Seedling nutrient loading to improve planting success. A Mediterranean perspective

• Juan A. Oliet (juan.oliets@upm.es)
  Universidad Politécnica de Madrid. SPAIN
• Jaime Puértolas Simón. Lancaster University
• Rosa Planelles González. Universidad Politécnica de Madrid
Content

1. Introduction
2. A Mediterranean perspective?
   Specificities about artificial regeneration in the Mediterranean
3. Importance of seedling nutrient status at planting in Mediterranean zones: why loading?
4. Nutrient loading in Mediterranean nurseries
5. Future research lines
Introduction
Afforestation in Spain from the 1940s to the 1980s led to more than 3 M of ha transformed to forests

Many highly degraded areas were afforested on harsh dry sites

Low nursery technologies and low seedling quality requirements

Soil erosion control and forest production improvement were main objectives
Introduction
Keystone aspects of the establishment success?:

- Mostly pines were used
- High planting densities guaranteed stand establishment
- Low labor costs permitted fails replacement from year to year
Changes from the 1980s to present:

- From soil erosion control to forests and other ecosystems restoration
- Much higher forestation costs
- Plant production in larger and centralized nurseries
- Needs to widen the pool of species
- Global change is the “dressing of every salads”, even more important in Mediterranean areas

The necessity to improve seedling quality clearly emerges …
...and there is room for improvements:

![Graph showing survival vs. [N] Needles (mg·g⁻¹) for two experiments: "El Caballón" and "El Toyo". The graph indicates a positive correlation between nitrogen content in needles and survival rate for both experiments.]

Even for pines species

*Pinus halepensis.*

(Oliet et al., 1997, 2009)
A Mediterranean perspective?

Specificities about artificial regeneration in the Mediterranean
Specificities about Mediterranean artificial regeneration

• Mediterranean climate
  – Strong summer drought preceded by unpredictable springs
Field constraints and facts: planting window. We must plant ASAP, from early fall rains to February.

- Seedlings must emit new roots in depth as soon as possible to avoid subsequent summer drought.
- Early frost after planting in fall can damage the seedlings.
Specificities about Mediterranean artificial regeneration

• Nursery production facts.
  Raising seedlings outdoors:
  – **Frosts** occur during fall in inland (continental) nurseries (*hidden death* of seedlings prior to plantation)
  – **Late growth** occurs during fall in mild (coastal) nurseries:

  ![Diagram of temperature and growth phases]

  **End of fall**
  **End of summer**

<table>
<thead>
<tr>
<th>Shoot</th>
<th>Root</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>4.5</td>
</tr>
<tr>
<td>2.0</td>
<td>5.5</td>
</tr>
</tbody>
</table>

  Andivia et al 2011, *Quercus ilex*
Importance of seedling nutrient status at planting in Mediterranean zones: why loading?
Photosynthesis activation to resume growth after planting is strongly related to nutrient (mostly N) status.

*Ceratonia siliqua*

- Photosynthesis activation to resume growth after planting
- Nutrient status: N

![Graph showing A (μmol m⁻² s⁻¹) for Ceratonia siliqua](graph_image)

- January: 30 mg/l N, 150 mg/l N, 250 mg/l N
- March: 30 mg/l N, 150 mg/l N, 250 mg/l N
- May: 30 mg/l N, 150 mg/l N, 250 mg/l N
- August: 30 mg/l N, 150 mg/l N, 250 mg/l N
- November: 30 mg/l N, 150 mg/l N, 250 mg/l N

*(Planelles 2004)*
Why loading in Mediterranean zones?

- Nitrogen loaded seedlings of sclerophyllous species increase stomatic conductance after planting.

![Graph showing stomatal conductance for Quercus ilex](image)

(Quercus ilex)

(Oliet et al. unpub data)
• A large body of evidence shows how nitrogen loaded seedlings survive better under very dry conditions.

Why loading in Mediterranean zones?

- Oliet et al. 2006

\[ \text{Survival (\%)} \quad \text{Leaf [N] (mg/g)} \]

\[ \text{Zizyphus lotus} \]

Oliet et al. 2006
• Is only nitrogen? **Phosphorus** loaded seedlings also show a superior response after planting

![Graph showing the relationship between P supplied and survival/root DW](image)

**Acacia salicina**

*Oliet et al. 2005*
**Cold resistance** of seedlings in both nursery and plantations can be critical. Cold resistance is closely related to nutrient (mostly N) status.

![Graph showing visual damage of different species under varying nitrogen levels and temperatures.](image)

- **E. globulus (-6°C)**
- **Q. ilex (-8°C)**
- **Q. ilex (-10°C)**
- **Q. ilex (-14°C)**

- **Pinus halepensis**

Interaction N × environment on frost resistance

Puértolas et al. 2005

Fernández et al. 2007

Andivia et al., 2011
How can we nutrient load our seedlings in Mediterranean nurseries?
• Is exponential regime effective in nutrient loading every species?
Nutrient loading in Mediterranean nurseries

- Oak species like *Quercus ilex* exhibits a rhythmic growth pattern in the nursery:

Several active growth periods are followed by lag stages. Those intervals are not synchronized.

Roots still grow during late fall.
How nutrient availability during growth affects ontogeny of species with rhythmic growing pattern (*Quercus ilex*):

1. Higher synchronicity for highly fertilized seedlings during second lag
2. More seedlings reaching advanced stages in ontogeny

Nutrient loading in Mediterranean nurseries

Vizcaíno et al. In preparation
• Potential ability of exponential regime to nutrient load species with growth patterns at intervals is very low

*Quercus ilex* (Oliet et al. 2009)
• **Controlled release fertilizers** are a good alternative to nutrient load seedlings by using high rates with high fertilizer recovery.

![Graph](image)

**Pinus halepensis**

Oliet et al 1999
CRF provide nutrients till late fall to avoid nutrient dilution.

**Nutrient loading in Mediterranean nurseries**

- Electrical conductivity
- Nitrate concentration
- Stem volume
- Pinus halepensis

Oliet et al 2004
Nutrient dilution during fall occurs precluding nutrient loading. Is fall fertilization a solution?

Fall fertilization promotes growth ...

... but also nutrient loading

---

**Pinus halepensis**

Puértolas et al unpub data
Nutrient loading in Mediterranean nurseries

- **Early** fall fertilization is more effective to load Holm oak, specially with P

Oliet et al. 2011
Fall fertilization is an adequate strategy to nutrient load these species (Holm oak)
Future research

• Developing fertilization programs for Mediterranean species of interest to reach effective nutrient loading:
  – Improve the knowledge of specific growing patterns in the nursery
  – Understand nutrient dynamics during hardening and fall (uptake and remobilization) to improve efficiency of late season fertilization
  – Improve knowledge of interactive relationships between cold acclimation, nutrient uptake and environment during hardening. Cold resistance of roots deserves special attention.
Thank you very much! ¡Muchas gracias!

Special thanks to people from: