The grape root system

Shedding light on the dark side of grapevine

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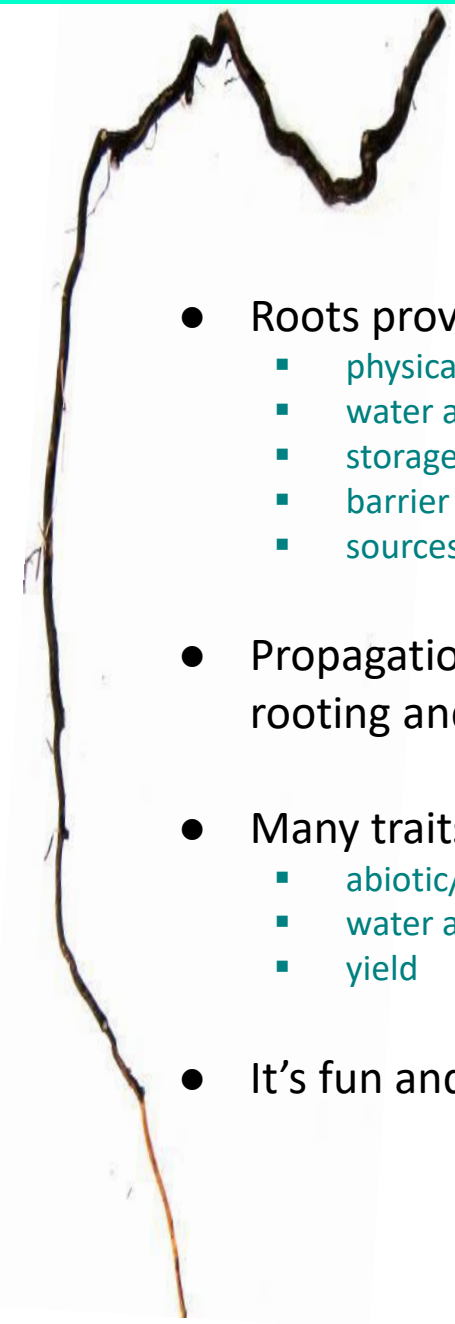
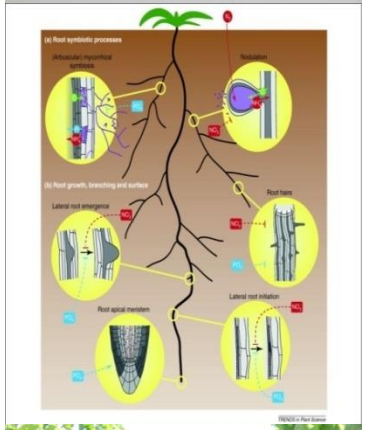
Studying the hidden half of the grape – Why ?



- Roots provide essential functions.
  - physical anchorage
  - water absorption & nutrient uptake
  - storage organ
  - barrier against soil pathogens
  - sources of hormones for root-to-shoot signalling
- Propagation success of a grafted grape is mainly related to rooting and early RSA.
- Many traits required in future vines are linked to root properties.
  - abiotic/biotic stress tolerance
  - water and nutrient use efficiency
  - yield
- It’s fun and challenging !!



