The hidden half of the plants for 'deep-rooted' organic agriculture

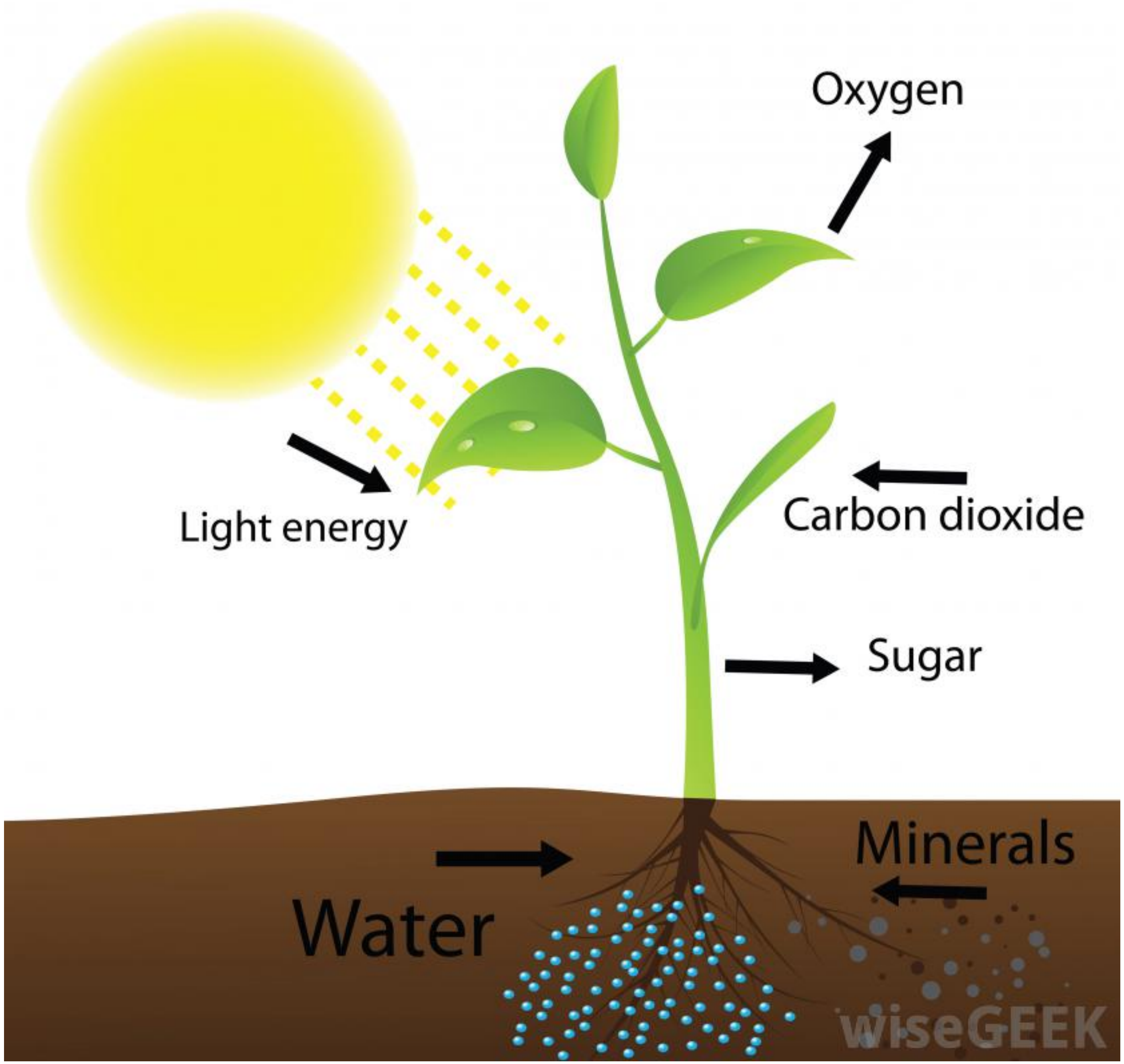
Eusun Han

Changzhou, October 28

Outline

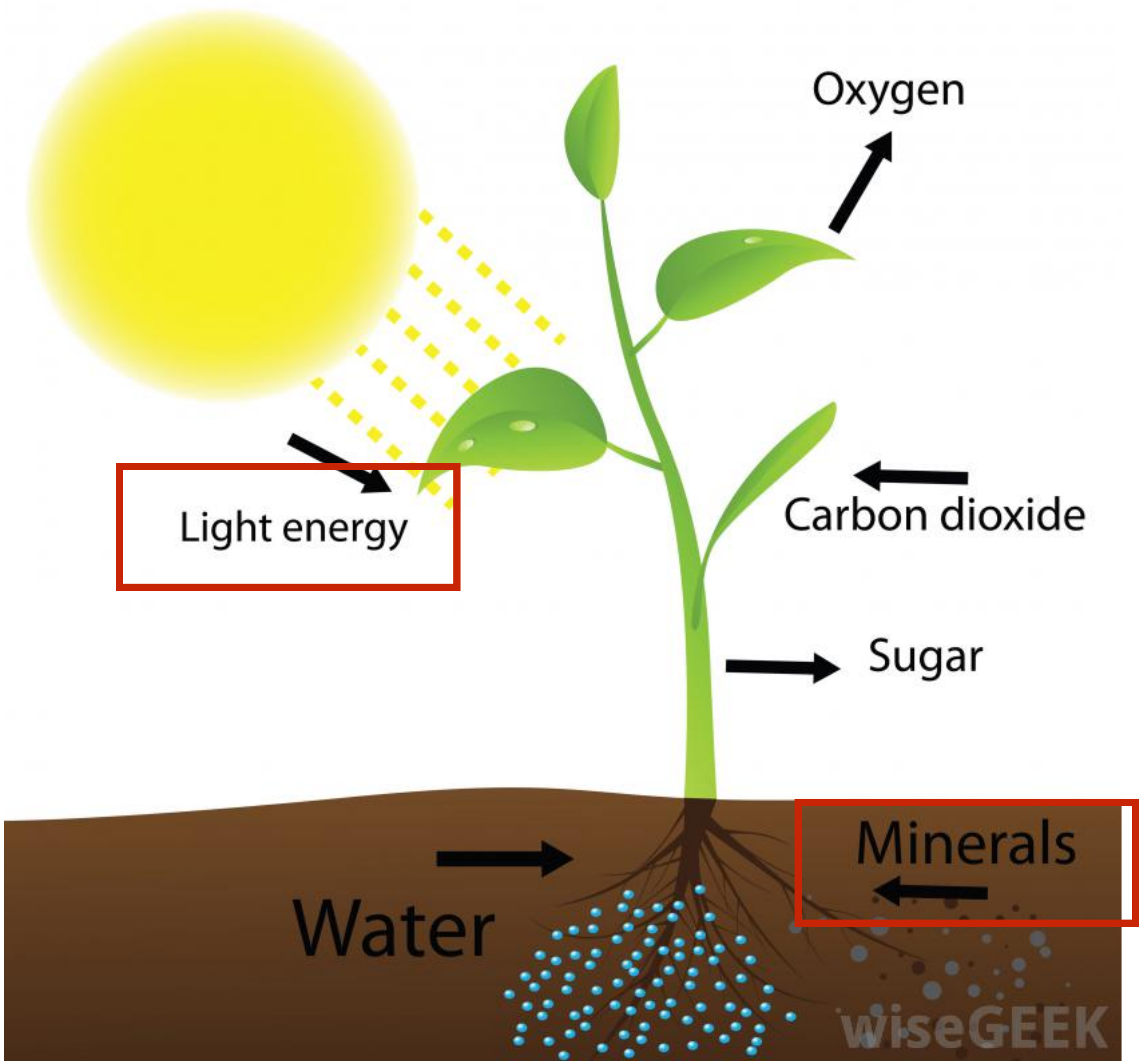
- Background
- Precrop effects
