Plant quality in forest restoration: morphological and physiological components

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Factors that determine revegetation success

If selected species are suitable and climatic conditions are not unusually extreme

1) Soil preparation

2) Plant care in the field:

herb competition and in some cases shrub competion

herbivores exclusion

3) The quality of seedlings or of any other material used in afforestation (stecklings, emblings, and seeds)

What is a plant of high quality?

- Plants that meet defined levels of survival and growth on a particular site.

If seedlings fail to meet these out-planting performance standards then seedlings need to be replanted (Duryea, 1985).

- In Spain, many reforestation projects define 80% survival as a tolerable limit

Plant quality is more relevant the harsher the planting environment is

Plant quality changes through time

Plant quality has short- and long-term consequences

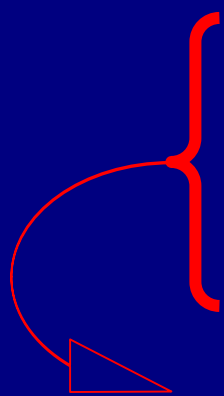
Why it is important to use and produce high-quality plants?

- Ecological reasons

- Economical reasons
  - Reduces plantation costs
  - Warrants the prestige of nurseries
  - Allows to identify precisely the factors that explain low out-planting performance

Plant quality is defined by 4 components

1) Genetic
2) Sanitary
3) Morphological
4) Physiological



Can be defined by a set of attributes: MATERIAL attributes

Sanitary quality

Avoid plants infected or damaged by diseases or pests because they can jeopardize all the restoration

Sanitary quality

.... but do not confound fungi diseases (mould) with mycorrhizas

Morphological quality

- It is defined by a set of attributes (material attributes) related to the form and structure of the plant
- Morphological attributes are the basis of the plant quality legislation of the European Union
- Quantitative and qualitative

Qualitative morphological attributes

In EUROPEAN legislation

Avoid injured plants, specially if wounds are recent and not related to pruning

Qualitative morphological attributes

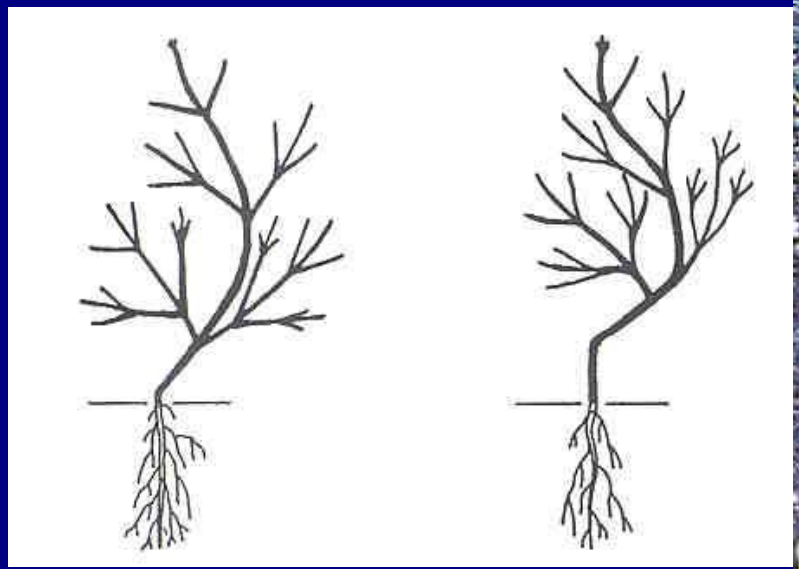
In EUROPEAN legislation

Avoid plants with signs of desiccation, overheating, specially if they have been stored

Qualitative morphological attributes

In EUROPEAN legislation

Avoid plants with excessive stem curvature



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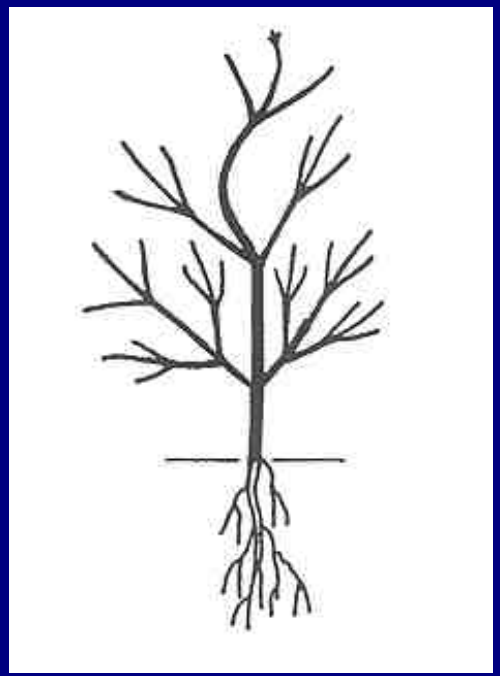


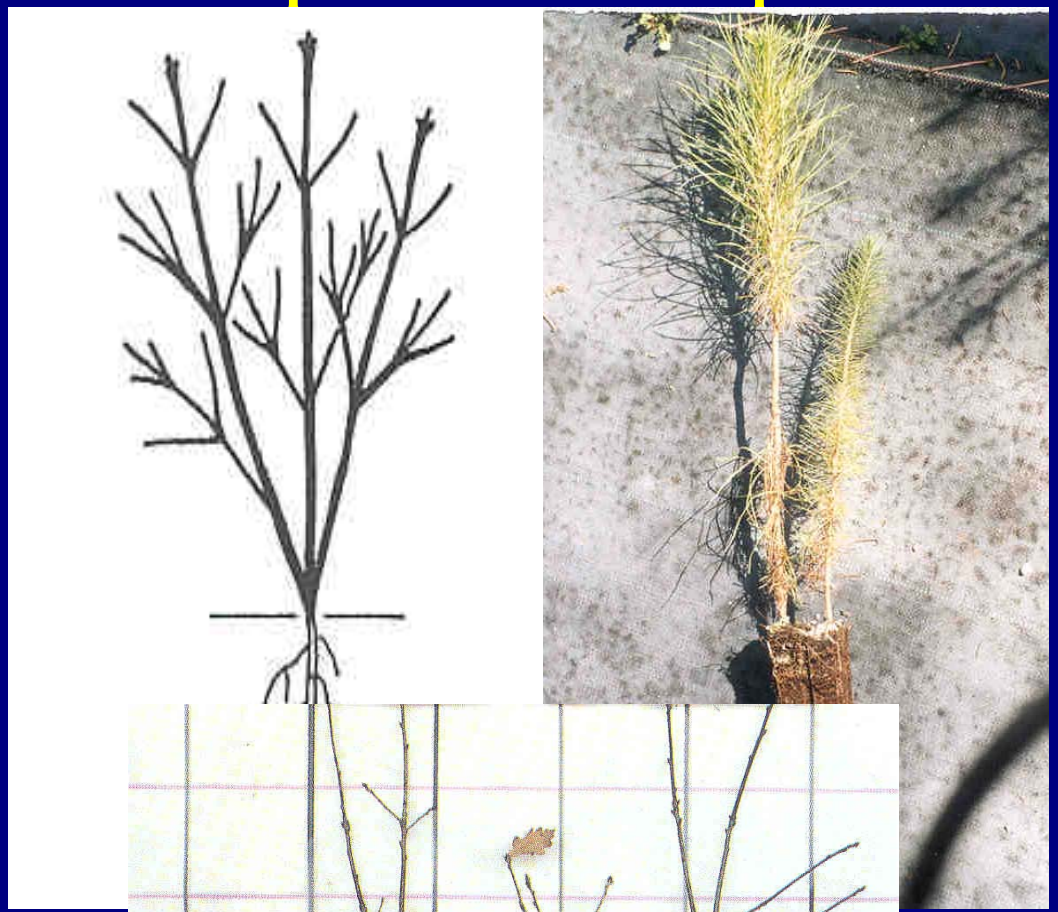
Accepted

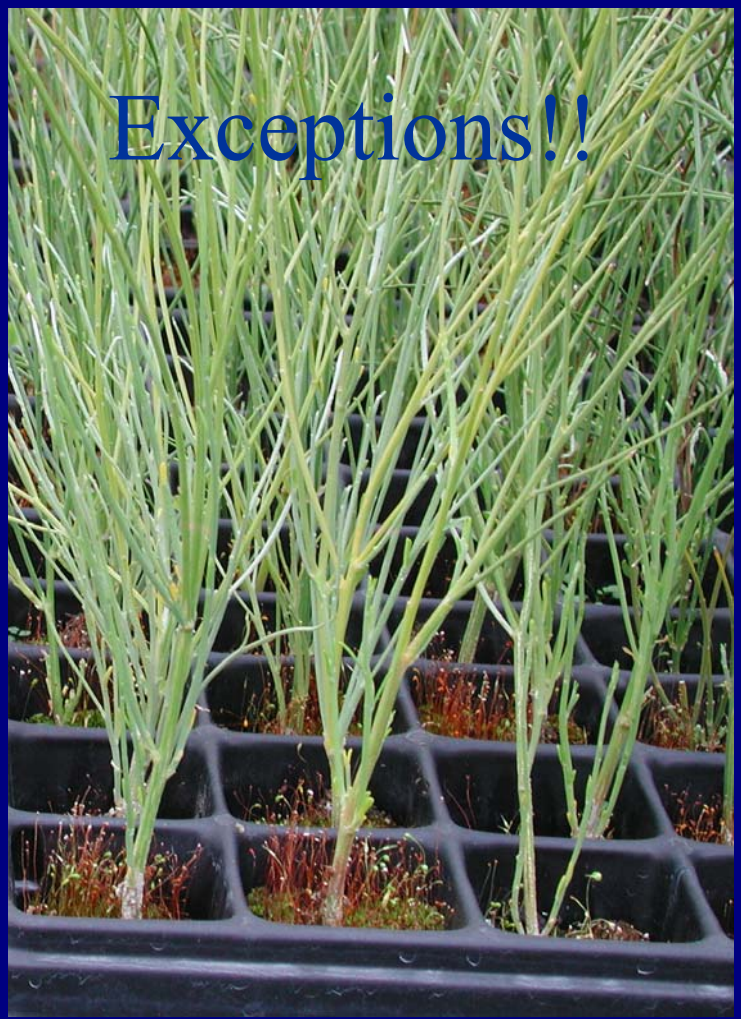
If crooking affects the upper shoot part

Qualitative morphological attributes

In EUROPEAN legislation

Avoid plants with multiple stems

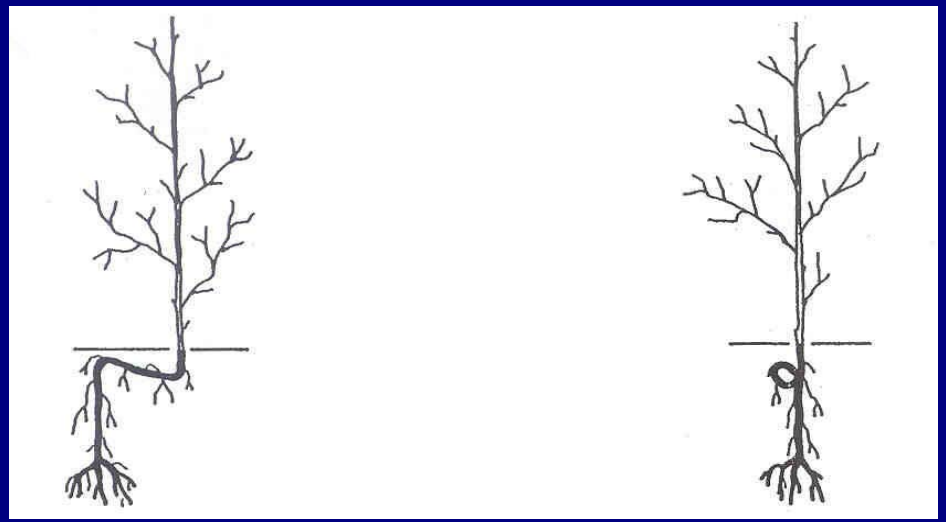




Qualitative morphological attributes

In EUROPEAN legislation

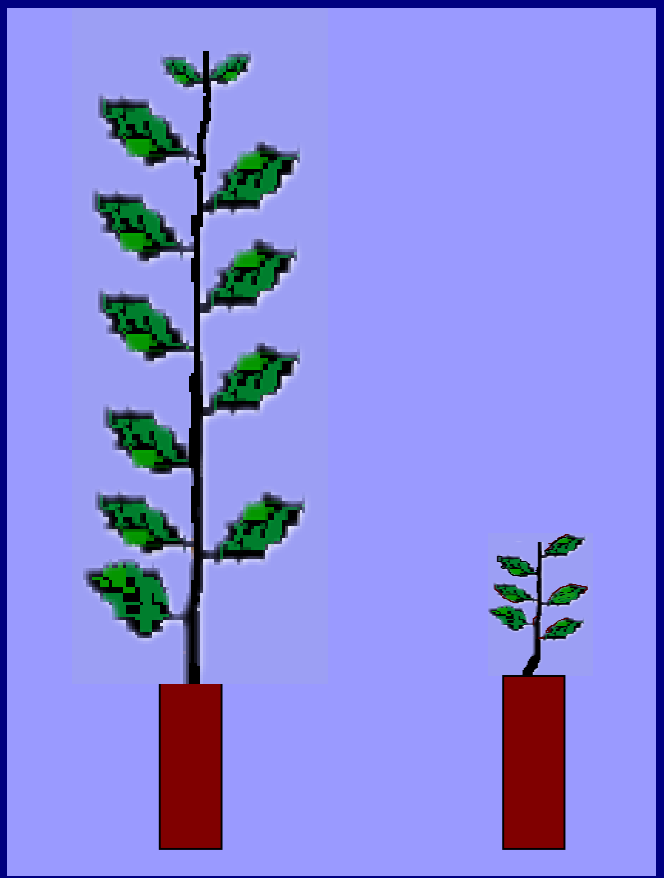
Avoid plants with strongly deformed roots



