NIBIO
NORWEGIAN INSTITUTE OF
BIOECONOMY RESEARCH

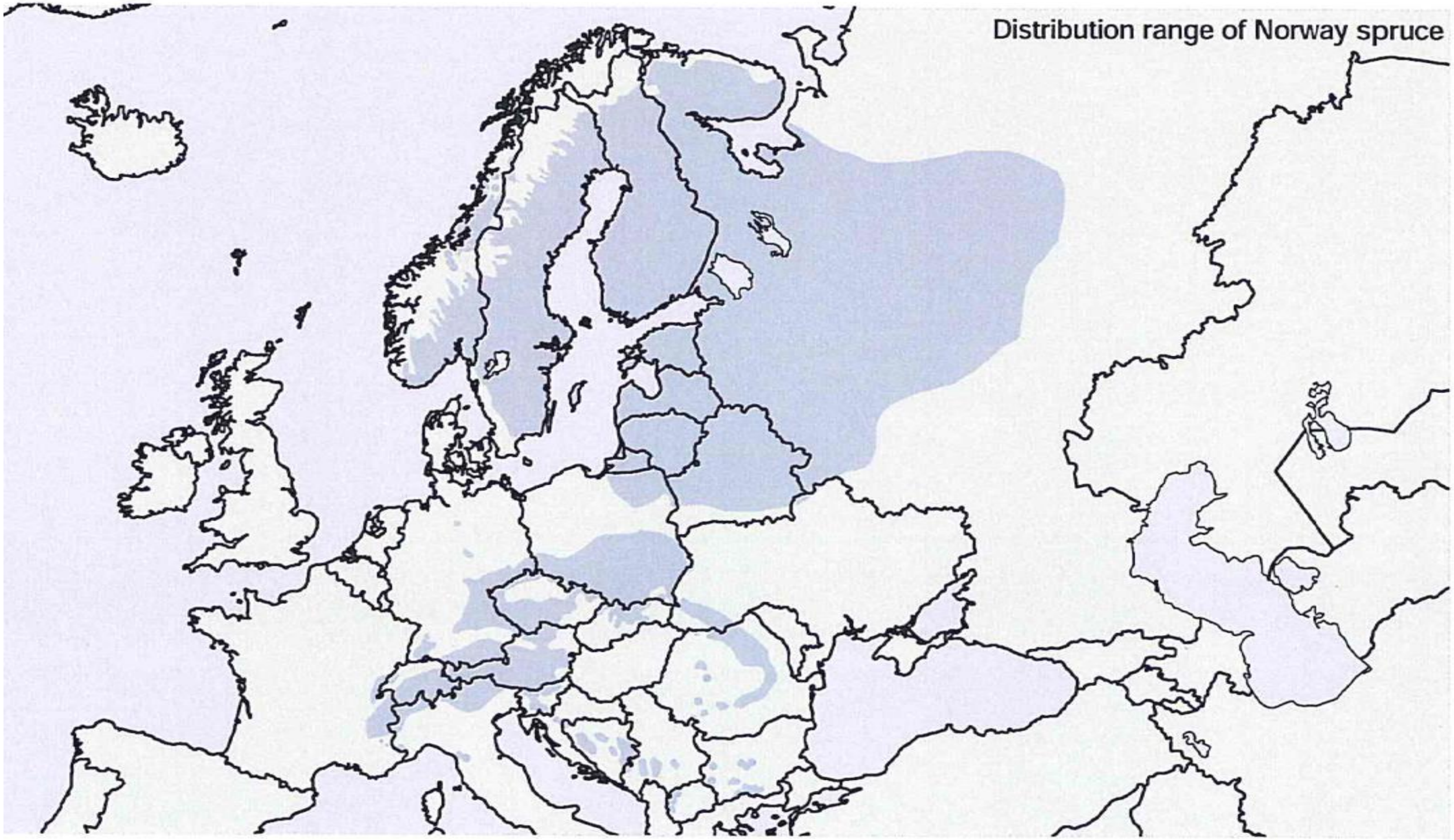
Performance and phenotypic stability of Norway spruce provenances, families and clones tested under different climatic conditions in the Nordic countries

