Universidad de Talca

Facultad de Ciencias Forestales

Centro Tecnológico del Álamo

(Poplar Technology Center)

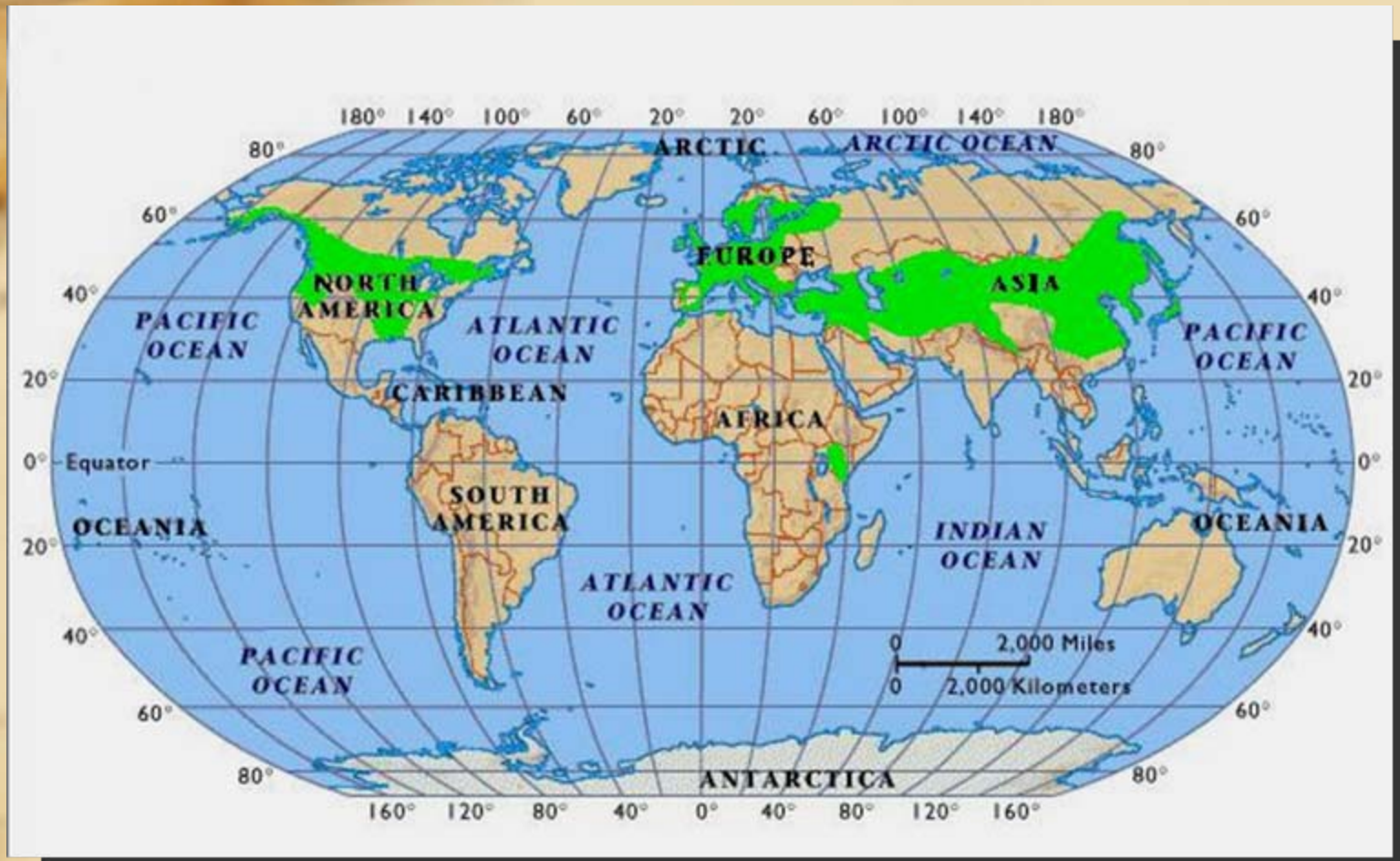
Strategies for Clonal Selection of Poplar Hybrids in Chile Based on Superior Wood Properties

Concepción, November 11, 2008

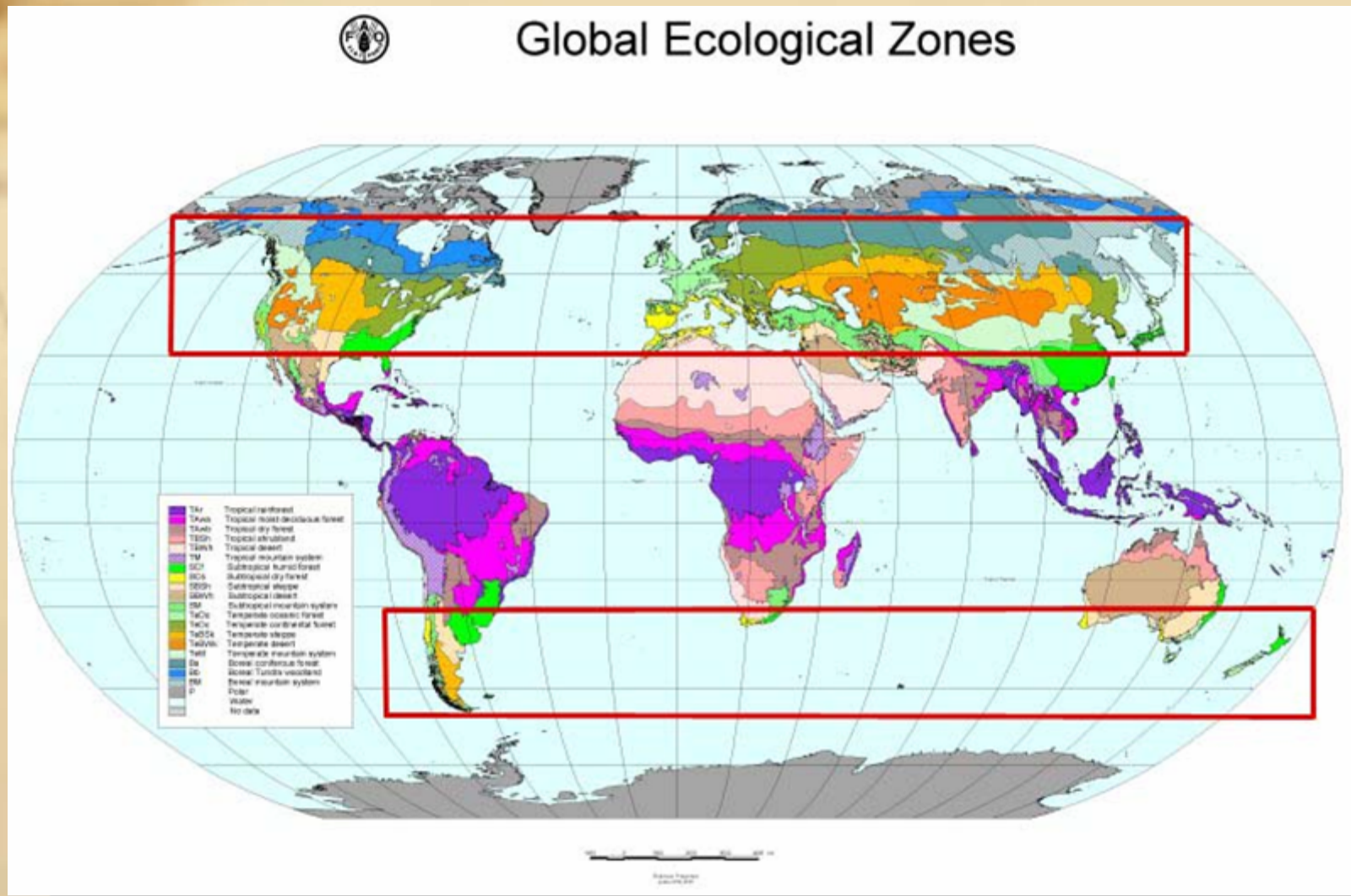
Fondef

FONDO DE FOMENTO AL DESARROLLO CIENTÍFICO Y TECNOLÓGICO

Poplars in the world



Where can we plant poplars?



Fuente: FAO

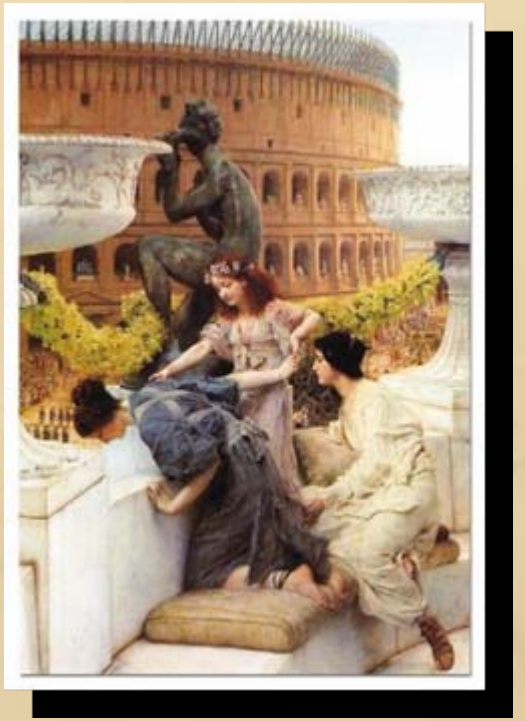
Arbor populi

SPQR: Senatus Populesque Romanus

During Roman times, poplars were frequently planted in public places and meetings were held beneath them. In the meantime, leaves were noisily flutter in the slightest breeze. These trees became known as ***arbor populi****, or* ***"the people's tree"***

JuliusCesar

Roman landscape: Il Tempo. D. Jeffrey Mims



The Coliseum . Sir L. Alma-Tadema

“Antigua cañada de Santiago”. Oil on canvas. By Giovatto Molinelli. 1861

“El huaso y la lavandera”. By Mauricio Rugendas

Poplars in Chile …since 1810

“Una Trilla”. Oil on canvas. By Claude Gay. 1835

Why do we think about poplars ?

Thinking about forestry → ***We need to diversify***

Thinking about forest industrial plantings → ***There are soils where poplars could perform better than radiata pine and eucalypts***

Thinking about agriculture → ***Poplars can be used in agroforestry***

Thinking about the environment → ***Poplars can help to resolve some problems***

Let's think about today…

Sunlight effect under the poplars. By Claude Monet. 1887.

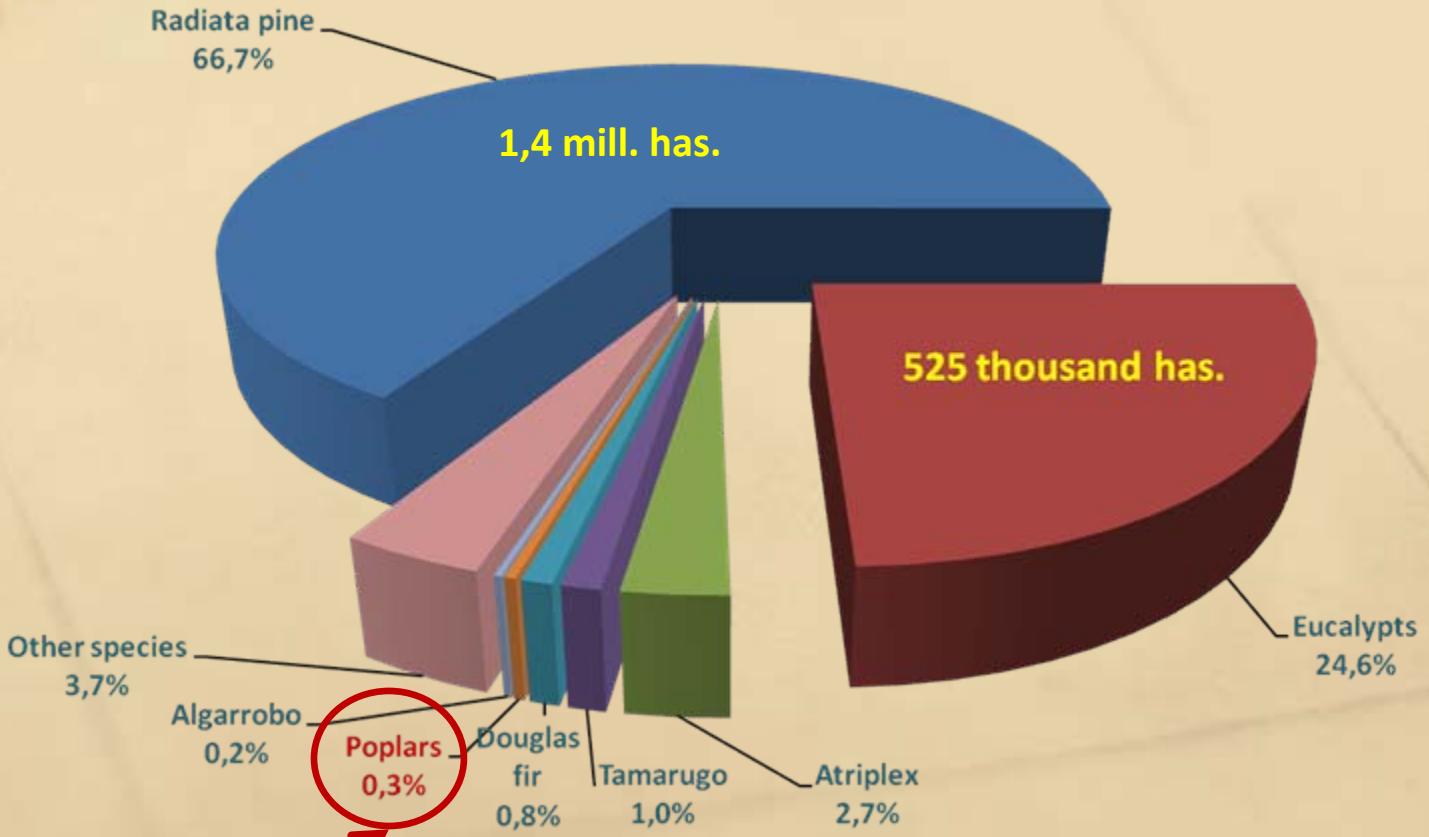
Poplars in General Carrera lake, Patagonia

… genetic selection to improve (the use of) poplar wood

Today, … how is the poplar wood in Chile?

