Synopsis
Topic Summary for the Operational Forester

Mounding for Site Preparation

Introduction

One of the more promising techniques for site preparation in the interior of British Columbia is the creation of raised planting spots by mechanical mounding. This leaflet summarizes what is currently known about the ecology and operational practice of mounding.

Why Create Mounds?

When correctly prescribed, mounding creates planting spots that favor conifer seedling establishment and encourage rapid initial growth. The raised microsite created by mechanical mounding can:

- increase soil temperatures within the rooting zone;
- improve soil drainage on wet sites;
- improve aeration in wet, clayey, or compacted soils;
- reduce interference from surrounding vegetation;
- provide the benefits of a mineral soil planting spot while avoiding the drawbacks associated with scalping;
- provide a rooting medium rich in organic matter.

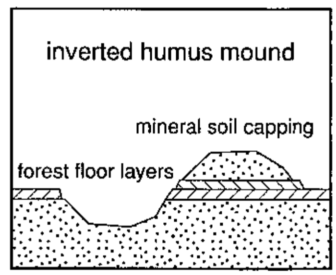
Mound Types

A **mound** is a discrete, raised planting spot suitable for one tree seedling. Continuous, raised planting berms, beds, or ridges are not considered to be mounds, and are not described in this summary.

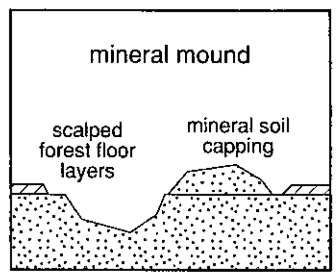
The size, shape, and makeup of mounds vary with local site and soil conditions and with the machinery and techniques used to create the mound. Two of the most important features are the amount and distribution of organic matter within the mound and the depth of the mineral soil capping.

There are three basic mound types:

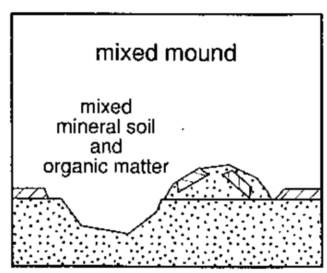
Inverted humus mounds are made when a scoop of the forest floor and underlying mineral soil is removed and placed upside-down on top of an adjacent patch of undisturbed forest floor.



To create **mineral mounds**, forest floor layers are first removed by scalping. Mounds of loose mineral soil are then placed directly on the exposed mineral soil surface.



Mixed mounds consist of intermixed mineral soil and forest floor layers. The mixed material can be deposited on top of undisturbed or scalped forest floor layers.



Each of these mound types creates a slightly different seedling environment. The choice of an appropriate mound type depends on the ecological characteristics of the site and the objectives of the site preparation treatment.

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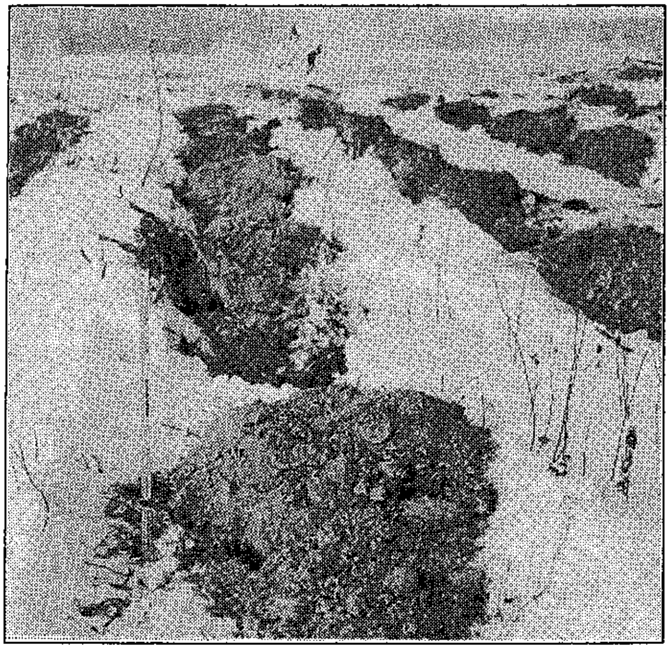


Mounds are discrete raised planting spots

How Mounding Affects the Micro Environment

Temperature

Soil Temperature Soils within a mound warm up earlier in the spring than untreated or scalped soils and reach higher daytime temperatures throughout the growing season. Mounding removes shading vegetation and insulating forest floor layers and exposes an increased surface area of mineral soil to the sun. The warming effect of mounding is particularly important on wet sites because well-drained soils heat up far more quickly than wet soils. All three types of mounds provide substantial increases in soil temperature compared with unmounded planting spots.

Although mounds become warmer during the day than do other kinds of planting spots, they also cool down faster at night and tend to be colder in winter.

Air Temperature Mounding reduces shade and increases air circulation around the planting spot. During the night, the mineral soil capping of the mound radiates some of the heat absorbed during the day back into the air. The net impact of mounding on day and night air temperatures and on the incidence of frost is complex and not yet fully understood.