1/ Root phenotyping in the vineyard is still a laborious task…

VINEYARD

Partial root profiles

- Excavation
- Soil cores
- Profile wall
- Minirhizotrons

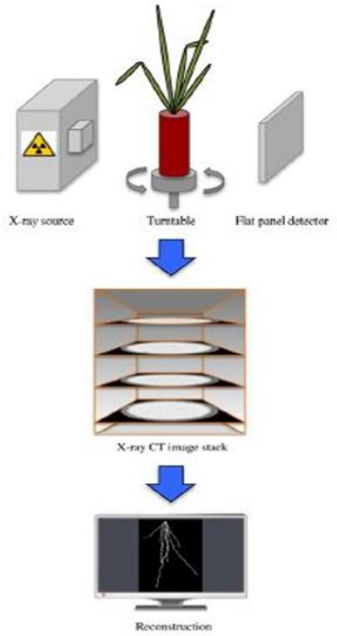
CLIMATE CONTROLLED FACILITIES

Whole root system and architecture

- Rhizoboxes
- Mesocosms

- Hydroponics
- Artificial media
- Growth pounches

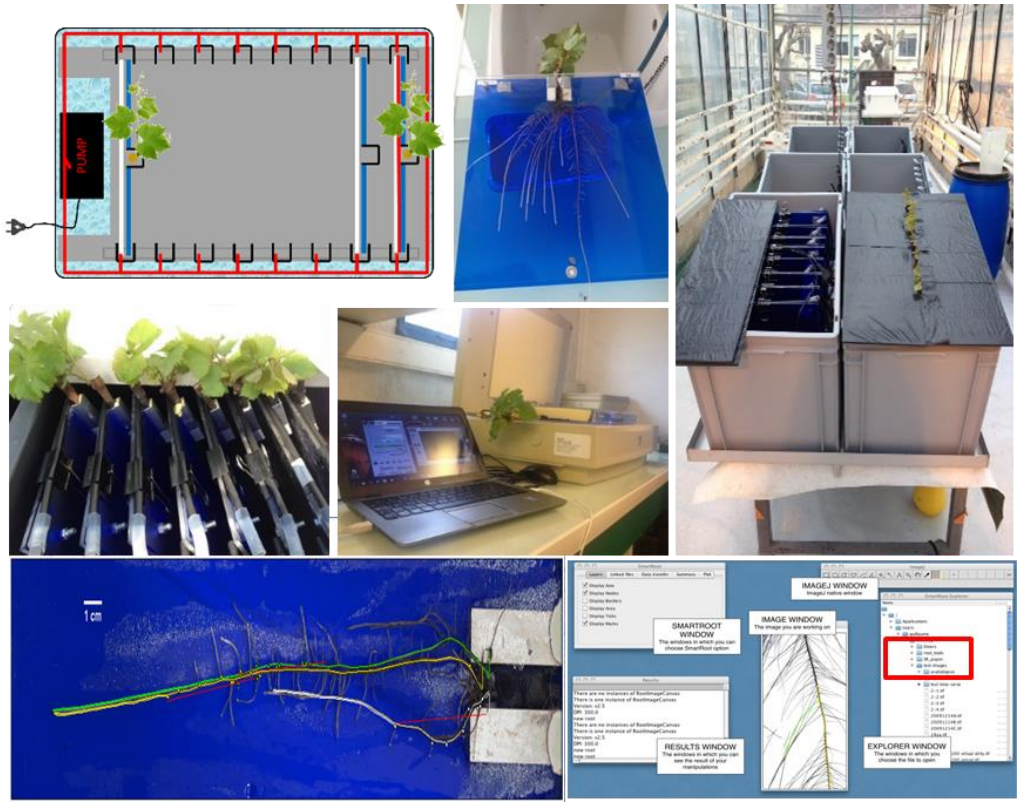
- MRI
- Xray CT
- Neutron tomography



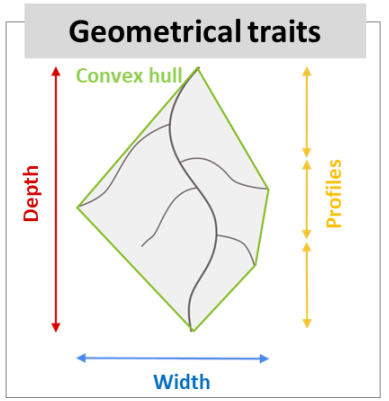
None is without shortcomings

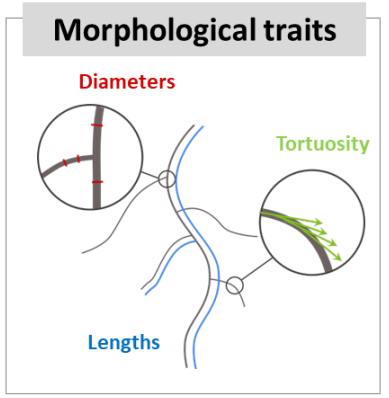
- Spatial/temporal resolution
- Physiological relevance
- Costs & labor time
- High-throughput data acquisition

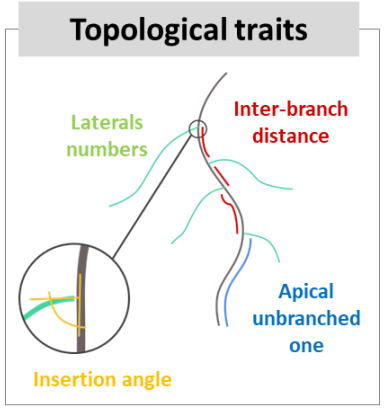
In situ phenotyping of RSA using 2D digital images from rhizotrons



SmartRoot Rhizovision Explorer







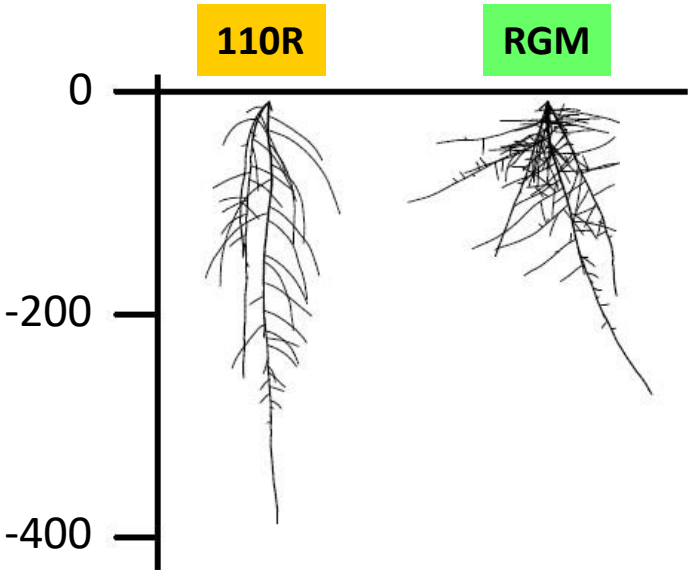
adapted from Lobet et al.

Functional-structural 3D root models are promising tools

ARCHISIMPLE

PROCESS	PARAMETERS
Emission	- Emission rate - Max root number
Radial growth	- Section areas ratio
Elongation	- Elongation rate - Max tip diameter - Min tip diameter - Growth duration - Gravitropism
Self-pruning	- Life duration - Root tissue density
Branching	- Inter-branch distance - Mother:daughter diameter - Variation of daughter diameter

