Conventional Breeding Strategies and links with tools and process

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Most of forest tree varieties in use at present are fruit of conventional breeding strategies and allow genetic gains for volume production and adaptability of ≈ 15-20%


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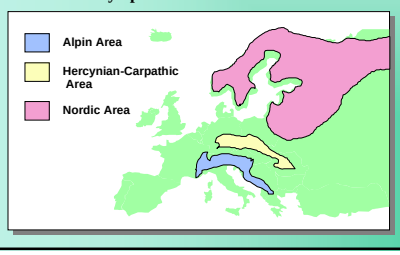
Characteristics of conventional forest tree breeding strategies

- *High level of genetic diversity over large areas*
- *Most of genetic variability within populations*

Norway Spruce Natural distribution area



Large breeding populations to evaluate

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Characteristics of conventional forest tree breeding strategies

- *Long lived species with late sexual maturity*

Late evaluation


Late recombination

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Characteristics of conventional forest tree breeding strategies

- *Increasing size of individuals*
- *Heterogeneity of environmental conditions*

Constraints in forest trials : thinning, heterogeneity control


Large genotype archives

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Characteristics of conventional forest tree breeding strategies

- *Selection objectives = complex and cumulative traits*

Adaptation (climate, pests)

Volume production

Stem form

Wood quality

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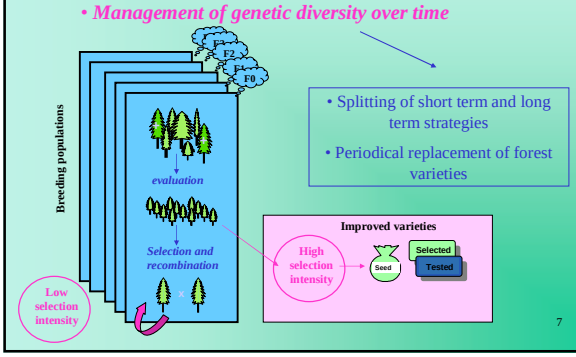
Characteristics of conventional forest tree breeding strategies

• *Management of genetic diversity over time*



• Splitting of short term and long term strategies

• Periodical replacement of forest varieties

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Characteristics of conventional forest tree breeding strategies

• *3 main constraints : time, space, multitrait objectives*

↑ *Experimental costs*

• *3 main questions to tree breeders*

- Improve early selection
- Explore hybridisation between species or between populations
- Improve mass deployment methods of the genetic progress

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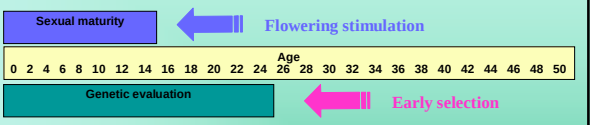
Objectives of early selection in forest tree breeding



- **Shorten the evaluation period and generation interval**
- **Improve precision of genetic evaluation for mature age**
- **Increase selection intensity**
- **Reduce field testing size and experimental costs**

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Adaptation to changing environments

Present perspectives of early selection for forest trees : Adaptation to changing environments

Autumn and Winter Frost resistance

• Efficiency of artificial freezing test at juvenile stage for resistance to autumn and winter frost

Pinus sylvestris : autumn frost , 1 yr-old seedlings , (Aho, 1994 ; Norell et al. 1986, Nilsson & Eriksson, 1986)

Pinus contorta : autumn and winter frost, 1 yr-old seedlings (Jonsson et al. 1986)

Pseudotsuga menziesii : autumn and winter frost, 7 yr-old shoots (Aitken &Adams 1996)

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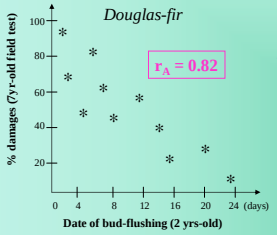
Present perspectives of early selection for forest trees : Adaptation to changing environments

Late Frost resistance : an easy indirect early test



• Efficiency of indirect selection for resistance to late spring frost through earliness of bud-flushing

Picea abies (Hannerz 1999), *Pseudotsuga menziesii* (Heois 1994)

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"Downward" Decomposition of pest resistance
(Poplar rust resistance Melampsora ssp.)

Field evaluation

natural inoculation :

mixture of races, several cycles of infection

intensity of symptoms score 1-9

tree level

1 trait

Laboratory 16h 15-19°C

artificial inoculation :

5 races E1, E2, E3, E4, E5

1 yr-old cuttings

3 epidemiological components : latent period, nb. uredia, size of uredia

15 traits

susceptibility index

h^2 = 0.2-0.3

Higher h^2 ?
Selection of more durable resistance ?

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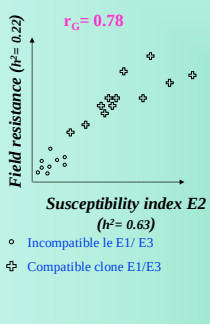
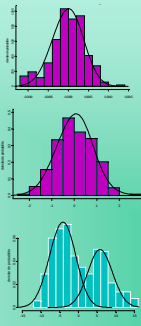
"Downward" Decomposition of pest resistance
(Poplar rust resistance Melampsora ssp.)