Qualitative morphological attributes

In EUROPEAN legislation

Avoid plants not well balanced (shoot and root system)

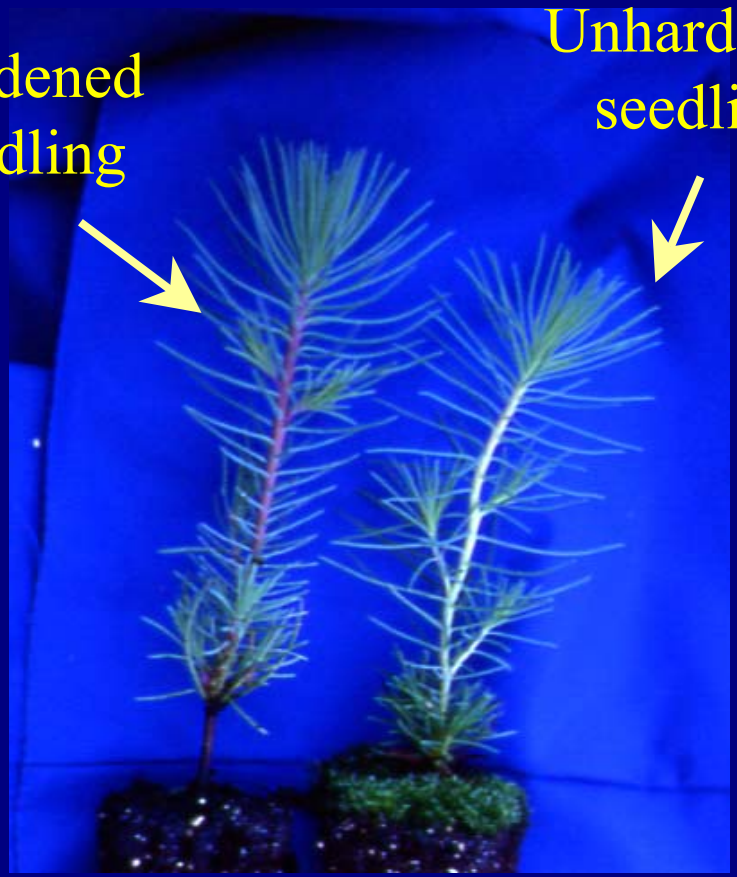


However legislation doesn't define what is an unbalanced plant

Qualitative morphological attributes

NOT in EUROPEAN legislation

Avoid plants with growing and not hardened shoots



Presence of apical buds helps to recognize hardened seedlings. However not all species develop apical buds

Qualitative morphological attributes

NOT In EUROPEAN legislation

Avoid seedlings with no or few branches (but not all species)

In many species the lack of branches in 1-year old seedlings is the rule

Qualitative morphological attributes

NOT In EUROPEAN legislation

Avoid plants with poorly developed secondary roots or with excised roots

Quantitative morphological attributes

Shoot length

Root collar diameter

Shoot and root mass

Root to shoot mass ratio

Cheap, easy to measure and predicts quite well out-planting performance potential if plants are not damaged

Quercus faginea

6 - 30 cm / 2 mm

10-50 cm / 3mm

Quercus ilex

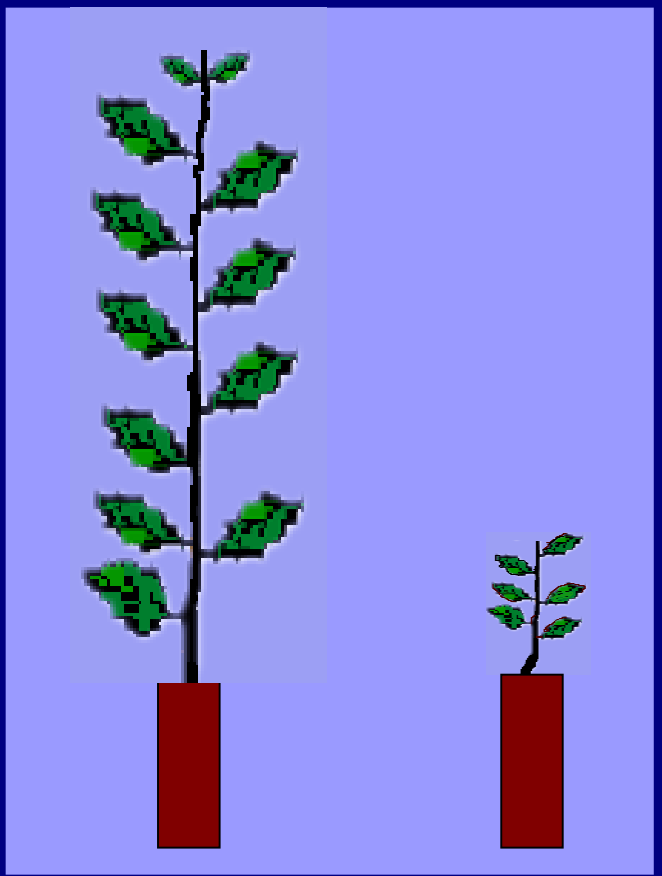
8 - 30 cm / 2 mm

15 - 50 cm / 3mm

Pinus halepensis

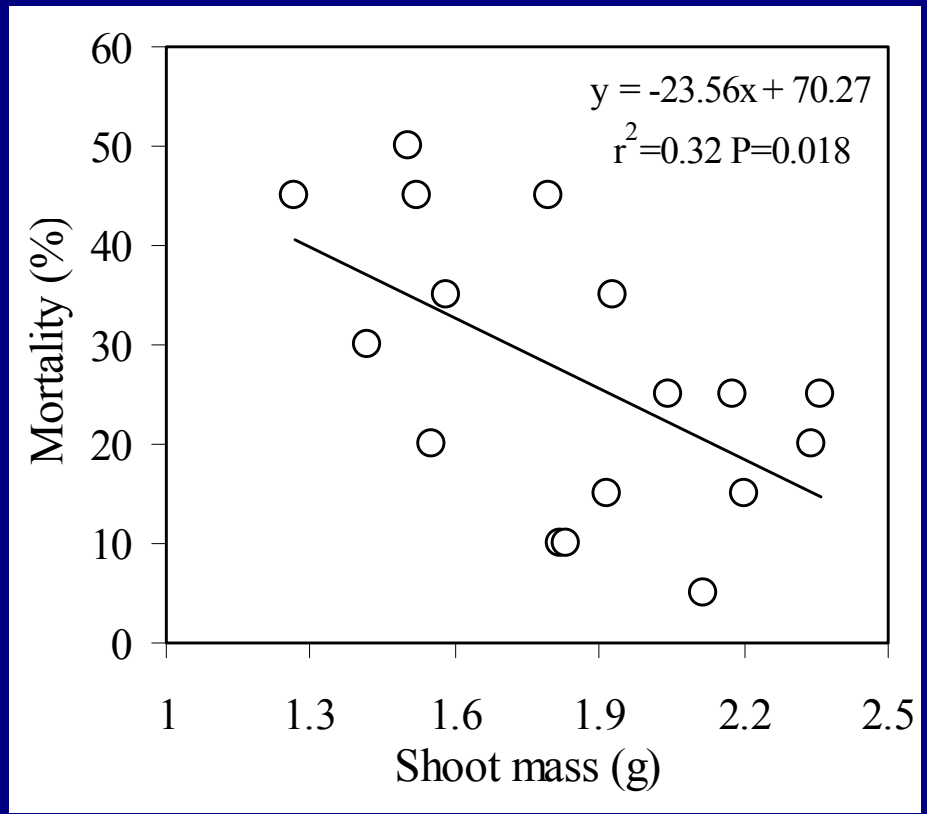
10 - 30 cm / 2 mm

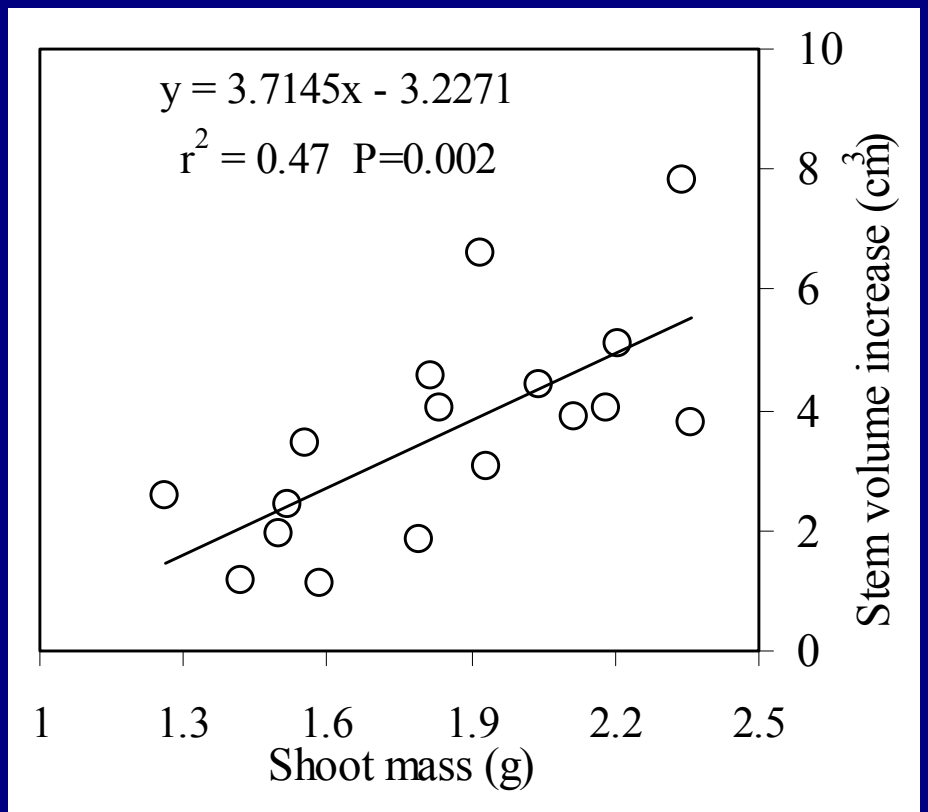
15 - 45 cm / 3 mm



Plant size and out-planting performance

Quercus ilex (holm oak)