- How to promote plant deep roots?
- Future research
- Conclusions

Plants eat air



Source: http://images.wisegeek.com/photosynthesis.jpg

Plants eat air



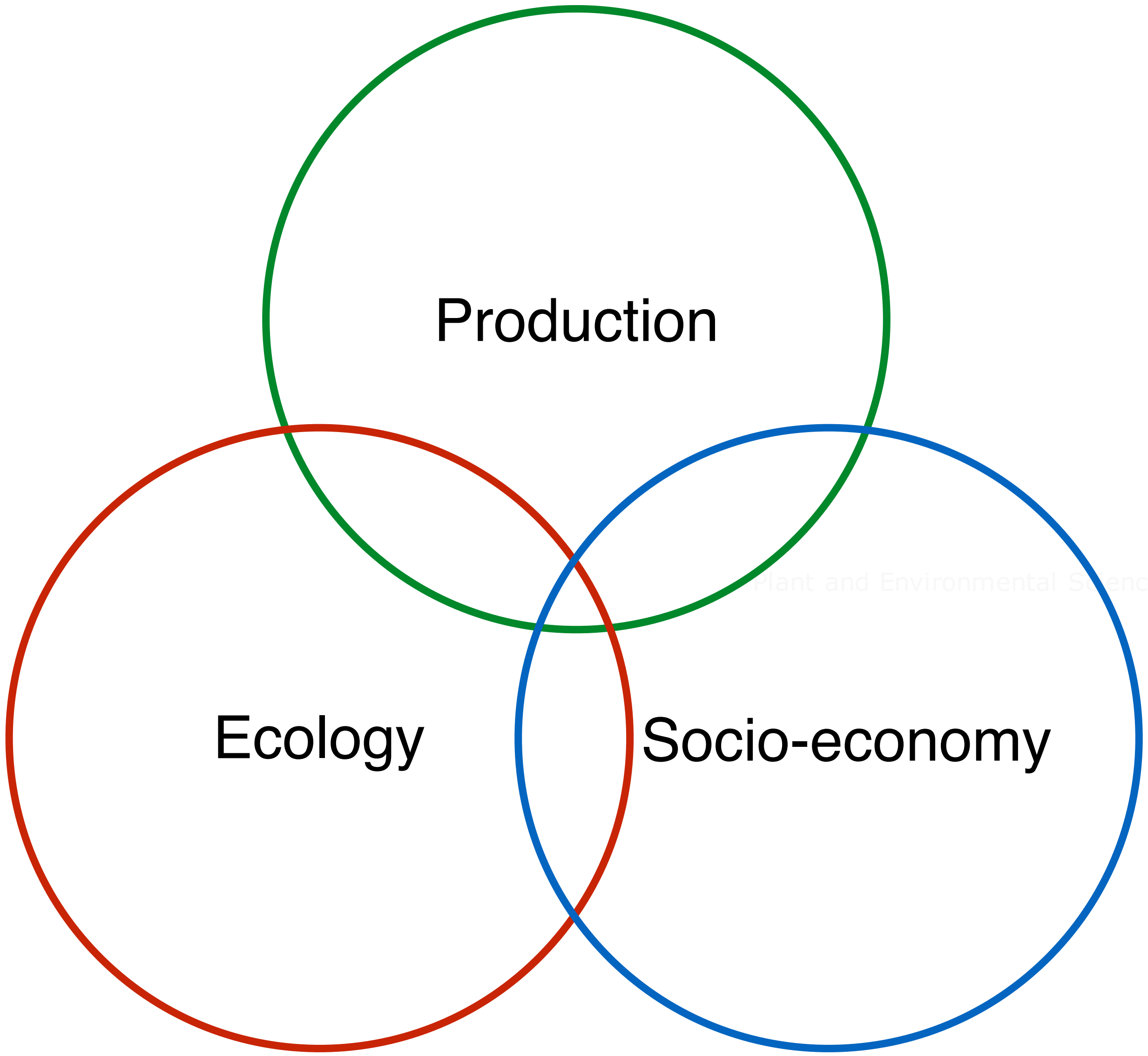
Source: http://images.wisegeek.com/photosynthesis.jpg

