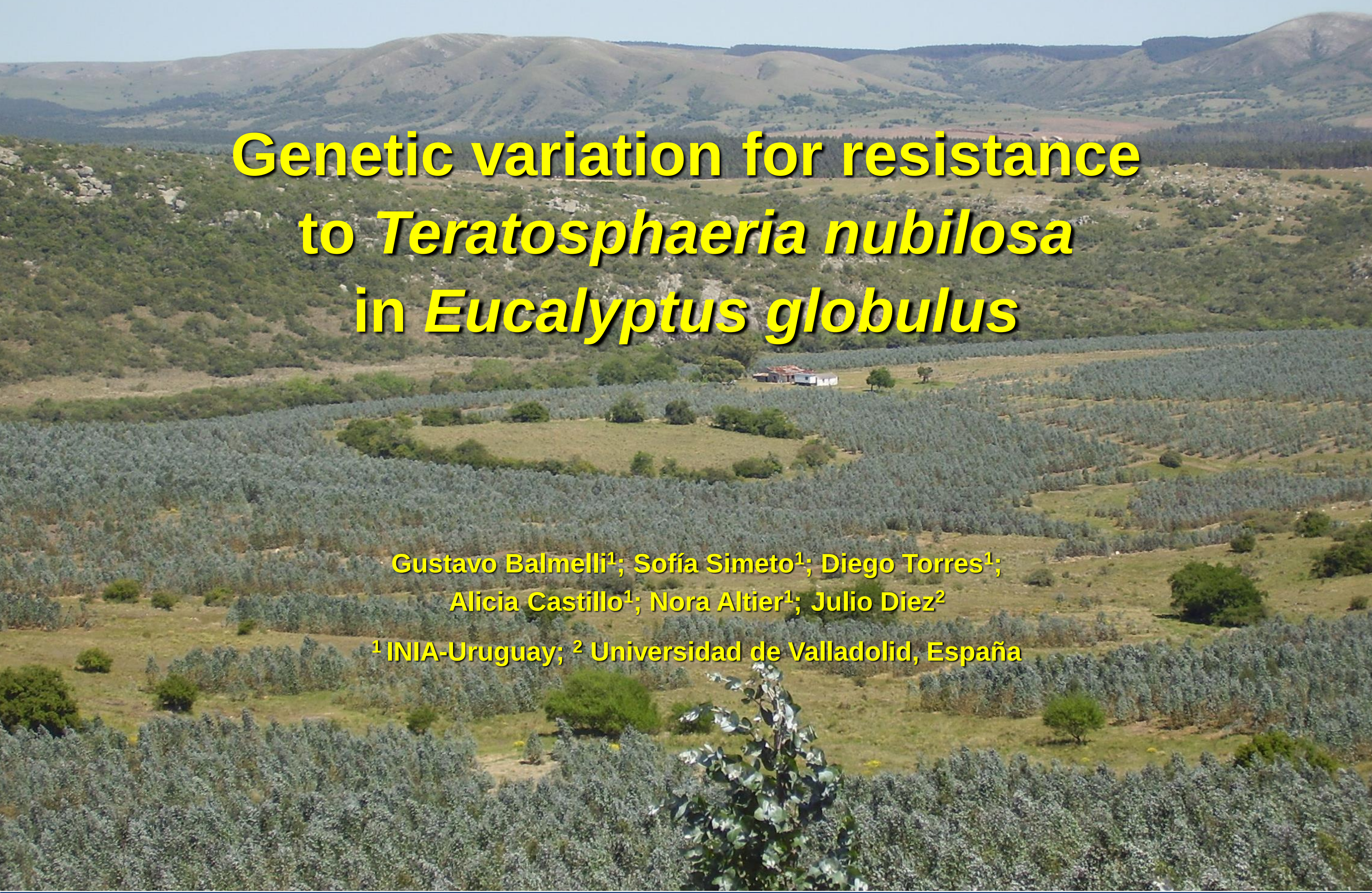

Genetic variation for resistance to *Teratosphaeria nubilosa* in *Eucalyptus globulus*

Gustavo Balmelli[1]; Sofía Simeto[1]; Diego Torres[1]; Alicia Castillo[1]; Nora Altier[1]; Julio Diez[2]

[1] INIA-Uruguay; [2] Universidad de Valladolid, España

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Introduction

- Commercial forestry in Uruguay: ≈ 1 million hectares.
- *Eucalyptus globulus*: ≈ 250.000 hectares.
- Planted for pulp production, on short rotations (≈ 10 years).
- *Teratosphaeria nubilosa* entered Uruguay in 2007.
- It affects mainly juvenile foliage, causing leaf spots and defoliation.
- *E. globulus* is the most susceptible species.
- The high frequency and severity of epidemics causes severe damages on young plantations.

- Different management alternatives for *T. nubilosa* have been proposed, e.g. intensive forestry; use of activators of the plant defenses; application of fungicides; re-fertilization to accelerate the recovery of damaged plants. However these alternatives have not proven to be effectives in the control of the disease.

- **The most economical and feasible approach to minimize the impact of this disease is the use of resistant planting stock.**

- **As there is no local availability of resistant genetic stock, forest companies are replacing *E. globulus* with other species.**

- **In 2012, INIA started a Tree Breeding Plan for *E. globulus* with the aim to develop genotypes of good productivity growing under frequent and severe epidemics of *T. nubilosa*.**

- **The first step of the breeding plan was to know the genetic variability for different traits:**
  - **resistance (low level of damage),**
  - **escape (early change to adult foliage),**
  - **tolerance (good growth despite of damage).**

- **The second step was to know the best selection strategy, that is, the most appropriate selection criteria and the optimal age of selection.**

Objectives

- **To quantify the genetic variation on *E. globulus* for disease-related traits and to predict the genetic gains expected through selection.**
- **To determine the most efficient selection strategy to obtain genetic stock of *E. globulus* of good productivity on sites with *T. nubilosa*.**

Materials and methods

- This work was performed in a progeny test of *E. globulus* which in its second year was naturally affected by *T. nubilosa*.
- The genetic material included 194 open-pollinated families.
- The experimental design was a randomized complete block, with 3 reps and 8-tree row plots (the trial initially had a total of 4656 trees).
- Disease-related traits were assessed between 14 and 26 months of age.
  - Susceptibility to *T. nubilosa* was assessed through:
    - Severity of leaf spots (% of leaf area affected) (SEV)
    - Defoliation (% of leaves prematurely abscised) (DEF)
    - Crown Damage Index (% of canopy affected) (CDI)
  - Precocity of phase change (% of adult leaves) (ADFO)

- Tree growth was measured from ages 26 to 74 months.
  - Diameter at breath height (DBH)
  - Individual tree volume (VOL)

Genetic parameters were estimated with an individual-tree mixed model in ASREML:

$$y = Mu + Rep + \textit{Fam} + \textit{Rep*Fam} + \textit{Error}$$

- **Phenotypic variance:** $\sigma_p^2 = \sigma_F^2 + \sigma_{RF}^2 + \sigma_E^2$

- **Aditive variance:** $\sigma_A^2 = \dfrac{\sigma_F^2}{r}$

- **Individual-tree narrow sense heritability:** $h^2 = \dfrac{\sigma_A^2}{\sigma_p^2}$

- **Aditive genetic correlations:** $r_A(xy) = \dfrac{\sigma_A(xy)}{\sqrt{\sigma_{A(x)}^2 * \sigma_{A(y)}^2}}$

- **Genetic gains expected through selection on each trait:** $GG = \sigma_p * h^2 * i$

- **Genetic gains expected in VOL at 74 months through selection of disease-related traits:** $GGy = \dfrac{\sigma_{py} * h_y * h_x * r_{A\,(xy)} * i}{t}$

Results

Phenotypic and genetic variation on *E. globulus* for disease-related traits.

Trait - age	Mean	σ_p^2	σ_A^2	CV_P (%)	CV_A (%)
SEV 14	10.5	14	6	35	23
DEF 14	31.6	78	18	28	13
CDI 14	38.7	77	22	23	12
DEF 21	52.7	104	30	19	10
ADFO 14	9.8	275	163	169	130
ADFO 21	16.9	397	235	118	91
ADFO 26	29.2	489	288	76	58

Genetic gains expected through selection of 20% of the best trees for disease-related traits.

$$GG = h^2 * \sigma_P * i \qquad (i = 1.4)$$

Trait - age	Mean	h^2	σ_P	*GG*	*GG* (%)
SEV 14	10.5	0.40	3.7	2.1	19.7
DEF 14	31.6	0.24	8.8	3.0	9.4
CDI 14	38.7	0.30	8.8	3.7	9.5
DEF 21	52.7	0.29	10.2	4.1	7.9
ADFO 14	9.8	0.59	16.6	13.7	140
ADFO 21	16.9	0.57	19.9	15.9	94
ADFO 26	29.2	0.56	22.1	17.3	59

Genetic gains expected for productivity (VOL 74 m) through indirect selection of disease-related and growth traits (20% of the best trees).

$GGy = * h_y * h_x * r_{xy} * \sigma_{Py} * i$ ($h_y = 0.59$ $\sigma_{Py} = 0.053$ $i = 1.4$)

Ind. trait - age	Mean	h_x	r_{xy}	GG_y (%)	GG_y / year (%)
SEV 14	10.5	0.63	-0.11	4.2	3.6
DEF 14	31.6	0.49	-0.12	3.5	3.0
CDI 14	38.7	0.55	-0.14	4.4	3.8
DEF 21	52.7	0.54	-0.43	13.8	7.9
ADFO 14	9.8	0.77	0.32	14.8	12.7
ADFO 21	16.9	0.75	0.38	17.1	9.8
ADFO 26	29.2	0.76	0.35	15.3	7.1
DBH 26	5.5	0.52	0.62	19.2	8.8
DBH 38	8.3	0.58	0.79	27.3	8.6
DBH 50	9.9	0.54	0.88	28.0	6.7
DBH 62	11.1	0.54	0.94	30.0	5.8
VOL 74 (m^3)	0.074	0.59	1	35.2	5.7

Conclusions

- **The heritability of resistance to *T. nubilosa* is moderately good in *E. globulus*. However, both phenotypic variation and genetic variation are very low, which limits the possibilities of selection by resistance.**

- **By contrast, both the phenotypic and genetic variation and the heritability for precocity of vegetative phase change are high, resulting in high genetic gains through selection for this trait.**

- **The evaluation of the timing of vegetative phase change can be done independently of pathogen presence, which means that selection by precocity of change to adult foliage could be used preventively in countries where *T. nubilosa* is not yet present.**

Conclusions

The estimated genetic parameters indicate that the proportion of adult foliage at 14 months is the selection criteria that would generate the greatest increase in productivity.

In other words, selection by precocity of vegetative phase change, that is, by escape to disease, is the most efficient selection strategy to obtain genetic stock of *E. globulus* of good productivity on sites with *T. nubilosa*.


THANK YOU!