Latent period
CV_G = 15-20%
h^2 = 0.35 - 0.55

Nb. Uredia
CV_G = 25-40%
h^2 = 0.40 - 0.65

Size of Uredia
CV_G = 30-45%
h^2 = 0.77 - 0.89

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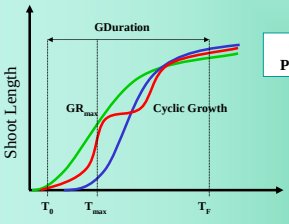
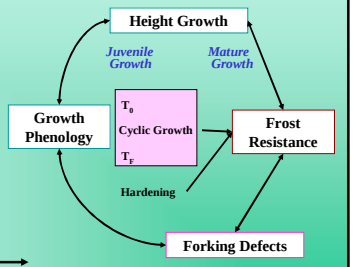
"Downward" decomposition of Volume production
Dynamical decomposition of volume growth

Phenology of annual height increment





Pseudostuga menziesii, Picea abies

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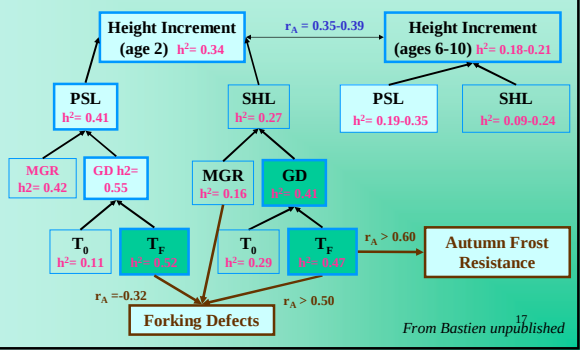
"Downward" decomposition of Volume production
Dynamical decomposition of Douglas-fir height Growth



From Bastien unpublished

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Optimal age of early selection for volume growth
(Synthesis for forest trees)

After validation in retrospective early tests

Species	optimal selection age	Mature age	References
Pinus taeda	3-4 yr-old	23 (35)	Gwaze et al. 1997
Pinus contorta	6-7 yr-old	20 (60)	Xie & Ying 1996
Pinus pinaster	10-12 yr-old	25 (45)	Magnussen & Kremer 1994
Pseudotsuga m.	3 yr-old	15 (45)	Bastien & Roman-Amat 1990
Populus delt.	3-4 yr-old	10 (15)	Pichot 1994
Juglans nigra	8 yr-old	20 (50)	Rink & Kung 1995
Eucalyptus sp.	1.5 yr-old	8 (8)	Pereira et al. 1997

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Branching Habit

Stem form

Early Evaluation of form

Larix eurolepis **Stem Straightness**

Stem form
=
complex trait difficult to evaluate before age 10

difficult to measure

strongly exhibited at young age

Interest of juvenile explanatory predictors ?

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Early Prediction of forking defects
(*Pseudotsuga menziesii*, Bastien et al 1998)

% Plants with Forking Defects

- **a major stem defect in 10-15 year-old Douglas-fir plantations in fast growing conditions (forking trees frequency 40-60%)**
- **unfavourably linked to height growth (r_G > 0.4)**
- **with significant genetic variation but strongly influenced by environmental factors (low h^2, GxE interaction)**

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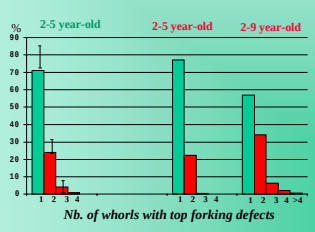
Frequency of top forking defects in Douglas -fir

Annual frequency of trees with top forking defect

Farm-field tests (2-5 year-old)	Forest site (6-9 year-old)
6-40%	3-15%

Repetition of top forking defects over years

Significant progeny effect



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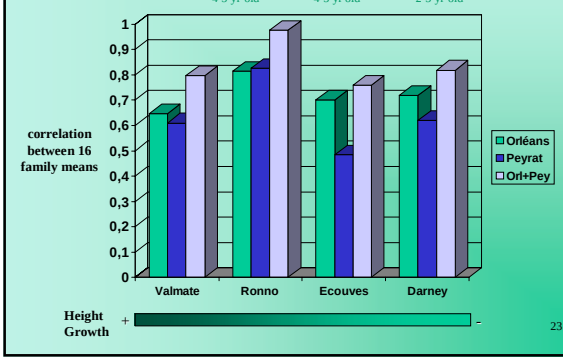
Prediction of Douglas-fir forking in farm-field tests

***Predictors* = *% polyc. trees* (4-5 yr-old) + *% SSL/ASL* (4-5 yr old) + *Nb. yrs with defects* (2-5 yr-old)**



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Prediction of Douglas-fir forking in farm-field tests