Definition of organic agriculture

"Organic Agriculture is a **production system** that sustains the **health of soils**, **ecosystems** and **people**. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved."

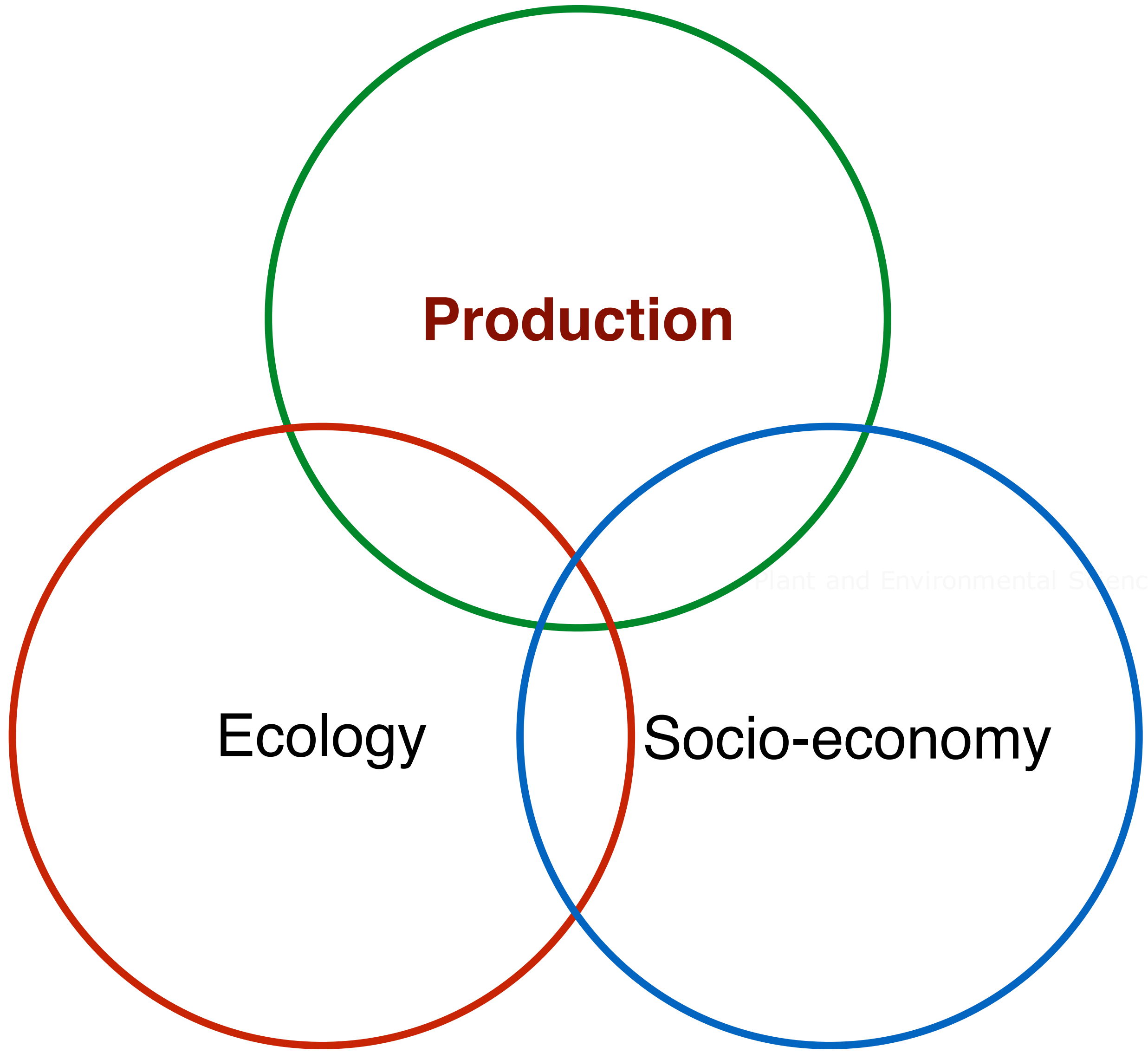
Source: http://www.ifoam.bio/en/organic-landmarks/definition-organic-agriculture