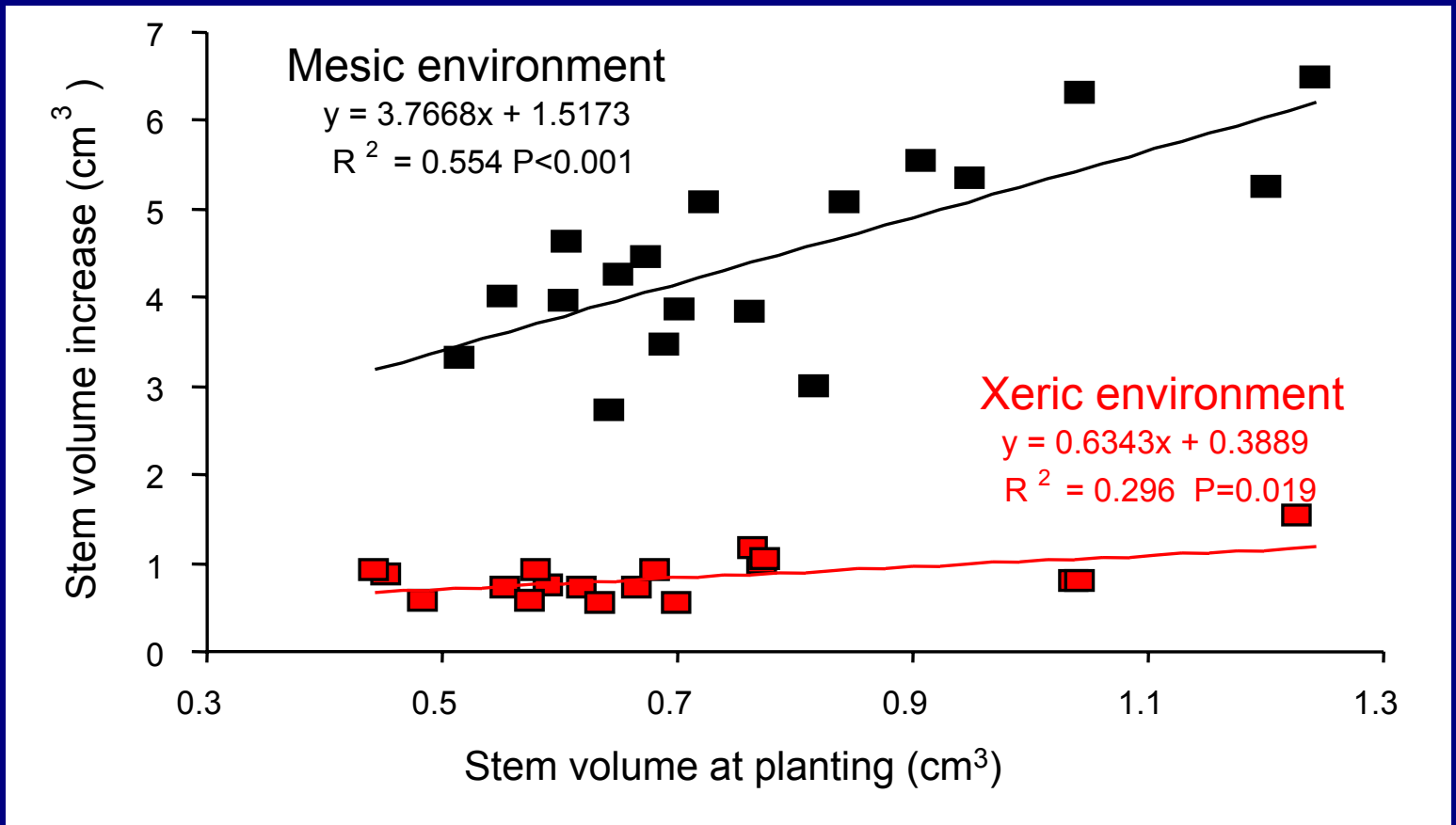




Villar-Salvador et al. 2004 Forest Ecology and Management 196:257-266

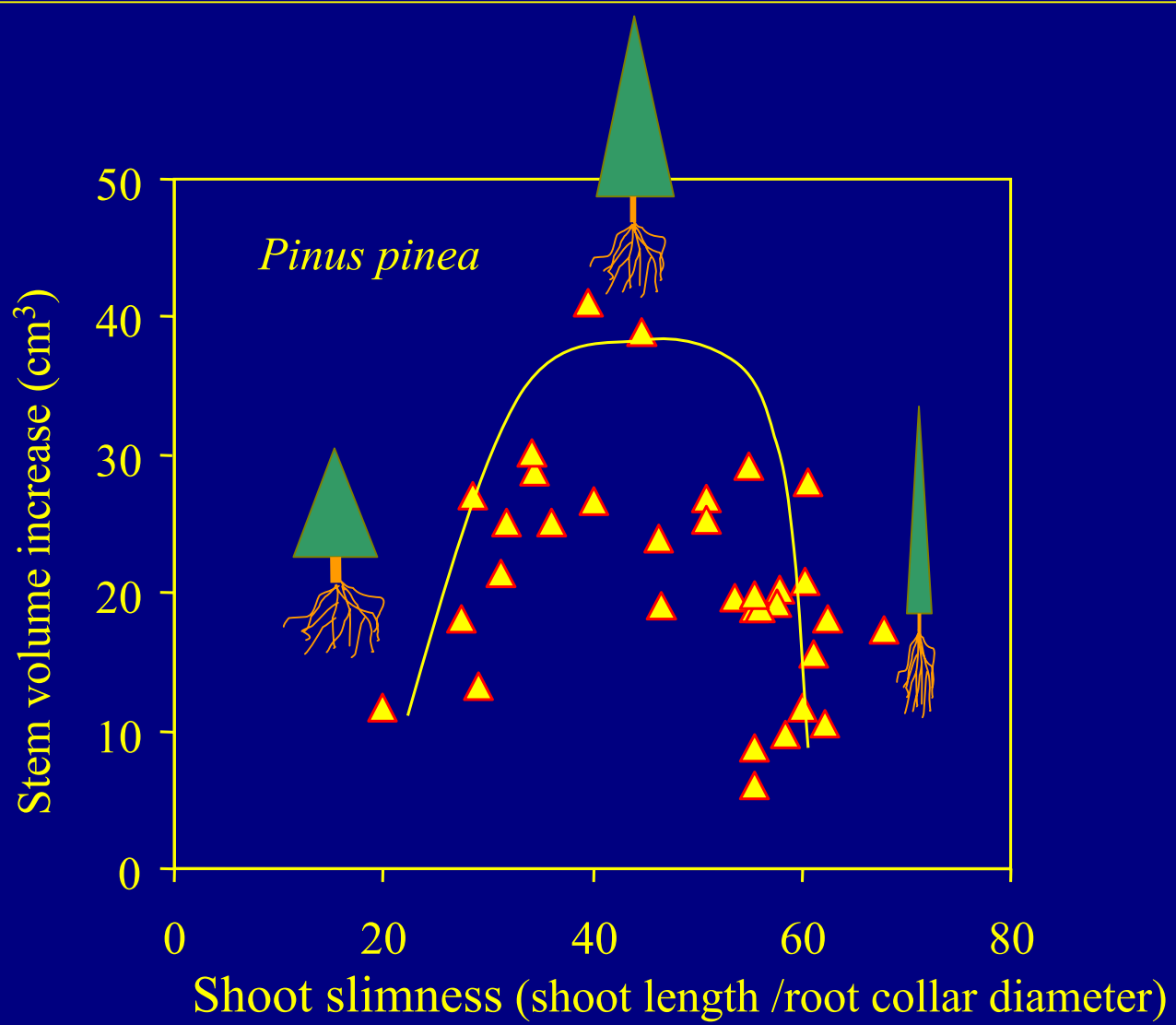
Plant size and out-planting performance

Pinus pinea



Experimental results suggests that large plants do also tend to perform better in Mediterranean environments

The balance between plant dimensions is also important



Proportion between the size of the shoot and the root

Shoot /root ratios

Quercus ilex < 1

Quercus faginea < 1

Pinus halepensis 1 - 2

Pinus pinea: 1.4 - 2

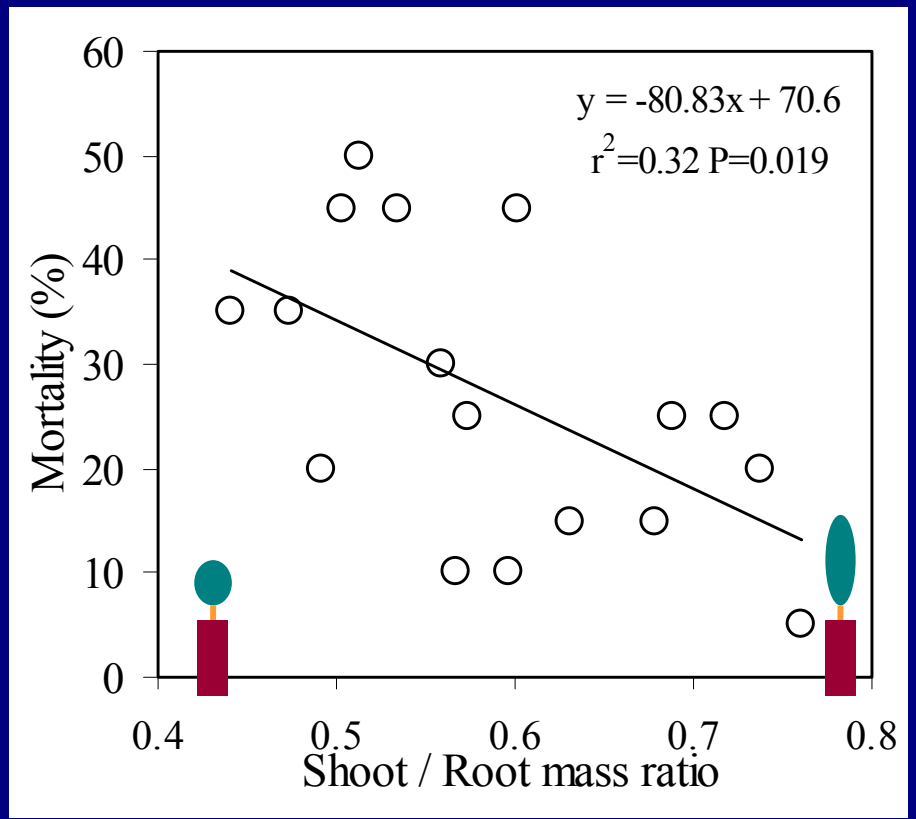
Juniperus thurifera: 1 - 2

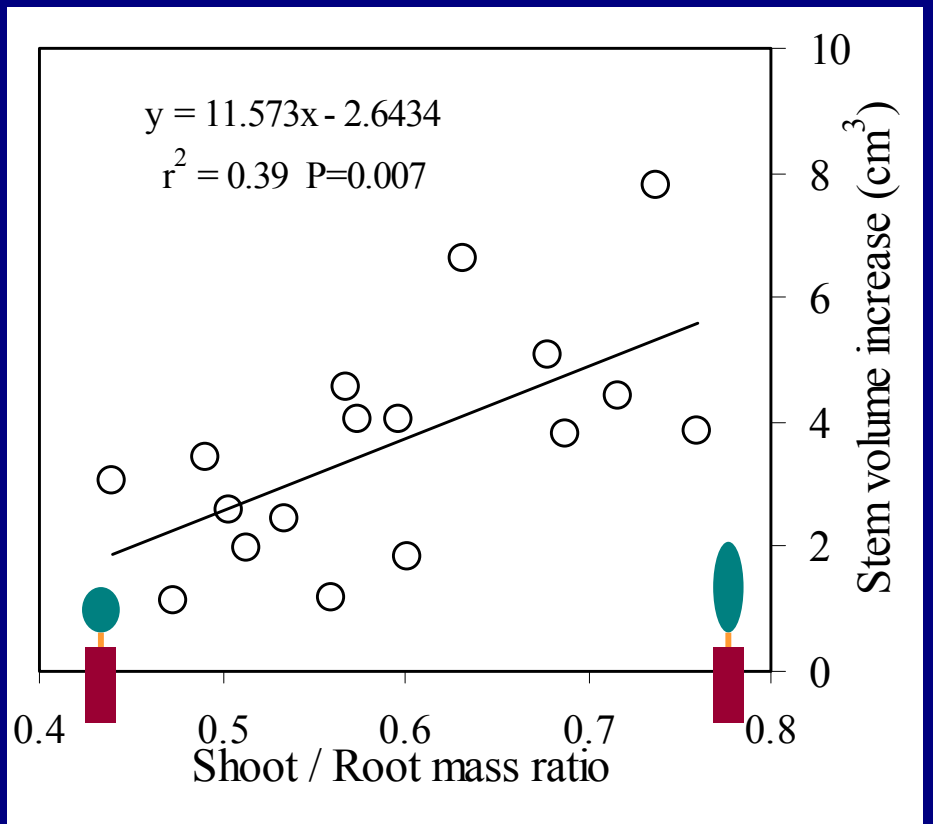
Olea europaea: 1 - 4

Increasing vulnerability to drought??