% forking trees at 10-15 year-old in fast growing conditions

Adaptive traits :
- earliness of budflushing
- polycyclism ability

Repetition over years

Advantages of early prediction in farm-field tests

- *homogeneity* of environmental conditions

- *better evaluation* of polycyclic ability at juvenile stage 2-6 year-old

- *intensive* measurements at a *lower cost*

- *combined selection* for adaptation, growth and stem form

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Wood Quality

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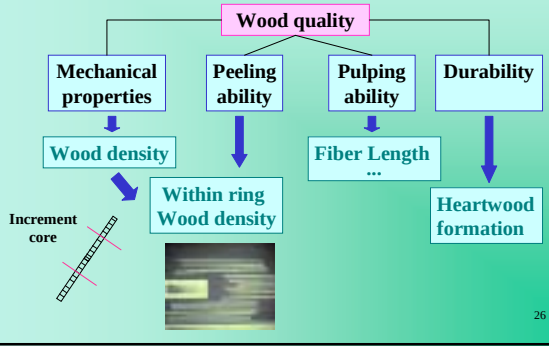
Early Evaluation of wood quality



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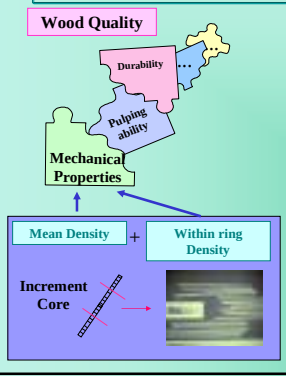
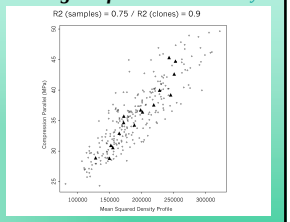
Optimal age of early selection for wood density
(Synthesis for forest trees)



Douglas -fir : *clonal vatiability*



☛ *Good prediction of behaviour in compression through within ring density*

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Optimal age of early selection for wood density
(Synthesis for forest trees)

Estimation from age-age correlations

Species	Additive age-age correlation	Age range	References
Pinus taeda	0.76-0.9	2-50 yrs	Williams & Megraw 1994
Pinus radiata	0.79	5-20 yrs	Cown et al. 1992
Pinus sylvestris	0.88	8-33 yrs	Hannrup & Ekberg 1996
Pseudotsuga m.	0.83	6-13 yrs	Woods et al. 1995
Picea sitchensis	0.95	5-17 yrs	Lee 1997

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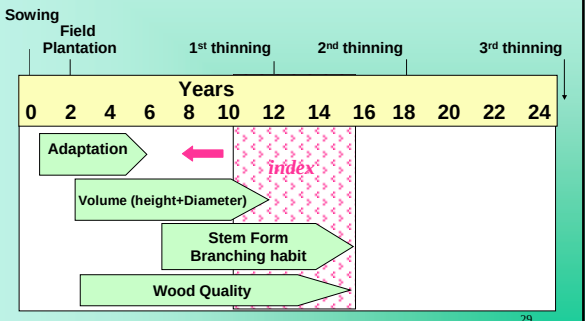
Optimum Selection Ages
One Step : index selection



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Relative efficiency of two-stages selection with Lodgepole pine
(from Wu 1998 Silvae genetica 47,2-3, 146-152)

First stage selection : 2 yr-old basal diameter in greenhouse
Second stage selection : 9 yr-old total height in field test
final selection of 11 families from the 110 families tested in the field

Base population size	110	122	138	157	183	220
Nb families culled at early stage	0	12	28	47	73	110
Efficiency $E_{xy.y}$	1	1.051	1.096	1.135	1.185	1.239
Gain increase	0%	5.1%	9.6%	13.5%	18.5%	**23.9%**

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Inter-specific or inter-population hybridisation

- Get a good *complementarity* between traits
- Valorise heterosis when it exists

Hybrid vigour (% of average parent) in hybrid Larch
diallel 18 x18 4 years 1 site

%	Hybrid Vigour at : Specific level	Family level min.	Family level max.
Total Height	12,9	-4	31,1
Strightness	-6,1	-24	9,5
Flushing	14,2	-20,4	53,1

Prediction of inter-specific SCA still remain dificult !

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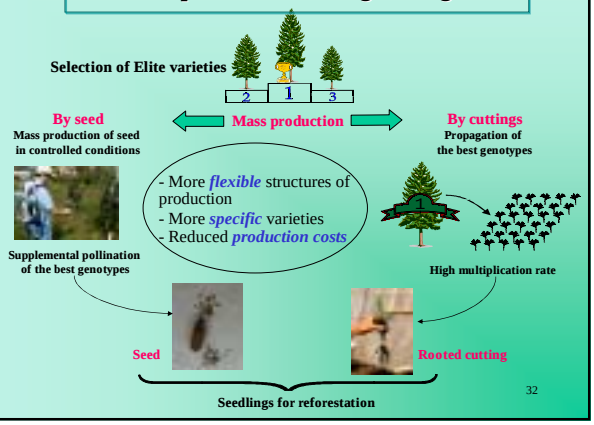
Improve transfer of genetic gain



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Research perspectives

- Multi-generation management of breeding programs : structuration of breeding populations (simulation).
- Application of MAS to create clonal varieties of Poplar resistant to rusts.
- Reduce negative effects linked to increased proportion of juvenile wood.
- Evaluate relationships between genetic diversity and plasticity (in space and time) of improved varieties.

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