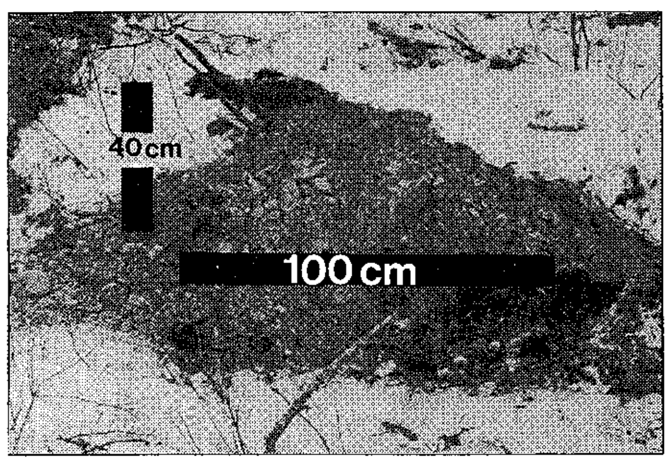
Soil aeration and porosity

Forest soils in British Columbia are often poorly aerated or so dense that root growth is impaired. Mounding improves soil aeration in wet soils by providing drainage. In clay-heavy soils, or soils compacted by glaciers or machine traffic, mounding improves aeration by loosening up the soil and increasing the amount of pore space. Mixed mounds that incorporate organic matter into the mineral soil provide the greatest increase in soil porosity.

Soil moisture

Mounds dry out more quickly than unmounded soils. The drier soil conditions are beneficial to seedlings on wet sites because they improve soil temperature and aeration. However, there are many sites where mounded soils can become unacceptably dry. To prevent their drying out, mounds should have a low profile and a large top surface. Capping depth must be greater than 10 cm, but overall mound height should not exceed 40 cm. Mounds that are flat or concave on top capture rainfall better than cone-shaped mounds which shed moisture rapidly.

In inverted humus mounds, the mineral soil capping can become desiccated because the capillary connection between the mineral soil capping and underlying soil is broken by layers of organic matter. However, water is available in the undisturbed mineral soil and organic layers at the base of the mound. The roots of planted seedlings must extend into the base of the mound to tap this moisture on sites where mounds are prone to drying out. In mineral mounds, and to a lesser extent in mixed mounds, the capillary connection is maintained and there is less of a risk of the mounds drying out.



Mounds should have flat or concave top surfaces. Overall mound height should not exceed 40 cm.

Both inverted humus and mixed mounds may contain air pockets caused by slash and other debris, which also interrupt the flow of water. A thick mineral soil capping improves the contact between the mound and the ground surface.

Nutrient availability

Soil nutrients, expecially nitrogen, may be more available to seedlings on mounded planting spots than on an untreated or scalped planting spot. Higher soil temperatures within a mound promote increased chemical and biological activity that releases nutrients for uptake by plant roots.

Because most of the important nutrients for plant growth come from the breakdown of soil organic matter, inverted humus and mixed mounds will tend to have higher nutrient availability than mineral mounds.

The volume of soil and organic matter within a mound is small and the supply of nutrients can quickly be depleted. Seeding roots must grow out of the raised mound to obtain nutrients from the surrounding soil within a few growing seasons.

Competing vegetation

Inverted humus and mineral mounds can be very effective in suppressing the growth of competing vegetation, provided the mineral soil capping is sufficiently thick and relatively free of surface organic matter.

Mixed mounds provide little or no vegetation control because the capping of the mound is a favourable medium for growth and is full of chopped roots, rhizomes, and seeds.

The larger the mound (both surface area and capping thickness) and the less organic matter it contains, the more effective it is in suppressing vegetation regrowth. Cappings of finer-textured clay or silt soils may also provide better vegetation control than sandy-textured or loamy cappings.

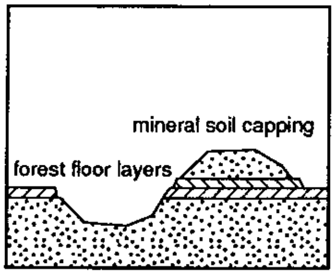
Protection from competition is usually short-lived (2-4 years), but on many sites this may be enough to allow a free-growing stand to be achieved.

Mounds with a thick capping of fine textured soil can effectively suppress vegetation regrowth.

Mounds with a thin capping containing abundant organic matter are quickly overgrown.

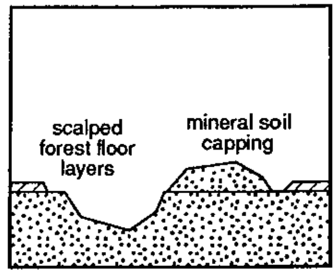
SUMMARY

Inverted humus mounds



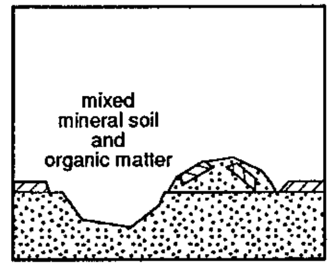
- good on nutritionally poor sites;
- good for rich sites with fine textured soil;
- not recommended for drought-prone sites or sites with deep, loose duff.

Mineral mounds



- best for cold, but slightly drought-prone sites.
- not recommended for nutritionally poor sites.

Mixed mounds



- best for slightly drought-prone, nutrient-poor sites,
- not recommended for sites with abundant competing vegetation;
- avoid creating large chunks of organic matter that cause air pockets.

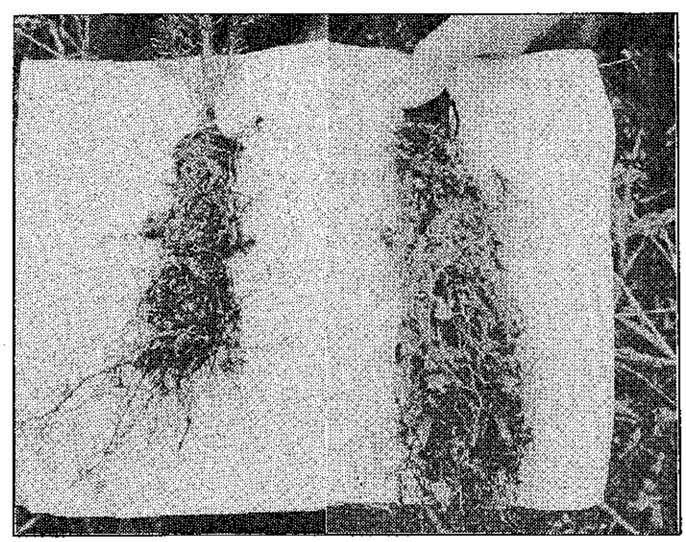
NOTE: None of these mound types is recommended for sites with a significant risk of summer drought.

How Mounding Affects Seedling Growth

Root Growth

Roots require warm soil temperatures and abundant oxygen for optimum growth. Higher soil temperatures within mounds stimulate the initiation of new roots. Early initiation of fine root growth may be especially advantageous following spring planting, when untreated soils are often too cold for root growth to occur.

When seedlings are planted into wet soil, lack of oxygen severely impairs root growth. Mounding can ensure that seedling roots are not exposed to flooding. On sites with heavy, compacted soils, mounding can also stimulate root growth by providing a loose, well-aerated rooting medium.



Seedling roots after two growing seasons on untreated (l) and mounded (r) planting spots.

Water and Nutrient Uptake

The rate of water and nutrient uptake largely determines the rate at which a planted seedling can grow. Rapid uptake of water and nutrients requires warm soil temperatures (cold water moves slowly) and a large surface area of actively growing fine roots. Thus, the rate of seedling water uptake may actually be higher in the drier soil of a mound, than in wetter but colder, unmounded soils.

Shoot Growth

Correctly applied mounding can significantly increase early height and diameter growth of planted seedlings compared with that in untreated or unmounded planting sites. The higher growth rates are due to a combination of the following factors:

- a more actively growing root system
- higher rates of water and nutrient uptake
- reduced competition and more light
- warmer air temperatures

Longer-term studies are showing that the benefits of rapid early seedling growth carry through to the free-growing stage and beyond.

Seedling Damage

Physical damage to seedlings can be reduced by mounding and the associated exposure of mineral soil. Mounding might, for example,

- reduce the incidence or severity of growing season frost.
- reduce damage from vegetation press.
- reduce damage by Warren's root collar weevil (*Hylobius warreni*).
- reduce damage by small mammals (hares, voles, lemmings).

Negative Impacts of Mounding

Mounding may not benefit seedlings when the treatments are poorly executed or applied under inappropriate site and soil conditions. Some problems associated with mounding include:

Moisture stress

- shallow planting on mounds prone to drying out.
- loose mounds, full of air pockets.
- cone-shaped mounds that drain rapidly.

Erosion and root exposure

- steep-sided mounds (slopes >20%)
- poor soil cohesion.
- frost heaving (not common in British Columbia, but has caused serious problems elsewhere).

Root restriction and deformation

- roots fail to grow out from the mound. This leads to lack of windfirmness (toppling) and may cause moisture and nutrient deficiencies.
- on wet sites, roots may be confined to the mound by a surrounding moat of water
- poor planting; seedlings J-rooted at base of the mound.
- heavy clay soil in mound becomes too hard for roots to penetrate.

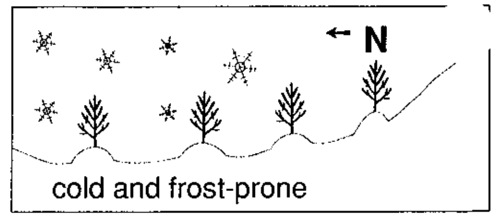
Winter damage

- in low snowfall areas, less insulation and earlier snowmelt around mounds can cause winter injury to newly planted, climatically unadapted seedlings.