Proportion between the size of the shoot and the root

Quercus ilex

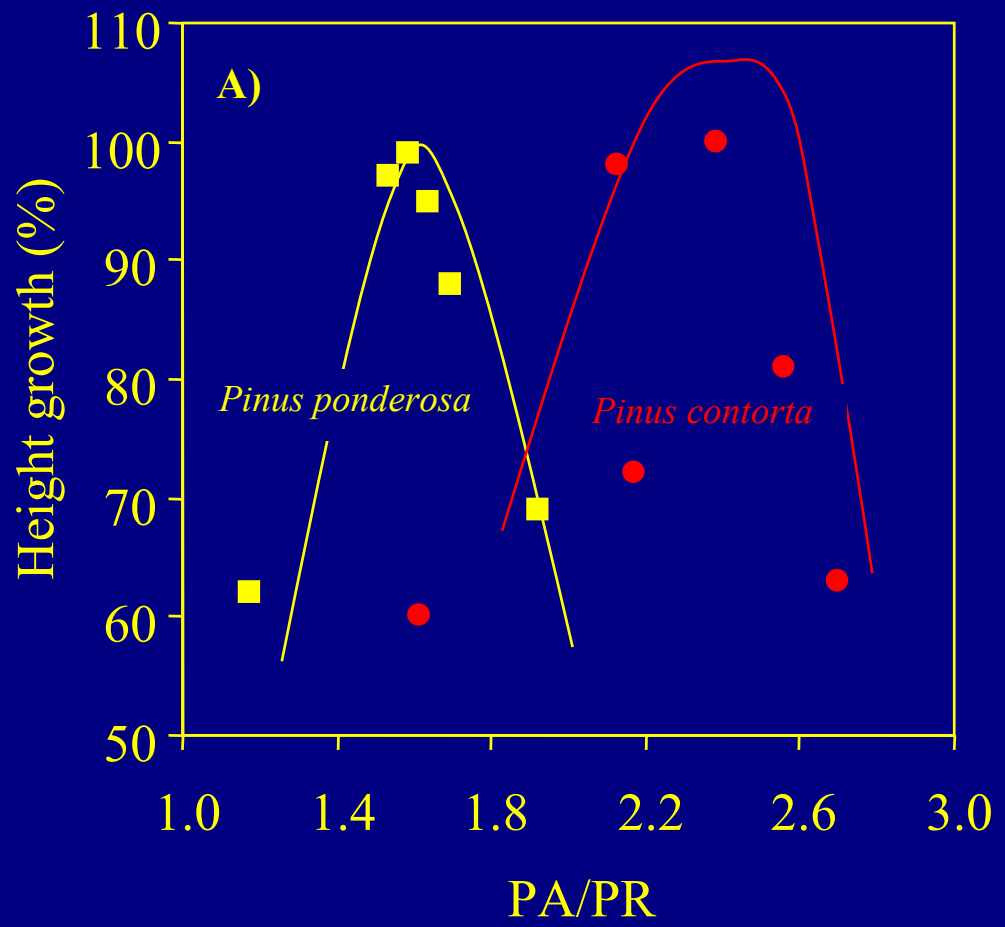




Villar-Salvador et al. 2004 Forest Ecology and Management 196:257-266

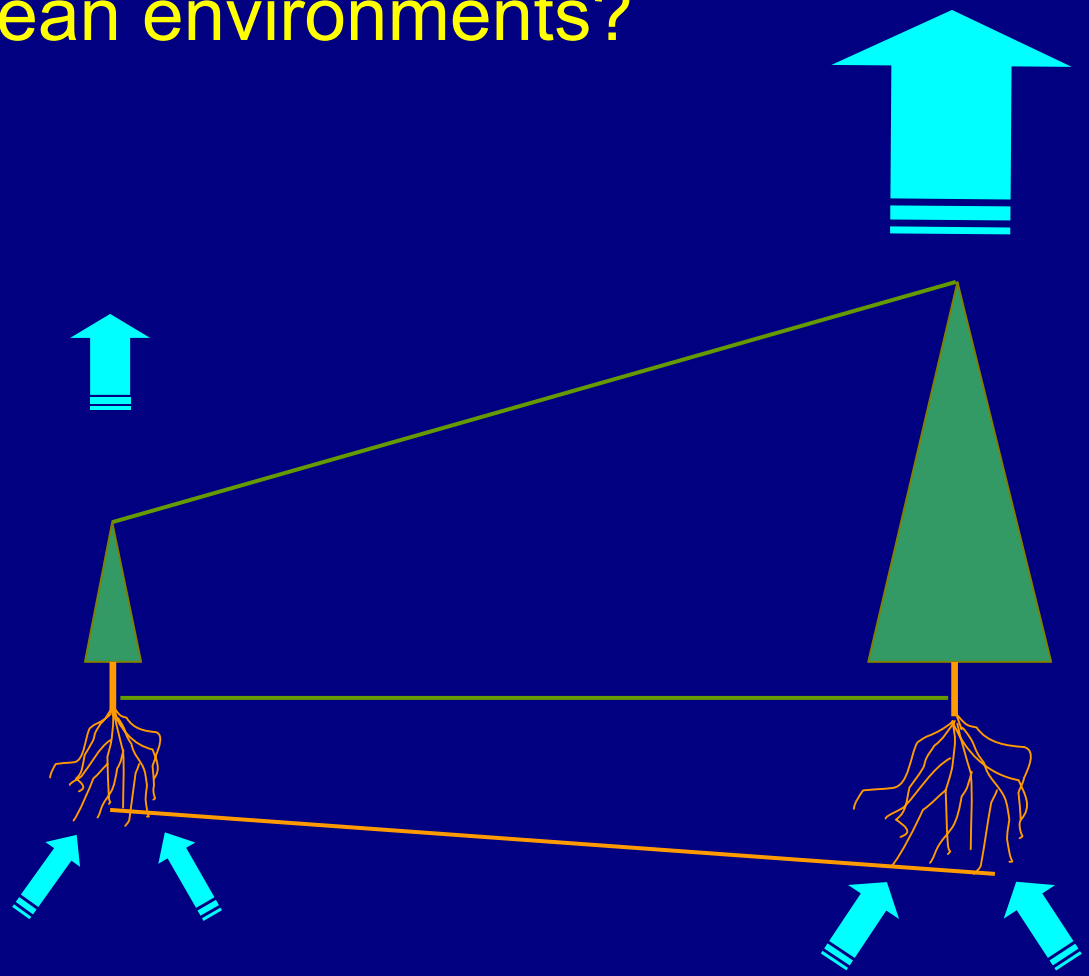
A very low shoot to root ratio can impair out-planting performance

Proportion between the size of the shoot and the root



Mc Donald *et al.*, 1984. J. Env. Hort. 2:5-8

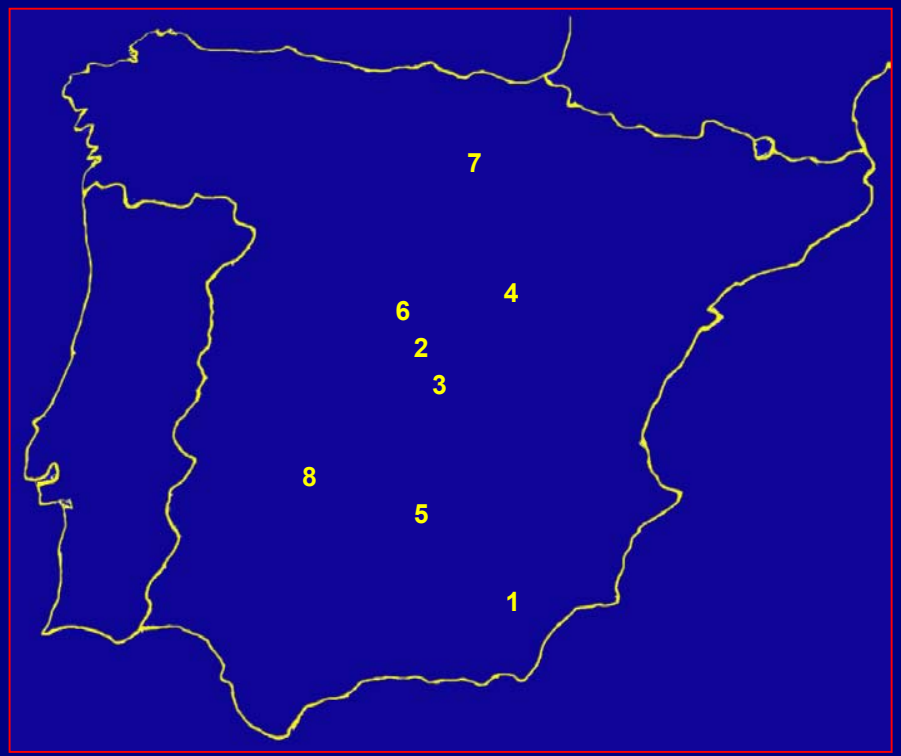
¿Do seedlings with small shoots and root to shoot ratios have better out-planting performance than seedlings with large shoots and root to shoot ratios in Mediterranean environments?



21 Experimental plots

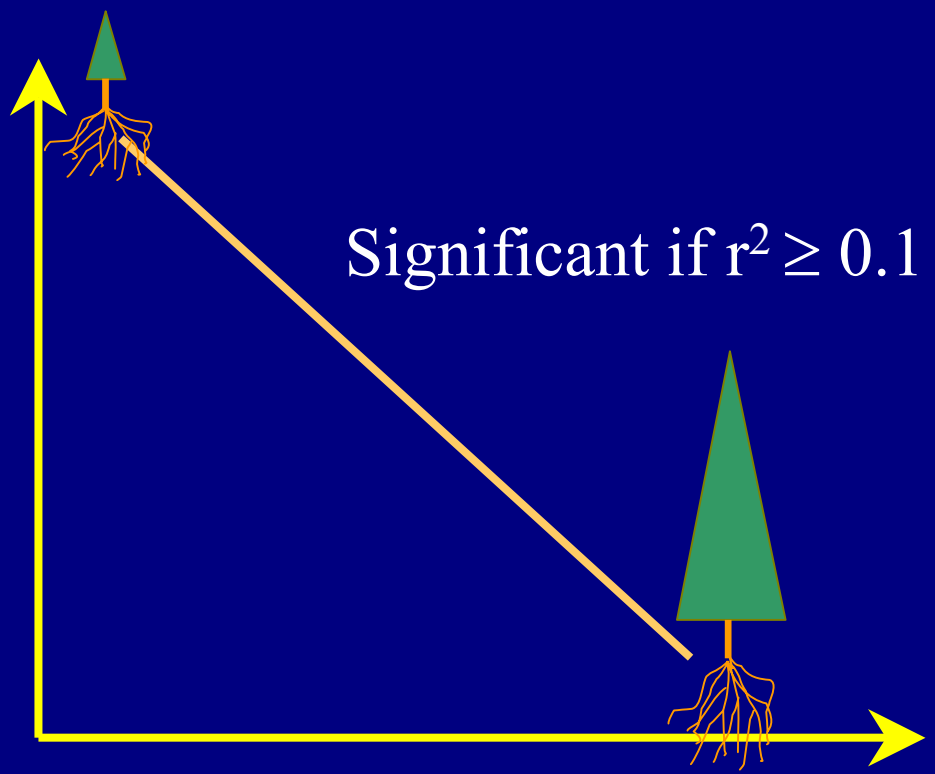
- *Pinus pinaster* (7) and *P. halepensis* (7)
- *P. pinea* (5)
- *P. nigra* (1) and *P. sylvestris* (1)

Locations	Rainfall (mm)	Mean max. Temp July (ºC)
1- Pto Lumbreras	350	34.0
2- El Serranillo	414	32.1
3- Almoguera	415	33.7
4- Munébrega	440	31.0
5- Almagro	450	34.1
6- Uceda	567	31.7
7- Priéjano	660	24.4
8- Los Navalucillos	690	33.7



Hypothesis

- Survival
- Growth



Significant if $r^2 \geq 0.1$ at $\alpha=0.1$

- Shoot size: mass, diameter, height
- Shoot mass / root mass

Results

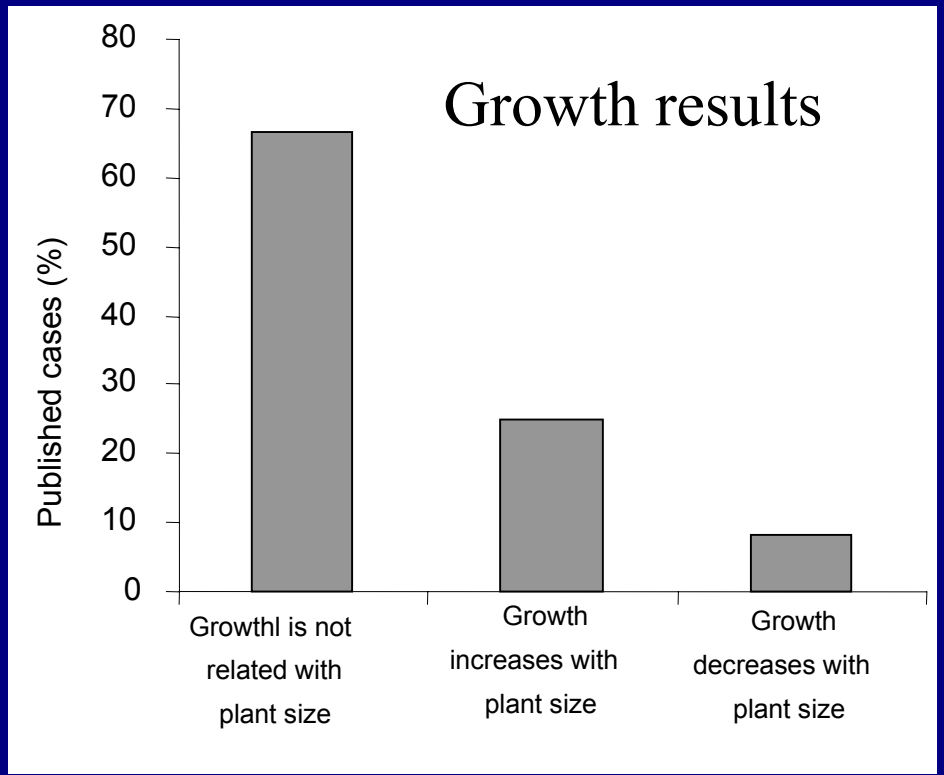
SURVIVAL

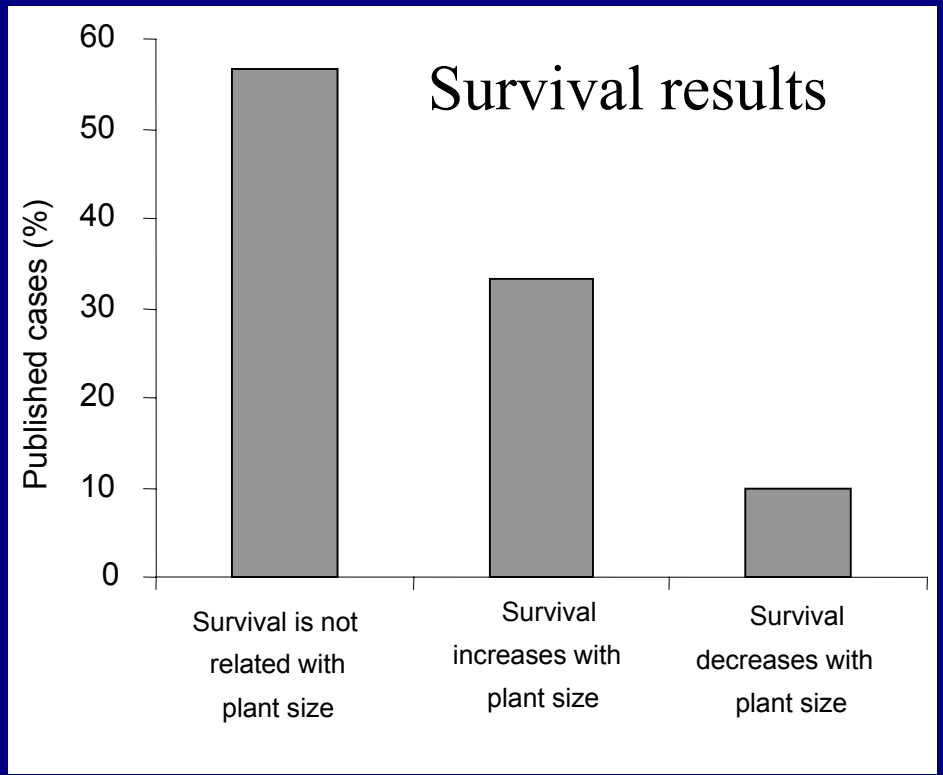
Variables	All species		
	+	-	0
Height	4	0	13
Diameter	3	0	14
Shoot mass	2	0	12
Shoot / Root mass	0	1	13

