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Norway spruce (Picea abies (L.) Karst) planted under shelterwood

– a need for new adaptation targets?

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Preface

This manuscript was presented as a volunteer paper at the WFGA-meeting (Western Forest Genetics Association) in Newport, Oregon, July 29-31 1996. The theme of the meeting was "Genetics of adaptation". Proceedings from the meeting will only contain abstract from the presented papers. In this work report the complete manuscript is presented. Language revision of the presentation has been done by Nigel Rolison.

Introduction

This presentation will focus on some questions related to the adaptation of Norway spruce in Sweden, and how the adaptation problems and targets depend on how we use Norway spruce in practical forestry.

In Swedish forestry, clear-cutting has been the predominant method for final felling since at least the 1950's. After clear-felling the ground is site-prepared and planted. Norway spruce is the most commonly planted tree species in southern Sweden and Scots pine in northern Sweden. For Scots pine, as a pioneer species, the clear-cutting system suits well in terms of adaptation. Norway spruce, in contrast, is a secondary tree species, adapted to regenerate in shade, under a tree canopy. When young Norway spruce seedlings encounter the clear-cut environment, they suffer from many problems, where climate-induced damage is the most important. Early summer frost can kill the current shoots, and in the autumn and winter the seedlings can be harmed by autumn frosts or frost desiccation.

Many of the climate-related problems can be reduced, but not avoided, if we consider the genetic variation in growth rhythm. Late-flushing spruces have a lower probability of sustaining frost in spring and early summer. We have calculated the potential risk for frost occurring after bud burst, and timing of bud burst is defined in terms of temperature sum. Frost risk is defined as the percentage of years with temperatures below 0ºC at 1.5 m level occurring within approximately 2 weeks after bud burst. The calculations were based on climate recordings from 11 meteorological stations throughout Sweden. It is obvious that the risk is greatly reduced if we use late-flushing provenances or clones, as shown by the example in figure 1.

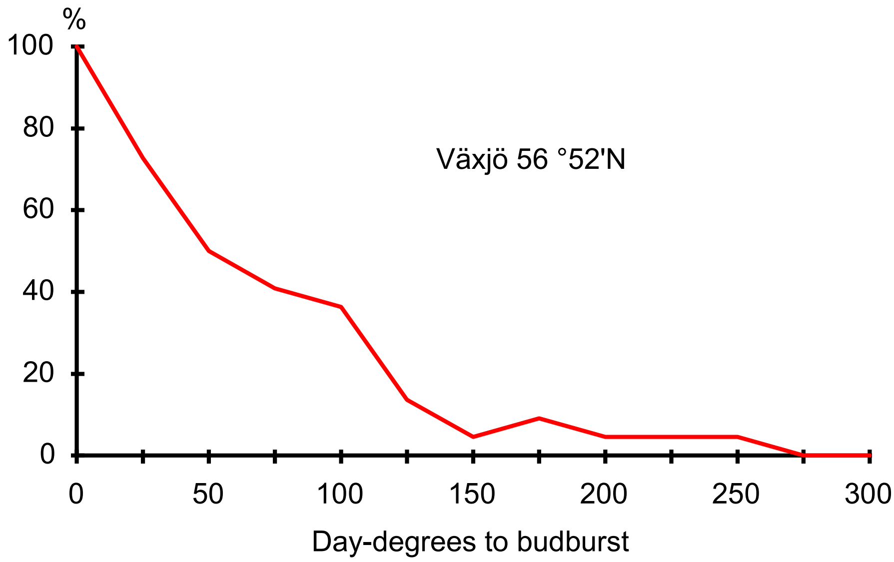

Figure 1.
Potential risk for a damaging frost occurring after bud burst at the Växjö meteorological station. Data from 25 years (from Hannerz, 1994).

The observed results of frost damage on frost-prone sites confirms the theoretical prognosis. Figure 2 shows the cumulated frost injuries during a six-year period in a trial. The clones in the trial were classified according to time of bud burst in the nursery. Early-flushing clones had almost 80% of their cuttings damaged by frost, whereas late-flushing clones have suffered from very low levels of frost injury. On the other hand, late-flushing provenances and clones have, on average a late growth cessation and a later hardening
in the autumn. This has to be considered, especially on sites in central and northern Sweden, where autumn frost and an incomplete hardening can become serious.