Suitable Mounding Conditions

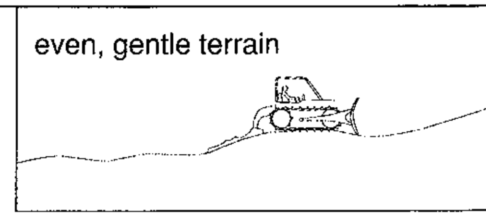
Climatic conditions

- short growing seasons and cool temperatures (most subzones of BWBS, SBS, SBPS, and ESSF; also ICHmk, mc, wk, vk, vc, and wetter MS)
- cool, shady north-facing slopes, especially at higher elevations
- frost pockets and areas of cold air drainage



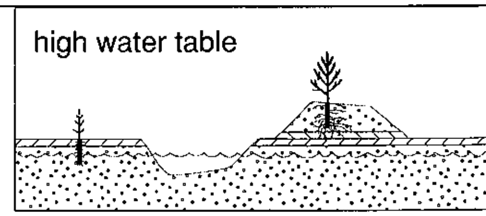
Terrain

- even or rolling terrain
- slopes less than 30% (or up to 50% if excavator or flex-track prime mover available)
- deep soils



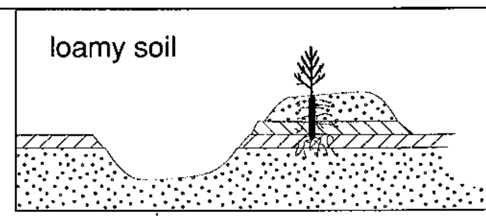
Soil moisture

- mesic and especially subhygric, hygric, and subhydric moisture regimes
- no significant risk of drought
- poorly aerated soils with seasonal or year-round high water tables (but prime mover access may be difficult)



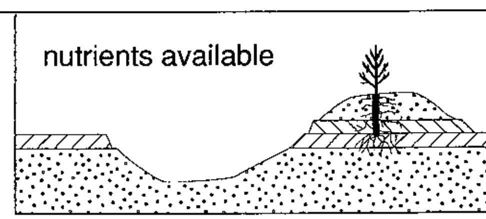
Soil texture

- sandy loam to clay loam soils best
- clayey or silty soils acceptable (if no other treatment option available)
- gravels or stones less than 30%
- compacted subsurface layers (hardpan) - (only if equipment with sufficient down pressure is available)



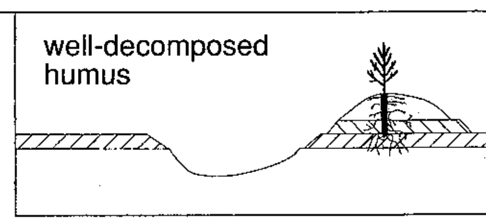
Soil nutrients

- inverted humus mounds will benefit seedlings on nitrogen-deficient, nutritionally poor sites



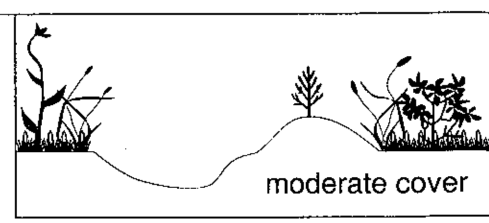
Soil organic layers

- duff layers less than 15-20 cm thick (unless excavator available)
- well decomposed organic matter (H layer) can be an acceptable planting medium on wet sites



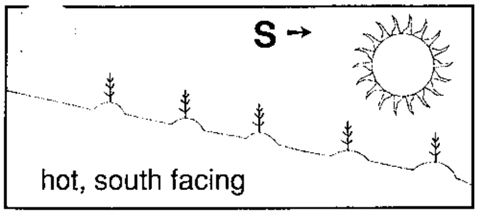
Competing vegetation

- light to moderate herbaceous or shrub cover
- dense, but short grass cover



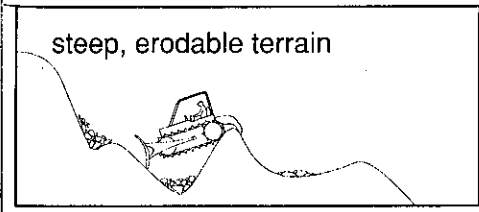
CAUTION: Mounding is an expensive treatme' b

Unsuitable Mounding Conditions



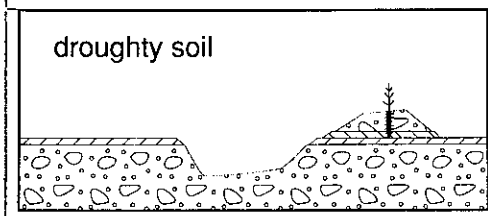
Climatic conditions

- warm, dry growing seasons with significant risk of summer drought (IDF; PP; drier MS, ICHdk, dm, dw, mw, xw; SBSdh, dk, dw, mh, mw,mm)
- sunny, exposed south-facing slopes and ridges.