Tore Skrøppa & Arne Steffenrem

This presentation

- Results from trials with provenances, families and clones in 17 trials in four Nordic countries
- Demonstrate effects of selection
- Show G x E interactions and phenotypic stability at the three genetic levels
- Demonstrate the importance of the annual growth rhythm, characterized by phenology traits
- Discuss the concepts of phenotypic plasticity and stability; how to measure and how to select

The natural distribution range of Norway spruce



Norm of reaction

- the response function of a given genetic material to changing environmental conditions

Phenotypic plasticity

- the property of a genotype to produce different phenotypes in response to distinct environmental conditions

Norm of reaction of a clone

- due to phenotypic plasticity

Norm of reaction of families and provenances

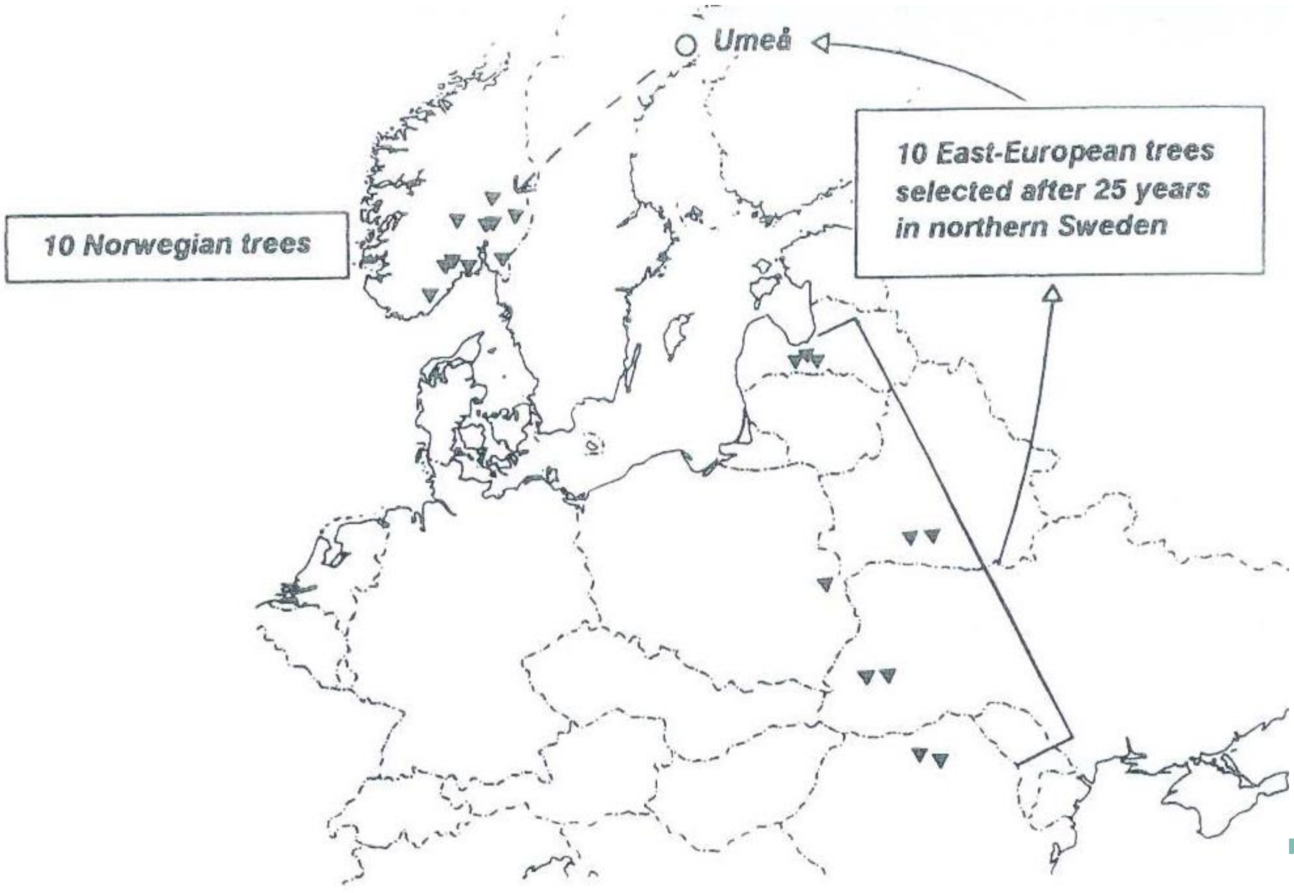
- due to phenotypic plasticity and genetic variation

Operational definition of stability:

- A material is stable if it produces near the production level at sites with different environmental conditions
- Does the stability of a given material depend on its genetic diversity?

The first IUFRO provenance trial with Norway spruce was planted in 1942

Selections were made after 25 years in a trial in northern Sweden, 30 selected trees were grafted in a seed orchard together with 30 Norwegian plus trees. Ten clones from each group were crossed.



NIB

100 controlled crosses were made in a factorial design (1983), with 10 N and 10 E parents

Male Female	11 N	12 N	13 N	14 N	15 N	16 E	17 E	18 E	19 E	20 E
1 N	X	X	X	X	X	X	X	X	X	X
2 N	X	X	X	X	X	X	X	X	X	X
3 N	X	X	X	X	X	X	X	X	X	X
4 N	X	X	X	X	X	X	X	X	X	X
5 N	X	X	X	X	X	X	X	X	X	X
6 E	X	X	X	X	X	X	X	X	X	X
7 E	X	X	X	X	X	X	X	X	X	X
8 E	X	X	X	X	X	X	X	X	X	X
9 E	X	X	X	X	X	X	X	X	X	X
10 E	X	X	X	X	X	X	X	X	X	X

Clones (rooted cuttings) were produced from 20 families (X)

Materials included in trials

- 100 full-sib families
- 240 clones, 12 from each of 20 families
- 20 provenances from the natural distribution of Norway spruce

Short-term trials at 2 sites in Norway

- 100 full-sib families

Estimates of day of growth start and growth cessation from weekly shoot growth measurements at ages 5 and 6 years

Field trials

Families and provenances

- 7 sites in Norway, Sweden and Finland

Clones

- 8 sites in Norway, Sweden, Finland and Denmark

Traits reported here:

- Survival and stem damage after 10 years

- Height after 10 years

Field trials

Mean annual temperature sum in brackets

Large climatic differences among trial sites

	Range of variation
Annual mean temperature:	2.8 - 8.8 °C
Accumulated annual temperature sum :	930 - 1840 dd
Last day of spring frost:	43 days
First occurrence of autumn frost:	50 days

Can we find any effect of the selection made after

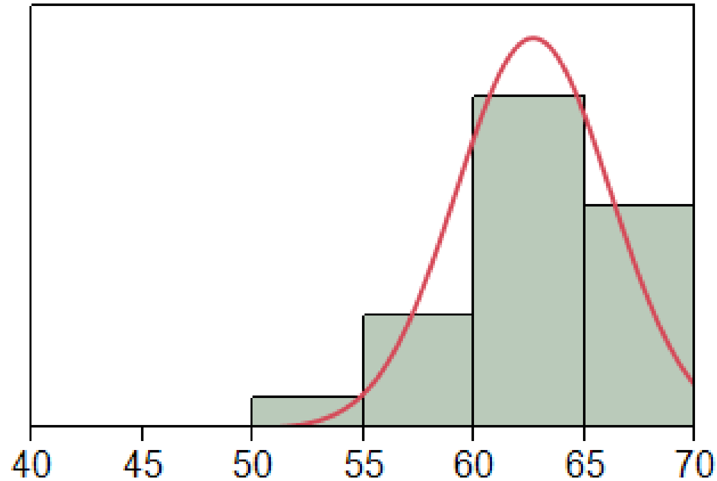
25 years in the provenance trial from 1942?

Comparison of the distributions of the 25 families

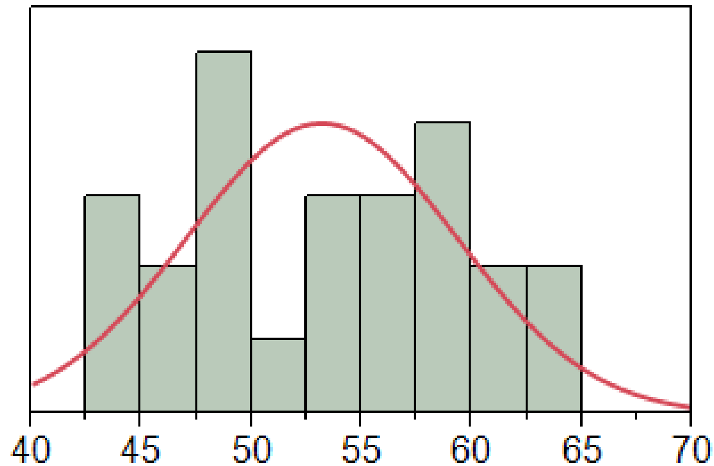
in each of the N x N and E x E family groups

Day of start of annual shoot growth

E x E families



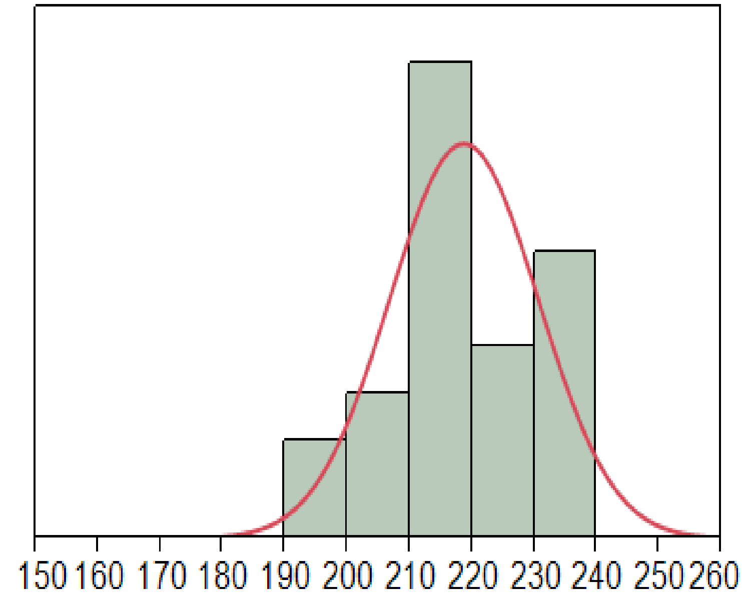
N x N families



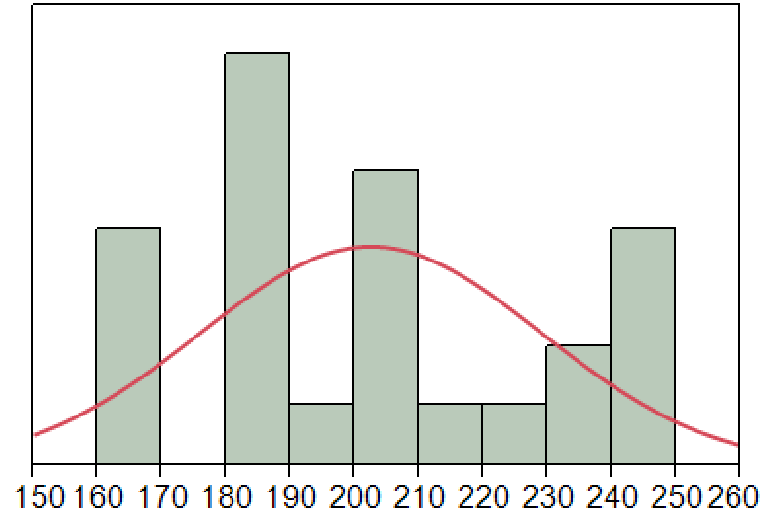
Day number, after April 1

Mean height after 10 years across 7 sites

E x E families



N x N families



Mean family height cm

NIBIO

Yes,

selection has reduced the variation among the families in the E x E group for the timing of shoot elongation and height

A very large variation is still present among the families from the selected N “plus” trees

Height year 10

20 provenances at 7 sites	% of variation
Provenances	3.5
Prov. x site	2.5
Error	94.0

