June 1990 Memo No. 152

Synopsis

Topic Summary for the Operational Forester

Seedling Microclimate and Reforestation

WHAT IS MICROCLIMATE?

Seedling microclimate is determined by the interaction of weather conditions, site factors and forest management activities. Atmospheric weather conditions (e.g., sunshine, precipitation) largely determine the microclimate. Site factors such as topography, vegetation cover, and soil type can significantly modify the effect of the weather conditions.

Seedling microclimate has a large daily and seasonal variability in the following:

- Solar radiation (sunlight)
- Precipitation
- Air humidity
- Wind
- Air temperature
- Soil moisture
- Soil temperature

Each of these regimes is discussed in this synopsis—how they affect seedlings, what factors affect the regime, and how silvicultural treatments can modify the regime. Silvicultural treatments can be used to affect the light, air temperature, soil temperature, and soil moisture regimes significantly. Precipitation, air humidity and wind are less easily modified.

RELEVANCE OF SEEDLING MICROCLIMATE TO REFORESTATION

Microclimate plays an important role in the establishment of conifer seedlings. It influences the seedling's physical and physiological processes, which in turn affect survival and growth. Microclimatic extremes can cause visible damage or sometimes kill seedlings. Sub-lethal effects can change seedling growth rate and phenology, and increase vulnerability to other microclimatic stresses, and to disease and insects.

The silvical requirements of a species must be matched to the site environment. Silvicultural treatments can be applied to maximize the microclimatic resources available to the seedling. Evaluating potential site microclimate limitations is an important part of the pre-harvest prescription. This allows the forester to determine whether site preparation should:

- ensure adequate light.
- minimize the frequency and severity of summer frosts.
- conserve moisture, increase soil water-holding capacity, or improve drying.
- warm or cool the soil.

Silvicultural treatments can then be evaluated to determine which can best produce the required seedling microclimate within the limitations of factors such as cost, treatment feasibility, and equipment availability.

FOREST RESOURCE DEVELOPMENT AGREEMENT

Canada BC

TABLE 1. Effect of silvicultural treatments on the physical environment of seedlings. Increase or decrease refers to a change relative to no treatment of dense competing vegetation.

Site treatment	Light	Soil temperature	Soil moisture	Soil evaporation	Transpiration	Frost hazard	Area of impact
Herbicide	Increase	Increase	Large increase	Little change	Decrease to zero	Depends on vegetation	Either whole site or around seedlings
Mulch	Increase	Decrease at depth	Large increase	Large decrease	Large decrease	Increase	Around seedlings
Slash piles	Increase, some shading	Increase	Small increase	Some increase	Little change	Decrease	Variable and not uniform on site
Shadecard	Decrease, shaded	Decrease at surface	Small increase	Little effect	Little change	Decrease	Very small area around seedlings
Scalping	Increase	Increase	Increase	Increase	Decrease	Decrease	Around seedlings
Broadcast burn	Increase	Increase, wider range	Increase	Slight increase	Decrease	Decrease	Whole site
Trench	Increase	Increase	Increase	Increase	Decrease	Decrease	Around seedlings
Ripping	Increase	Increase	Increase	Increase	Decrease	Decrease	Whole site
Rototilling	Increase	Increase	Increase	Increase	Decrease	Decrease	Around seedlings
Mounds	Increase	Increase, wider range	Decrease, (increased drainage)	Increase	Decrease	Decrease	Around seedlings
Deep ditches	Increase	Increase, wider range	Decrease, (increased drainage)	Increase	Decrease	Decrease on berm	Around seedlings
Shelter-wood/ Partial cut	Decrease, sunflecks	Decrease, narrower range	Slight increase	Slight decrease	Increase but from depth	Large decrease	Whole site but not uniform over site

SOLAR RADIATION/LIGHT

Effect on seedlings

Provides energy for:

- photosynthesis (Figure 1)
- heating soil and air
- evaporating water

Low light levels can result in:

- a spindly growth form (often accompanied by vegetation press) (Figure 2)
- low soil temperature due to a reduction in soil heating (see "Soil Temperature")

Inadequate light is often a problem in the wetter subzones which frequently have a dense growth of competing vegetation.

Factors affecting the light regime

Weather:

- cloud cover – reduces solar radiation
- time of year – affects day length, solar angle

Site:

- slope, aspect – over a growing season a steep south-facing slope receives 3 times as much light as a north-facing slope.
- vegetation cover – density, phenology and rate of canopy development (e.g., aspen and fireweed canopies develop earlier than thimbleberry).