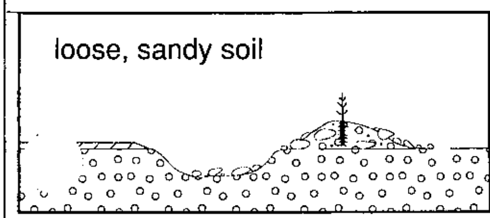
Terrain

- significant erosion hazard present
- slopes greater than 30% (or 50% if excavator available)
- irregular terrain with shallow soils and frequent rock outcrops



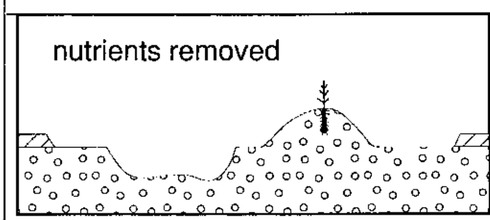
Soil moisture

- submesic, subxeric, or xeric moisture regimes
- significant risk of drought
- coarse-textured or shallow soils with low moisture-holding capacity;
- rapidly drained ridge crests or upper slopes



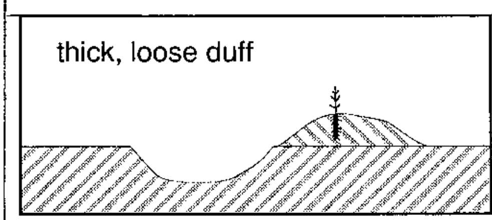
Soil texture

- loamy sand to sandy soils lacking cohesion
- use with caution on fine-textured or silty soils prone to frost-heaving
- gravels or stones greater than 30%



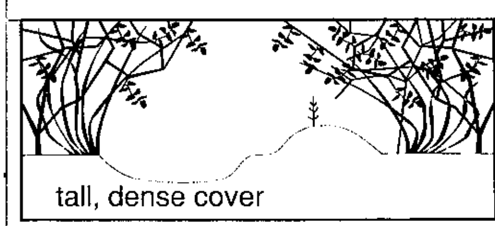
Soil nutrients

- scalping with mineral mounds not recommended for nitrogen-deficient, nutritionally poor soils



Soil organic layers

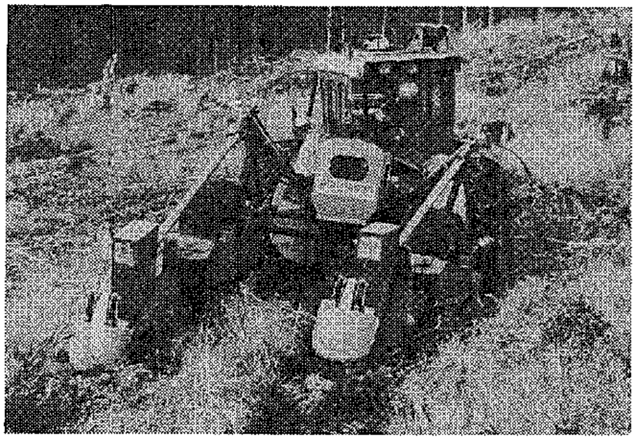
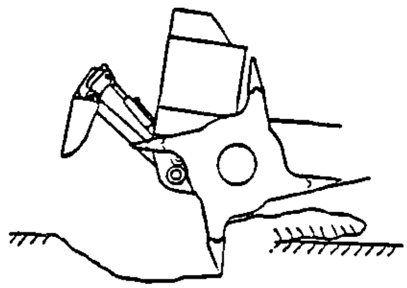
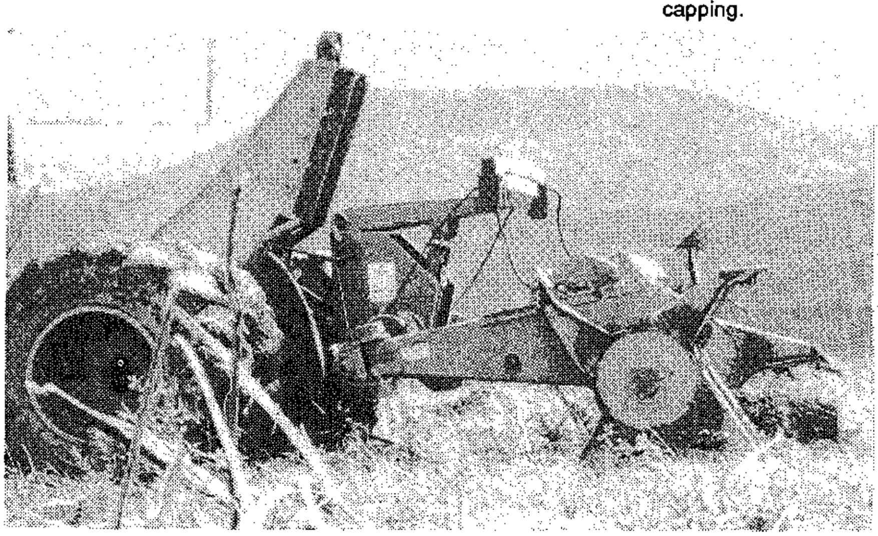
- poorly decomposed duff greater than 20 cm thick (must be removed before mounding)