No interactions for 8 Nordic provenances

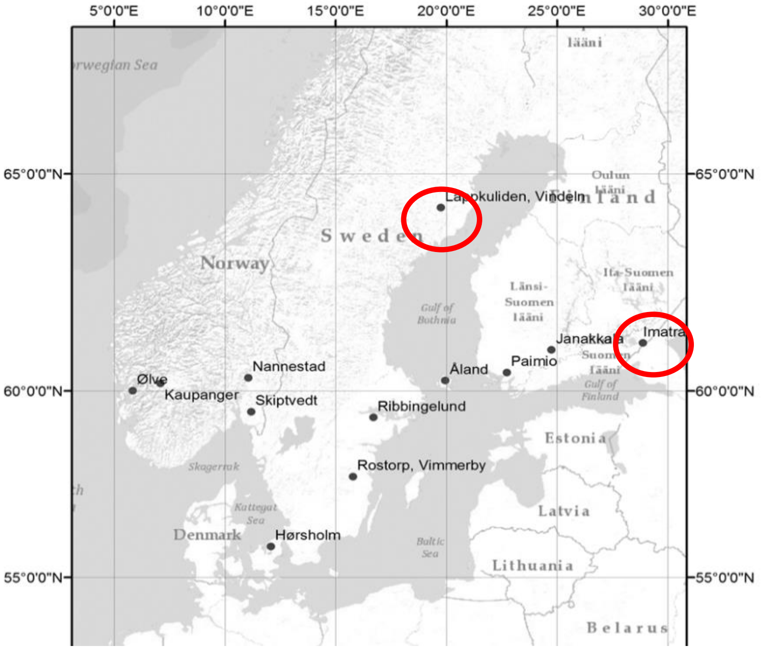
25 N x N families at 7 sites	% of variation
Family	10.7
Family x site	2.5
Error	86.8

