Ash-fertilisation – a successful way to accelerate establishment and growth of birch (*Betula pubescens* Ehrh.) stands on cut-away peatlands

Noora Huotari[1] and Eila Tillman-Sutela[2]

[1] Finnish Forest Research Institute, Muhos Research Unit, Kirkkosaarentie 7, 91500 Muhos, Finland
Phone: +358 40 7382897, e-mail: noora.huotari@metla.fi

[2] Finnish Forest Research Institute, Muhos Research Unit, Kirkkosaarentie 7, 91500 Muhos, Finland
Phone: +358 10 211 3719, e-mail: eila.tillman@metla.fi

Summary

We studied the effect of fertilisation on the establishment of vegetation including birch seedlings on a cut-away peatland. Six treatments of wood-ash, peat-ash, biotite or PK-fertiliser were replicated in three plots using different mixtures and quantities. Immediate colonisation of fire-loving mosses followed by herbal species ensured full vegetation coverage on ash-fertilised plots. The amounts of birch seedlings were 2-fold on the ash-fertilised compared to the PK-fertilised areas, whereas the unfertilised plots remained non-vegetated. Birch seedlings were four times higher on ash-fertilised than on unfertilised plots already after the first growing season. Consequently, our results support the recycling of ash-based fertilisers for the afforestation of cut-away peatlands.

Key index words: afforestation, vegetation cover, peat-ash, wood-ash, recycling

Introduction

Harvesting of peatlands for energy production changes the original mire ecosystem completely and practical methods for the after-use of these disturbed habitats are of major importance for both landscape and environment. In Finland peat producers operate mainly on leased areas and the landowners prefer afforestation to the other forms of using the cut-away areas (Selin, 1999). Important objectives of afforestation are the diminution of nutrition loads and production of energy wood in an efficient and economic way. Downy birch (*Betula pubescens* Ehrh.) is a suitable species for afforestation of cut-away peatlands due to its ability to grow on moist soils and the relatively short rotation time to produce energy wood on fertile sites (Ferm, 1993).

The remaining peat layer on cut-away areas is typically rich in organic nitrogen, but poor in mineral nutrients, especially phosphorus and potassium (Paavilainen and Päivänen, 1995). Traditionally this deficiency is compensated using commercial fertilisers, although simultaneously hundreds of tons of both peat-and wood-ash are produced annually as a by-product of energy production in Finland. Due to its high quantities of mineral nutrients and positive effect on the mineralization of organic nitrogen (Park *et al.*, 2005), ash may be advantageous to plant establishment on cut-away peatlands.

Most studies on the effects of ash fertilisation on the afforestation results of cut-away peatlands or peatlands drained for forestry have had a goal of growing conifers for sawmill industry or to produce biomass in monocultures of short-rotation willow species (Hytönen, 1998; Park *et al.*, 2005). Especially wood-ash is known to promote tree growth on peatlands drained for forestry and the influence is reported to last up to 50 years or more (Silfverberg, 1996; Moilanen *et al.*, 2002), whereas peat-ash is considered to be less valuable as a fertiliser. The effect and duration of ash-fertilisation may be, however, different on cut-away peatlands where the original vegetation has been completely removed and the depth of the remaining peat layer varies considerably. In addition, the results on the effect of wood-ash on the germination of pine or birch seeds have been contradictory (Rikala and Jozefek, 1990; Reyes *et al.*, 1997; Reyes and Casal, 2004), and the research on the early development of seedlings or on the afforestation methods on the ash-fertilised cut-away peatlands is very scanty (Huotari *et al.*, 2007, 2008). For these reasons we studied the effect of ash-fertilisation on the early establishment of vegetation including downy birch seedlings on a cut-away peatland.

Materials and methods

The experimental area is located in Northern Ostrobothnia (64° 44' N, 25°16' E, 45 m a.s.l.), in Finland. Peat harvesting on the area ceased in 1996 and the depth of the remaining peat layer (SC-p, H_5) was 20-53 cm. The ground water level in the area was about 50 cm and the average yearly temperature sum 1040 d.d. The amount of precipitation from 1st April to 15th July in 2001 was 236 mm, in 2002 76 mm, in 2003 116 mm and in 2004 194 mm. The nitrogen content in the residual peat-layer was on average 2,3 %, which is higher than the N concentrations evaluated to be adequate (1,5-2,0 %) for tree growth on drained

peatlands (Moilanen, 1993; Pietiläinen and Kaunisto, 2003). Birch stands of 8-12 m (dominant height) surrounded two sides of the area at a distance of 100-150 m.