Competing vegetation

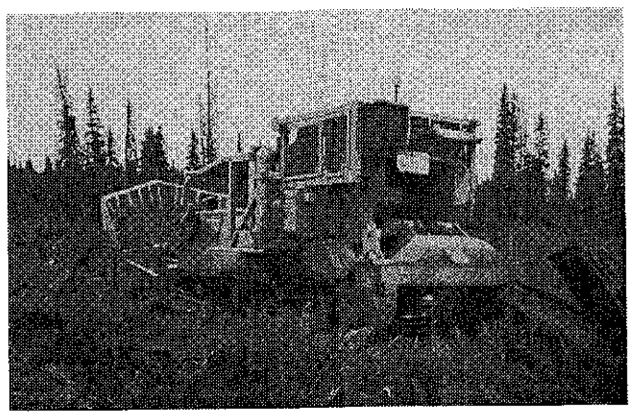
- dense, tall grass, herbs, or shrubs (must be removed before mounding)

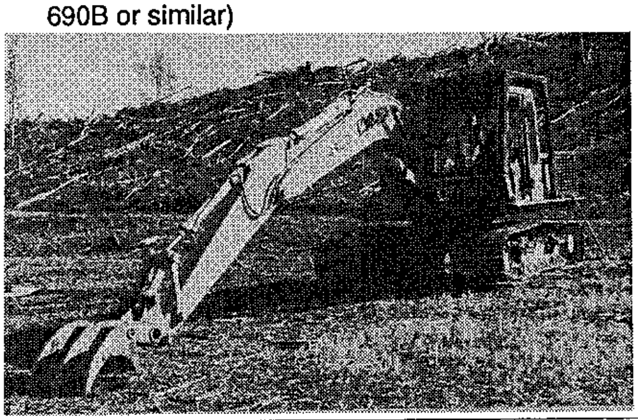
Equipment options for mounding

Equipment	Mound Description	Best Features	Worst Features
BRÄCKE MOUNDER (2-row)  	Inverted humus mounds Mineral mounds Smaller mounds than other machines Test mounds averaged 16-26 cm in height with 3-19 cm mineral capping. Functions poorly when duff depth exceeds 10-15 cm; thin mineral capping mixed with organic matter.	Available and in operational use. Consistent performer High productivity and relatively inexpensive Small mounds may be well-suited to sites where drought or frost-heaving is a concern. Versatile; produces inverted humus and mineral mounds, and scalped patches	Limited to relatively easy sites. Performs poorly in deep duff, compacted, or frozen soils. Access limited on wet, steep or obstacle-filled terrain. Produces smaller mounds with thinner mineral capping than may be desired on many sites.
SINKKILÄ (HMF) SCARIFIER  	Inverted humus mounds Mixed mounds Mound size intermediate between Bräcke and Spot Mounder Test mounds averaged 28-41 cm in height with 3-20 cm mineral capping.	Versatile. Can be used for scalping or trenching where mounds not desired. High productivity when functioning properly Manoeuvrable	Limited availability and experience in B.C. Newer models (which apparently rectified mechanical problems experienced at test site) have not been field tested in B.C. Limited to relatively clean, easy sites.

Equipment options for mounding

Equipment	Mound Description	Best Features	Worst Features
SPOT MOUNDER (formerly Ministry Mounder)	Inverted humus mounds Mineral mounds (if scalped with blade) Produces large mounds 80 x 100 cm surface Test mounds averaged 22-44 cm in height with 6-20 cm mineral capping Fresh mounds can have very steep sides, but overwinter settling occurs.	Very successful at producing large mounds with a thick mineral soil capping. Rugged machine. Down pressure enables shovels to penetrate compacted, stony soils or frozen snow-covered ground.	Preproduction model had mechanical/ hydraulic breakdowns. Improved commercial model [available Sept. 89] not yet field tested. Will be expensive to operate and purchase.
SMALL EXCAVATORS (Cat 205,215; JD 490 690B or similar)	Inverted humus mounds Mineral mounds Mixed mounds Mound size and type can be infinitely varied to meet site-specific needs. Capable of producing much larger mounds than other equipment.	Capable of preparing difficult sites that can't be treated by other machines. Extremely versatile. Site preparation technique can be adapted to microsite conditions.	Slow and very expensive to operate. Not recommended where other equipment can effectively treat the site. Requires skilled operator and close supervision.
SKIDDER-MOUNTED BACKHOE	(see excavator)	Similar to excavator, but has greater mobility. Useful for treating small units dispersed over a large area.	Similar to excavator, but has reduced trafficability and access on steep or wet sites.