25 E x E families at 7 sites	% of total variation
Family	2.1
Family x site	1.9
Error	96.0

Height year 10

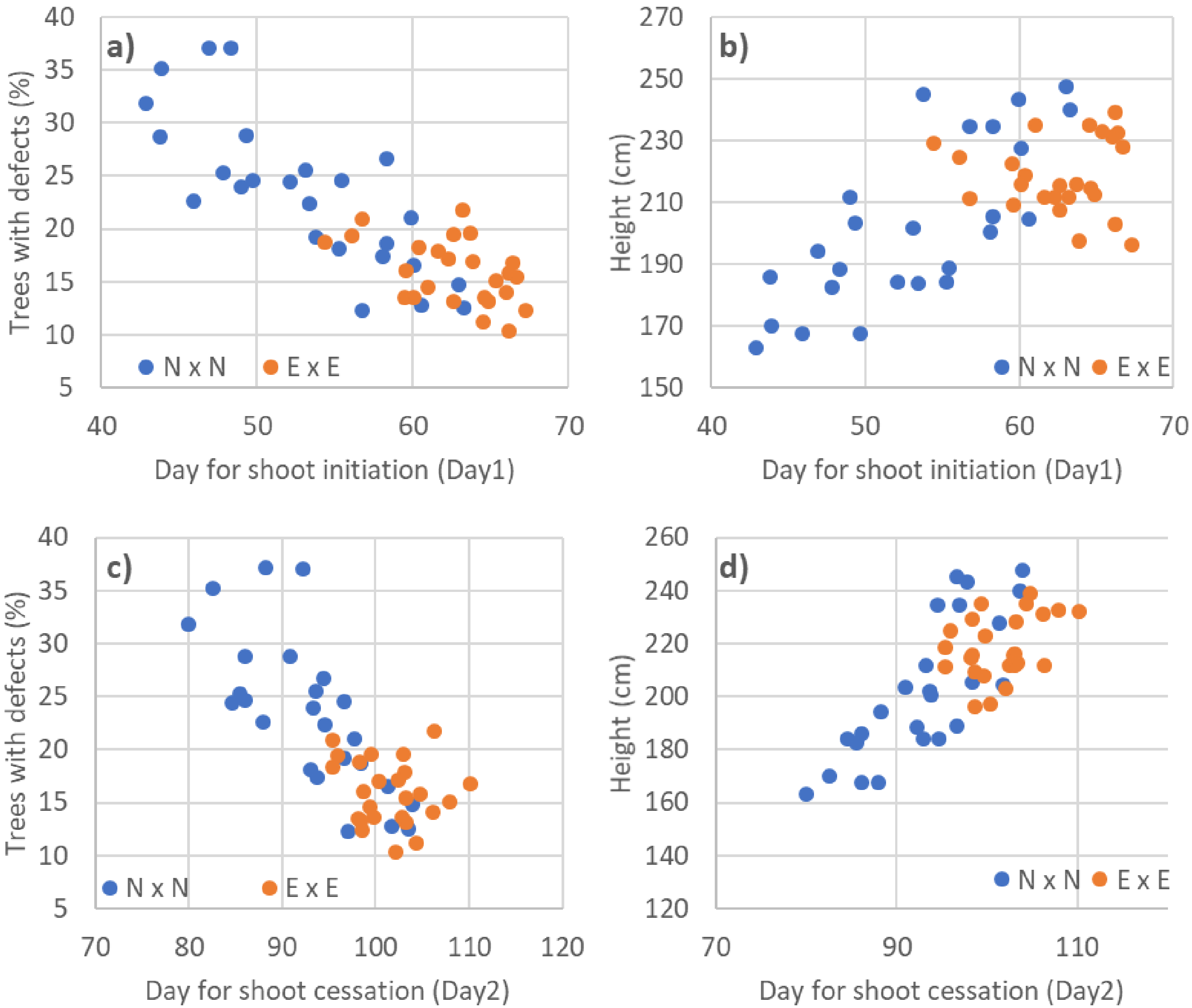
240 clones from 20 families at 8 sites

	% of variation
Family	9.7
Family x site	3.7
Clones (family)	10.4
Clones x sites	3.8
Error	72.4



Exclusion of two extreme sites reduced the interactions only slightly

Relationships between phenology traits and height and stem defects



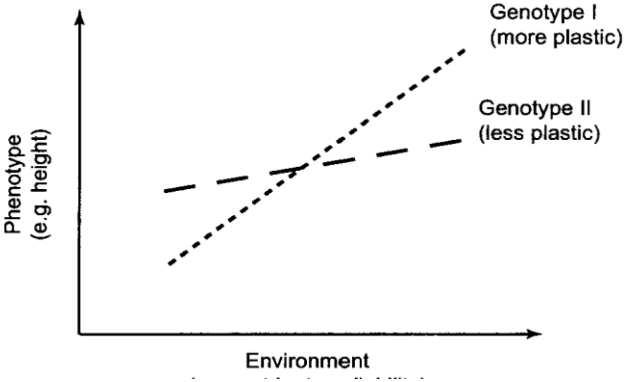
Conclusions so far

- Significant G x E interaction both for clones, families and provenances
- The level of interaction depends on the type of material in each group
- Exclusion of two extreme sites did not remove the interactions
- Strong relationships between phenology traits and stem defects and height for the N x N families

How to characterize the environmental conditions for growth at the trial sites?

- **Mean annual temperature**
- **Accumulated degree days**
- **Mean height of all trees**
- **Mean height of 10 % tallest trees**

Joint regression analyses of means of provenances, families and clones on total site means for mean annual increment



The regression coefficient characterizes a linear norm of reaction to the site conditions, and is a measure of relationship between the interaction effects of the genotype and the environment