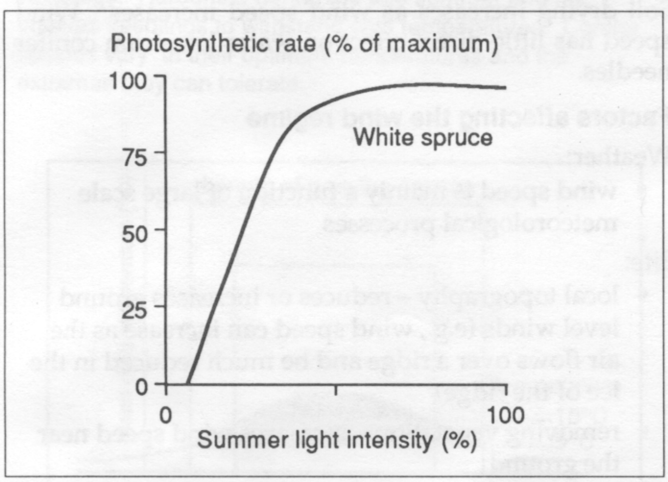

FIGURE 1. Seedling photosynthesis increases as light increases. Maximum rates are achieved at a level of a third to a half full summer sunlight. The maximum rate can be achieved for much of the day from spring to late summer, even under light shade from competing vegetation.

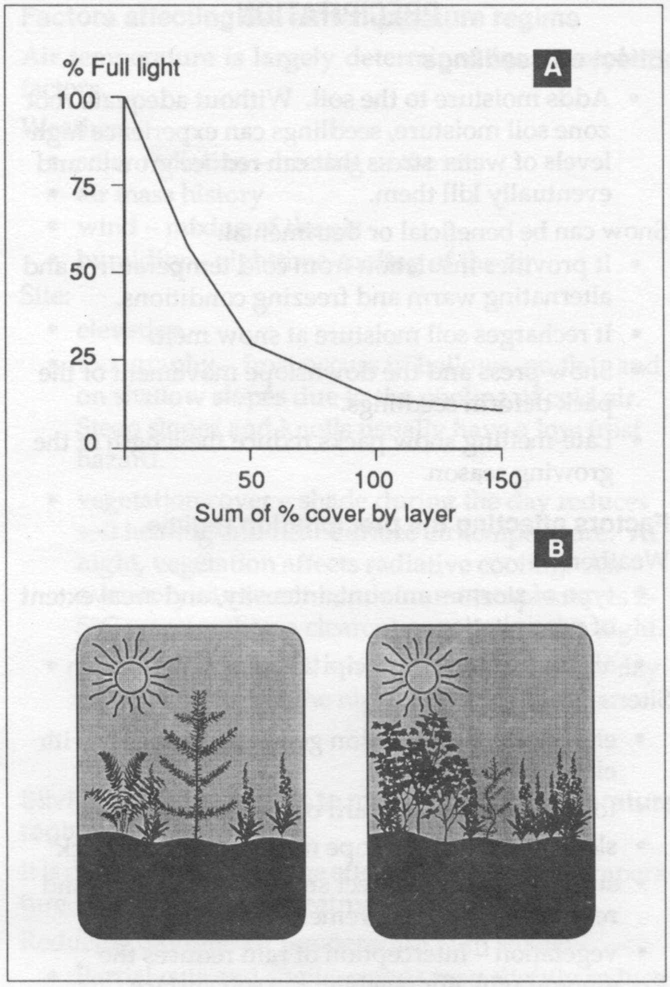

FIGURE 2. (A) Increasing vegetation cover reduces the intensity of light beneath the vegetation. Seedling photosynthesis will be significantly reduced by greater than 50% cover. Vegetation press will also be a problem.
(B) Seedling growth form is poor under heavy shade.

Silvicultural treatments to modify the light regime

Removing shade:

- Herbicides, prescribed burning, and mechanical treatments control competing vegetation.

Maintaining shade:

- In hot, arid areas a reduction in heat stress is more important than a reduction in photosynthesis. This can be achieved through partial cuts or shelterwoods.

PRECIPITATION

Effect on seedlings

- Adds moisture to the soil. Without adequate root zone soil moisture, seedlings can experience high levels of water stress that can reduce growth and eventually kill them.