Function of organic agriculture



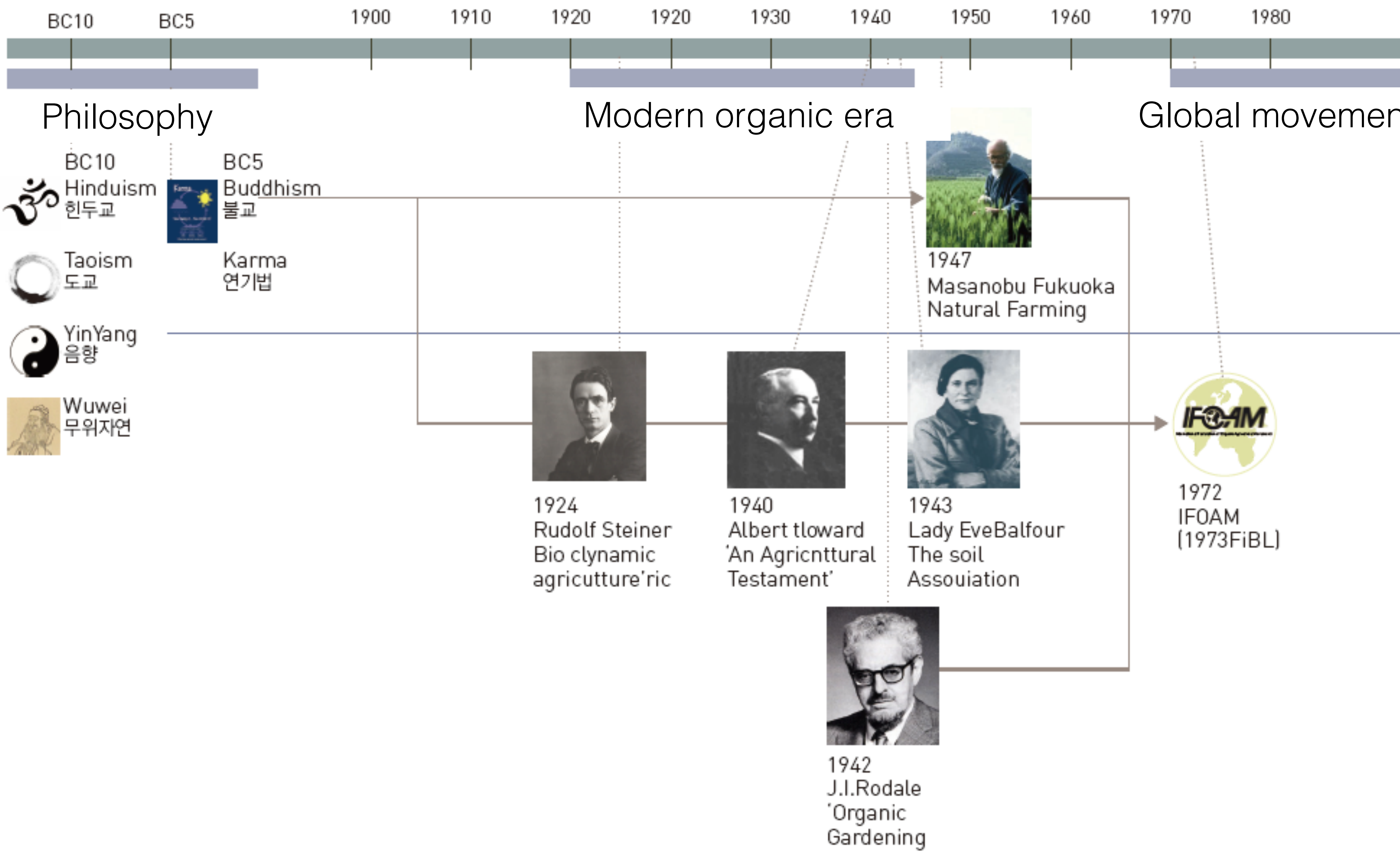
Source: http://www.ifoam.bio/en/organic-landmarks/definition-organic-agriculture