Deep root system

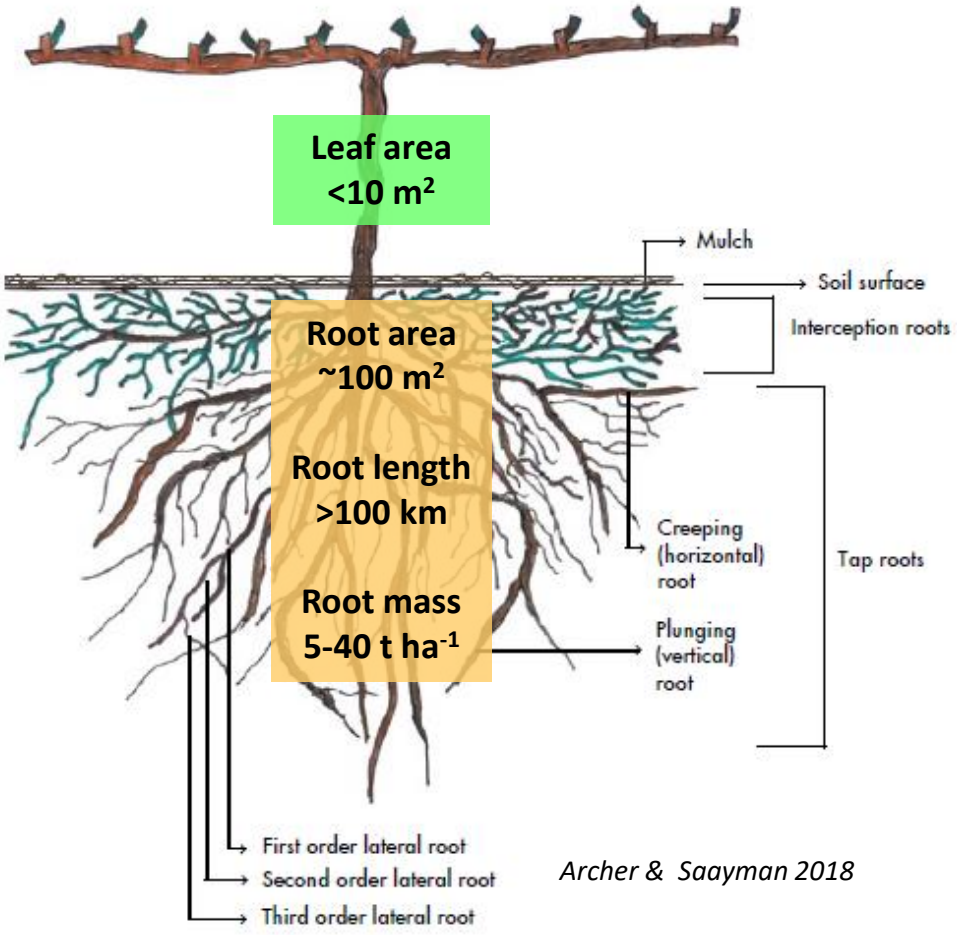


Shallow root system

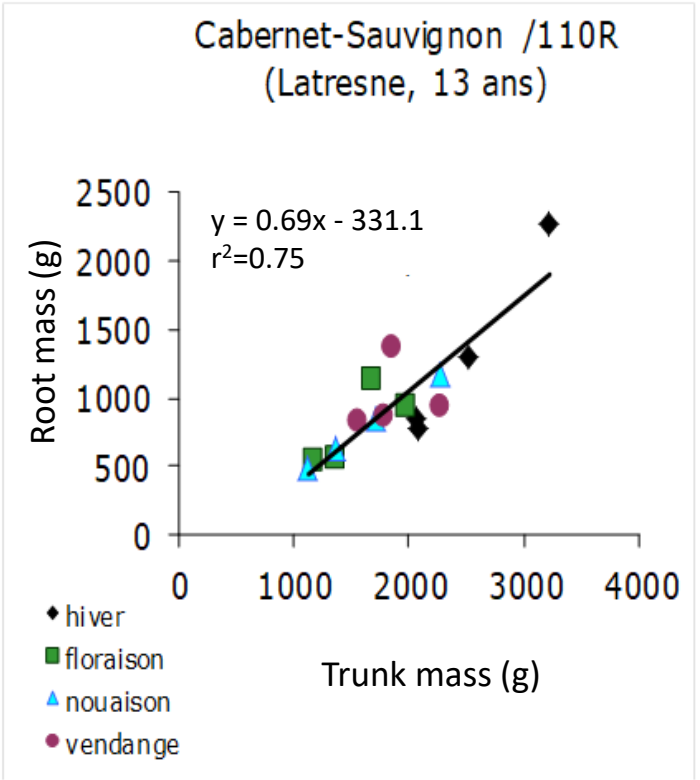
2/ Grape root system is a complex 3D structure exhibiting a specific spatial and temporal configuration of root types

Archer & Saayman 2018

Grape root system structure and distribution



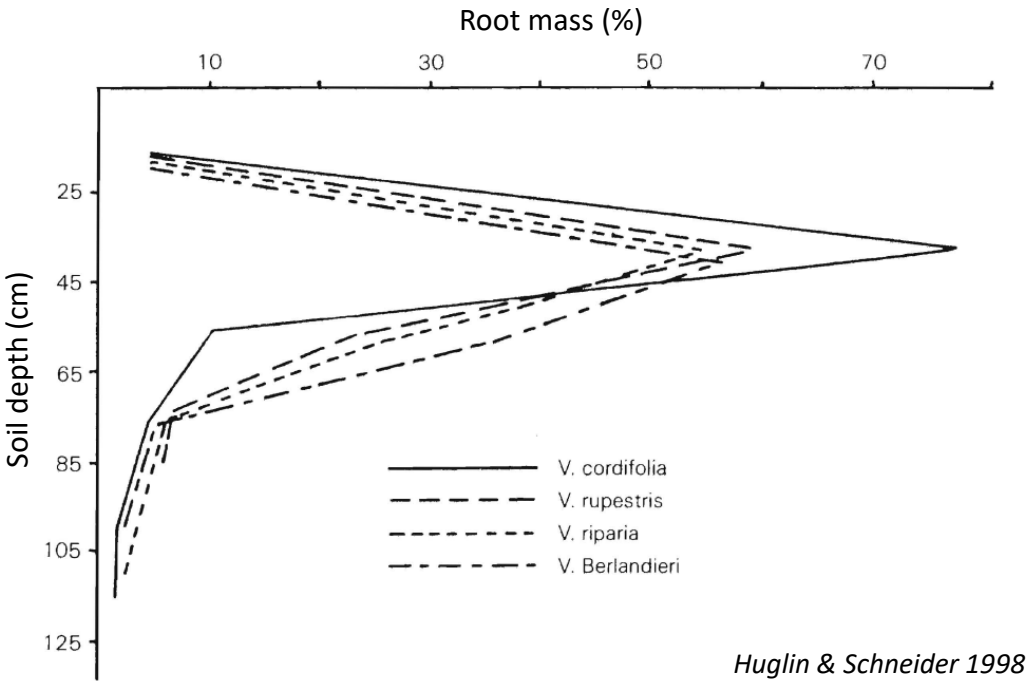
Archer & Saayman 2018



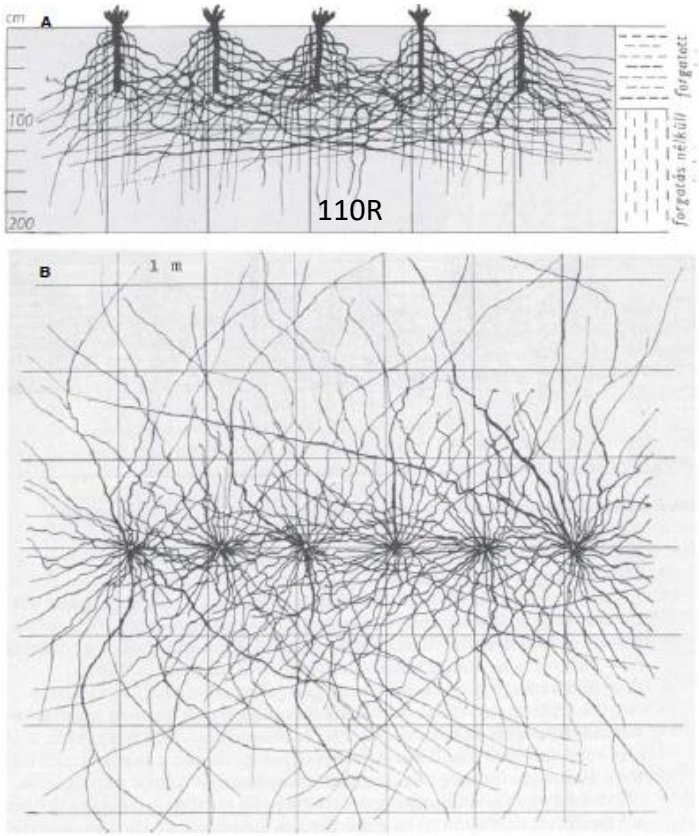
Gaudillère et al., unpublished

- **Primary roots** branch into secondary, tertiary etc. **lateral roots**
- Older, woody root provide anchorage, transport, and storage
- Young, fine roots (<12 wk) are responsible for water and nutrients acquisition
- Number and placement of lateral roots are highly flexible and not restricted to the unbranched apical zone
- Vine size is highly correlated with the size of the root system

