Cross-resistance against diseases and insects in a breeding population of *Pinus pinaster*

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Genetics of Host-Parasite Interactions in Forestry, 2011, Eugene, Oregon, USA

1. Introduction

Plant–microbe interactions

Plant–herbivore interactions

1. Introduction

Trees have a broad arsenal of defensive traits

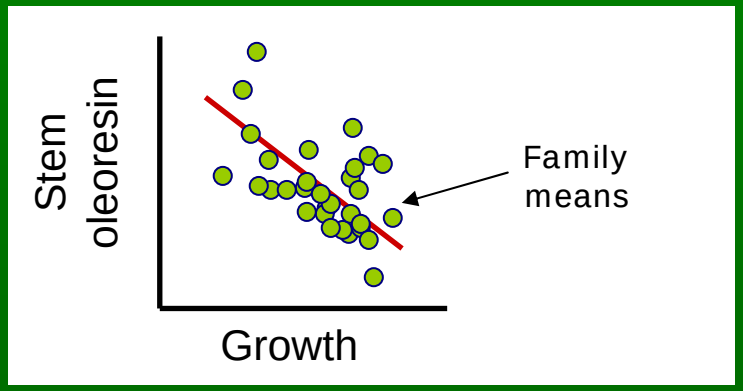
Synergistic interactions

Trade-offs among different plant defenses or
among redundant plant defense strategies

Agrawal and Fishbein 2006, Ecology

Trade-offs among defenses, growth or reproduction

Herms and Mattson 1992, Quarterly Rev Biol



Sampedro et al 2011 *J Ecol*

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Short communication

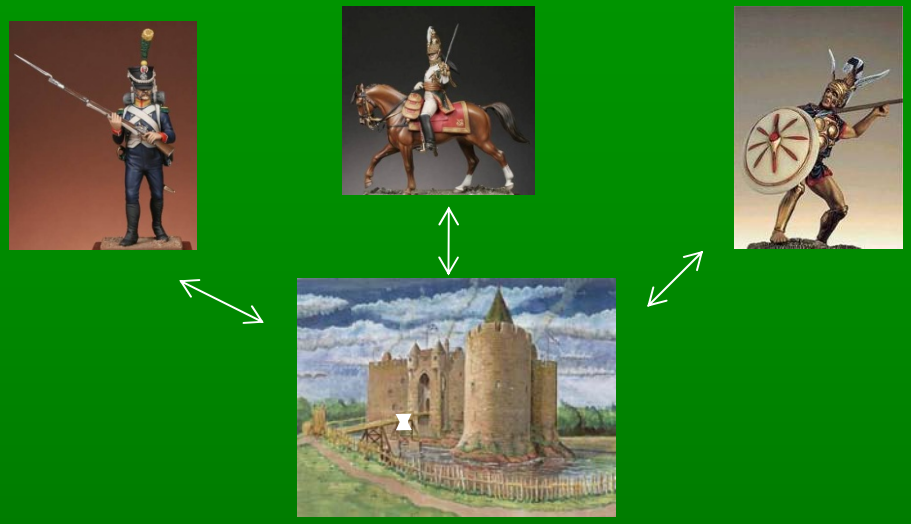
No negative correlation between growth and resistance to multiple herbivory in a deciduous tree, *Betula pendula*

Olli-Pekka Tikkanen[a,*], Matti Rousi[b], Tiina Ylioja[b,1], Heikki Roininen[a]

1. Introduction

Cross-resistance: Resistance against many classes of insects and pathogens

Rippi *et al*. 2005. Can J For Res; Andrew *et al*. 2007. Oecologia



MULTIPLE RESISTANCE

Cross-resistance: Exposure of trees to low levels of one stress can induce a subsequent increase in resistance to the same or unrelated stress

Eyles *et al*. 2010. New Phytol

CROSS-PROTECTION

Fusarium oxysporum

Fusarium circinatum

Armillaria ostoyae

Thaumetopoea pityocampa

Dioryctria sylvestrella

Hylobious abietis

Water stress

Pinus pinaster

Field experiments

MULTIPLE RESISTANCE?

Induction experiments

CROSS-PROTECTION?

2. Objectives

(i) Put together data from several independent experiments of the same genetic material and explore whether resistances to an array of different pests and diseases are genetically related