Function of organic agriculture



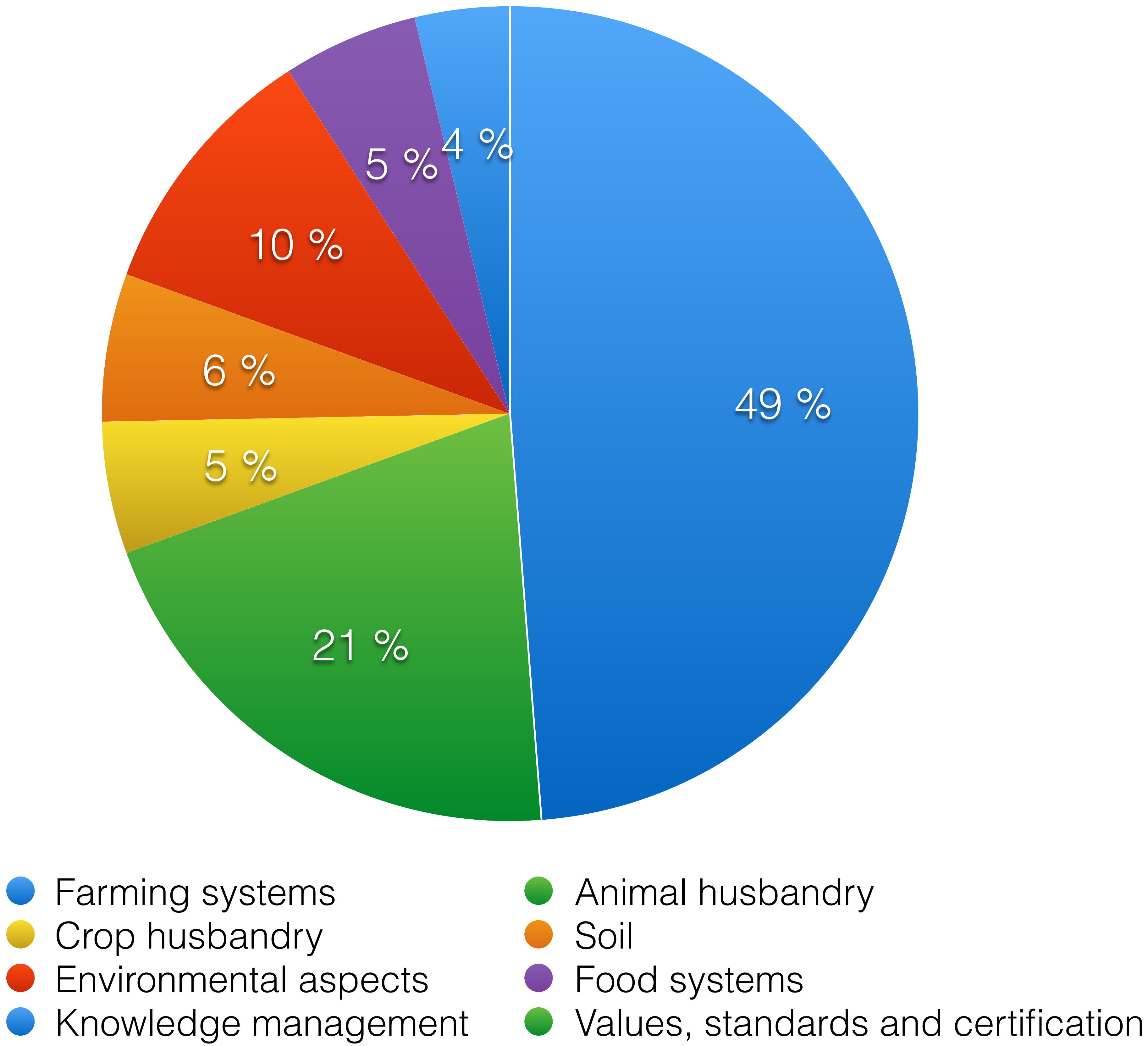
Source: http://www.ifoam.bio/en/organic-landmarks/definition-organic-agriculture

