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Effects of mounding and soil clay content on postplanting success of Norway spruce

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ABSTRACT

Effective soil preparation by mounding is a common practice that precedes the outplanting of Norway spruce (*Picea abies* (L.) Karst.) in Finland, because of the improved survival and early growth of seedlings. On fine-grained soils, however, the postplanting performance of seedlings with mounding has been poorer than on coarser soils. The ecology of seedling growth and the effects of mounding on it on sorted fine-grained soils are still poorly known.

This study examined the effects of mounding and soil clay content on the postplanting performance of Norway spruce container seedlings on soils ranging from medium-grained tills to fine-grained sorted clay soils in reforested sites in south-western Finland. First, regeneration results were inventoried on five plantations of differing soil texture. These reforestation sites had been mounded and planted with Norway spruce five to six years earlier through practical forest management. Secondly, mounding treatments (normal ditch mounding with a mound height of 15–25 cm, ditch mounding with a lowered mound height of 5–10 cm, spot mounding and unprepared treatment) were applied on five clearcut sites with different soil textures. These sites were mounded in the autumn and planted in the following spring, and the postplanting performance was measured after three growing seasons.

The results showed that mounding decreases early postplanting seedling mortality and increases growth, thus promoting plantation establishment on forest soils with varying soil textures. The mounding method or mound height showed no clear difference in seedling growth in the studied soils and years. Early postplanting seedling height growth and survival (three years from planting) were slightly and root-collar diameter a bit better related to the soil clay content; the seedling attributes tended to be poorest on silty soils with a clay content of 20–30% (or silt and fine sand content of over 60%), compared with coarser or finer (clayey) soils. The results suggest that even effective soil preparation cannot fully alleviate all of the inherent disadvantageous effects of sorted silty soils on early postplanting and later growth; but corroborative research is still needed.

1. Introduction

Norway spruce (*Picea abies* (L.) Karst.) is widespread in the boreal zone and grown in the northern forestry (Grossnickle, 2000). In Finland, spruce is planted on about 70% of the annual outplanting area (Finnish Statistical Yearbook of Forestry, 2014). Soil preparation commonly precedes the outplanting of spruce, since it eases planting work and enhances the survival and early growth of planted seedlings (Ritari and Lähde, 1978; Örlander et al., 1990; Sutton, 1993; Hallsby and Örlander, 2004; Saksa et al., 2005; Kankaanhuhta et al., 2009). Especially mounding, in which slight elevations is formed consisting of an upturned mineral soil layer on top of a double humus layer, has increased in recent years. It has been considered to result in better postplanting seedling growth because of increased soil temperature and N availability from the buried humus layer, as well as decreased damage by ground vegetation and the pine weevil (*Hylobius abietis* L.) (Örlander et al., 1998; Örlander and Nilsson, 1999; Nordborg, 2001; Nordborg et al., 2003; Heiskanen and Viiri, 2005; Smolander and Heiskanen, 2007; Heiskanen et al., 2013).

In the Finnish national forest inventory, mineral soils are classified by visual and tactile evaluation into three main categories according to median particle size (Mälkönen, 2003). Medium-grained soils are sandy (0.06–2 mm) and coarse soils gravelly (2–20 mm). Fine-grained soils contain silt and clay, and have the

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median grain size smaller than 0.06 mm. Fine-grained soils are found on Norway spruce dominated site types that cover about 12% of the forested upland soil area in Finland (Finnish Forest Research Institute, 9th National Forest Inventory). Geological Survey of Finland also defines that fine-grained soils contain at least 30% fine fractions (<0.06 mm) and 5% clay (<0.002 mm).

The survival and growth of outplanted Norway spruce seedlings on fine-grained soils have been shown to be weaker on coarser soils, despite the use of mounding as a soil preparation method in Finnish forest plantation inventories (Miina and Saksa, 2006; Saksa and Kankaanhuhta, 2007; Kankaanhuhta et al., 2009). There are several potential reasons for reduced growth, such as competing surface vegetation, frost-heave damage, soil wetness, or compactness or mound subsidence over time (Wilde and Voigt, 1967; Heiskanen et al., 2013). Spruce seedlings have been observed to root more poorly in fertile but very fine-grained forest soils (Repo and Valtanen, 1994; Heiskanen and Saksa, 2010), which also have a lower inherent site quality index than coarser soils (Tamminen, 1993; Johansson, 1995).

