NON INVASIVE VITALITY EVALUATION OF TREE SEEDS (*Fagus sylvatica* L.) BY MEANS OF MAGNETIC RESONANCE IMAGE ANALYSIS

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ISTA basic tests

- Germination
- Tetrazolium

Pinus mugo var. uncinata Mill. ex Mirb.

Abies alba Mill.
Other analysis for seed testing quality/1

• X-Ray test

quick, non destructive

but expensive,

and...precautions

against radiation are required
Other analysis for seed testing quality/2

- Excised embryo test (EET)

  destructive

  preparation time consuming

  quite long (from 5 to 14 dd)
Innovative analysis for testing seed quality

Magnetic Resonance Imaging (MRI)

Human health

Food (kiwi)
Why Magnetic resonance imaging?

- A lot of information
- Fast
- Non-invasiveness
- Small lots of rare and wild species
- Dormant seed
- Species with difficult tetrazolium preparation
MRI images with different weighed factors

*Jatropha curcas* L. axial image

*T₂* weighed image

*Jatropha curcas* L. sagittal image

Cotyledons
Information from MRI

Double embryos (Beech)

Empty seed (Fir)

Seed coat

Empty seed
Fruits and seeds

A. alba Mill.

T₂ weighed MRI image 4 layers
Jatropha curcas L.

Leaves, fruits and seeds

MRI applied to tree seed species/2

J. curcas L.

T₂ weighted MRI image
Fagus sylvatica L. seed structure

T₂-weighted MRI image of Fagus sylvatica seed

Seed coat
Cotyledons
Viable vs non-viable *Fagus sylvatica* L. seeds

- **Viable**
  - Evidence of internal structure

- **Non-viable**
  - No evidence of internal structure

Dead embryo
Viable *Fagus sylvatica* L. seeds
Non-viable *Fagus sylvatica* L. seeds
Materials & Methods

KS-400 V3.0 - Carl Zeiss Vision
(KLic program language)

Macro MRI Fagus.mcr

8 Densitometric features
22 Textural features
Materials & Methods

Original image  Threshold image  Segmented image  Contour image
Materials & Methods

3D densitometric image

Histogram of grey levels
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LDA

SPSS Ver.16.0 Software
30 densitometric/textural features

Measured features

Seed grouping

Discriminant functions

Training Set (known)  Test Set (unknown)
### Materials & Methods

Percentages of correct identification. In brackets the number of seeds

<table>
<thead>
<tr>
<th></th>
<th>Viable seeds</th>
<th>Non viable seeds</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viable seeds</td>
<td><strong>98.2% (110)</strong></td>
<td>1.8% (2)</td>
<td>100% (112)</td>
</tr>
<tr>
<td>Non viable seeds</td>
<td>2.6% (2)</td>
<td><strong>97.4% (74)</strong></td>
<td>100% (78)</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td><strong>97.9% (180)</strong></td>
</tr>
</tbody>
</table>

5 Steps
5 Features
1 Discriminant function 100% statistical variability
## Materials & Methods

### Densitometric features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
<th>Haralick Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_{\text{mean}}$</td>
<td>Density Mean value</td>
<td>$\text{Har4}$</td>
<td>Sum of squares value</td>
</tr>
<tr>
<td>$D_{\text{sd}}$</td>
<td>Density std. deviation</td>
<td>$\text{Har4}_{sd}$</td>
<td>Haralick feature 4 standard deviation value</td>
</tr>
<tr>
<td>$D_{\text{min}}$</td>
<td>Density minimum value</td>
<td>$\text{Har5}$</td>
<td>Inverse difference moment value</td>
</tr>
<tr>
<td>$D_{\text{max}}$</td>
<td>Density maximum value</td>
<td>$\text{Har5}_{sd}$</td>
<td>Haralick feature 5 standard deviation value</td>
</tr>
<tr>
<td>$S$</td>
<td>Skewness</td>
<td>$\text{Har6}$</td>
<td>Sum average value</td>
</tr>
<tr>
<td>$K$</td>
<td>Kurtosis</td>
<td>$\text{Har6}_{sd}$</td>
<td>Haralick feature 5 standard deviation value</td>
</tr>
<tr>
<td>$H$</td>
<td>Energy</td>
<td>$\text{Har7}$</td>
<td>Sum variance value</td>
</tr>
<tr>
<td>$D_{\text{sum}}$</td>
<td>Density sum</td>
<td>$\text{Har7}_{sd}$</td>
<td>Haralick feature 5 standard deviation value</td>
</tr>
</tbody>
</table>

### Haralick textural features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
<th>Haralick Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Har1}$</td>
<td>Angular second moment value</td>
<td>$\text{Har9}$</td>
<td>Entropy value</td>
</tr>
<tr>
<td>$\text{Har1}_{sd}$</td>
<td>Haralick feature 1 standard deviation value</td>
<td>$\text{Har9}_{sd}$</td>
<td>Haralick feature 5 standard deviation value</td>
</tr>
<tr>
<td>$\text{Har2}$</td>
<td>Contrast value</td>
<td>$\text{Har10}$</td>
<td>Difference variance value</td>
</tr>
<tr>
<td>$\text{Har2}_{sd}$</td>
<td>Haralick feature 2 standard deviation value</td>
<td>$\text{Har10}_{sd}$</td>
<td>Haralick feature 5 standard deviation value</td>
</tr>
<tr>
<td>$\text{Har3}$</td>
<td>Correlation between horizontal and vertical transition value</td>
<td>$\text{Har11}$</td>
<td>Difference entropy value</td>
</tr>
<tr>
<td>$\text{Har3}_{sd}$</td>
<td>Haralick feature 3 standard deviation value</td>
<td>$\text{Har11}_{sd}$</td>
<td>Haralick feature 5 standard deviation value</td>
</tr>
</tbody>
</table>
## Materials & Methods

<table>
<thead>
<tr>
<th>Used Feature</th>
<th>F to Remove value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kurtosis</td>
<td>68.592</td>
</tr>
<tr>
<td>Har7</td>
<td>45.183</td>
</tr>
<tr>
<td>Har4</td>
<td>39.893</td>
</tr>
<tr>
<td>Har4$_{sd}$</td>
<td>27.630</td>
</tr>
<tr>
<td>Har1$_{sd}$</td>
<td>8.774</td>
</tr>
</tbody>
</table>
Materials & Methods

Non viable seeds

Viable seeds
Magnetic Resonance Imaging

- **Disadvantages**
  - Expensive instruments;
  - complicated and expensive maintenance;
  - low sensibility;
  - specialized personnel necessary

- **Advantages**
  - Non destructive analysis;
  - relatively quick technique;
  - a lot of information from a single measurement;
  - complementary to the other NDT in use;
  - different weighting factors can be used allowing several measurements,
  - a single measurement for testing a lot of seeds
Conclusions

MRI technology:

1. Could be used as a new method among the ISTA seed testing methods;
2. More research on this application is necessary for standardization;
3. Joint working with MRI technicians to improve the method is also necessary;
4. In the future cheaper MRI technology and instrumentation will be available
And about the costs....

- Wright Brothers
- Mobile
Acknowledgements

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