Total surface of forest plantings in Chile as of 2006

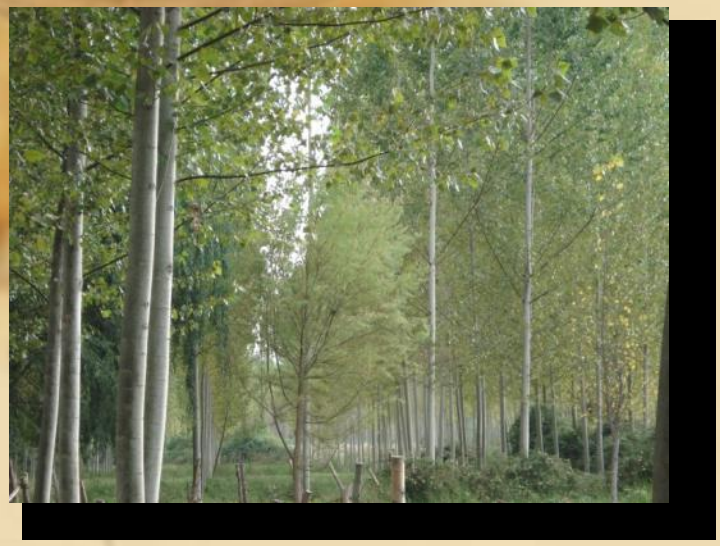
Total : 2.135,3 thousand of hectares



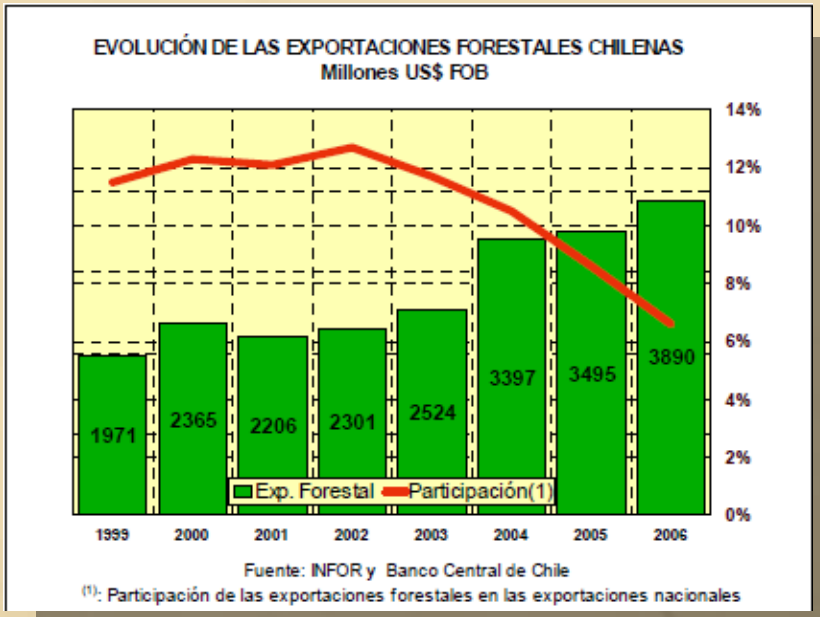
6.000 hectares

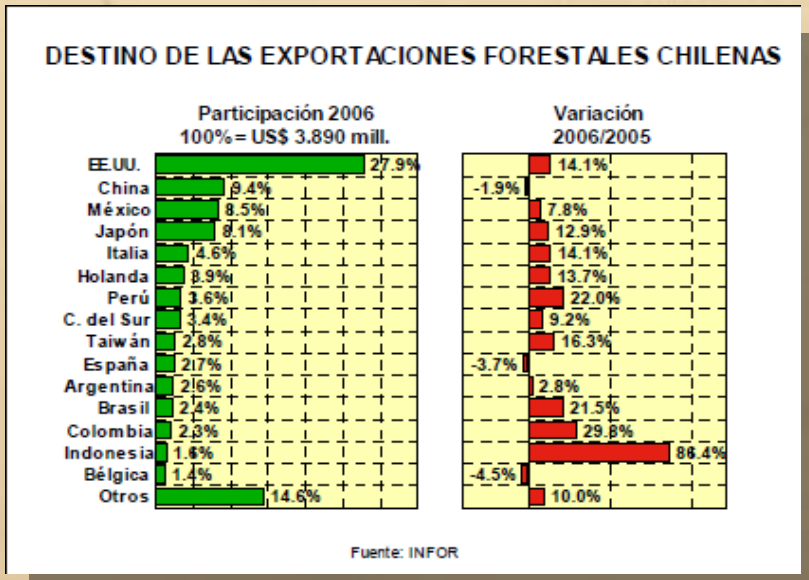
Source: INFOR - ODEPA

Forest exportation from Chile?



Coinco, VI Región





Source: INFOR (Forest Institute) - www.infor.cl

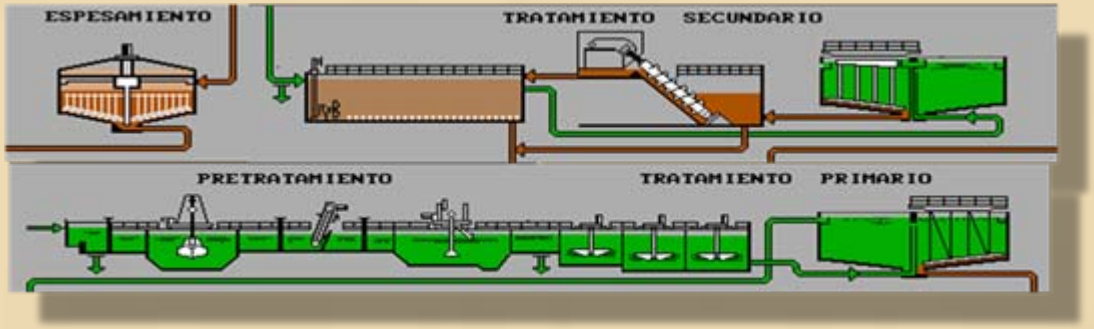
Let's think about tomorrow…

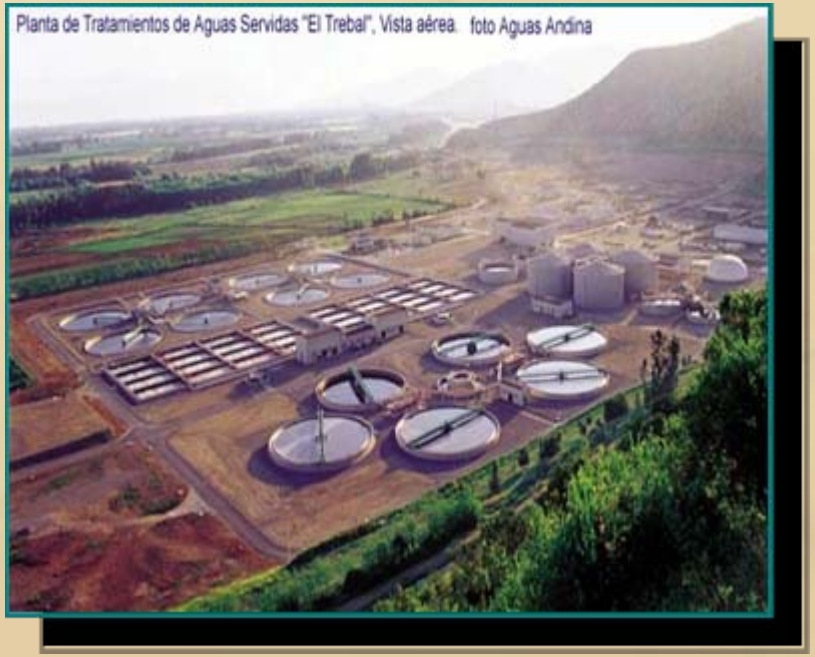
Trimming poplars in a lining road, France

Lombardy poplar

… genetic selection to Improve our environment

Use of biosolids generated from the treatment of municipal wastewaters



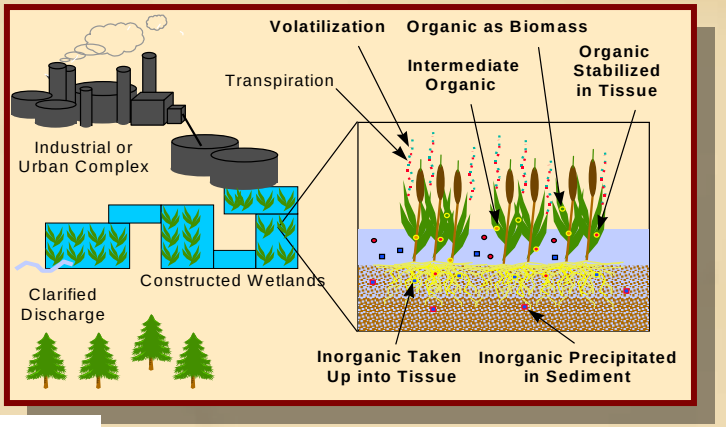


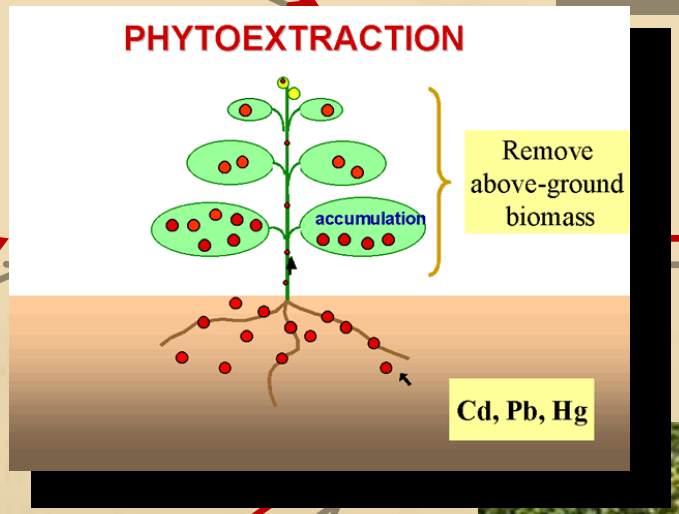
Gentileza: Dr(c) Fernando Guerra G. UCM

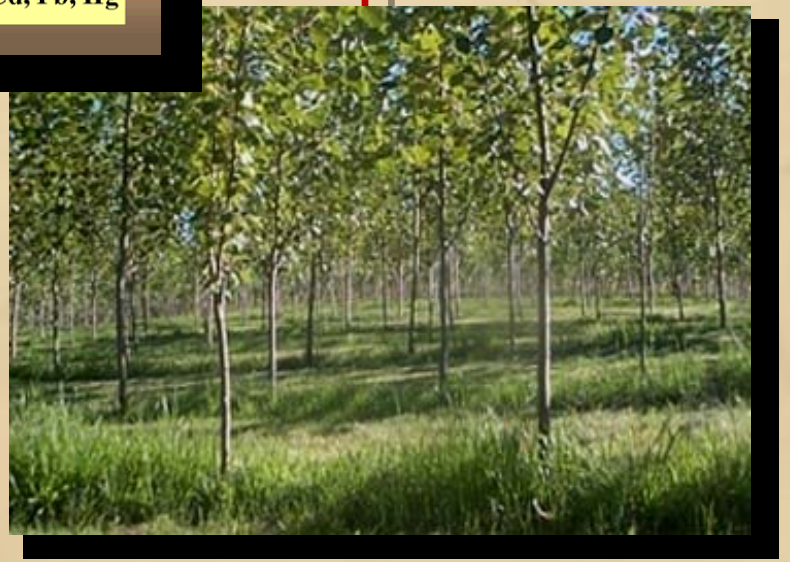
Mine tiling (copper, molybdenum, etc.)

Mine tiling from CODELCO. Division “El Teniente”

Source: Dr Fernando Guerra G. UCM







Gentileza: Dr Fernando Guerra G. UCM

The Poplar Tree:
Advancing Alternative Energy Sources

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USDA And DOE Fund Genomics Projects For Bioenergy Fuels Research

U.S. Department of Agriculture
8/9/2006 1:03:41 PM

WASHINGTON, Aug. 9, 2006 - Energy Secretary Samuel Bodman and Agriculture Secretary Mike Johanns today announced that the Department of Agriculture and the Department of Energy (DOE) have jointly awarded nine grants totaling $5.7 million for biobased fuels research that will accelerate the development of alternative fuel resources.

WebWire Related Industries

- Agriculture/Aquaculture
- Environment
- Government
- Oil/Energy
- Utilities

Bodman commented, "These research projects build upon DOE's strategic investments in genomics, to accelerate scientific discovery and promote the development of alternative energy sources vital to America's energy and economic security."

"To be a reliable renewable energy source, farmers and ranchers will need to be able to grow biomass in large quantities," Johanns said. "This joint research initiative will address our nation's need for alternative energy resources and improve the efficiency with which biomass and plant feedstocks are used to produce renewable fuels such as ethanol."

USDA's Cooperative State Research, Education and Extension Service (CSREES) and DOE's Office of Biological and Environmental Research (OBER) awarded the grants. CSREES and OBER jointly initiated this fundamental research program to facilitate the use of woody plant tissue, specifically lignocellulosic materials, for bioenergy or biofuels. The research projects will focus on poplar, alfalfa, sorghum, wheat and other grasses.