For additional information on these machines, refer to the publications listed on the last page. Mounding equipment not yet tested in British Columbia is described in FRDA Report 031.

Preparing and Implementing a Silviculture Prescription for Mounding

Delineating the treatment unit to be mounded

- *This can be done at the preharvest stage, following a stocking survey that indicates the unit is NSR, or as a rehabilitation treatment for an area of backlog or non-commercial cover.*

The entire cutblock, or just a portion of the cutblock, may require mounding. Remember, mounding is an expensive treatment that should be reserved for problem sites.

Deciding whether additional site preparation will be required for brush, slash, or duff reduction before mounding

- *Objectives:*
  - to facilitate prime mover access.
  - to allow sufficient ground contact for the mounding device to operate properly
  - to ensure that planting spots are free of excessive competing vegetation.
- *Options:* broadcast burn, pile or windrow and burn, brown and burn, chemical site preparation, mechanical clearing, manual slashing.
- Can the necessary site preparation be accomplished in a single operation with a blade mounted on the front of the mounding device?

Deciding on mounding objectives

- *Mound size and type (inverted humus, mineral, mixed).* Consider the risk of drought or flooding, nutrient availability, and competing vegetation. Depth of the mineral soil capping should be at least 10-20 cm, but overall mound height should not exceed 40 cm. The top of the mound should be flat or concave to collect rainfall. Larger mounds are more effective at supressing competing vegetation. Equipment available and the prior site preparation may dictate the type of mound produced.
- *Depth of prior scarification (if required).* Blade can be set to leave surface organic layers mostly intact, reduce the thickness of organic layers, or fully expose the mineral soil. Avoid over-scarification.
- *Number of plantable spots per hectare and desired inter-tree spacing (determines row spacing and distance between mounds).* With all machines, some allowance must be made for unsuccessful mound attempts (10-30%), but additional planting spots can generally be found if planters take advantage of naturally raised microsites.

Scheduling the mounding treatment

- *How long can the treatment be delayed following harvesting?* Mounding after vegetation is well established can still be effective, but it is far more costly, requiring larger mounds and larger planting stock.
- *Season of treatment.* On wet sites, mounding may have to be carried out in late summer or fall when soils are driest, or even in winter on frozen or snow-covered ground. On brushy sites, carrying out the treatment when plants are not in full leaf improves visibility. In fireweed areas, delaying mounding until after seeds have flown may provide an additional year of vegetation control.

Logistical considerations

- *Equipment and operator availability.* Choice of equipment and timing of treatment may be constrained by limited access to mounding equipment, appropriate prime movers, and trained operators.
- *The need for additional supervisory personnel.* Close supervision by personnel who understand the objectives of the treatment is very important, especially for excavator treatments. Additional supervision of the planting operation is also required.
- *How much area can be treated at one time?* For efficiency, particularly if treatment units are small, activities should be co-ordinated so that several nearby areas can be mounded in the same project. On the other hand, a versatile machine capable of different types of site preparation can be used to treat large areas, mounding only where mounding is required (e.g. on wetter ecosystems with fine-textured soils) and scalping, mixing, or leaving untreated those areas where mounds are not desired (e.g. on drier ecosystems with thin forest floors and coarse-textured soils).

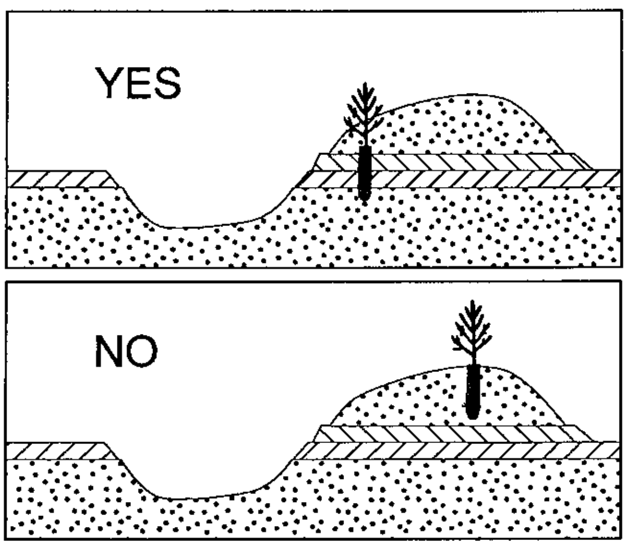
Site disturbance

In theory, mounding minimizes the potential for damage to the site by leaving the area between mounds undisturbed. Substantial site damage can occur, however, when mounding is inappropiately prescribed or poorly executed:

- Large mounds create large craters, which act as water catchments and can be hazardous to humans, wildlife, and livestock.
- Prime movers, blades, and rakes can cause rutting, compaction, and unnecessary gouging and scalping.