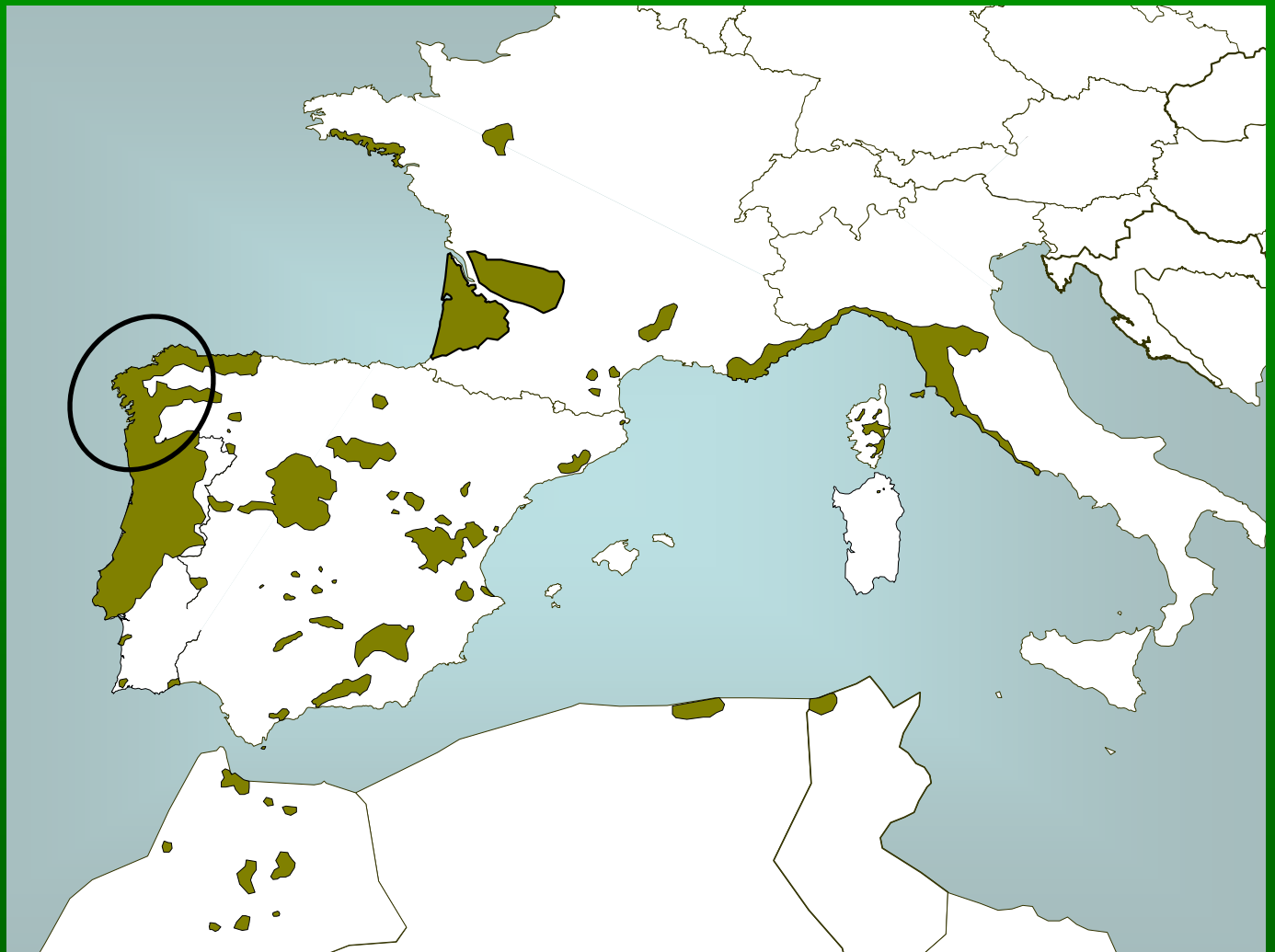
(ii) Determine at what extent resistances are genetically related with quantitative defensive traits

(iii) Check for possible trade-offs between resistances and other fitness related traits such as growth and cone production

(iv) Identify genotypes with multiple resistances, or genotypes able to show cross-protection, to be used for breeding

3.1 Plant material

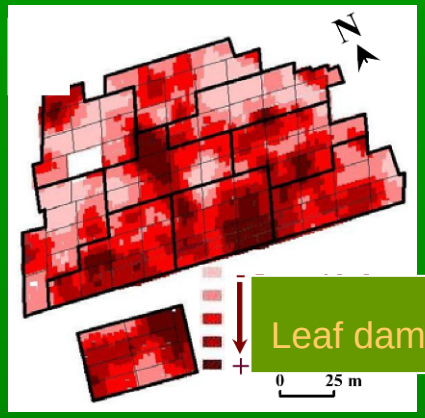
39 *Pinus pinaster* plus trees
1 unimproved seed lot



3. Materials and methods

3.2 Susceptibility to diseases and insects

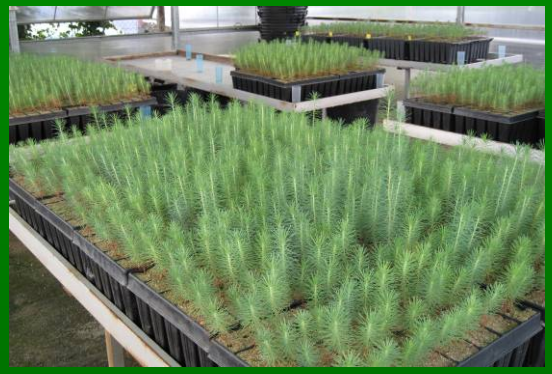
Fusarium oxysporum
Leaf pathogen



Leaf damage

Martíns *et al*. 2008, SECF Congress

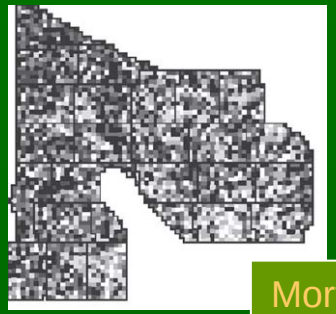
Fusarium circinatum
Stem pathogen



Mortality

Vivas *et al*. 2011, Forestry

Armillaria ostoyae
Rot root pathogen



Mortality

Zas *et al*. 2007, Forestry

3. Materials and methods

3.2 Susceptibility to diseases and insects

Thaumetopoea pityocampa
Lepidoptera: Thaumetopoeidae

Leaf damage

Unpublished results

Dioryctria sylvestrella
Lepidoptera: Pyralidae

Stem damage

Vidal *et al*. 2005. SECF Congress

Hylobious abietis
Coleoptera: Curculionidae

Debarked area

Zas *et al*. 2005, Annals For Sci

3.3 Susceptibility to water stress

0.5-year-old seedlings daily watered
Treatment: 3 weeks under drought and 30ºC
Mean mortality (%)