Three blocks were established on the experimental field and each of them was divided into six trial plots. The plots were split and 1 kg ha^{-1} of downy birch seeds was hand-sown in early September 2000 on randomized halves, while the other halves were afforested naturally. In May 2001 six treatments of peat-ash, wood-ash, biotite, or PK-fertiliser in different mixtures were randomized between the plots and replicated in the three blocks. The nutrient contents of the ashes were analyzed in the laboratory of Muhos Research Station of the Metla (Huotari *et al*., 2007, Table 1) and the doses of fertilisers per plot were adjusted corresponding to 50 kg ha^{-1} of phosphorus, the quantity recommended in peatlands drained for forestry (Paavilainen and Päivänen, 1995).

The percentage coverage of established vegetation was estimated and heights of birch seedlings were measured yearly in 2001-2004. The dominant height refers here to the tallest seedling of each species and age group in the circular sample plot.

Results

All the fertilisers accelerated the plant establishment on a cut-away peatland significantly but ash-based fertilisers had the greatest and most immediate impact on the formation of vegetation. Immediate colonisation of small fire-loving mosses followed by rich variety of herbal species ensured full vegetation coverage on the ash-fertilised plots, whereas establishment of plants on the unfertilised areas was non-existent even several years after the cessation of peat harvesting.

One growing season after the fertilisation the amounts of birch seedlings were on the ash-fertilised areas even 16-fold compared to the unfertilised plots and 2-fold in comparison to the PK-fertilised areas. Between the sown and the naturally regenerated areas there was no major differences in the quantity of birch seedlings. Four years after the fertilisation more than 80 % of the birch seedlings, which had germinated in 2001 were still alive on the fertilised plots and the total number of seedlings had even increased due to natural dissemination. Meanwhile, the number of original birch seedlings on the unfertilised plots had decreased drastically and only 14 % of the seedlings germinated in 2001 were alive four years later.

Ash-fertilisation had a significant effect also on the dominant heights of birch seedlings. A mixture of wood- and peat-ash resulted in four times larger heights of birch compared to the unfertilised plots already after the first growing season. This difference even accentuated during the subsequent years.

Discussion

Our results proved, that ash-fertilisation in particular improved the germination and early establishment of downy birch seedlings on a cut-away peatland. The results were even more prominent than those obtained using wood-ash on nutrient-poor peatlands (Silfverberg, 1995). The newly risen moss cover apparently facilitated seed germination and early establishment of plants on the ash-fertilised areas by stabilizing the loose substrate and the moisture contents of the peat surface, which are reported to be major barriers to the formation of vegetation on mined peatlands (Campbell *et al*., 2002). Surprisingly, also the dense herbaceous vegetation seemed to facilitate rather than prevent early development of birch seedlings. Due to closeness of surrounding birch stands with abundant seed crops the amounts of seedlings in naturally regenerated areas were equal to sown areas. Sufficient precipitation by mid-July in 2001 also favored seed germination, since moist environmental conditions in early summer are known to have a major impact on the germination and successful establishment of young seedlings on mineral soils (de Chantal, 2003).

Fertilisation had a major impact also on the dominant heights of the birch seedlings. After one growing season the highest seedlings on the unfertilised plots were about 2 cm, which is reported to be the maximum height attainable when using only the food reserves in the endosperm of the birch seeds (Miles and Kinnaird, 1979). At the same time the mixture of wood- and peat-ash resulted in four times larger dominant heights and this difference even accentuated during the subsequent years. Later on, the accumulation of plant-derived litter apparently contributes to the sustainable circulation of nutrients and thus advances tree growth.

In conclusion, our study showed that recycling of wood- and peat-ash ensured the rapid formation of ground vegetation and thus promoted sustainable forestry on mined peatlands (Huotari *et al*. 2007, 2008). Our present results thus support regular use of ash as a fertiliser instead of being regarded as a mere waste.