Put a poplar in your tank !!!!

biofuel review

a primary news source for the biofuel industry

Poplar/switchgrass rotations promise greater reduction in greenhouse emissions

Posted by Giles Clark, London

Monday, 11 June 2007

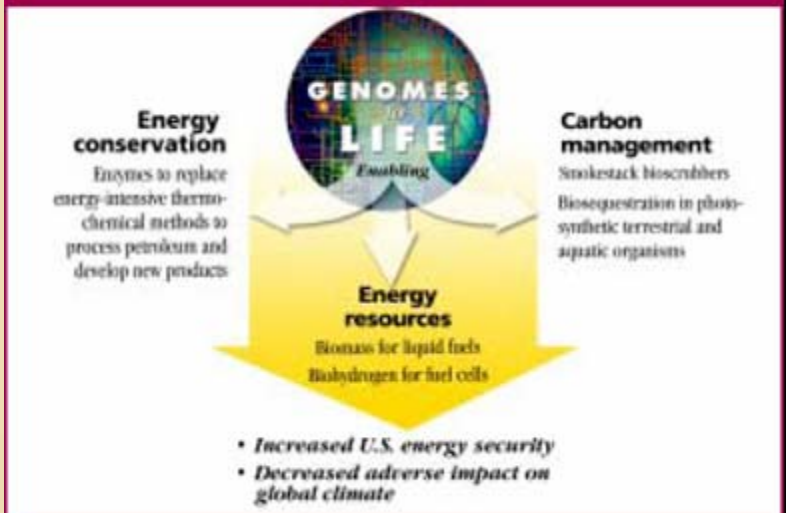
By Jan Suszkiw

"....using switchgrass and **hybrid poplar would produce nearly a three-fold greater reduction in greenhouse gas emissions compared to corn-soybean rotations.**

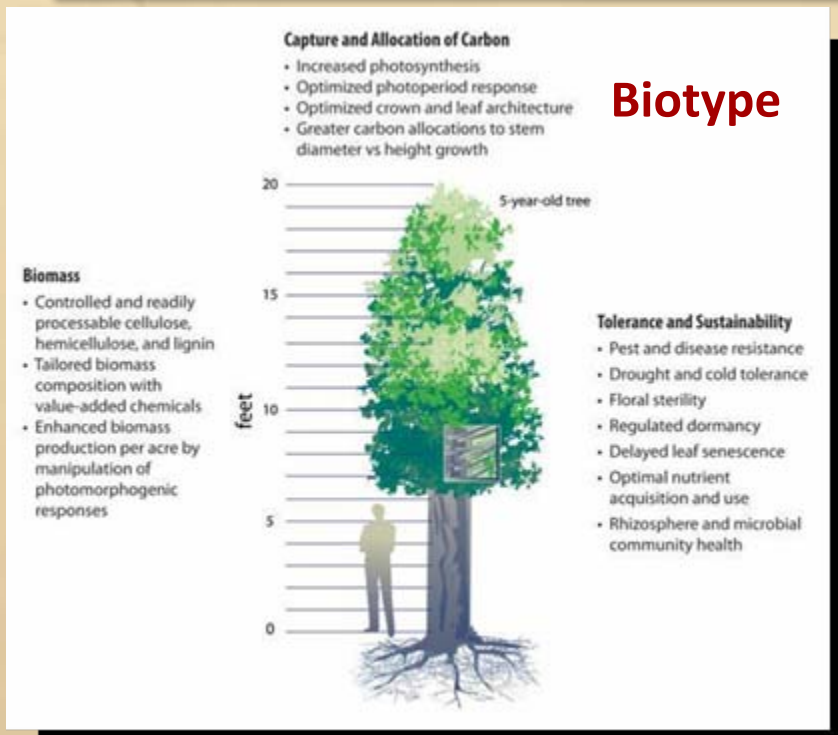
This research shows that biofuels do indeed have potential to remove greenhouse gases from the atmosphere while helping reduce U.S. reliance on foreign oil..."

U.S. Energy Security and Global Climate Stabilization

Complementary Goals



Biotype



Energy Security and Climate Stabilization

GENOMES to LIFE

BIOLOGICAL SOLUTIONS FOR ENERGY CHALLENGES

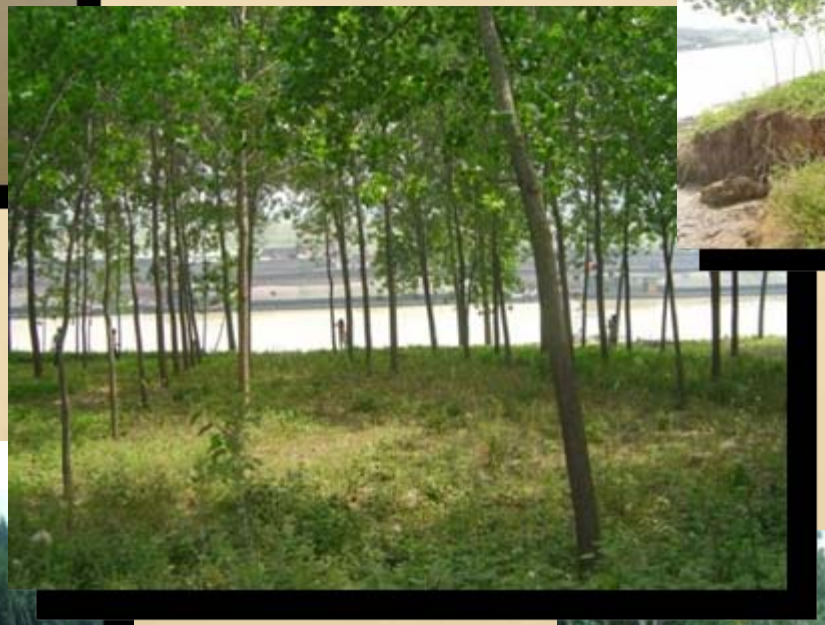
U.S. DEPARTMENT OF ENERGY

Office of Science

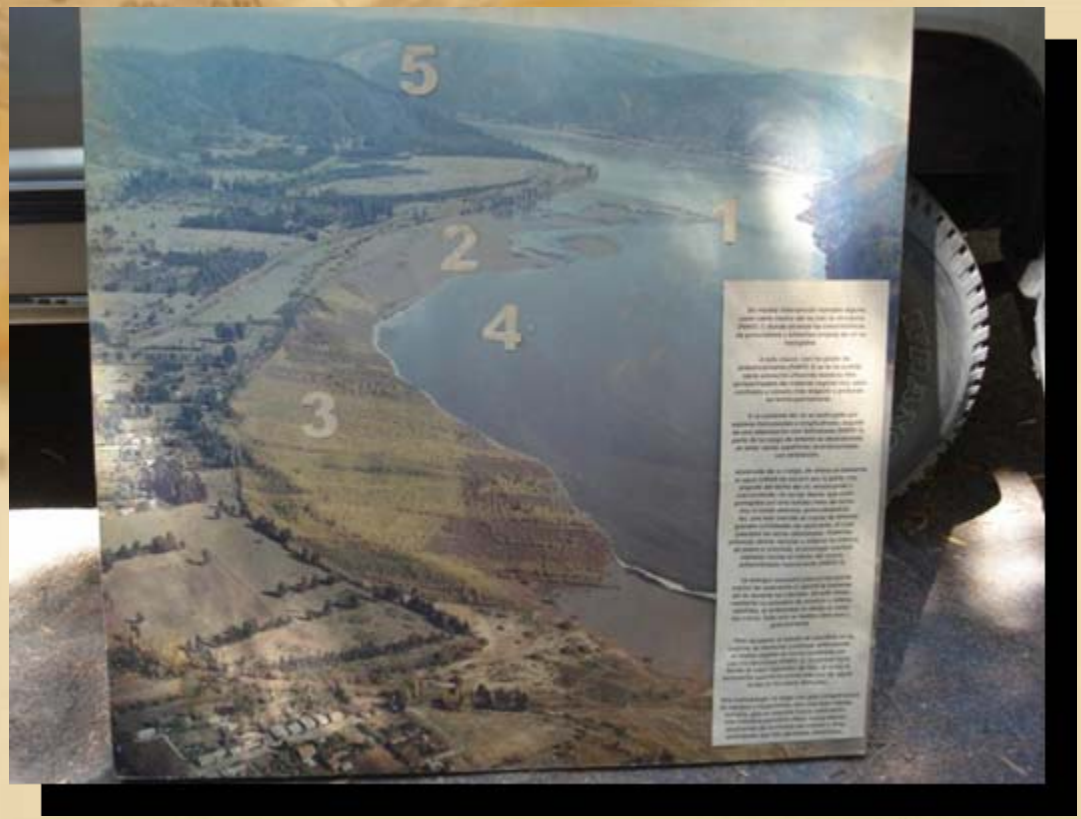
DOEGenomesToLife.org

Erosion control and river bank stability

Grand Channel, Siyang county, China



River bank, Laja river, Yumbel, Chile.



Hualqui area, Bio-Bio river
VIII Región

Meadow with poplars. By Claude Monet

Research lines for period 2009 - 2018

Line of research N° 1: → ***Selection of superior poplar varieties capable to produce high wood quality products.***

Line of research N° 2: → ***Selection of superior poplar varieties suitable for biomass production, useful for: a) bioenergy generation and b) carbon sequestration.***

Line of research N° 3: → ***Selection of superior poplar varieties suitable for phytoremediation and phytoestabilization of: a) mining tiles and (b) biosolids generated from the process of treating municipal water.***

Line of research N° 4: → ***Selection of superior poplar varieties specially adapted for river restoration.***

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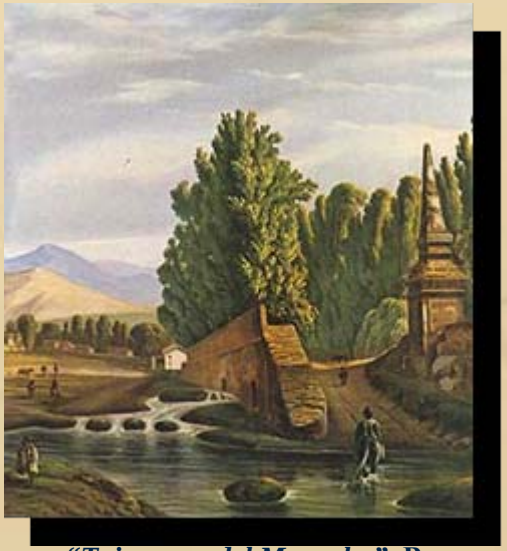
IUFRO

Poplar Molecular Genetics Cooperative
University of Washington

Plan of Action ...since 1999

conaf
PNDF

INRA
Institut National de la Recherche Agronomique



***"Tajamares del Mapocho"*. By Giovatto Molinelli. 1855**

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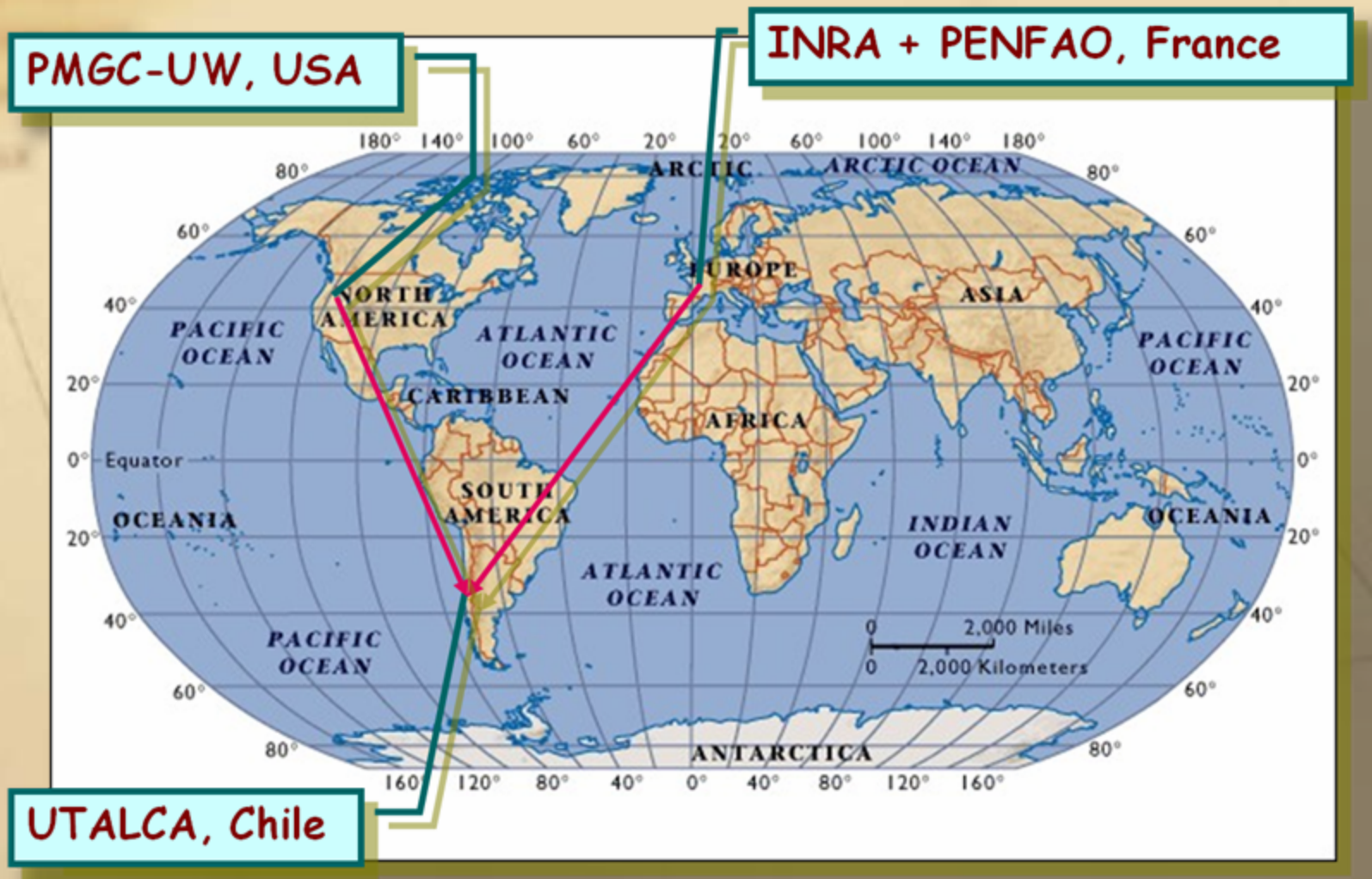
Project: D98I1086