3.4 Tree traits

Root assessment (fine root length)

Early plant growth
Tree growth
Cone production

Cubera *et al*. 2009 Soil Till Res

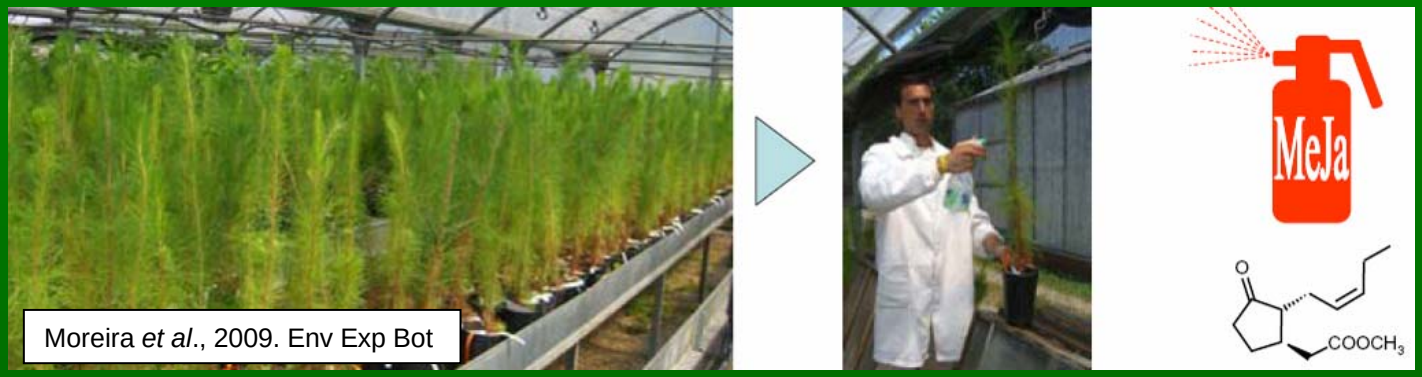
3.5 Chemical defense traits

Diterpenes
Total phenolics
Condensed tanins
— toxicity

Starch
Soluble sugars
— nutritional quality

CONSTITUTIVE

INDUCED



Moreira *et al*., 2009. Env Exp Bot

Inducibility: $MeJa_f$ (INDUCED) – CTR_f (CONSTITUTIVE)

Data processing and statistical analysis

Breeding values were estimated independently in each trial

Normalization of scores, 0 (most susceptible), 1 (most tolerant)

Pearson's correlations between breeding values

among resistance scores
between resistance scores and traits

Disease and insect resistance are genetically variable

	Variable	h_i^2	Reference
Fusarium oxysporum	Leave damage	0.23	Martíns *et al*., 2008. SECF Congress
Fusarium circinatum	Mortality	0.45	Vivas *et al*., 2011. Forestry
Armillaria ostoyae	Mortality	0.35	Zas *et al*., 2007. Forestry
Thaumetopoea pityocampa	Leave damage	0.08	Unpub. results
Dioryctria sylvestrella	Stem damage	0.17	Vidal *et al*., 2005. SECF Congress
Hylobious abietis	Stem damage	0.23	Zas *et al*., 2005. Annals For Sci
Water stress	Mortality	0.31	Unpub. results

Blakeslee *et al*. 1982. Phytopathology
Wargo and Harrington, 1991. Armillaria USDA book

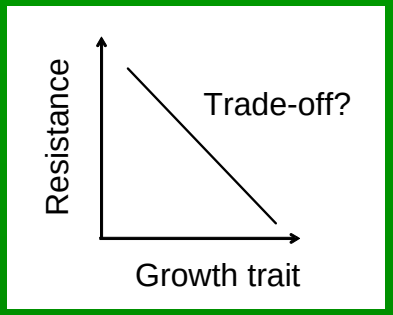
Relationships between resistances

	F. oxysporum	*F. circinatum*	*A. ostoyae*	*T. pityocampa*	*D. sylvestrella*	*H. abietis*	Water stress
F. oxysporum	1.00	0.33**	-0.62***	ns	ns	ns	ns
F. circinatum		1.00	-0.29*	ns	ns	0.40*	0.29*
A. ostoyae			1.00	ns	ns	-0.48**	0.30*
T. pityocampa				1.00	ns	ns	ns
D. sylvestrella					1.00	ns	ns
H. abietis						1.00	ns
Water stress							1.00

* $P < 0.10$
** $P < 0.05$
*** $P < 0.01$
ns = not significant

	Fungal diseases	Insect pests	Water stress
Fungal diseases	1.00	ns	0.35**
Insect pests		1.00	ns
Water stress			1.00

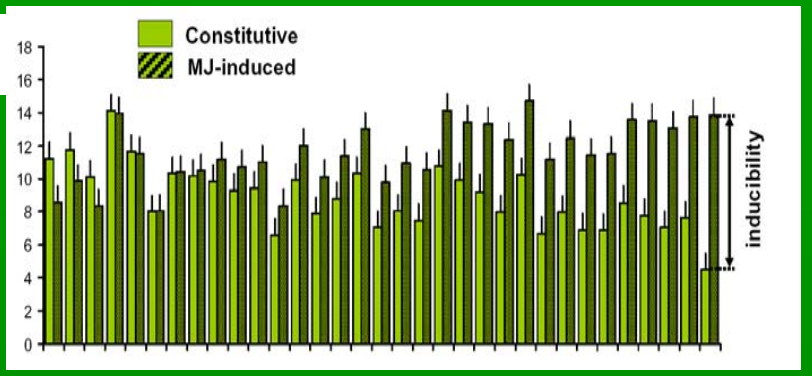
Resistances *vs* other traits



	Fine root length (%)	Tree growth (m yr^{-1})	Cone production (cones ramet^{-1})
Fusarium oxysporum	ns	ns	-0.55***
Fusarium circinatum	ns	ns	ns
Armillaria ostoyae	0.34*	ns	0.40***
Thaumetopoea pityocampa	ns	ns	0.34**
Dioryctria sylvestrella	ns	ns	ns
Hylobious abietis	ns	− 0.32*	ns
Water stress	0.30*	ns	ns