Snow can be beneficial or detrimental:

- It provides insulation from cold temperatures and alternating warm and freezing conditions.
- It recharges soil moisture at snow melt.
- Snow press and the downslope movement of the pack deform seedlings.
- Late-melting snow packs reduce the length of the growing season.

Factors affecting the precipitation regime

Weather:

- type of storm – amount, intensity, and areal extent of precipitation
- air temperature – precipitation as snow or rain

Site:

- elevation – precipitation generally increases with elevation
- topography – windward or leeward slopes
- slope angle – downslope movement of the pack
- surface residues – affect snow accumulation, and resist downslope movement of the snow pack
- vegetation – interception of rain reduces the amount of water reaching the soil surface

Silvicultural treatments to modify the precipitation regime

Increasing snow accumulation:

- Surface residues (slash, stumps) help minimize snow drift in low snow areas.
- Small openings (up to 10 tree heights in width) can enhance snow accumulation.

Reducing snow press:

- Reducing vegetation press helps to reduce snow press.
- Barriers such as stumps or partial cutting can reduce downslope movement of the snow pack.

ATMOSPHERIC HUMIDITY

Effect on seedlings

Atmospheric evaporative demand for moisture:

- operates in combination with air temperature. Low relative humidity results in a higher transpiration demand on the seedling.

Factors affecting the air humidity regime

Weather:

- air mass – source and history of the air mass determines water content of the air
- air temperature – relative humidity decreases during the day as air temperature increases

Site:

- canopy development – a tree canopy can increase relative humidity by shading the forest floor and reducing near-surface air temperature. This is most effective under a dense forest canopy.

Silvicultural treatments to modify the air humidity regime

Site preparation will have little effect on the amount of moisture in the air. Shading the soil surface under partial cuts and shelterwoods decreases near-surface air temperatures, which slightly increases the relative humidity.

WIND

Effect on seedlings

Mechanical effects:

- breaking branches, twisting seedlings
- wind scour – removes insulating snow cover, and reduces snow available for melt and recharge of root zone moisture reserves

Soil drying increases as wind speed increases. Wind speed has little direct effect on water loss from conifer needles.

Factors affecting the wind regime

Weather:

- wind speed is mainly a function of large scale meteorological processes

Site:

- local topography – reduces or increases ground level winds (e.g., wind speed can increase as the air flows over a ridge and be much reduced in the lee of the ridge)
- removing vegetation – increases wind speed near the ground

Silvicultural treatments to modify the wind regime

Clearcutting dramatically increases the wind flow at the ground. Residues left on the surface can reduce near-surface wind speed.

AIR TEMPERATURE

Effect on seedlings

- Influences physiological process (Figure 3)
- Plays a major role in determining the length of the growing season (Figure 4)

Air temperatures at seedling height (15 cm) may be 3-8°C warmer during the day and 2-5°C cooler at night than air temperature at 2 m. Seedling needle temperature is usually within 1° of air temperature.

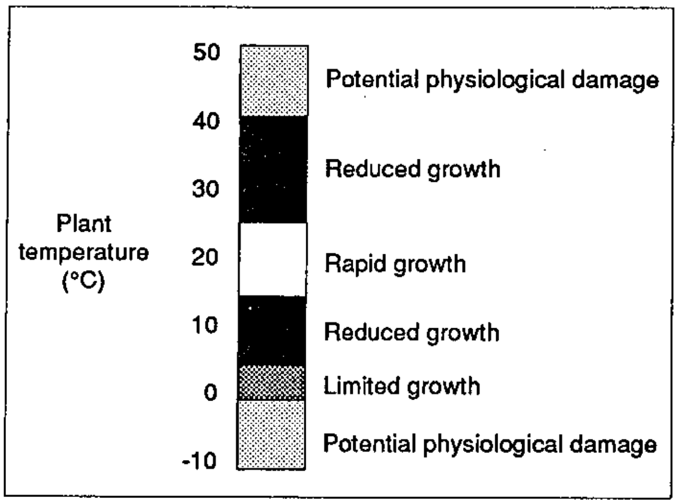

FIGURE 3. Optimum growth occurs over a narrow range of plant temperature. Extreme high or low temperatures can kill seedlings. Hardening during the late summer and fall enables seedlings to withstand cold temperatures. Conifer species vary in their optimum temperatures and the extremes they can tolerate.

