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The effect of mechanical site preparation methods on the establishment of Norway spruce (*Picea abies* (L.) Karst.) and Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) in southern Sweden

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The aim of this study was to gain a deeper knowledge of the effects of mechanical site preparation on the survival and growth of Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) and Norway spruce (*Picea abies* (L.) Karst.) seedlings in southern Sweden. The experiment was conducted on a fresh clearcut at the Asa experimental forest (57° 10′ N). The effects of five different site preparation treatments were investigated: control, patch, mound, invert and mix. In each treatment, 40 seedlings of Norway spruce and 40 of Douglas fir were planted in each of four blocks. Site preparation had little or no effect on the survival and growth of Norway spruce: only a few seedlings died during the first 2 years. For Douglas fir, however, all site preparation treatments increased survival compared with the control, where mortality was high. The most intensive soil preparation treatment, mix, significantly increased root growth and total biomass. Pine weevils caused more severe damage to Douglas fir seedlings than to Norway spruce and targeted different locations in the two species, causing comparatively more damage to the leading shoots of Douglas fir seedlings.

Introduction

Norway spruce (*Picea abies* (L.) Karst.) is the most common tree species in Sweden.[1] However, the increasing warmth and length of the Swedish growing season due to climate change is likely to provide opportunities for growing additional species such as Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco). Douglas fir is one of the premier timber trees worldwide, mainly because of its combination of desirable wood properties and yield.[2] In its natural range, Douglas fir grows under various climatic conditions, from maritime climates in the coastal regions to continental climates in mountainous areas.[3] It can currently grow well in southern Sweden, but the establishment of young seedlings is hampered by problems such as frost sensivity, browsing and pine weevil damage.[4,5] While Douglas fir have been planted in Sweden over the last century, this has only been done on a very small scale why there is relatively little information available on its establishment.

When planting on a clearcut, it is important to maintain a high initial growth rate in order to minimize the length of the establishment period during which the seedlings are exposed to stress factors. Rapid early root growth facilitates the uptake of nutrients and water and thereby increases seedling growth rates.[6,7] Mechanical site preparation has been demonstrated to greatly improve seedling establishment and is widely used in Sweden.[8] Importantly, it increased soil temperature, which is essential for improving the root growth in northern latitudes.[9] There are a variety of methods of mechanical site preparation that can be used, each of which affects seedling growth in different ways. Patch scarification increases soil temperature and reduces competition from undesired vegetation but may also decrease access to nutrients due to the removal of the humus layer.[10] Mounding creates elevated spots with increased soil temperatures but also presents an increased risk of drought.[11] Inverting creates planting spots at the same level as the surrounding ground.[12] Despite their differences, the latter two preparation methods both create spots where the humus layer is buried under a covering of mineral soil. If the seedling is planted correctly, the roots will have access to a loose nutrient-rich layer, which should facilitate the root growth. In addition, the covering of pure mineral soil surrounding the seedling will reduce the damage caused by pine weevils.[13] The purpose of mix (see *Materials and methods*) was to create loose spots with elevated soil temperatures and rates of mineralization. In addition to the above-mentioned effects, all of the different site preparations methods reduce competition from field vegetation.[11]

The aim of this study was to investigate the effects of different mechanical site preparation methods on the survival, growth and biomass of newly planted Douglas fir and Norway spruce seedlings on a fertile site in southern Sweden. The hypotheses tested were: (i) site preparation reduces mortality and promotes shoot development; (ii) the site preparation mix increases the soil