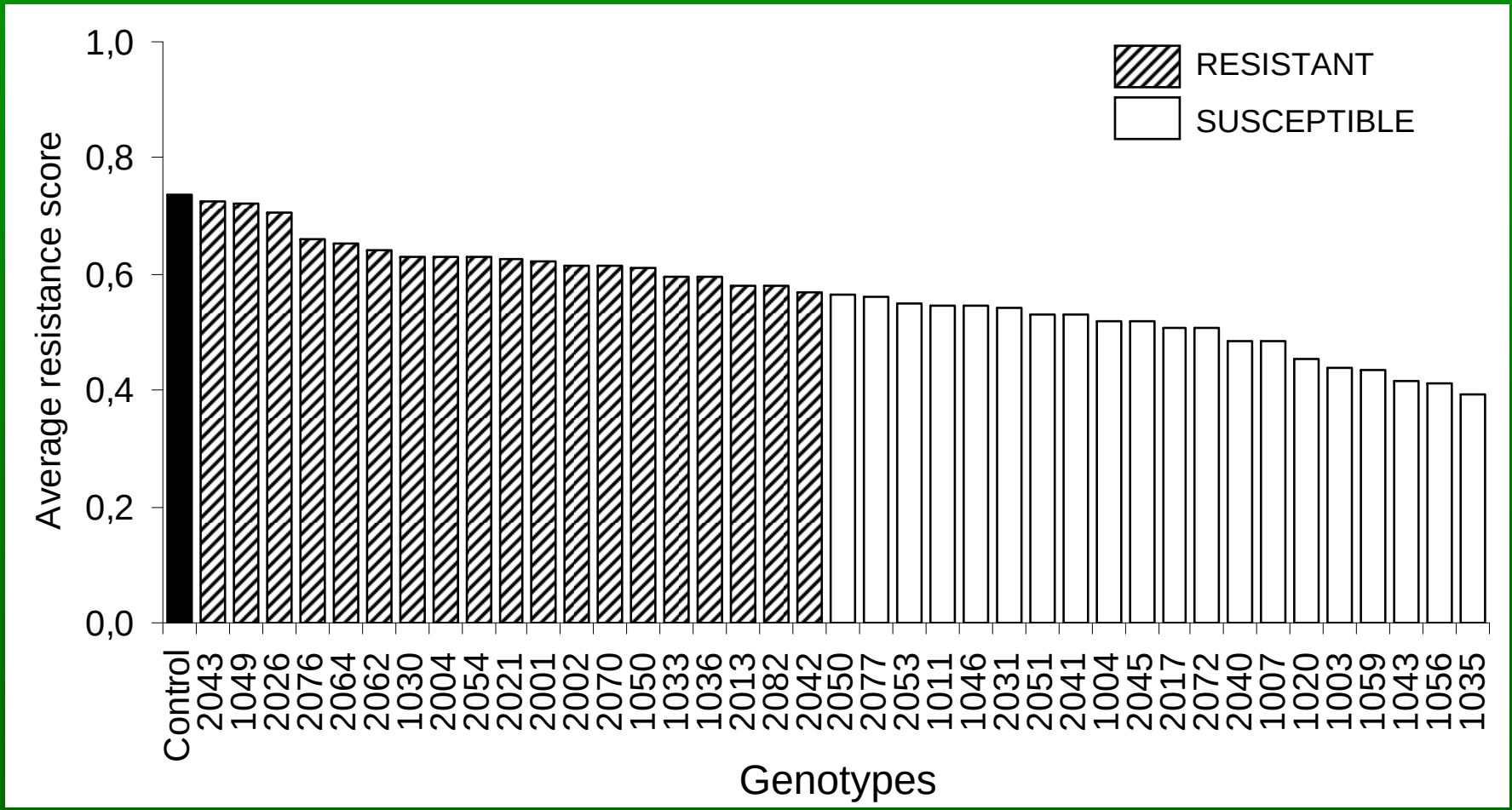
4. Results and discussion

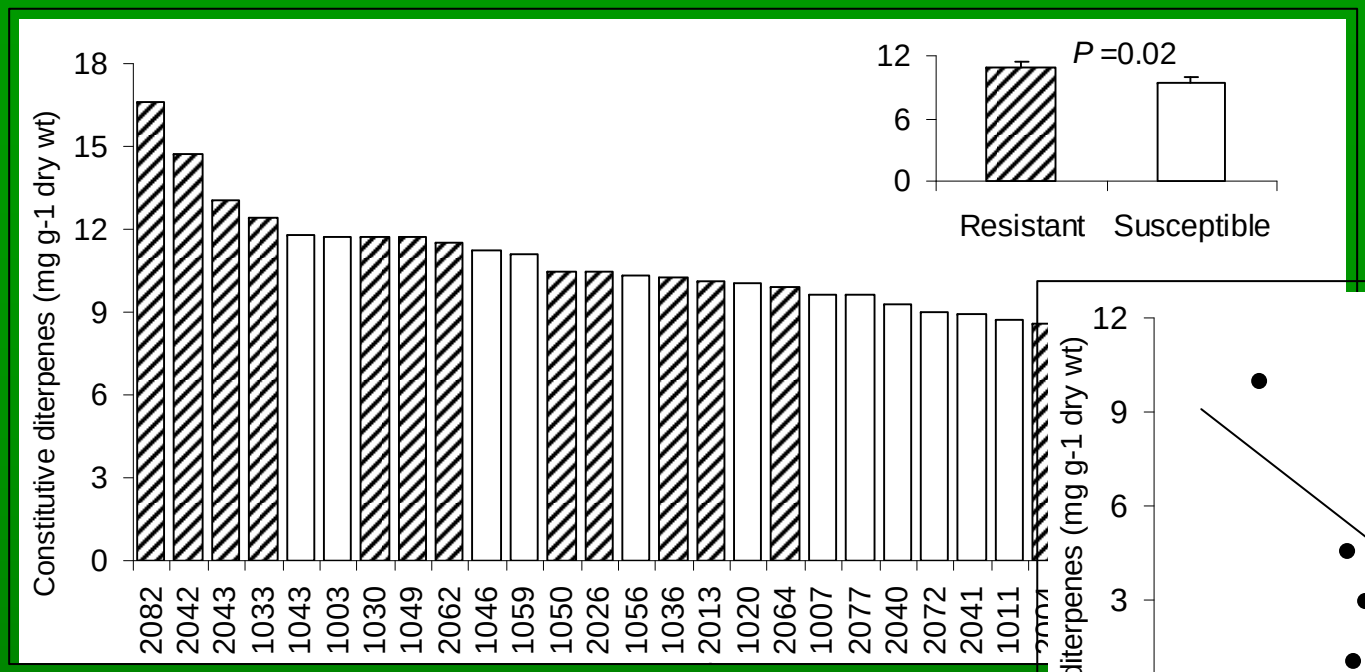
Resistances *vs* chemical defense traits