Grape root system structure and distribution



Huglin & Schneider 1998



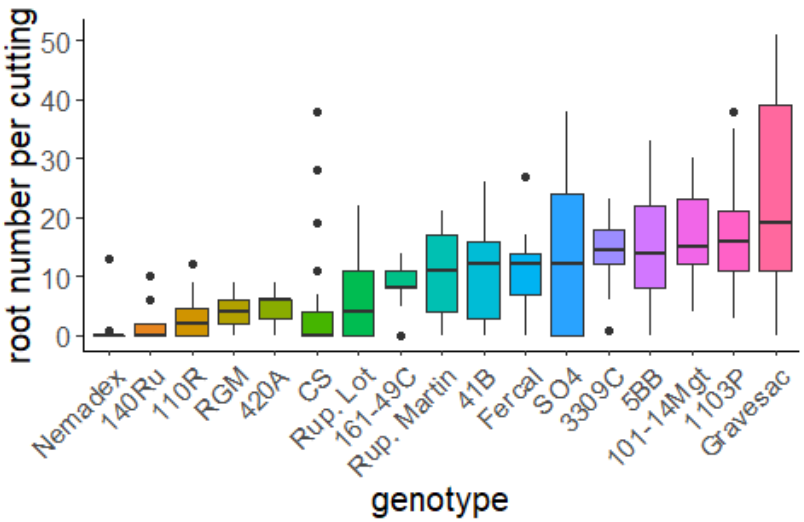
Kozma 1967 in Smart et al. 2006

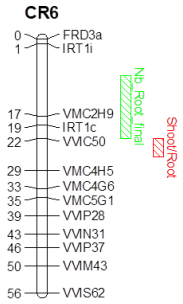
- Woody roots of mature vines are widely distributed horizontally and vertically with low density
- Majority of roots, especially the fine roots, are found in the **top 0.3-1.0m** of soil
- Roots can grow deeper when no impermeable barriers (>30m)
- Investigations characterizing lateral spread of roots are rare
- **Root density** rather than **rooting depth *per se*** is a key difference among rootstocks

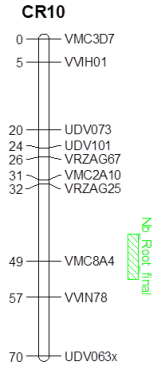
Adventitious roots originate from the cambium of woody cuttings, near the nodes in vegetatively propagated vines.

from Huglin 1986

- ARF is a complex developmental process regulated by both **environmental** and **endogeneous factors** (involving hormones and C/N reserves)
- Not all *Vitis spp.* have the same ability to form ARs.
- Underlying genomic information about rooting control is scarce.



