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SHORT COMMUNICATION

An alternative of soil scarification treatment for forest restoration: effects of soil replacement

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Abstract We examined an alternative natural regeneration practice with a scarification treatment, in which removed soil is replaced on the scarified area, in northern Japan. The effect of the soil replacement on tree establishment was quite obvious; the basal area of trees, composed mostly of *Betula ermanii*, in the soil-replaced site was about 150-fold greater than that of the normally treated site. The greater growth rates together with higher density, both of which seemed to be enhanced by improved (i.e., deeper, tender, and nutrient-rich) soil properties, produced the marked difference to the normally treated site. The expected enhancement of species diversity owing to utilizing buried seeds in the replaced soil was not found. The current study revealed that the soil replacement could substantially improve forest restoration management with emphasis on biomass production for large nonwooded sites.

Keywords *Betula ermanii* · Natural regeneration · Site preparation · Soil properties · Tree growth

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Introduction

Afforestation has received much attention in recent years for resource management, including carbon sink activity. Numerous studies have thus been conducted to seek more effective natural regeneration practices in many regions (e.g., Archibold et al. 2000; Simard et al. 2003; Haeussler et al. 2004; Gastaldello et al. 2007). In Hokkaido, northern Japan, nonwooded forestlands comprise 1.8% (98,000 ha) of the total forested area (Hokkaido Prefectural Government 2006). These sites are frequently dominated exclusively by dwarf bamboo [*Sasa kurilensis* (Rupr.) Makino & Shibata and *S. senanensis* (Franch. & Savat.) Rehd.], which inhibit tree regeneration through limiting available resources and substrates (Nagaike et al. 1999; Noguchi and Yoshida 2004). This has been made worse by human impacts, such as tree harvestings (Noguchi and Yoshida 2005). Accordingly, to enhance tree restoration on these sites, mechanical site preparation (scarification) has been used since the 1970s (Umeki 2003). Scarification is surface soil displacement with machinery to improve the substrate and remove understory competitors for successful tree regeneration.

Although in many regions scarification is generally effective for tree stand establishment (e.g., Wurtz and Zasada 2001; Nilsson et al. 2002; Allison et al. 2003), it is important to have rapid stand development with increased species diversity for ecologically sustainable cost efficiency management. Scarification removes surface soil that contains abundant nutrients (e.g., Munson and Timmer 1995) and has a potential to reduce growth of established trees (Yoshida et al. 2005). The resultant delay in vegetation recovery might increase sediment and nutrient loads (Ahtiainen 1992; Ozawa et al. 2001), which is actually the greatest concern in this kind of practice. In addition, the treated sites are often occupied mostly by a particular plant