Root architecture and anchorage: what we learned from maritime pine on sandy soils in the Landes forest

Frédéric Danjon¹, Pauline Défossez², Ming Yang², Clément Saint Cast¹², Antoine Danquechin Dorval¹, Céline Meredieu¹ ¹INRA & Université de Bordeaux UMR1202 BIOGECO, Cestas ²ISPA, Villenave d'Ornon, France
Anchorage is a key factor in wind damage by stem leaning/toppling/uprooting.
Experiments to determine anchorage parameters

-> **Winching** = maximum turning moment

Anchorage strength is related to the size of the tree (H DBH²)

variation for a same size:
- e.g. root depth x soil type x species [database of British tree-pulling experiments Nicoll et al. 2006]

-> inventory of storm damage

But winching a large amount of trees can be tedious and winching is not predictive

-> **Empirical relationships**
Potential contribution of explanatory approaches

What we would need is quality of anchorage as a function of factors like species, genotype, nursery conditions (cutting/seed), installation techniques (planting/sowing), soil profile, soil water content, soil preparation

-> explanatory approach:
 Root architecture & material properties assessment

Anchorage strength is given by:
Winching / storm damage / stem straightness / biomechanical models

Thanks to explanatory approaches, we may provide anchorage parameters for a range of factors with extrapolations at a given age and from age to age
Particularities of anchorage

- soil can be a highly heterogeneous medium + variable water content -> **high variability in root systems**

- all is **hidden in the soil**, entangled in roots from other plants.

- tree anchorage failure is a **discrete** phenomenon:

  - leaning
  - toppling
  - uprooting

Cucchi (2004)
Root architecture and anchorage in trees: what's known?

Coutts, Nicoll, Gardiner et al.: very shallow soil (< 40 cm), larger trees, ditches

Uprooting

Shallow root guying the ZRT

Coutts (1983)
Root architecture and anchorage in trees: toppling

Crook, Ennos, Goodmann, Mickovski et al.: deeper tap-rooted species (*Mallotus*, *Larix*, *Pinus*)

taproot: 80% anchorage

sinkers predominant


3-9 laterals, 3.2 cm diameter

very simple root system or simplified description of root architecture


Larix, Crook Ennos (1996)
The way we choose to study relationship between architecture and anchorage

media

woody plants
full deployment of RSA

in the field

in pots

in agar

hydroponics

Mechanical uprooting
In-depth phenotyping of complex root architectures

**Media**
- in the field
- in pots
- in agar
- hydroponics

**Measurement**
- manual
- 3D magnetic digitizer
- CTscan
- Laser scan
- GPR

whole architecture
In-depth phenotyping of complex root architecture

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**Coding**
- MTG format
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**Analysis**
- Architectural analysis
Architectural analysis

= classifying roots in 9 root types

- Shallow
- Intermediate
- Deep

Laterals

1st order root

Stump
Taproot

Horizontal
Oblique
Vertical

Sinkers

Shallow beyond ZRT

ZRT
Shallow beyond ZRT
Deep Phenotyping of Coarse Root Architecture in *R. pseudoacacia* Reveals That Tree Root System Plasticity Is Confined within Its Architectural Model

Frédéric Danjon¹,²*, Hayfa Khuder³, Alexia Stokes⁴

¹ INRA, UMR1202 BIOGECO, Cestas, France, ² Université de Bordeaux, UMR1202 BIOGECO, Cestas, France, ³ Université de Bordeaux, UMR 5295, Institut de Mécanique et d'Ingénierie - Bordeaux (I2M), Département Génie Civil et Environnemental (GCE), Bordeaux, France, ⁴ INRA, UMR AMAP (Botanique et bioinformatique de l’architecture des plantes), Montpellier, France

Abstract

This study aims at assessing the influence of slope angle and multi-directional flexing and their interaction on the root architecture of *Robinia pseudoacacia* seedlings, with a particular focus on architectural model and trait plasticity. 36 trees
Martin storm (1999)
12 undamaged and 12 uprooted trees
35 cm DBH

Guyed windward by branched roots

Cage trapping the soil

Stump united to the cage

Danjon et al. (2005)
Wind

Resulting force

windward

leeward

guying zone

root-soil plate weight (requires a rigid cage)

flexion = hinge

soil cohesion

neutral zone
Large selective acclimation to prevailing wind

Very large acclimation:
Selective reinforcement as a function of constraint experienced (tension/flexion)

Danjon et al. (2005)
Large acclimation to soil depth/soil profile

Water table: brushes

Hard pan: shields

50 cm
-> soil profile is determined by the micro-topography

-> large plasticity of root system as a response to available soil depth

Danjon et al., 2005
*Pinus Pinaster*, architectural scheme

- tap-rooted
- secondary sinkers
- No retarded branching

Atger & Edelin (1994)
Stable

Instable

Danjon et al. (2013c)
Klaus storm (2009)
48 trees, including 12 toppled
17 cm DBH

Estimation of roots lost during uprooting = yellow - (Danjon et al. 2013)
Wind direction

straight planted tree 57
Ai: 1.6  Sl: 1°

straight seeded tree 34
Ai: 2.7  Sl: 1°

toppled seeded tree 21
Ai: 1.2  Sl: 21°

straight planted tree 5
Ai: 1.4  Sl: 3°

straight seeded tree 35
Ai: 2.1  Sl: 4°

toppled planted tree 42
Ai: 0.6  Sl: 28°
maximal tensile load

flexural stiffness

Central root system has to be rigid to prevent a small displacement of the stump.

A large taproot guyed by deep roots is still the main component of anchorage + soil depth.
From literature

"guyed stake"

From experiment

Dominance of drought avoidance characteristics
Unclear results for artificial selection
**Turf plug planting**: 300 three-years-old trees. no clustering, clumping of shallow roots, generally good regeneration of taproot.

retrospective approach : what happened at plantation ?

Danquechin Dorval PhD (2015)
Prospective approach: portion of crop trees in stands

from taproot and shallow root characteristics

half the plots had less than 50% crop trees

large variation in perturbations of architectural model: could not been attributed to sylvicultural practices.
In a sandy soil: influence of soil preparation on root architecture

Strip ploughing leaving a ditch + mapping shallow roots/sinker branching point in situ: roots follow soil surface
Danjon et al (2013b)

control

shaking

steep slope

shaking + slope
Conclusion: potential contribution of explanatory approaches

We have static data, we could quantify factors effect on root architecture

Growth model for interpolation/extrapolation/summarizing knowledge

Anchorage assessed with the biomechanical model (Yang et al. 2014)

Input in wind risk models:

e.g. planting technique: could not be linked to anchorage strength

low stem straightness: higher probability of anchorage failure
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