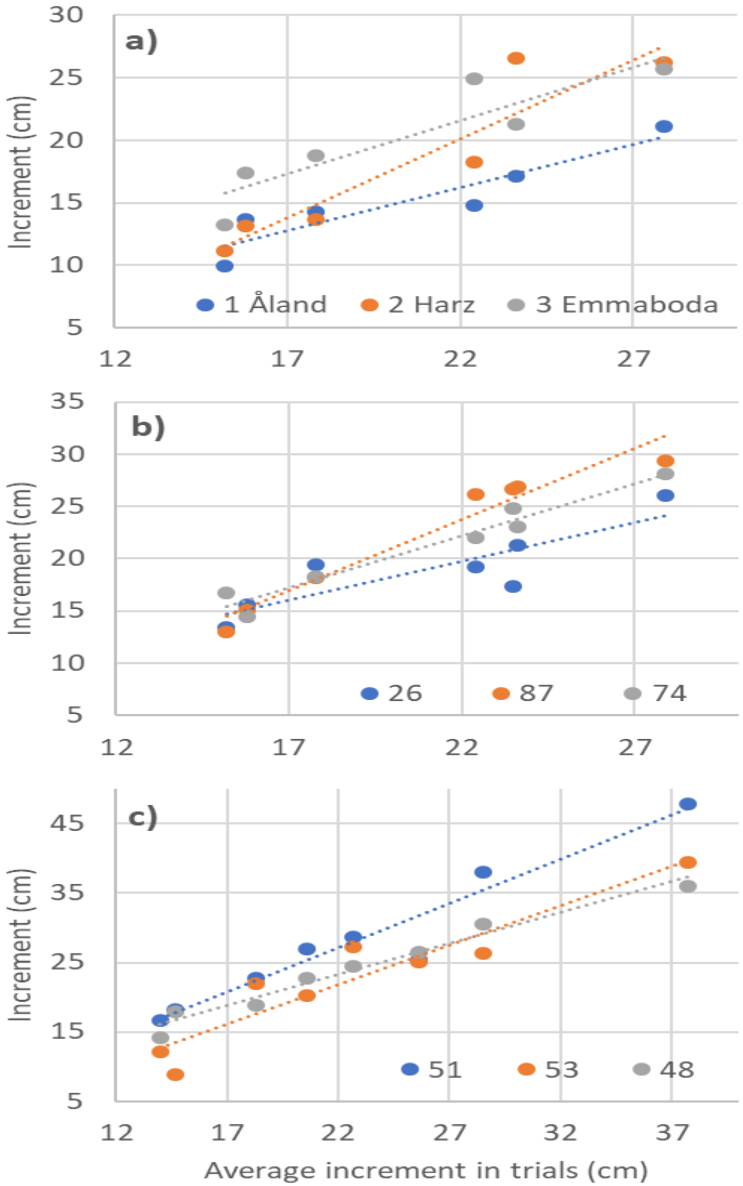
Phenotypic stability is characterized both by the regression coefficient and the deviation of the observations from the regression line

Joint regression analyses

	range of regression coefficient
• 20 provenances:	0.70 – 1.52
• 100 families (seedlings):	0.66 – 1.45
• 240 clones:	0.35 – 1.65
• 20 families (12 clones):	0.76 – 1.21
• 20 families (seedlings):	0.76 – 1.23

Estimated regression lines for

- **a) provenances**
- **b) independent families**
- **c) clones within one family**