GROWTH

All species		
+	-	0
7	0	12
7	0	11
9	0	8
1	0	16

Revision of 30 studies published by Spanish authors





CONCLUSION: In Mediterranean environments, in most cases (50-60% cases) plant size is not related with out-planting performance. However, when it is related larger plants tend to perform better than smaller ones

	Shoot length (cm)	**Root collar diameter (mm)**
Pinus halepensis	15 - 30 (10 - 25)	3 - 4 (>2)
Pinus pinea	20-30 (10 - 30)	3.5 – 4.5 (>3)
Quercus ilex	20 - 30 (8 - 30)	4-5 (>2)

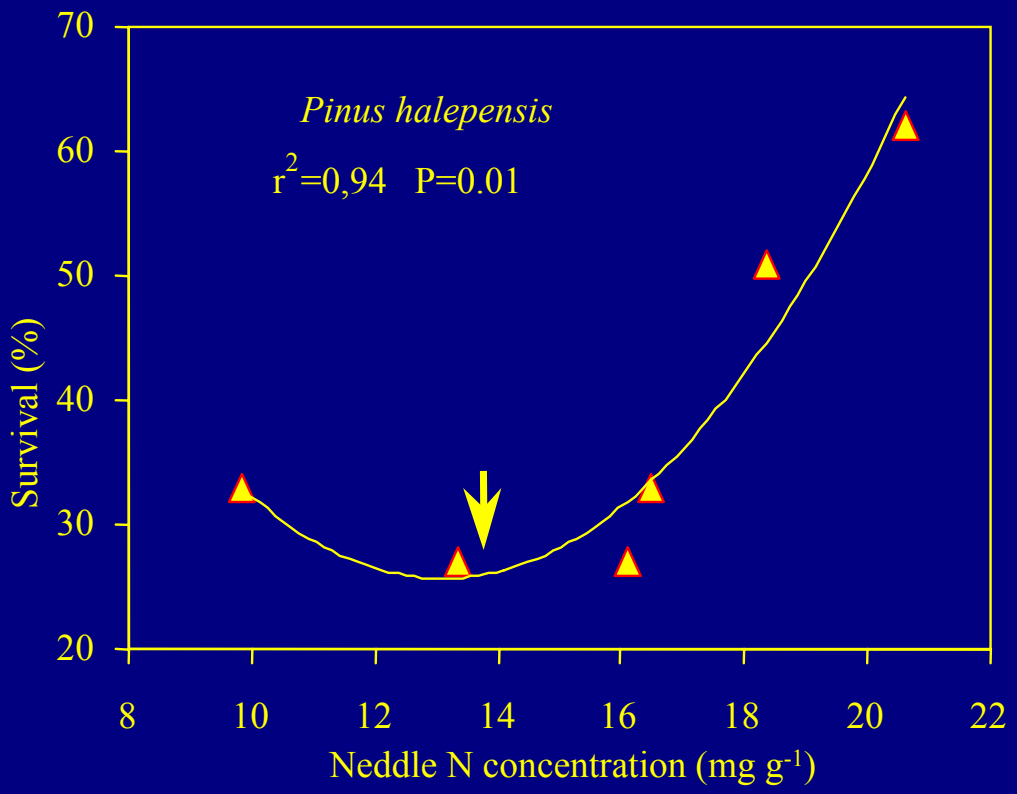
Physiological quality: physiological attributes

- Set of attributes (material attributes) related to the function of the plant
- Most of them are expensive and time consuming
- Provide information that morphological attributes cannot. Therefore they should complement morphological attributes

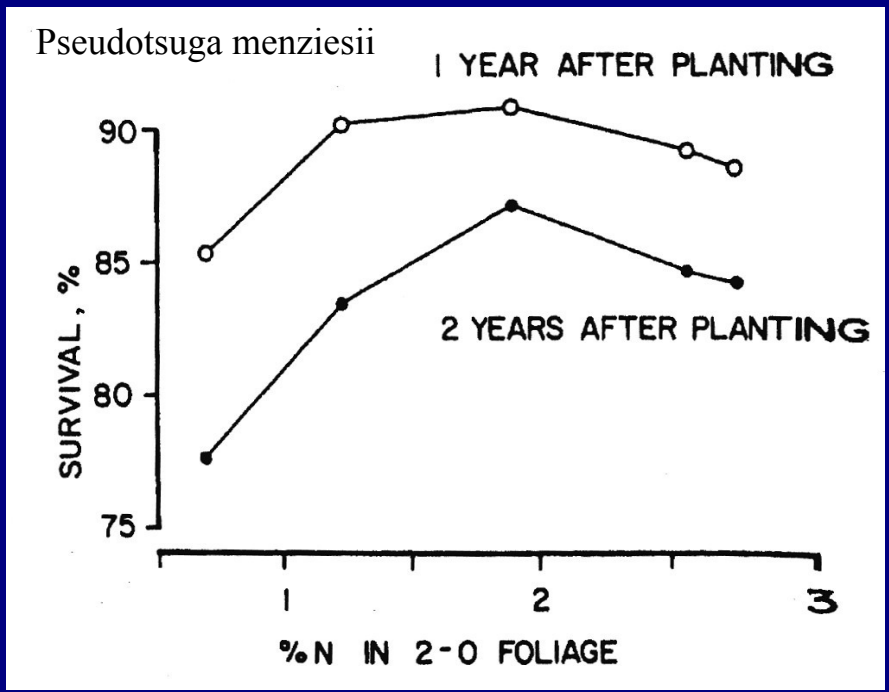
- Concentration of mineral nutrients and storage carbohydrates
- Dormancy of apical buds (Mitotic index and days to budburst)
- Chlorophyll fluorescence

- Infrared thermography
- Stress-induced volatile emission
- Plant vigour estimation by vital colorants
- Chlorophyll concentration
- Stomatal conductance and photosynthetic rate
- Water potential

Nutrient concentration and out-planting performance

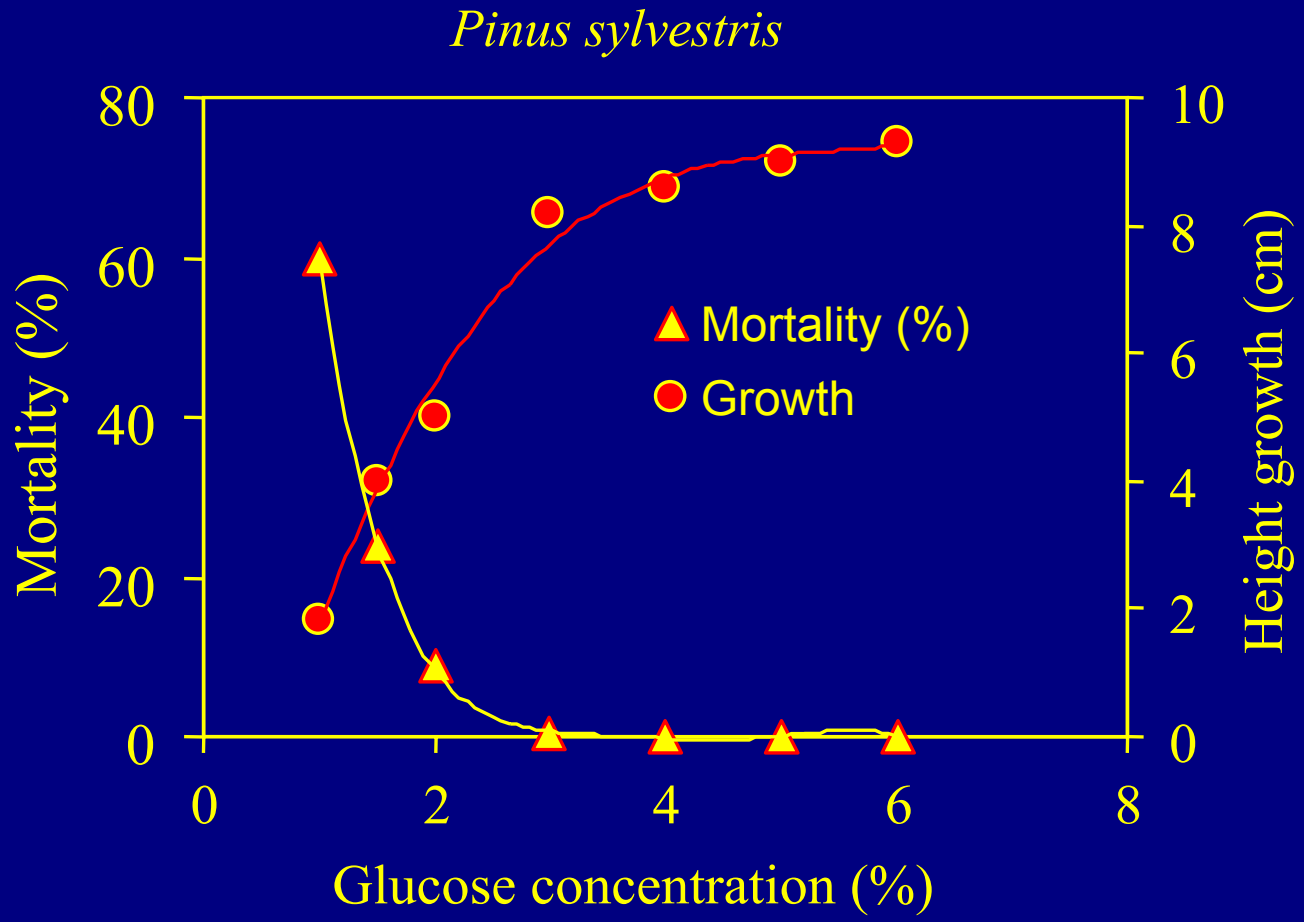


Oliet *et al*., 1997 Cuadernos Soc. Española C. For.4:69-79



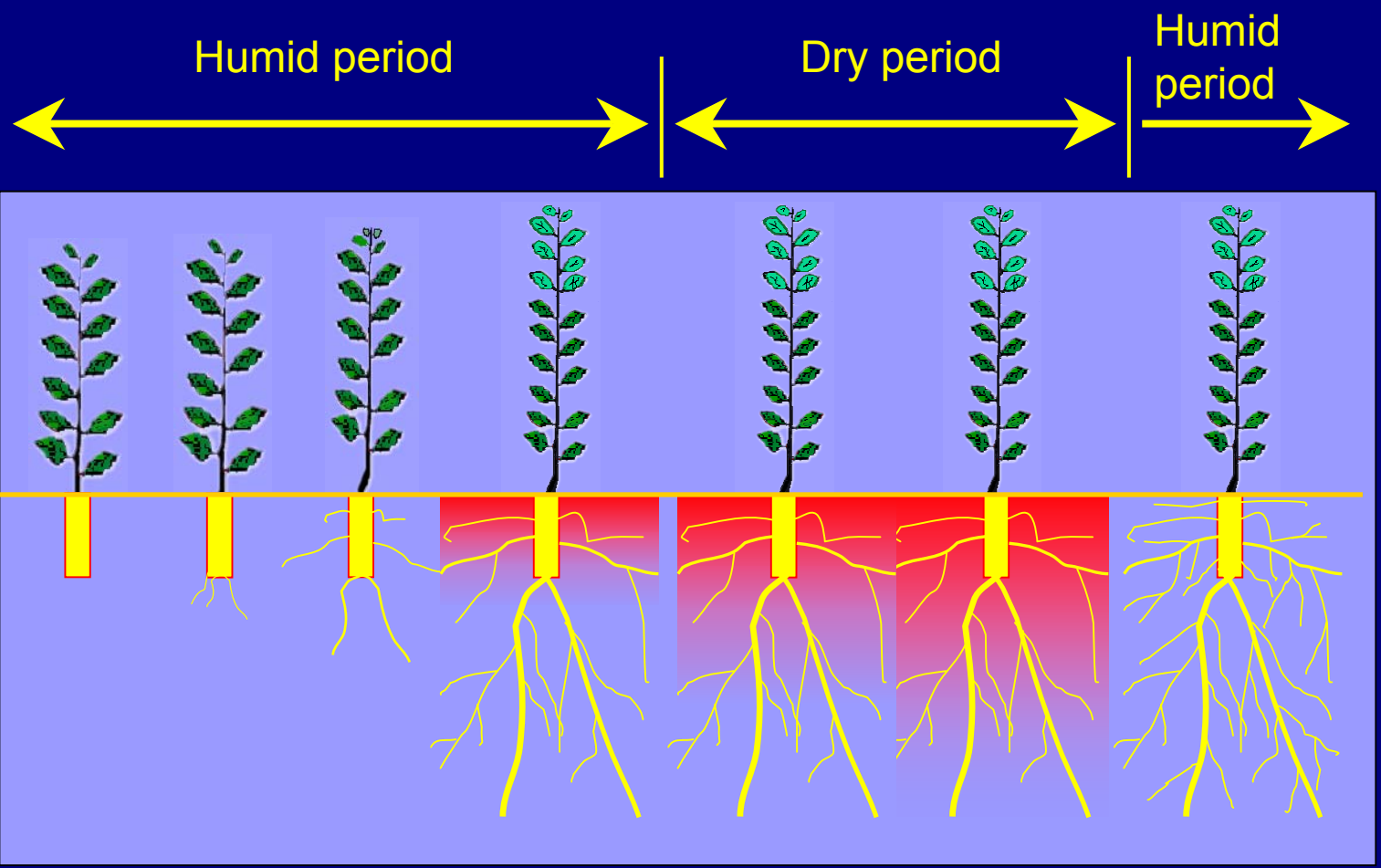
Van den Driessche, R. (1980). Can. J. For. Res. 10:65-70

