Root traits as key proxies to unravel plant and ecosystem functioning - entities, trait selection and outlook


EGU2020: Sharing Geosciences Online
Session: Soil-Plant interactions, 05.05.2020, 14.00-15.45 o’clock, online
The hidden half

Root systems play key roles in plant functioning and performance and affect many ecosystem processes and functions.
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⇒ Nothing too new ... e.g. Harry von Pistohlkors 1898. Wurzelkenntnis und Pflanzenproduktion: Die Wurzelkenntnis - eine Bedingung des rationellen Anbaues unserer landwirtschaftlichen Kulturpflanzen („Root knowledge and plant production: Root knowledge - a prerequisite for the rational cultivation of our agricultural crops”). O. Paul, Bonn
The hidden half

Root systems play key roles in plant functioning and performance and affect many ecosystem processes and functions

→ So why is the hidden half of plants still largely „uncharted territory“?
The hidden half

Root systems play key roles in plant functioning and performance and affect many ecosystem processes and functions

→ So why is the hidden half still largely „uncharted territory“?

→ In this talk, we propose 3 major topics hampering root research
1) ... well, its hidden ...
Hidden half

1) ... and while there are many methods, it remains challenging (to get the whole picture)

- Trenches
- Cores
- Minirhizotron
- Shovellomics
- NMR
- Phenotyping platforms

Image analysis

Interference between ontogenetic stages


see Soffer et al. CNN MR Analysis THIS SESSION
Hidden half

2) Botanical root ‘literacy’ limited

Turning ROOT ZOMBIES (AKA just ‘Roots’) into TALKIN’ ROOTS (i.e. being able to name Specific root entities)
Root entities

Developmental classification

Generic Nomenclature
Monocotyledons

ISRR Nomenclature

Generic Nomenclature
Dicotyledons

Adventitious / fibrous root

Brace root

Nodal root

Crown root

Seminal root

Lateral / secondary root

Primary (seminal) root

Node

Mesocotyl

CN

S

SN

Tap root

Lateral root

Lateral / secondary root

Hypocotyl

(Soil surface)

Node

Internode

Cotyledons

Adventitious root

Root collar

Tap root
Root entities

Developmental classification

Ordering schemes dependent on aim ≠ universal
Root entities

Morphometric, Topological, Functional classification

Morphometric

Topological

Functional classes

Long FR

Short FR

Coarse roots

Root entities

Root classification … to be continued!

E.g. differences in root tips’ specific respiration rates

E.g. differences in laterals’ phenology, anatomy and growth rates


Root entities

Root classification ... to be continued!

E.g. With / without or different types of Endosymbionts (EM, AM,...)

3) Root ecological science still

- Interference from aboveground traits to root traits limited
- Too many simple traits used
- Methodologies not standardized
- Trait interrelations unclear
Plant functional traits

Functional traits of organisms \(\rightarrow\) morpho-physio-phenological traits that impact the fitness of individual species via their effects on growth, reproduction and survival (Violle et al., 2007)

Functional traits as community averages \(\rightarrow\) effects on ecosystem services

Trait convergence across organs

Large divergence of hydraulic trait values
coarse roots vs. 2nd year branches

Hidden half

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Root traits & Plant functioning

Resource Acquisition (Basic trait set)

Plant N acquisition
- Ability to fix N
- Root N concentration
- Mycorrhizal association types
- Maximum rooting depth
- Horizontal and Vertical root distribution index
- Root length density
- Root mass fraction / Root:Shoot ratio
- Specific root length / area

Plant P acquisition
- Cortical thickness
- Hydraulic conductance
- Xylem lumen area

Plant water acquisition
Root traits & Plant functioning

Resource Acquisition
(Basic trait set)

Do we consider too many ‘easy’ traits?

Plant N acquisition

- Ability to fix N
- Root N concentration
- Mycorrhizal association types
- Maximum rooting depth
- Horizontal and Vertical root distribution index

Plant P acquisition

- Root length density
- Root mass fraction / Root:Shoot ratio
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Plant water acquisition

- Cortical thickness
- Hydraulic conductance
- Xylem lumen area

Do we consider too many ‘easy’ traits?
Root traits & Plant functioning

Resource Acquisition
(Extended trait set)

Plant N acquisition
- Net N uptake rate
- Michaelis-Menten constant (Km)
- Ability to fix N
- Nitrogen fixation rates
- Max. net uptake capacity (I_max)
- Specific root respiration
- Root N concentration
- Root exudation rate
- Ability to grow cluster and dauciform roots
- Rhizosphere phytase and phosphatase activity
- Mycorrhizal hyphal length
- Mycorrhizal association types
- Mycorrhizal colonisation intensity
- Maximum rooting depth
- Later root extent
- Horizontal and Vertical root distribution index
- Root length density
- Root mass fraction / Root:Shoot ratio
- Specific root length / area
- Root branching density
- Root elongation rate
- Root branching angle
- Root hair length and density
- Persistence of connection between ramets
- Lateral spread
- Mycorrhizal genetic diversity
- Cortical thickness
- Fraction of passage cells in Exodermis
- Hydraulic conductance
- Suberin concentration
- Xylem lumen area
- Lignin concentration

Plant P acquisition

Plant water acquisition
Root traits & Plant functioning

Resource Acquisition
(Extended trait set)

Plant N acquisition

Trait importance?

Net N uptake rate
Michaelis-Menten constant (Km)
Ability to fix N
Nitrogen fixation rates
Max. net uptake capacity (I_max)
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Plant P acquisition

Trait importance?

Plant water acquisition

Trait importance?
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Standardizing trait measurements

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Root trait relationships & Hierarchies

Soil reinforcement against landslides

Traits related to the amount and location of roots

Root branching density
Vertical root distribution index
Root area ratio
Root branching angle
Lifespan

Traits related to the mechanical resistance of roots

Root bending resistance
Root tensile strength
Root elastic modulus

Traits related to the root-soil mechanical interaction and soil drying

Root hair length and density
Root hydraulic conductance
Mycorrhizal colonization intensity
Outlook & Steps forward

1) Start analysing roots → Deposit data in databases (e.g. FRED, https://roots.ornl.gov/)

2) Know your root entity and report it!

3) Identify (demonstrated) functional traits and not ‘just the simple ones’

4) Use standardized methodology whenever possible, report deviations

5) Consider trait interrelations and hierarchies
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Thank you for your attention!

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