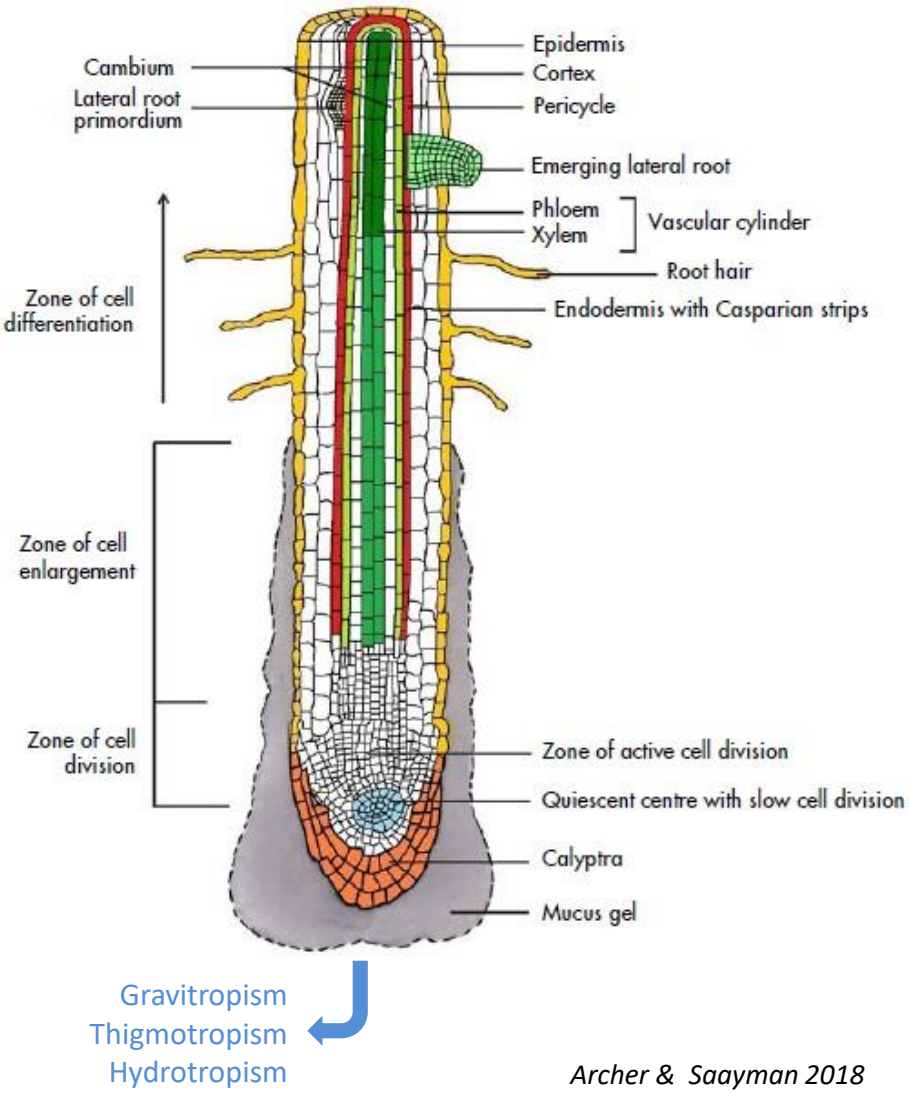




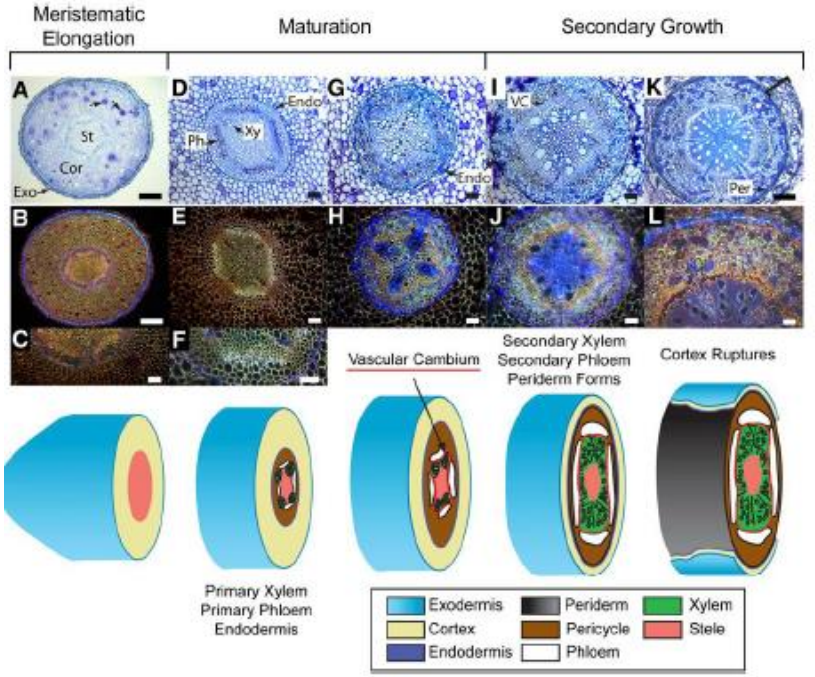
Origine

The root system is not uniform

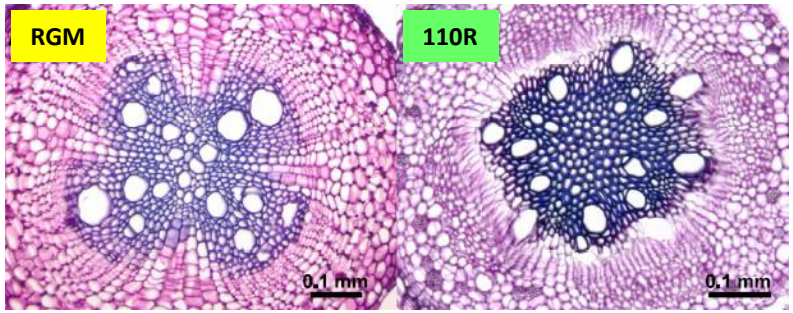
- Root system is formed by different roots with distinct stages of differentiation that are anatomically and physiologically different



Archer & Saayman 2018

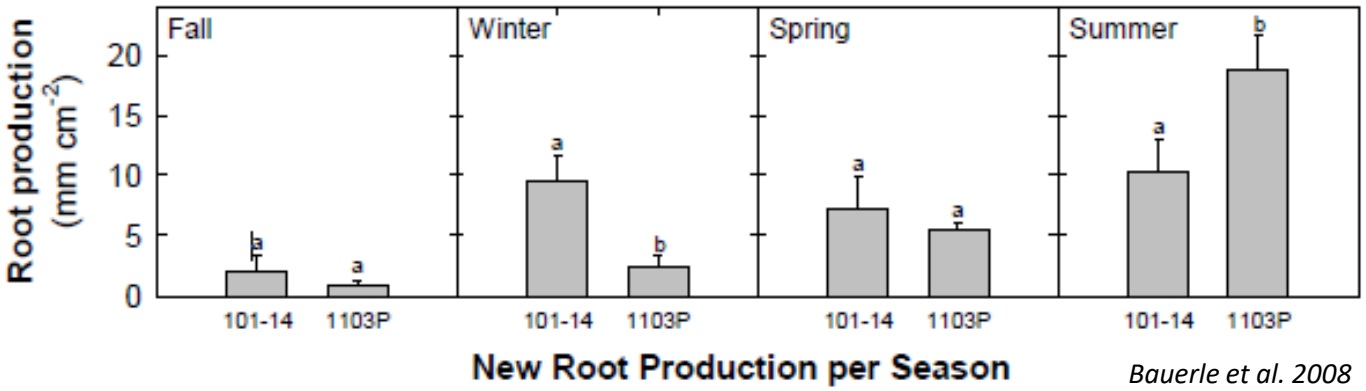


Gambetta et al. 2013



PhD Peccoux 2011

The root system is dynamic



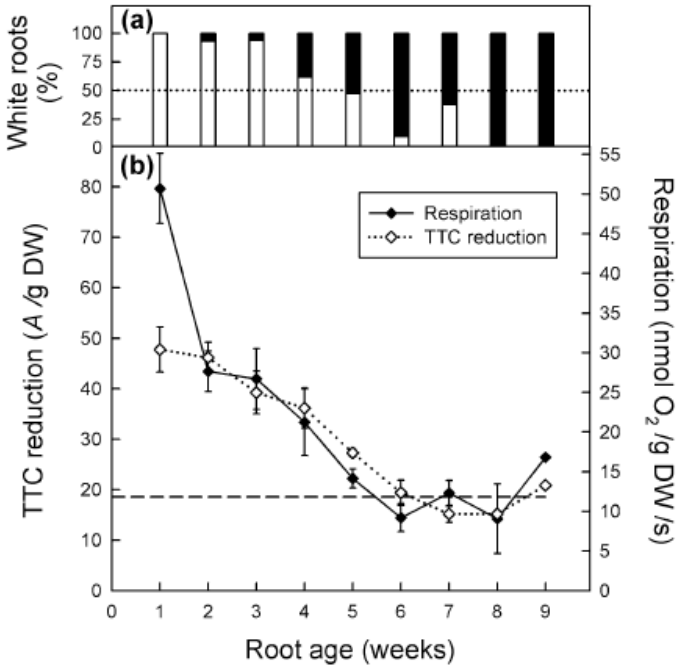
Bauerle et al. 2008

Seasonality

- Seasonal production of roots appeared to be governed by a balance of both endogenous and exogenous factors (*i.e.* warming temperatures, soil moisture and carbohydrate supply from the shoot)

Root ageing

- Roots change with age in a number of physiological parameters including phenolic compounds, respiration and nutrient uptake kinetics
- Roots in deeper soil layers have a longer lifespan than those in shallow soil