Storage carbohydrates and out-planting performance



Puttonen, 1997 Scan. J. For. Res. 1:181-193

Why do large plants and with high nutrient content have better out-planting performance? A mechanistic explanation



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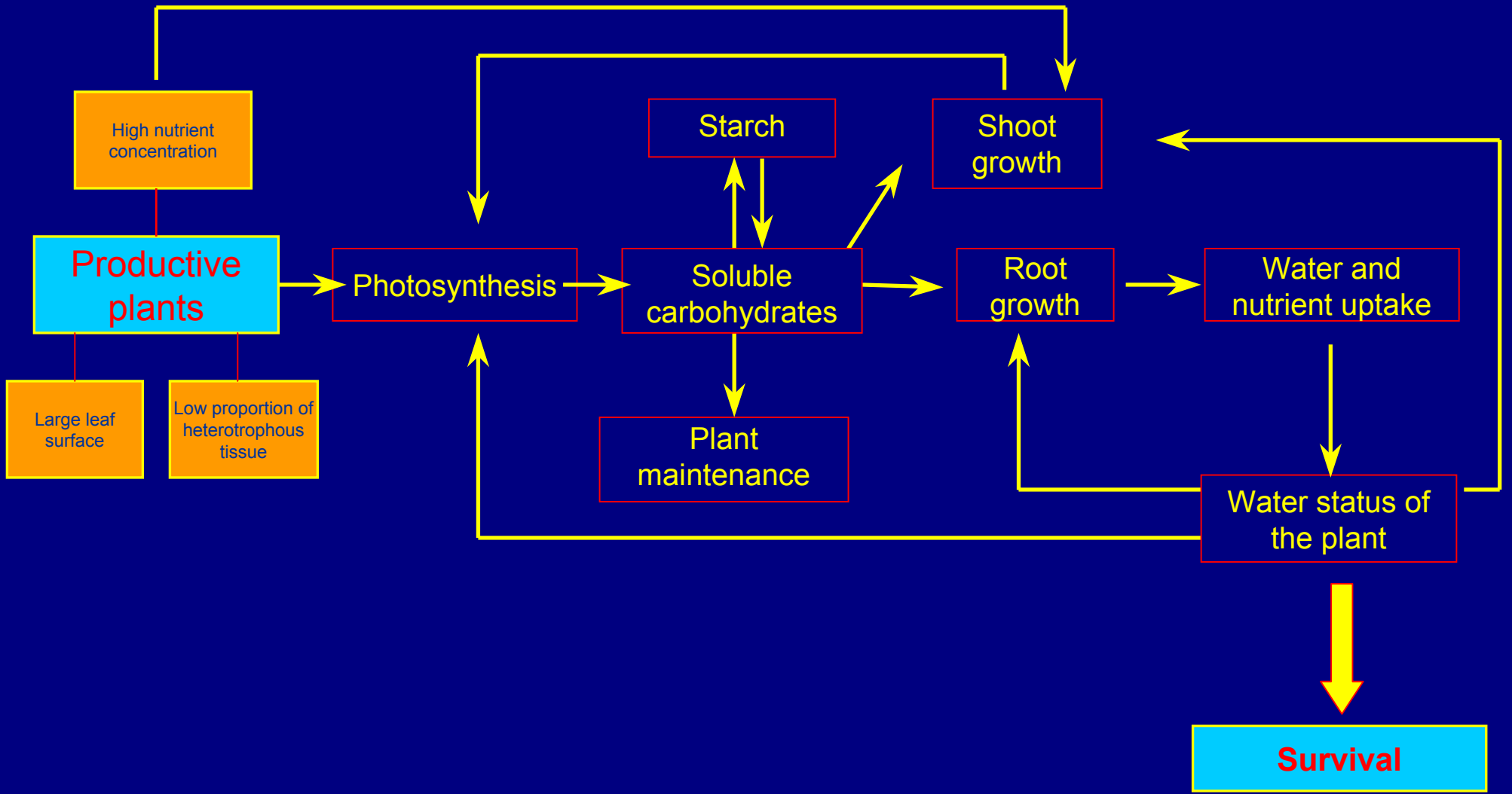


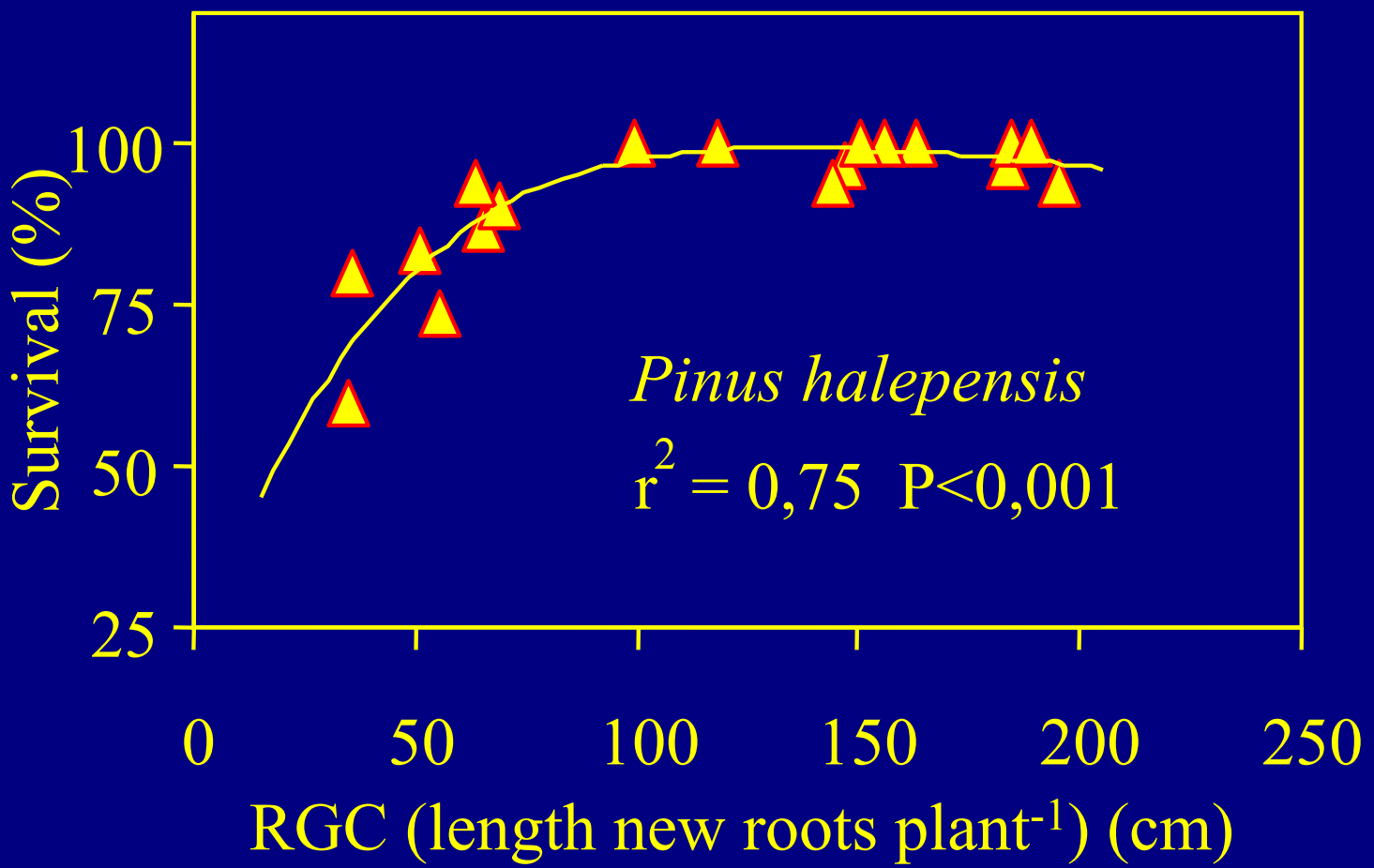
Performance attributes

They measure the response of plants when subjected to specific conditions

- Root growth potential (root growth capacity)
- Frost resistance
- Desiccation resistance

Disadvantage: are expensive in comparison with morphological attributes, most are time consuming and in some cases personnel involved in their determination need a qualified training

Performance attributes: root growth capacity



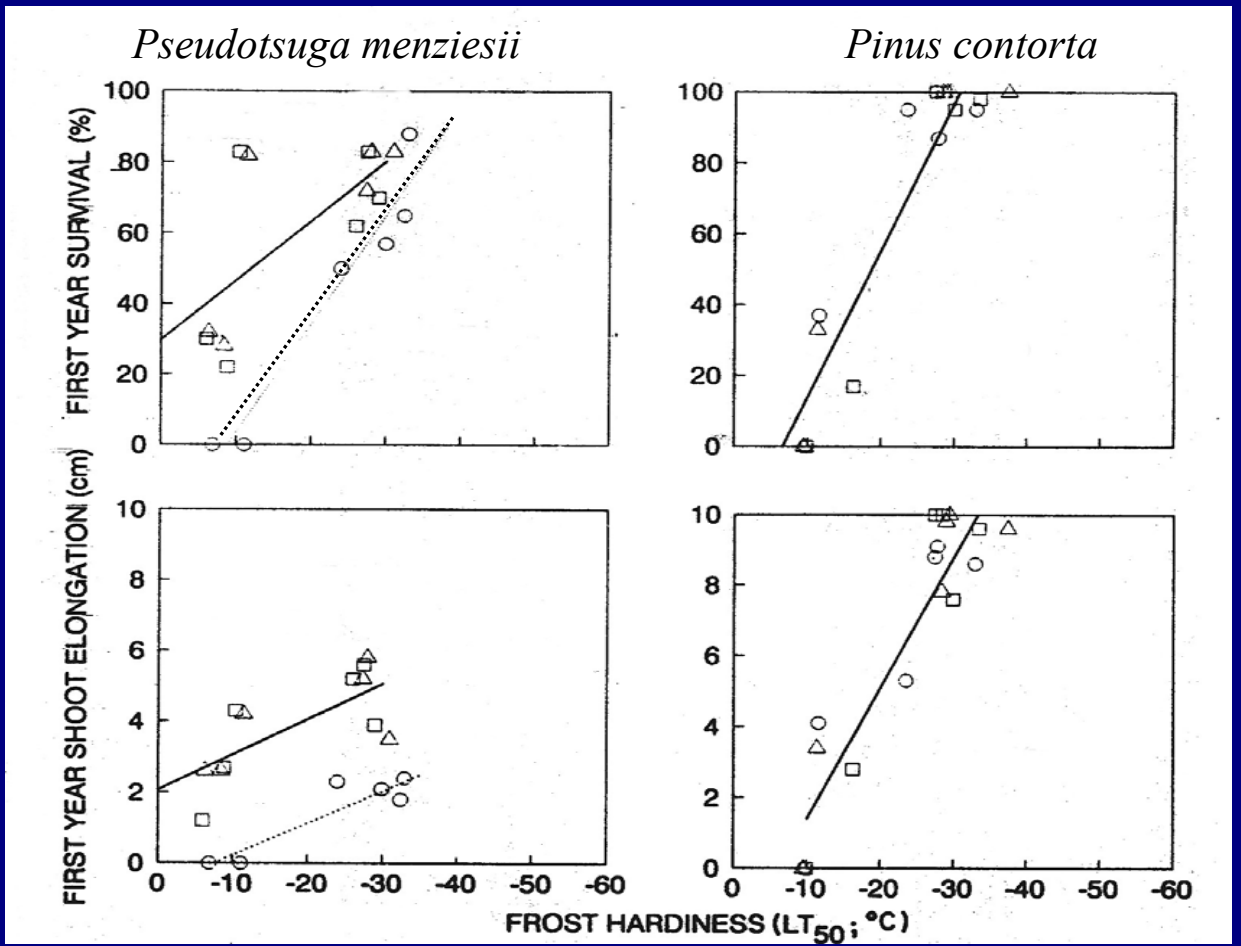
Performance attributes: frost resistance

Plants are frozen and their viability tested:

-electrolyte leakage

-visual damage score

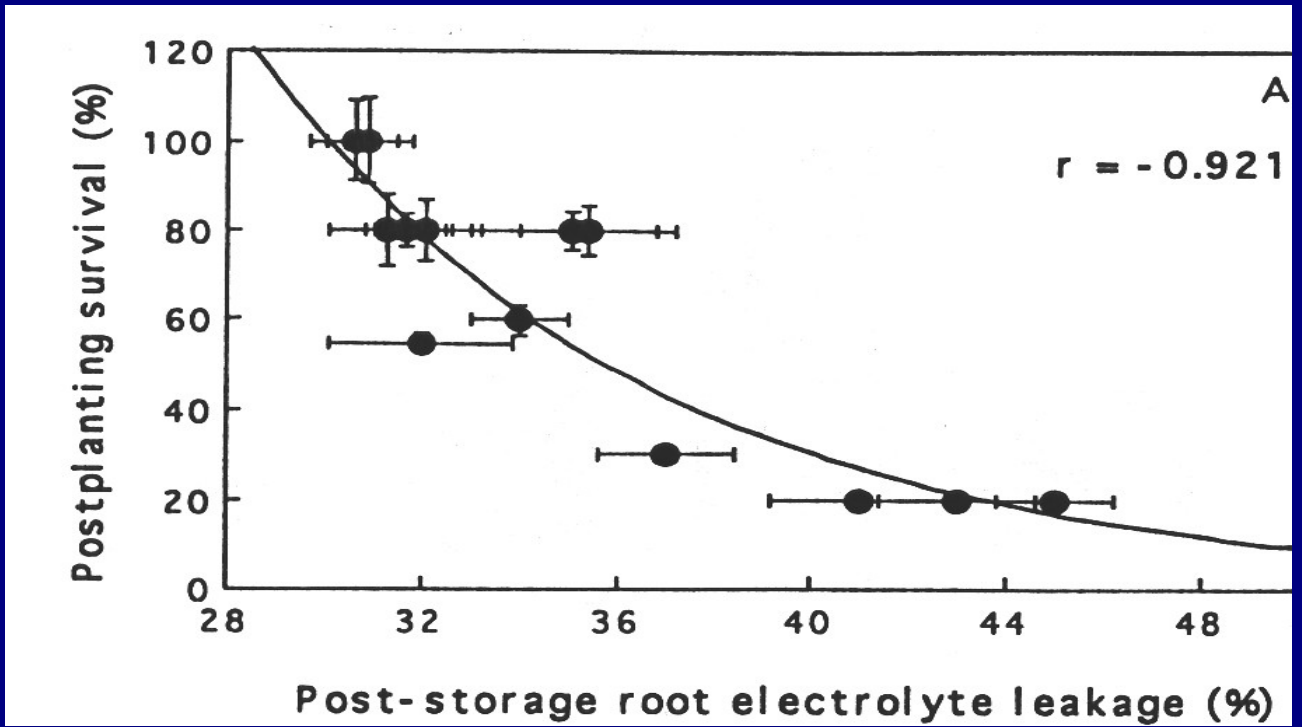
-chlorophyll fluorescence



Simpson, D. (1990) Can. J. For . Res. 20:566-572

Performance attributes: drought resistance

Plants are subjected to a specific level of drought and then their viability tested: mainly by electrolyte leakage



Mena-Petite et al. (2001). Trees. Structure and Function 15:289-296

Some take-home messages about the predictive capacity of plant quality attributes

It is impossible to predict the exact out-planting survival and growth of seedlings

Performance attributes

1) Tell us if seedlings are damaged: this allows to distinguish plant lots with high death probability

2) Tell us if seedlings are resistant to stress factors

3) Tell us about the potential out-planting performance (specially growth) of plants and therefore it permits to classify plant lots

Morphology, nutrient concentration and most material attributes tell us about the potential out-planting performance of plants IF THESE ARE NOT DAMAGED

The best case for plant quality assessment is to characterize plant morphology, nutrtional status and complement it with any performance attribute

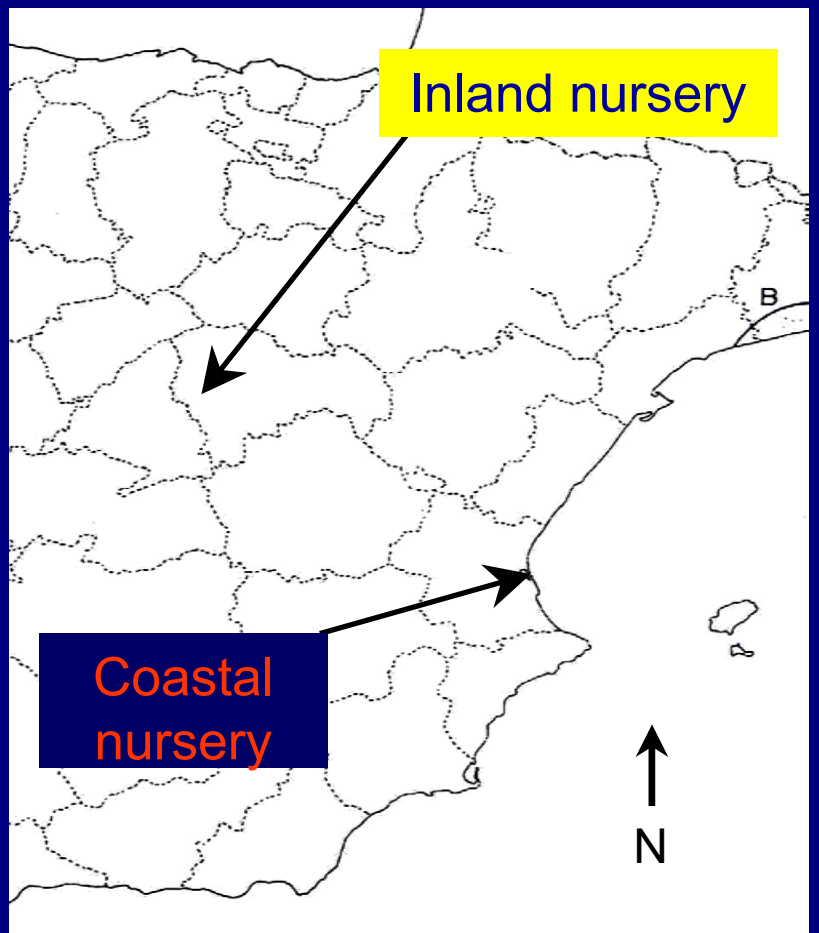
Factors that determine plant quality

- Growing conditions in the nursery

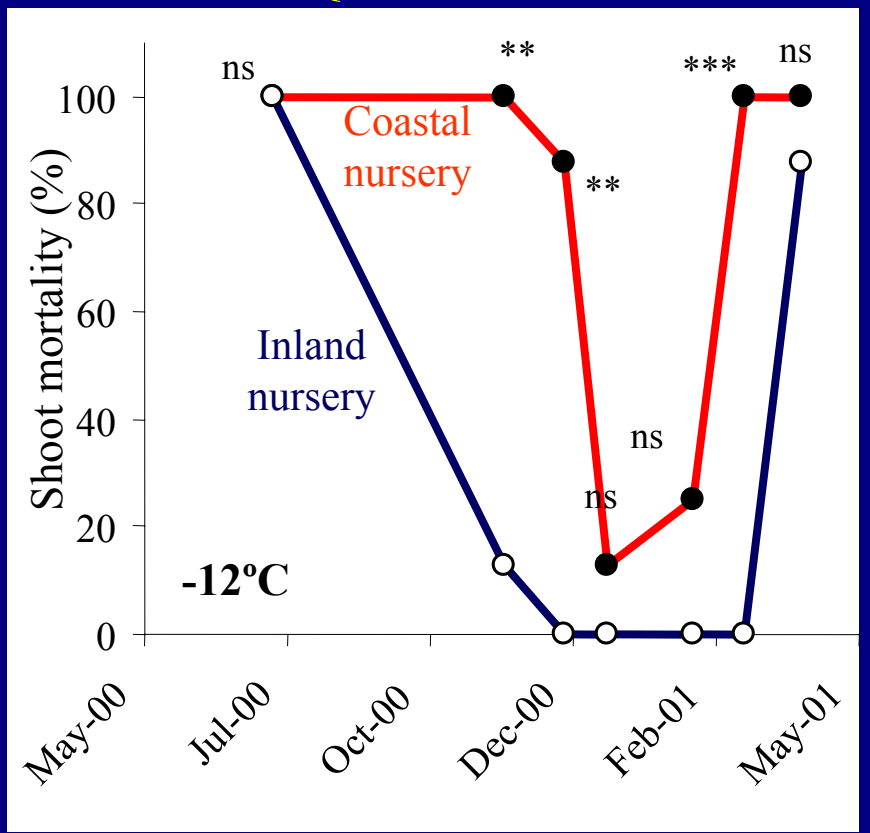
FERTILIZATION	Determines plant morphology and nutrient concentration. Fertilization should be moderate to high
CONTAINER	1) Volume >250 mL 2) plant spacing <250 plants m^{-2} 3) Container height: must be high in species with tap root
IRRIGATION	1) Quality of water 2) Amount of water
GROWING MEDIUM	Plant morphology and nutrition
SHADING	Excessive in shade in shade intolerant species can reduce quality

Factors that determine plant quality

- Nursery location: it is important when winter conditions differ between nurseries



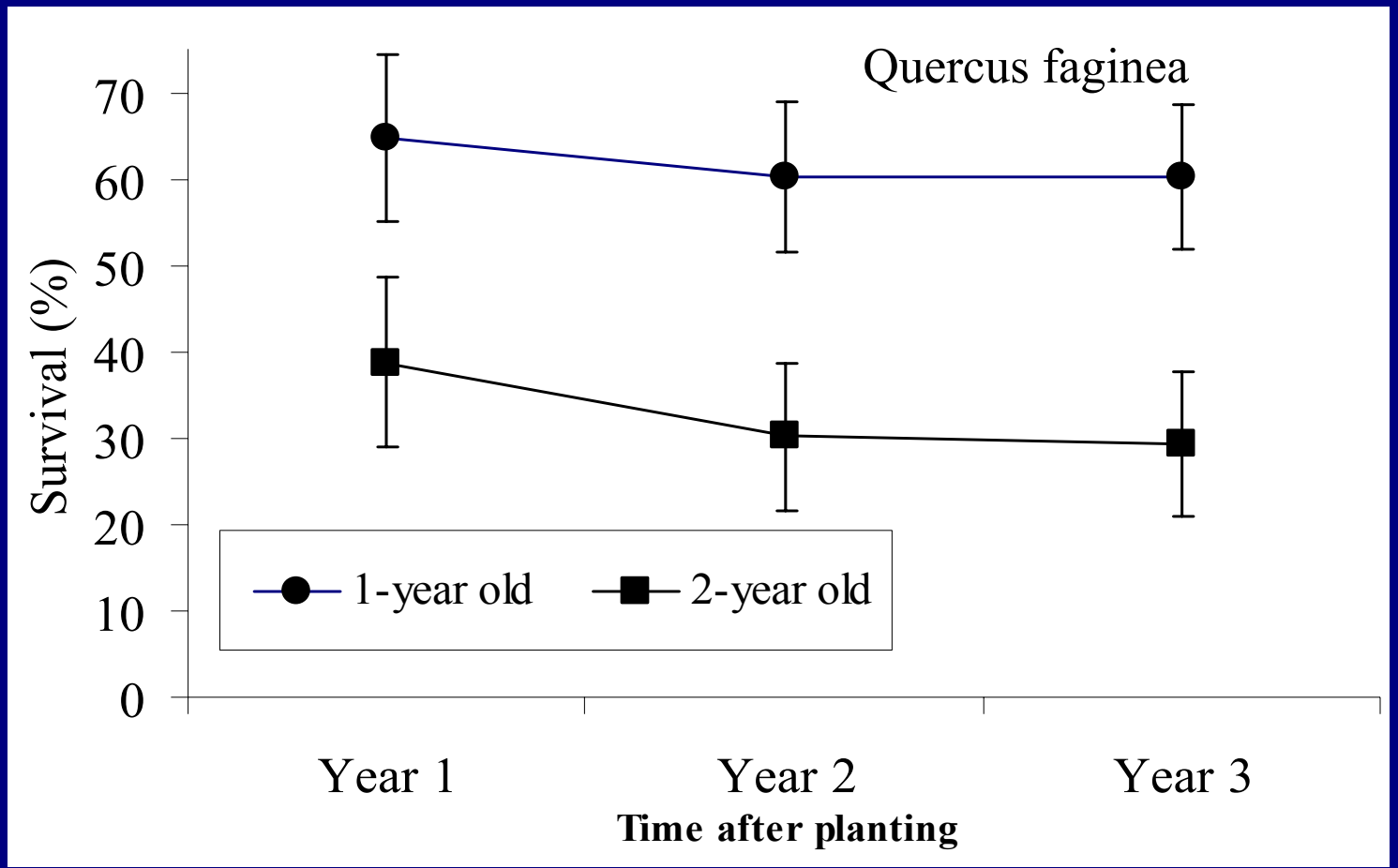
Quercus ilex



Mollá et al. (unpublished data)