The beginning: 1999 – 2001. Introducing new germplasm in Chile



Species & Provenances

PMGC- UW

Populus balsamifera

Prov.: British Columbia, Canada

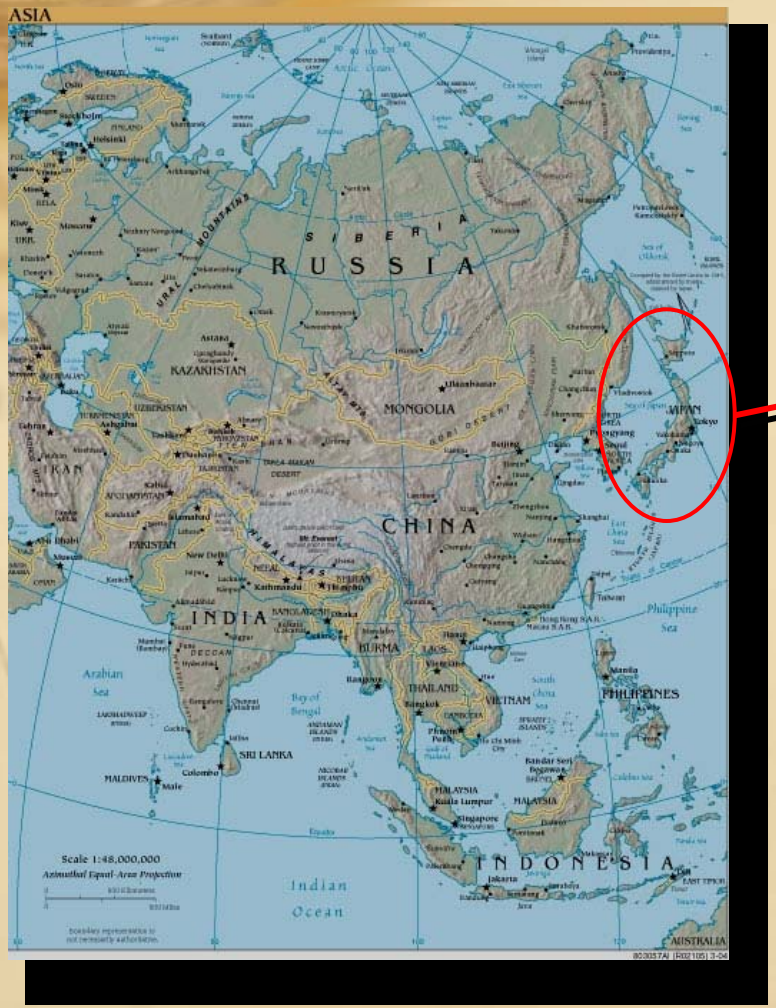
P. deltoides

Prov.: Savannah River, GO; Mississippi; Fort Supply, OK. USA.

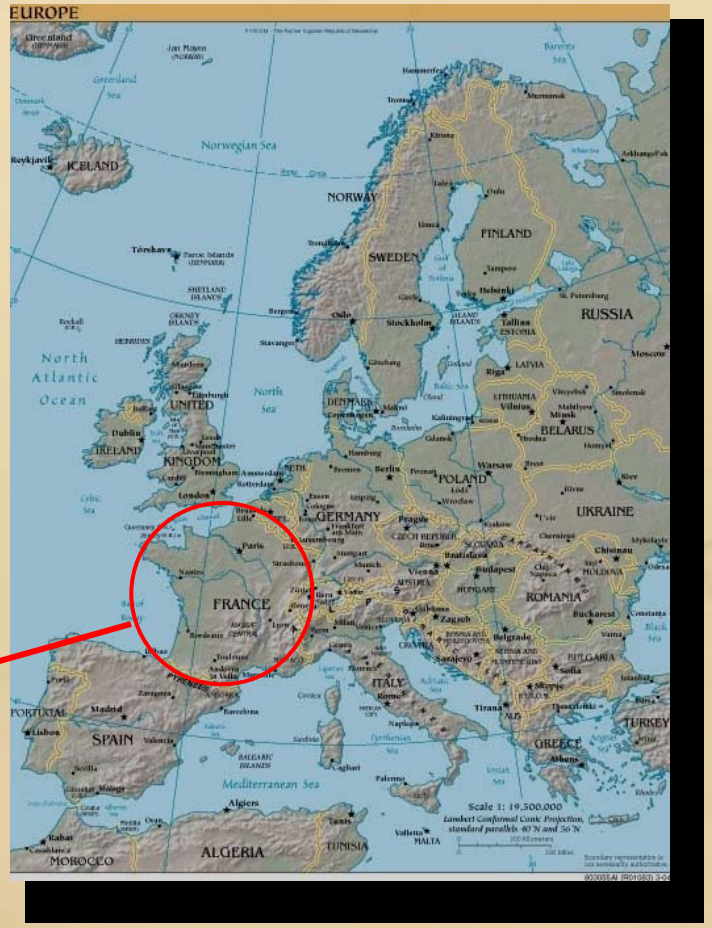
P. trichocarpa

Prov.: Eugene, OR and Nisqually River, WA; Clearwater River, ID, USA

Species & Provenances



Populus maximowiczii
Prov.: Japan



Populus nigra
Prov.: France

PMGC - UW

Quarantine regime

Talca: 1999

First importation from the PMGC-UW

Taxa:

1). DxB
2). TxD
3). TxM
4). TxN
5). TxT
6). TDxD
7). TDxT
8). TDxTD
9). TDxTN
10). TMxM
11). TMxT
12). TMxTM

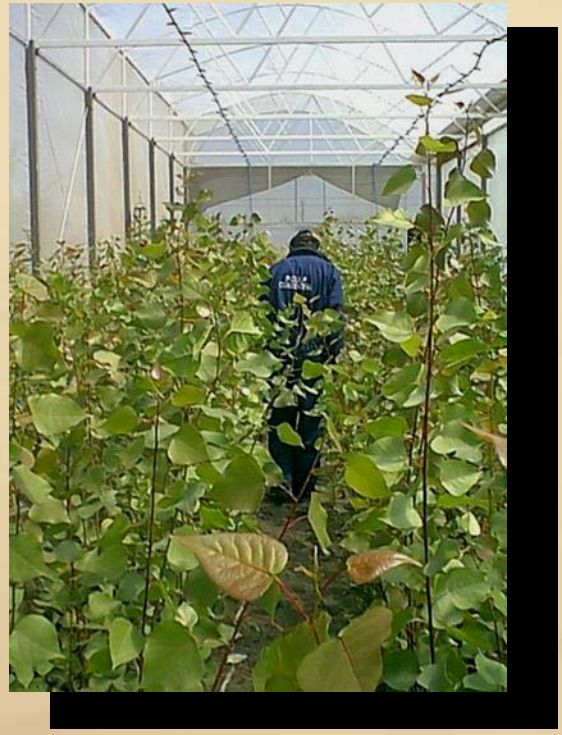
2.400 hybrids

Talca: Sept. 1999

Planting of cuttings

First importation from the PMGC-UW

November -1999



January - 2000

February - 2000

Initial growth under quarantine

First importation: from the PMGC-UW

Genetic differences in :

Rust resistance

April 2001

Initial growth

Nursery + Clonal Bank

Second importation: from INRA-PENFAO, France

February, 2001

20 commercial hybrids from the European catalog

April, 2001

Taxa:

1). A

2). D

3). DxN

4). T

5). TxD

Third importation: from PMGC – UW, USA

February, 2001

30 days (March)

Taxa: 1). TxD

250 hybrids

150 days (July)

150 days (July)

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Project: D01I1131

2002 – 2005: Initial screening. The beginning of level 1 type of clonal testing

GreenWood Res. Inc, USA

INRA, Francia

UTALCA, Chile

Nursery + Clonal Bank

Collecting branches in nursery + clonal bank

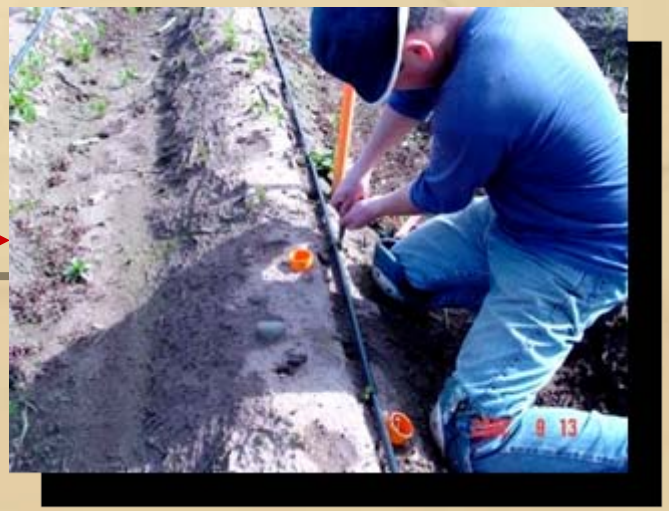
Preparing cuttings for field testing

Preparing cuttings for field testing

Classifying cuttings and working with the experimental design

Establishing of level 1 clonal tests: "nursery trials"

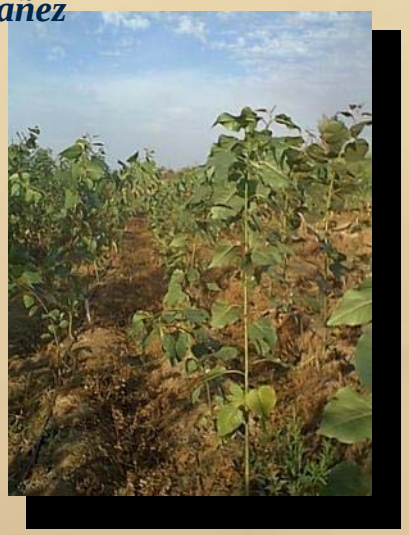
2002 - 2004



"Lay-out" de los ensayos de "determinación inicial"

- *Número de híbridos por ensayo = 1,600*
- *Número de bloques = 2*
- *Número de estacas por híbrido y bloque = 1*

A cargo de: Marco Yañez



Measurements

Height & Diameter Growth

2003
2004
2005

Rust resistance

Híbridos discriminantes de INRA, Francia, en cuarentena

2003

2004

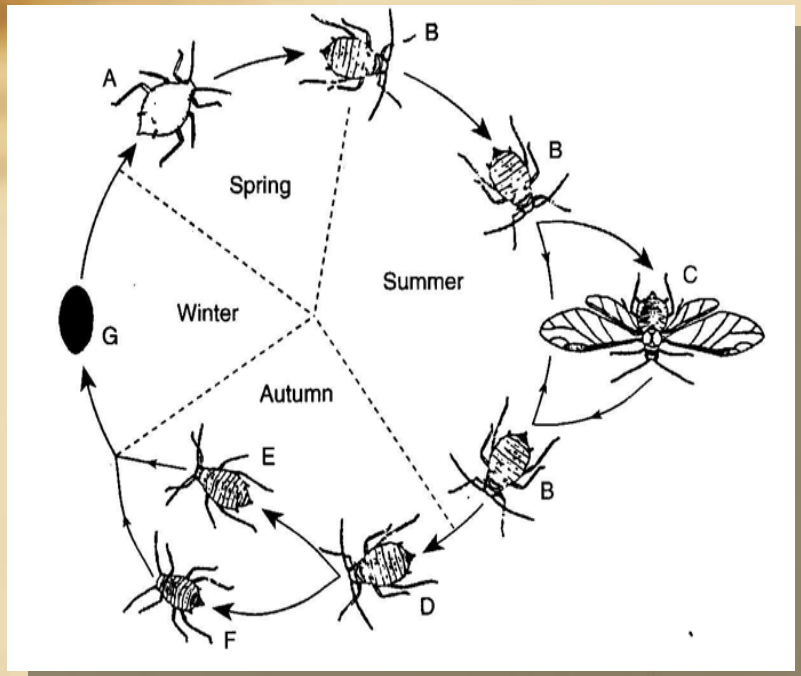
2005

Coinco, VI Región

Temuco, IX Región

Los Niches, VII Región

Pest resistance



2003

2004

2005

Dr. Claudio C. Ramirez

Centro de Investigación en Biotecnología Silvoagrícola

Instituto de Biología Vegetal y Biotecnología. UTALCA

Where were trials located?