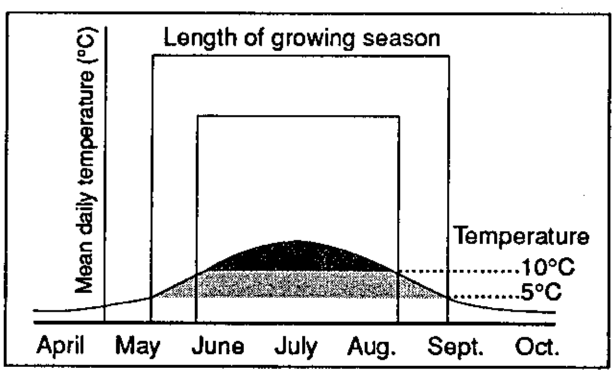

FIGURE 4. Air temperature controls the length of the growing season. Temperatures above 10°C and below 30°C give the best growth response.

Factors affecting the air temperature regime

Air temperature is largely determined by atmospheric factors.

Weather:

- solar radiation – heating of the air
- air mass history
- wind – mixing of the air
- humidity – nighttime cooling of the air

Site:

- elevation
- topography – frost occurs in hollows, on flats and on shallow slopes due to the pooling of cold air. Steep slopes and knolls usually have a low frost hazard.
- vegetation cover – shade during the day reduces soil heating and near-surface air temperature. At night, vegetation affects radiative cooling. An overstory can result in minimum temperatures 2-5°C warmer than a clearcut on a clear, calm night.
- exposed mineral soil – heat stored during the day is released during the night, reducing the chance of frost.

Silvicultural treatments to modify the air temperature regime

It is difficult to have a large effect on daytime air temperature with silvicultural treatments.

Reducing daytime air temperature with shade:

- Partial cuts and shelterwoods may slightly reduce daytime air temperatures close to the soil surface.
- Microsites shaded by logging debris or by stumps may be slightly cooler during the day and warmer at night.

Increasing nighttime air temperature:

- Exposing mineral soil by scalping, discing, ripping, or mounding may reduce the frost hazard on level and lower slope sites where cold air ponding does not occur.
- Partial cuts and shelterwoods reduce nighttime radiative cooling of the soil surface, increasing nighttime minimum temperatures, and thus reducing the severity and frequency of radiation frosts.

Cutblock boundaries or microsites that impede cold air drainage can cause frost pockets.

SOIL MOISTURE

Effect on seedlings

- Soil moisture replaces water lost through transpiration, and maintains an internal water status favourable to the operation of the seedling's physiological processes.

Excess soil moisture:

- reduces the amount of oxygen available for root respiration
- reduces soil heating, resulting in cold soils
- slows seedling growth and causes chlorosis

Flooding can occur after snow melt or heavy rains, and because of poor soil drainage.

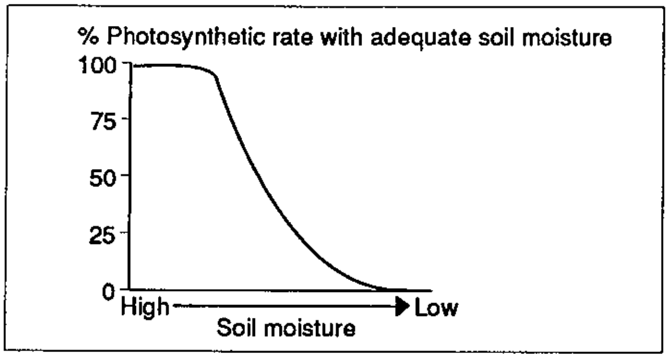

FIGURE 5. Increasing plant moisture stress through a reduction in soil moisture decreases photosynthesis. Response and tolerance to stress varies with species. Stress caused by soil moisture develops when about two-thirds of the available soil moisture is used up (drier than 2 bars).

Factors affecting the soil moisture regime

Weather:

- evaporative demand of the air (solar radiation, air temperature and humidity, wind speed)
- precipitation (amount and timing)

Site:

- slope position, microtopography – draining or receiving water
- vegetation cover – competition for soil moisture
- soil texture – storage of water available to seedlings, infiltration, and drainage. Loams have a greater available water storage capacity than clays, which are greater than sands. Infiltration and drainage of water are best in sands, followed by loams and then clays.
- soil stone content – stones reduce water storage
- soil bulk density – increasing bulk density reduces water storage, and decreases infiltration and drainage capabilities
- soil organic matter content – improves soil moisture storage

Silvicultural treatments to modify the soil moisture regime

Reducing the loss of water by evapotranspiration:

- Herbicides, burning, or mechanical treatments remove or reduce the vegetation cover.
- Creation of surface mulch through herbicide use can reduce soil evaporation.