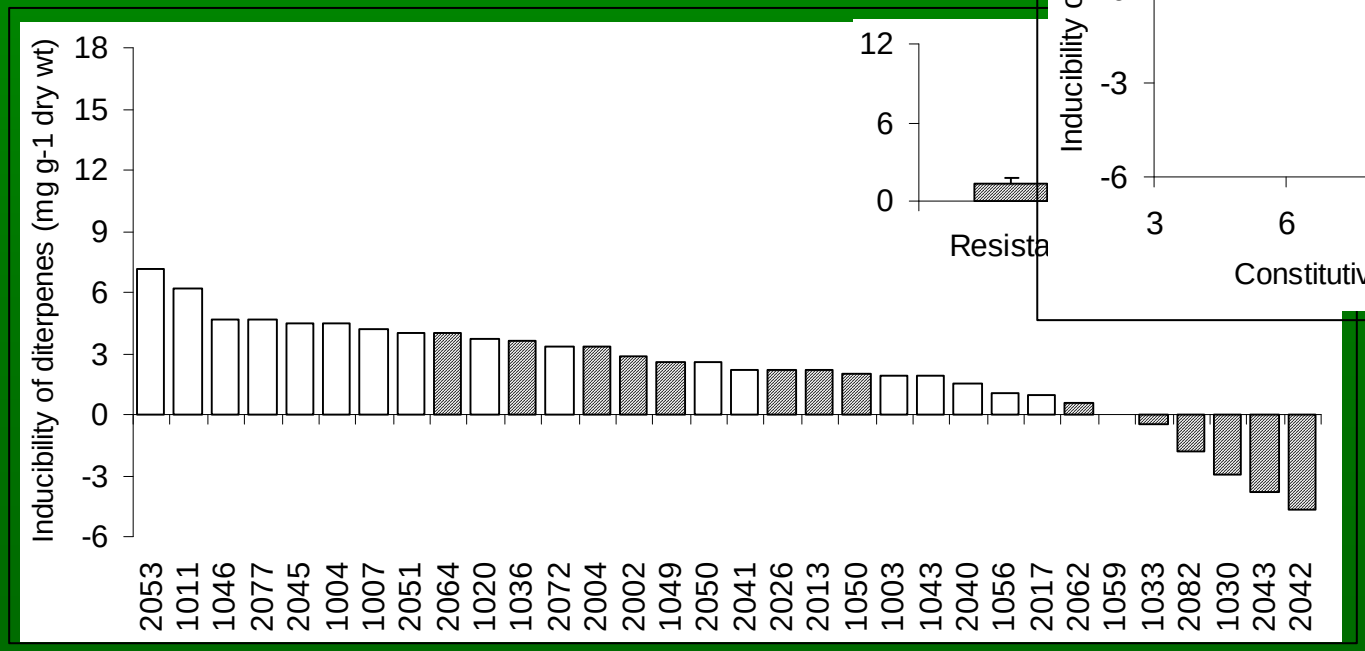


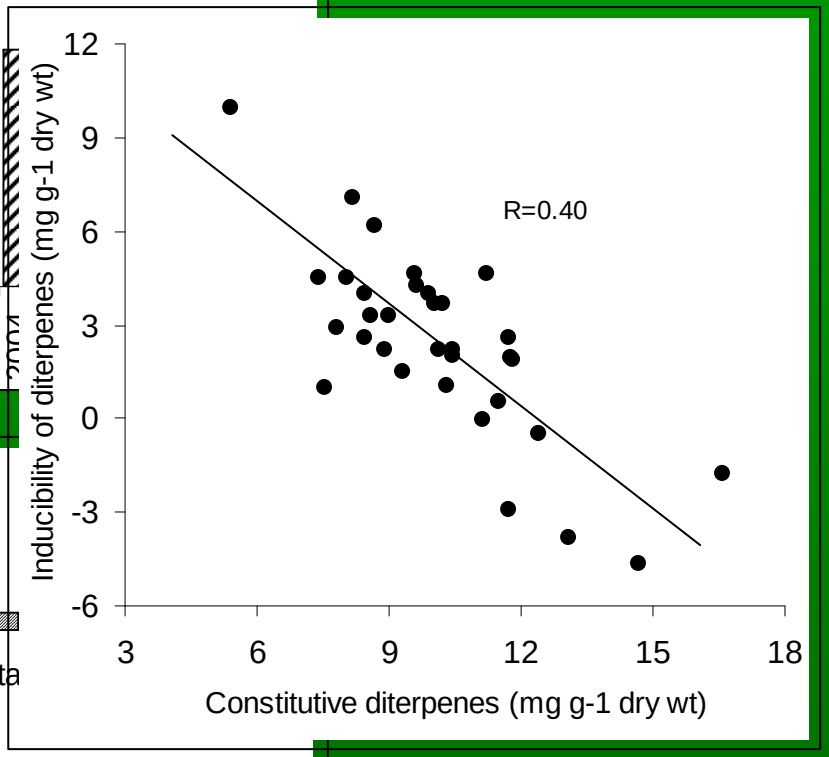
	Constitutive					Inducibility of				
	Diterpenes	Total phenolics	Condensed tanins	Starch	Soluble sugars	Diterpenes	Total phenolics	Condensed tanins	Starch	Soluble sugars
F. oxysporum	0.33**	0.55***	0.33**	-0.49***	ns	ns	ns	ns	ns	ns
F. circinatum	ns	ns	ns	-0.53***	-0.29*	ns	ns	ns	0.29*	ns
A. ostoyae	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
T. pityocampa	ns	ns	ns	ns	ns	ns	ns	ns	-0.40***	0.37**
D. sylvestrella	ns	ns	ns	ns	-0.36**	ns	ns	ns	ns	ns
H. abietis	0.27*	0.59***	ns	ns	-0.62***	ns	ns	-0.55***	-0.37**	0.76***

Ranking of clones (water stress score excluded)



