of the mosses is still evident in this seedbed, and colour ranges from a pale straw colour to yellowish-brown. This seedbed can be produced by removing the living portions of *Sphagnum* mosses by winter shearblading, prescribed fire or by the scraping action of harvesting equipment and skidded trees. Black spruce establishes very well on this seedbed, because the water-supplying characteristics of *Sphagnum* cells maintain a moist surface and competition by living mosses has been eliminated. *Sphagnum* peat is a nutrient-poor medium, however, and seedling growth can be slow on this material.

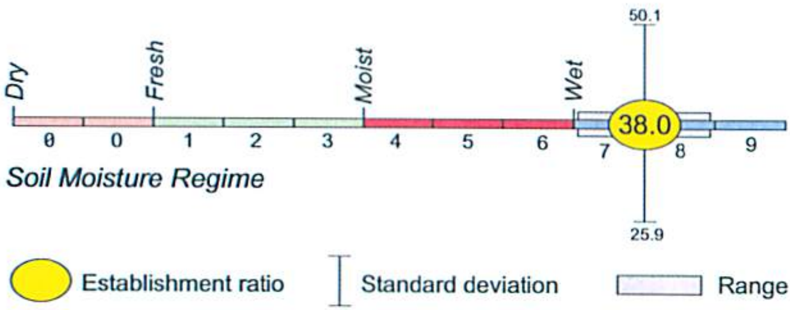
Poorly decomposed Sphagnum peat

Exposed following mechanical site preparation

Seedbed Number 4







5

Poorly decomposed feathermoss peat

BLACK SPRUCE (Lowland Sites)

A thin layer of poorly decomposed feathermoss peat over a well-decomposed feather-moss layer.

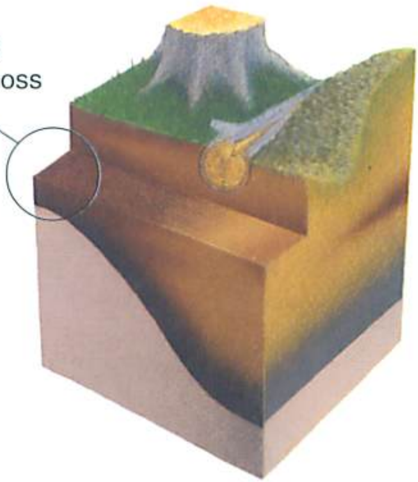
Seedbed Description:

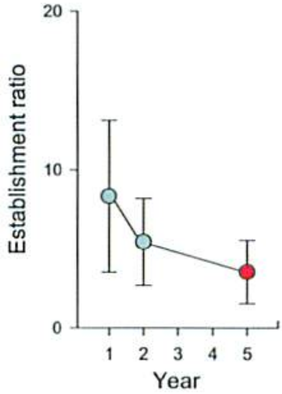
Stems and foliage of feathermosses in the initial stages of decomposition. Some of the original structure of the mosses is still evident in this seedbed, and colour ranges from a light brown to brownish-black. This seedbed can be produced by removing the surface layer of feathermosses by mechanical site preparation, prescribed fire or harvesting disturbance. Seedling establishment is poor on this seedbed, because the surface layer dries very rapidly after rainfall. Establishment improves if only thin layers of this seedbed occur over mineral soil, better decomposed organic matter or *Sphagnum* peat.

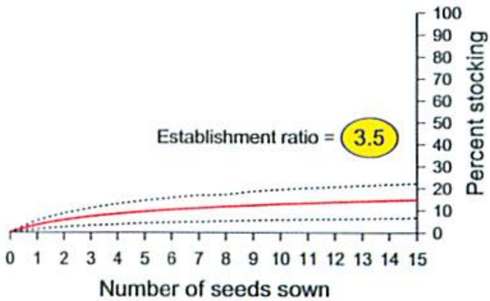
Poorly decomposed feathermoss peat

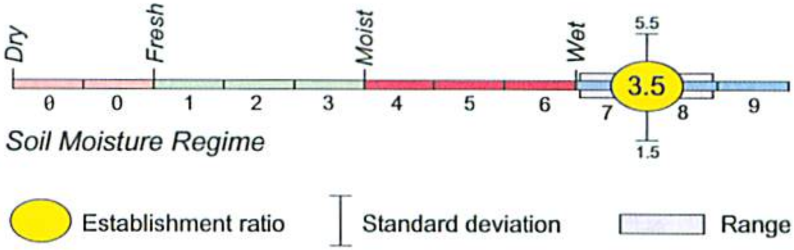
Exposed following mechanical site preparation

Seedbed Number 5









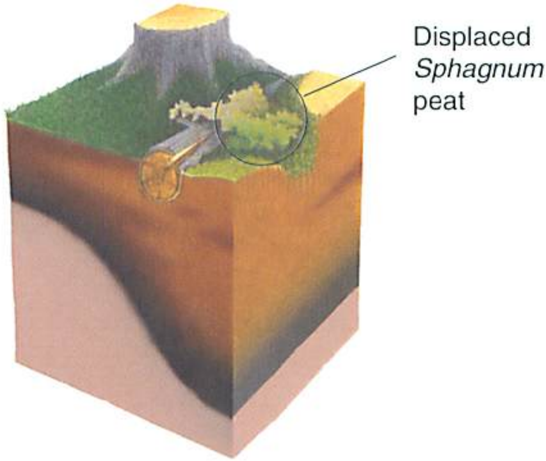
Displaced Sphagnum peat

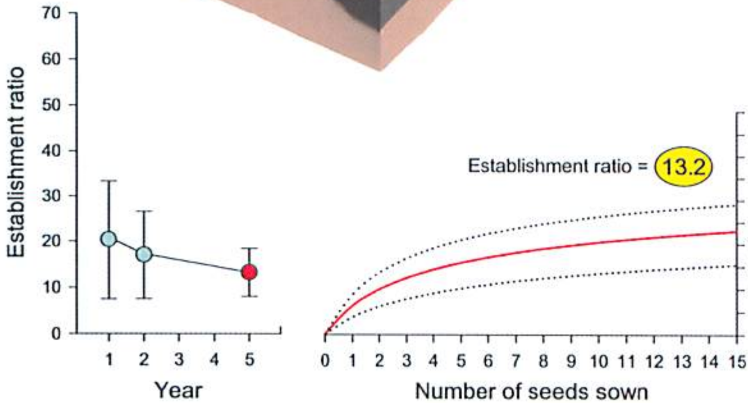
Seedbed Description:

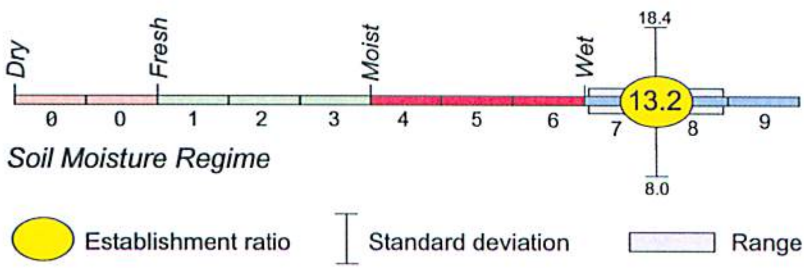
On peatland types, winter shearblading, or more rarely, harvesting disturbance, can detach chunks of *Sphagnum* peat and deposit them on the soil surface. The suitability of this material for seedling establishment depends upon the size of the chunk and the degree of contact with the underlying peat soil. Larger chunks have greater moisture reserves and dry less quickly. If the chunk rests on slash, it will dry because moisture cannot be absorbed from the soil. In general, seedling establishment is poorer on this material than on *Sphagnum* peat in situ.

Displaced Sphagnum peat

Exposed following mechanical site preparation







Moderately to well-decomposed organic matter

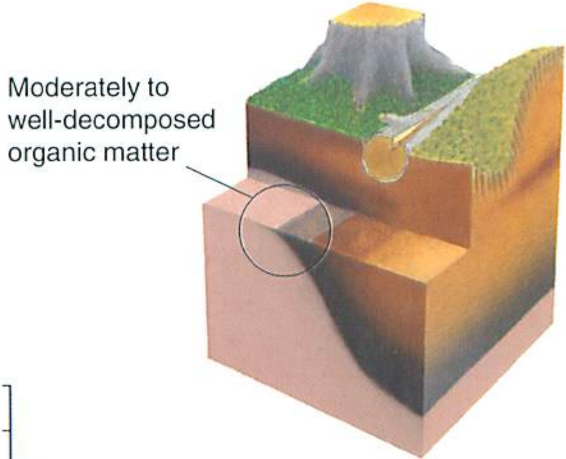
Seedbed Description:

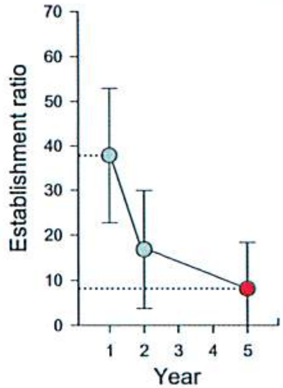
On peatland types, disturbance by harvesting or site preparation equipment can expose better-decomposed layers of peat. This substrate is dark brown or black in colour when wet, and originates from the Oh or Om layers. Proximity to the water table and fine texture maintain a constant supply of moisture at the surface of this seedbed, promoting seed germination. High mortality is usual, however, because of flooding, frost-heaving, erosion and competition from other vegetation, especially grasses and sedges, which often establish aggressively on this material.

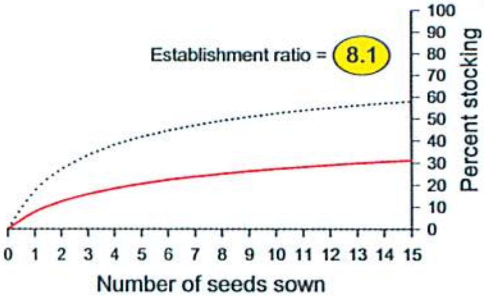
Moderately to well-decomposed organic matter

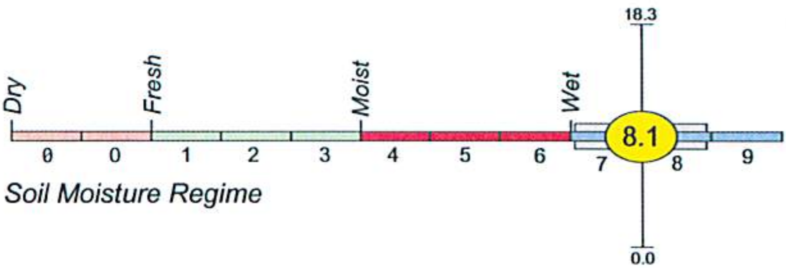
Exposed following mechanical site preparation

Seedbed Number 7









Establishment ratio — Standard deviation — Range

8 *Moderately to well-decomposed wood fiber*

BLACK SPRUCE (Lowland Sites)

Moderately to well-decomposed wood fibre

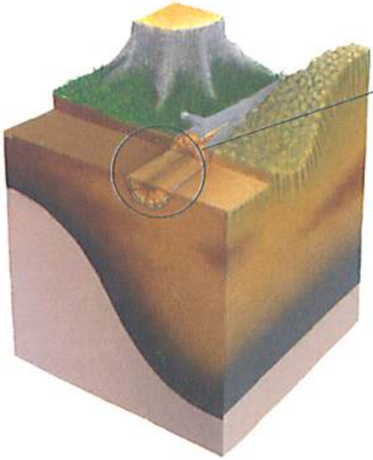
Seedbed Description:

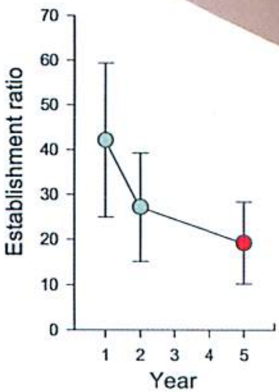
Partially decomposed stumps and fallen logs are present on most forest floors. In the initial stages of decay, the wood becomes somewhat spongy and it is possible to rub off some fibres. With more advanced decay, wood develops a buttery consistency. Rotten wood has good moisture-retaining characteristics and permits good seed germination. Significant mortality usually occurs, however, because of frost-heaving, and, on well-decomposed wood, erosion.

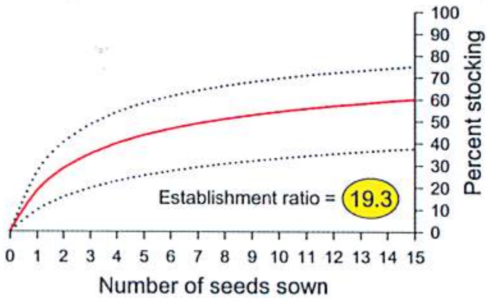
Moderately to well-decomposed wood fiber

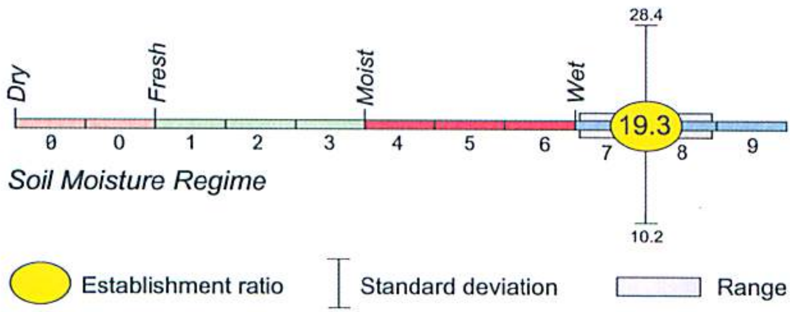
Exposed following mechanical site preparation

Seedbed Number **8**









Litter: Undecomposed organic matter
BLACK SPRUCE (Upland Sites)

Surface litter

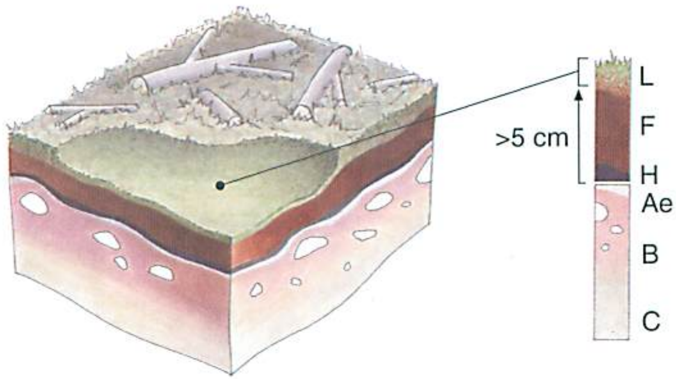
Sub-surface L horizon

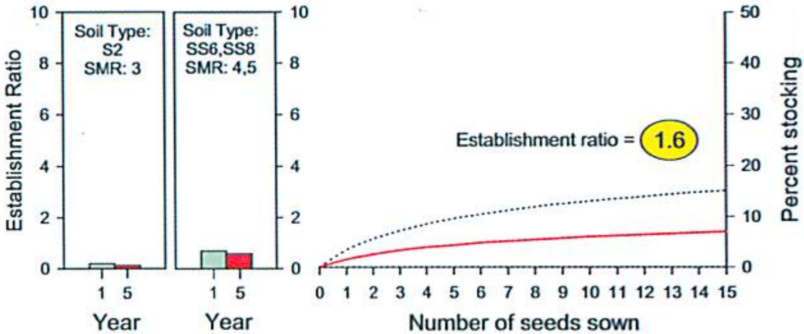
Seedbed Description:

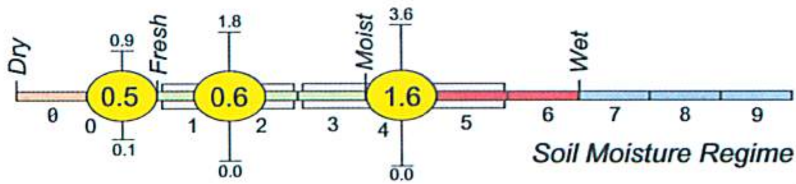
This material forms the L horizon of upland forest soils, the uppermost layer of the forest floor. There are many varieties of litter seedbeds, depending on vegetation and soil characteristics, but all are characterized by an accumulation of leaves, needles, twigs and woody materials. Most of the original structures are easily discernible. It forms the substrate for feathermoss growth in the understory of developing stands. Following clearcutting, these seedbeds are characterized by extreme temperatures and lack of available water.

Litter

>5 cm above the mineral soil/humus interface







Establishment ratio | Standard deviation | Range

10 *Thin-F: Partially decomposed organic matter*

BLACK SPRUCE (Upland Sites)

Thin F horizon

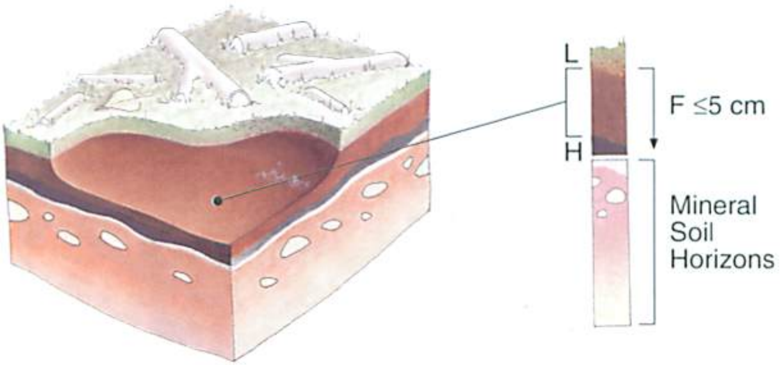
Seedbed Description:

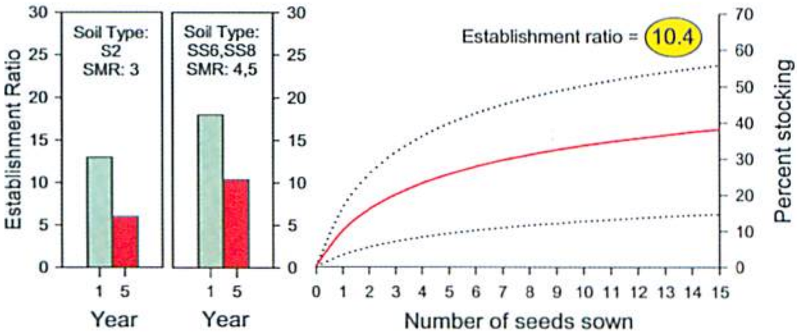
This material forms the F horizon of upland forest soils. It is characterized by an accumulation of partly decomposed organic matter derived largely from leaves and woody material. Some of the original structures are difficult to recognize and may be altered by soil fauna (moder) or permeated by fungal hyphae (mor). This seedbed type is found just above thin-H and/or shallow mineral seedbeds and is commonly exposed by light disturbance.

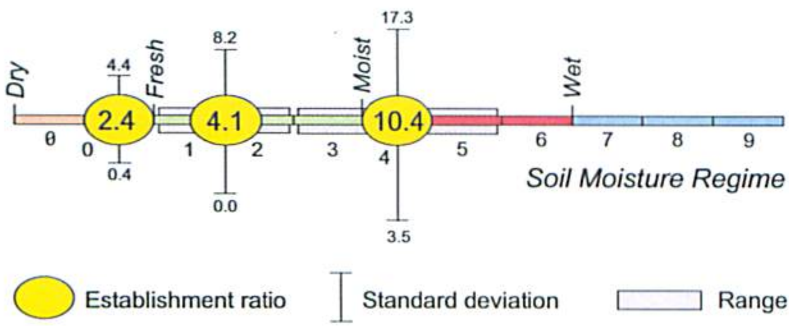
This seedbed type changes less with time than other types. Most changes occur between years three and five, generally developing into litter seedbeds on drier sites, dense graminoids on productive sites and pioneer mosses on the more moist sites.

Thin-F

≤5 cm above the mineral soil/humus interface







Thick-F: Partially decomposed organic matter

BLACK SPRUCE (Upland Sites)

Thick F horizon

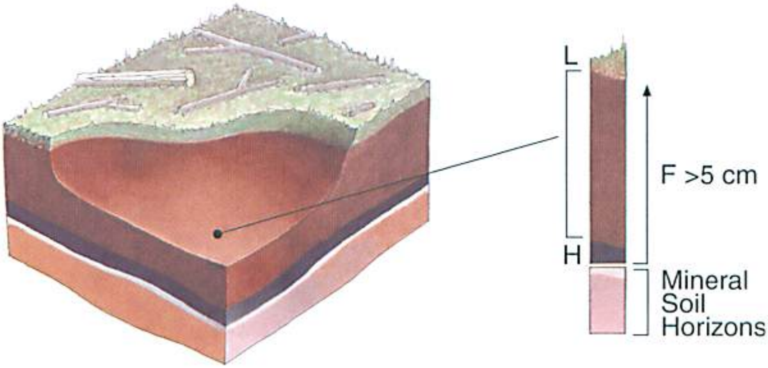
Seedbed Description:

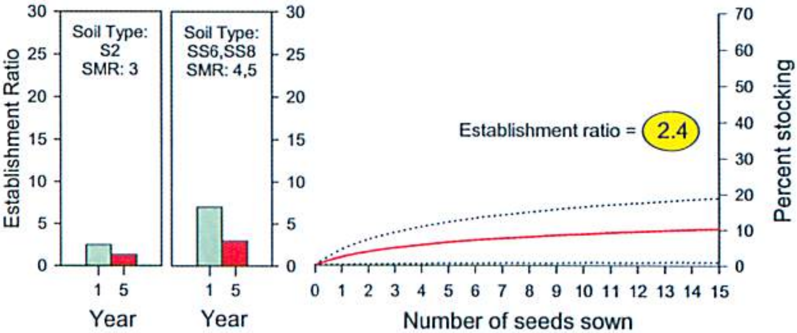
This seedbed is same as seedbed 10 but is thicker and thus further away from the soil/humus interface. Because this seedbed is in the initial stages of decomposition its texture predisposes it to desiccation following exposure. It also lacks the nutrients required for early seedling development. Generally the thicker the layer the poorer the establishment ratio. The only condition where this substrate would have some potential is if it was allowed to settle onto a firm base and was situated on deep soils with higher water contents (SMR >4).

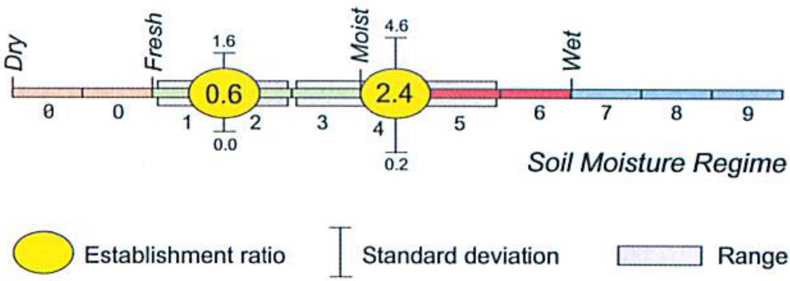
Thick-F

>5 cm above the mineral soil/humus interface

Seedbed Number 11







12 *Thin-H: Well decomposed organic matter*

BLACK SPRUCE (Upland Sites)

Thin H horizon

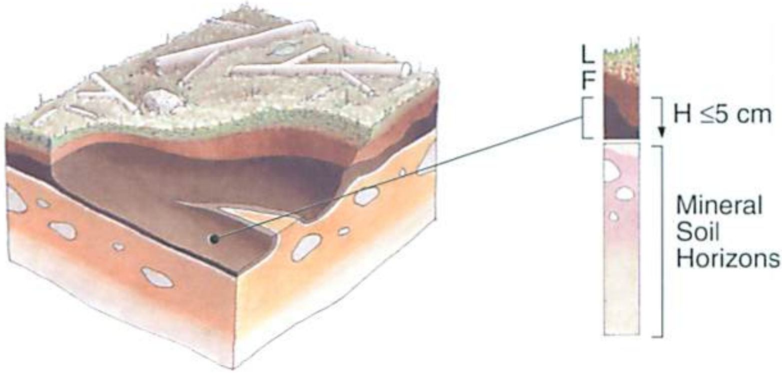
Seedbed Description:

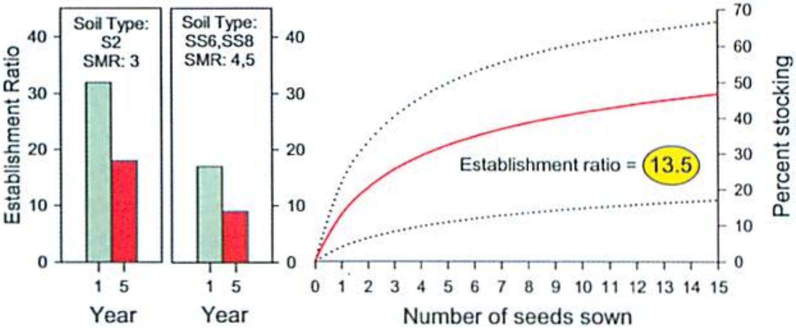
This material is composed of the H and Hi horizons of upland boreal forest soils (<40 cm of organic matter over mineral soil) under coniferous stands. It is characterized by an accumulation of decomposed organic matter in which the original structures are indiscernible. These horizons are found just above, and may be sharply delineated from (mor) or partially incorporated into the mineral soil (moder, mull). Although uncommon in boreal conifer forests, Ah horizons, mineral soils enriched with organic matter, are also included in this category.

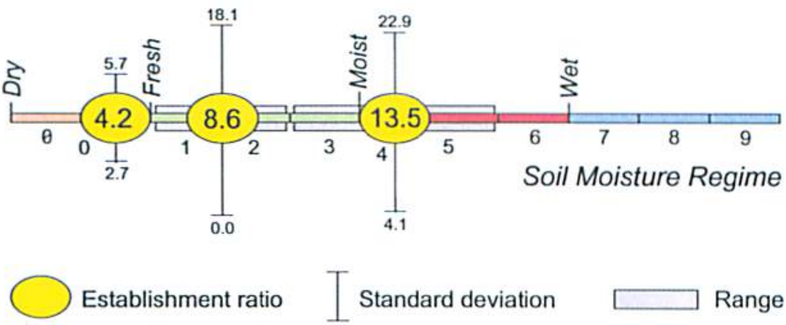
This seedbed type weathers rapidly; the frequency of occurrence can be reduced by 50% within a year of site preparation. By year five less than 10% of this type may still be present.

Thin-H

≤5 cm above the mineral soil/humus interface







Upper mineral soil horizon

BLACK SPRUCE (Upland Sites)

Upper mineral soil exposure

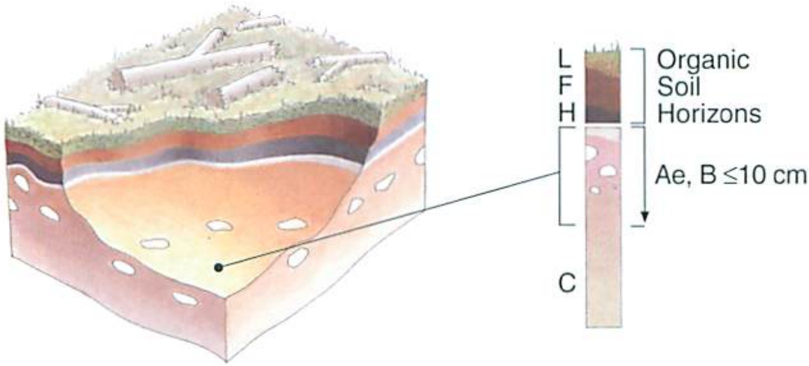
Seedbed Description:

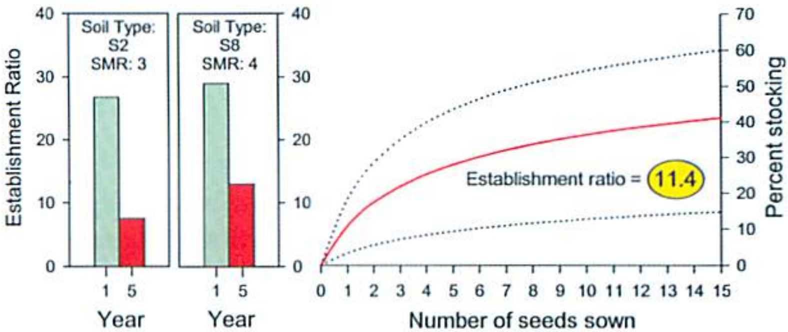
This material consists of Ae and B mineral soil horizons. Ae horizons are light-coloured surface horizons characterized by the loss (eluviation) of clay, iron, aluminum and/or organic matter. B horizons are characterized by enrichment in clay organic matter, iron, aluminum or clay; by soil structure development; or by a colour change denoting reduction or oxidation. These include Bt horizons, which are greyish-brown subsurface horizons enriched with clay; Bf horizons, which are reddish-brown subsurface horizons with accumulations of iron, aluminum and organic matter; Bm horizons, which are brownish subsurface horizons with only a slight addition of iron, aluminum and/or clay; and Bg horizons, which are mottled or greenish to bluish grey subsurface horizons characterized by periodic or permanent saturation. The quality of these seedbeds is greatly affected by soil texture, and to a lesser degree, Soil Moisture Regime. Coarse sandy mineral soils are often too dry to support good establishment, whereas fine loamy-clayey mineral soils often suffer excessive frost heaving. Best results are often obtained on fine sandy to silt loamy textures.

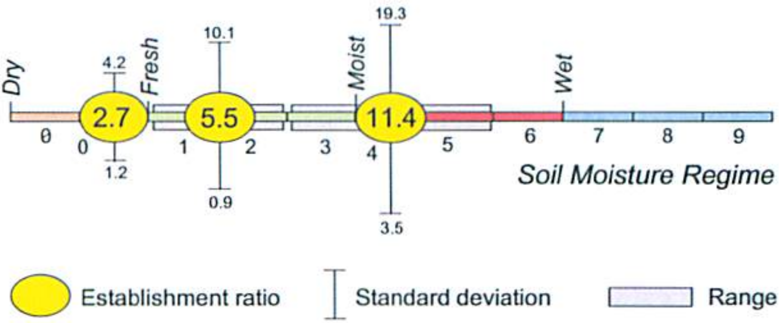
This seedbed type can retain over 50% of the original cover up to year three; cover declines markedly thereafter as a result of invasion by pioneer mosses.

