Norway spruce breeding in Sweden is based on clone testing

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Norway spruce in Sweden

- Economically about as important species as all other combined.
- About 50% of plants from seed orchards, increasing.
- New seed orchards established now.
- Almost no clonal forestry (≈1/1000 of plants).
Swedish Norway spruce cuttings in forestry

Million cuttings annually
(of 180 million Norway spruce plants, breeding trials excluded)

Based on Sonesson (2002)
Testing with cutting propagated clones

- Large efforts since long time to get operative clone forestry have failed
- But gave:
  - Experience (know how)
  - Clone tests
• Norway spruce flowers late, and has very irregular flowering. Therefore progeny tests with controlled crosses were established late. But plenty of clone tests existed, so it was natural to turn attention to them.

• Calculations in the end of the 80ies suggested that it was beneficial to combine progeny-testing and clone testing, thus to clone offspring to plus-trees before testing.

• This became a common praxis in the 90ies, and is now standard in Norway spruce breeding.
Gain in new seed orchard as a function of the time since plus tree (start genotype) selection (at the same cost) (based on Lindgren and Werner 1989)

Genetic value versus time

- Selection of OP progeny tested parents
- Selection of best phenotype in best full sib
- Selection from tested clones
Clone-testing offer advantages:

• Replications
• Reproducibility
Norway spruce breeding with clone test (Variant of Swedish program)

Select best clone in each family at age 15-20 and cross

Make 20 copies of each seedling and field test the clones

Selected plus trees

Mate plus trees (Double Pair Mating)

Take 20 seedlings per family (parent)

Select best clone in each family at age 15-20 and cross
Comparison (same test size) of clonal and seedling based testing for the Swedish Norway spruce long term breeding program. Clonal testing adds around 30% to gain. (Rosvall et al. 1998)
Clone test seems to result in almost double as high gain as alternatives. Simulation of Swedish breeding by breeding cycler, Danusevicius and Lindgren (2002)
New seed orchards are often established with cuttings of tested clones, but grafts of tested clones tested as cuttings works also.
“Conventional clone test” Norway spruce breeding cycle

Long-term breeding

Mate good parents, takes long time and complicated 5-10 years

Select at age 15-20

Clonal test

Cloning of progeny (20 ramets from each)
Breeding without Breeding


• Idea is to eliminate controlled crosses, and rely on open pollination and marker identification of the parent(s) instead.
Radicale new way of making forest tree breeding!

• Needed markers, marker competence and breeding theory competence!

• I like to be a part of the development of this concept in the research frontier! I push two projects in the area, here I talk about one of them.
Idea

• Let Nature do the recombination!
• No controlled crosses in Tree breeding any more!
• Get pedigree by markers instead of crosses!
• Can be applied in a large scale immediately after pilot study.
• No higher ”risk” than conventional breeding. Actually less as it eliminates a ”non-natural” element: *artificial* crosses.
• Brand new and fastly expanding research area!
• Here I suggest an implementation of the concept to a breeding program with clonal testing of Norway spruce.
Possible breeding Without Breeding Cycle

* Harvest wind pollinated seeds from best mothers
* Grow seedlings

Identify fathers of promising seedlings, select those with good fathers

0-3? years

Measure when flowering ≈ age 20

Intensive thinning to get rid of inferior clones and to stimulate flowering

Clonal test

Long-term breeding

Cloning (20 ramets from each)
Harvest wind pollinated seeds from best selections when flowering at age $\approx 18$

Grow seedlings

Test clones in the field

Analyze seedlings for fathers and select some with good fathers

Multiply these in 20 copies and make a field trial

Test clones in the field

Thin away bad clones to improve pollen cloud
Advantages:

• No artificial crosses
• No clone archives, no top-grafting
• Robust, optimal testing design, little lost if BwB is never applied!
• Norway spruce flowers irregular, but nothing has to be done until a good cone set observed
• Intensive genetic thinning helps flowering and focus on good fathers
• Measurements done the seed maturation year, thus decisions made without delay, no unproductive wait!
• Clonal propagation takes some years, but most of the breeding cycle is used for the gain generating testing!
• The breeding cycle will be shortened.
Costs

• That it is clones with many copies makes the genotype number manageable.

• A good set of markers must be developed, BwB may require better and cheaper techniques, but molecular techniques improves contineously.

• If seedlings is too tough, female gamete and embryo assay improves safety.

• Marker analyses in this scenario is optimistically guessed to a third of all breeding costs after some development. High, but not forbiddingly high.

• The scenario is optimized for conventional breeding, but can be optimized for BwB instead.
• The markers cannot safely separate hundreds of fathers, thus only the best genotypes close to the mothers are genotyped and considered. A large fraction, say 90% of all tested seedlings will be rejected to achieve say 30% selection of fathers.

• For cost reasons more systems may be run on the say 15% of seedlings which are judged as maybe good father after the first cycle of analyses.

• The cost per selected genotype will be high and practical implementation may require cheaper marker methods than existing today.
Flowering

- The loss in breeding efficiency if flowering does not occur until 25 years may be rather small, but considerable if it takes longer time.
- Only a few seeds needed.
- Acceptable male flowering is prognosed to have developed after 20 years in cutting seed orchards, but in clone trials abundant male flowering may wait longer.
- Maybe male flowering can be triggered in the best males by hormone injections? Think on other methods to improve male flowering.
- Breeding clone trials in Sweden are repeated at 4-5 localities, the one with most abundant male flowering and earliest female flowering could be used.
Old clone tests

• BwB can be used to harvest the gains from existing old clone tests, it need not be planned in advance.
Collection of material at Ekebo

- At Ekebo (south Sweden) there is a clone archive with cuttings. It has been thinned rather intensively and partly genetic. It has been used for crosses and for setting up clonal seed orchards.
- Female and male flowering was good 2007.
- There are breeding value estimates of the clones (clone tested).
- Commercial seed collection has been done and thus we could get collection at a rather cheap price as the equipment is there.
- Clones grow in rows.
- We get seed samples from about 50 clones in an approximate 10*5 (square pattern).
- Of these, 12 clones in an approximate square pattern 3*5 with 3 ramets in each row are collected from each ramet.
- We go there and collect needle samples from test trees in end of May 2008.
- The material will give valuable information about pollination by neighbours (gene flow, neighbourhood size) besides the BwB information.
- We have got a small grant for getting the material, we have applied for a grant to do the analyses.