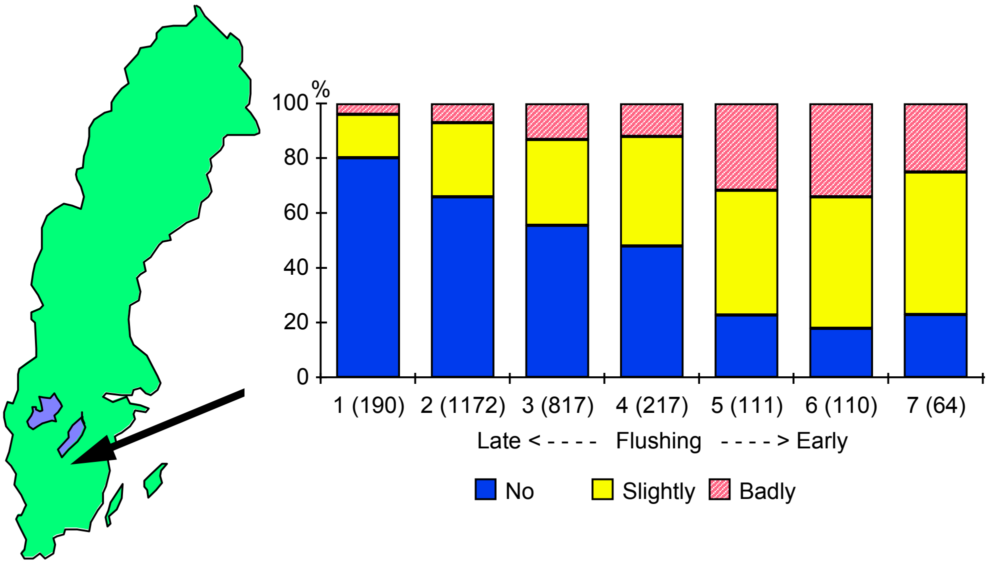

Figure 2.
Cumulated frost damage in a clonal trial with Norway spruce in Västra Ryd, Småland, 6 years after planting. Damage was recorded in three classes: No, slightly and badly damaged. The clones were classified according to flushing in the nursery prior to planting (from Bo Karlsson, unpublished).

The genetic variation between populations of Norway spruce is used in the provenance transfer guidelines. Norway spruce is almost always moved from south to north. In southern Sweden we use provenances from Romania, Poland and Belorussia, and in northern Sweden domestic provenances are moved northwards (figure 3). The transfer results in later bud flush and later growth cessation compared with the local provenances. The growing season is used more efficiently and the yield increases. Late flushing provenances have a great advantage during the establishment phase on frost-prone sites. However, late growth cessation is also followed by a risk of having insufficient hardy material in winter-time, a problem not only related to the establishment phase of the rotation. It is important to remember that guidelines for provenance transfer, as well as the selection in the tree breeding programme, are based on trials established on clear-cuts, many of which are located on frost-prone fields.

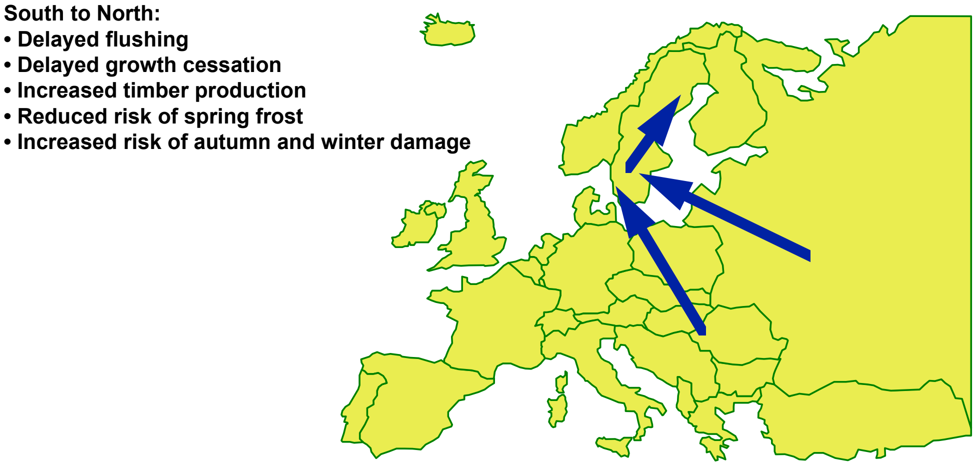

Figure 3.
Provenance transfer of Norway spruce in Sweden.