Upper mineral soil horizon

Mineral Soil ≤10 cm below the mineral soil/humus interface







Lower mineral soil horizon

BLACK SPRUCE (Upland Sites)

Photo by D. Cormier (FERIC)

Lower mineral soil exposure

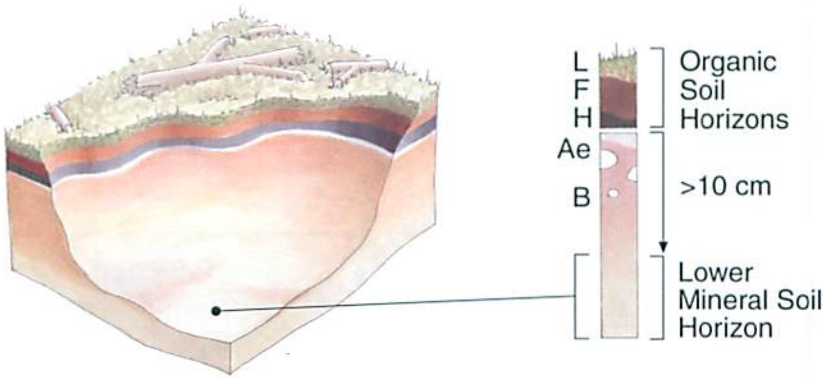
Seedbed Description:

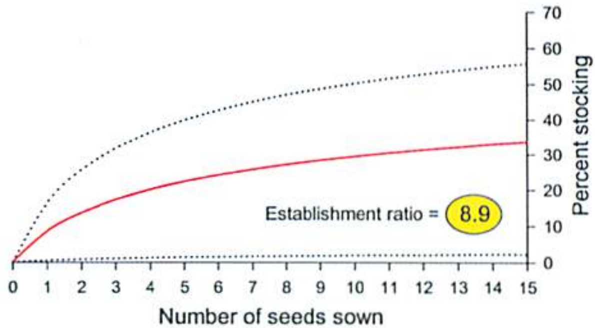
This material consists of the lower B and C horizons, usually exposed by excessively deep scarification or rutting. C horizons are subsurface mineral soil horizons, below the A and B horizons, which are relatively unweathered and represent the soil parent material. The quality of these seedbeds is greatly affected by the micro-site created (e.g., deep ruts or depressions vs broad expanses) as well as soil texture and Soil Moisture Regime.

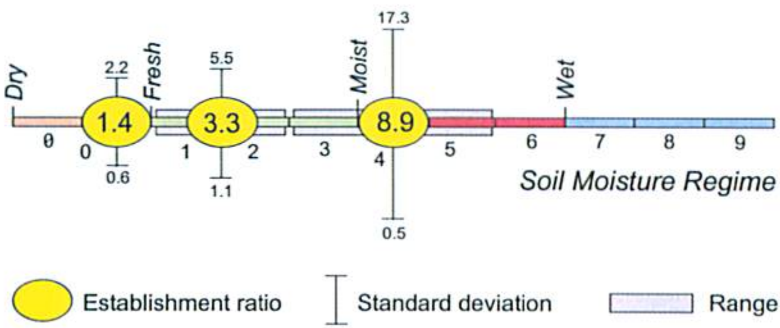
Lower mineral soil horizon

Mineral soil >10 cm below the mineral soil/humus interface

Seedbed Number 14







Pioneer moss
BLACK SPRUCE (Upland Sites)

Pioneer moss

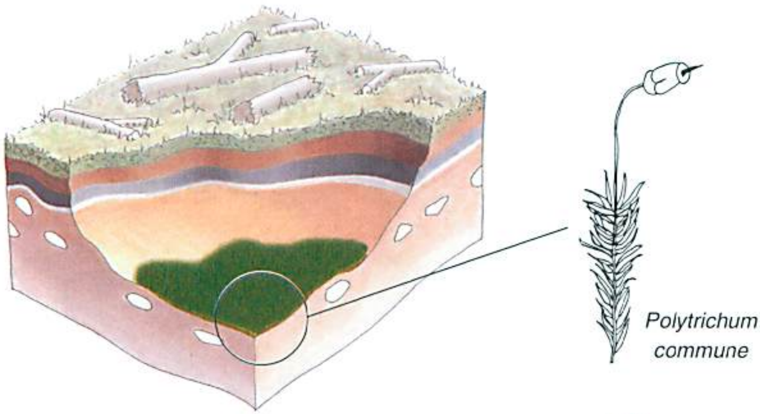
Seedbed Description:

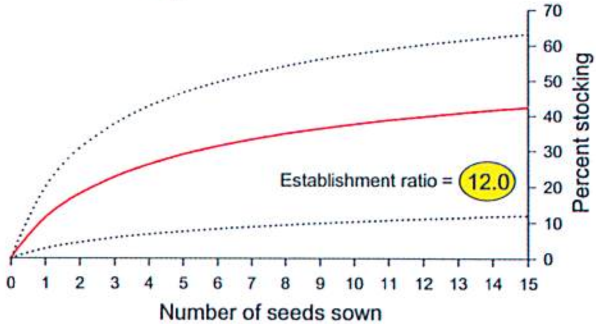
Pioneer mosses such as *Polytichum commune* and *Polytichum juniperinum* colonize recently disturbed organic and mineral soil surfaces and are particularly common on soils near the mineral soil/humus interface. They are found on a broad range of Soil Moisture Regimes and are seldom suppressed by heavy leaf fall. On moist, favourable locations, annual height growth may vary from 3-6 cm. Low, open growth of these mosses is favourable for germination, but rank growth is not. Other short, mat-like pioneering mosses, such as *Ceratadon purpureus, Pohlia nutans* and *Funaria hygrometrica,* which commonly invade freshly disturbed upland sites can also provide good seedbed media.

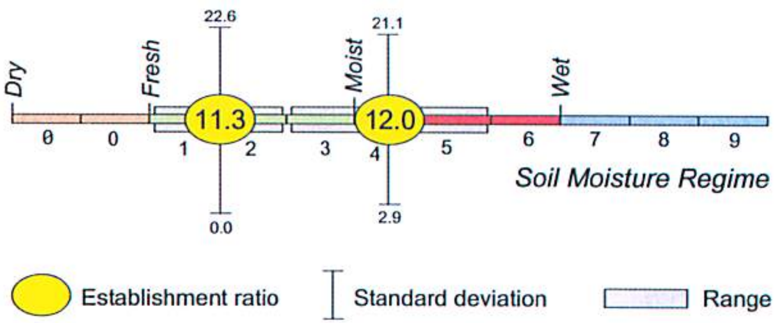
Pioneer moss

Polytrichum commune and Polytrichum juniperinum

Seedbed Number 15







Upturn

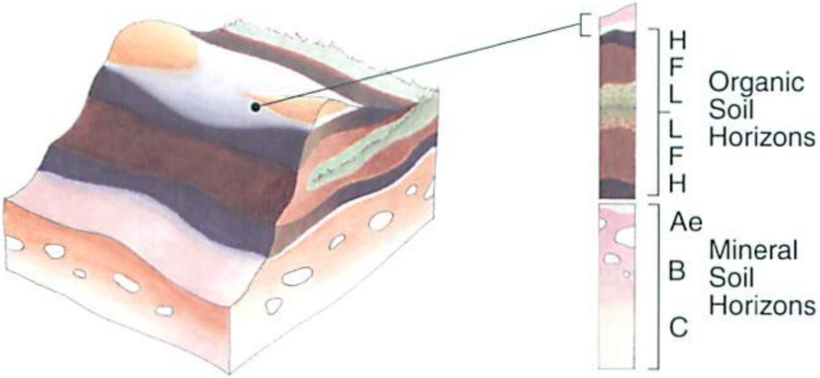
Seedbed Description:

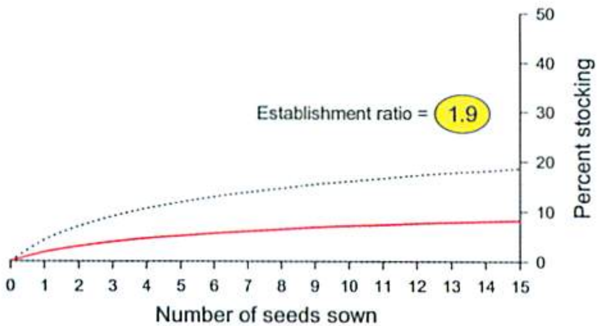
This material is formed from inverted mineral soil and lower organic horizons (F, H and Hi) separated from the underlying mineral soil by a layer of undecomposed or poorly decomposed organic matter. It also includes loose mixtures of mineral and organic material. It is commonly found in spoil banks, mounds or berms created by scarification or during harvesting. These seedbeds are prone to desiccation because of lack of capillary contact with the underlying mineral soil, and are often too dry during many growing seasons for dependable seedling establishment.

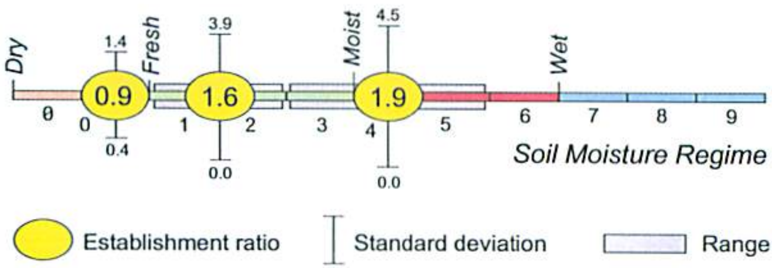
Upturn

Inverted mineral/organic horizons over undecomposed organic

Seedbed Number 16







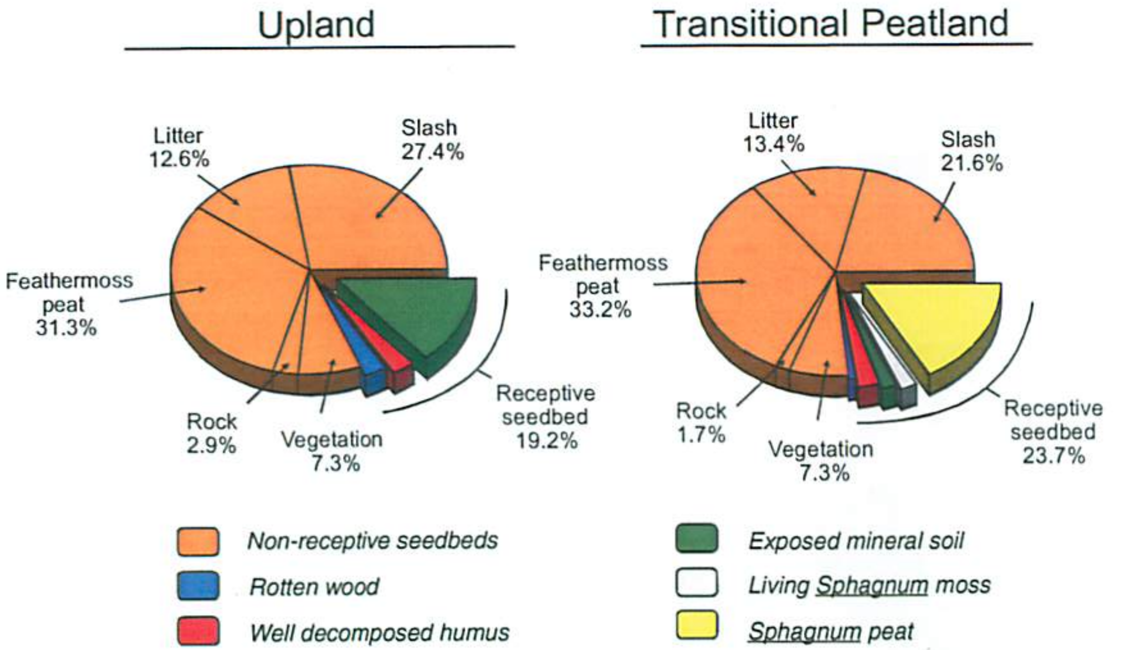
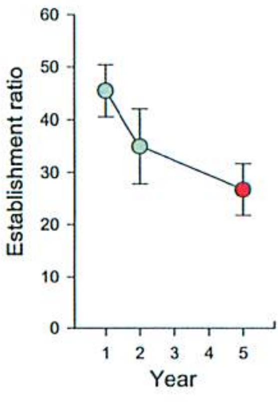


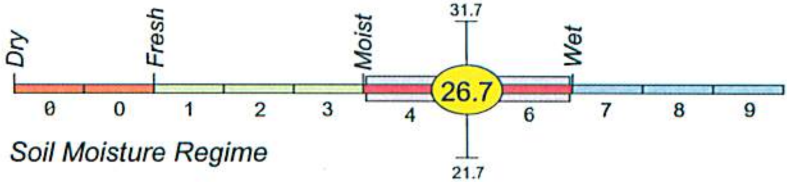
Figure 6.4 Proportions of receptive and non-receptive seedbed types following prescribed burning on three upland and three transitional peatland black spruce sites in northern Ontario *(Adams 1993)*.

Living compact Sphagnum

Seedbed Description:

Wet living *Sphagnum* mosses can inhibit the rate of spread and depth of burn of prescribed fire. In low lying areas where *Sphagnum* mosses proliferate, fire may merely scorch the mounds of *Sphagnum* and burn off slash and litter accumulation. This results in a patchwork of burned, scorched and unburned seedbeds. Residual pockets of unburned *Sphagnum* may account for an average of only 2 percent of the area burned but will provide an excellent seedbed for black spruce germination. In some cases *Sphagnum* growth can be temporarily put into check by fire; more often however, competition from living *Sphagnum* will cause significant mortality during the early establishment years.



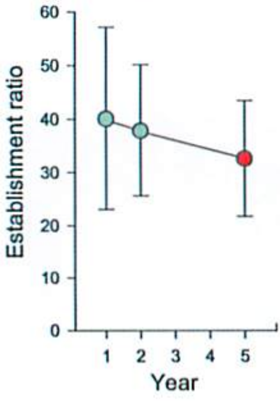


18 **Seedbed Number**

Sphagnum peat

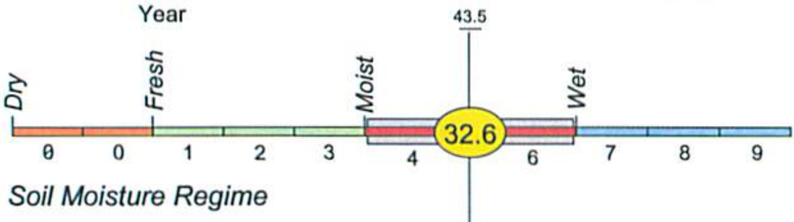
BLACK SPRUCE (Prescribed Burns)

Sphagnum peat



Seedbed Description:

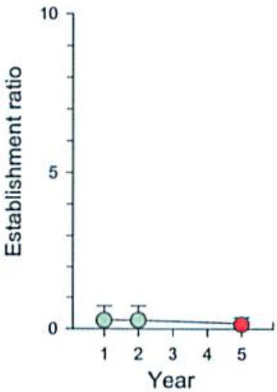
This seedbed comprises dead, scorched or moderately decomposed *Sphagnum* moss. The living layer has either been removed by mechanical means during the harvest or pre-burn tramping or consumed by the fire. Because of its excellent moisture retention this substrate usually does not burn appreciably. Colour may vary from dark brown when scorched by fire to straw colored to yellowish-brown when exposed mechanically. The original *Sphagnum* stems should be readily identifiable and the seedbed will feel moist to the touch. Recorded cover values on transitional and lowland sites range from 3 to 35 % of the area burned. This seedbed provides the best opportunity for germination and seedling establishment.



Burned feathermoss peat

BLACK SPRUCE (Prescribed Burns)

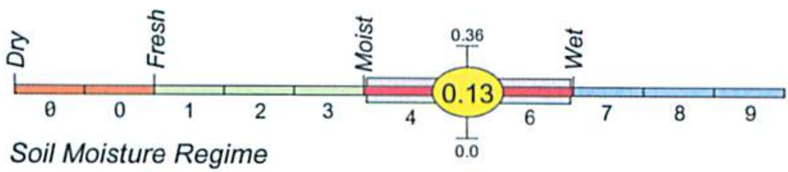
Burned feathermoss peat



Seedbed Description:

Even though feathermosses and *Sphagnum* can grow in close proximity, they have quite different physical properties. Feathermosses, unlike *Sphagnum*, do not have a well established capillary connection to moist underlying layers and do not sustain a high moisture content once the protective canopy is removed. Feathermosses are shade dependent and die quickly following harvesting. The resulting surface layer of dry dead moss is readily consumed by fire, leaving a black fibric substrate. The underlying feathermoss mat can be quite thick and requires a fairly intense burn to expose the moist, compact and better decomposed humus layers below. If a deep burn is not achieved the resulting burned, poorly-decomposed feathermoss peat will provide a hostile environment for germination. Due to its colour and texture this substrate is subject to extreme surface temperatures and desiccation. This non-receptive seedbed can make up a considerable portion of the blackened area of an upland black spruce burn (Figure 6.4).

Because of the large difference in receptivity between burned feathermoss peat and scorched *Sphagnum* peat, it is important that survey crews be able to distinguish these two seedbed types.

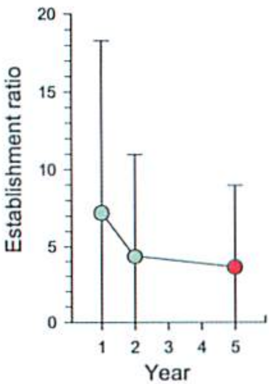


20 Seedbed Number

Exposed mineral soil

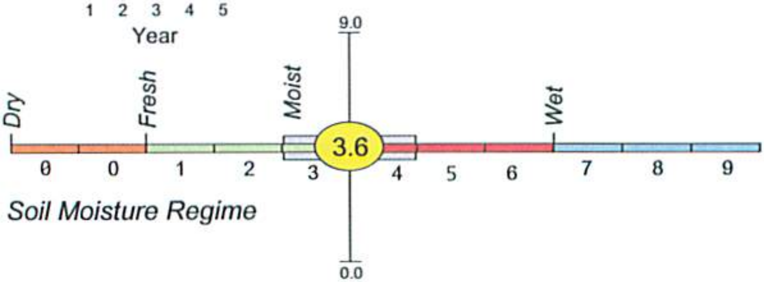
BLACK SPRUCE (Prescribed Burns)

Exposed mineral soil



Seedbed Description:

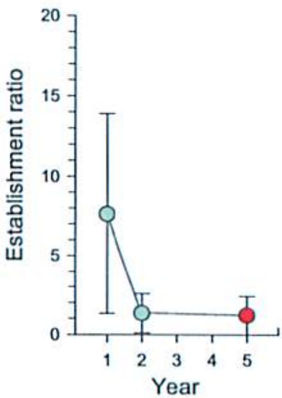
Large expanses of exposed mineral soil, where fire has completely removed the surface organic layer, provide unfavorable conditions for black spruce establishment. Better results can be achieved on smaller patches of exposed mineral soil that are in close proximity to residual organic substrates. Conditions are slightly more favorable on sites with wetter soil moisture regimes or when some shade is available. Some mineral soils that have been exposed to intense heat can appear fluffy or powder-like and require time (e.g., overwintering) to settle and maintain good contact with moist underlying layers. The quality of this seedbed is also greatly affected by the surface soil texture (the coarser the material the less water retention capability). This seedbed will benefit from higher than normal rainfall, but is generally not recommended as target seedbed.



Partially decomposed rotten wood

BLACK SPRUCE (Prescribed Burns)

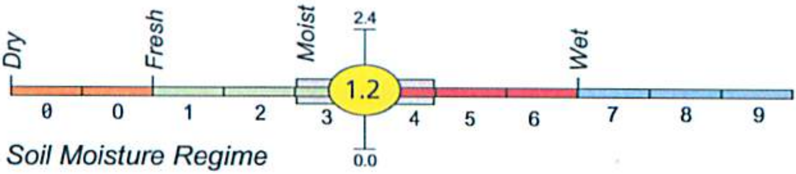
Partially decomposed rotten wood



Seedbed Description:

Rotten wood occurs in fallen trees and stumps and is exposed by harvesting, tramping or prescribed fire. This substrate can be in various stages of decomposition ranging from fibrous, to spongy, to buttery. It appears that much of the finer well decomposed material gets eroded by rain or volatilized by the heat of the fire leaving less decomposed material which is less likely to maintain adequate moisture reserves. This could account for the significant drop in establishment ratio between the first and second year. The average cover value for this seedbed is quite variable and is related to the condition of the original stand, method and timing of harvest and depth of burn, but usually represents less than 3 percent of the area burned.

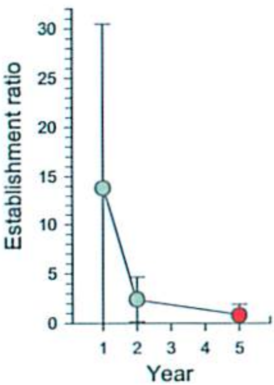
This seedbed, like many of the marginally receptive substrates, will benefit from frequent rainfall throughout the growing season.



Exposed well-decomposed humus

BLACK SPRUCE (Prescribed Burns)

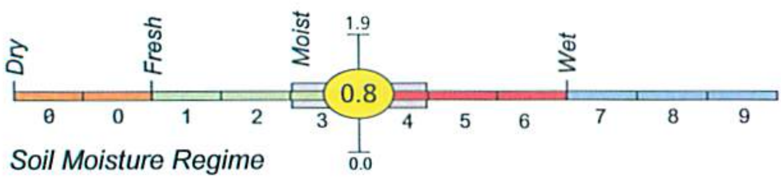
Exposed well-decomposed humus



Seedbed Description:

This seedbed is created when fire is intense enough to consume the fibric portions of the organic layer exposing the better decomposed underlying layers. This material originates in the Oh (humic) organic horizon and is the most well decomposed substrate, containing only small amounts of well preserved fiber. Its colour is dark brown or black when wet and feels greasy to the touch. Expect to find this seedbed at the base of stumps where fire has had a chance to burn deep into the duff or in close proximity to exposed mineral soil.

Initially this seedbed is reasonably receptive, however it is prone to flooding, frost heaving, erosion and competition from other vegetation resulting in high mortality. It accounts for a relatively low cover value (<3%).



Jack Pine Seedbeds

Mechanically Site Prepared Seedbeds

Prescribed Burn Seedbeds

Jack pine seedbeds

Exposed following mechanical site preparation

Figures 6.5 (a), (b) and (c) represent some of the more common micro-sites that may be present following various methods of mechanical site preparation. Specific seedbed types are identified with numbered circles. The colour of the circle provides an indication of their relative receptivity to seeding. Each seedbed is further described in more detail in the following seedbed data sheets.

Differences in depth of organic, soil texture and moisture regime within micro-sites is reflected in a sometimes highly variable establishment ratio [ER]. The standard deviation associated with each ER, to a large degree, reflects year to year climatic variation. All of these aspects should be taken into consideration when estimating the seeding potential of individual seedbeds.

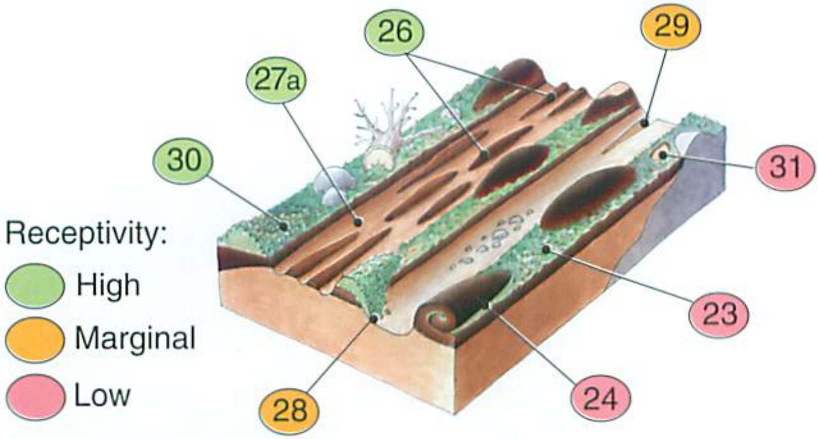


Figure 6.5(a) A conceptual illustration of seedbeds created by screefing which removes or displaces the organic layer to expose and/or lightly disturb the underlying mineral soil. Drag units consisting of light to heavy barrels, anchor chains/tractor pads, blade attachments and disk trenchers are some of the pieces of equipment commonly used to create this condition *(adapted from Sutherland and Foreman 1995)*.

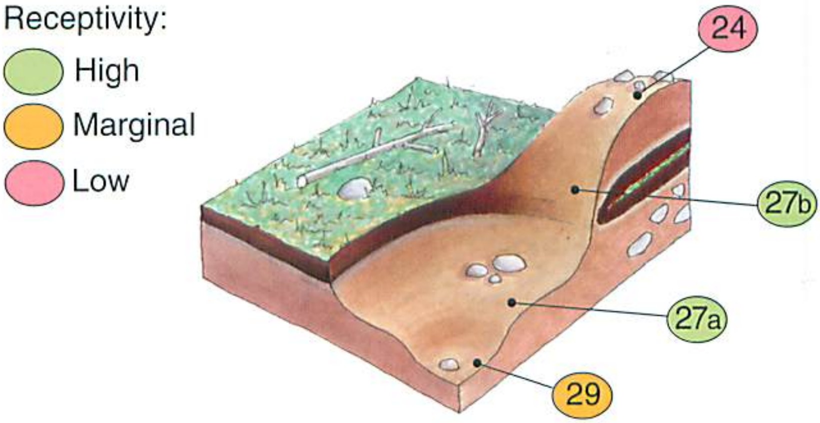


Figure 6.5(b) An illustration of the scalp produced when the organic and upper mineral soil horizons are excavated and inverted over the adjacent undisturbed LFH layer. This condition is commonly created by spot inverting (e.g. Bracke) and continuous inverting (e.g. mold-board plows) (*adapted from Sutherland and Foreman 1995*).

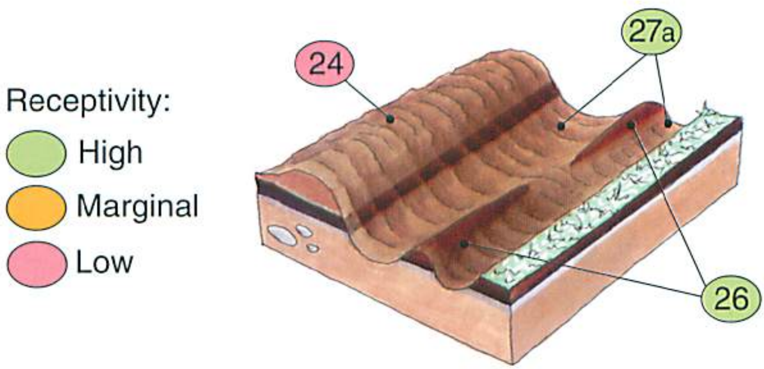


Figure 6.5(c) An illustration of the trench produced when organic and upper mineral soil horizons are removed and subsequently deposited in berms beside the trench. Disk trenchers, cone trenchers and heavy barrel drags are commonly used to create this condition *(adapted from Sutherland and Foreman 1995).*

23 *Litter: Undecomposed organic matter*

JACK PINE (Mechanical Site Preparation)

Litter

Seedbed Description:

This undisturbed seedbed is characterized by accumulations of needles, leaves, twigs and woody materials in which the original structures are easily discernible.

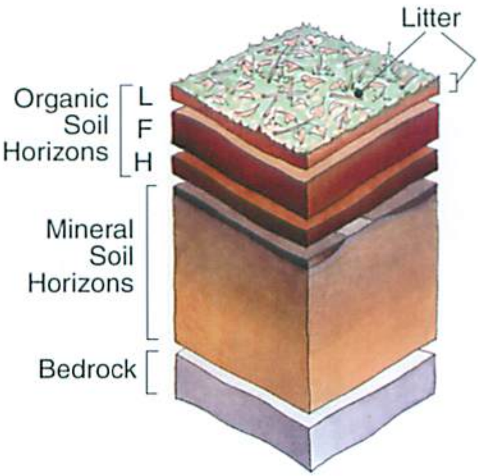
Following harvesting and removal of the protective canopy this seedbed is exposed to extreme temperatures and moisture deficits. This seedbed may include a minor component of mosses. Most of these mosses are shade tolerant and quickly die off following exposure which in turn contributes to the amounts of litter present.

Litter

Depending on site conditions and the type of site preparation used, undisturbed litter can represent a considerable portion of the seeding chance. Because of its low potential for seedling establishment it is not normally considered a target seedbed, however, it does have a receptivity value and as such should be separated from truly unreceptive conditions such as deep slash, rock and stumps when conducting a post site prep assessment survey. A seedbed with a seemingly insignificant ER has the potential to affect seeding prescription if it represents a significant amount of the surface area.

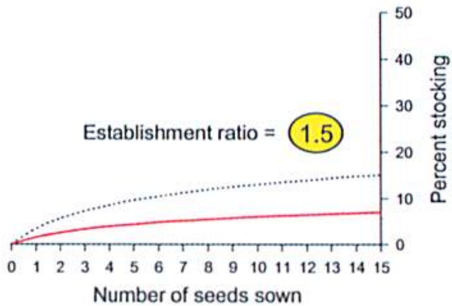
Litter

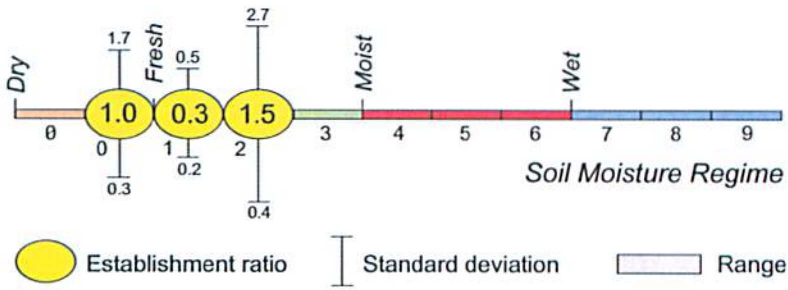
Undistubed L horizon of upland forest soils



This seedbed can produce large seedlings if establishment is successful because of the undisturbed nature of the underlying substrates and the retention of below surface moisture.

A thinner LFH and wetter SMR may help to improve establishment.





24 *Upturn*

JACK PINE (Mechanical Site Preparation)

Side berm with logging slash

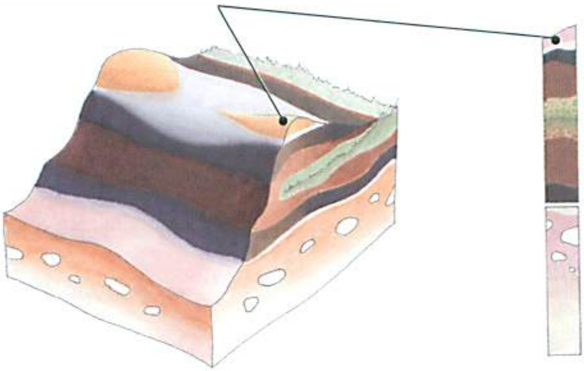
Seedbed Description:

These seedbeds are a product of site preparation or harvesting operations.