History of organic research



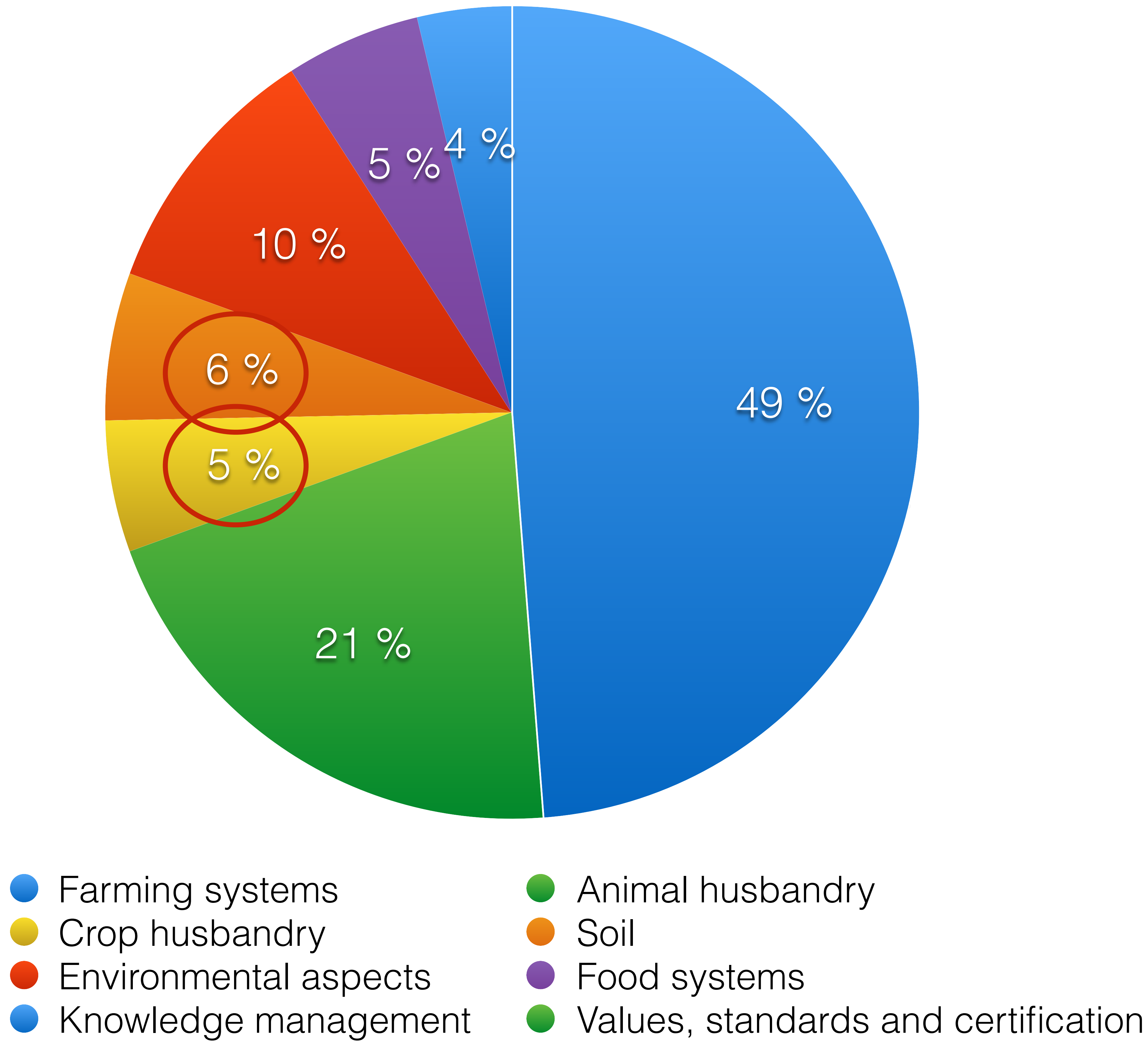
Source: OWC 2011 exhibition

Trend of organic research



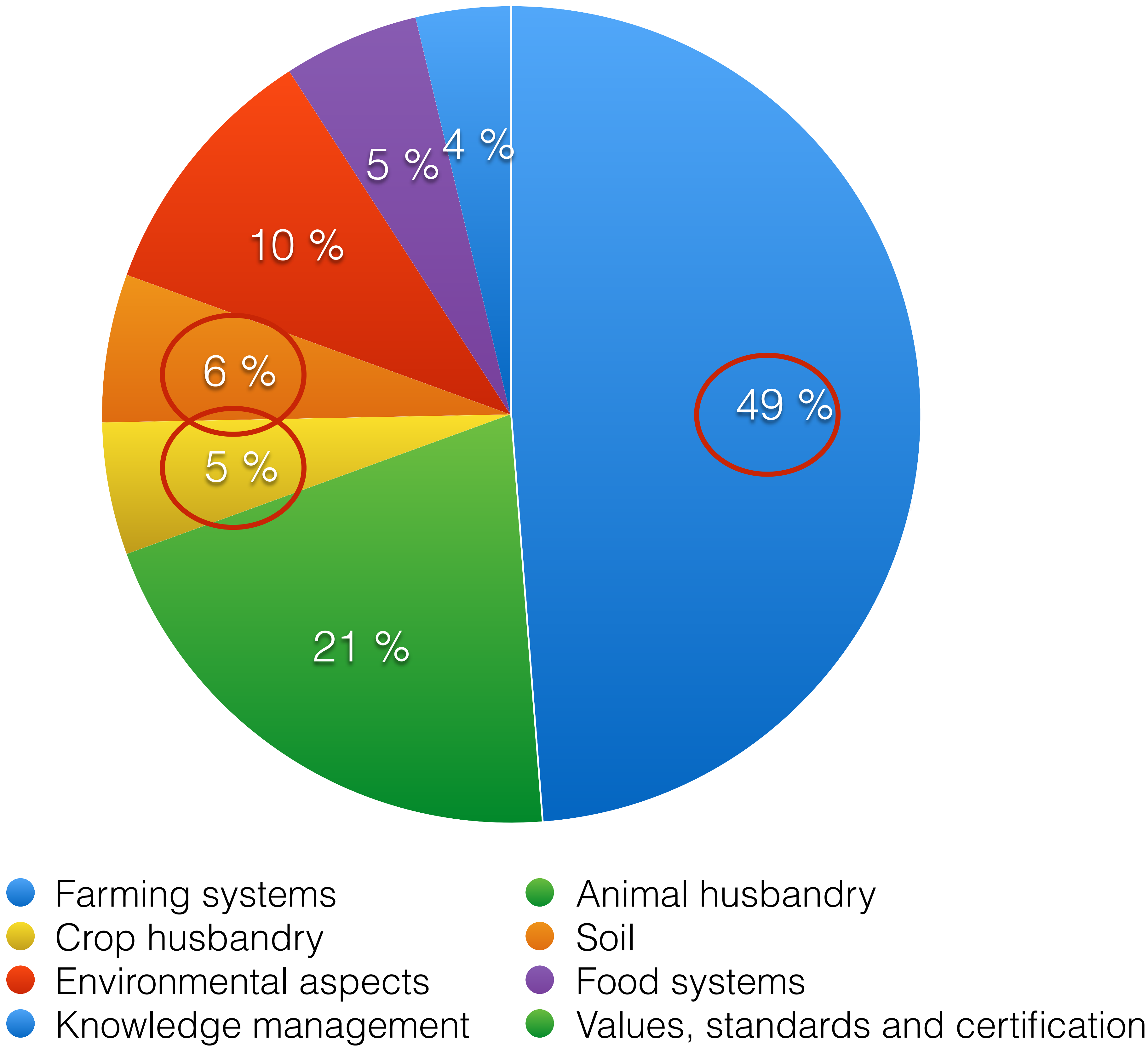
Source: Organic Eprints

Trend of organic research