Genetic variation in the regression coefficient

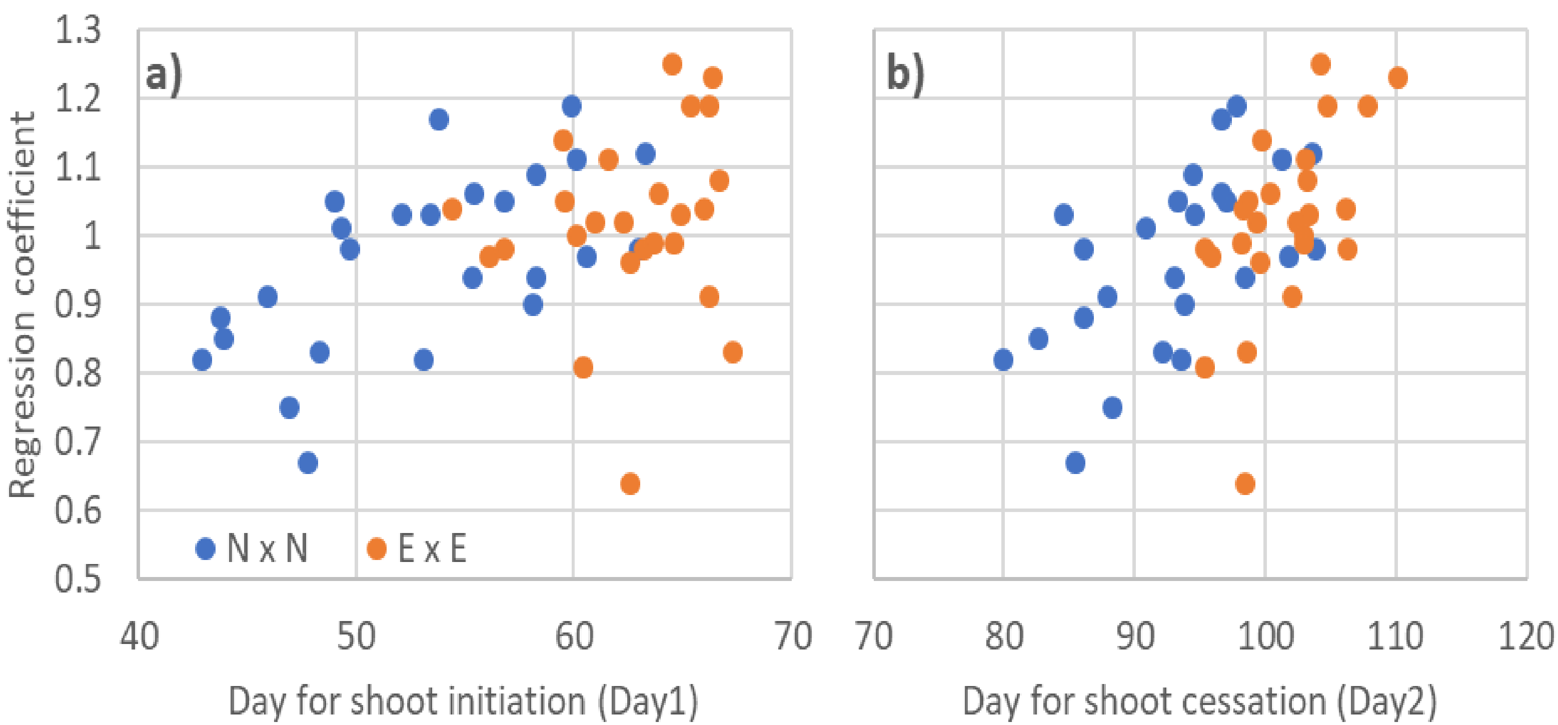
Analysis of variance between families - seedlings

	% variance component	p-value
Mother	31.1	<0.0001
Father	18.0	0.0001
M X F (error)	50.9	

Analysis of variance between and within families - clones

	% variance component	p-value
Families	21.7	<0.0001
Clones (families)	78.3	

Relationships between regression coefficients and phenology traits



No relationship between level of heterozygosity and plasticity

- 11 nuclear microsatellite markers were developed for genotyping the 240 clones
  No relationships were found between the level of heterozygosity and the phenotypic traits or the plasticity parameter neither at the clonal nor at the family level

More conclusions

- This phenotypic plasticity parameter is under genetic control; genotypes have different degrees of phenotypic plasticity
- The levels and variation of plasticity of families based on 12 clones or 25 – 40 seedlings are similar
- The patterns of plasticity will vary in different sub-populations
- The variation in plasticity is related to adaptive traits such as the timing of the growth period
- Selection can be made for stability both for clones, families and provenances, but not based on the regression coefficient alone

Discussion points

- How to measure phenotypic plasticity?

  Is the regression coefficient a good measure?

- Is phenotypic plasticity a trait in itself?

  In this case: no

- Differences between plasticity and stability

- In tree breeding we are more interested in stability.

  How to select for stability?

Many colleges in the Nordic countries have contributed to this study. We thank them all for their contributions

References

Skrøppa, T; Steffenrem, S. 2016. Selection in a provenance trial with Norway spruce (*Picea abies* (L.) Karst) produced a land race with desirable properties. Scand. J. For. Res 31: 439-449.

Skrøppa, T; Steffenrem, S. 2021. Performance and phenotypic stability of Norway spruce provenances, families and clones tested under different climatic conditions in the Nordic countries. Forests 221, 12, 230.

Thank you for listening!