They can be characterized by:

a) side berms, spoil banks and loose mixtures of mineral soil, organic material and logging debris.

b) mineral soil/humus upturns where displaced mineral and upper organic horizons have been removed and heaped onto an undisturbed substrate.



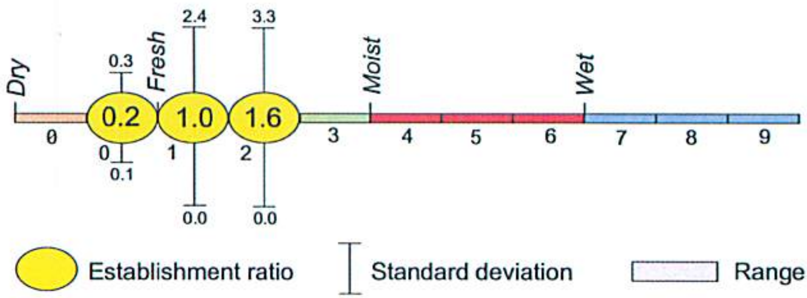
Upturn – displaced mineral/organic inverted over undisturbed substrate

c) inverted scalps (mineral soil cap over organic). This inclusion refers to the top portion of the inverted scalp only; not the lower slope or hinge area of the mound.

In all of the above cases the extracted mineral soil and upper organic horizons (L, F, and H) are separated from the underlying mineral soil by a layer of undecomposed or poorly decomposed organic matter. Considerable variation exists in the capillary contact with underlying layers which predisposes these substrates to periodic desiccation. Consequently these seedbeds are often too dry during many growing seasons to support seedling establishment with any dependability.

As in the case of litter, these seedbeds have an associated ER value and as such, the area taken up by these seedbeds should be recorded in the post site preparation assessment (Appendix F) and included in the predictive model's work sheet so that an accurate prescription can be developed.

Soil Moisture Regime



25 *F horizon: Partially decomposed organic matter*

JACK PINE (Mechanical Site Preparation)

F horizon (fermentation layer)

Seedbed Description:

This substrate is characterized by an accumulation of partly decomposed organic matter derived mainly from leaves, twigs and woody materials; some of the original structures are still recognizable and fungal hyphae may be present. Exposure of this substrate is usually associated with light disturbance.

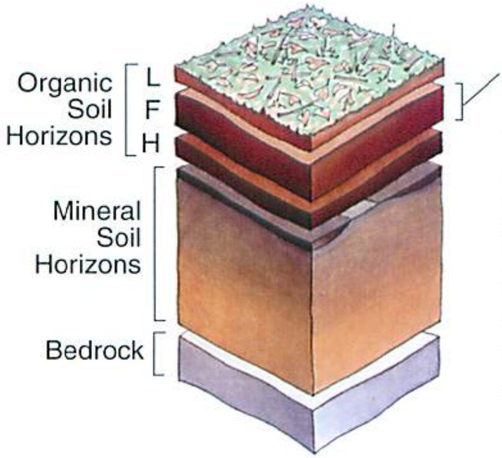
When subjected to excessive sun exposure the usually dark surface layer of this seedbed will often take on an ash grey colour and have a crusty texture. At this stage moisture availability for newly established seedlings is negligible and desiccation soon follows. Because of this, seedling establishment is generally considered to be poor. However, this substrate may be considered marginally receptive on sites with a high water table.

F horizon (fermentation layer)

F horizon

Exposed fermentation layer

Seedbed Number 25



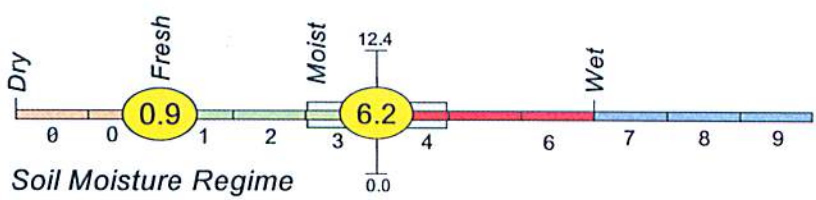
Fermentation layer

There is little formal receptivity data available for this seedbed type. However, it has been observed that both moisture regime and thickness of the substrate play a significant role in its performance.

RECOMMENDATIONS

The following recommendations should be considered:

- Thick F can *only* be considered a target seedbed on deep soils with a high water content (SMR >4).
- Seeding onto a thin F plus H (<1.5 cm) layer which readily forms a firm base can be considered as recommended for deep sands and coarse or fine loams with SMRs greater than 3 only.
- On shallow soils this substrate is subject to desiccation and should be avoided.



26

H and Ah horizons: Well-decomposed organic matter

JACK PINE (Mechanical Site Preparation)

H horizon (humus layer)

Seedbed Description:

The H horizon is characterized by an accumulation of well decomposed organic matter in which the original structures are indiscernible. It differs from the F horizon by having greater humification chiefly due to the action of micro-organisms.

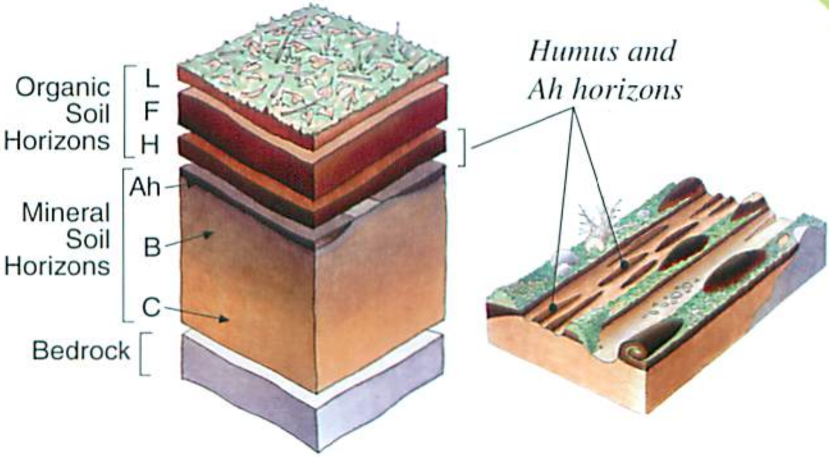
Ah is a mineral horizon enriched with organic matter (<17% organic by weight). This material is very dark in colour and feels greasy to the touch. Unfortunately, H and Ah horizons are often not well delineated and for the purposes of this manual have been lumped together to simplify field identification.

Ah horizon (organic enriched mineral soil)

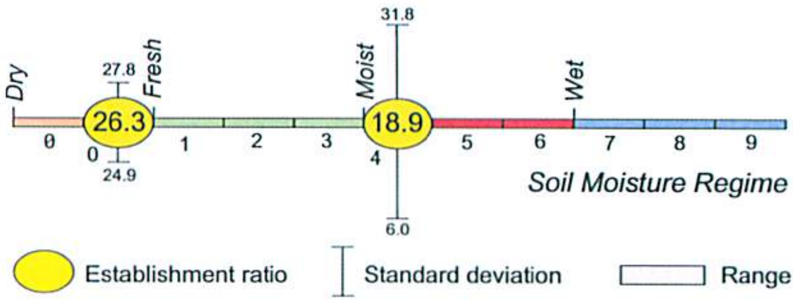
H and Ah horizons

Exposed humus layer

Seedbed Number 26



The combination of moisture retention and nutrient availability makes this seedbed the ideal micro-site for seedling establishment and early growth. Because of the variable nature in thickness of the H/Ah horizon (in some cases only a few millimeters thick), exposure is often more by happenstance than design. However, site preparation operators should be made aware of the potential of this seedbed and strive to expose as much of it as possible. The H and Ah horizons are the most susceptible to deterioration, where the frequency of occurrence can be reduced by over 50 percent within a year of site preparation; by year five less than 10 percent of this seedbed type may still be present.



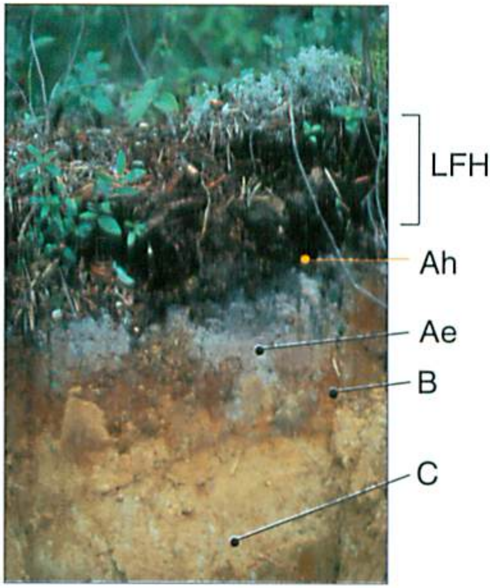
27a *Upper mineral soil horizon (furrow)*
JACK PINE (Mechanical Site Preparation)

Exposed upper mineral soil horizons

Seedbed Description:

This seedbed can be found in the bottom of shallow troughs, scrapes and furrows. It usually consists of Ae and B mineral soil horizons. Ae horizons are light-coloured surface horizons characterized by the loss (eluviation) of clay, iron, aluminum and/or organic matter.

B horizons are characterized by enrichment in clay organic matter, iron, aluminum or clay; by soil structure development; or by a colour change denoting reduction or oxidation. These include Bt horizons which are greyish-brown subsurface horizons enriched with clay; Bf horizons which are reddish-brown subsurface horizons with accumulations of iron, aluminum and organic matter; Bm horizons which are brownish subsurface horizons with only a slight addition of iron, aluminum and/or clay; and Bg horizons which are mottled or greenish to bluish grey subsurface horizons characterized by periodic or permanent saturation.



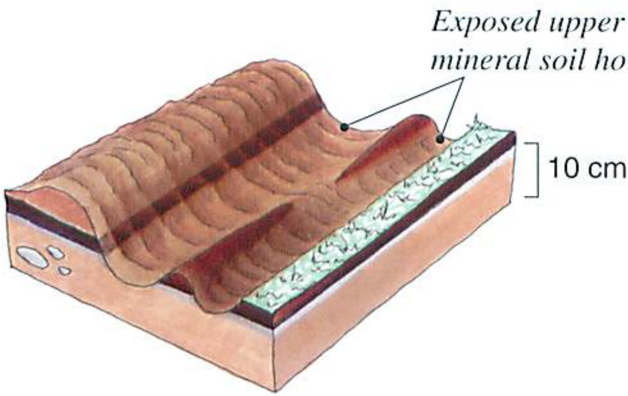
Mineral soil horizons

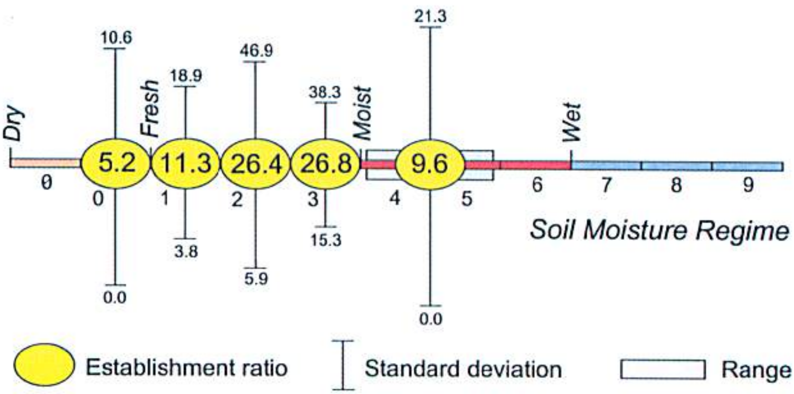
Upper mineral soil horizon (furrow)

Mineral Soil <10 cm below the mineral soil/humus interface

Seedbed Number 27a

Shallow mineral soil exposure with a firm base on deep sands with SMR 1-3 is considered to be a good micro-site for jack pine establishment. Any position within the trench is acceptable as long as the seed lands no higher than the original mineral/organic interface. Avoid depressions on moist deep sands and coarse or fine loams that are not well drained or if excessive sedimentation is anticipated.





27b *Upper mineral soil horizon (scalp)*

JACK PINE (Mechanical Site Preparation)

Mid-slope position in a Bräcke scalp

Seedbed Description:

The mid-slope of the scalp is considered to be a target micro-site.

Ideally this micro-site should be allowed to settle to a firm base prior to seeding. Compaction of this micro-site through manual or mechanical means will stabilize the slope, reduce erosion and significantly improve stocking potential.

The base and lower slope of the berm on furrowed sites have very similar properties to the mid-slope position within the scalp. On dry sites there is a certain amount of protection afforded by the berm. In the case of east-west scarification, the base of the north-facing slope benefits from the berm's shade, which tends to mitigate temperature extremes and provides some soil moisture conservation.

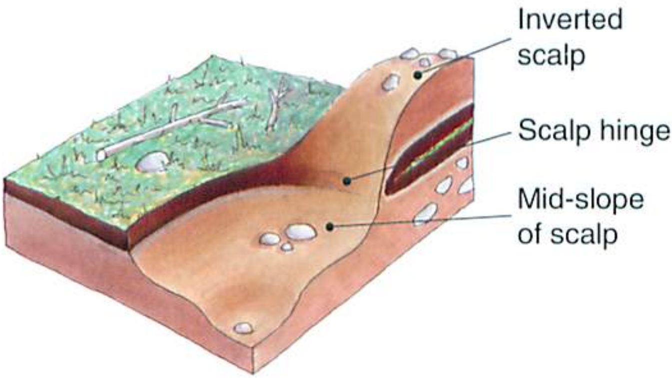
Base of the berm

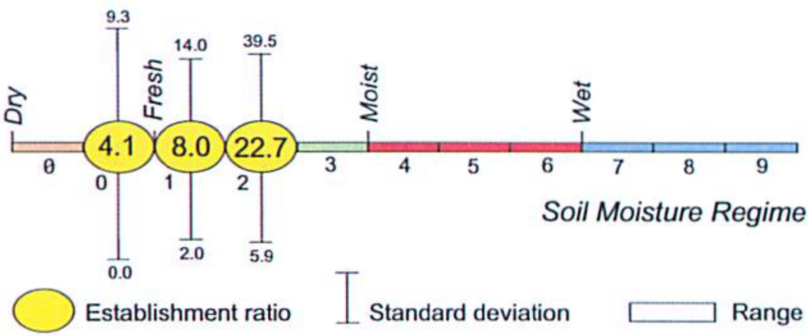
Upper mineral soil horizon (scalp)

Mid-slope of a scalp or base of a berm

Seedbed Number 27b

The upper slope or hinge area of an inverted scalp is considered as conditionally recommended as target seedbed on moist sites only, because of its predisposition to desiccation. If establishment is successful, seedlings will benefit from their proximity to the mineral/ humus interface. On richer sites, incursion of competing vegetation from the sides may also favor seeding the hinge area.





Incidental FH/mineral mixes

JACK PINE (Mechanical Site Preparation)

Thin FH/mineral mix on a firm mineral soil base

Seedbed Description:

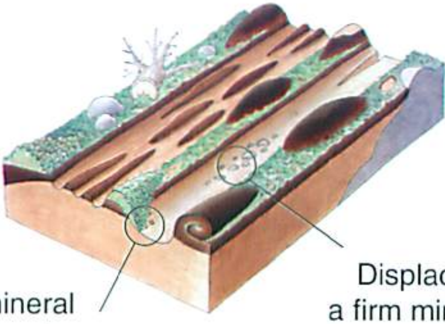
This seedbed is created by the disking or dragging action of some scarification equipment (e.g., barrels and chains and power trenchers). While these mixes are not overly common occurrences on most site prepared blocks they may, under some moisture conditions, be considered a target seedbed. Incorporation of humus layers with mineral soil by mixing has been found to increase the soil's water-holding capacity in the rooting zone and can improve soil moisture by reducing the density of competing vegetation, particularly in coarser-textured soils. On fine-textured soils, mixing can increase the infiltration of moisture and can avoid capillary discontinuity in raised beds (Sutherland and Foreman 1995).

The same scarification action that produces a FH/mineral mix can result in displaced mineral soil on a mineral soil base. The receptivity of this seedbed is directly related to its proximity to the mineral/humus interface, the degree of settling that has occurred and the moisture regime of the site. Generally, if it is not in good contact with the underlying mineral layer or is perched too far above (10 cm) the mineral/humus interface it should be considered as having poor potential.

Displaced mineral on a firm mineral soil base

Incidental FH/mineral mixes

and displaced mineral on a firm mineral soil base



No formal establishment ratio data exists for these seedbed types, however the following recommendations will give an indication of potential success relative to soil moisture regime.

RECOMMENDATIONS

- A thin (<1.5cm) FH/mineral mix that readily forms a firm base is recommended as a target seedbed for deep sands and coarse or fine loams with dry to fresh SMRs and is considered the micro-site of choice for shallow soils <100 cm.
- Moderately thick (1.5-3 cm) FH/mineral soil mixes may result in only marginal success on moist substrates. FH/mineral soil mixes thicker than 3 cm are not recommended under any site conditions.
- Seeding on displaced mineral soil on a firm mineral soil base is recommended on moist deep sands and course or fine loams.

Lower mineral soil horizon

JACK PINE (Mechanical Site Preparation)

Lower mineral soil exposure

Seedbed Description:

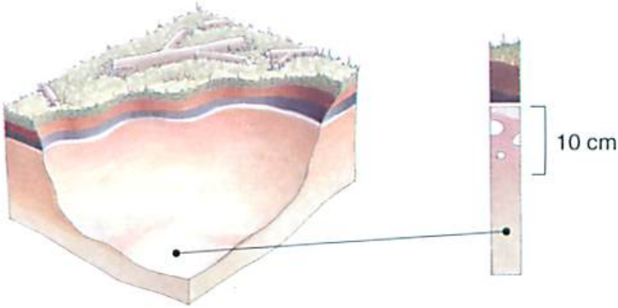
This material consists of the lower B and C horizons, usually exposed by excessively deep scarification or rutting. C horizons are subsurface mineral soil horizons, below the A and B horizons, which are relatively unweathered and represent the soil parent material. The quality of these seedbeds is greatly affected by the micro-site created (e.g., deep ruts or depressions vs broad expanses) as well as soil texture and Soil Moisture Regime.

Limit the amount of this type of exposure. On many site preparation operations however, a certain amount of deep mineral soil exposure is generally unavoidable and is a function of site type, operator experience, ground bearing capacity and equipment suitability. Regardless of how it is created it will be a substrate that will be encountered and as such should be identified and quantified.

Water-filled furrow

Lower mineral soil horizon

>10 cm below the mineral soil/humus interface



The lack of nutrient availability, especially on coarse textured soils, will have a negative impact on seedling performance. If a stand is established primarily on deeply screefed micro-sites, experience suggests site index class (index height at age 50) may be reduced by as much as two site classes.

Cold air and water often pond in these depressions; subjecting germinants to low soil temperatures, frost or frost heaving and flooding.

Unfortunately, no formal establishment data exists for this substrate. Consider the following recommendations.

RECOMMENDATIONS

- Rarely are deeply screefed micro-sites desirable. However, small (<1 m^2), deeply screefed seedbeds with good air drainage may provide acceptable jack pine establishment on some dry (SMR Ø) to moderately dry (SMR 0) sites.
- Avoid seeding into deep furrows or scrapes on sites with SMRs >3. Water ponding in these depressions is anticipated.
- Avoid seeding on slopes prone to erosion. Deep screefs tend to act as channels for runoff.

30 *Living Sphagnum and Sphagnum peat*

JACK PINE (Mechanical Site Preparation)

Seedbed Description:

Living *Sphagnum* or *Sphagnum* peat may occur on moist portions of the seeding chance (SMRs >4) or on imperfectly drained very shallow soils. Expect good initial establishment on this seedbed but the lack of available nutrients and overly moist growing conditions may reduce seedling performance.

31 *Very shallow soil: (5-30 cm) over bedrock*

JACK PINE (Mechanical Site Preparation)

Seedbed Description:

Direct seeding may be the only available regeneration option on very shallow soils with extensive bedrock outcrops, boulder pavements or excessive surface boulders. Soil moisture regimes on these sites can be highly variable. Drainage classes can range from rapid to imperfect. This can result in a range of conditions, from water ponding in depressions to moisture deficits on perched seedbeds. Recommending specific target micro-sites may be inappropriate. Thus, as a rule of thumb, seed as close to the mineral soil/ humus interface as possible.

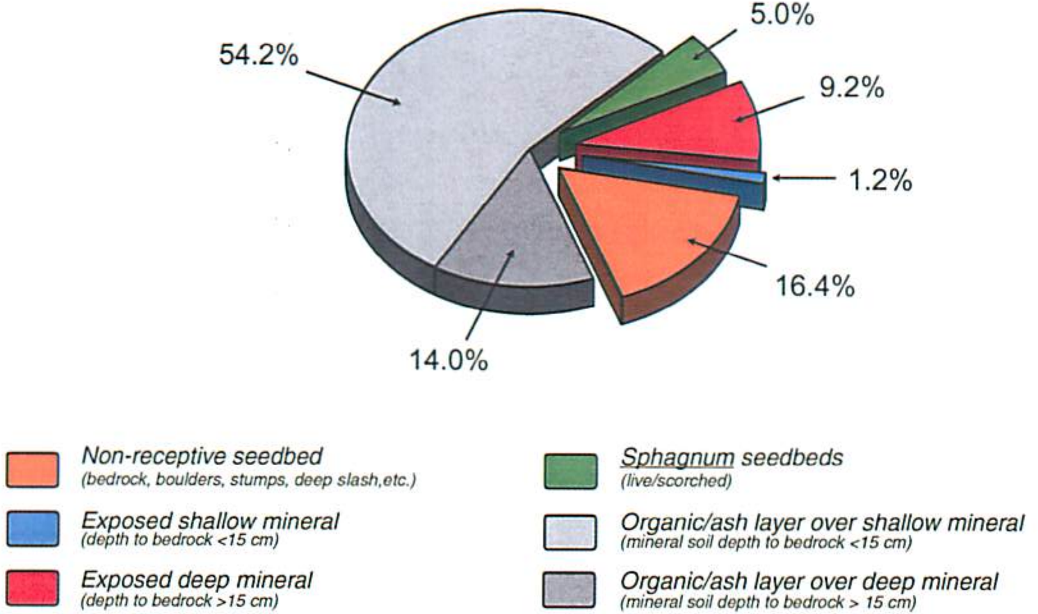


Figure 6.6 Proportion of receptive and non-receptive seedbed types following prescribed burning on three jack pine sites in northern Ontario *(Foreman 1997)*.

Sphagnum/Sphagnum peat

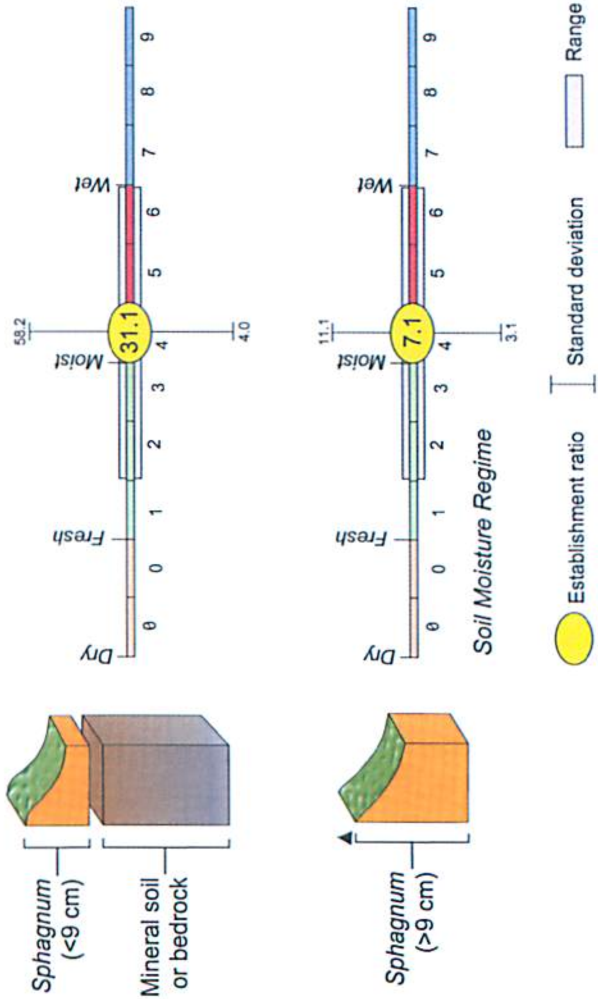
JACK PINE (Prescribed Burns)

Seedbed Description:

Sphagnum mosses are not abundant on jack pine sites, but small pockets (1-10m diameter) of *Sphagnum* occur in association with water holding bedrock depressions on very shallow soils. Establishment ratios are highest on the periphery of these pockets. Recorded cover values average 5 percent (Fig 6.6).

This seedbed category includes living undisturbed, scorched, dead and partially charcoal covered *Sphagnum*. In dry years *Sphagnum* seedbeds provide the sustained moisture required for jack pine germination; in years with regular plentiful rainfall establishment may be poor. Chlorotic seedlings have been observed on *Sphagnum* substrates, suggesting that this medium is not well suited for jack pine growth.

Sphagnum/*Sphagnum* peat
JACK PINE (Prescribed Burns)



33 *Organic material and ash over very shallow mineral soil*

Seedbed Description:

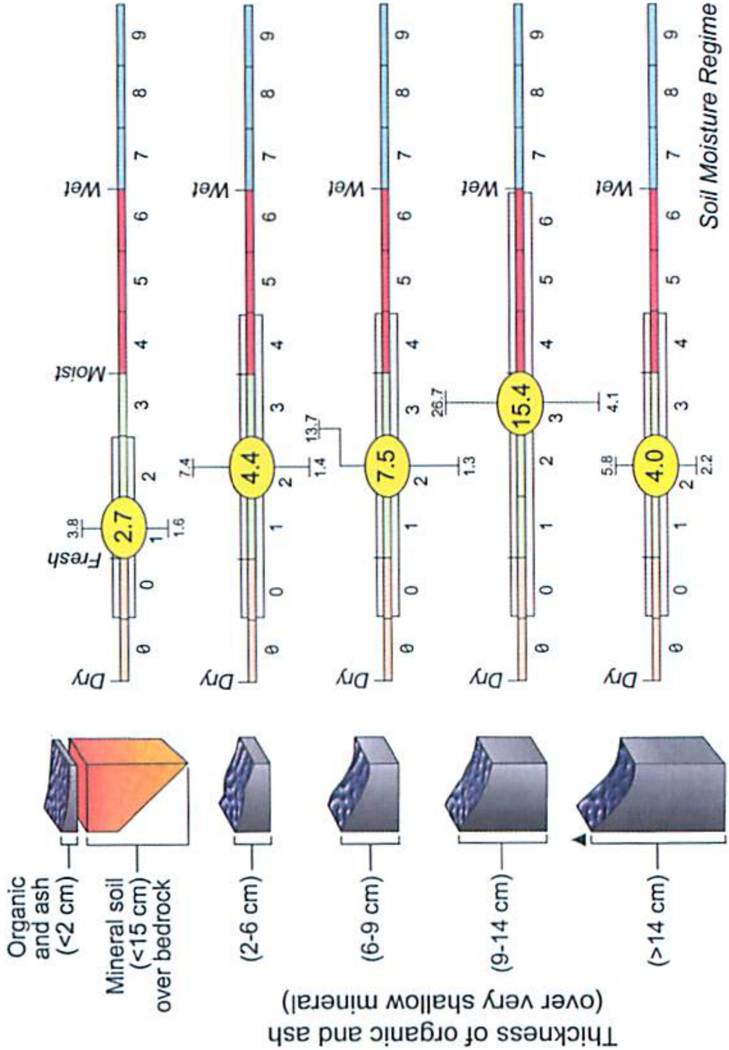
This group of substrates includes the burned and unburned soil organic horizons (LFH layers) as well as ash, charcoal, rotten wood, and dead moss. These materials can occur separately or in mixture with each other. The depth of the underlying mineral soil is less than 15 cm over bedrock.

The thickness of ash and organic material after prescribed fire depends largely on the intensity of the burn, but also upon the moisture content of the organic layer. Organic layer moisture content shows considerable spatial variation on shallow soil sites because the undulating bedrock and boulder sub-surface topography causes variation in the soil moisture regime. Most of the organic material on dry moisture regimes is burned, while thicker layers of organic material remain after fire on wetter moisture regimes. Jack pine establishment ratios on ash and organic material seedbeds vary with the thickness of this layer and with soil moisture regime.