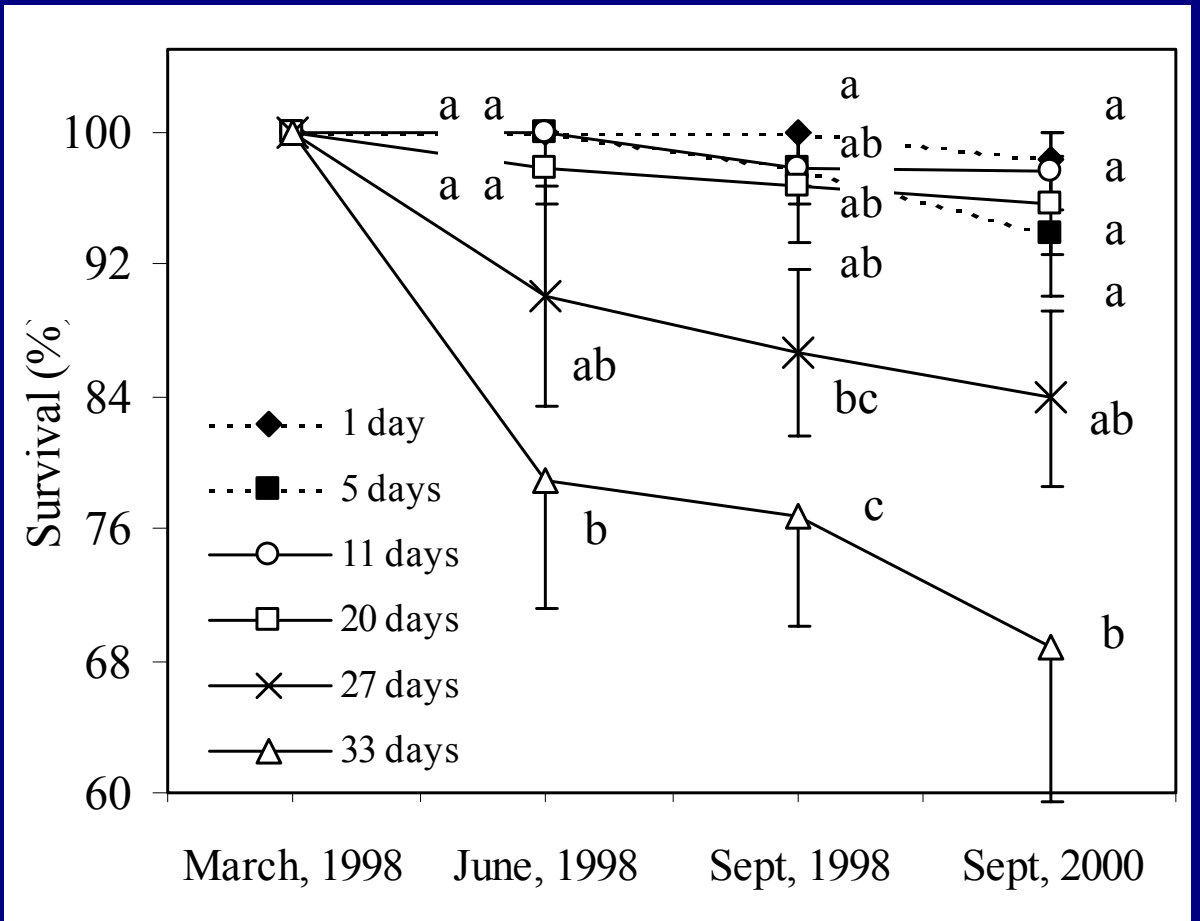
Factors that determine plant quality

- Plant age: 1-year old seedlings tend to perform better than 2-year old plants



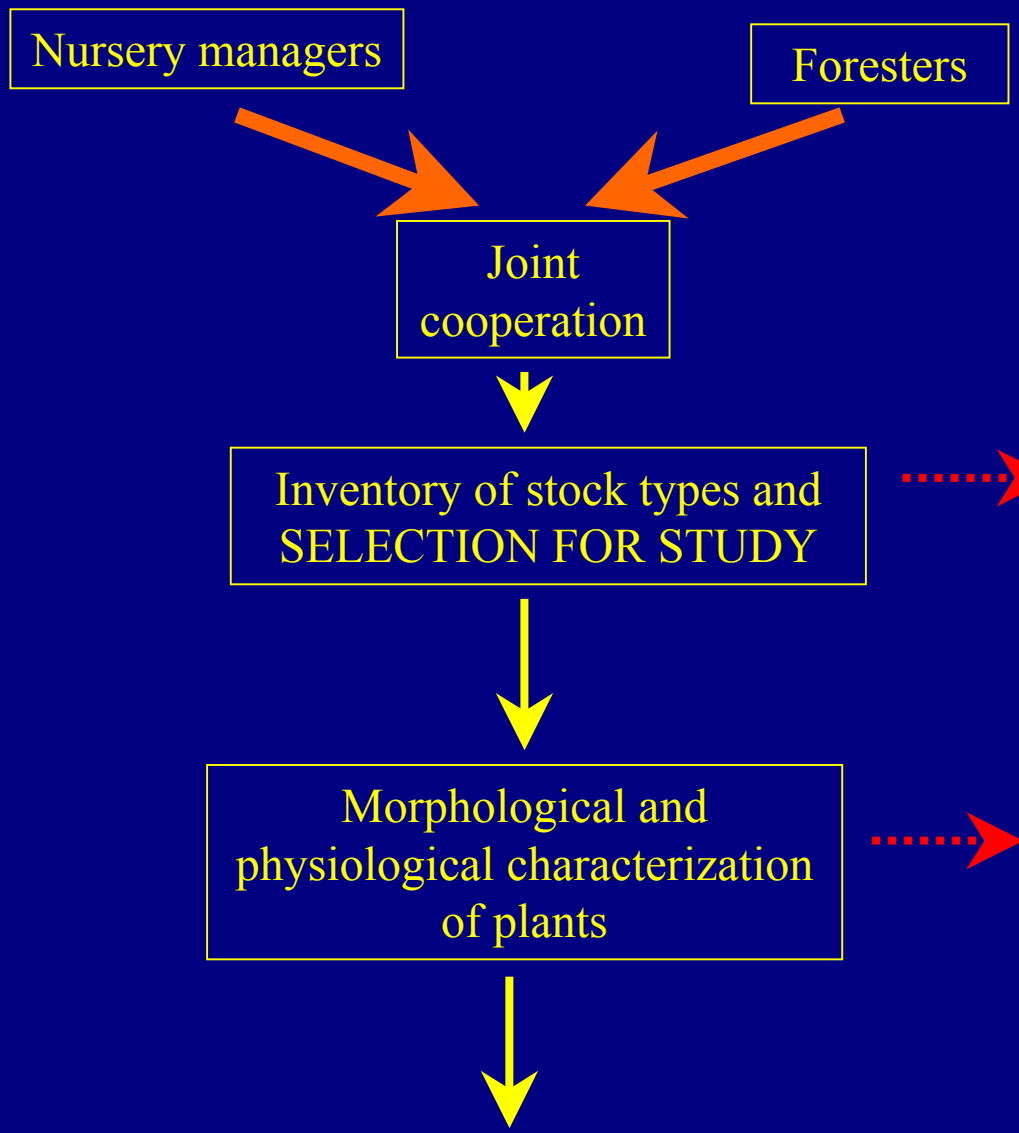
Factors that determine plant quality

Transport, plant storage and rough handling



Pinus halepensis

HOW TO IMPLEMENT A PLANT QUALITY PROGRAM



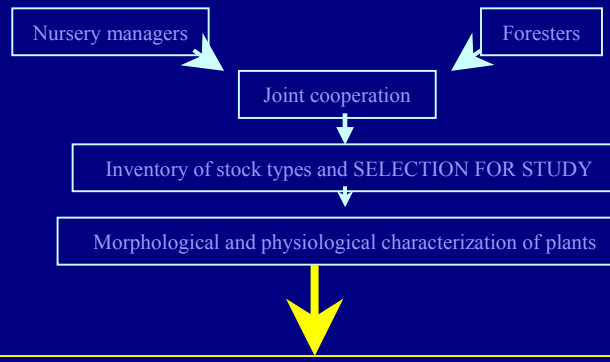
From each stock type we must know

1. Provenance of reproduction material
2. Cultivation conditions (fertilization, container, irrigation, plant age, environmental conditions, etc.)
3. Sanitary status

From each stock type

1. Sample randomly 100 plants for MORPHOLOGY: height, diameter, and shoot and root mass
2. Separate the 100 plants in at least 5 groups and measure NUTRIENT CONCENTRATION (N, P, K, Fe, Mg, Ca, Mn)
3. Carry out at least one PERFORMANCE ATTRIBUTE TEST: frost test

1. Plant in three contrasted environments
2. Use 100 plants /stock in each environment, distributed in at least 5 repetitions
3. Planting personnel must be professional and motivated with the study. Use the same personnel for planting all stock types in the three environments
4. Soil preparation must be the same in all places
5. Remove competing/facilitating plants in the experimental plots



Make plantations with each stock type

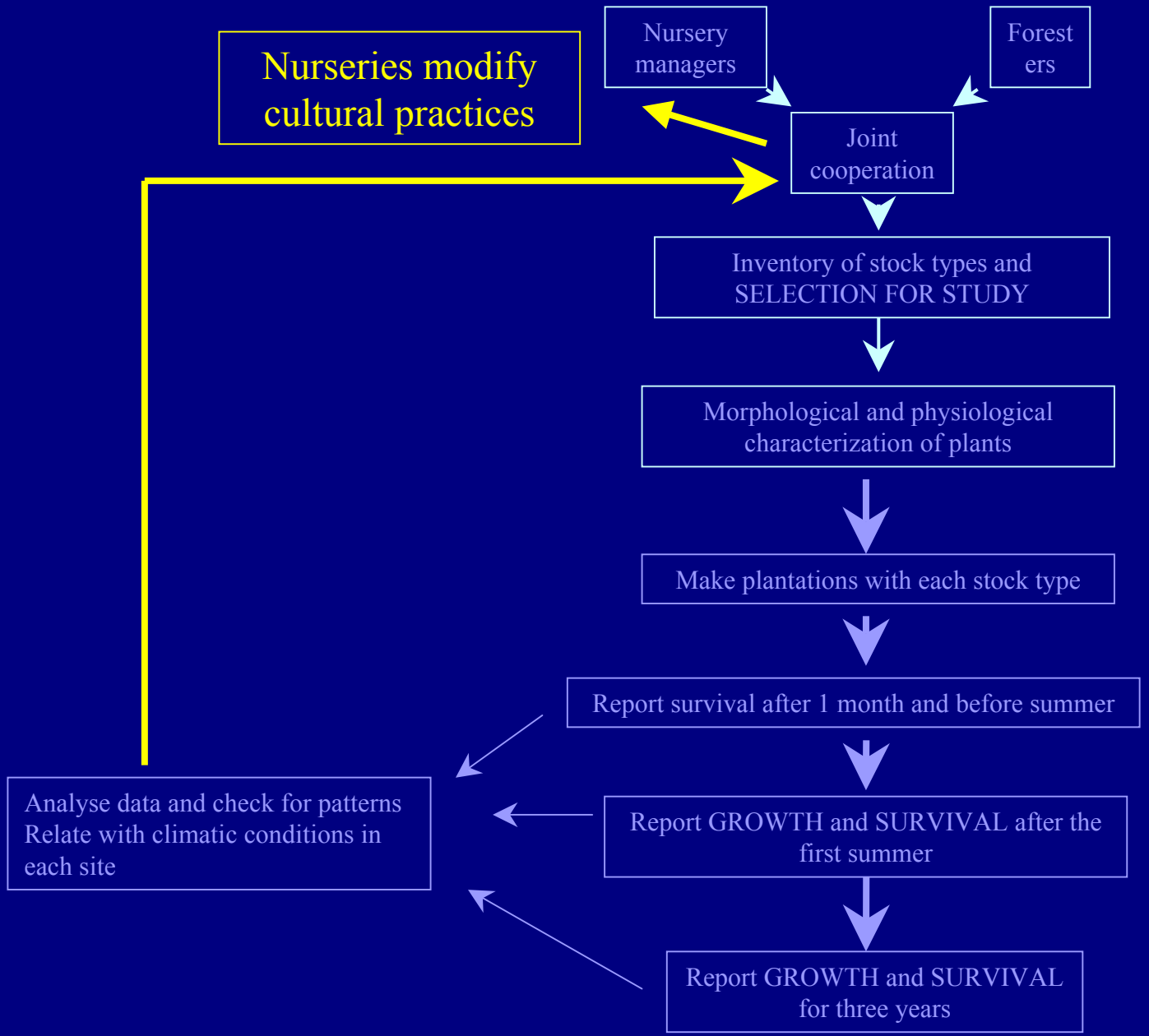
Report survival after 1 month and before summer

Report GROWTH and SURVIVAL after the first summer

Report GROWTH and SURVIVAL for three years

-Analyse data and check for patterns

-Relate with climatic conditions in each site


Nurseries modify cultural practices
Nursery managers
Forest ers
Joint cooperation
Inventory of stock types and SELECTION FOR STUDY
Morphological and physiological characterization of plants
Make plantations with each stock type
Report survival after 1 month and before summer
Report GROWTH and SURVIVAL after the first summer
Report GROWTH and SURVIVAL for three years
Analyse data and check for patterns Relate with climatic conditions in each site