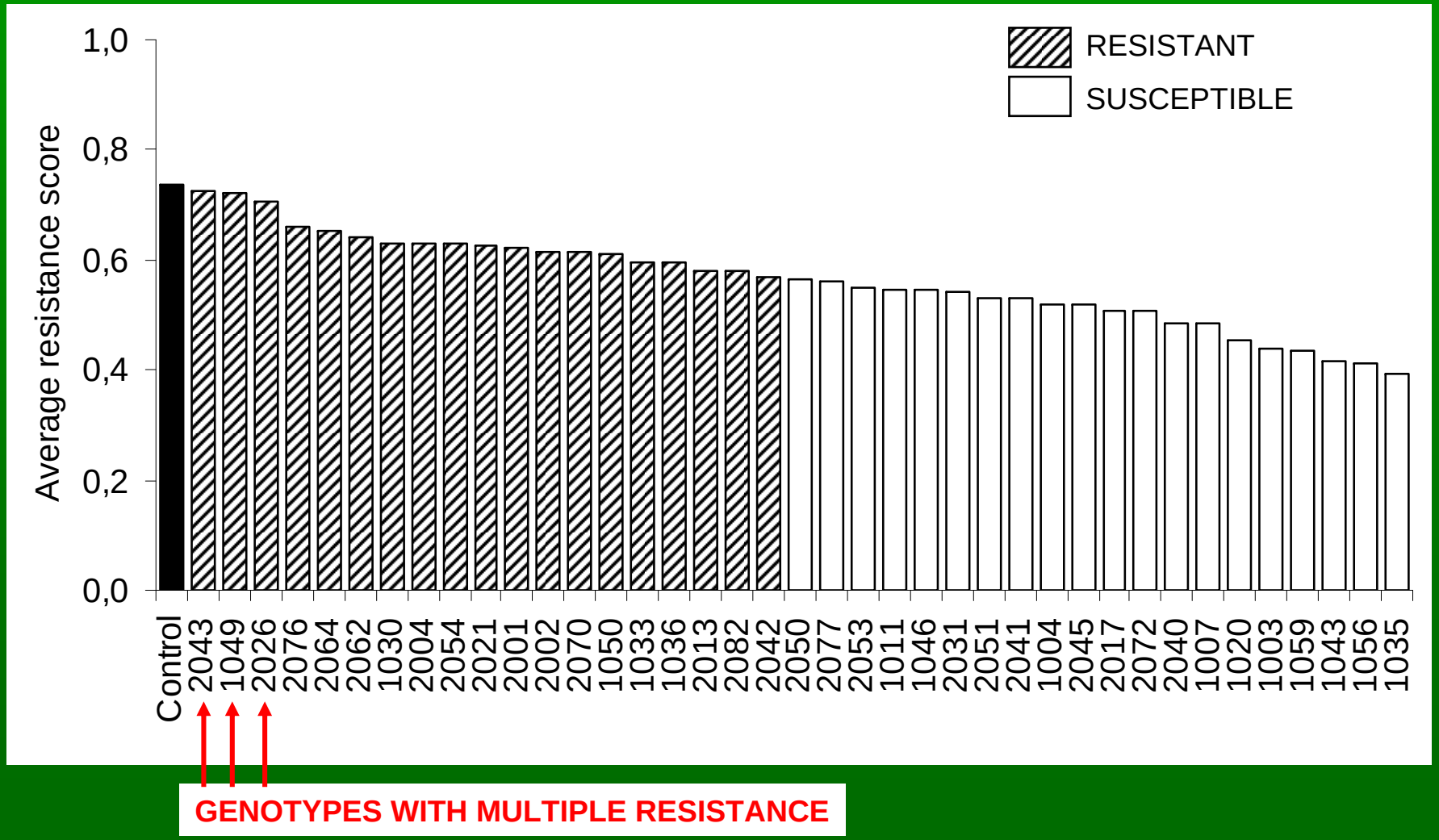


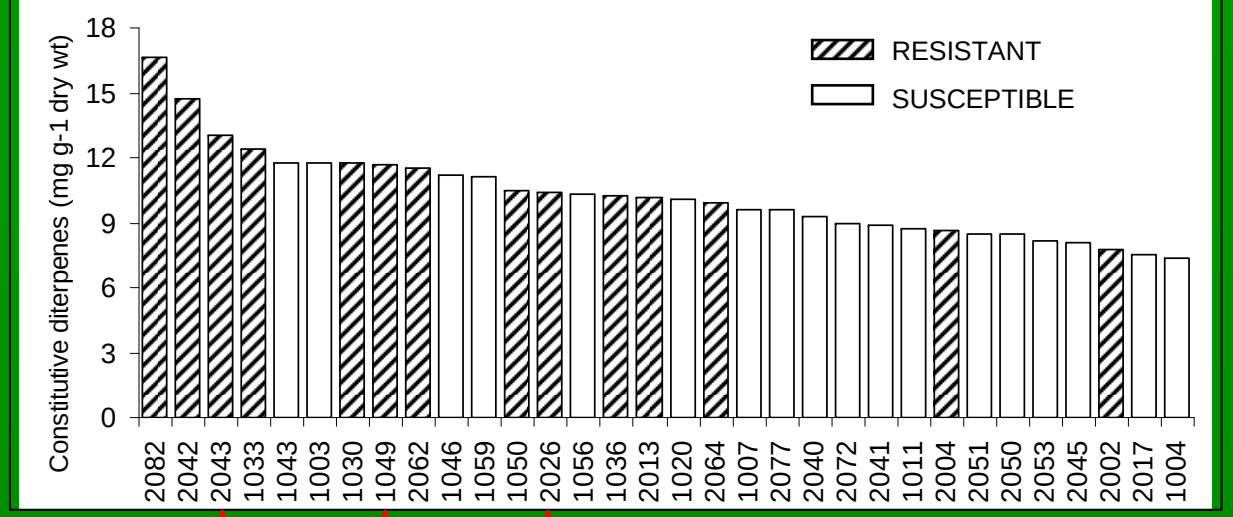


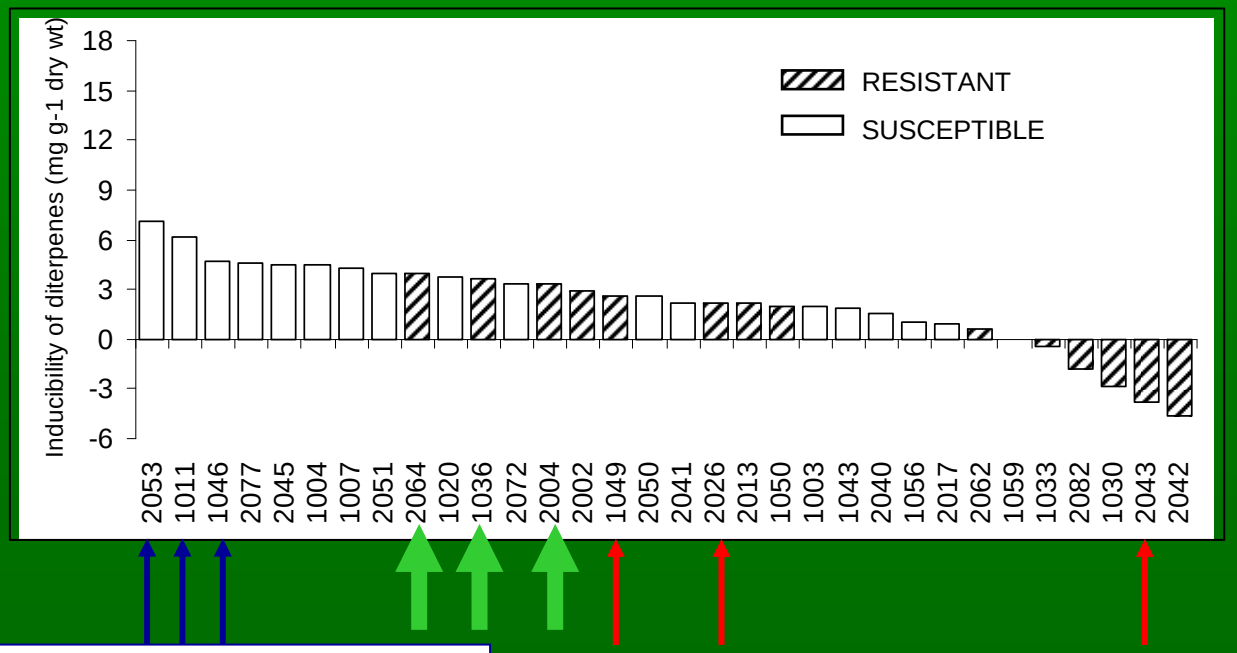


Sampedro et al 2011. *J Ecology*

Ranking of clones







GENOTYPES MORE ABLE TO PRODUCE CROSS PROTECTION

Zas *et al*. PANEL. The potential of breeding for enhanced inducibility in *Pinus pinaster* and *P. radiata*

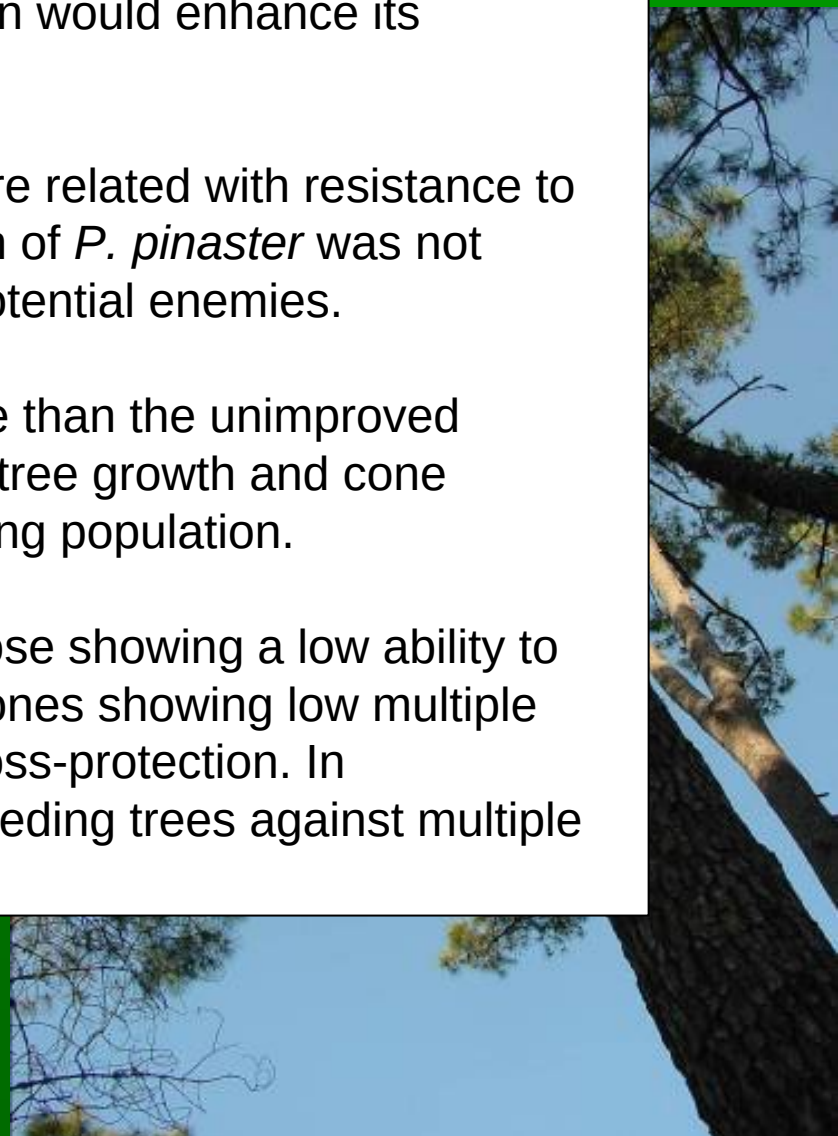
5. Conclusions

1. Heritabilities of *Pinus pinaster* are high enough to improve resistance against all the studied pathogens and pests. However, breeding *Pinus pinaster* for resistance to a particular pathogen would enhance its susceptibility to another pathogen or pest.

2. Although resistances to fungal pathogens were related with resistance to water stress, the Spanish breeding population of *P. pinaster* was not simultaneously resistant to a wide range of potential enemies.

3. All plus trees were generally more susceptible than the unimproved control. Trade-offs between tree resistances, tree growth and cone production were not general within our breeding population.

4. Clones showing multiple resistances were those showing a low ability to produce cross-protection. On the contrary, clones showing low multiple resistance were able to induce or produce cross-protection. In consequence, cross-resistance applied to breeding trees against multiple enemies should be taken with caution.



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