VI Region

VII Region

VIII Region

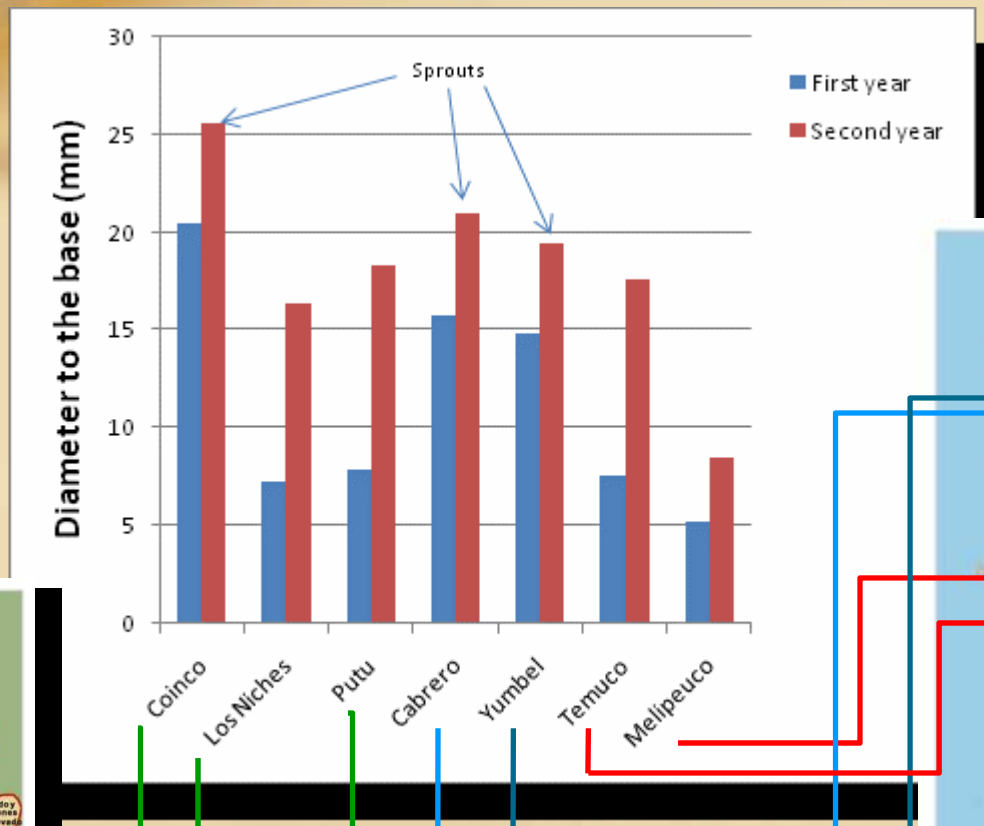
IX Region

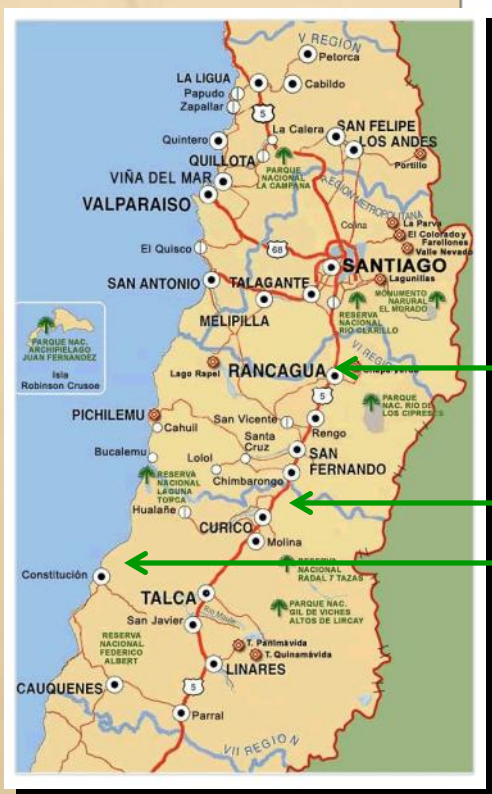
34° S

39° S

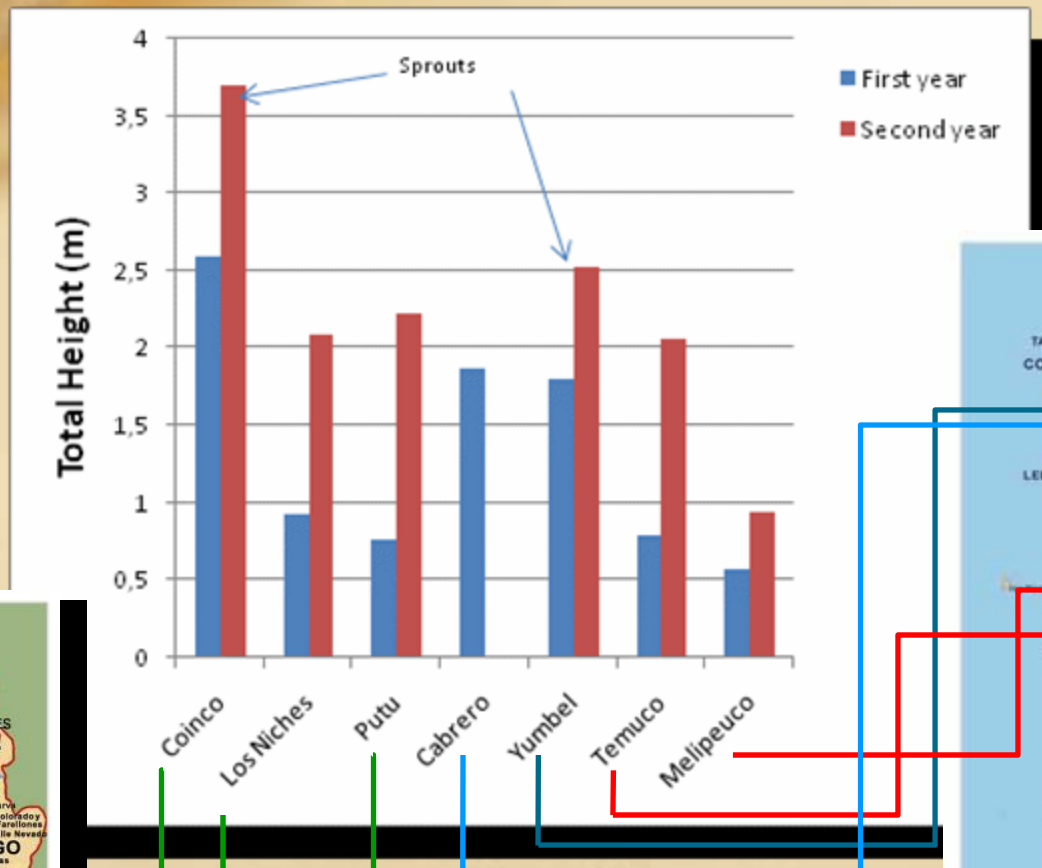
39° N

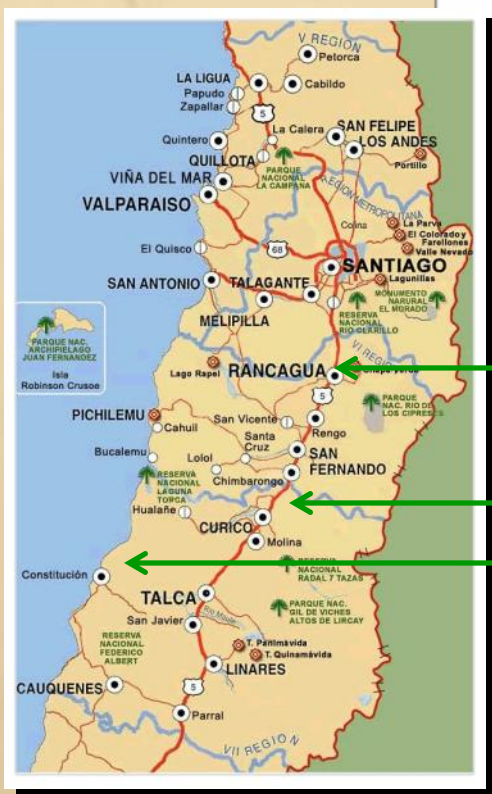
34° N





Total mean values for diameter at the base of the stem (40 cm above ground) in seven nursery tests





Total mean values for total height in seven nursery tests

3rd growth period

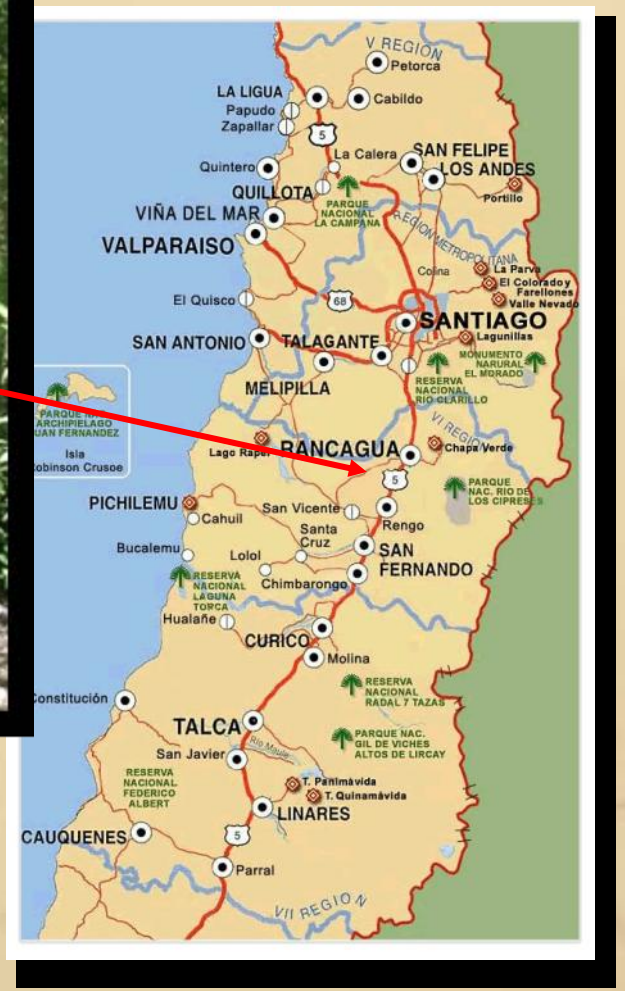
Growth of the best hybrid (diameter):
Diameter = 5,3 cm / growth period
Height = 5 m / growth period

Test average:
Diameter = 2,1 cm / growth period
Height = 2,7 m / growth period

Coinco
VI Region

Period : 2004 - 2005

Coinco, VI Region



Period : 2004 – 9 de enero 2008

(… 3 years and 4 months)

3er período de crecimiento

Growth of the best hybrid (in diameter):
Diameter = 4,0 cm / growth period
Height= 3,9 m / growth period

Test average:
Diameter = 1,6 cm / growth period
Height = 1,9 m / Growth period

Colicheu
VIII Region

Growth period: 2004 - 2005

FORESTAL MININCO

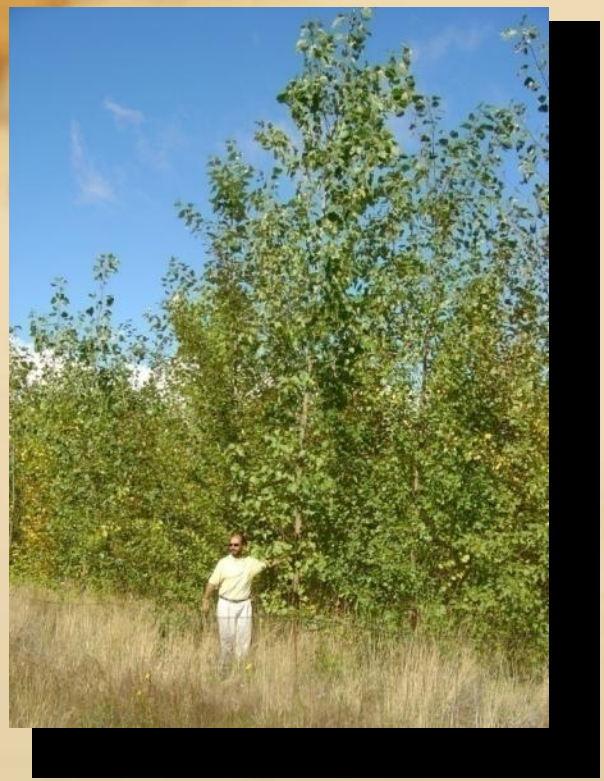
Growth period: 2004 - 2005

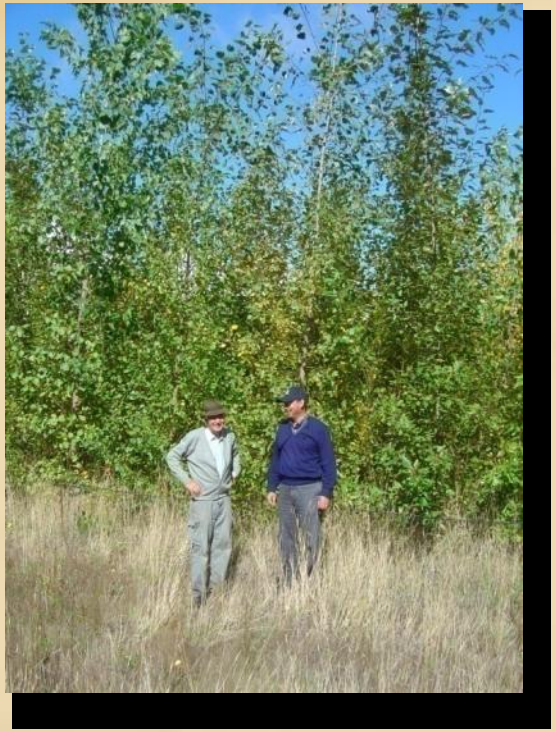
Yumbel
VIII Region

Growth period: 2004 - 2006

Growth of the best hybrid (in diameter):
Diameter = 3,4 cm / growth period
Height = 3 m / growth period

Test average:
Diameter = 1,5 cm / growth period
Height = 1,8 m / Growth period





Yumbel
VIII Region

Growth period:

2004 - 2007

Yumbel
VIII Region

Thinning: July 2007

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Project: D04I1027

2006 – 2008: Candidate testing. The beginning of level 2 type of clonal testing

PROMASA

UNIVERSIDAD CATÓLICA DE TEMUCO

Srs:

Jaime Ureta M.

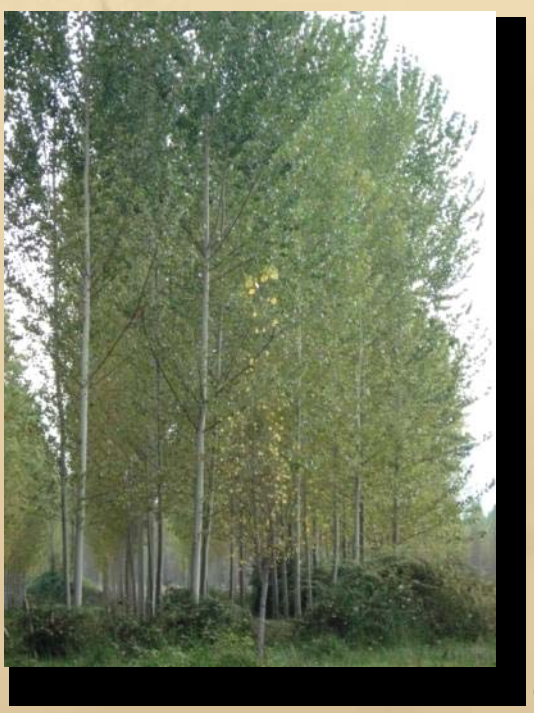
Enrique Matthei J.