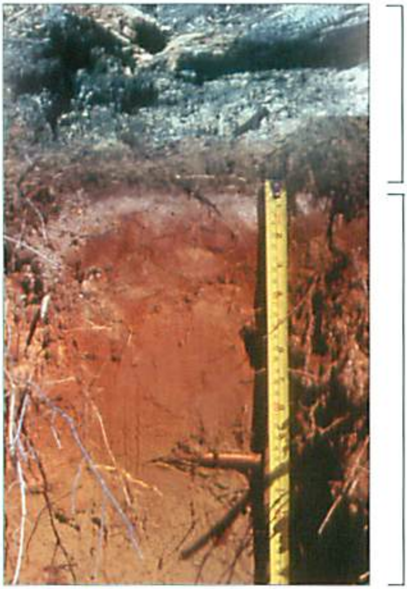
Organic material and ash *(<15 cm of mineral)*

JACK PINE (Prescribed Burns)

Seedbed Number 33



34 *Organic material and ash over shallow-to-deep mineral soil*



Seedbed Description:

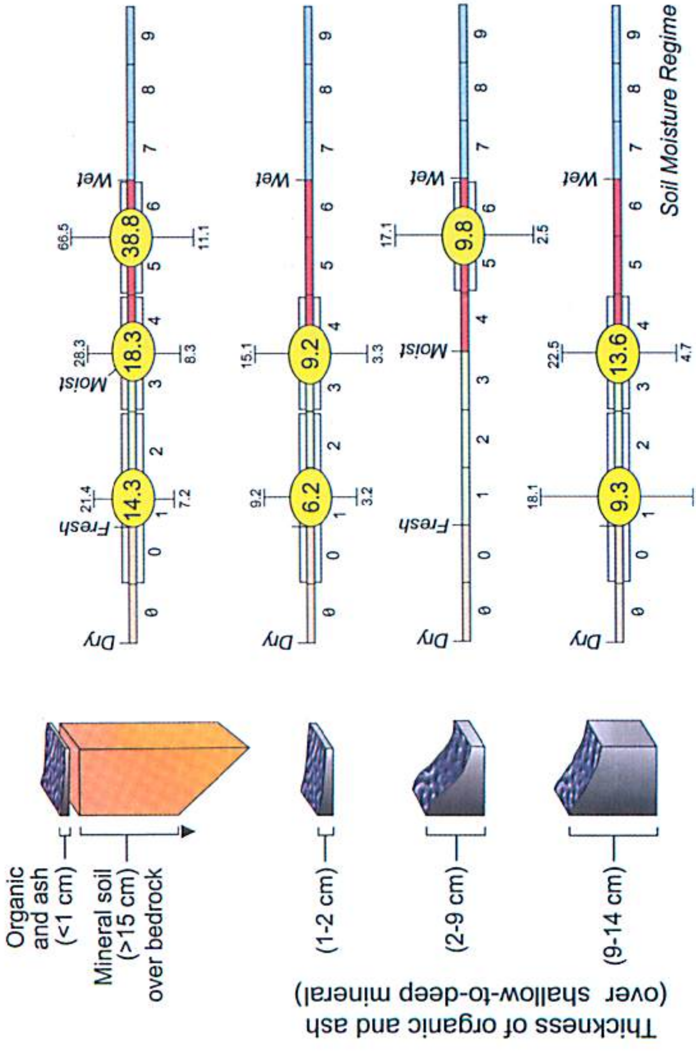
Similar to the previous group, this group of substrates includes the burned and unburned soil organic horizons (LFH layers) as well as ash, charcoal, rotten wood, and dead moss. These materials can occur separately, in mixture with each other, or in mixture with mineral soil. In this instance the underlying mineral soil depth to bedrock is greater than 15 cm.

Establishment ratios on this material generally decrease as the thickness of the organic layer increases or as soil moisture regimes become drier. On sites typically occupied by jack pine, soil moisture regimes are commonly dry to moderately moist. Moist and very moist moisture regimes may occur as smaller inclusions.

Organic material and ash *(>15 cm of mineral)*

JACK PINE (Prescribed Burns)

Seedbed Number **34**



35 *Exposed mineral soil*

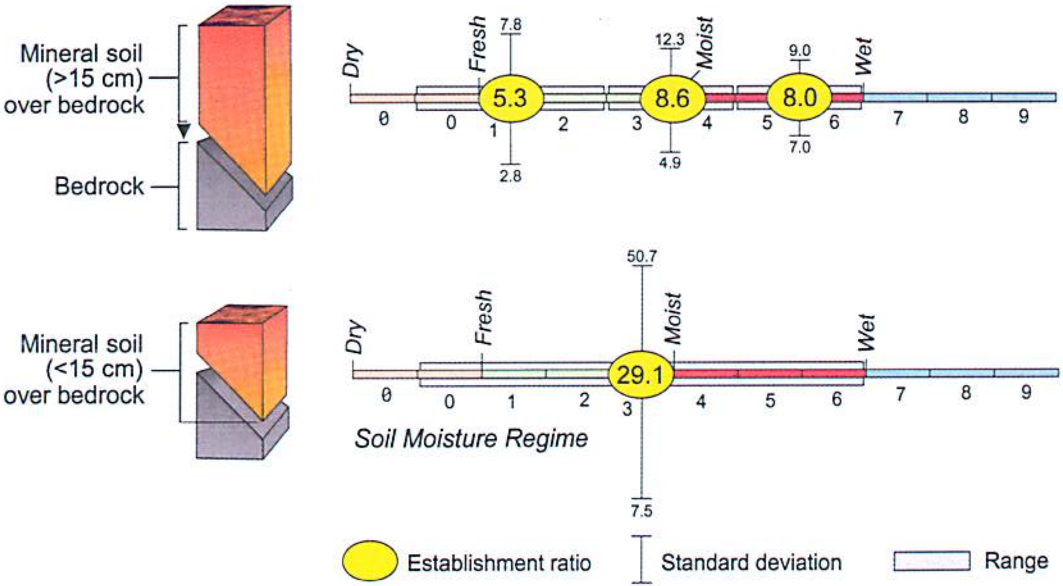
JACK PINE (Prescribed Burns)

Seedbed Description:

This substrate is exposed mainly by removal of the organic layer by fire, but also by timber harvesting and transportation activities.

Jack pine establishment ratios are lowest on the driest (SMR 0-2) and most frequently occurring conditions, and are moderately low on more moist (SMR 3-6) shallow to deep (depth to bedrock >15 cm) mineral soils. The cover of moist to very moist conditions (SMR 4-6) is small; these conditions occur as occasional inclusions.

The moisture regimes of very shallow soils (depth to bedrock <15 cm), and consequently the establishment ratios, vary considerably because of undulating subsurface bedrock and boulder topography. Water seepage into and retention within local bedrock depressions coupled with the removal of excessive moisture by rapid to very rapid drainage result in very favourable establishment conditions, resulting in high average establishment ratios for this condition.


Mineral soil (>15 cm) over bedrock
Bedrock
Dry
Fresh
Moist
Wet
7.8
5.3
2.8
12.3
8.6
4.9
9.0
8.0
7.0
θ
0
1
2
3
4
5
6
7
8
9
Mineral soil (<15 cm) over bedrock
50.7
29.1
7.5
Soil Moisture Regime
Establishment ratio
Standard deviation
Range

7.0 SITE PREPARATION

Receptive seedbed is essential for direct seeding. The objectives of site preparation are: to expose or create seedbed in the amount and distribution specified in the seeding prescription (Section 9); to create microsites with favourable temperature and moisture conditions; and, to reduce as much as possible vegetative competition to seedlings. In the case of hand spot seeding, an additional objective is to allow unimpeded movement of workers over the site by aligning and /or redistributing slash and other obstacles.

On upland sites, site preparation is normally required because the disturbance caused by harvesting equipment alone seldom produces enough well-distributed, receptive seedbeds for direct seeding to be successful. On peatlands, however, the harvesting disturbance can sometimes expose enough seedbed to eliminate the need for subsequent site preparation.

7.1 General Principles

On uplands, site preparation must remove slash and soil layers with poor moisture-supplying capability (typically the L and F layers of the forest floor) and expose seedbeds located just above, at or just below the mineral soil-humus interface (thin F, thin H, and upper mineral soil horizons). Establishment ratios on these seedbeds are usually many times greater than on relatively undisturbed soils (litter and deep F), or on inverted mounds (spoil banks) (Figure 7.1); see also Section 6). As the Soil Moisture Regime (SMR) increases, the optimum seedbed is found higher in the soil profile, from shallow mineral horizons for drier SMRs to the H or F horizon for wetter SMRs.

The main benefit of removing a large portion of the forest floor layer on uplands is an improvement in the surface moisture conditions for seedling germination and establishment, but other benefits include soil warming, less extreme surface temperatures, and frequently a reduction in vegetative competition.

Inappropriate site preparation on uplands can have negative consequences for seedling establishment. The incidence of frost-heaving increases when fine-textured soils are exposed, the risk of moisture deficits increases when coarse-textured soils are mounded; nutrient supply to seedlings is reduced when lower mineral soil horizons (B and C) are exposed. These consequences can be avoided by careful planning and proper execution of the site preparation prescription.

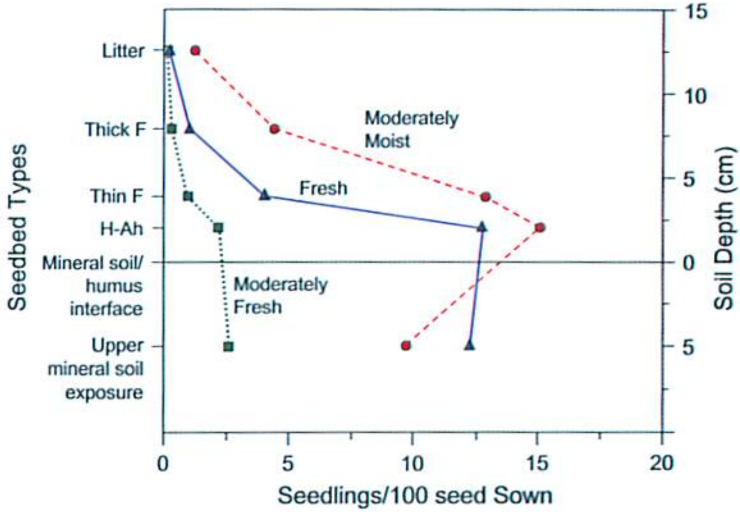


Figure 7.1 Mean fifth-year seedling establishment ratios by Soil Moisture Regime category and seedbed type for black spruce on upland coarse-textured soils. (*Fleming et al. 1995*)

On uplands, site preparation implemented in a regular pattern can potentially result in minimal quadrat-to-quadrat variability in seedbed areas, although typical operations result in considerable variability.

On peatlands, site preparation should aim to remove the living portions of *Sphagnum* moss and remove layers of living feathermoss and feathermoss peat. The soil surface of lowlands is a mosaic, typically dominated by patches of *Sphagnum* and feathermosses. In addition to this horizontal variation, the vertical profile of the peat may exhibit a layer of peat formed by one of these moss types above a layer of peat formed by another moss type. Living feathermosses and feathermoss peat are not acceptable seedbeds because they dry rapidly even on peatlands. Poorly decomposed *Sphagnum* peat is superior to living *Sphagnum* moss, because the living moss can engulf newly established seedlings. On peatlands, the combined vertical and horizontal variability in substrates preclude low quadrat to quadrat variability in seedbed areas. Consequently, the distribution of receptive seedbed on peatlands resulting from both harvesting and site preparation is often more variable than on uplands.

Site preparation should be carried out as soon as possible after harvesting so that seeded species become established before competitive species can dominate the site. Site prepare prior to the release of seeds from supplementary seed sources, such as slash and seed trees, so these seed sources can contribute to stocking.

7.2 What Are Some Points to Consider When Planning for Site Preparation?

The prescription for site preparation must specify an amount and distribution of receptive seedbeds: (i) that will result in regeneration success; and (ii) that is operationally achievable. The prescription must take into account the site preparation methods that are available, and their capabilities and limitations. Proper execution of the site preparation prescription is a prerequisite for direct seeding success, but may sometimes be difficult, particularly on shallow-soil sites (e.g., NWO SS1, SS2, SS3).

Prescription development and execution may be complicated by the fact that many seeding blocks are made up of a patchwork of associated but distinct site types; optimum treatment requires site adapted site preparation.

Considerations for choosing a site preparation method fall into three main categories:

- biological: How well does the method prepare receptive seedbed on a given site?
- economic: Is it cost effective, given the site and its location?
- technical: Can the selected method be applied effectively on the site?

7.3 What Site Preparation Methods Are Available?

Site preparation methods include manual (boot-screefing, hand tools, etc.), motor manual (commonly, an end tool adapted to either a brush saw or chainsaw), mechanical site preparation (MSP), prescribed fire, chemical site preparation and combinations of two or more of the foregoing.

Both manual and motor manual methods of site preparation are labour intensive. Generally, they are suitable for either small scale regeneration efforts or supplementary in-filling of localized failures in otherwise successfully regenerated large scale sites. Manual and motor-manual methods may be associated with either spot seeding including shelter cones or planting.

Both mechanical site preparation methods and prescribed burning are options on a range of sites; disturbance by full-tree harvesting may be an additional option on lowland sites (Figure 7.2).

MSP is commonly used to prepare large industrial scale sites for aerial broadcast seeding. However, on some sites seed application may be integrated with MSP as in row seeding (e.g., Bart seeder with disc trenchers or the Bräcke patch-scarifier-seeder), or manual spot seeding may be used. The time window for combined seeding and site preparation is relatively narrow. However, if a range of upland site conditions are available, MSP may be carried out throughout the frost free period. Similarly, on both peatlands and transitional-to-upland sites, MSP may be carried out when the soil is either frozen or partially thawed – when the surface is sufficiently thawed to be tilled / relocated and the subsurface frozen substrates will support the heavy machinery (Sutherland and Foreman 1995).

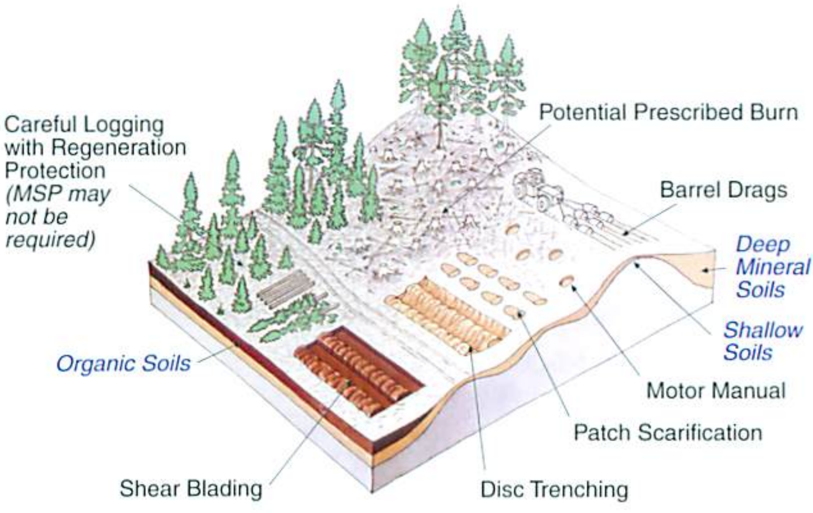


Figure 7.2 An illustrated example of how to match the site preparation method to the site. *(adapted from von der Gönna 1992)*

7.3.1 Mechanical site preparation methods on uplands

The method selected should match the slash and soil conditions and the species to be seeded. Because site conditions (SMR, soil type, slash loading, humus depth) often vary within a cutover, ensure that the equipment operator understands the objectives of the site preparation prescription and how to adjust the implement to achieve consistent results as conditions change across the site.

Of the eight classes of MSP methods described by Ryans and Sutherland (2001), only screefing, trenching, occasionally inverting and mounding, and, rarely, mixing are suitable for preparing receptive seedbeds for direct seeding. However, other described methods including clearing and shearing, raking and chopping may be used in conjunction with chemical site preparation and/or prescribed fire. The effectiveness of such equipment in creating specific seedbed conditions suitable for direct seeding is presented in Table 7.1.

There are many impediments to mechanical site preparation that can significantly inhibit the ability of the equipment to carry out the desired effect. These difficulties may be directly related to the site: excessive slope, poor trafficability due to interrupted drainage patterns and variable plasticity within the soil profile, which influence bearing strength and traction capacity of the prime mover. These site related difficulties may be overcome by allowing some flexibility in the timing of the operation and ensuring that a site appropriate scarifier/prime mover combination is used.

Impediments may also come in the form of physical obstructions such as surficial erratic boulders, overly stony or cobbled soils, dense stump fields and high slash loading following harvesting. It may be possible to overcome some of these impediments by increasing the power of the prime mover, installing a slash-parting blade or increasing the weight of drag units or downward pressure of discing units. If these adjustments are not effective in achieving the required exposure with a single pass, a second pass may be required.

If slash or stony conditions are too harsh for effective mechanical site preparation, consider motor manual or manual screefing of individual seed spots. On shallow or extremely coarse-textured soils, maintain nutrient availability by prescribing shallow site preparation in small patches or narrow furrows.

Black spruce has more exacting seedbed requirements than jack pine. Monitor the site preparation operation carefully to ensure that the prescription for seedbed quantity and quality is fulfilled.

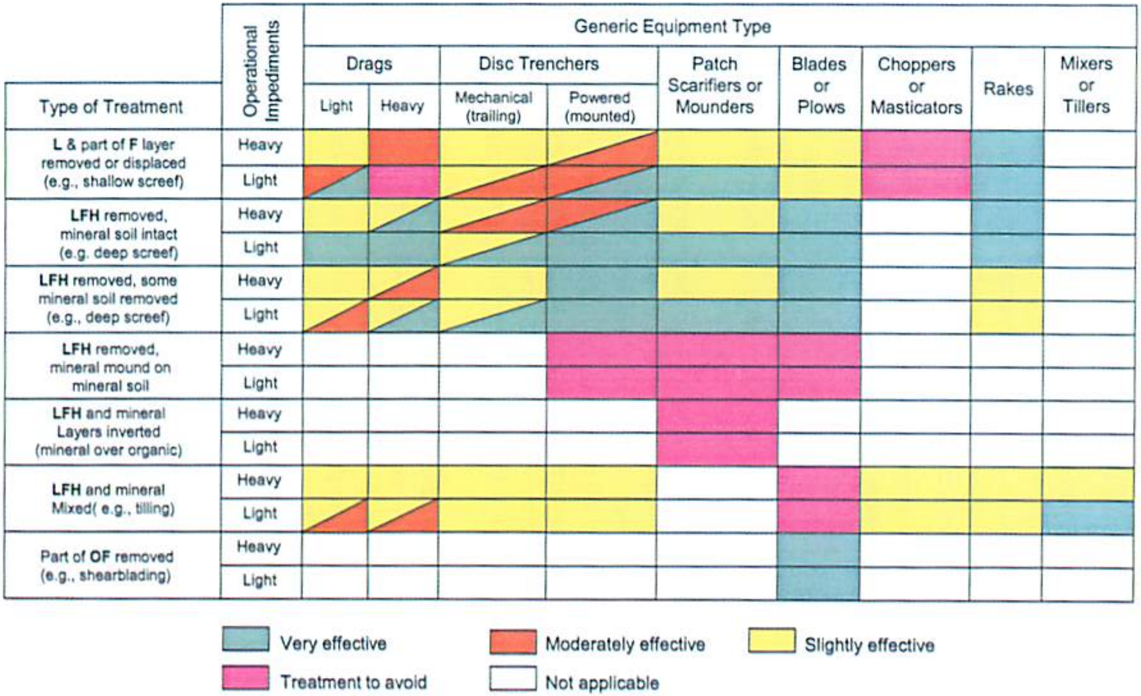


Table 7.1 Effectiveness of site preparation equipment in creating specific soil microsites suitable for direct seeding *(adapted from Ryans and Sutherland 2001)*.

7.3.2 Mechanical site preparation methods on lowlands

Tractor-mounted shearblades (e.g., Rome, Fleco, and Superior V-blade) have been used to prepare lowland seedbeds for black spruce. The peat soil must be thoroughly frozen so that the tractor pads do not create ruts. Blading can move slash into windrows, and depending on the microtopography, remove a thin layer of surface moss and peat, or remove the tops from moss hummocks. Deep blading is not desirable on peatlands because of shallow water tables. Clumps of *Sphagnum* peat detached by deep blading are not good seedbeds because they are not well connected to the underlying water supply.

7.3.3 Prescribed burning

When considering prescribed burning for site preparation, take into account the following factors: fuel loading, soil substrate, SMR, landforms, stage of green-up, and boundary controls (Racey et al. 1989; Archibald et al. 1994). Choose a harvesting method that will provide the fuel load required to carry combustion. Do not use prescribed burning when preservation of advance growth is an objective.

The degree of burn achieved is dependent on weather conditions and the ignition technique. Fairly intensive burn conditions are needed to sufficiently reduce slash and organic matter and create receptive microsites for seeding. Refer to Duff Moisture Codes and the Prescribed Burn Manual (Ontario Ministry Natural Resources 1987) to assist in carrying out the burn.

7.3.3.1 Prescribed burning on upland sites

The fire must be intense enough to burn sufficient duff and raw humus to achieve some degree of mineral soil exposure (Chrosciewicz 1990a). In general, burn to reduce the thickness of the LFH horizon to just above the mineral soil/humus interface. If the burn is too severe, and the humus layer is completely removed, an inhospitable environment for seedling establishment can result. In northern Ontario, summer prescribed burning programs traditionally began July 15, but extending the burning window into early summer can significantly increase the availability of suitable burning days in a season (Archibald et al. 1994).

For some NWO FEC V-types (20, 31, 33, and 34), burning can be effective on fresh to moist, fine textured, deep to moderately deep S-types (S5CS10, SS7, and SS8). Fire should produce about 50 percent mineral soil exposure in a patchwork of residual, partially burned humus. However, on these types of sites there is a higher risk of seeding failure due to drought.

Jack pine V-types (17, 18, 28-30, and 32) that are tree-length harvested may be well suited to burning because of their slash loading. However, if V-types 18, 29, and 32 (jack pine/feathermoss) are full-tree logged, it is not likely they will burn well unless a continuous cover of feathermoss is present to carry the fire. Though prescribed fire will open jack pine cones in the slash, most of the seeds are destroyed.

Do not burn on poor quality, coarser-textured sandy uplands (V30). These soils are nutritionally poor and have thin organic layers. Deep burning destroys this organic layer resulting in decreased soil water holding capacity, soil moisture content, soil nutrients and increased potential for erosion resulting in lower long-term site productivity.

7.3.3.2 Prescribed burning on lowland sites

This site preparation method may be effective on lowland sites in reducing slash coverage and in slowing *Sphagnum* moss growth. The use of heavy equipment may be too costly or unwarranted on these sites because of the potential for site degradation (e.g., sites where the permanent water table is less than 1 m below the surface).

Because *Sphagnum* is an excellent black spruce seedbed, burning is not considered essential to regenerate *Sphagnum*-rich sites, unless there is a heavy cover of slash (i.e., NWO FEC S11, S12S, and SS9, and NEO FEC STs 11, 12 and 8). However, moderate-to-severe burning can improve the success of black spruce seeding. It scorches living *Sphagnum* and subsequently slows its growth, burns feathermosses and feathermoss peat down to wetter layers, eliminates slash that often covers significant portions of the seedbed, improves seedbed fertility and, sets back competition from shrubs and grasses for a time.

On sites with a high speckled alder cover, mild burns can favour black spruce regeneration by reducing alder densities without totally removing it. If too much alder is removed, other competitors are favoured, which negates the advantage for black spruce. In NW Ontario, speckled alder is an important competitor in V-types 22, 23, and 35; and may be so in V-types 34 and 36; in NE Ontario, in ecosites 12 and 13.

7.3.4 Disturbance by harvesting equipment on lowland sites

Full-tree harvesting on lowland sites (NEO FEC STs 11 and 12; NWO FEC V-types 35,36 and 37) can be an effective and economical method of exposing *Sphagnum* peat seedbeds. Full-tree harvesting reduces the amount of slash coverage of seedbeds, and the dragging of tree crowns along skidways prunes away the living portions of the *Sphagnum* and exposes the poorly decomposed peat below. Sufficient coverage of receptive seedbeds is likely to occur mainly with summer harvesting, and will be concentrated along equipment trails.

Direct seeding of the equipment trails will complement preservation of black spruce advance growth between the skid trails.

This technique is not appropriate for site types that are susceptible to rutting (e.g., NEO STs 12 and 13).

RECOMMENDATIONS

- Identify fragile sites (e.g., very shallow-soiled uplands and rich organic sites) and minimize their disturbance.
- Prior to treatment, determine slash loadings, stocking, and density of advance growth, topographic uniformity, competition potential, soil depth, and Soil Moisture Regime.
- Ensure that seedbeds are well distributed over the site.
- Avoid prescribing any form of site preparation treatment on sites that have high levels of post-harvest advance growth.
- Ensure that the site preparation equipment operator is well aware of the objectives and adjusts the machinery to achieve consistent results as conditions change over the site.

8.0 SEEDBED ASSESSMENT

8.1 Why Do a Seedbed Assessment?

A seedbed survey should be carried out after site preparation and before seeding to assess the area and distribution of available seedbeds, and to identify portions of the seeding block where site preparation is inadequate. The survey will determine whether the site preparation prescription has been satisfied, and to some extent, allows for adjusting the seeding rate prescription.

8.2 Seedbed Survey for Broadcast Seeding

Most seedbed surveys are plot-based. The size of the sample plot (quadrat) should be the same as the size of the stocking unit used to assess regeneration (typically 4 m^2).

The number of plots needed to adequately describe the seedbeds in the proposed seeding chance can be determined statistically. However, this requires pre-sampling the area to ascertain seedbed variability and then calculating the total number of quadrats necessary. In an operational setting, this approach may be impractical; therefore, it is recommended that a minimum of 100 quadrats per seeding chance be used, 200 being preferable. This approach will normally provide an accurate estimate of the area of most seedbed types.

Ideally, the quadrats should be randomly located: overlay a map of the seeding block with a numbered mylar grid (similar to those used to calculate stand areas), and use a table of random numbers to choose the quadrat locations. Systematic location of quadrats can simplify positioning and navigation within the cutover, but invalidates the statistical basis for determining accuracy. Clustering quadrats reduces the amount of walking time required, but clustered quadrats are then not independent, and individual quadrats cannot count fully to the required sample size (Figure 8.1). For example, the accuracy provided by 20 randomly located clusters of 10 quadrats is less than that provided by 200 randomly located quadrats. Thus, more quadrats must be sampled when using clusters.

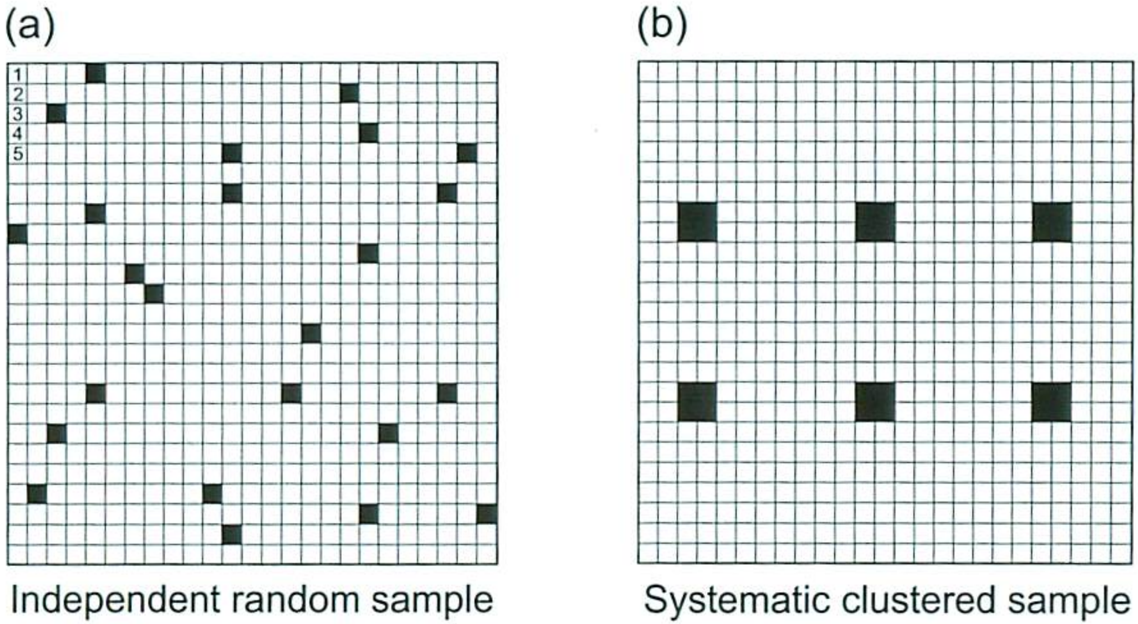


Figure 8.1 An illustration of two sampling techniques: (a) an independent random sample, and (b) a systematic clustered sample.

The following combinations provide roughly equivalent accuracy:

- 200 individual quadrats
- 102 clusters of 2 quadrats
- 54 clusters of 4 quadrats
- 30 clusters of 8 quadrats
- 25 clusters of 10 quadrats

If a random clustered design is selected (e.g., a 20-m line segment containing 10 quadrats), ensure that the site preparation and sampling patterns do not coincide and result in bias. Survey lines should cross the mechanical site preparation furrows at a 90° angle (perpendicular to the direction of site preparation). Close attention should be paid to the variable direction of the site preparation, and the angle of the sampling pattern should be adjusted as required.

Areas with wide variation in site type or in uniformity of site preparation should be stratified before sampling is carried out to provide greater accuracy. This work may be done in the office if maps or aerial photographs are available.

Appendix E gives a step-by-step guide to establishing baselines, transects, and quadrats to achieve a random clustered sampling pattern.

8.2.1 Quadrat assessment

Determine seedbed types and their percent coverage for each 4-m^2 quadrat. Use Section 6 to identify common seedbed types, to determine their relative position within the soil horizon, and their potential receptivity. Note that the term seedbed not only refers to those surfaces that have been exposed by site disturbance (mechanical site preparation, prescribed burning, or the logging operation) but may also include surfaces that are in an undisturbed state (e.g., living *Sphagnum* and litter).

The seedbed classification used in the survey must provide enough detail to allow the development of a sound prescription, but should not be so detailed that it makes the survey and subsequent analysis inefficient. Generally, all seedbeds with high receptivity should be identified, unless they are very rare. Identify seedbeds with high area coverage even if they have low receptivity, since they may significantly augment stocking. Seedbed types with similar characteristics (especially similar ERs) can be lumped together. Do not identify non-receptive substrates (rock, water, thick slash, stumps etc.)

For lowland black spruce sites the main seedbed types are typically:

- compact living *Sphagnum* moss
- loose living *Sphagnum* moss
- exposed *Sphagnum* peat
- living or dead feathermoss
- exposed feathermoss peat
- rotten wood
- moderately to well-decomposed organic matter

For upland black spruce and jack pine sites the main seedbed types are typically:

- upturn
- litter
- thick - F
- thin - F
- thin - H
- upper mineral soil horizon [<10 cm below mineral/humus interface]
- lower mineral soil horizon [>10 cm below the mineral/humus interface]

Appendix F provides step-by-step methods for assessing quadrats.

Besides the above, information on advance growth, cone quantities, and site conditions can also be gathered for silvicultural planning purposes. An example of a quadrat survey tally sheet (Figure F.1) is provided in appendix F. Electronic data recorders can also be used to facilitate the entire operation.

The time required to carry out a seedbed assessment entailing 150-4 m^2 sample plots (not including block layout) would take a trained two person crew approximately 12 to 14 working hours.

8.3 Seedbed Assessments for Spot Seeding or Row Seeding

The objective of a spot seeding survey is to determine the number of seedable spots per ha (e.g., for use in conjunction with a seed shelter operation). The criteria for the selection of a seedable spot must be established prior to the assessment. Section 6 of this Guide can help identify the most suitable seedbeds for a particular species and site type. The minimum acceptable distance between seed spots must also be determined, because it strongly influences the number of seedable spots per ha. It is undesirable to place seed spots too close together; this could lead to overcrowding. However, for many seedbed types, the percentage of stocked seedbeds will be much lower than 100 percent: to establish a given number of stocked spots per ha, it is necessary to set out a substantially higher number of seed spots. The distance between spots must decrease as the percentage of stocked spots decreases.