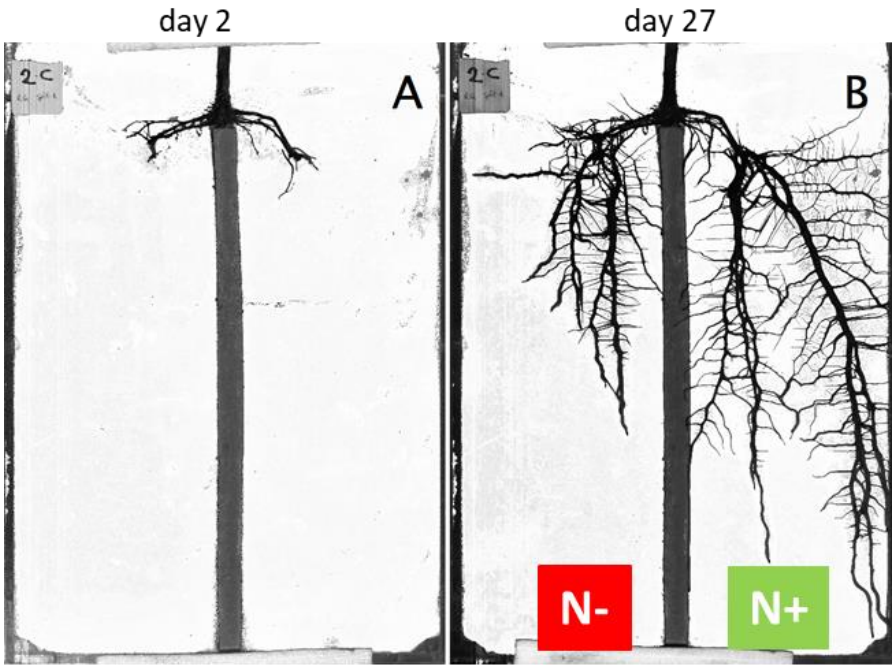


Comas et al. 2010

The root system is highly plastic

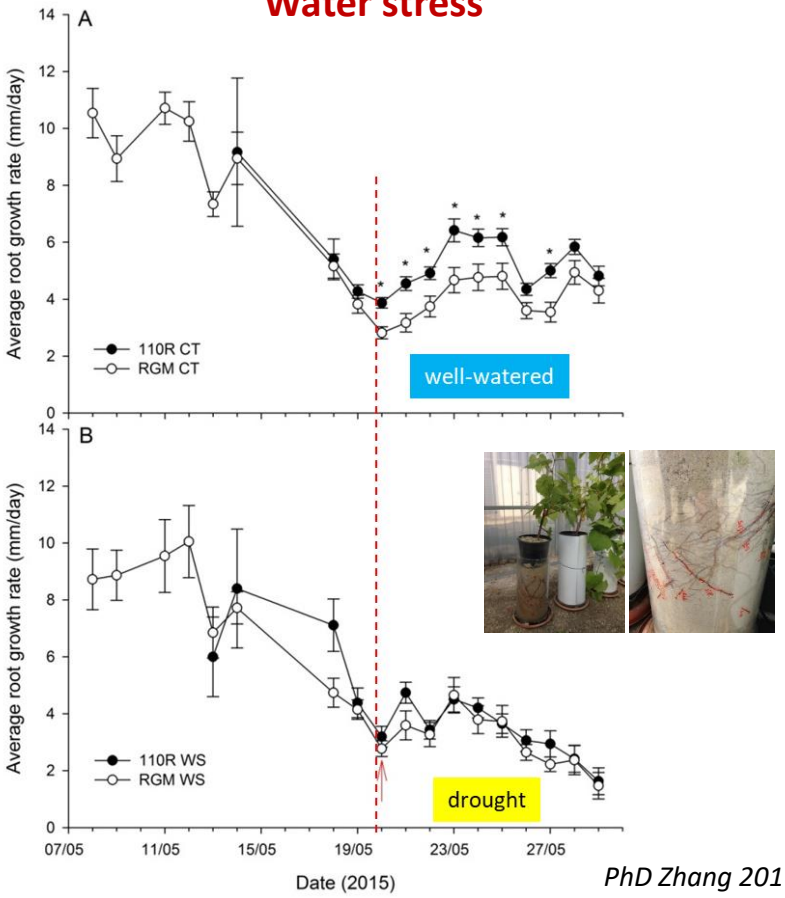
- The root system has significant developmental plasticity as a consequence of the perception and integration of environmental information into the root development program.
- Roots detect resource availability and grow preferentilly in water- and nutrient-rich patches
- Changing root distribution among different patches and layers of soil moisture over the season involve shifting zones of root production

Nutrient availability



Vivin, unpublished

Water stress

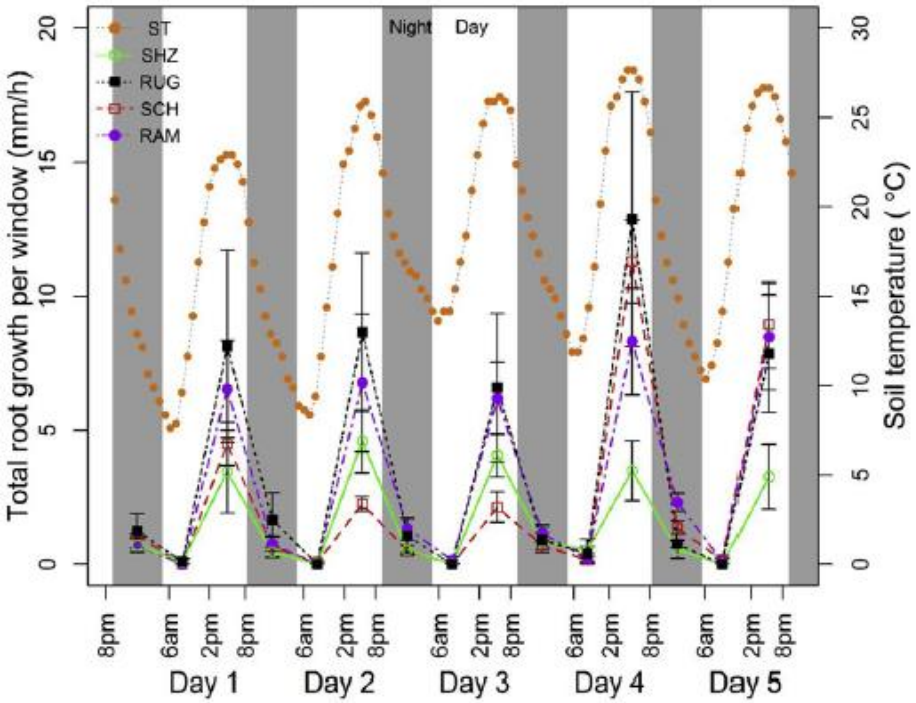


PhD Zhang 2017

Root-zone temperature regulates root growth

- Optimum root growth occurs at around 30°C depending on the genotype.
- Warmer soils stimulated root starch and N mobilisation, root growth and primary nutrient uptake with further consequences on canopy growth

