Treeshelters : designing the perfect climate?

Christian Dupraz, INRA, France
Various concerns
A key observation:
Stem diameter growth unbalanced
Well, what’s wrong with treeshelters?
Early hypotheses about tree growth in treeshelters

- Main Hypothesis: excess of humidity
- Experiments in 1986 and 1987 (Cornwall & Mid England)
- Perforate tubes to increase ventilation, hence decrease humidity within the treeshelters.
- Disappointing: erratic results on growth
Experiment 1986 Cornwall

1.2 m Treeshelters

- **Control**
  - Mesh
  - Guard

- **Brown**
  - Plain
  - 12 holes
  - 6 mm
  - Base

- **Brown**
  - 30 holes
  - 6 mm
  - Base

- **Brown**
  - 30 holes
  - 6 mm
  - Length

- **White**
  - Plain
First ventilated treeshelters

Growth increments of Beech in various treeshelters after 1 and 3 growing seasons.

1 Year: significant difference bw Control (mesh guard) & Treeshelters

1986 Cornwall

No significant differences bw treeshelters.
Experiment 1987 Cornwall & Mid-England

1.2 m Treesheelters

Control
Mesh
Guard

Brown
Plain

Brown
4 holes
10 mm
Base

Brown
48 holes
10 mm
Base
First Ventilated treeshelters

1987 Cornwall and Mid-England – 3 growing seasons

Increased ventilation significantly improved the growth height of Beech.

![Height growth (cm) of Beech in Cornwall in various treeshelters.](image1)

- Good soil
  - Control: mesh guard

![Height growth (cm) of Beech in Mid England in various treeshelters.](image2)

- Poor soil
  - Control: unprotected tree
• But what if…. Height growth was NOT the key issue?

These experiments lack a key combination?

• This was the start of a long investigation
A long story .. in 7 papers


Long-term experiments on hybrid walnut trees

Standard unventilated brown 1.8 m tall treeshelters
Long-term experiments on hybrid walnut trees

Portiragnes experiment, France

Standard unventilated brown 1.8 m tall treeshelters
Key finding 1

Early DBH growth more important than early height growth
Impact of treeshelters on the root/shoot balance

<table>
<thead>
<tr>
<th>Année</th>
<th>Auteur</th>
<th>Site</th>
<th>Essence</th>
<th>Proportion de biomasse souterraine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Témoins</td>
</tr>
<tr>
<td>1988</td>
<td>Dupraz, données inédites</td>
<td>Montpellier, conteneurs</td>
<td>Merisier</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Noyer commun</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Noyer noir</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Noyer hybride</td>
<td>73</td>
</tr>
<tr>
<td>1989</td>
<td>Bergez, 1993</td>
<td>Montpellier, conteneurs</td>
<td>Merisier</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Noyers hybrides</td>
<td>85</td>
</tr>
<tr>
<td>1990</td>
<td>Bergez, 1993</td>
<td>Montpellier, conteneurs</td>
<td>Merisier</td>
<td>57</td>
</tr>
<tr>
<td>1991</td>
<td>Bergez, 1993</td>
<td>Montpellier, pleine terre</td>
<td>Merisier</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Noyer commun</td>
<td>83</td>
</tr>
<tr>
<td>1991</td>
<td>Cemagref données inédites</td>
<td>Montoldre, (Allier) pleine terre</td>
<td>Merisier</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Noyer commun</td>
<td>82</td>
</tr>
<tr>
<td>1992</td>
<td>Balandier et al, 1995</td>
<td>Montoldre (Allier) pleine terre</td>
<td>Merisier</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Noyer commun</td>
<td>79</td>
</tr>
</tbody>
</table>

**Moyenne**

<table>
<thead>
<tr>
<th></th>
<th>Merisier</th>
<th>Noyers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Témoins</strong></td>
<td>58</td>
<td>37</td>
</tr>
<tr>
<td><strong>Abrités</strong></td>
<td>79</td>
<td>63</td>
</tr>
</tbody>
</table>

Abris de 120 cm, standards (non ventilés)

20% shift of the total biomass to the aboveground biomass in treeshelters
Key finding 2

Root deficit with
treeshelters
Transpiration rate of *Prunus avium* L. seedlings inside an unventilated treeshelter

J.-E. Bergez ¹, C. Dupraz ²
Trees in treeshelters… save a lot of water!
While their stomata are wide open
Tree Leaf temperature very close to air temperature in treeshelters
Very small VPD in treeshelters
But the key finding is:

Unventilated treeshelter with a wild cherry tree
But the key finding is: extremely fast Air CO$_2$ depletion

Unventilated treeshelter with a wild cherry tree
Key finding 3

Photosynthesis impeded by lack of CO$_2$
Fig. 1. Design and set-up of the treeshelters used in experiments A, B and C.
Photo 1 : Dispositif expérimental de Notre-Dame de Londres (Hérault) sur merisier : comparaison de différentes modalités d’abris-serres modifiés en luminosité et aération sur la croissance des arbres
Air temperature cooling by the chimney effect

Les températures sont mesurées à 80 cm de hauteur dans les abris
Tree transpiration stimulation by the chimney effect
Improved photosynthesis at low radiation levels in treeshelters

Fig. 5. Net assimilation flux density of *Prunus avium* leaves versus available radiation for sheltered and control trees. Day: 4 July; Air temperature: 26.5°C; Relative humidity: 38%; [CO2]: 360 μl l⁻¹.
Tree photosynthesis stimulation by the chimney effect

Fig. 4. Diurnal variations of CO₂ concentration inside different types of treeshelters. Data recorded on 4 September 1991 at mid-canopy height.
Key finding 4

When CO$_2$ is back, more light is useful
Ventex
Equilibre
Treeshelter
Prunus avium (cv Monteil)

NSW : No Shelter and wind
S : Ventilated Shelter

Shoots

Roots
Fig. 1. The experimental device for bending sheltered trees. (A) View of the SB treatment. (B) The stem inside the shelter is attached to two fixed points and a moving arm piloted by an air-pressurised piston imposes a lateral displacement, which results in the bending of the stem.
Prunus avium (cv Monteil)

Fig. 6. Biomass partitioning between shoots and roots before and after treatments, expressed as a percentage of the total biomass of the tree.
Key finding 5

Stem swinging and bending by wind is important

The sooner the tree emerges from the shelter, the better. So height growth is important
Ventilation failures

- When water stress is too high
- When light availability is too reduced
- When the seedlings emerge from the shelter very early or from the start
Light transmission of visible light of 4 twin walled treeshelters

Light green colour provides:

- High light transmission close to non pigmented tube (Photosynthesis),
- Good mix of blue and red radiation for the Photo Active Radiation while keeping the tubes green for blending in the fields.
- Red/Far Red =0.94 (Photomorphogenesis).
**Standard**

- $T_{in} > T_{out}$
- Insolation
- Insulation
- No convection

- $RH_{in} > RH_{out}$
- VPD* decrease as moisture increases in the tube due to transpiration, no convection.

**Ventilated**

- $T_{in} = T_{out}$
- Convection

- $RH_{in} = RH_{out}$
- Moisture equilibrium

*Summer Day time*
Transpiration of a tree

- Sun
- Controlled flow
- CO$_2$ > 300 ppm

Chimney Holes

Transpiration

Outside

Ventex

Standard
Temperature due to air flow

Air flow increases with sunlight.

Tree is in good harmony with Heat / moisture / CO₂

Dupraz C., Bergez J.E., Amelioration de protections individuelles d’arbres a effet de serre. Patent 9204295.1, February 1992
See also USA study: B. R. Swistock, K.A. Mecum, W.L. Sharpe, Summer temperatures inside ventilated and unventilated brown plastic treeshelters in Pennsylvania, NJAF, 1999, 16(1), 7-10.
Standard

Minimum CO₂
Excess H₂O

Ventilated

Optimum CO₂
Good H₂O

Over ventilated

Maximum CO₂
Low H₂O

H₂O

CO₂
Ventex and walnut tree

Stem growth in diameter (1/10 mm)

- Ventex
- Montoidre (Allier)

Standard TS
Control
Tubex Ventex

1 year
2 year
3 year
Ventex and red oak

3rd year emergence

- Standard TS
- Control
- Tubex Ventex

Stem growth in diameter

30  40  50  (0.1 mm)
New Beech Shelters

- Transparent
- White
- White Ventex
- Light green
- Upper Ventilated
Take home messages

- Early Diameter growth is more important than early height growth
- \( \text{CO}_2 \) is more important than humidity
- Light is required when \( \text{CO}_2 \) is available
- Stem movement is the ultimate challenge
Take home message

- Never use unventilated shelters if the tree canopy spends more than 2 growing seasons fully inside the shelter.

- With unventilated shelters,
  - the short term positive impact on height growth is deceptive.
  - the long term impact on DBH growth is negative.
Vielen Dank für Ihre Aufmerksamkeit
https://agroforestry2019.cirad.fr/