Base the survey on a minimum acceptable distance between seed spots; about 1 m is appropriate for most circumstances. Confine sampling to the site-prepared sections of the seeding chance, since this is where seeds will be applied.

Unlike a plantability assessment, it is not necessary to define the spots as receptive, marginal or non-receptive. Simply identify the seedbed type.

Appendix G provides details on carrying out a seed spot survey.

CONSIDERATIONS

- The results of the assessment for spot seeding can be entered into PC SEED to provide an estimate of stocking.
- If the stocking is less than desired, consider:
  - (i) decreasing spacing between spots.
  - (ii) carrying out manual spot screefing at the time of seeding to increase spot density.
  - (iii) increasing the number of seeds per spot.

For row seeding carried out simultaneously with site preparation, a seedbed assessment is not necessary. However, to ensure that the prescribed seeding rate is followed, regularly monitor seed deposition on the prescribed microsite and ensure proper inter row spacing during the operation.

9.0 DEVELOPING DIRECT SEEDING PRESCRIPTIONS

Three factors that have an important bearing on stocking and that can be influenced by the forest manager are described in the "seeding success triangle" (Figure 9.1):

- seedbed receptivity (percent);
- seeding rate (e.g., 50,000 seeds/ha);
- seedbed area (amount and distribution) (e.g., 20 percent of the gross area, uniformly distributed).

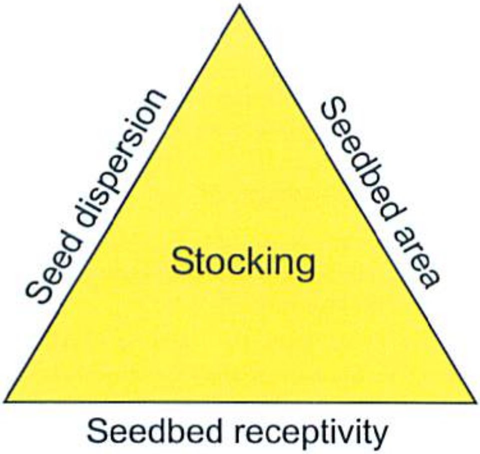


Figure 9.1 The three elements that determine stocking in broadcast seeding *(Groot 1994).*

The prescription for direct seeding should specify the area and distribution of receptive seedbeds and the seeding rate. Prescriptions that make use of information about site types and seedbed receptivity have the greatest likelihood of success, but often prescriptions are developed with less than complete information. Depending on the information available, several approaches to the development of prescriptions are possible.

9.1 What Information Sources Exist?

Information on seedbed availability

• The typical seedbed availability associated with a particular site preparation technique on a certain site may be known from local experience or published reports. Using such information does not require a visit to the site, but prescriptions based on such information may be invalidated if the particulars of the situation produce markedly different seedbed availability. A site inspection is highly recommended.

• An inspection of the site can provide a subjective estimate of seedbed availability. The quality of this information is dependent on the ability of the inspector to estimate seedbed amounts.

• A thorough survey can be carried out to determine seedbed availability (see Section 8). This approach provides the most accurate seedbed information.

Information on seedbed receptivity

Because of variable weather and site conditions, it is not possible to have exact knowledge of seedbed receptivity prior to the seeding operation. Probable or typical values can be determined, however.

• Local experience can be the basis for a relative ranking of receptivity for different seedbeds, but does not provide absolute values for establishment ratios.

• The seedbed data sheets (Section 6.5) provide establishment ratios for a number of common seedbed types. This information was obtained from a number of direct seeding experiments, and has greatest applicability to areas that have similar site types and weather patterns.

• Locally collected information on seedbed receptivity (seed spots or less direct techniques) is the best source of receptivity information. (see Section 11)

Information on site type

• Site type can be interpreted from aerial photographs, maps and general knowledge of the region.

• Site types can be identified during an inspection of the site. The intensity of this inspection can vary from a cursory examination to a detailed survey (Section 3).

9.2 What Approaches Can be Used to Develop Prescriptions?

Use a standard prescription based on local experience.

The combination of site preparation and seeding rate that will result in successful stocking and density for a given site type may be known. Local experience can provide good prescriptions, but it also involves risks. If conditions (e.g., site type, quality of site preparation) change, local experience may offer little immediate guidance for changes to prescriptions. If regeneration fails, it may be difficult to identify the cause of failure.

The main requirement when using a standard prescription is that the site is similar to sites where the prescription has succeeded previously. Because site type can be interpreted from maps and aerial photographs, a visit to the site, although highly desirable, is not strictly necessary.

The availability of more detailed information on seedbed receptivity, site conditions or seedbed availability (e.g., from a survey conducted after site preparation) may prompt modification to a standard prescription. This modification could include changing the seeding rate, or, in cases of grossly inadequate site preparation, to prescribe site preparation re-treatment or planting of the site.

Develop a prescription based on published statistical relationships.

Broadcast seeding experiments have provided statistical relationships between seeding rates, seedbed amounts and stocking for jack pine in northeastern Ontario and black spruce on peatlands in the Ontario clay belt. In both cases, the relationships provide a basis for prescribing combinations of seedbed amounts and seeding rates.

Riley (1980) developed curves relating stocking to receptive seedbed availability for several seeding rates of jack pine in northeastern Ontario (Figure 9.2). Based on these curves, Riley (1980) considered the optimum receptive seedbed[1] area to

[1] Receptive seedbed was defined as: a) exposed mineral soil with a firm base, or b) a thin (<13 mm) duff/mineral soil mix which should readily settle to a firm base, or c) firm mineral soil with a very thin duff cover, generally not more than 7 mm thick.

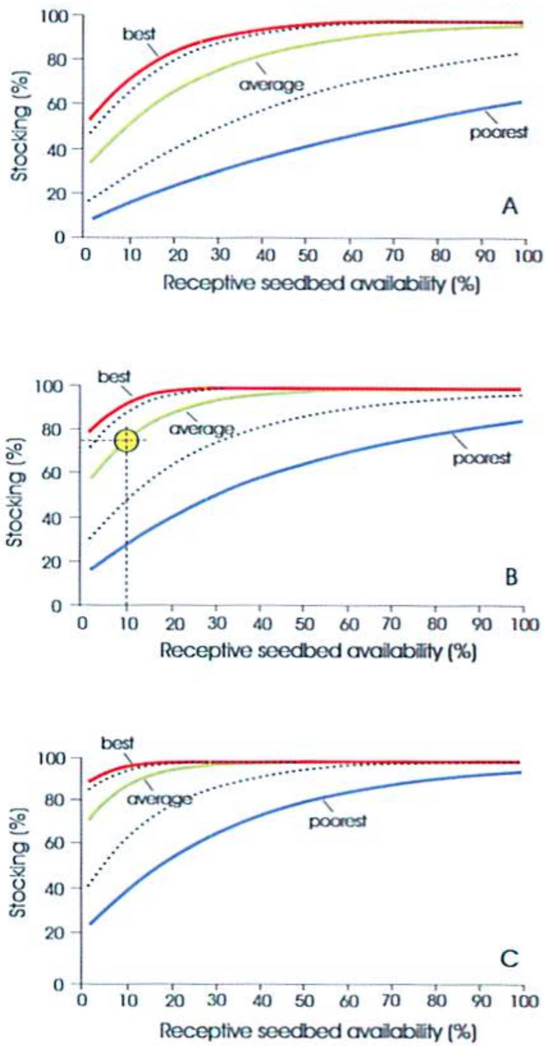


Figure 9.2 Jack pine stocking probability curves for a range of growing conditions by seedbed availability class for deposition rates of (A) 25,000, (B) 50,000 and (C) 75,000 seeds/ha three years after seeding *(Riley 1980)*.

be 15 to 25% with a seeding rate of 50,000 seeds per ha. The effects of altering seedbed availability or seeding rate can be examined using these curves. For example, a mean 3rd year stocking value of 76 to 77% can be achieved with 10% receptive seedbed area and a seeding rate of 50,000 seeds per ha, or with 30% receptive seedbed and a seeding rate of 25,000 seeds per ha.

Groot and Adams (1994) developed a relationship between stocking and effective seeding rate (actual seeding rate x receptive seedbed[2] area) for broadcast seeding black spruce on peatlands in northeastern Ontario (Figure 9.3). From this relationship, an effective seeding rate of 6 or 7 seeds per quadrat[3] (4 m^2) was recommended to achieve 80% stocking. The following combinations of seeding rate and seedbed area all result in an effective seeding rate of 6 seeds per quadrat: 50,000 seeds per ha and 30% receptive seedbed area; 100,000 and 15%; and, 200,000 and 7.5%. If lower stocking is acceptable, the relationship in Figure 9.3 can be used to determine the appropriate effective seeding rate, leading again to varying combinations of actual seeding rate and receptive seedbed area.

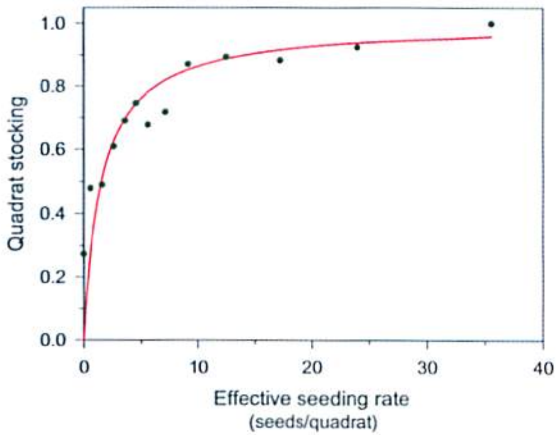


Figure 9.3 Relationship between quadrat stocking and effective seeding rate (number of seeds per quadrat x area of receptive seedbed per quadrat) *(Groot and Adams 1994).*

2 Receptive seedbed was defined as: compact *Sphagnum*, poorly decomposed *Sphagnum* peat (in situ) or, sheared *Sphagnum*.

3 [Effective seeds per quadrat = viable seeds per ha. / 2,500 quadrats per ha. x receptive seedbed area]

Both the jack pine and black spruce relationships give the stocking probability for quadrats with a given amount of seedbed and seeding rate. The relationships would be immediately applicable to the whole seeding block, if each quadrat had the same seedbed area. Seedbed areas typically vary from quadrat to quadrat, however, and Riley (1980) outlined a procedure to take this variation into account. Essentially, the procedure involves the following steps: (i) conduct a seedbed survey; (ii) determine the percentage of quadrats falling into receptive seedbed area classes; (iii) for a selected seeding rate, determine the probability of stocking for each receptive seedbed area class; and (iv) sum the products of the values determined in (ii) and (iii). The same procedure can be used with the peatland black spruce relationships.

It should be recognized that these statistical relationships may not be valid in different regions, on different site types, or when the relative proportions of different seedbed types change.

Develop a prescription based on probabilistic models.

Probabilistic models use information on seedbed availability, seedbed receptivity and seeding rate to estimate stocking. Such models are more complex and have not previously been used operationally. The PC-SEED program included with this manual is designed to simplify the use of probabilistic models.

PC-SEED is a spreadsheet-like DOS-based program that can be used to explore the relationship of stocking and density to seedbed characteristics and seeding rate. The PC-SEED manual provides details on the commands used to operate the program.

PC-SEED requires information on seedbed area and receptivity for each seedbed type. The name of the seedbed type ("Seedbed Type") is entered into the first column, and seedbed receptivity is entered into the second column ("Recept"). Sources of information for receptivity data are outlined in section 9.1. Ideally, seedbed areas are determined from a seedbed survey, and are entered into the "Q1" ... columns in PC-SEED. If only an estimate of the average area of a seedbed is available, it is also possible to enter this value in the "Area" column (select **|Calculate|Areas|Generate** from the menu). To incorporate the effect of variability in seedbed areas, PC-SEED generates quadrat areas with a selected value of variance.

When the required information has been entered, the probability of each quadrat being stocked can be displayed along the bottom line of the screen (**|Setup|Bottom Line|Stocking**). These probabilities are based on a seeding rate that can be set in **|Calculate|Broadcast|Seeding Rate**. The effect of varying seeding rate can be examined by selecting **|Graph|Stocking** and a graph scale.

9.3 Considerations in developing broadcast seeding prescriptions

Diminishing returns

It is evident from Figures 9.2 and 9.3 that stocking does not increase with seedbed area and seeding rate in a linear manner. Instead, the law of diminishing returns applies and increases in seedbed area or seeding rate eventually produce smaller and smaller increases in stocking. As a result, it is often not feasible to compensate for insufficient seedbed area or low seedbed receptivity with higher seeding rates.

Natural seed sources

Natural sources will often make a substantial contribution of seed in direct seeding operations. This seed can originate from residual trees on or adjacent to the harvested area, or from cones in the logging debris. If the natural seed input is expected to be significant, it must be considered when developing prescriptions.

In PC-SEED the effect of natural seed input can be taken into account by adding it to the planned seeding rate in **|Calculate|Broadcast|Seeding Rate**. For example, if the planned seeding rate is 100,000 seeds per ha, and the estimated natural input is 20,000 seeds per ha, then a value of 120,000 should be entered in this area.

Estimating natural seed inputs can be problematic. One method is to compare seedling densities on areas that have been seeded at a known rate with areas that have not been seeded. If the density on the area seeded at known rate A is D_{n+a}, and the density on unseeded area is D_n, then the estimated natural seeding rate is

$$\frac{AD_n}{D_{n+a} - D_n} .$$

This equation is valid only if the site conditions and the arrangement of seed sources is similar on both the seeded and unseeded areas.

Stratifying seeding blocks

If the seeding block contains areas that differ significantly in seedbed receptivity, type or amount, then the block should be stratified into more uniform sub-blocks (see Section 8.2). Potential stocking should be evaluated separately for each sub-block using local experience, statistical relationships or PC-SEED. This will provide an indication of how regeneration success will vary among the sub-blocks if a single prescription is used over the whole seeding block, or it can provide guidance for tailoring prescriptions to best suit each seeding block.

Confidence limits

Accurate prediction of the outcome of a direct seeding operation is not possible because of the many sources of variability involved. These include weather, natural seed input, seed application, site conditions, and site preparation. As a result, stocking results can show wide variation (Figure 9.2). Information about standard deviation of seedbed receptivity can help a forest manager assess the range of potential results of a seedling operation.

The seedbed data sheets (Section 6.5) provide the standard deviation in receptivity for a number of seedbeds. If the mean receptivity of a seedbed is 25% and the standard deviation is 10%, then a lower confidence limit one standard deviation from the mean would be 25% - (1 x 10%) = 15%. Assuming a normal distribution, receptivity values greater than this lower confidence limit would occur on 84% of all seeding blocks (see Table 9.1 for other values).

Table 9.1 Lower confidence limits and probability of greater values.

Lower confidence limit for receptivity	Probability of a greater receptivity value
mean - 0.5 x standard deviation	69%
mean - 1.0 x standard deviation	84%
mean - 1.5 x standard deviation	93%
mean - 2.0 x standard deviation	98%

These lower confidence limits for receptivity can be used to assess the likelihood of a successful direct seeding operation. In Figure 9.2, the lower dashed line is the stocking result that occurs when receptivity is one standard deviation less than the mean. Stocking will be above this line in 84% of all cases. Similar analyses can be carried with PC-SEED by entering lower confidence limits into the "Recept" column.

Traditional seeding rates

The seeding rate traditionally used for jack pine is 50,000 viable seeds/ha, and 100,000 for black spruce. However, a single seeding rate is not applicable to all situations. A "one size fits all" approach cannot bring about consistent results, because it addresses only one side of the seeding triangle.

Developing spot seeding prescriptions

In planning spot seeding operations (see Section 10.4.4), it is necessary to identify the desired seedbed types, and to prescribe the number of spots per hectare and the number of seeds per spot. It should be noted that the determination of spacing in spot seeding differs from that in tree planting. In planting, the survival of planted seedlings is often sufficiently high that the spacing of surviving trees is similar to the initial spacing. In spot seeding, however, the percentage of stocked spots will be substantially less than 100 percent for most seedbeds. To establish a given number of stocked spots per ha, it is necessary to set out a considerably higher number of seed spots. For example, to obtain 2,000 stocked seed spots/ha when the percentage of stocked spots is 40% requires setting out 5,000 spots/ha.

If the spot seeding is done in combination with mechanical site preparation, the closer initial spacing can be achieved by decreasing the distance between rows of site preparation, or by decreasing the distance between seed spots along a row, or both.

The **Calculate | Seed spot and Graph | Seed spot** options in PC-SEED can be used to explore how seedbed receptivity, number of seeds per spot and seed viability influence stocking in spot seeding.

It is evident that increasing the number of seeds per spot generally cannot compensate for low seedbed receptivity (Figure 9.4). It is possible to compensate for low seed spot stocking by increasing the number of seed spots initially set out, but there is a point at which this becomes impractical. Regeneration using seed spots is most feasible when high receptivity seedbeds are available, or whenseedbed receptivity can be improved using treatments such as seed shelters (see 10.4.4). When seedbeds have high receptivity, a low number of seeds per spot can be used and the proportion of stocked spots is high.

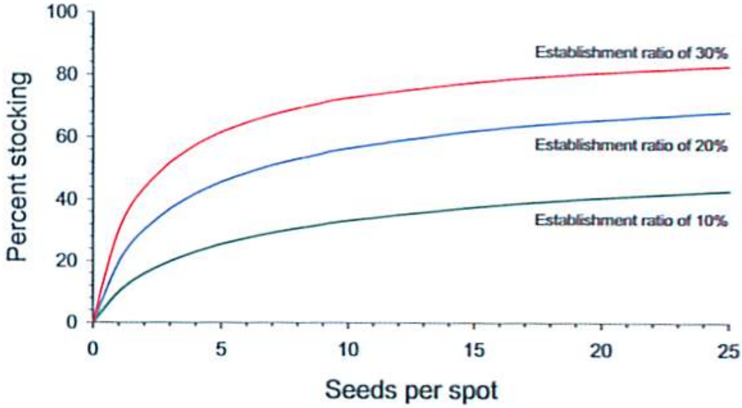


Figure 9.4 Relationship between seeds per spot, establishment ratio and stocking.

Developing row seeding prescriptions

If the row seeding operation deposits single seeds, then the seeding density can be estimated from:

$$\text{density} = \sum_{I=1}^{n} \text{proportion of seeds deposited on seedbed I} \times \text{ER for seedbed I} \times \text{seeding rate.}$$

For example, suppose that a seeder is used to deposit seeds onto mineral soil (ER = 20%) in trenches. The trenches are 2 m apart and seeds are deposited every 50 cm (i.e., 10,000 seeds/ha.). About 90% of the seeds land on the target seedbed and 10% fall on litter seedbeds (ER = 2%) beside the trench.

The density = 90% x 20% x 10,000 seeds/ha
+ 10% x 2% x 10,000 seeds/ha
= 1,820 seedlings/ ha

If the row seeding operation deposits more that one seed per spot, then the procedures used for developing spot seeding prescriptions should be used.

10.0 SEED APPLICATION

The likelihood of regeneration success is increased if the seed is applied at the appropriate time with suitable equipment and methods.

10.1 What Season Is Best?

Generally, black spruce and jack pine should be seeded onto the snow in late winter or in the spring soon after the snow melts. Seeding on the snow is preferable because seeds are able to take advantage of the available soil moisture as the snow melts in the spring. Another advantage of sowing early is that the germinants also benefit from the rainfall occurring in April and May.

Sowing either species later than mid-June is not recommended – stocking will be typically much lower than in spring sowing. Both black spruce and jack pine can be fall-seeded, but there is increased risk that seeds will be lost due to predation, burial, or other causes. Fall seeding should be done as late as possible to prevent premature germination.

10. 2 How Soon After Site Preparation Should Seeding Occur?

Seeding should be carried out after newly prepared seedbeds have stabilized, but before seedbed receptivity begins to decline with age.

After mechanical site preparation, seedbeds may be unfirm because of high porosity and unstable microtopography. Some experienced foresters advise that seeding be delayed for 1 to 6 months after site preparation to allow some soil settling to occur, thus reducing the number of seeds and germinants lost by burying. This is of particular concern for black spruce because of its small seed size. A significant rainfall will achieve much of the weathering required to stabilize mechanically site prepared seedbeds.

Seedbed chemical conditions may be unfavourable for seedling establishment immediately after prescribed burning. Allowing prescribed burns to overwinter will permit burned seedbeds to undergo weathering and leaching resulting in a lower pH, reduced toxicity and improved hydraulic conductivity. Overwintering may not be required for prescribed burns carried out from early July-to-late August and seeded in mid-to-late November.

Seedbed receptivity often declines as seedbeds age, because of re-colonization by vegetation and physical changes in soil structure. Consequently, seeding should be carried out within a year of site preparation. Establishment can be significantly reduced if seeding is delayed on sites that are predisposed to invasion by herbaceous or graminoid competition (Section 3).

When seeded within a year, stocking of jack pine is often in the 68-78 percent range. When seeding is delayed for 1 to 2 years, stocking rates of 18-32 percent are not uncommon.

For black spruce, the greatest establishment ratios on preferred upland seedbeds usually occur in the first year following scarification. However, factors such as near-surface soil moisture, soil and air temperature, frost heaving, and insect and disease conditions vary greatly from one year to the next, and can have a profound effect on seedling establishment ratios. Because of this, seeding black spruce within the first year of site preparation and repeating the seeding one year later may increase the probability of success.

On lowlands, prompt seed application is less critical because of the predominance of seedbeds such as living *Sphagnum* or *Sphagnum* peat; seeding on these types may be successful even if delayed for several years.

10.3 What Seeding Methods Are Used?

Four sowing methods are commonly used operationally with associated site preparation methods:

1. Aerial seeding:
   - in furrows;
   - on intermittent scalps;
   - on burned areas;
   - on surfaces disturbed by harvesting (e.g., peatlands).
2. Mechanical ground seeding:
   - in rows;
   - on patches.
3. Spot seeding with or without seed shelters
4. Ground broadcast seeding

Aerial seeding is the method most used in Ontario. It is well-suited to jack pine, which represents approximately 80% of all seeding done in the province. Research and development are ongoing to improve mechanical ground seeders that sow at the time of scarification. Hand seeding has been carried out on relatively small areas, usually in conjunction with seed shelters. Ground broadcast seeding using the Brohm seeder was practised in the early 1970s using snowmobiles, and worked well for relatively small areas.

Row seeding and hand seeding methods require less seed than aerial seeding where over 75% of the seeds applied fall on non-receptive seedbed.

10.3.1 Aerial seeding

The Brohm aerial seeder is the most commonly used seeder in Ontario. It was developed in the late 1950s and early 1960s by the MNR, and is of slinger design. It is now used in combination with fixed-wing aircraft, most notably the Piper Super Cub (Table 10.1).[1] The Brohm seeder consists of a hopper from which the seed is metered by a variable-speed auger via a flexible duct to a constant-speed slinger beneath the aircraft (Figure 10.1). The rate of seed application can be controlled in flight by adjusting the auger speed (Foreman 1995). Several aerial seeder/helicopter combinations have been developed and used operationally in both northwestern and northeastern Ontario (Figure 10.2). All seeders have unique seed-metering mechanisms. Both the Alberta Forest Seeder, developed by the Alberta Forest Service for turbine-powered helicopters and the Tembec Aerial Seeder, developed by Tembec Inc. (Spruce Falls) use rotating, large-diameter cylinders or wheels, with seed pick-up on the outer surface of the cylinder, to transfer seed from the hopper to the slinger. The Isolair Broadcaster, developed by Isolair, uses a pneumatic seed delivery system (Reynolds 1997).

Table 10.1 Capacity of the Piper Super Cub (PA-18A) Brohm Seeder Combination

Flying Time	5 hours
Area coverage rate	50 to 75 ha per hour
Seed Hopper Capacity	55 kg (approx. 15 million jack pine seed)

1 In Ontario only one contractor (General Airspray, Lucan) has the PA-18A Aircraft Brohm seeder equipment. They first operationally sowed in 1967. As of 2005 they had four aircraft dedicated to aerial seeding. Over time this firm has acquired proprietary knowledge and skills.

Piper PA-18A Aircraft

Brohm Seeder

Figure 10.1 The Brohm seeder has traditionally been used in combination with the Piper PA-18A aircraft.

Jeff Leach (Tembec Inc.)

Alberta Forest Seeder

Tembec Inc. Seeder

Figure 10.2 Examples of two aerial seeder/helicopter combinations

10.3.1.1 Calibration and seed distribution

If possible, the seeder should be calibrated on the ground to determine an output rate that will provide the prescribed application rate for the proposed aircraft ground speed and inter-pass spacing (see Appendix H for the Brohm seeder calibration procedure).

Variation in seedling stocking and density would be least if the seed could be deposited uniformly over the site, but uniform distribution of seeds at the quadrat scale cannot be achieved with broadcast seeding. Random distribution is potentially achievable by broadcast seeding devices, but in practice uneven distribution occurs. Even with completely random distribution, low seeding rates will result in a significant proportion of quadrats receiving far fewer than the average number of seeds per quadrat (Figure 10.3).

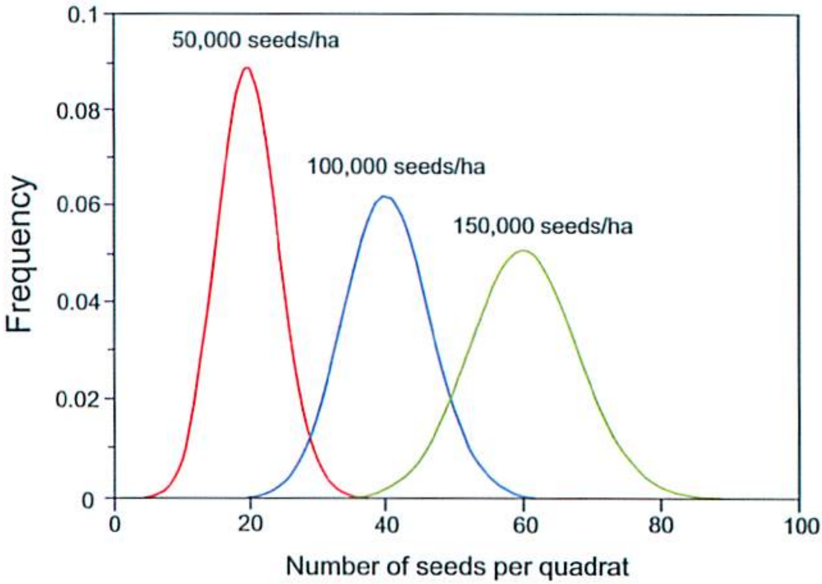


Figure 10.3 Frequency distribution of number of seeds per 4-m² quadrat, for three broadcast seeding rates with random seed distribution *(Groot 1994)*.

In aerial seeding, seed is broadcast in long, parallel swaths; variation in distribution occurs both across and along the swath (Figure 10.4). Based on knowledge of the seed deposition characteristics for particular equipment and operating conditions, the forest manager and the aerial seeding applicator should try to reduce these variations. The following standard has been suggested as a measure of adequate seed distribution: minimum seed deposition on a 4-m^2 quadrat basis should be ≥50% of the mean deposit rate over >90% of the seeding chance (Fleming et al. 1985).

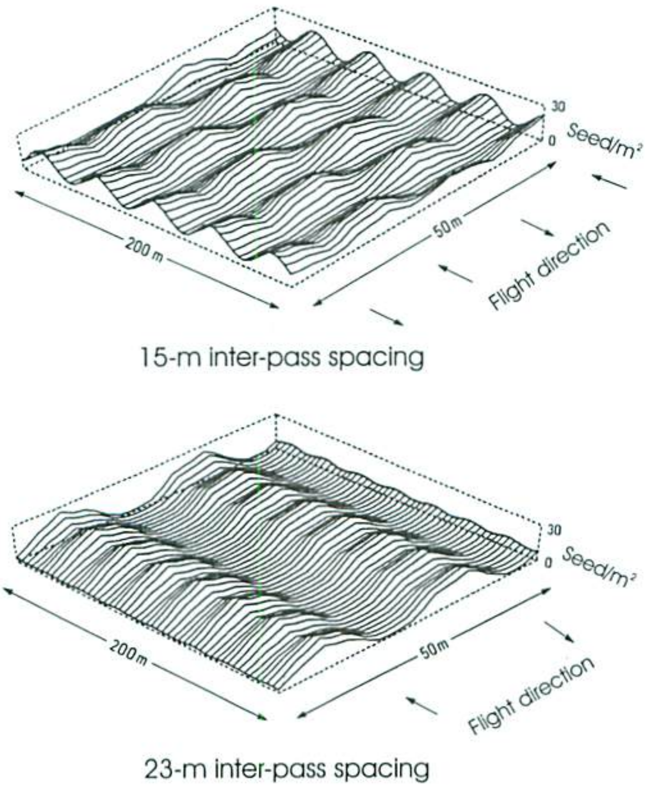


Figure 10.4 Expected black spruce seed distribution across and along the flight path at 15 and 23-m inter-pass spacing, 100,000 seeds/ha. *(Fleming et al. 1985).*

The distribution of seed across and along the swath is influenced by several factors. A primary factor is the pattern of turbulent airflow about and in the wake of the aircraft, which in turn is affected by the particular aircraft-seeder combination in use, crosswind, headwind, aircraft speed and flying height. Seed distribution is also influenced by the flight characteristics of the seed and by the rate of seed discharge.

Seed distribution across the swath determines the inter-pass flight spacing in aerial seeding operations. For example, if most of the seed is deposited within a swath of 20 m, then the spacing of flight passes should not exceed this distance. The Brohm Seeder/Piper PA-18A distributes jack pine and black spruce differently across the swath, likely because of differences in the aerodynamic characteristics of seeds of the two species. Black spruce seed distribution is more symmetrical than that of jack pine seed (Figure 10.5 and 10.6), but requires a narrower inter-pass spacing. The most effective inter-pass spacing for both black spruce and jack pine is 15 m; however, a swath width of 18 m is acceptable for jack pine if flight paths can be maintained within 2 m.

Because the seed output of seeders is not completely steady, but varies in a cyclical pattern, the distribution of seed along a swath can show a wave-like repeating pattern (Figure 10.7). With the Brohm seeder, the surging output of single land augers produced an especially pronounced pattern. Increasing both the number of lands on the auger and its pitch has reduced the variation of distribution along the swath.

To maintain consistent uniform site coverage, gyroscopes are used to maintain parallel flight lines over the site. In the past, ground flag persons were used to improve precision of coverage over (free-flying). Now navigation can be carried out with GPS units (Figure 10.8) (Reynolds 1999a). Correction signals can be obtained from satellites in stationary geo-synchronous orbit (e.g., Landstar).

Jeff Leach (Tembec Inc.)

Figure 10.8 GPS-based AGNAV navigational system

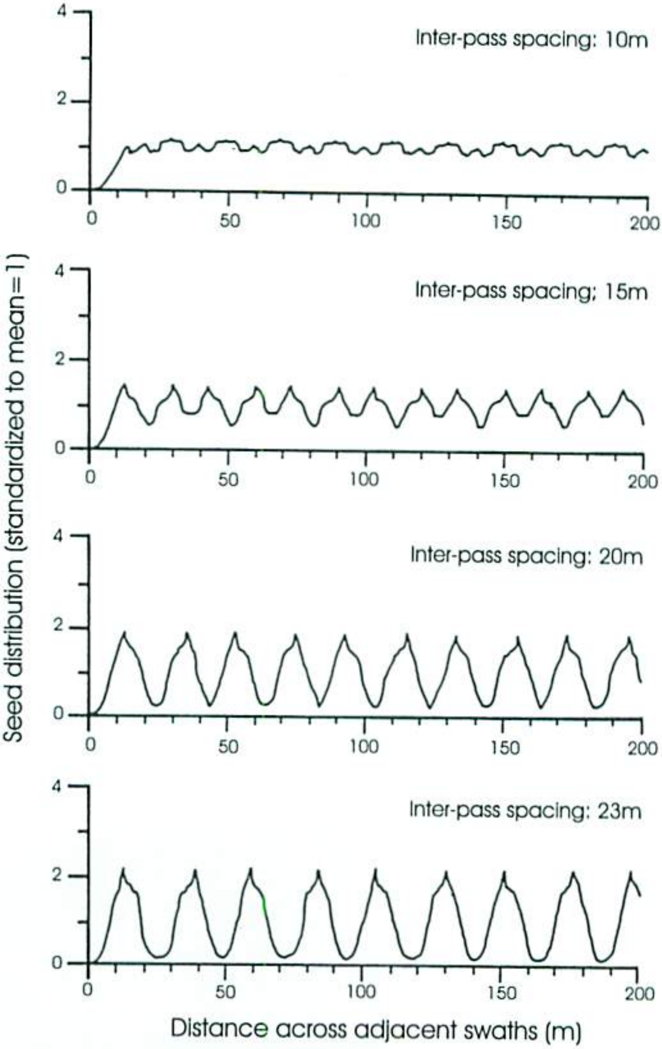


Figure 10.5 Black spruce seed distribution across adjacent swaths at four inter-pass spacings *(Fleming et al. 1985)*.

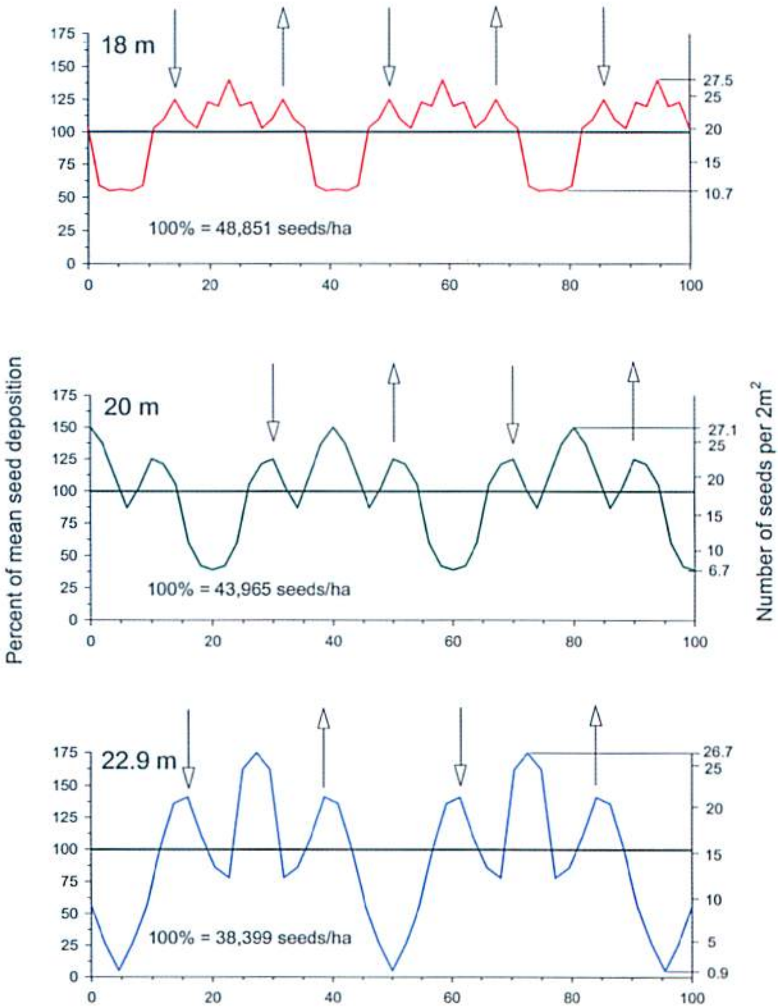


Figure 10.6 Jack pine seed distribution across adjacent swaths at three inter-pass spacings. Arrows indicate location and direction of aircraft track in relation to seed swath *(Riley 1980)*.

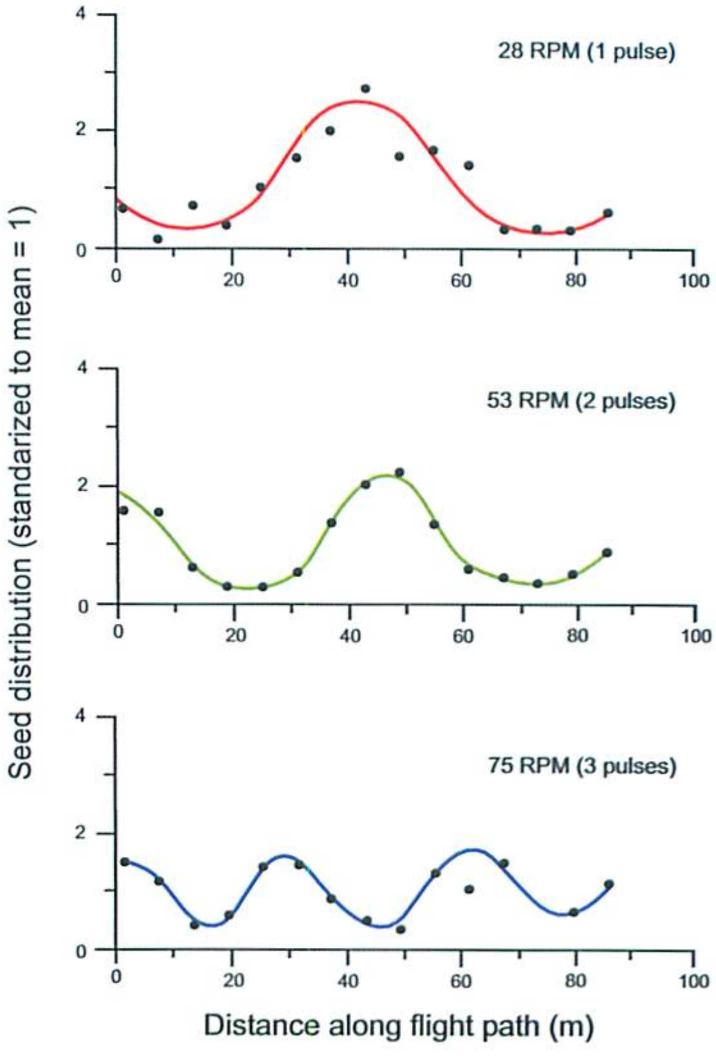


Figure 10.7 Black spruce seed deposition along the flight path *(Fleming et al. 1985)*.

RECOMMENDATIONS

For all aerial seeding equipment combinations careful and consistent calibration and flying procedures are necessary to ensure satisfactory seed deposition and distribution.

For the Brohm Seeder/Piper PA-18A aircraft configuration, the following steps should be taken:

1. Calibrate the seeder carefully using the instructions in Appendix H.
2. Sow at 15-m inter-pass spacing for black spruce and 18-m for jack pine using an accurate guidance system.
3. To avoid large variations in distribution along the flight path, do not sow at auger speeds of less than 70-75 rpm.
4. Seed only when wind speeds at 1.5 m above the ground are less than 10km/hr, and avoid seeding when winds are variable or shifting, regardless of average wind speed.
5. Select a reasonable flying height (25-35 m) and aircraft ground speed (130-150 km/hr), and maintain these throughout the seeding operation. This is of much greater benefit than attempting to fly as low or as slowly as possible (Fleming et al. 1985).

10.3.1.2 How is the seeding deposition rate monitored?

Seeding operations that are accessible should be monitored to quantify the seeding rate and provide the forester with information needed to analyze seeding results. Seed traps are useful for this purpose, and can consist of a wooden frame and a base made of aluminum mesh screening covered with finely woven fabric, such as cotton sheet material or curtain sheers (Figure 10.9). A trap size of 0.25 m^2 (0.5 m on a side) has often been used in experimental seeding projects, but other sizes may be equally or more effective.

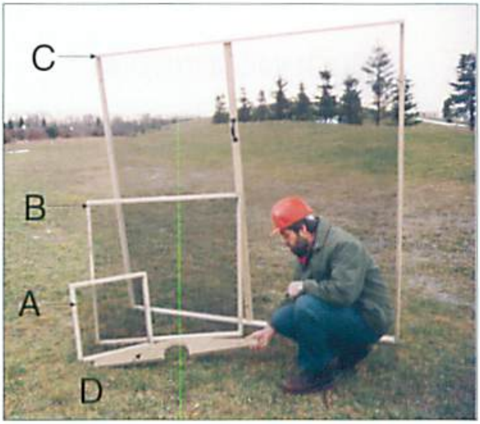


Figure 10.9 Three trap sizes displayed: (A) 0.25 m², (B) 1 m², and (C) 4 m². The 4 m² trap, is equipped with a handle and centre-mounted screw eye to facilitate carrying when using the (D) yoke *(Cameron and Foreman 1995).*

Trap sizes of 4 m² (2 m x 2 m) are suitable to monitor seeding rates of 50,000 to 100,000 seeds/ha; with this size only 25 traps are needed to achieve an estimate that is within 10 percent of the actual rate, 19 times out of 20. For seeding rates of 150,000 or more, use smaller traps (e.g., 1 m²). With 1 m² traps, only 30 traps are required at a seeding rate of 150,000 seeds per hectare, and 25 traps at 200,000 seeds per hectare or more.

To reduce the total number of trap locations in the sample area, clusters are recommended for the 0.25 m² trap size. If trap clusters are used, determine the number required by using the TRAPS program provided with this manual or using the table provided in Appendix I. Enter the prescribed seeding rate (seeds/ha), the acceptable error in the estimate of the mean seeding rate (seeds/ha), the surface area of a single seed trap (m²) and the number of seed traps that will be positioned at each cluster location. TRAPS will determine the appropriate number of clusters.

Alternatively, enter the number of clusters to be established and TRAPS will determine the associated error limits. Because the number of seed traps required increases rapidly as error limits become smaller, narrow error limits are impractical. Appendix I provides an estimate of the number of traps required to sample an aerial application of seed at various seeding rates and confidence intervals.

Set traps out randomly, so that all traps have an equal chance to sample the various seed distribution patterns. An all-terrain vehicle may facilitate trap delivery and gathering. As nearly as possible, arrange trap clusters in a square pattern. Enough space should be left between traps to allow access between them on foot.

A simple method to randomly choose the cluster or individual trap locations is to establish a numbered grid of points on a map of the seeding block. The number of points should be at least several times greater than the number of individual traps or clusters to be established. Points can then be selected using a table of random numbers.

Transport the traps to the site before the seeding operation and distribute them on the day of seeding. If the traps are placed in the final position several days ahead of time, accumulated seeds and foreign materials will introduce errors, or at least make the task of counting seeds more difficult. Count the captured seed and retrieve the traps immediately after the seeding operation.

To determine the actual seeding rate, summarize the trapped seed counts by cluster as follows:

$$\text{Seeding rate/ha} = \frac{\text{average total number of seeds in the cluster} \times 10{,}000}{\text{trap area (m}^2\text{)} \times \text{number of traps per cluster}}$$

Average the seeding rate values for each cluster to obtain the actual seeding rate.

When individual traps are used rather than clusters, follow the same procedures as outlined above, substituting the number of traps for the number of clusters.

10.3.2 Mechanical row and patch seeding

This method has most frequently been used for seeding jack pine while site preparing with the Bräcke patch cultivator, or more recently, row seeding with a disk trencher in combination with the Bartt Mark IV and the TTS Sigma precision seeders. Both mechanical row and patch seeding are less expensive than mechanical site preparation with aerial seeding, reduce the amount of seeds required and may give better control over seedling density and spacing (van Damme 1988; Reynolds 1999b).

The sowing season for row and patch seeding is limited to two seeding windows, a 7–8 week period in early spring, and about 4 weeks in the late fall. Because of poor road conditions, especially during the spring thaw period, some areas may not be accessible.

The Bräcke patch scarifier is capable of a wide range of between row and within row scalp spacings, and can site prepare and seed 2,500 scalps per hectare at the rate of 0.8-1.2 ha per hour. The main problems with patch seeders are seed clumping due to imprecise seed metering, clogging of seeds in the seeder, and inaccurate targeting of seeds to the most receptive microsites. Mechanical problems and weather-related limitations may result in significant losses of production time.

With spring seeding using the Bräcke, 60 percent or greater stocking can be obtained at a seeding rate of 15 seeds per seed spot. However, Sidders (1993) found fall seeding at seeding rates as low as five viable seeds per scalp to be the optimum treatment, with little or no clumping. Seeding rates generally range from 12,400 to 25,000 seeds/ha. Seedbed compaction done at the time of scalping can significantly improve jack pine establishment (Van Damme et al. 1992), but does not improve black spruce establishment.

Unlike the patch type scarifiers, skidder-mounted row seeders are designed to singulate seed and deliver it at prescribed intervals during site preparation by a furrow type scarifier (Davidson 1992). Singulation is done using a vacuum pressure, revolving orifice or screw auger system and the seed is pneumatically delivered through seed delivery hoses to the target microsite. Computerized monitor systems or infrared sensors are used to ensure the prescribed sowing rates are being met. Disc trenchers set at a two metre spacing and an in-row application spacing of 30 cm, would yield 16,666 seeds/ha.

On uplands in general, ground seeding combined with scarification is more difficult for black spruce than for jack pine. This is due in part to the more narrow spectrum of receptive seedbeds available and the difficulty in accurately targeting specific microsites.

10.3.3 Spot seeding with and without seed shelters

Spot seeding involves the application of seeds to a prescribed microsite using hand-held seeding devices. This technique provides the most reliable method of seed placement and allows manual microsite manipulation at the time of seed application. It is, however, the most labour intensive method of seed application.

Early methods used seed-filled jars with perforated lids to shake seeds onto exposed seedbeds. However, this technique offered little control over seedling density. Over the years, numerous mechanical hand seeding devices have been developed for dispensing conifer seeds, i.e., the German-made R and S seeder, the Cerbo seeding tool, the Panama direct seeder, and the Accuseeder. Precision metering for black spruce, however, has always been problematic because of the small seed size. More recently, to overcome the inaccuracies of metering devices, methods of seed encapsulation or pre-attaching seed to peat wafers have been used to deliver an exact number of seeds to a specific microsite, while at the same time providing a medium for early seedling establishment.

On uplands, site preparation is necessary before spot seeding to prepare receptive seedbeds. Continuous furrow scarification is the preferred method because it promotes the ingress of naturals, facilitates microsite selection, and contributes to higher worker productivity. Patch scarifiers create a narrower range of microsites than do continuous scarification methods, and unless soil conditions are uniform, the seeding operation is more difficult than that for row scarification.

Similar to other methods, the best season to spot seed is in early spring when soil moisture and weather conditions are conducive to seed germination and seedling growth.

Seed shelters

Seed shelters improve seedling establishment by ameliorating the microenvironment for both germination and early seedling development. Shelters come in a variety of shapes and sizes and can be fabricated from a host of biodegradable materials, including plastic, paper, peat, or polypropylene cloth.

The most common types are open-ended translucent plastic cones that are anchored to the seedbed surface and seeded through the top, either manually or by a variety of hand operated mechanical seeders (Figure 10.10).They are constructed of photodegradable polypropylene or polyethylene and break down into carbon dioxide and water when exposed to ultraviolet radiation. Above-surface decomposition usually occurs after 2 to 5 years, but the shelter's base may persist under the soil surface for as long as ten years.

These semi-translucent plastic shelters acts as a "mini-greenhouse" that both enhances microclimate and protects against frost, burial, and predation. Shelters increase air humidity and both soil and air temperatures to levels that favour germination and early development. The use of such shelters has often resulted in substantial increases in seedling establishment of both black spruce and jack pine, and in some cases height growth can match or exceed that of planted container stock by year five.

Figure 10.10 A successfully stocked polyethylene seed shelter following two growing seasons.

The best results with shelter seeding have been obtained on well-drained upland sites with little competition. Conversely, poor results are common on more productive uplands and on rich organic sites because of vegetative competition. Peatland sites with an abundance of *Sphagnum* seedbeds may not require seed shelters because of their naturally receptive qualities (Figure 10.11).

The inherent inaccuracy of metering devices designed for use with seed shelters has prompted the development of pre-seeded shelter cones. This technique involves attaching a predetermined number of seeds to a small flap or flange located at the apex of the shelter. The seeds are held in place by a water-soluble adhesive and are released during the first rainfall. Experimental trials have shown promising results (Adams 1994).

Non-transparent seed shelter designs, or "shade" shelters made from peat, paper, or mesh have also been effective in improving direct seeding performance. They protect soil surfaces from rapid changes in temperature and moisture, thus reducing evaporative stress and providing a stabilizing effect on the seedbed. They also protect against excessive microsite erosion and dislocation during periods of excessive rainfall. Adams and Henderson (1994) found that peat shelters significantly moderated soil surface temperature, had comparable stocking results to plastic shelters in jack pine seed spot experiments, and were considerably less expensive.

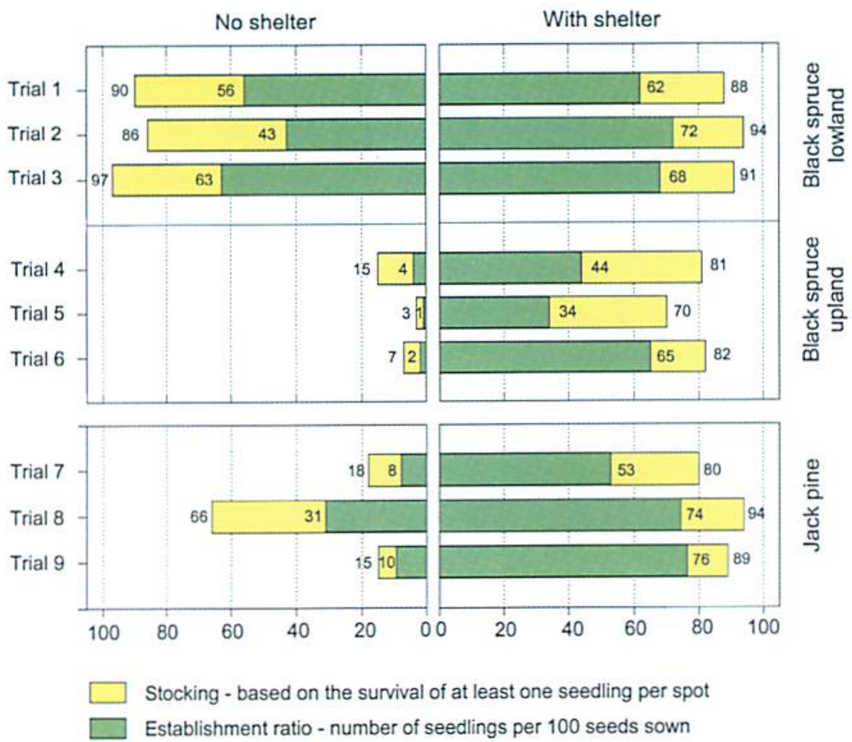


Figure 10.11 Fifth-year stocking and establishment ratio of sheltered and non-sheltered black spruce and jack pine seed spots *(Adams 1994).*

Production rates for seed shelter installation are approximately the same as for container stock planting.

Regeneration crews must be trained in microsite and seedbed selection and in shelter placement, anchoring, and seed dispensing techniques. Refer to the following recommendations box for tips on seed shelter installation.

RECOMMENDATIONS

How to properly install shelter cones:

1. Choose the best micro-site within the spacing requirements.
2. Select a mid-slope location within the furrow or scalp.
3. Scuff the micro-site with the toe of the boot.
4. Lightly compress the soil under the boot to provide a firm base for shelter placement.
5. Place the shelter onto the prepared microsite and completely cover the bottom lip of the shelter with loose soil.
6. If the shelter is not pre-seeded, dispense seeds through the top of the shelter. When using a mechanical seed dispenser, wait long enough for the seed to fall the length of the delivery shaft prior to disengaging it from the shelter.
7. Make sure the seeding device has been properly calibrated for the desired seeding rate prior to use. Periodically check the seeder's calibration during the seeding process.

(Adapted from Campbell and Baker 1989)

Some of the advantages and disadvantages of seed shelters are listed below:

Advantages:

1. Provides a good micro environment for germination and early seedling establishment.

2. Stabilizes the immediate seedbed and reduces the effect of soil washing and incidents of seed burial.

3. Higher establishment ratios within seed shelters allow fewer seeds to be used and subsequently reduces the incidence of excessive numbers of seedlings in clumps.

4. Enables greater control over spacing across the treated area, and a more conservative use of seeds, when compared to broadcast seeding.

5. Eliminates the cost of production, transport, and on-site storage of nursery stock.

6. Results in the development of a natural, undisturbed root system.

Disadvantages:

1. Is the most expensive method of seed application.

2. Is labour intensive, with productivity similar to that of container stock planting.

3. Is limited to sites with lower productivity.

4. During the critical establishment stages, seedlings originating from shelter cones lag behind nursery stock by at least one year.

5. It may result in clumping of seedlings.

6. Planters require a greater knowledge of microsites than for tree planting.

10.3.4 Ground broadcast seeding

10.3.4.1 Cyclone hand seeder

This seeder has sometimes been used operationally to seed scarified cutovers, but has been employed most often in experimental or pilot-scale applications to simulate operational broadcast seeding. The seeder is carried on a harness and seeds are broadcast across a 5 m swath as the operator turns a hand crank (Figure 10.12).

The seeder should be calibrated using seed traps before being used operationally. The operator calibrates the walking and cranking speeds needed to distribute the correct seed volume. Because of the small size of black spruce seed it must be mixed with a carrier. Vermiculite and sand (Arnott 1970) have been used as carriers in cyclone seeders in the past, while Groot and Adams (1994) found mixing black spruce seed with single-cut red clover provided a good distribution pattern. If seed such as clover is used as a carrier, it should be killed by heating in an oven or microwave prior to mixing with the conifer seed.

The productivity of the cyclone seeder is approximately 1.5 ha/hour, based on the following assumptions:

- Walking speed: 3 km (3,000 m) per hour
- Seeding swath: 5 m
- Production rate: 15,000 m^2/hr = 1.5 ha/hr

or 2 km of walking to seed one hectare.

Figure 10.12 Broadcast seeding with the cyclone hand seeder.

10.3.4.2 Snowmobile-mounted Brohm seeder

In the late 1960s and early 1970s, the Brohm seeder was adapted for use on snowmobiles. Reportedly, this application worked well in cutovers that were too small to seed from the air. Seeding was done in the late winter and in some cases productivity was reported as approximately 25 hectares per hour with a 15 m treatment swath.

Though the method has not been used for many years, it may be applicable in areas with good winter access where clearcut blocks are relatively small, such as in strip cuts after the leave strips have been harvested.

RECOMMENDATIONS

- For aerial applications, seed both jack pine and black spruce in late winter (mid-to-late March) or in early spring.
- Do not seed for at least 1 month after mechanical site preparation to permit the soil to settle.
- Seed within 1 year of site preparation, before significant vegetative competition has occurred. This period may be extended on *Sphagnum* sites.

11.0 ASSESSING SEEDLING ESTABLISHMENT

The results of direct seeding projects should be assessed to: (i) determine if the project was successful, (ii) determine the need for subsequent treatments (spacing, cleaning etc.), and (iii) provide data that can be used to forecast stand development. The type and timing of seedling assessment depends on which of these goals is being addressed.

Conventional seeding assessment procedures in Ontario recommend that a quadrat-based regeneration survey be carried out following the first and second growing seasons, while a survey following the third growing season is considered optional (Chaudhry 1981). This may be an acceptable practice for row seeding, Bräcke seeding, or shelter cone seeding because seed deposition occurs on prepared seedbeds that have readily discernible boundaries. It is very difficult, however, to carry out an effective regeneration assessment the first growing season following aerial seeding due to the random nature of seed dispersal and the small size of first year seedlings (especially black spruce) (Figure 11.1). Thus, we recommend that a complementary seed spot trial be established at the time of aerial seeding to provide an indication of the success of the operational seeding.

Figure 11.1 The small size and random distribution of first year black spruce seedlings makes it difficult to carry out an effective quadrat-based regeneration assessment.

11.1 How Can Seed Spots Be Used to Forecast Seeding Results?

The establishment and monitoring of seed spots on the most frequently occurring seedbeds in the seeding block will provide an early indication of seedling establishment. Observation of seed spots also helps to develop local knowledge of seedbed receptivity.

A seed spot trial will not however, provide information about the contribution of advance growth and ingress of naturals.

11.1.1. Procedures for seed spot trial establishment

The recommended procedure for establishing seed spots is as follows:

1. Place seed spots on only the two or three most common receptive seedbed types in the seeding block:

Upland spruce sites:

- Upper mineral soil horizon (<10 cm below the mineral soil/humus interface).
- Thin F (<5 cm above the mineral soil/humus interface).

Lowland spruce sites:

- Living compact *Sphagnum*.
- Sheared *Sphagnum* or exposed (compacted) *Sphagnum* peat.

Jack pine sites:

- Exposed mineral soil with a firm base.
- Thin F/H horizon (<5 cm)

2. Use a specific number of seeds per seed spot (usually 5). Ensure that the same number of seeds are dispensed at each seed spot. This can be done by pre-counting the exact number of seeds per spot and placing them into individual containers prior to application or by closely monitoring seed deposition at the time of seeding using a suitable spot seeding device such as the R&S hand seeder. Use seeds from the same seed lot used in the direct seeding project.

3. Establish seed spots in clusters along a transect. The more seed spots established, the greater the reliability of the results. However, it would likely be sufficient and cost effective if 50 to 100 seed spots were placed on each of the principal seedbeds throughout the seeding block in clusters of 4 to 5 spots.

4. Identify seed spot locations with flagged and numbered wire pins (Figure 11.2).

Figure 11.2 A successfully stocked seed spot identified by a numbered wire pin. Each seedling is marked by a plastic swizzle stick.

5. Establish the seed spots at the time of aerial seeding or shortly afterward, so that the same environmental conditions are experienced.

6. During the first year assessment, mark each germinant with a swizzle stick (placed on the north side of the seedling at a distance of approximately 5 cm) for easy relocation on subsequent visits.

To gain some perspective on the effectiveness of the artificial seeding, compare the germination data collected during the first year seed spot assessment with establishment ratios for specific seedbed types found in Section 6. PC SEED can be used at this stage to explore the consequences of these initial results.

11.2 When Should Seeding Assessments Take Place?

11.2.1 Black spruce

Over 90% of winter or early spring seeded black spruce germinants emerge by mid-to-late July of the first growing season, and nearly all seedling emergence takes place in the first growing season following seeding. Thus the number of seeded trees is at a maximum during the first growing season; seedling mortality will cause a decline in numbers in subsequent years.

If a seed spot trial has been established, seed spots should be assessed at the end of the first or second (or both) growing season, usually from late August onwards. Poor establishment at the end of the first growing season indicates failure, but good establishment does not necessarily indicate success, because of the possibility of subsequent mortality. Good establishment at the end of the second growing season is a better, though not certain, indication of success.

Quadrat-based assessments of black spruce seeding are not recommended during the first two growing seasons. The small size of the seedlings during this period makes detection difficult, and unless very careful and time-consuming assessments are undertaken, seedling establishment will be underestimated. Quadrat-based assessments are feasible in the third-to-fifth year following seeding. Results become increasingly reliable with increasing time since seeding, because of improved seedling detection, and because mortality rates decrease with time.

The quadrat-based survey will determine the combined stocking and density of direct seeded and naturally seeded trees, and can also provide information about advance growth.

11.2.2 Jack pine

First year jack pine seedlings are larger and better developed than are black spruce, and can usually be detected on patches of receptive seedbed. Thus, the establishment of an on-site seed spot trial may not be essential; however, it is recommended as a means of isolating the performance of artificially applied seeds, independent of the presence of seedling ingress from natural seed sources and to improve local knowledge of seedling establishment. If a seed spot trial is undertaken, assessment of the seed spot trial should be carried out at the end of the first growing season. An assessment at this time may underestimate establishment, since there is evidence that the germination of some jack pine seed may be delayed until the second or third season after seeding.

Seed spots will not reflect the ingress of seedlings from natural seed sources. Natural ingress varies depending on site, stand age, method and season of harvest, site preparation technique, slash density and microclimatic exposure, but it is usually substantial. The seed source for natural ingress is primarily cone-bearing slash, but residual trees on or adjacent to the site may also contribute some seed. There is even evidence that old cones buried in the forest floor can release small amounts of viable seed when exposed by fire or site preparation.

Figure 11.3 A quadrat-based regeneration assessment at year three will reflect establishment from both artificial and natural seed sources.

Because of ingress from natural sources, and, possibly, delayed germination of sown seed, stocking and density in jack pine seeding trials has been observed to increase from the first to the third growing season. Thus a quadrat-based regeneration assessment (Figure 11.3) should be conducted after three growing seasons. An assessment at this time will provide a good indication of regeneration resulting from both artificially applied and natural seed sources.

In some cases, further increases in stocking and density may occur when jack pine seedlings established in the seeding operation begin to produce cones and contribute seed. This may occur as early as the sixth year after establishment.