Hourly soil temperature

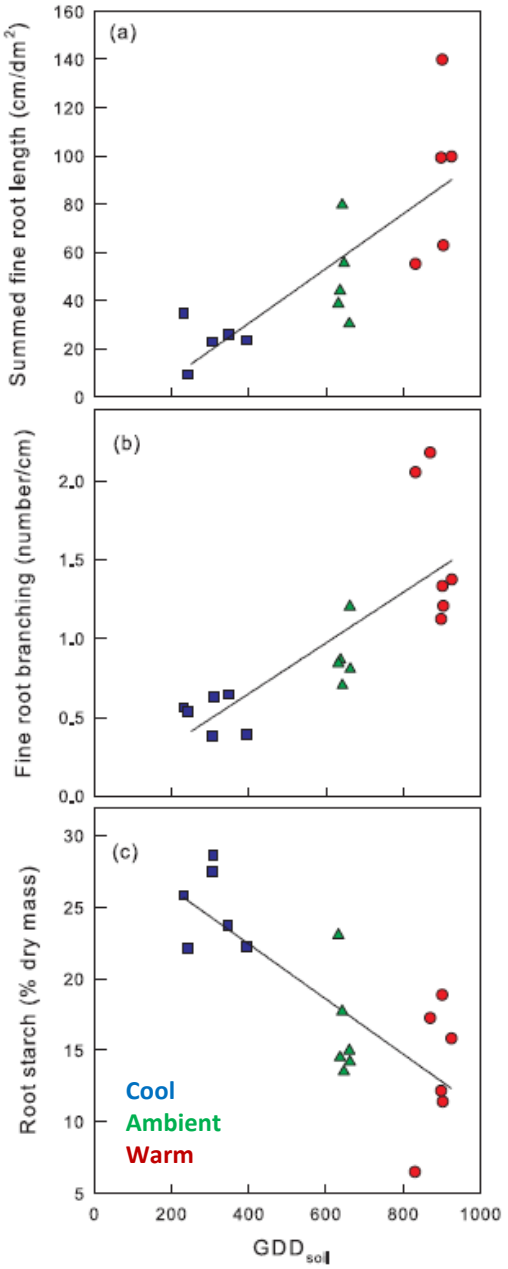


Mahmud et al. 2019

Root length

Root branching

Root reserves

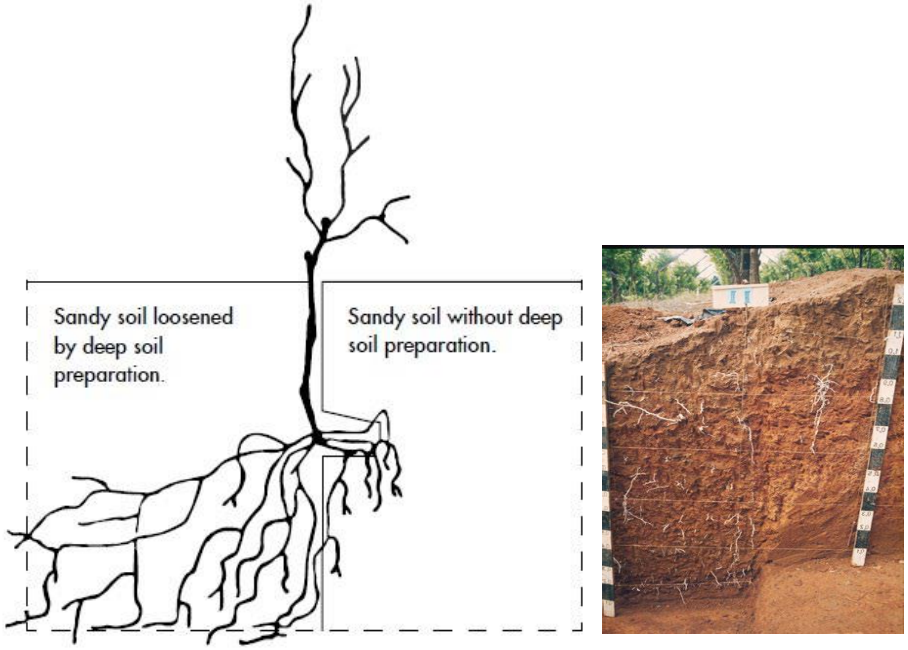


Clarke et al. 2015

Soil properties have the highest effect on RSA

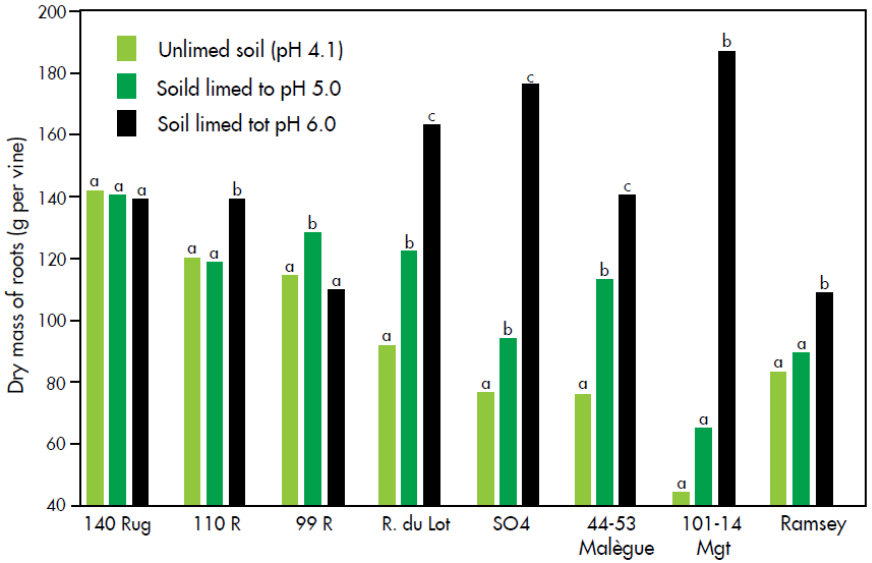
- The **physical properties** (structure and texture) and the **chemical composition** of the soil have strong effects on root development.
- It is especially the water holding and water supply ability, soil strength, bulk density, textural differences and clay percentage of the soil that play a role, whereas soil pH and P content are often also determining factors.

