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Frost-heaving damage to one-year-old *Picea abies* seedlings increases with soil horizon depth and canopy gap size

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Abstract: We studied first winter frost-heaving damage to one-year-old *Picea abies* (L.) Karst. seedlings planted in gaps made by group fallings (large circular gaps, ca, 500 in) and singletree selection cuttings (small irregularly shaped gaps, ca. 175 m²), as well as in uncut forest. One-month-old seedlings were planted on manually exposed LF, Ac, and B hori - zoos that emulated various intensities and depths of scarification, The three experimental sites were located in multistoried *Pious sylvestris L.* or *P. rabies* forests on sandy loam or silt loam in soot caster a Norway. Altogether, 5% of seedlings sustained frost heaving damage on the LF horizon, compared with 20% on the Ac horizon and 45% on the B horizon, On average, 3l % of the seedlings in large gaps incurred frost-heaving damage compared with *20(1* in small gaps and *19%* in uncut forest. Exposed roots and poorly anchored or uplifted seedlings were recurring classes of damage, especially on the B horizon and in large gaps. The above. versus below ground biomass ratio of seedlings was higher on the B than on the Ae horizon in uncut threat and large gaps. inferring broken roots. Therefore, to reduce the risk of frost-heaving damage. shallow soil preparation and smaller gap sizes should be used,

Résumé : Nous awns étudié les dommages dus not déchaussement par le gel chez des sends de *Picea abler (L.)* Karst, urges dun et plantés daps des trouées créées par des coupes de jardinage par groupe (grandes trouées circulaires d'en-iron 500 m²) et par arbre (petites trouées de forme irréguliére d'environ 175 m) aussi biers qu'en fork non coupée. Des semis ages d'un moil dint etc plantés sir des horizons T F. Ae et 13 exposes manuellement qui reproduisaient diverses intensités et profondeurs de scarifiage. Les trots sites expérimentaux étaient sues dons des foréts de *Firms sylvestris L.* ou *de P. abies* pluriétagées établies sir Iles loam sableux ou des loam limoneux dans to sud-est de la Norvége. Globalemen, *5 f* des semis out subi des dommages dos an déchaussement par le gel sur l'horizon LF comparativement a 20 o stir l'horizon Ac et 45 *Rio* sur l'horizon 13. En moyenne, 3l (1 des semis dans les grandes trouées ont subi des dommages dus au déchaussement par le gel comparativement *a 20 `I* dens les petites trouées et 19 f dens la forth non coupée. Les classes tie dommages qui revenaient le plus souvent étaient lee semis dons les ravines étaient exposers et les semis mal an-crés on soulevés, particuliéremeut sir l'horizon 13 et dens les grandes trouées. he rapport de la biomasse aérienne á la bio-masse souterraine était plus élevé sir l'horizon B que stir l'horizon Ae dans Ia forét non coupée et les grandes trouées, sans doute a cause des bris de racines. Par consequent, on devrait favoriser 10 preparation superficielle du soil et les trouées de plus foible dimension pour réduire les risques de dommages dos au déchaussement par le gel,

[Traduitpar la Rédaction]

Introduction

In the boreal forest, many seedlings die from frost heaving in the early regeneration stages (Winsa and Bergsten 1994: Chalet 1995; de Chantal et al, 2003). Frost heaving occurs because of the growth of ice crystals from below and upwards, forming needle ice at the soil surface (Goulet 1995), This occurs when the near-ground air temperature is a few degrees below the freezing point and there is a constant supply of water to the freezing surface, which is often the case when there is thin or no snow cover on the ground (Goulet 1995; Bergsten or al. 2001). During this process, seedlings may be totally or partly uplifted from the soil, especially if their root system is small and shallow (Goulet 1995: de Chantat et al. 2003). Alternatively, seedlings may remain its the soil, but their roots may be broken by the heaving process. Both see-

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