RECOMMENDATIONS

- Use seed spots to check on performance and to develop local knowledge of seedbed receptivity.
- In the case of black spruce, if stocking levels are not acceptable following the first assessment, remedial action should be taken as soon as possible.
- Quadrat-based regeneration assessments should be conducted between 3 and 5 years following seeding, depending on site quality and expected growth rates, to capture both artificially seeded trees and those resulting from ingress.

11.3 What Kind of Survival Can Be Expected From Seeded Trees?

11.3.1 Black spruce on uplands

On upland coarse-textured soils, substantial mortality occurs until the end of the third growing season, with a steady decline in annual mortality rates thereafter; great variation in mortality occurs in different seeding years on the same site and seedbed types (Figure 11.4).

Insufficient moisture in the surface soil (possibly combined with high surface temperatures) and frost heaving appear to be the main causes of seedling mortality on upland sites. On thin F and upper mineral soil horizons, two of the most common types of upland seedbeds, more mortality may occur on the drier sites (S2, S3, and SS3) than for the same seedbeds on wetter sites (S8, S9, and SS8).

11.3.2 Black spruce on lowlands

The main causes of seedling mortality on lowland black spruce sites are competition from rapidly growing *Sphagnum*, frost heaving, and erosion of well-decomposed materials.

On seed spots, stocking and establishment ratios decline throughout the initial 5 years of growth on almost all seedbed types, but declines are most marked on pioneer mosses and well-decomposed organic matter, followed by rotten wood and living, slow growing *Sphagnum* seedbeds (Figure 11.5).

11.3.3 Jack pine

The combination of lethal surface temperature and drought are considered the greatest cause of jack pine seedling mortality during the initial stages of germination and establishment (Sims 1975). Heat injury may not kill a seedling but may weaken it and leave it more susceptible to drought. Early germinants have a slightly higher chance of survival. However, if germination is too early, mortality from spring frost may occur. In terms of survival, the last week of May and the first 2 weeks of June is the optimum time to obtain germination.

Total germination and mortality increase and decrease respectively from dry to fresh moisture regimes (Sims 1970). Unlike upland black spruce, jack pine seedlings surviving through the year of germination are essentially established; subsequent mortality is low and occurs mainly during the second year (Sims 1975).

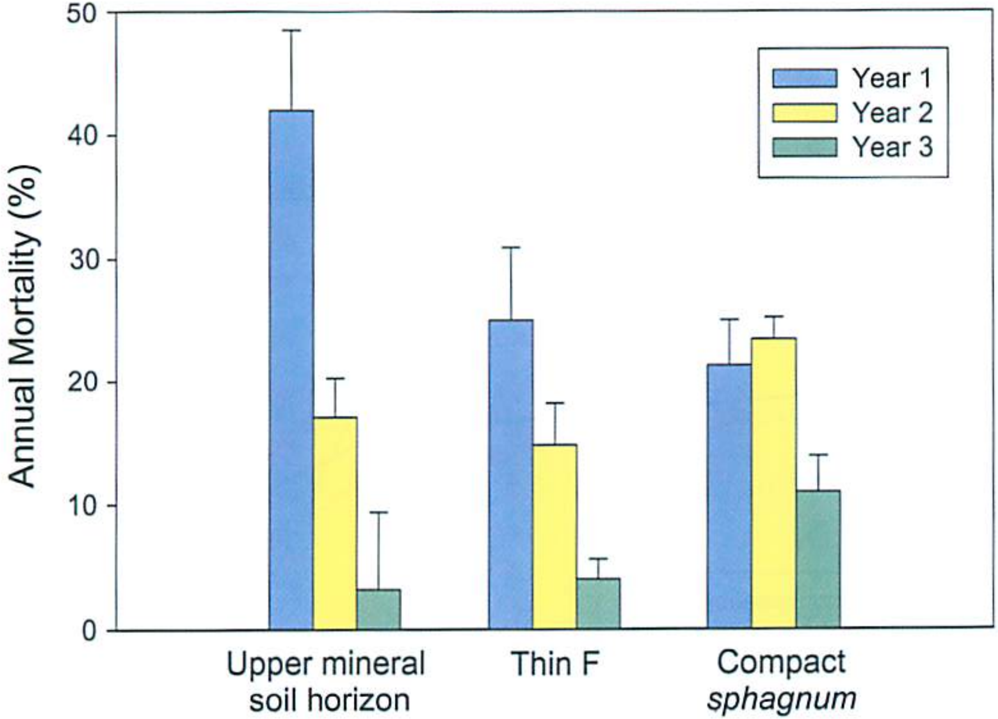


Figure 11.4 Annual mortality of Black spruce (mean and standard deviation) by seedbed type *(Fleming and Mossa 1994).*

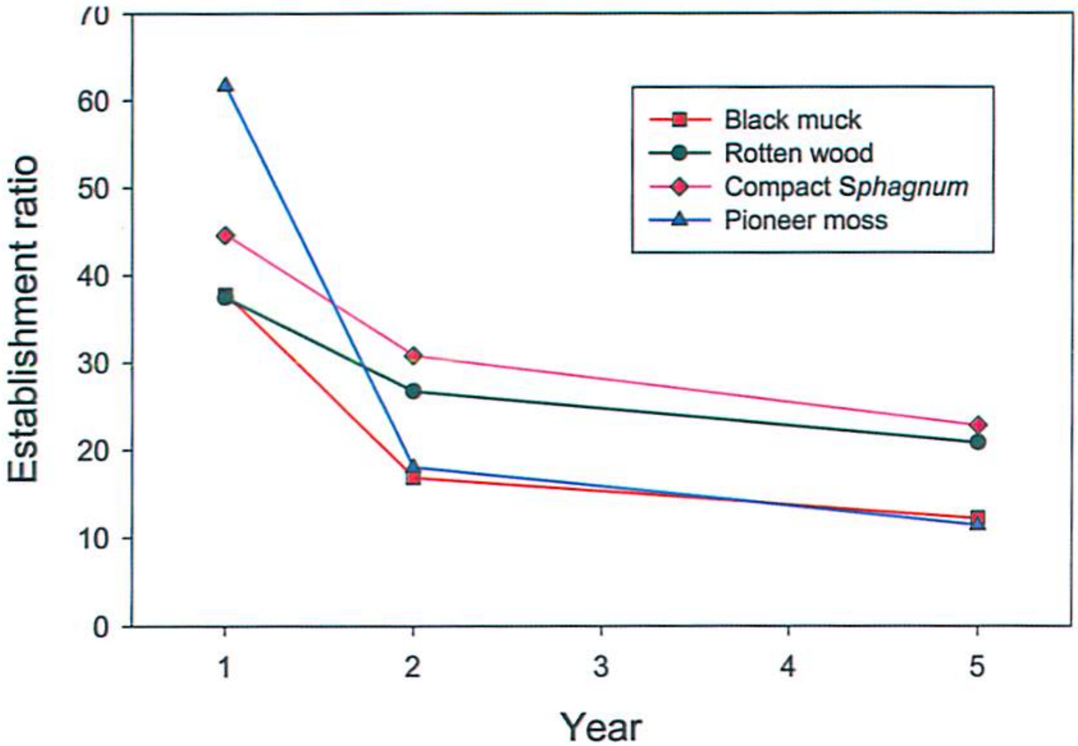
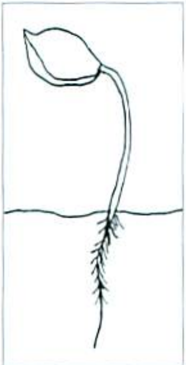


Figure 11.5 Mean black spruce establishment ratios (no. of established seedlings per viable seeds sown) on selected lowland seedbed types *(Groot and Adams 1994)*.

11.4 How Do Weather and Damaging Agents Affect Seeding Success?

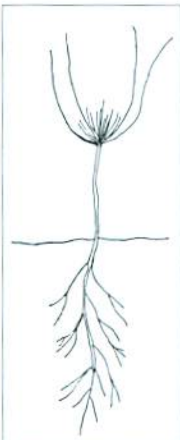
This section focuses on the risks to seedlings during the first growing season, when most mortality occurs.



Germination phase

Germination phase: radicle emerges and seed coat is lifted off the surface of the soil (1 to 7 days).

Technically, the germinative process begins when chemical changes are initiated within the seed, brought on with the imbibition of water, favourable temperatures and in the presence of oxygen. However in practical terms, germination begins with the extrusion of the radicle through the broken seed coat (Baker 1950). The greatest cause of mortality at this stage is an inadequate supply of surface moisture to allow the radicle to become established, and to supply the moisture required for cotyledon development (Arnott 1973) Also, damping-off fungi can cause serious losses at this stage; in warm, moist years on fresh sites damping-off may account for half of the mortality in newly established jack pine. Seedlings growing on mineral soils are less susceptible to this disease (LeBarron 1944; Sims 1975).

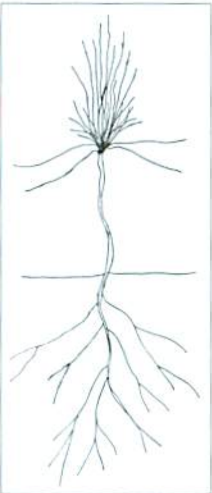


Succulent phase

Succulent phase: about 25 days from germination

For a few weeks following germination, the young seedling is frail, delicate, and watery, having no specialized strengthening tissues and only a very rudimentary vascular system (Baker 1950). At this stage, high air and soil temperatures are an important limiting factor for seedling survival. High solar irradiance can be a cause of seedling mortality because of a combination of high air temperature that causes transpirational stress, and high surface temperatures that desiccate the seedbed surface. Seedling mortality occurs if there is an insufficient supply of soil moisture to replenish its requirement for water. Heat injury and mortality occur when the seedling crown is exposed to air temperatures of approximately 50°C or greater. This is why soils with poor thermal conductivity, such as duff and litter, are poor seedbeds: they quickly heat up to lethal temperatures but do not supply moisture, as do mineral soils.

The total amount of rainfall in a given year is less important than its distribution throughout the growing season (Arnott 1973). Regular rainfall is needed immediately after germination and during the succulent phase to prevent seedbed drying and seedling desiccation. On lowland sites, moist *Sphagnum* and peat seedbeds do not present the same degree of risk as do uplands because of the generally plentiful supply of moisture.



Juvenile phase

Juvenile phase: hypocotyl (stem) becomes hardened

Seedling mortality at this stage of development is mostly due to drought, brought about indirectly by slow root development or by competition for limited water. For jack pine on dry to moderately fresh sites (SMR Ø-1), singular precipitation events producing more than 6-7 mm of rain every 5-7 days are required. Mortality will be noticeable after five days of drought and become significant by seven days and approaching total mortality after ten days of drought (Sims 1970, 1972, 1975). It is essential that a growing root system keep ahead of the deepening soil drying front as the season progresses (Arnott 1973). Black spruce is more vulnerable than jack pine in this respect, because of its slower early root growth and lateral root growth habit. High atmospheric demand (vapour pressure deficits) and low soil moisture reserves lead to moisture deficits in young seedlings, resulting in wilting and death.

Complete shading by competing species can also cause mortality at the juvenile stage. However, low to moderate shading may be beneficial, by moderating ambient air and soil temperatures. The degree of competition is dependent upon the effective life of prepared seedbeds. Competition is most severe on fertile sites. Where broad-leaved plants are abundant, smothering of first-year seedlings by litterfall may cause mortality.

Frost heaving can be an important cause of mortality on moist sites and those with fine textured soils. Spruce is more susceptible than pine because of its more shallow rooting habit. Severe rain or hailstorms may physically damage fragile seedlings, wash them out of the substrate, bury them with splashed soil or cause mortality by flooding. Frost damage to new foliage can be problematic for those seedlings, which have become established in low lying areas (Figure 11.6).

Flooding

Competition

Defoliating insects

Frost damage

Juvenile seedling predation

Figure 11.6 A variety of damaging agents can have a significant impact on seeding success.

High populations of defoliating insects can cause localized seedling mortality (e.g., spruce budworm (*Choristoneura fumiferana* (Clem.), European spruce sawfly (*Gilpinia hercyniae* (Htg.), Black army cutworm (*Actebia fennica* (Tausch.)) white grubs of the June beetles (*Scarabaeidae*), Cicadas (*Cicadidae*) and grasshoppers (*Camnula spp.*) (Rudolph and Laidly 1998).

Deer mice, meadow voles and hares have been reported to actively seek out and consume jack pine seedlings in the first few weeks after germination (Buckner 1972).

SUGGESTION

When conducting a seeding operation on sites in the dry-to-moderately fresh moisture regime range, it is suggested that an on-site recording rain gauge be used to monitor local rainfall events and the length of drought periods. These devises are relatively inexpensive and can be preprogrammed to operate maintenance free over the entire growing season. Early detection of potential failures can lead to swift remedial action.

12.0 EARLY GROWTH, TENDING AND SPACING

12.1 What Early Growth Can Be Expected?

12.1.1 Black spruce on uplands

Height growth of seedlings over the first three growing seasons is slow regardless of seedbed type, site, or seeding year. Mean total height of between 5 and 10 cm can be expected by the third year. Current annual height increment accelerates between years 3 and 5, and often reaches its highest rate by age 10. Thereafter, it decreases slowly with time largely due to the impact caused by intraspecific competition. Early seedling growth rates are difficult to predict on upland sites using standard site classification systems. Microclimate, local nutrient status, and rooting conditions of particular microsites are important factors in determining seedling growth within given site types.

The major difference in the growth of upland black spruce among different seeding years is likely a function of the degree of competition from surrounding vegetation (Figure 12.1). The superior height growth usually associated with trees that came from the first seeding year, compared with seedlings from subsequent seeding years, is attributed to the differences in the size and development of competitors (Fleming and Mossa 1995b).

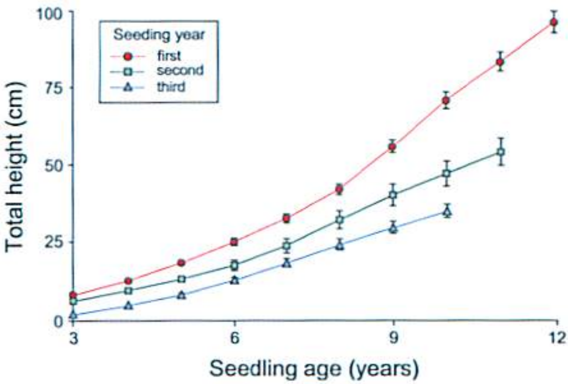


Figure 12.1 Mean black spruce seeding height as a function of seedling age, for three consecutive seeding years *(Fleming and Mossa 1995b).*

12.1.2 Black spruce on lowlands

On peatland sites, the height development of trees established from seed is slow, and foresters should expect lengthy regeneration periods. After two growing seasons seedling heights average 2 to 4 cm. Fifth-year height average 8 to 17 cm, and fifth-year height increments average 4 to 5 cm. Although *Sphagnum* peat and *Sphagnum* moss are good seedbeds from the point of view of establishment, they do not provide good conditions for seedling growth. Conversely, seedlings establish poorly on feathermoss peat, but once established grow much more rapidly than on *Sphagnum* peat, likely because of nutritional differences. Height growth can vary considerably from location to location (Figure12.2). Growth of seeded black spruce will be very slow on *Ledum* site types (NEO FEC ST11), especially those that grade into the unmerchantable Chamaedaphne site types (ST14). Extremely long regeneration periods should be expected when direct seeding such sites.

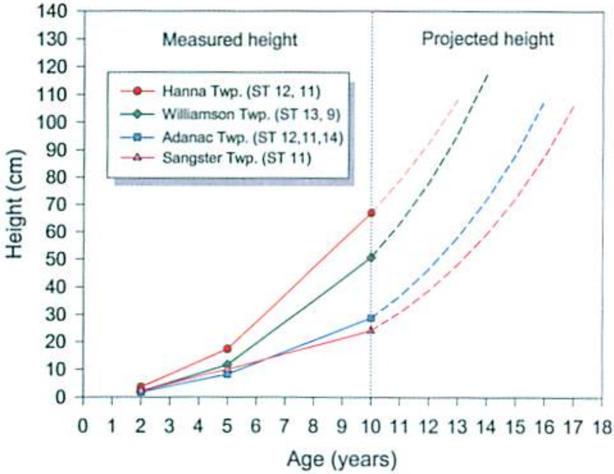


Figure 12.2 Average black spruce seedling height development at four experimental locations. Broken lines indicate projected height growth *(Groot 1996)*.

Height growth also varies considerably within a given location (Figure 12.3). Improved height growth on lowland sites may be obtained by applying seeding prescriptions that achieve high overall seedling densities, which will result in a greater number of taller seedlings. The risk of an eventual reduction in individual

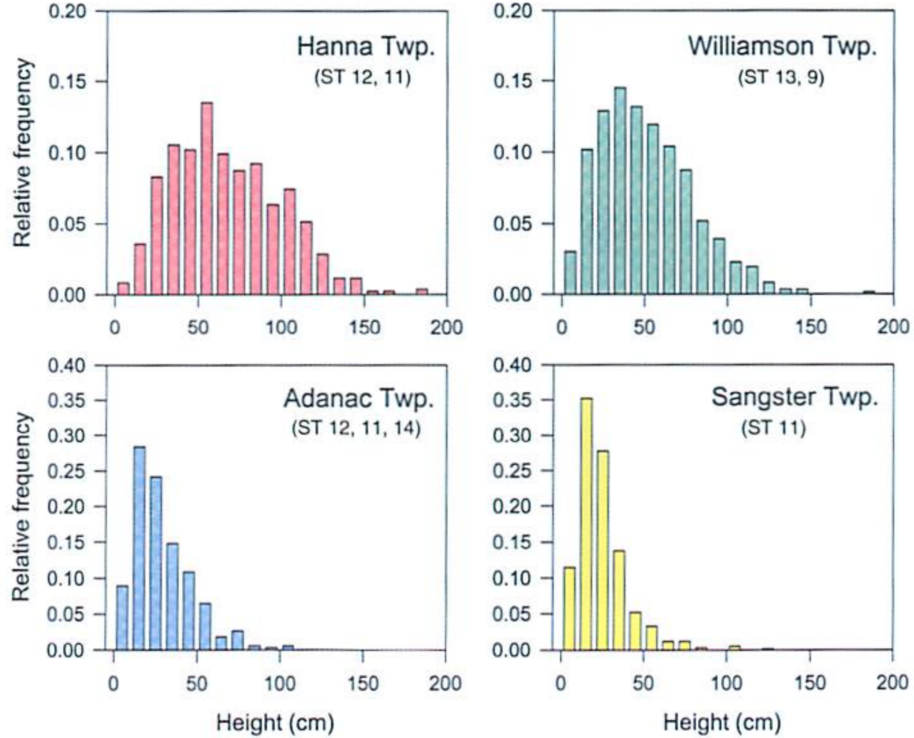


Figure 12.3 Black spruce seedling height frequency distribution at year ten at four experimental locations *(Groot 1996)*.

tree growth due to high seedling densities is mitigated by the uneven size distribution of the stand. As the stand develops (Figure 12.4), the large number of smaller seedlings will become increasingly suppressed and will have little impact on the growth of larger trees (Groot 1996).

Figure 12.4 Twentieth year re-measurement of broadcast seeded black spruce at 100,000 seeds per ha. Williamson Twp., Kapuskasing Dist., Site Type 13 and 9.

12.1.3 Jack pine

Early height growth of jack pine can be quite variable – site, substrate, exposure, micro climate and competition all have a significant influence on early height growth (Figure 12.5).

Some reported 3rd year average heights include: 62.5 cm (maximum 80 cm) in full light and 17.6 cm in 43% light on a moderately fresh to fresh moisture regime (Lebarron 1944); 13.6 cm on a very fresh to moist moisture regime and 12.5 cm on a moderately dry to moderately fresh moisture regime (Winston 1973); 4.6-24.9 cm for five distinct substrates and three levels of exposure on a dry site (Sims 1975) and 16.8-23.4 cm on a wildfire (St. Pierre et al. 1992). Fleming

Figure 12.5 Results after five growing seasons following mechanical site preparation (CFS Fire Plow) and aerial seeding at 50,000 seeds per ha. Topham Twp., Chapleau District.

et al. (1995) (Figure12.6) found 12-year average height growth of naturally seeded jack pine established on fresh to moderately moist sites to average 3.7 m. Roe (1949), reported 10-year average heights of 3.6-4.3 m and dominant heights of 4.3-4.8 m from an operational spot seeding on rich soils in northeastern Minnesota; average height declined and maximum height increased with increasing numbers of trees per seed spot. Goble and Bowling (1993) reported 10 year average heights of 3.4-3.8 m following hand seeding on a Jack Pine Mixedwood/ Feathermoss site with a dry to fresh soil moisture regime.

12.2 When Should a Free-Growing Regeneration Assessment be Conducted?

The timing of the assessment should be based on site productivity, crop species, competitor species, and the chosen minimum crop tree height standard. These are all inter-related with the method of harvest, the renewal method, and management objectives. Field procedures for conducting the free-to-grow regeneration assessment are outlined in the Free-Growing Regeneration Assessment Manual for Ontario (OMMR 1995). The recommended window for the assessment is 7-11 growing seasons after harvest. This takes into consideration the time needed for ingress establishment. However, some measure of flexibility should be built into the timing of the assessment to compensate for the initial slow growth of black spruce on sites of low productivity.

12.3 What Kind of Competition Control is Required?

Vegetation management is an integral part of forest management. Non-crop vegetation often limits the survival and growth of young trees by reducing available light, moisture, and nutrients. The proper timing and choice of vegetation management treatments can mean the difference between success and failure of regeneration programs (Buse and Baker 1991).

12.3.1 Black spruce on uplands

On most upland sites, tending will be necessary if seeded black spruce are to attain free-to-grow status within 10 to 15 years (Fleming et al. 1995). Species such as jack pine, trembling aspen, white birch, pin cherry, alder, and willow quickly invade scarified sites, and after 12 years their mean height can be over 2 m more than the average height of seeded black spruce (Figure 12.6). Because competitive species cause the current annual height increment to decrease between age 7 and 9, tending should be done before this period to prevent a growth lapse.

12.3.2 Black spruce on lowlands

Competition control requirements will vary with site type and site preparation. On nutrient poor sites (e.g., NEO FEC ST-11) tending is often not necessary, whereas it will probably be required on rich sites (e.g., NEO FEC ST-13). Tending regimes for direct seeded lowland sites have received little attention to date.

12.3.3 Jack pine

On sites prone to competition, seeded jack pine stands should be treated within 2 to 5 years of establishment to prevent growth reduction or mortality caused by faster growing woody species, and to ensure that seedlings reach free-to-grow status as quickly as possible. Given an equal or head start, jack pine may cope with low-to-moderate levels of competition, and, depending on the complex of species, may also cope with rather high levels of competition. Once established, thrifty jack pine seedlings tend to gain height as rapidly as many competitors – however, the rate of increase in diameter may be limited until the jack pine either dominates or is released.

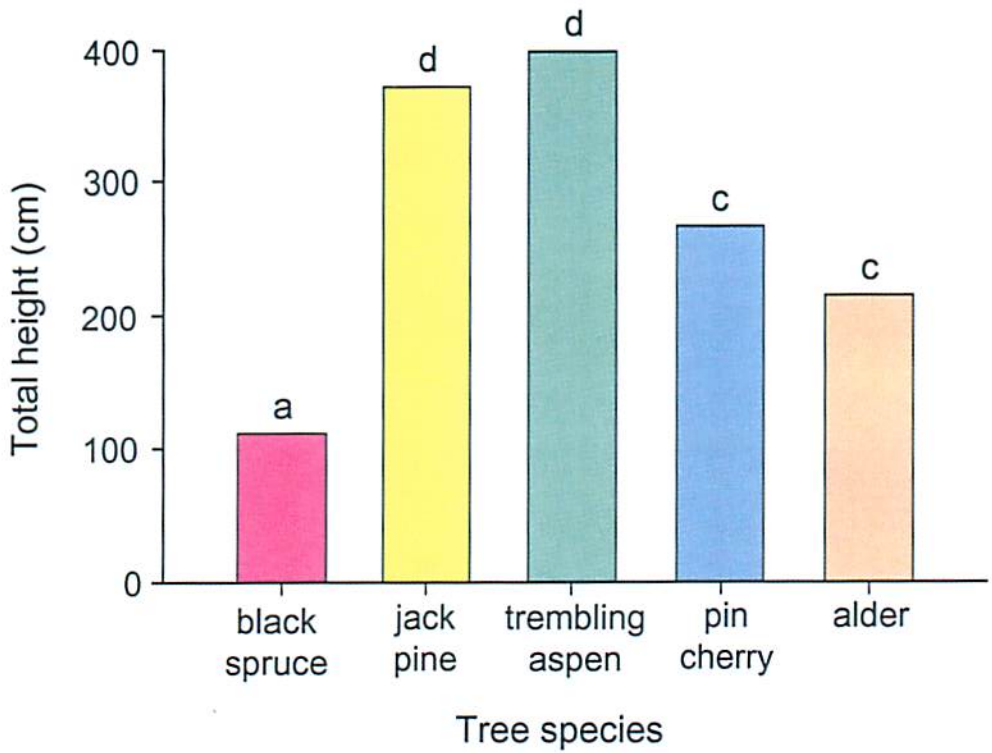


Figure 12.6 Mean heights of dominant competitors and black spruce, 12 years after seeding. Values (bars) with the same lower case letter above them are not significantly different (p>0.05) *(Fleming and Mossa 1995b).*

12.4 Is Juvenile Spacing Always Required?

Because of the excessive density that can occur when direct seeding, especially the clumping of seedlings following ground seeding, spacing (pre-commercial thinning) of overly dense parts of the stand will ensure that the full growth potential of the individual trees is captured.

As a general rule, maximum biological benefits accrue when proper spacing is achieved early in the life of the stand (Riley 1973). The target optimum density should be somewhat flexible, and should reflect the management objectives for the stand.

Spacing can be used to achieve a number of management objectives: release selected crop trees, control or adjust species composition, shorten the rotation period of a stand, increase product value, and increase the merchantable growth of the stand.

From both biological and operational standpoints, the ideal time for spacing is generally from age 7 to 25 years. This will vary depending on stand density, tree height, tree form, and bole diameter. There may be less of a requirement for pre-commercial thinning in black spruce because slower growth and more variable initial growth can allow larger trees to dominate the stand.

12.4.1 Black spruce

Though 5,000 to 20,000 seedlings per hectare can become established on uplands following direct seeding (Fleming and Mossa 1989), only a fraction of them will express dominance within a few years. The height distribution shows substantial size inequality among individual seedlings with a long tail into the larger height classes (Figure 12.7). This can be attributed to genotypic variation, microsite differences, or irregular competition indices. Dominant seedlings can attain heights of 1.5 m on fresh and moist seedbeds by age 10, significantly overtopping average seedlings, which have a median height of approximately 0.6 m. This condition is commonly observed in developing stands, and suggests that variation in growth prevents stagnation through intraspecific competition. Furthermore, spacing may reduce total net merchantable pulpwood yields at biological rotation ages (maximum mean annual increment) on better sites (Fleming et al. 1995). Because of this phenomenon, overstocking of black spruce after broadcast seeding seldom demands spacing. However, spacing is required after spot seeding on scalps because a number of seeds sown together invariably results in clumping.

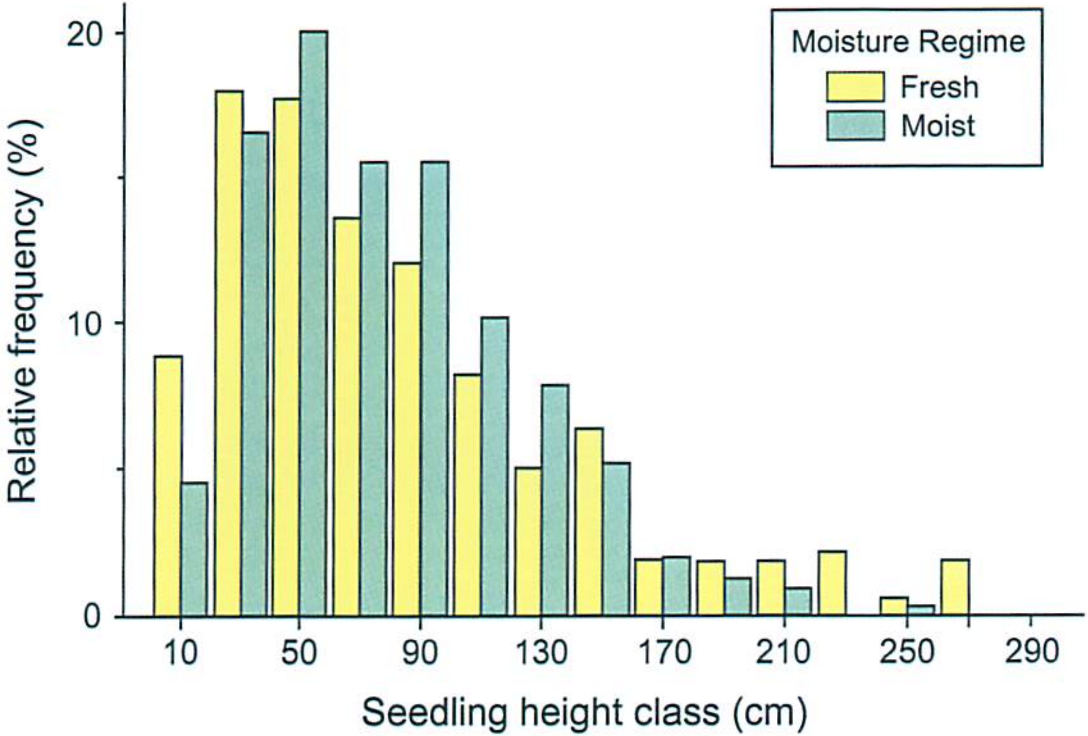


Figure 12.7 Relative frequency distribution of black spruce seedling heights by moisture regime, 12 years after seeding *(Fleming and Mossa 1989).*

12.4.2 Jack pine

Spacing is generally considered beneficial to jack pine stands that have originated from broadcast seeding. Several factors need to be considered when planning the intensity and timing of spacing. Early spacing often has the lowest cost, but spacing that is too early or too wide can lead to reduced wood quality (greater branchiness, larger knots, lower wood density, greater taper, and poorer strength and pulping characteristics), and greater risk for damage by snow and ice (Barbour 1991). Insect pests of jack pine shoots (white pine weevil and eastern pine shoot borer) may damage a portion of jack pine stems, especially those in full sunlight. It may be prudent to maintain higher densities to reduce the incidence of damage by these pests, and to ensure that sufficient numbers of undamaged trees are present when the stand is no longer susceptible to attack. Susceptibility decreases when crowns close or stands reach about 7 m in height, and becomes negligible when stands exceed 9 m in height.