Soil resistance as caused by the presence/absence of deep soil preparation



from Archer & Saayman 2018

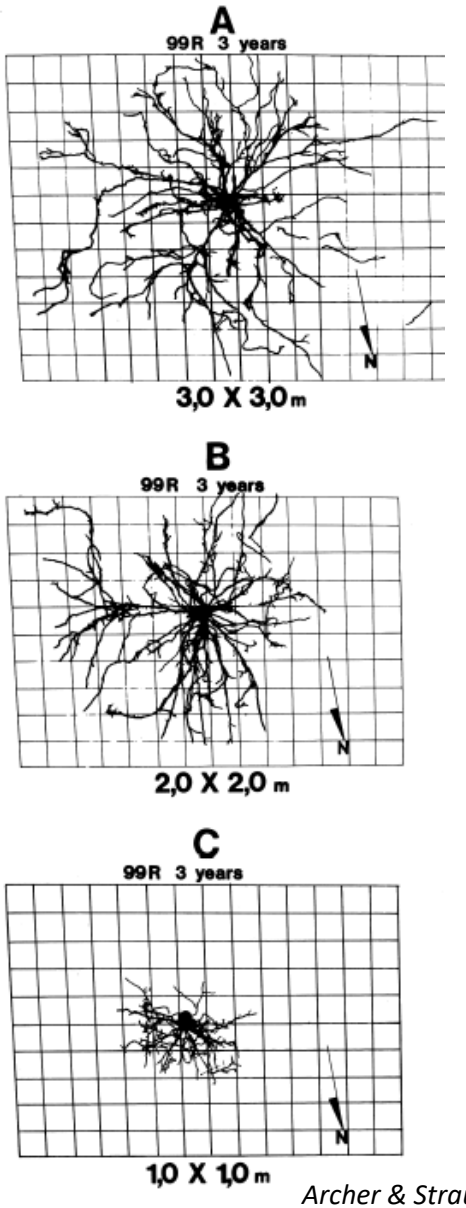
Soil acidity



from Archer & Saayman 2018

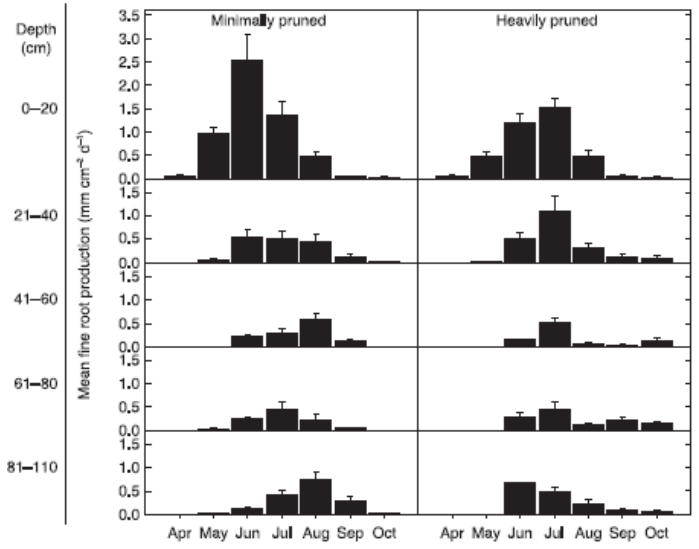
Vineyard management practices control root development

Planting density



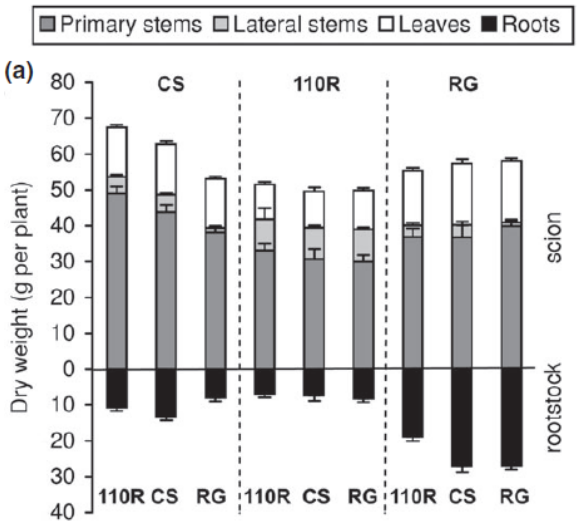
Archer & Strauss 1985

Shoot pruning



Comas et al. 2005

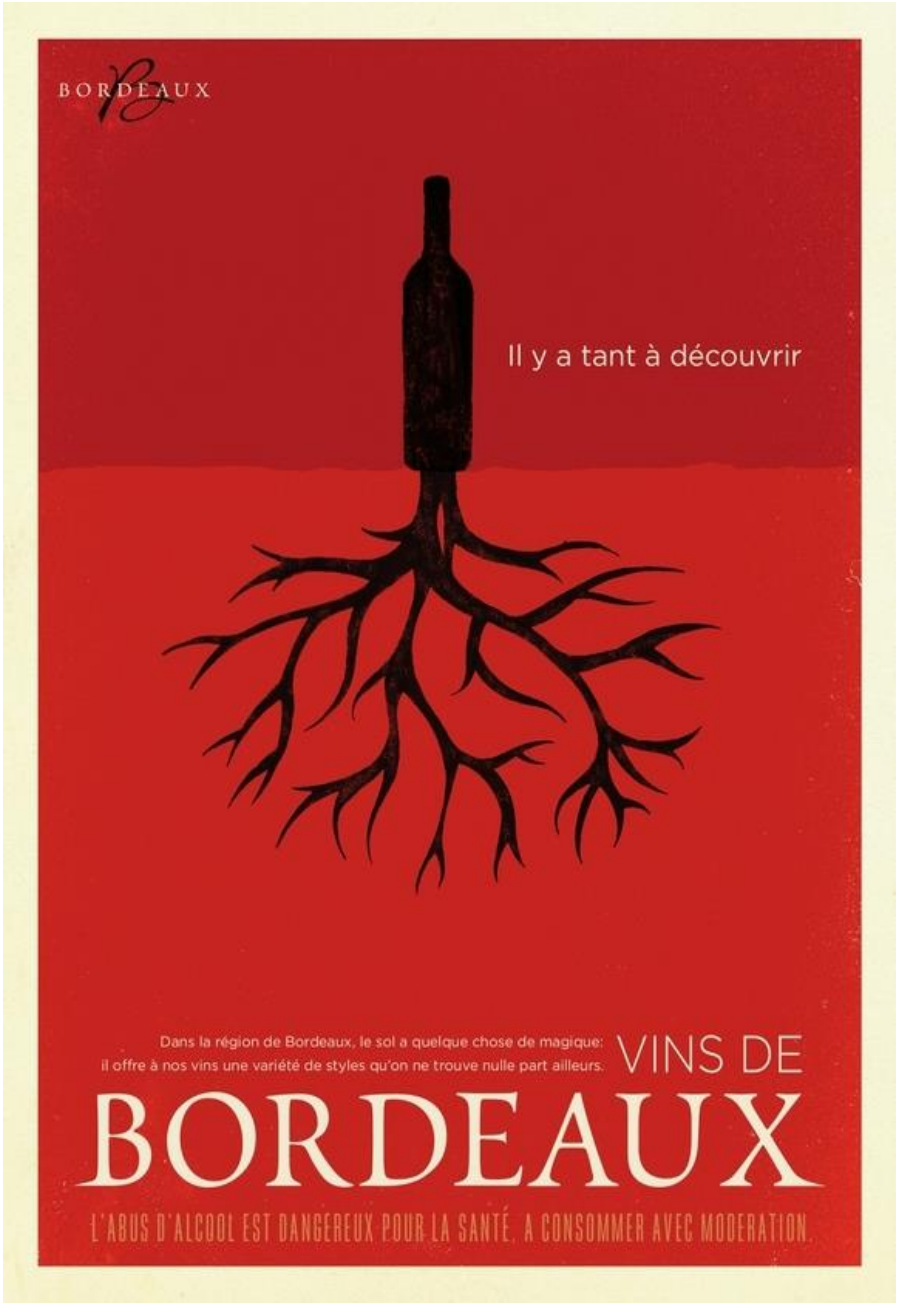
Scion genotype



Tandonnet et al 2010

Mechanical planting

Torregrosa 2020



Without roots no fruits !