During the 1990's the shelterwood system has become popular in Sweden. From being a very marginal method it is now performed on more than 5% of the Norway spruce final felling area. In some regions more than 20% of the regeneration is performed with shelterwood systems. In this system, a shelterwood of about 200-300 stems per hectare is left as a protection for the regeneration, which can be established either by advanced growth, new seed-fall or by planting. Combination methods with planting and natural regeneration have become more abundant during recent years.

A question can now be raised. Shall we make the same choice of planting material under a canopy of large trees, as we do on a clear-cut? We can expect quite different conditions on a clear-cut and in a shelterwood. Solar radiation is reduced in the shelterwood, as well as wind velocity and temperature amplitudes, i.e. the frost risk is greatly reduced. Available nutrition is lower for the young seedlings, the ground-water table is lower in the shelterwood and humidity is higher. On the clear-cut there is a risk of frost heaving which is absent in the shelterwood. Competition with weeds is higher on the clear-cut as well as damage by the pine weevil. Competition between seedlings and sheltertrees is, of course, avoided on the clear-cut. All these factors suggest that a shelterwood offers conditions that are completely different to those on a clear-cut. We may suspect that we will find a considerable genotype times environment interaction if we establish trials both on clearest and in shelterwoods. Do we even need new adaptive traits with the shelterwood system, and different breeding populations?

The experiment

To study some of these questions we established an experiment in 1994. The experiment is located to the north of Uppsala in central Sweden (figure 4). We used cuttings from 25 clones, selected to represent a wide variation in phenology from early to late-flushing clones. The clones were evenly represented in two sites with shelterwood and two sites which were clearcut. Forty ramets per clone were planted in each of the two environments. Damage has been assessed yearly, and the height and last year's height growth were assessed in this spring. We have also made temperature measurements and observations of bud burst, in order to estimate the required temperature sum for bud flushing.

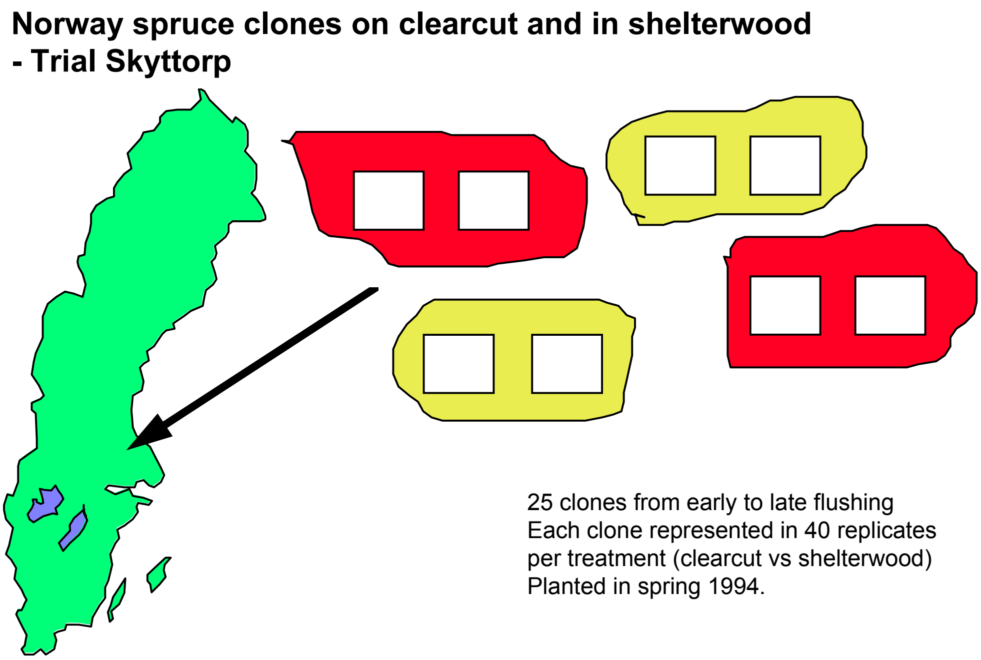

Figure 4.
The Skyttorp trial.