FORESTAL MININCO

GreenWood Resources

Lay-out of "candidate trial" in Colicheu, VIII Region

- *Number of hybrids =* *98*
- *Number of blocks =* *10*
- *Number of cuttings per hybrid and block=* *1*
- *Spacing=* *3 x 3 m*



Coinco, VI Región

Po River valley, Italy

Candidate trial: "Colicheu". VIII Region

January, 2005

March, 2005

Planted in September 2004

February, 2006

Candidate trial: "Colicheu". VIII Region

FORESTAL MININCO

Growth period:

2004 - 2007

Candidate trial: "Colicheu". VIII Region

FORESTAL MININCO

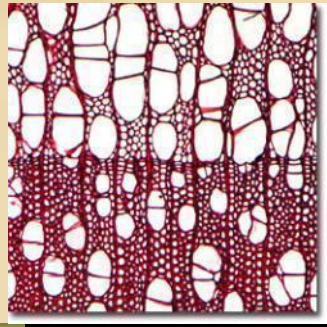
Growth period:

2004 – January 2008

FORESTAL MININCO

Candidate trial: "Colicheu". VIII Region

Getting wood samples: July 2007



Other candidate trials

Lay - out

Number of hybrids= 100

Number of blocks = 10

Number cuttings / block / hybrids= 2

Spacing = 3 x 3 m

September, 2006

Yumbel,
VIII Región

March, 2007

January 16, 2008

September, 2006

Los Angeles, VIII Región

March, 2007

Los Angeles, VIII Región

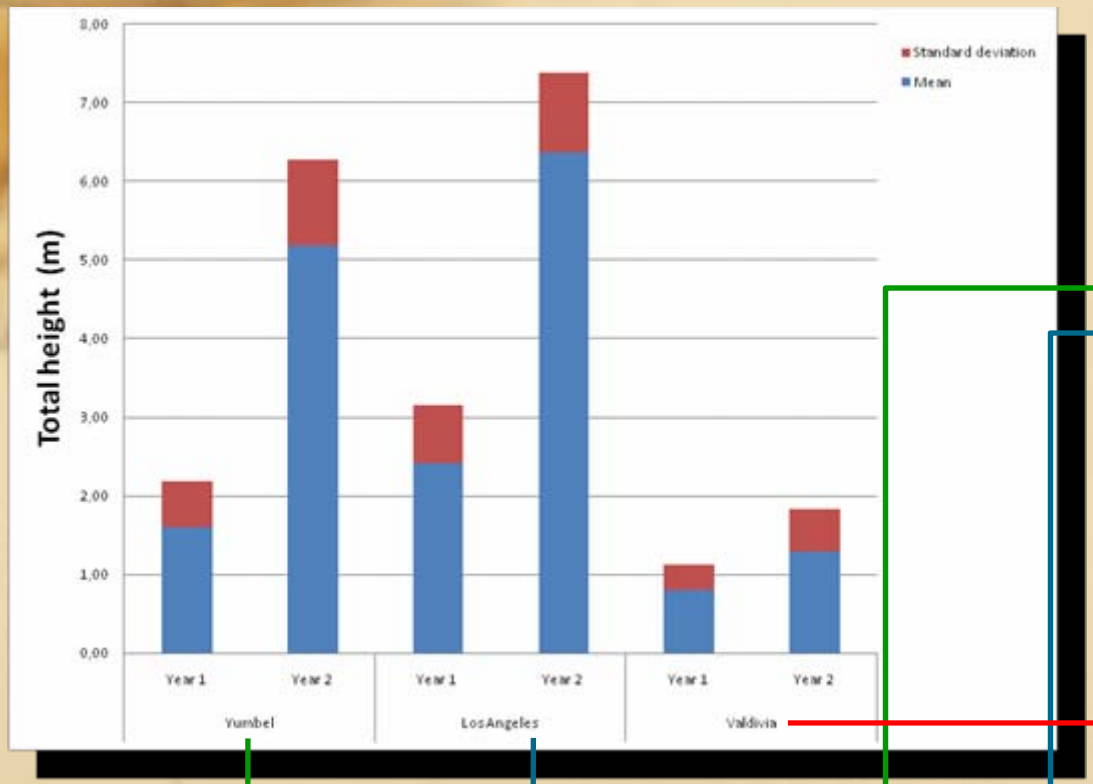
January 16, 2008

December, 2006

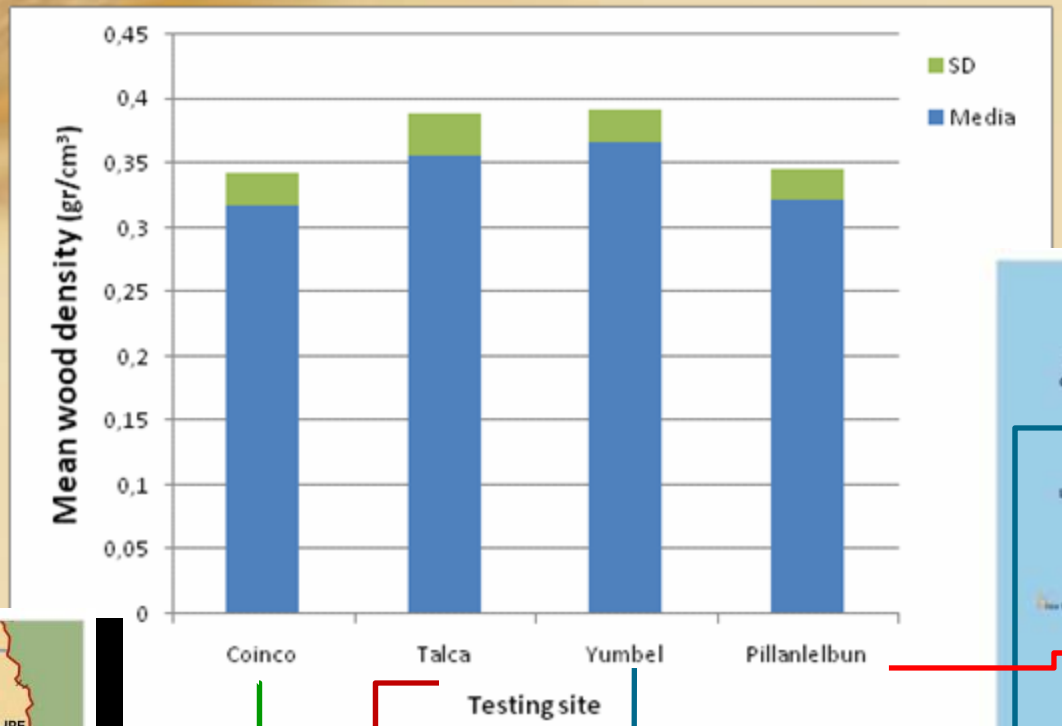
Valdivia, XIV Región

March, 2007

Total mean values for diameter to the base (0.4 m) in three candidate trials

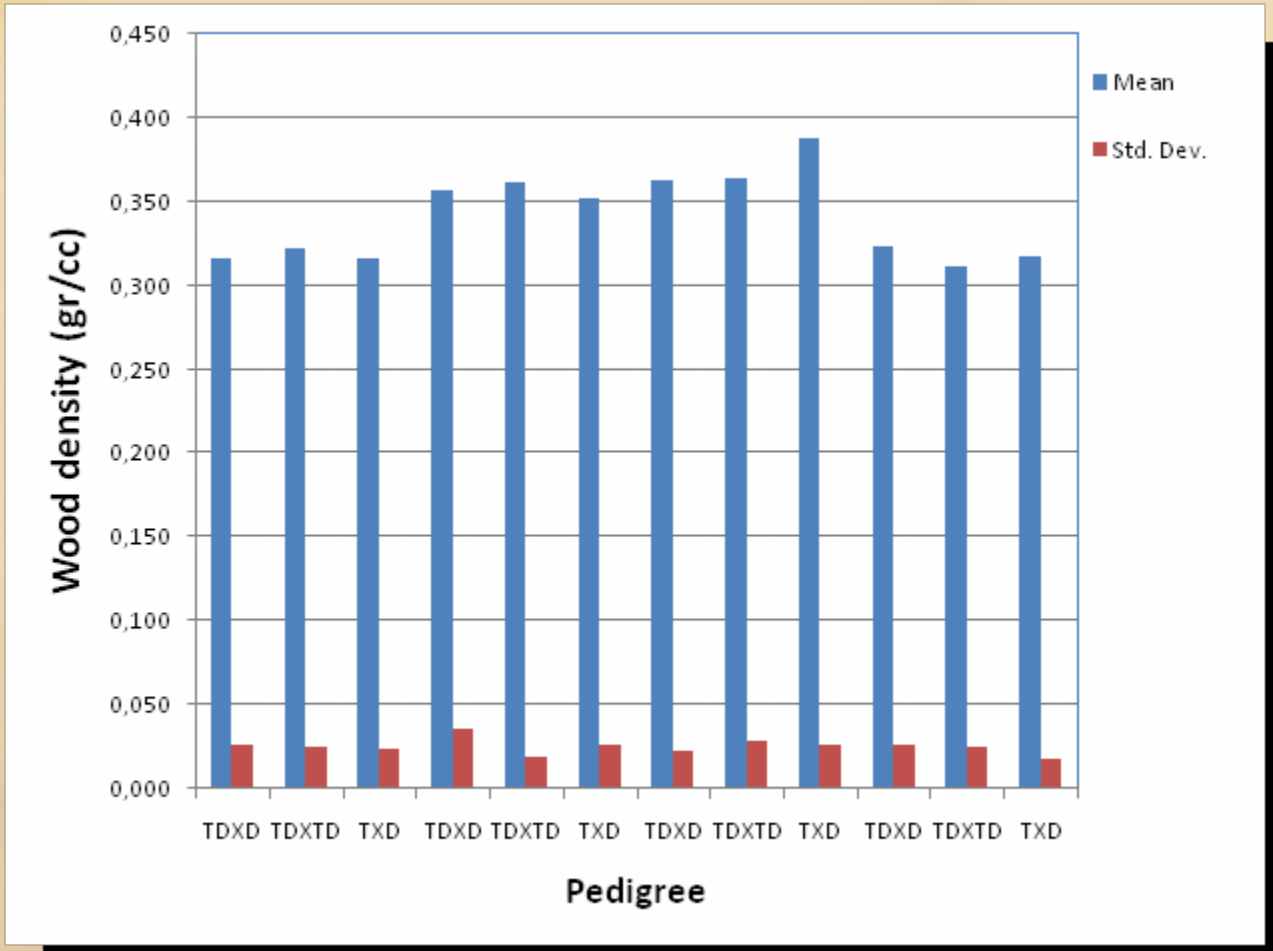


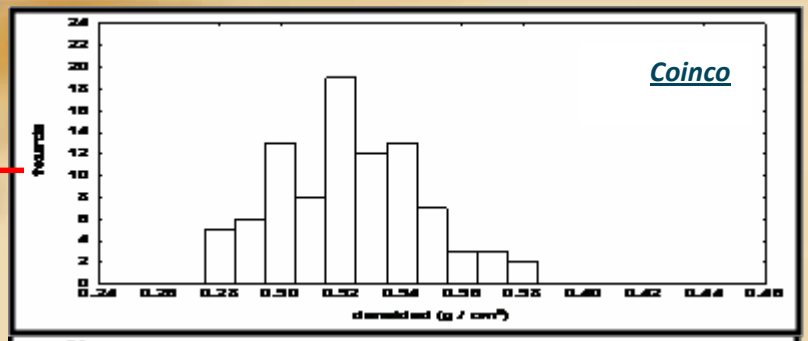
Total mean values for total height in three candidate trials

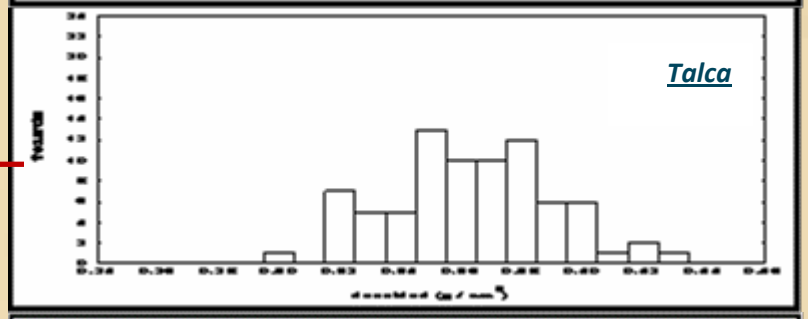


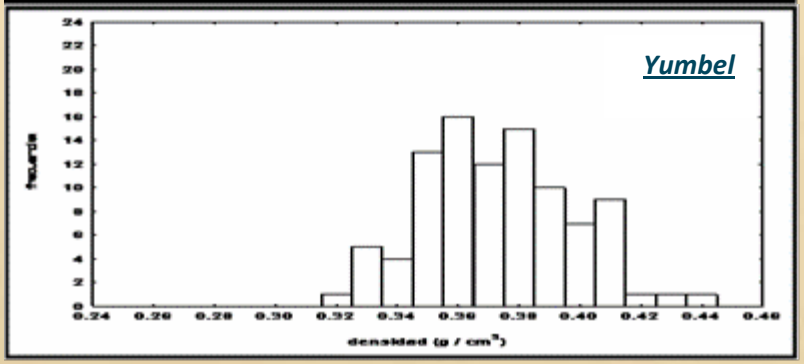
Average wood density in four nursery tests