Increasing soil water storage:

- Reduce bulk density with ripping and plowing.
- Increase organic matter content with rototilling.

Decreasing soil water storage:

- Improve drainage with mounding and ditching.

Scalping and trenching may result in water ponding at snow melt.

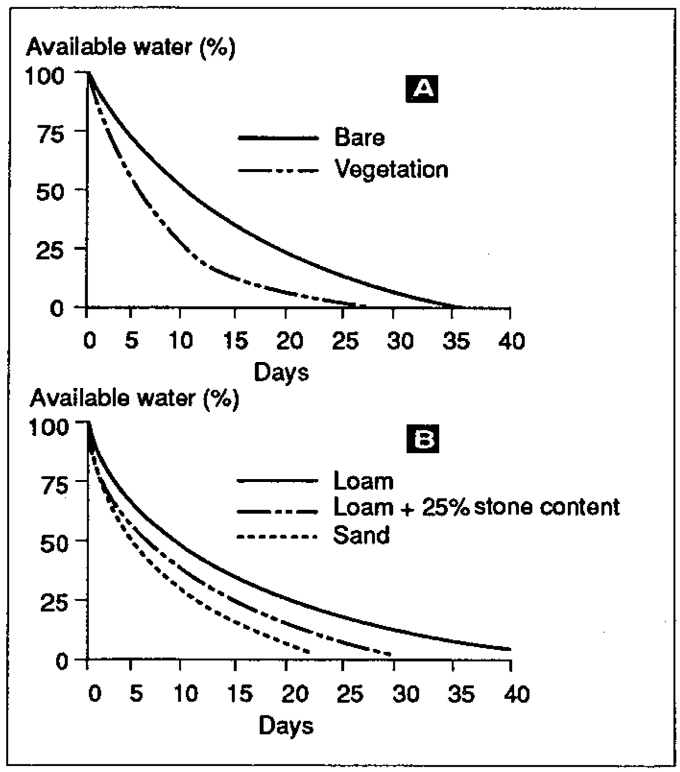

FIGURE 6. Available water in the surface 20 cm of soil decreases with time through evapotranspiration and lack of rain. (A) Competing vegetation dries the soil, reducing the amount of water available to seedlings. (B) Soil texture and stone content affect the amount of water that can be stored in the soil.

SOIL TEMPERATURE

Effect on seedlings

Influences:

- water uptake, affecting transpiration, photosynthesis, and root and shoot growth (Figure 7). Wet soils usually have low root zone temperatures.
- frost heaving of soil. This can be a problem on fine textured (silts and clays) soils when wet.
- dry organic surfaces, which may have high soil surface temperatures that can lead to damage of the root collar.

Factors affecting soil temperature

Weather:

- solar radiation
- precipitation – insulation of snow pack, soil moisture content

Site:

- elevation
- slope, aspect, and microtopography – south-facing slopes have greater solar heating; slope angle and position on the slope affect drainage
- vegetation – shading the soil
- soil texture – water storage and drainage. Wet soils heat slowly.
- surface organic layer – a layer greater than 5 cm thick can act as an insulator. This will result in high surface temperatures, while the underlying soil will be cool.

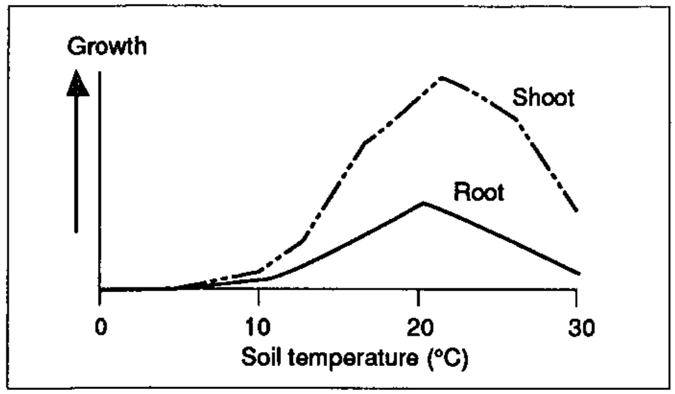

FIGURE 7. Soil temperature affects shoot and root growth. Response varies with species, but optimum temperatures are between 15°C and 20°C.