The results have to be considered as preliminary, as the observations only cover the first two years in the field. There were large differences between the clear-cut and the shelterwood (figure 5). Survival and vigour of the cuttings was much higher in the shelterwood. On average, only 18% of the cuttings were regarded as vital and undamaged on the clear-cut and 54% in the shelterwood. Survival was 89% in the shelterwood and 60% on the clear-cut. Average height of surviving plants was higher in the shelterwood. Height growth during the last year was 35% higher in the shelterwood than on the clear-cut.

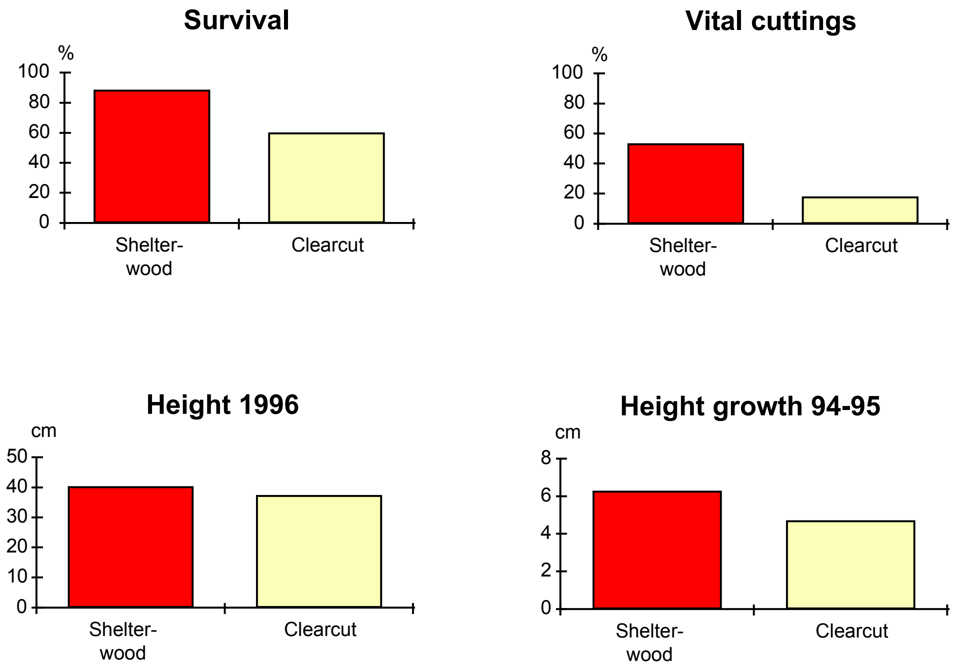

Figure 5.
Results in the Skyttorp trial 2 years after planting. Average survival, vitality, height and height growth from shelterwood and clear-cut plots.

Variance components were estimated with REML (figure 6). Clone had no effect on survival, but environment had. For plant-height there was a significant G · E component that was almost as high as for environment. For bud burst, observed on the clear-cut and in the shelterwood, clone was the most important source of variation, but a significant G · E-interaction was also shown.