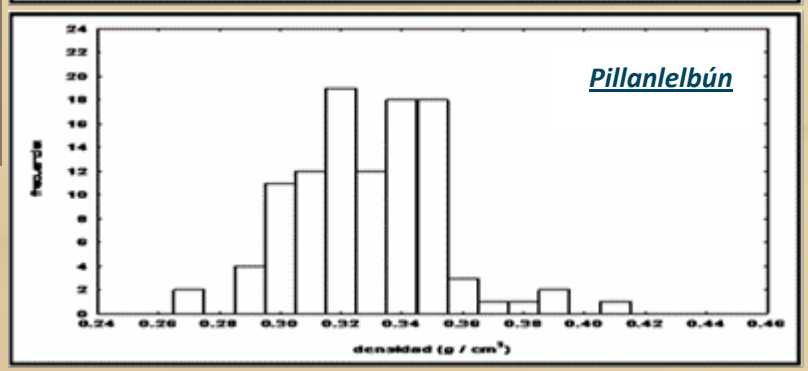
Average wood density by Pedigree



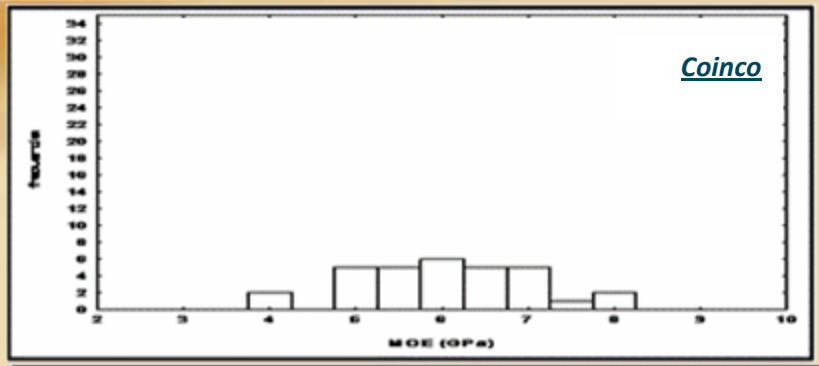


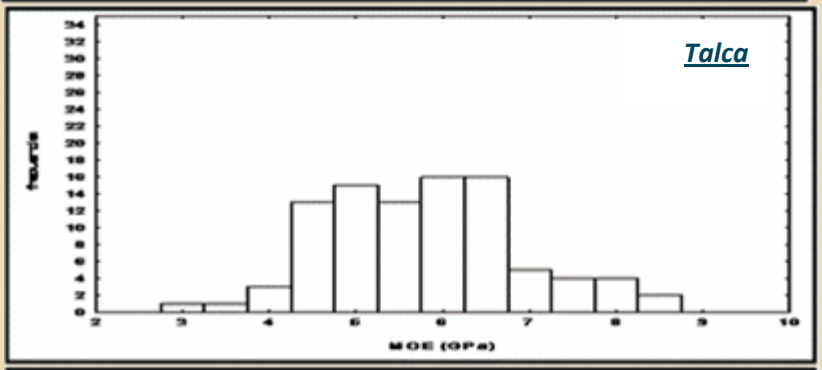


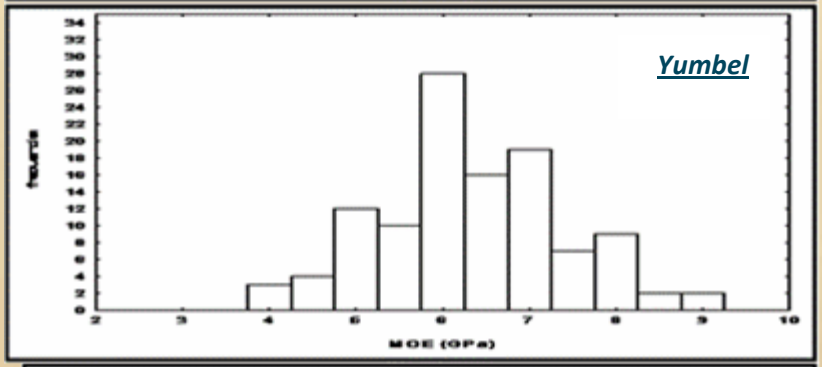


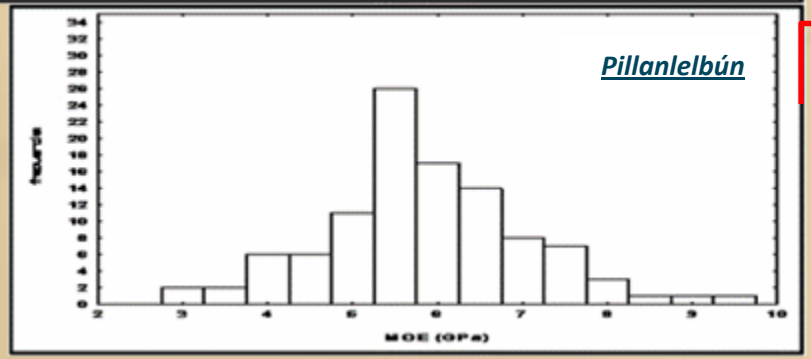


Histograms of wood density measured in wood samples obtained in four nursery tests after thinning at age 4.

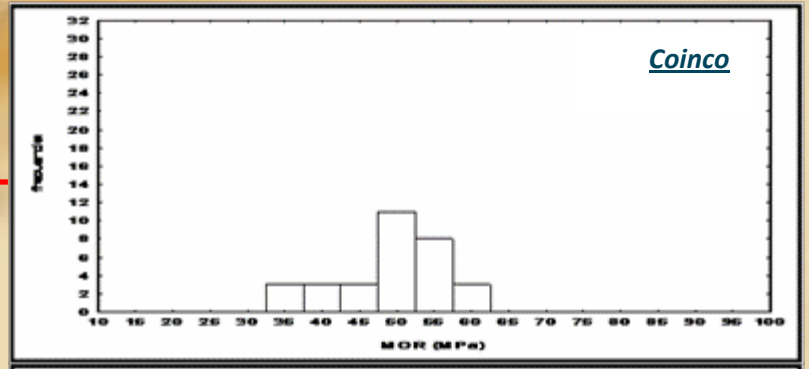


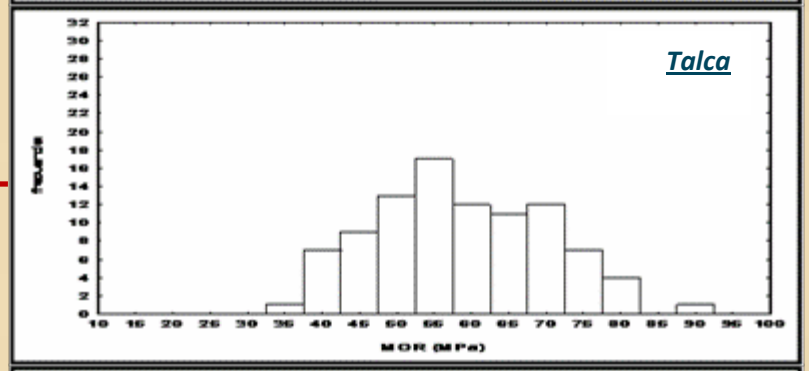


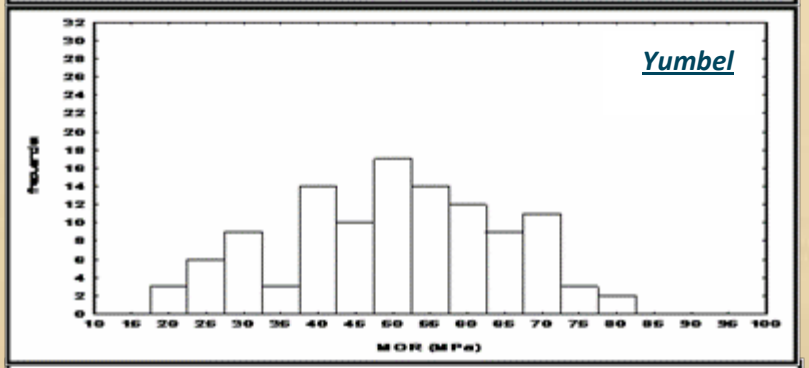


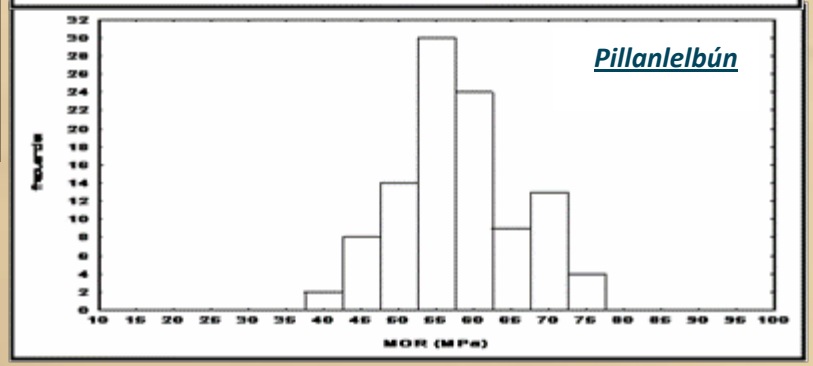


Histograms of* MOE *(Gigapascals) in wood samples obtained in four nursery tests after thinning at age 4.









Histograms of* MOR *(Megapascals) in wood samples obtained in four nursery tests after thinning at age 4.

…the future?

2009 – 2014: Clonal performance testing: ***we will begin a more extensive level 3 type of clonal testing of better candidate clones.***

Alberta, Canada

France

Chengtou Village, Sihong County, China

Coinco, VI Región, Chile

2014 – : Compatibility trials: ***we will begin to establish the level 4 type of clonal tests to identify sets of clones that can advantageously be grown in sequenced mixtures***

Research line N° 1.

Strategy for clonal selection of poplar hybrids in Chile based on superior wood properties

Main hypotheses

1a) The genetic control is moderate for growth related traits → $H^2 \approx 0.4$

1b) The genetic control is moderate to high for wood related traits → $0.4 \leq H^2 \leq 0.7$

2) The predicted genetic gain based on clonal selection will be in the order of 10 % for growth traits and 30 % for wood related traits → $\Delta G = H^2 \cdot i \cdot \sigma_P$

3) The genetic correlation between wood properties and either growth or adaptive traits (such as pest and disease resistance) is low or no significant → $r_{g_{XY}} < 0.3$

4) Genotype by macro-environment interaction is moderate in growth and wood related traits. → $r_{g_{E1E2}} \approx 0.3$

5) Genotype-by-micro-environment interaction in growth and wood related traits could be significant in particular testing sites. → $\begin{bmatrix} r_{g_{ee'}} < 0.1 \\ r_{g_{ee'}} \leq 0 \end{bmatrix}$

6) Age-age genetic correlations are not significant, or genotype-by-time interaction has a moderate effect on growth and wood formation → $r_{C_{tt'}} \approx 0.3$

Main goal

to select clones with the adequate combination of wood properties and growth pattern capable to support a wood transformation industry linked to poplar wood.

Specific objectives

1) to determine patterns of wood formation with cambial age and their relationship with growth patterns.

2) to determine the interaction patterns between wood formation and changes in environmental conditions, at the micro and macro level

3) to determine or classify poplar hybrids according to: (a) their growth and wood formation patterns and (b) their adaptability to local (specific) or general environmental conditions.

4) to select clones with the best pattern of wood formation and the fastest and most stable growth rate to be placed in the best environmental conditions available for poplar cultivation.

5) to select clones with the best pattern of wood characteristics (across cambial age) to be placed on environmental conditions with few limiting factors.

Selection Strategy

Initial population size under testing = N_0

Population size at selection time t=1 is = $N_1 = a_1 \cdot N_0$

Where a_1 is the selection intensity at time = 1 and $0 < a_1 < 1$

Population size at selection time t=2 is = $N_2 = a_2 \cdot N_1 = a_2 \cdot a_1 \cdot N_0$

Population size at selection time t=s is = $N_s = \prod_t^s a_t \cdot N_0$

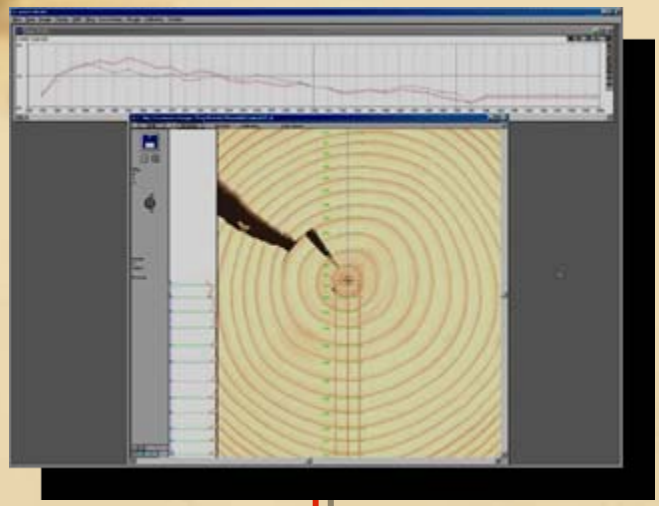
Poplar hybrids to be included in the selected population at any selection time will be those that maximize the genetic correlations:

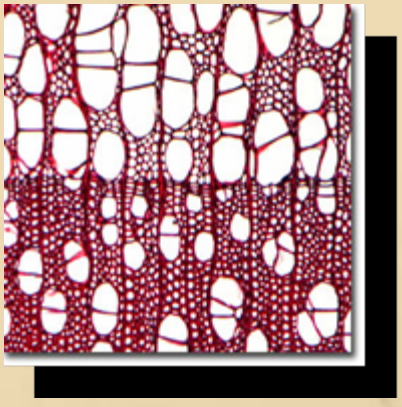
(a)between growth and wood related traits at the age of selection;
(b)between growth increments from different growth periods until the age of selection; and
(c)between wood characteristics measured at different cambial ages that make up the selection age.