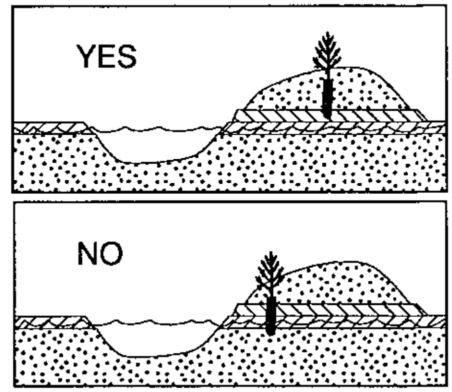
Planting mounds

- *Selecting stock types and species.* Either plug or bareroot stock can be planted on mounds. To avoid their drying out or being frost-heaved, seedling roots must be long enough to extend into the base of the mound; bareroot stock may be preferred over standard PSB 313 or 211 plugs. Special long-rooted plug stock (PSB 323 or 425) is being tested but is not yet available operationally. Both Sx and Pl grow well on mounded planting spots.
- *Scheduling planting time.* Mounds should be left to settle over one winter before planting. This improves ground contact, removes air pockets, and reduces the risk of soil erosion around roots. Mounds left for additional growing seasons will quickly be invaded by vegetation, and may require brushing before planting.
- *How to plant the mound.* On well-drained sites or soils prone to frost-heaving, seedling roots must extend into the undisturbed soil below the base of the mound.

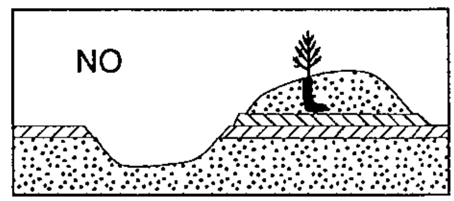


Plant the seedling on the slope of the mound or create a depression in the centre of the mound. Burying the seedling above the root collar may be necessary.

On sites prone to flooding, keep seedling roots above the high water level.



Special care must be taken to avoid J-rooting the seedling at the base of the mound. Planters may experience difficulty penetrating inverted humus layers or undisturbed mineral soil. Dry mounds are particularly difficult to plant because dry soil fills the planting hole. A special planting tool has been developed to make planting of long-rooted plugs easier, but it is not yet available for operational planting.



Planters may have to rework the mound to create an ideal planting microsite. In clay soils, mounds are often clod-like and must be broken down before planting. Inverted humus mounds with thick loose duff require extra care to ensure that the seedling is tight.

Monitoring and follow-up

Because there is so little long-term experience with mounding in British Columbia, careful monitoring to determine the reasons for success or failure of mounding projects is essential.

- *Assessments of seedling survival and performance.* Severe chlorosis after 2-3 years may indicate poor root growth out of mounds.
- *Do the mounds remain free of excessive competing vegetation or is brushing required?*
- *At the free-growing stage, seedling roots must extend well beyond the original mound for stability and to meet nutrient and moisture demands.*

FRDA-funded research projects related to mounding in the interior of British Columbia

Project No.	Contact Person	Project Location	Project Description
1.01	Dale Draper B.C.Ministry of Forests Red Rock Research Stn. R.R.#7, R.M.D.#6 Prince George,B.C. V2N4T5 963-9651	Beaver Road, Prince George East Forest District	Evaluates the biological effectiveness and cost of a variety of silvicultural regimes for establishing Sx on wet SBS ecosystems. Mounding, with and without chemical vegetation control, is included. D. Spittlehouse is studying the microclimate of mounds on this site (Project 1.26). Growth of long- rooted plugs (PSB 323) is also being studied (Project F52-31-014).
1.10	Lorne Bedford B.C.Ministry of Forests Silviculture Branch 31 Bastion Square Victoria, B.C., V8W 3E7 387-8909	Vanderhoof, Mackenzie, Ft. St. John, & Dawson Ck. Forest Districts	Field trials of mounding equipment (Bräcke mounder, Sinkkilä HMF, Ministry D7 mounder), and assessment of mound characteristics, soil properties, seedling growth and survival on mounds. Other UBC and MOF researchers are studying the microclimate and root growth of seedlings on these mounds. (Projects 1.24, 1.25).
1.16	Bob McMinn Millstream Rd. R.R.#6 Victoria,B.C. V8X 3X2	various locations	Examines the long-term cost effectiveness of mounding on older experimental sites ranging in age from 6 to 15 years.
1.17 & 3.35.14	Craig Sutherland B.C.Ministry of Forests Cariboo Forest Region 540 Borland St. Williams Lake,B.C. V2G 1R8 398-4387	Quesnel Forest District Horsefly Forest District	Evaluates site preparation options for reforesting ESSF backlog sites. Compares large excavator mounds with screefed and untreated planting spots.
1.35	Anne Macadam B.C.Ministry of Forests Prince Rupert Forest Region Bay 5000 Smithers, B.C. V0J 2N0 847-7431	Joel Lake, Chain Fire, Morice Forest District	Compares microclimate, seedling growth, and nitrogen availability on mounded and unmounded planting spots. Also studies growth of extra-long plugs (PSB 323) on mounds.

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