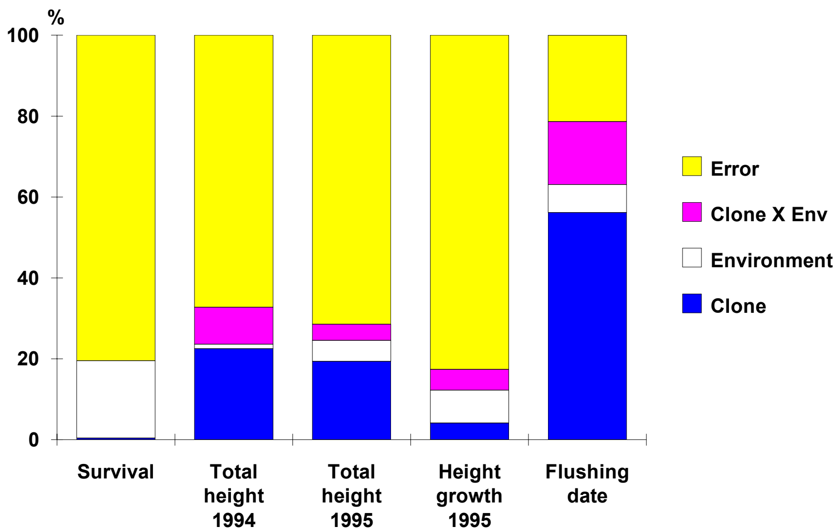

Figure 6.
Variance components in the trial at Skyttorp for height, survival and bud burst (flushing date) as proportions of the total variance. Model y=G + E + G · E + error.

A part of the G · E-interaction can probably be explained by the variation in phenology between clones. A large proportion of the damage on the clear-cut was caused by frost and frost desiccation. If the clones are sorted from early to late flushing we can observe a correlation with early summer frost injuries, registered in 1994 (figure 7). Almost all cuttings from early flushing clones suffered from injured shoots, whereas late flushing clones were unaffected. On the other hand, there was a weak correlation between frost desiccation in the spring of 1995 and flushing date. Late flushing clones suffered from a higher level of frost desiccation. This is probably caused by the fact that late-flushing clones also have a late growth cessation, and have a greater risk of becoming insufficiently hardy. None of these injuries were observed in the shelterwood.

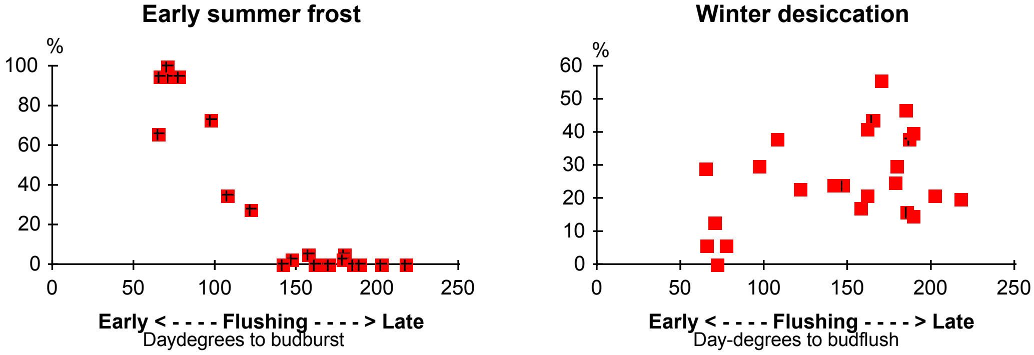

Figure 7.
Correlation between flushing date and level of early summer frost (left) and winter desiccation (right). The trial at Skyttorp, observations on clear-cut.

The vigour of the cuttings was also related to the phenology. Early flushing clones had a lower vitality both on the clear-cut and in the shelterwood (figure 8). The slope, however, was steeper for clones on the clear-cut. There was also a tendency that the most late-flushing clones had lower vitality on the clear-cut.

The relation between phenology and height showed a similar pattern, with a tendency to a curve with an optimum for clones with an intermediate bud flush. This was especially pronounced for clones on the clear-cut, and the greatest difference when comparing with the shelterwood seems to be for clones with an early bud burst. The "curve" for clones in the shelterwood was flatter.