Genetic and statistical analyses

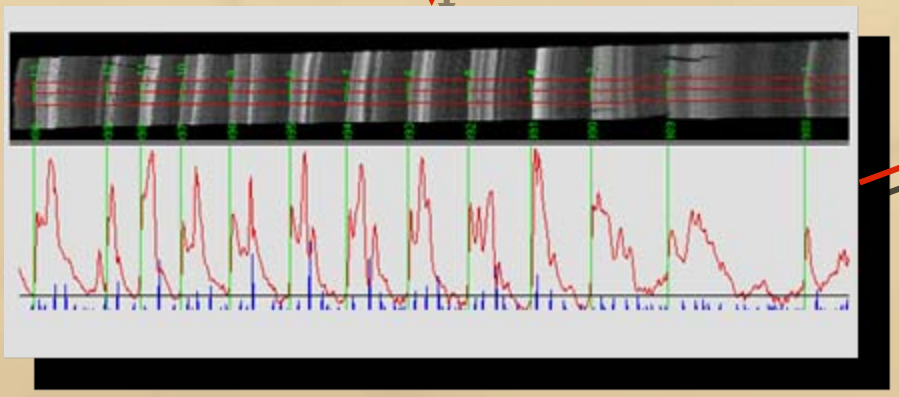
1a) Growth and adaptability traits will be measured in a yearly bases

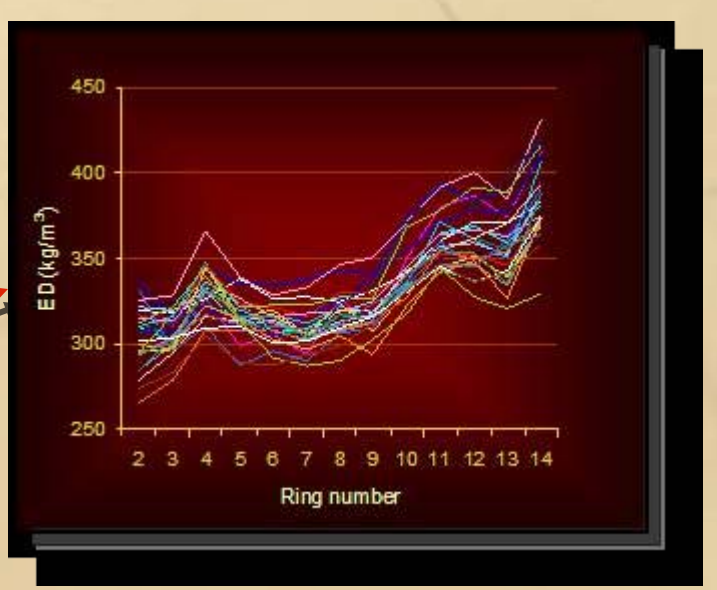
1b) Wood properties will be measured using both destructive and non destructive procedures





WinDendro®





Genetic and statistical analyses

2). Genetic control will be assessed for growth, adaptability traits, and relevant wood properties (physical and mechanical properties).

Genetic variance: $VG = \sigma_C^2 + \sigma_{e_k e_{k'}}$

Phenotypic variance: $VP = \sigma_C^2 + \sigma_I^2 + \sigma_e^2$

Broad sense heritability: $H^2 = \dfrac{\sigma_C^2 + \sigma_{e_k e_{k'}}}{\sigma_C^2 + \sigma_I^2 + \sigma_e^2}$

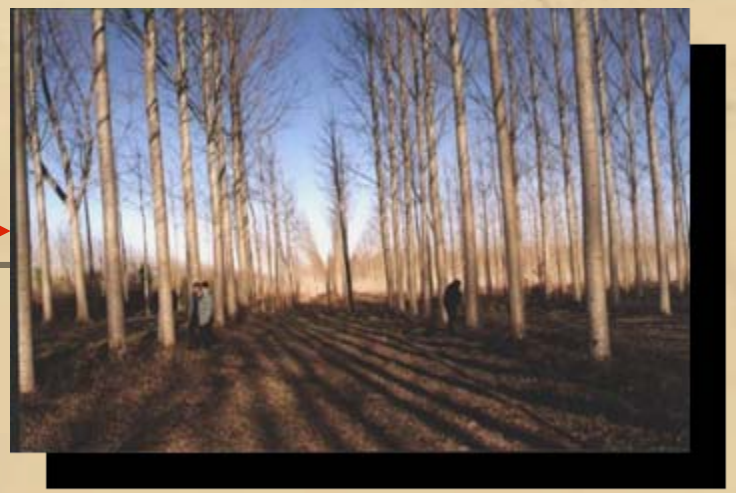
Variance of common environmental effects: $VE_C = \sigma_B^2 + \sigma_I^2$

Variance of specific environemtal effects: $VE_C = \sigma_e^2 - \sigma_{e_k e_{k'}}$

$$\Delta G = H^2 \cdot i \cdot \sigma_P$$

Genetic and statistical analyses

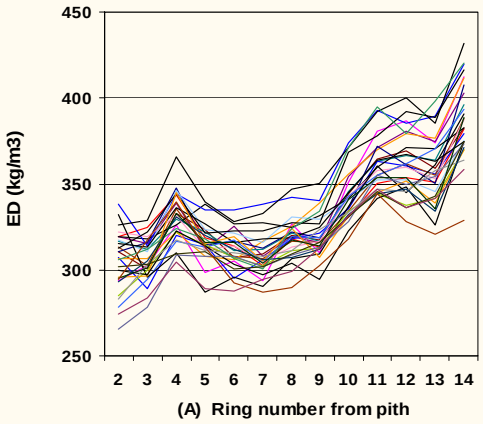
3). Genetic gain prediction for relevant traits and related response to selection will also be conducted.



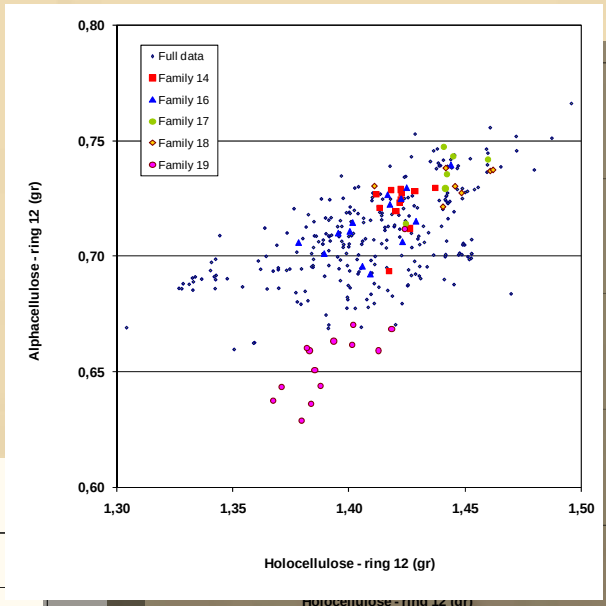
$$CR_Y = i \cdot H_X \cdot H_Y \cdot r_{g_{XY}} \cdot \sigma_{P_Y}$$

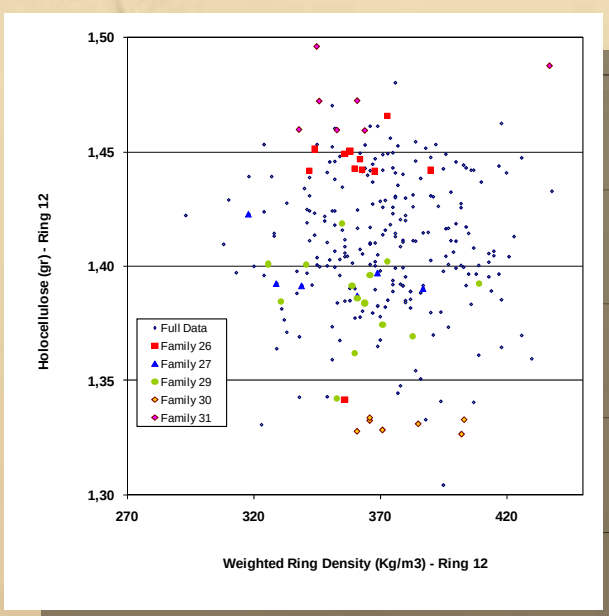
Genetic and statistical analyses

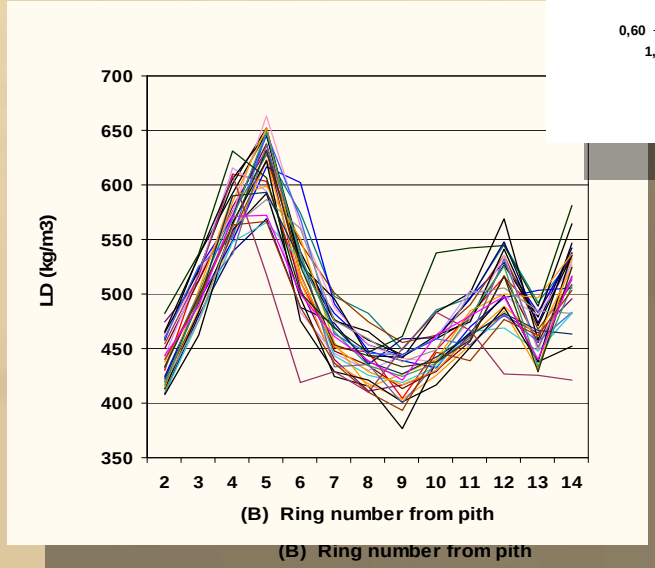
4). Genetic correlations between growth and wood properties at different cambial ages will also be assessed.



$$r_{g_{XY}} = \frac{\sigma_{C_{XY}}}{\sigma_{C_X} \cdot \sigma_{C_X}}$$





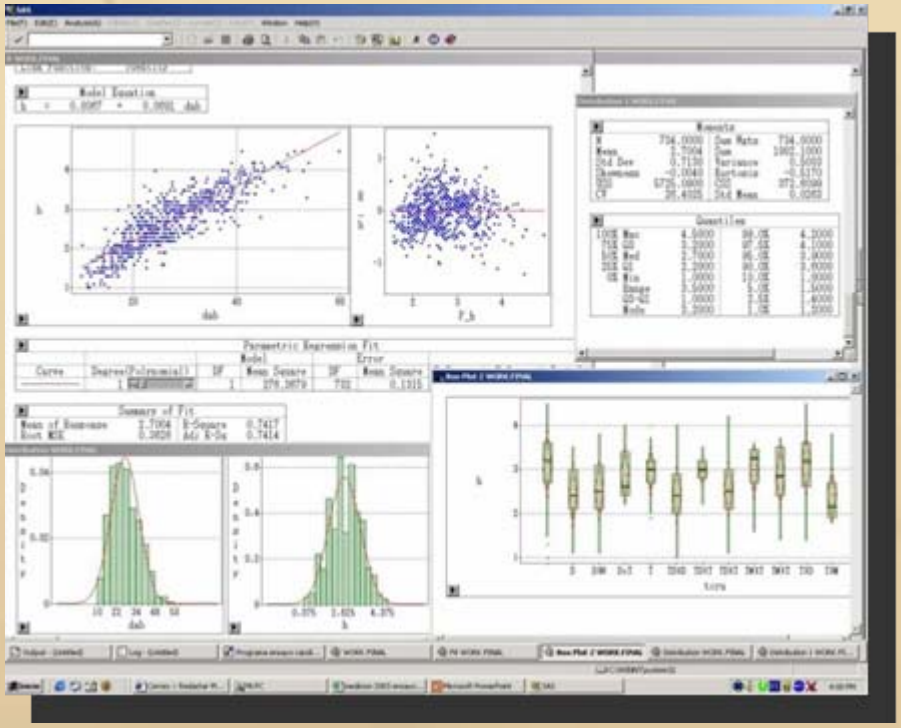


Genetic and statistical analyses

5) The presence of the genotype-by-macro-environment interaction will also be measured

6). The presence genotype-by-time interaction will also be measured in all trials.

7). Clonal selection will be based on the best linear unbiased prediction (BLUP) of the breeding value for each genotype under testing.



$$\mathbf{G} = \mathrm{Var}(\boldsymbol{\upsilon}) = \mathrm{Var}\begin{bmatrix}\boldsymbol{\upsilon}_b \\ \boldsymbol{\upsilon}_c \\ \boldsymbol{\upsilon}_I\end{bmatrix} = \begin{bmatrix}\sigma_b^2\mathbf{I}_p & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \sigma_c^2(\mathbf{I}_p \otimes \mathbf{I}_c) & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \sigma_I^2(\mathbf{I}_p \otimes \mathbf{I}_b)\end{bmatrix}$$

Henderson´s equations

$$\begin{bmatrix}\mathbf{X}'\hat{\mathbf{R}}^{-1}\mathbf{X} & \mathbf{X}'\hat{\mathbf{R}}^{-1}\mathbf{Z} \\ \mathbf{Z}'\hat{\mathbf{R}}^{-1}\mathbf{X} & \mathbf{Z}'\hat{\mathbf{R}}^{-1}\mathbf{Z} + \hat{\mathbf{G}}^{-1}\end{bmatrix}\begin{bmatrix}\boldsymbol{\beta} \\ \boldsymbol{\upsilon}\end{bmatrix} = \begin{bmatrix}\mathbf{X}'\hat{\mathbf{R}}^{-1}\mathbf{y} \\ \mathbf{Z}'\hat{\mathbf{R}}^{-1}\mathbf{y}\end{bmatrix}$$

$$\begin{bmatrix}\hat{\boldsymbol{\beta}} \\ \hat{\boldsymbol{\upsilon}}\end{bmatrix} = \begin{bmatrix}(\mathbf{X}'\hat{\mathbf{V}}^{-1}\mathbf{X})^{-}\mathbf{X}'\hat{\mathbf{V}}^{-1}\mathbf{y} \\ \hat{\mathbf{G}}\mathbf{Z}'\hat{\mathbf{V}}^{-1}(\mathbf{y} - \mathbf{X}\hat{\boldsymbol{\beta}})\end{bmatrix}$$

Clonal selection

Expected results

1) a stable growth through ontogeny. Each selected clone should contribute to a significantly high ring-to-ring genetic correlation → $r_{C_{tt'}} \geq 0.7$

2) stable wood properties with cambial age. Clones should also contribute to increase the ring-to-ring genetic correlation → $r_{C_{tt'}} \geq 0.7$

3) a high intra-clonal correlation between growth and relevant wood properties. Clones should contribute to increase the genetic correlation between both traits → $r_{g_{XY}} > 0.3$

4) a stable growth and homogeneous wood properties regardless of the site. Clones should not contribute to the genotype-by-macro-environment interaction → $r_{g_{E1E2}} \geq 0.6$

5) a stable growth and wood properties at specific sites. Clones will show minimum contribution to the genotype-by-micro-environment interaction → $r_{g_{ee'}} \geq 0.5$