According to a recent study conducted in central Finland, frost heave, surface vegetation and mound subsidence do not pose a major threat to mounded Norway spruce plantations on frost-heave prone till soils with a 30% fine fraction content (Heiskanen et al., 2013). The study indicated that ditch and spot mounding clearly promote plantation establishment, but a varying mound height or thickness of mineral capping make no clear difference to seedling growth. Inverting or having no soil preparation with or without herbicide lead to poorer seedling growth. However, fine-grained forest soils comprise soils in which the dominant fraction can range from fine sand to clay and where the conditions and physical and chemical properties may differ markedly. Fine silt, in particular, have been suggested to be the most troublesome soil fraction because of its high water retention and missing secondary structure and sufficient soil aeration for planted tree seedlings (Repo and Valtanen, 1994). Such problems in seedling establishment have been observed to alleviate if fine sand or clay is present in silty soils. Nevertheless, the effects of different mounding treatments on seedling performance on sorted fine-grained silty and clayey soils are still poorly known due to the scarcity of practical and experimental data on soil texture and plantation development on fine-gained sorted soils in Fennoscandia.

This study examined the effects of mounding and soil texture, particularly clay content, on the postplanting performance of Norway spruce container seedlings on soils ranging from medium-grained tills to fine-grained sorted clay soils at reforested sites in south-western Finland. The first data set consisted of regeneration results inventoried in five practical forestry plantations, which had been mounded and planted five to six years earlier. The second data set was based on a mounding experiment, in which mounding treatments were applied on five clearcut sites.

2. Materials and methods

2.1. Practical plantations

A seedling inventory based on circular measurement plots was performed in autumn 2013 on five sites, which were privately owned and managed using common forest management practices and were located within Loimaa town locality in southwestern Finland. The plantation sites have ETRS-TM35FIN projection coordinates within 6,745,529–6,771,194 in latitude and 276,035–287,953 in longitude. The sites had been spot or ditch mounded and planted five to six years earlier (2008–2009) with Norway spruce seedlings and were of differing soil texture. Spot mounding formed slight elevations consisting of a mineral soil layer on top of a double humus layer. In ditch mounding, mineral soil from dug ditches was placed on the undisturbed single humus layer (for more details on mounding and planting practices, see Heiskanen et al., 2013). Site selection for the inventory was based on the premeasured soil texture 2–10 cm below the humus layer (two samples taken per site; for more details, see the Soil analyses chapter).

Five random circular measurement plots of a size of 50 m^2 (r = 3.99 m) were placed on each plantation. On each measurement plot, all developable spruce seedlings were measured for height, collar diameter, yearly terminal height growth and damage (for more details, see Heiskanen et al., 2013). In all, 200 seedlings were measured (4–11 seedlings per plot). The height and top-view area of every third mound, the thickness of the humus layer and the forest type were also recorded. In addition, the final soil samples were taken 2–10 cm below the humus layer (one loose two-litre sample and one undisturbed soil core) from three random circular plots at a random unprepared spot in autumn 2012 (n = 3 per site).

2.2. Mounding experiment

Five sites suitable for Norway spruce were selected from private clearcut forest lands in Loimaa, based on the mineral soil texture 2–10 cm below the humus layer (two samples per site; for more details, see the Soil analyses chapter). The sites have ETRS-TM35FIN projection coordinates within 6,745,447–6,777,598 in latitude and 268,340–285,928 in longitude. These sites were mounded within a week in October 2012, using the same excavator machinery and supervisor.

Each site was divided into three blocks which were relatively homogeneous in vegetation and topography. Four treatment rectangles were then assigned to each block. One soil-preparation treatment (i) normal ditch mounding with a mound height of 15–25 cm, (ii) ditch mounding with a lowered mound height of 5–10 cm, (iii) common spot mounding or (iv) unprepared treatment was then randomly applied on each rectangle of a size about 15×37 m (555 m^2) (for more details about mounding practices, see Heiskanen et al., 2013). In spot mounding and unprepared treatments, ditching was performed aside the rectangle when needed. In ditch mounding, the ditches were dug in the middle of the rectangle.

Each soil-prepared rectangle had about 100 mounds, which were planted in next spring with two-year-old Norway spruce seedlings grown in Plantek 81F containers (Lannen Plant Systems, BCC Oy, Säkylä, Finland) with a density of about 1800 seedlings per ha. The planting was performed manually with a Pottiputki planting tube, using the same planters and supervisor during three days in May 2013.

In the middle of each rectangle, one circular plot of 100 m^2 (r = 5.64 m) was assigned from which all developable spruce seedlings were measured likewise as in the inventory of the older practical plantations. Also the height and area of every third mound, as was the seedling planting depth (distance between upper surface of plug and soil surface in cm) on the mounds. The forest type and humus thickness were recorded and the final soil samples (one loose two-litre sample and one undisturbed soil core) were taken 2–10 cm below the humus layer from the middle of each block at a random unprepared spot in spring 2013 (n = 3 per treatment and site).

On the circular measurements plots, seedling development and damage were determined in autumn 2013, 2014 and 2015 as were the visual subsidence and area of the mounds using measuring rods. The root-collar diameter was also measured in 2014 and 2015. A total of 1040 seedlings were measured in 2015 (13–22 seedlings per treatment in one block).

The weather conditions were relatively similar during the study summers 2013–15 (Table 1). May and June in 2013 were warmer