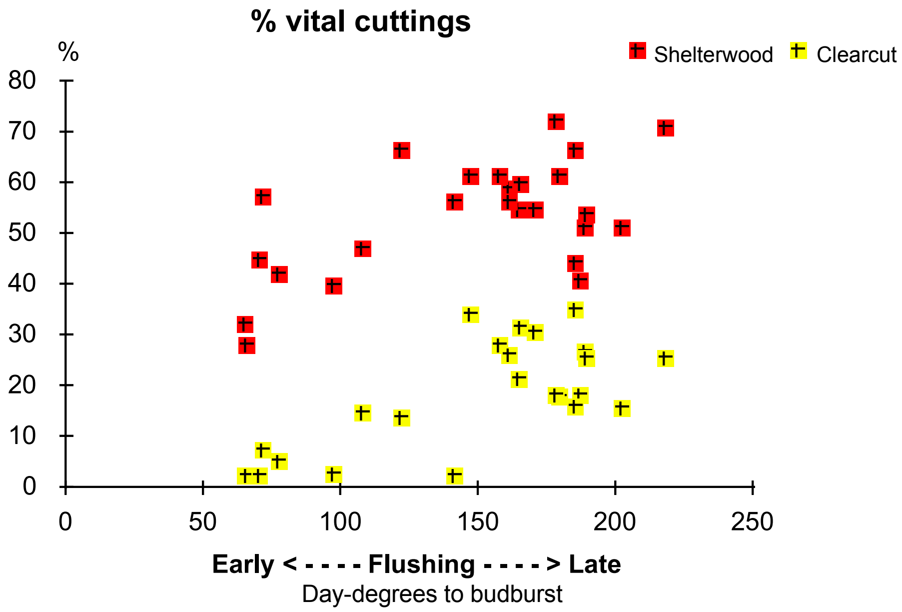

Figure 8.
Correlation between flushing date and vigour for clones in shelterwood and on clear-cut. The trial at Skyttorp.

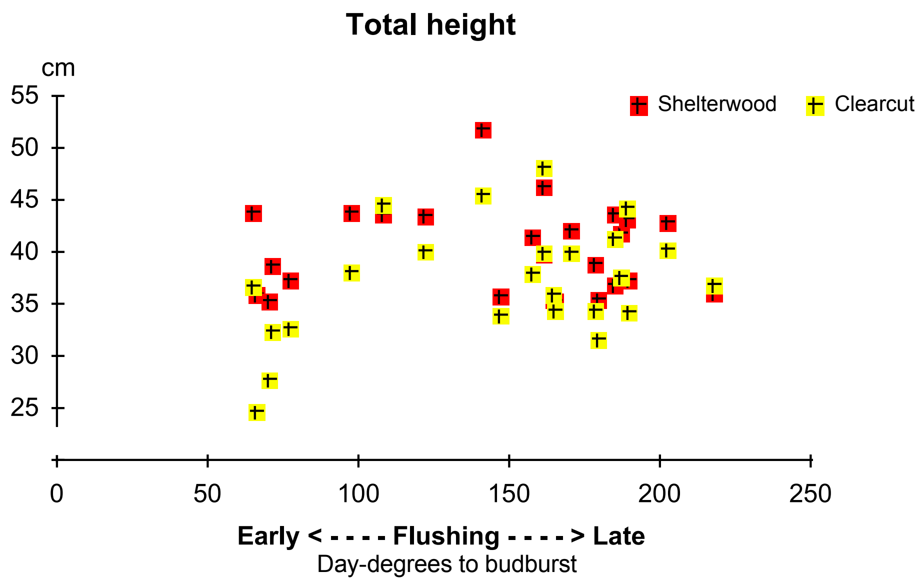

Figure 9.
Correlation between flushing date and height for clones in shelterwood and on clear-cut. The trial at Skyttorp.

The experiment is still too young to enable any conclusions to be drawn about whether planting under sheltertrees should result in new adaptation traits. However, it will become an important piece of the puzzle together with other ongoing experiments. Further questions that can be answered by the experiment are, e.g., how the competition with the sheltertrees affects the ranking, and the allocation of resources.

Conclusions

Finally, I wish to mention some conclusions and make some comments.

The experiment shows, as was known before, that a shelterwood has a protecting effect on the young plants, especially against frost and frost desiccation. There was a significant G · E interaction regarding height. This interaction can probably be partly explained by phenology of the clones. There is a tendency that "extreme" phenology, i.e. late or early bud burst, should be avoided when choosing material for clear-cut conditions, but these constraints are not as essential in the shelterwood. Height growth must be followed for a longer period before any further conclusions are drawn.

A final question is: which characters do we actually test for when we are establishing a progeny trial on a frost prone clear-cut? We may be interested in long-term yield, but we are actually evaluating the capacity to sustain frost. If, on the other hand, we establish our trials under sheltertrees, can we get a better estimate of long-term yield and efficiency to use water and nutrients?