Silvicultural treatments to modify the soil temperature regime

Shading the surface:

- Partial cuts, shelterwoods, and shade cards can be used for hot, dry sites with high surface temperatures.

Removing shading vegetation:

- Herbicides are effective for sites with a thin organic surface layer.

Exposing mineral soil:

- Blade and patch scarifying, rototilling, and plowing remove shade and insulating surface layers, improving surface drying.
- Mounding and ridging increase soil drying in wet environments.

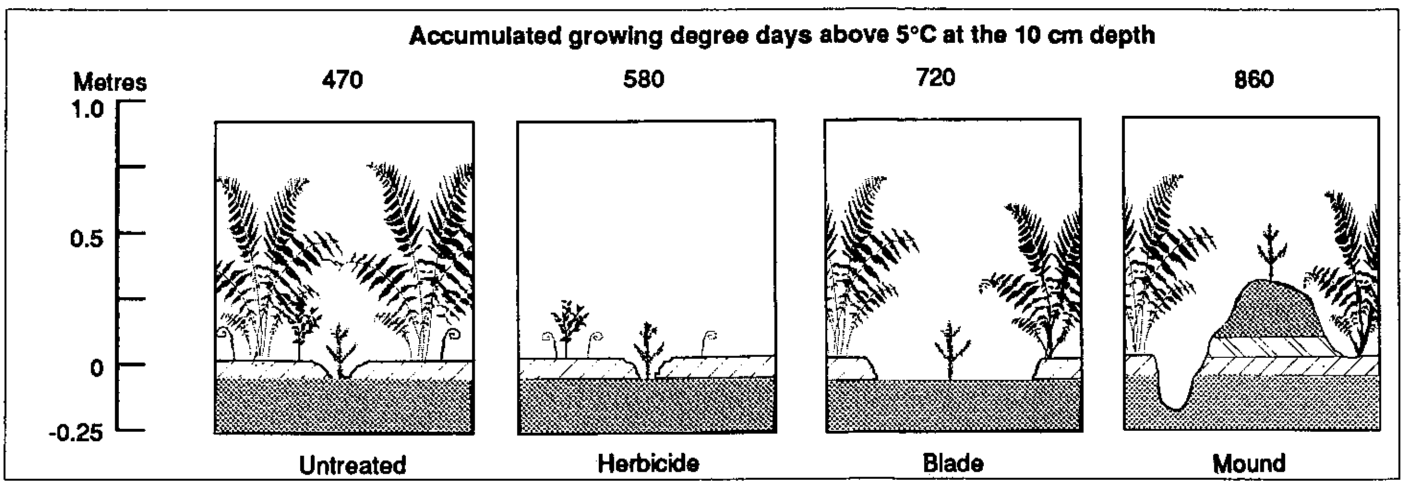

FIGURE 8. Site preparation improves soil warming at a wet Sub-Boreal Spruce site. Mounding provides the greatest accumulation of heat by exposing mineral soil (removing shade and insulation) and improving soil drying (drainage) and heating. The blade treatment exposes mineral soil, but does not provide as good drying as mounding. The herbicide treatment only removes the shading vegetation. Hatching indicates organic material; shading indicates mineral soil.

SUMMARY

Silvicultural treatments can improve and degrade aspects of seedling microclimate. Treatments have varying effects in different subzones, depending on factors such as topography, climate, soil composition, and vegetation cover. Identifying the primary stress which can occur on a site will aid the forester in determining the most appropriate silvicultural treatments.

Site preparation treatments never modify only one aspect of the seedling environment (Table 1). Removal of surface organic matter can improve the soil thermal regime, but the consequent loss of nutrients may be detrimental, especially in cold environments. On cold, wet sites a mounding treatment which improves soil warming while maintaining nutrients may be more suitable than scalping, yet also more expensive.

Table 1 can be used to help determine which silvicultural treatments can maximize the positive and minimize the negative changes in seedling microclimate. This information can then be balanced against other factors such as site conditions, treatment feasibility, equipment availability, and cost to determine which site treatments can be used. Often the added cost of better site preparation can be offset by a reduction in planting costs.

In the past few years, there has been an improvement in the success in establishing conifer seedlings. This has been achieved through better stock quality, different stock types, better stock handling, and more appropriate silvicultural treatments. Even greater success can be anticipated in the future as an improved understanding of the effects of silvicultural treatments on seedling microclimate is used to create favourable growing conditions for seedlings.

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