RECOMMENDATIONS

- For black spruce the key to encouraging vigorous, healthy stands that optimize site productivity and best serve diverse uses is to quickly obtain complete site utilization and canopy closure. Dense, well-stocked seeded stands in which vigorous competition is controlled should meet these objectives.
- There is a distinct lack of long-term, site-specific, growth and yield data in relation to spacing and thinning jack pine in Ontario. However, Density Management Diagrams (Archibald and Bowling 1995) that graphically portray relationships between average tree volume, tree height, stand diameter, and stand density can be used to make stand-level silviculture decisions to help optimize stand structure and product yields.

Appendix A: Sources for cost data

Seed costs were calculated from information supplied by the Ontario Tree Seed Plant at Angus. These included costs of cone crop forecasting, cone collection and shipment, cone and seed processing, seed germination tests, and seed storage. The costs of capital investment, energy, employee salaries, and operation and management of the seed plant are also included (Sarker et al. 1995).

The cost of container stock was obtained by averaging the cost of production from several nursery operations located in Northern Ontario. Aerial seeding costs were obtained from Reynolds (1999b) and verified by General Airspray Limited. Site preparation costs were also obtained from Reynolds (1999b). Many of the costs obtained from Reynolds (1999b) were derived with FERIC's *Interface* software, which summarizes individual project costs by analysing the range of cost components. Cost estimates for prescribed burning were supplied by the Forest Industries Section, Provincial Operations Branch of the OMNR.

Delivery and on-site storage costs for planting stock are based on FMA subsidy rates, and have been adjusted by the Consumer Price Index (CPI) to obtain present day cost estimates. To avoid year-specific random variations in cost estimates, a three year cost average was used. Shelter cone seeding costs were derived from time studies conducted by the Forest Engineering Research Institute of Canada (Dominy 1991a).

Mechanical site preparation for seeding may be more costly than for planting, because more seedbed area and better receptivity are required for successful stand establishment. In the absence of method-specific cost information, however, we have applied the same site preparation costs for both planting and seeding.

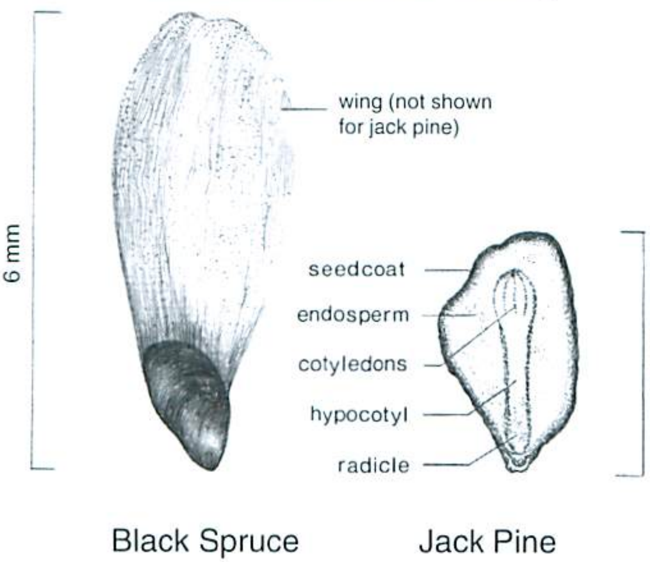
Appendix B: General relationship between generic treatment units and forested ecosites *(Racey et al. 1989)*

Generic Treatment Units	V-types and S-types	Ecosites
A	V1-V3, S6, S8-S10,S12F	ES30, ES36
B1	V5-V11, V19, S1-S4, S6	ES16, ES19, ES28, ES29
B2	V5-V11, V19, S7-S10	ES23, ES33
C	V4, S1-S3, S7, SS6, SS8	too specific for direct interpretation to ecosites
D1	V14-V16, V21, V24, V25, S1-S3, S6, SS6	ES17, ES27
D2	V14-V16, V21, V24, V25, S7-S10	ES17
E1	V19, V20, V31-V33, S1, SS6, SS3	ES14, ES22
E2	V19, V20, V31-V33, S2-S4, S6,SS6	ES14, ES20, ES25, ES26
E3	V19, V20, V31-V33, S7-S10, SS8	ES22, ES31, ES32
F	V18, V29, V31, V32, S1-S3, SS6	ES14, ES20
G	V11, V17, V28, S1-S3, SS6	ES20
H	V12, V13, V26, V27, S1-S3, SS6	ES11, ES15, ES18, ES24
I1	V30, SS1-SS3	ES12
I2	V30, S1, S2, SS5, SS6	ES13
J1	V22, V23, V35, S12S, S12F	ES35, ES36
J2	V34-37, S8, S11, S12S, S12F	ES34
K	V38, S12S	non-forested

Appendix C: Cone and seed characeristics of black spruce and jack pine *(OMNR 1986a)*

	Black spruce	Jack pine
Average viable seed per gram	873	270
Average viable seed per hectolitre of cones	352,555	162,226
Average number of cones per litre	192 - 440	68 - 82
Average number of viable seeds per cone	8 - 18	20 - 24
Average number of new cones per tree	580 - 1140	300 - 500

Seed Dimensions and Anatomy



Appendix D: Seed source identification *(OMNR 1986)*

All seed collections must be identified by a Seed Source Number (SSN).

The (SSN) consists of a string of five numeric codes representing the species, site region, geographic location, collection agency and type of collection (OMNR 1986a):

000-00-00-0-00

1) species
2) site region
3) geographic location
4) agency
5) collection type

1) Species Codes

013 Black spruce
003 Jack pine

2) Site Region Codes

12	1E
22	2E
24	2W
32	3E
33	3S
34	3W
42	4E
43	4S
44	4W
52	5E
53	5S
62	6E
72	7E

3) Geographic Location Codes (Northern Ontario)

10	**Northwestern Region**
11	Dryden
12	Fort Frances
13	Ignace
14	Kenora
15	Red Lake
16	Sioux Lookout
17	Wabigoon Nursery
20	**North Central Region**
21	Atikokan
22	Geraldton
23	Nipigon
24	Terrace Bay
25	Thunder Bay
27	Thunder Bay Nursery
30	**Northern Region**
31	Chapleau
32	Cochrane
33	Gogama
34	Hearst
35	Kapuskasing
36	Kirkland Lake
37	Moosonee
38	Timmins
39	Swastika Nursery
40	**Northeastern Region**
41	Blind River
42	Espanola
43	North Bay
44	Sault Ste. Marie
45	Sudbury
46	Temagami
47	Wawa

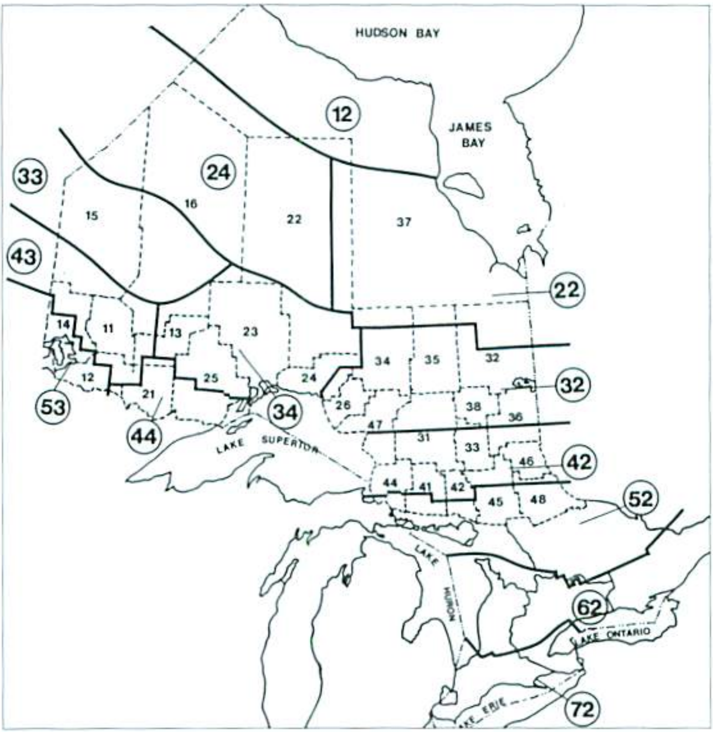
4) Agency Codes

0	Ministry of Natural Resources
1-9	Others

5) Collection Type Codes

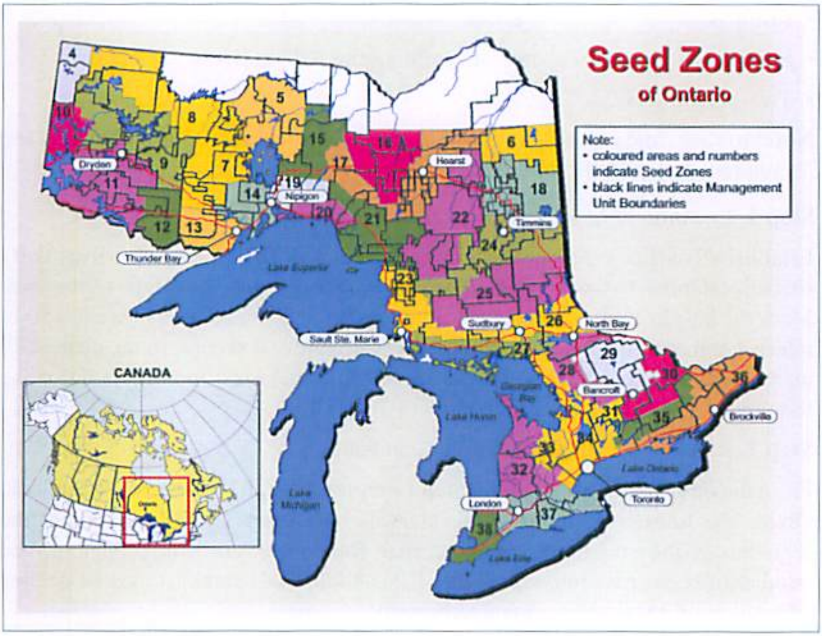
00	General Collection
01-19	Gene Pool Reserve
21-39	Seed Collection Area
41-59	Seed Production Area
61-79	Seed Orchard
81-99	Special Collection

Map of Site Region and Geographic Location



New Seed Zone Delineations for Ontario:

These new boundaries were defined using the Ontario Climate Model (OCM) by coupling climatic variables with a Digital Elevation Model (DEM) to generate homogeneous climate zones and made operational by delineating boundaries to coincide with geographic or administrative regions. The coloured areas and numbers indicate Seed Zones while the black lines indicate Management Unit Boundaries.



(Source: Ontario Tree Seed Plant [on-line]http://www.ontariotreeseed.com/).

Appendix E: A methodology for establishing base lines, transects and quadrats following site preparation

Equipment and Crew:

- Two 2-m rods (2-cm diameter marked off at 20-cm intervals);
- 50-m tape;
- Painted or flagged 1.5-m stakes;
- Compass;
- Shovel or soil auger capable of sampling the "C" horizon;
- Two-person crew.

Note: to save time in the field steps 1 and 2 can be done in the office if maps and /or photos are available.

Step 1. Location of baseline and establishment of grid system.

Establish a baseline bisecting the long axis of each block. If the block is irregularly shaped, establish two or more baselines to ensure adequate coverage of the area. Mark the baseline with flagged or painted stakes at 50-m intervals. At each 50-m interval and at right angles to the baseline estimate and record, to the nearest 20 m, the width of the treated area to the block boundaries on either side of the baseline.

Step 2. Random selection of transect segments.

From the information collected in Step 1 prepare a rough grid map of each block. Divide the lines crossing at 50-m intervals into 20-m segments. Number the segments serially beginning in one corner. Randomly select the predetermined number of segments required (Figure E.1). Additional segments may be needed depending on local and regional variability.

Step 3. Establishment of quadrats on selected transect segments.

Using a metre tape locate the predetermined (randomly selected) position of the first segment to be sampled. At this point lay the tape out 20 m at right angles to the direction of equipment travel. This represents the centre line of the ten 2-m x 2-m quadrats (Figure E.2). Starting at the first quadrat lay both 2-m rods on the ground perpendicular to the direction of the tape so that the tape crosses the centre line or the 1-m point of each rod. The rods are situated at the zero and 2 m points of the tape. Following assessment of the first quadrat move the rodmarking the zero point to the 4 m position in a "leap frog" manner, thus establishing the second quadrat boundaries. Refer to Appendix F for an outline of quadrat sampling and recording procedures.

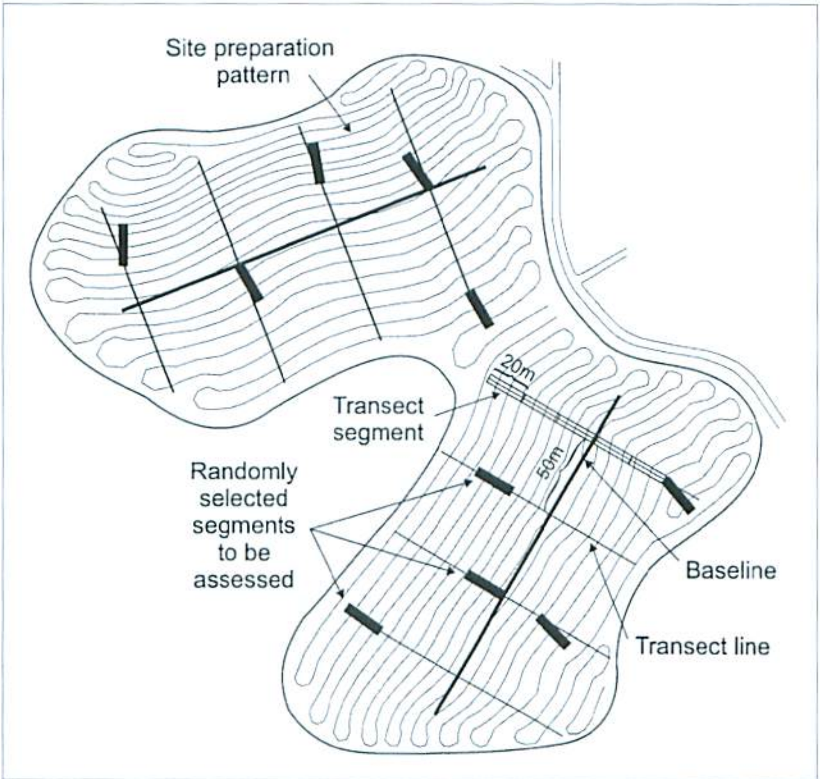


Figure E.1 Random selection of pre-numbered transect segments (*adapted from Sutherland 1986)*

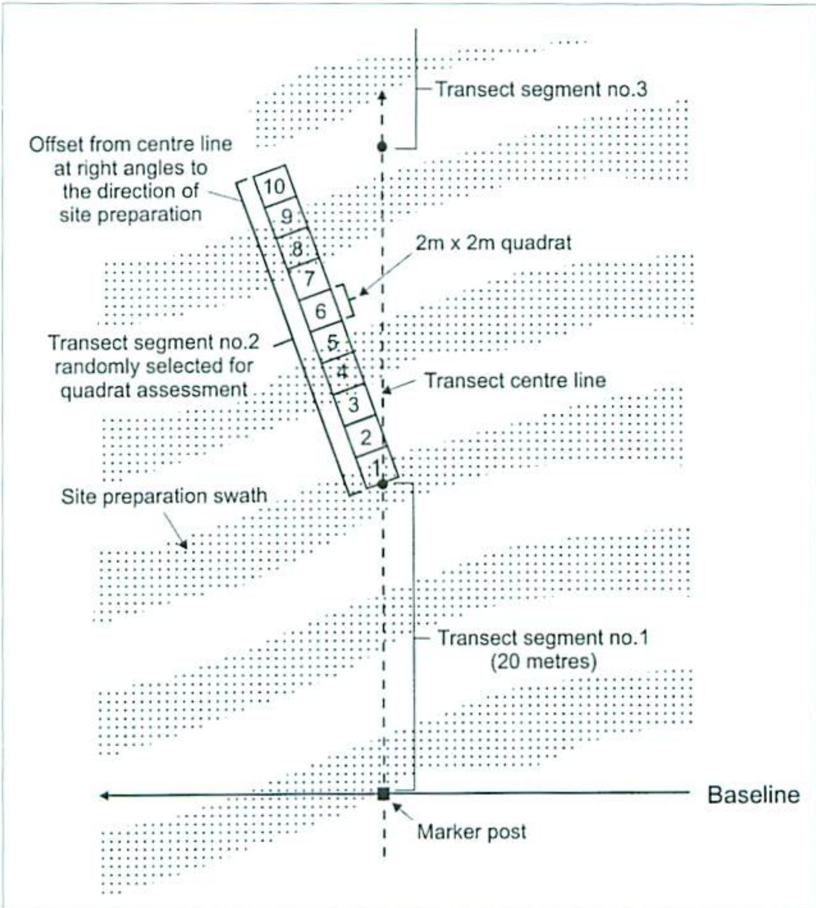


Figure E.2 Establishment of quadrats on selected transect segments *(adapted from Sutherland 1986)*

Appendix F: Quadrat assessment procedures

The following section outlines a method of assessing the amount and distribution of seedbeds on a given site. This information is used to develop the seeding prescription. The procedure works well with a two-person crew – one responsible for assessing the parameters of the quadrat and the other recording results.

Equipment and crew:

- Seedbed tally sheets, or a preprogrammed electronic data recorder;
- Two 2-m rods (2-cm diameter marked off at 20-cm intervals);
- 50-m tape;
- Compass;
- Shovel or soil auger capable of sampling the "C" horizon;
- A field manual for describing soils (Ontario Institute of Pedology 1985);
- Two-person crew (one assessor and one tally person)

Step 1. Locate the line segment previously selected during the baseline/transect establishment phase and position the 2m rods (as described in Appendix E) marking the boundaries of the first quadrat to be assessed.

Step 2. Identify all seedbed types that appear within the 2m x 2m area and estimate the coverage (percent of quadrat area) of each to the nearest 5%. The presence of trace amounts of distinct seedbed types less than 5% should also be recorded to the nearest 1%. Record all data on paper tally sheets or electronic data collection devices in a format similar to the example provided (Figure F.1). Make use of the cover percent charts (Figure F.2) to assist in defining area measurements. Note that a 20 cm x 20 cm patch represents 1 percent of the quadrat area (Figure F.3).

Record the cover of receptive seedbeds types (including low receptivity seedbeds with high area coverage), but do not record unreceptive substrates such as exposed rock, open water, stumps, slash, roots, dense vegetation, etc. Seedbeds must be free of overtopping obstacles (e.g., logging debris or residual vegetation) that may intercept seed deposition. Correctly identifying seedbed types and accurately estimating their respective cover is essential to the process of determining the prescribed seeding rate.

Block	Baseline	Transect seg.	Seedbed type.	Quadrat no.1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Transect seg.	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
1	1	1												2										
SEEDBED INFORMATION (percent cover)																								
ADDITIONAL SILVICULTURAL PLANNING INFORMATION			Number of advance growth stems (<2.5cm)																					
			Amount of Cone bearing slash?																					
			Micro relief / obstructions / others																					

Figure F.1 Sample tally sheet for quadrat seedbed assessment

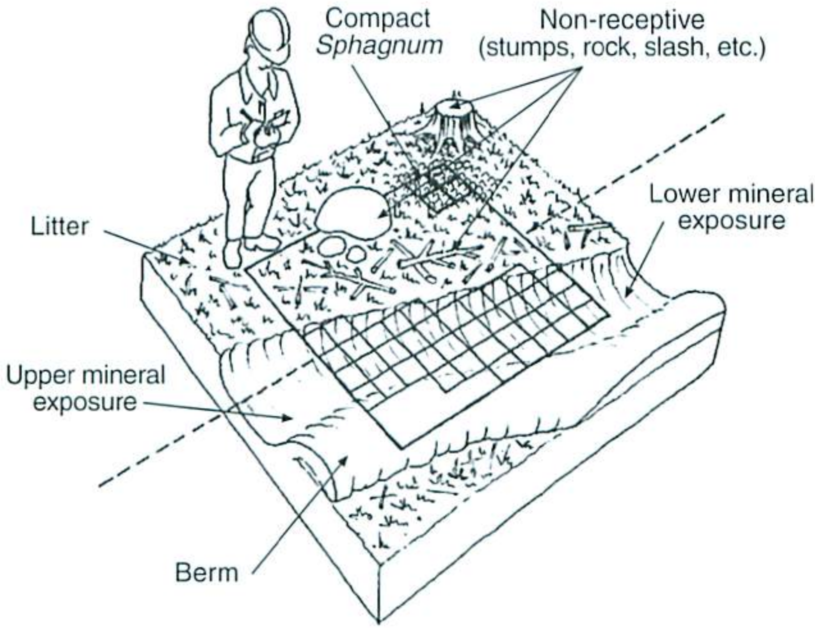


Figure F.2 Distribution of seedbed types within a 4 m² quadrat

Step 3. Record additional relevant information (e.g., number of stems of advance regeneration (must be rooted in the quadrat), the number of jack pine cones on receptive surfaces, the number of elevated cone laden black spruce tops, etc.)

Step 4. This step is for upland sites only. Once per line segment dig a soil pit to determine soil moisture regime by examining the soil's physical properties and profile characteristics. Locate the sampling point near the first quadrat of each selected line segment. Starting at the first quadrat of each selected line segment, offset approximately 2 m at a right angle from the centre line. From this point move in a parallel direction to the centre line until an undisturbed surface condition (not site-prepared) can be found. Using the techniques described in *A Field manual for describing soils* (Ontario Institute of Pedology 1985) determine and record soil moisture regime (SMR). An auger can be used to obtain this sample.

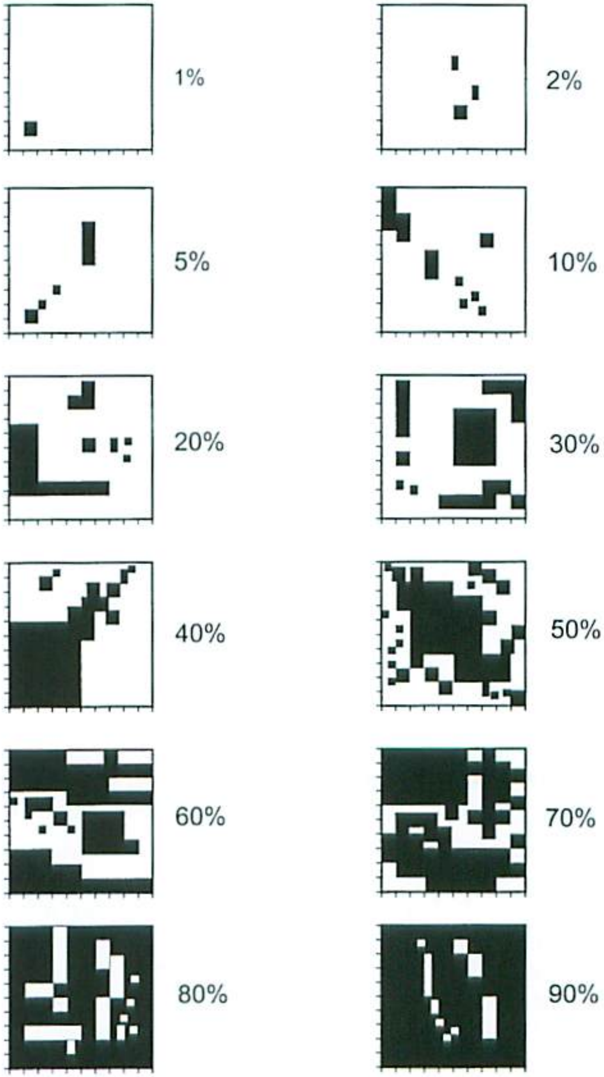


Figure F.3 Percentage cover charts

Appendix G: Procedures for carrying out a seedbed survey for spot seeding

The following information outlines a method of assessing the number of seedable spots per ha. The information collected can also be used by PC SEED to assist in determining the required number of seeds per spot.

Equipment needed:

- Spot seeding survey tally sheets (Figure F.1) or electronic data recorder;
- 50-m tape;
- Compass;
- Shovel or soil auger capable of sampling the "C" horizon;
- A Field manual for describing soils (Ontario Institute of Pedology 1985).

Step 1. Predetermine the spacing requirements and target seedbed types based on establishment ratios provided by the SDSs.

Step 2. In the case of disc trenching; walk at a right angle to the direction of site preparation and record the number of rows of site preparation per 100 m. Randomly select a bisecting trenched row. Walk up the trench for a distance of 40-m and record the best available seedbed type within the recommended target area of 1m ± 0.5 m from the starting point. A spot is not acceptable if it is closer than the minimum spacing. Record the best seedbed in the first 1-m segment. If there is no suitable seedbed, go to the next 1-m segment and repeat. Measure 1-m from the suitable seedbed and record the best seedbed in the next 1-m segment. When looking for an appropriate microsite it is acceptable to screef or compress the surface of the prepared area to improve its receptivity or create a suitable spot as would be done during an operational hand seeding exercise. If no suitable seedbed can found or created, record the spot as unseedable and go to the next 1-m segment.

In the case of spot scarification use the same type of procedure. Check the number of spot-making attempts over a 40 m length of row and record the number of attempts that resulted in acceptable spots for seeding.

For a bladed site several rows of spots may be established within a prepared swath. Prior to the survey, predetermine the minimum distance between rows within the swath [inter-swath spacing] and take this into account when calculating potential spot density.

Appendix H: Calibration of the Brohm Seeder in combination with the Piper PA-18A aircraft

Seeder description:

The output of the Brohm seeder is controlled by a variable speed auger that moves the seed from the seed tank to a duct leading to a revolving slinger attached to the belly of the aircraft. The pilot monitors the speed of the auger on a tachometer, and can adjust the auger speed in flight (Foreman 1995). The Brohm seeder can accept interchangeable augers with differing numbers of lands (flutes) and different pitches to accommodate different seed sizes and application rates. Using an auger with more lands and a finer pitch reduces the variation in deposition along the line of flight, but may cause more abrasion to the seed coat.

The seeder can apply seeds at a mean output within ± 10 percent of the desired application rate, except at low application rates (<40,000 seeds/ha for jack pine and <100,000 seeds/ha for black spruce).

Seeder calibration:

Calibrate the seeder on the ground over 30-second intervals using a stop watch and sensitive (± 0.1g accuracy) balance to meter seeds at the prescribed output rate for the proposed aircraft ground speed, inter-pass spacing, and application rate. The seeding unit should be warmed up prior to calibration, particularly if the ambient temperature is low (<10°C), and the electrical power supply to the unit should be supplemented if the aircraft battery is not being recharged during calibration. Adjust the speed of the auger for each successive test until the calculated weight of seeds equivalent to the prescribed output rate (viable seeds per second) is obtained consistently. These values can be plotted to identify the relationship between auger speed and output rate (e.g., Figure H.1, Fleming et al. 1985).

Accurate determination of the number of viable seeds per gram is critical for proper calibration of the seed-metering device. Information on seed viability and seed weight is provided by the seed plant for each seed lot number. However, this information reflects the state of the seed under cool storage and low relative humidity conditions. It is therefore advisable to condition the seed to the ambient field relative humidity and then determine the number of seeds/g, based on the weight of 0.1 gram samples (Foreman 1995).

Calculation example:

A prescribed seeding rate of 50,000 jack pine seeds/ha is desired. Assume an inter-pass spacing of 15 m and an aircraft ground speed of 130 km/h.

1. Calculate the area (ha) covered per minute of flight:

   [aircraft ground speed (m/min) x aircraft inter-pass spacing (m)/10,000]

   e.g., 130 km/h (2167 m/min) x 15 (m)/10,000 = 32,505 m^2 = 3.2 ha/min.

2. Determine the weight (g) of seeds required per ha:

   [application rate (viable seeds/ha)/number of viable seeds/g[1]]

   e.g., 50 000 seeds per ha/280 seeds/g = 179 g of seed/ha

3. Determine the output rate of seeds (g) required per 30-second interval to provide the prescribed seeding rate:

   [area covered per minute of flight x g of seeds required per ha/2]

   e.g., 3.2 ha/min. x 179 g/ha ÷ 2 = 286 g of seeds per 30 second test interval will meet the prescribed seeding rate of 50 000 seeds/ha.

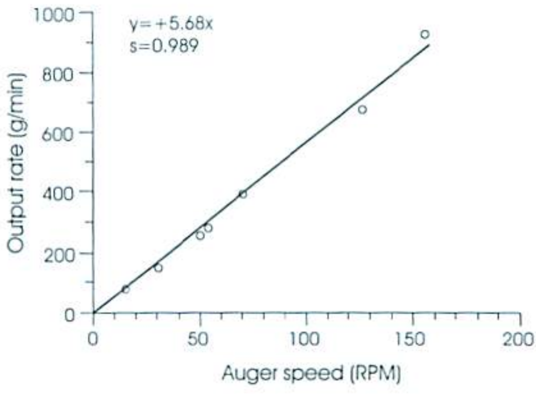


Figure H.1 A strong linear relationship exists between auger speed and output rate for black spruce seeds *(Fleming et al. 1985)*.

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1 Provided by the seed extraction plant, checked under field conditions

Appendix I: Number of traps required to sample aerial seeding at various seeding rates and confidence intervals *(Cameron and Foreman 1995)*

Seeding rate/ha	Level of confidence	Confidence interval	Trap size		
			0.25 m^2	1 m^2	4 m^2
50,000	19 times out of 20	+/- 10%	308	80	22
		+/- 5%	1230	308	80
	99 times out of 100	+/- 10%	531	133	37
		+/- 5%	2125	531	133
100,000	19 times out of 20	+/- 10%	154	41	12
		+/- 5%	615	154	42
	99 time out of 100	+/- 10%	236	71	21
		+/- 5%	1062	266	71
150,000	19 times out of 20	+/- 10%	106	28	9
		+/- 5%	410	107	29
	99 times out of 100	+/- 10%	177	48	15
		+/- 5%	708	177	48
200,000	19 times out of 20	+/- 10%	80	22	7
		+/- 5%	308	80	22
	99 times out of 100	+/- 10%	133	37	12
		+/- 5%	531	133	37
300,000	19 times out of 20	+/- 10%	54	16	6
		+/- 5%	205	54	16
	99 times out of 100	+/- 10%	93	26	10
		+/- 5%	354	93	26

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