Acknowledgements

This work is part of the joint project 'Metsähiisi' carried out by the Metla Muhos Research Unit and Vapo Co in 2001-2006. Vapo Co and Tekes (National Technology Agency of Finland) supported this study financially. Mr. J. Issakainen organized the field trial, and Mr. J. Pasanen did the field measurements. We thank sincerely all who have contributed to this study.

References

Campbell, D.R., Lavoie, C., and Rochefort, L. (2002). Wind erosion and surface stability in abandoned milled peatlands. *Canadian Journal of Soil Science* **82**, 85-95.

de Chantal, M. (2003). The effects of site and soil properties on the establishment and early development of *Pinus sylvestris* and *Picea abies* regenerated seeds. University of Helsinki, Department of Forest Ecology Publications **27**, 36pp.

Ferm, A. (1993). Birch production and utilization for energy. *Biomass and Bioenergy* **4(6)**, 391-404.

Huotari, N., Tillman-Sutela, E., Kauppi, A. and Kubin, E. (2007). Fertilisation ensures rapid formation of ground vegetation on cut-away peatlands. *Canadian Journal of Forest Research* **37**, 874-883.

Huotari, N., Tillman-Sutela, E., Pasanen, J. and Kubin, E. (2008). Ash-fertilisation improves germination and early establishment of birch (*Betula pubescens* Ehrh.) seedlings on a cutaway peatland. *Forest Ecology and Management* (in press).

Hytönen, J. (1998). Effect of peat ash fertilisation on the nutrient status and biomass production of short-rotation willow on cut-away peatland area. *Biomass and Bioenergy* **15(1)**, 83-92.

Miles, J. and Kinnaird, J.W. (1979). The establishment and regeneration of birch, juniper and Scots pine in the Scottish highlands. *Scottish Forestry* **33,** 102-119.

Moilanen, M. (1993). Lannoituksen vaikutus männyn ravinnetilaan ja kasvuun Pohjois-Pohjanmaan ja Kainuun ojitetuilla soilla (English summary: effect of fertilisation on the nutrient status and growth of Scots pine on drained peatlands in northern Ostrobothnia and Kainuu). *Folia Forestalia* **820**, 37pp.

Moilanen, M., Silfverberg, K. and Hokkanen, T. (2002). Effects of wood-ash on tree growth, vegetation and substrate quality of a drained mire: case study. *Forest Ecology and Management* **171**, 321-338.

Paavilainen, E. and Päivänen, J., (1995). *Peatland forestry, Ecology and principles*. *Ecological Studies* **111**. Springer-Verlag, Berlin-Heidelberg-New York.

Park, B.B., Yanai, R.D., Sahm, J.M., Lee, D.K. and Abrahamson, L.P. (2005). Wood ash effects on plant and soil in a willow bioenergy plantation. *Biomass and Bioenergy* **28**, 355-365.

Pietiläinen, P. and Kaunisto, S. (2003). The effect of peat nitrogen concentration and fertilisation on the foliar nitrogen concentration of Scots pine (*Pinus sylvestris* L.) in three temperature sum regions. *Suo* **54(1)**, 1-13.

Reyes, O. and Casal, M. (2004). Effects of forest fire ash on germination and early growth of four *pinus* species. *Plant Ecology* **175**, 81-89.

Reyes, O., Casal, M. and Trabaud, L. (1997). The influence of population, fire and time of dissemination on the germination of *Betula pendula* seeds. *Plant Ecology* **133**, 201-208.

Rikala, R. and Jozefek, H.J. (1990). Effect of dolomite lime and wood ash on peat substrate and development of tree seedlings. *Silva Fennica* **24**, 323-334.

Selin, P. (1999). Turvevarojen teollinen käyttö ja suopohjien hyödyntäminen Suomessa. *Jyväskylä Studies in Biological and Environmental science* **79**. Jyväskylän yliopisto, bio- ja ympäristötieteiden laitos. (In Finnish)

Silfverberg, K. (1995). Forest regeneration on nutrient-poor peatlands: Effects of fertilisation, mounding and sowing. *Silva Fennica* **29**, 205-215.

Silfverberg K. (1996). Nutrient status and development of tree stands and vegetation on ash-fertilised drained peatlands in Finland. *The Finnish Forest Research Institute, Research paper* **588**.