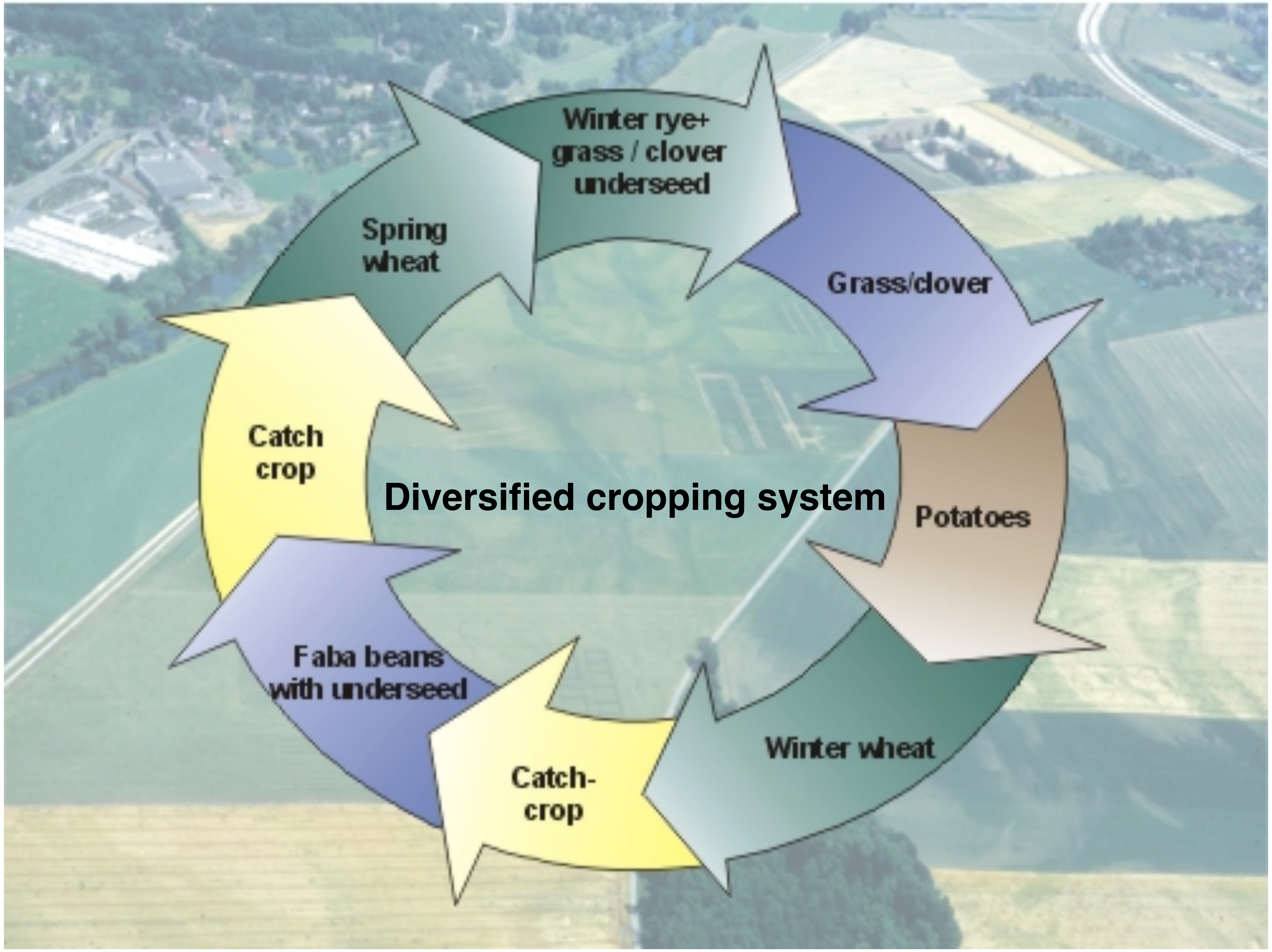
Source: Organic Eprints

Trend of organic research



Source: Organic Eprints

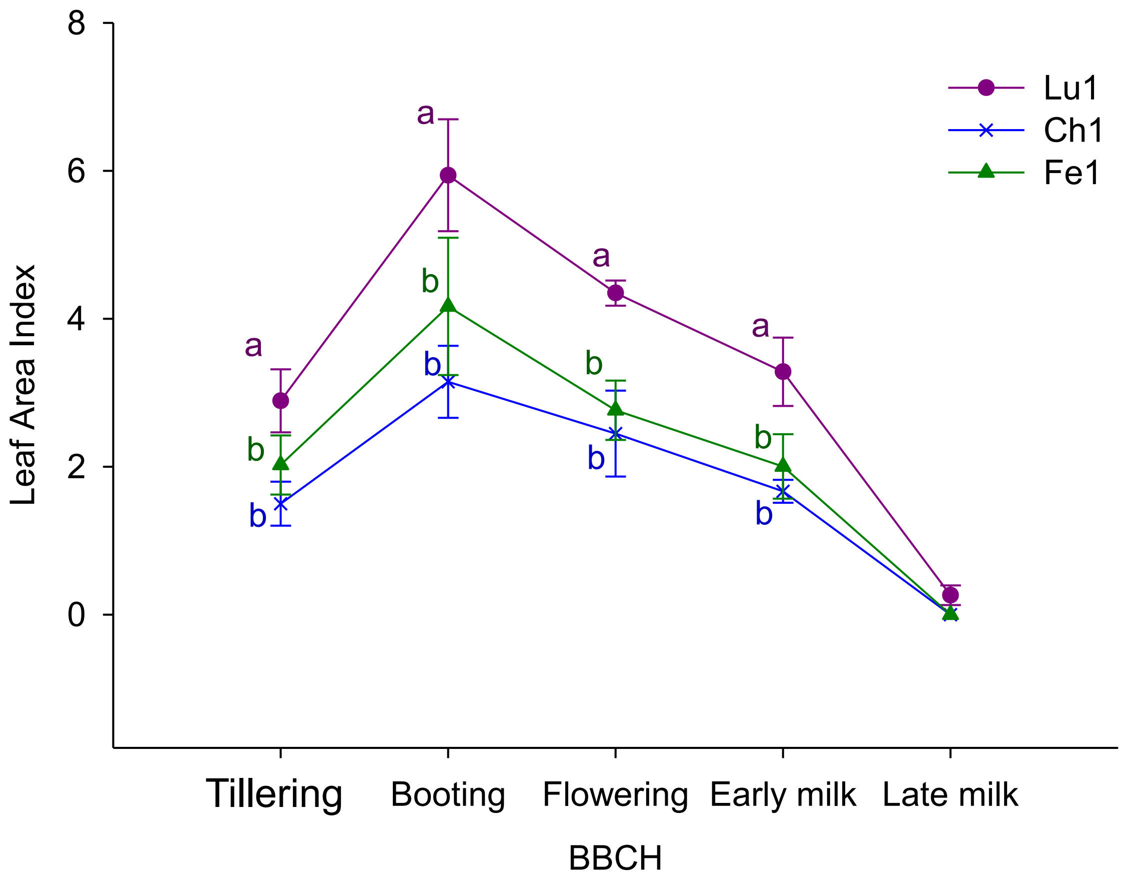
Organic agriculture and precrop effects

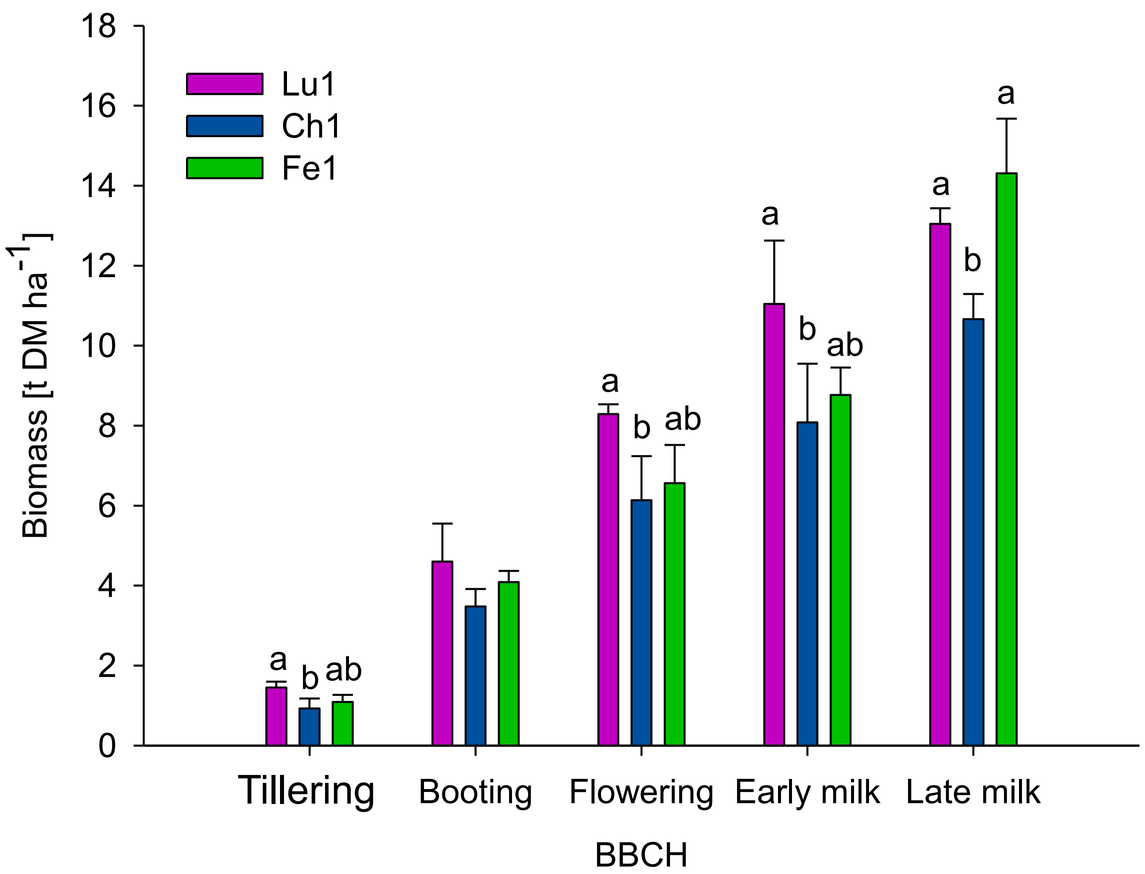


"In relation to nutrient management, we have to consider that in contrast to conventional agriculture management in organic agriculture has to deal with scarcity of nutrients."
(Köpke 1995)

Source: IOL

Biological N fixation





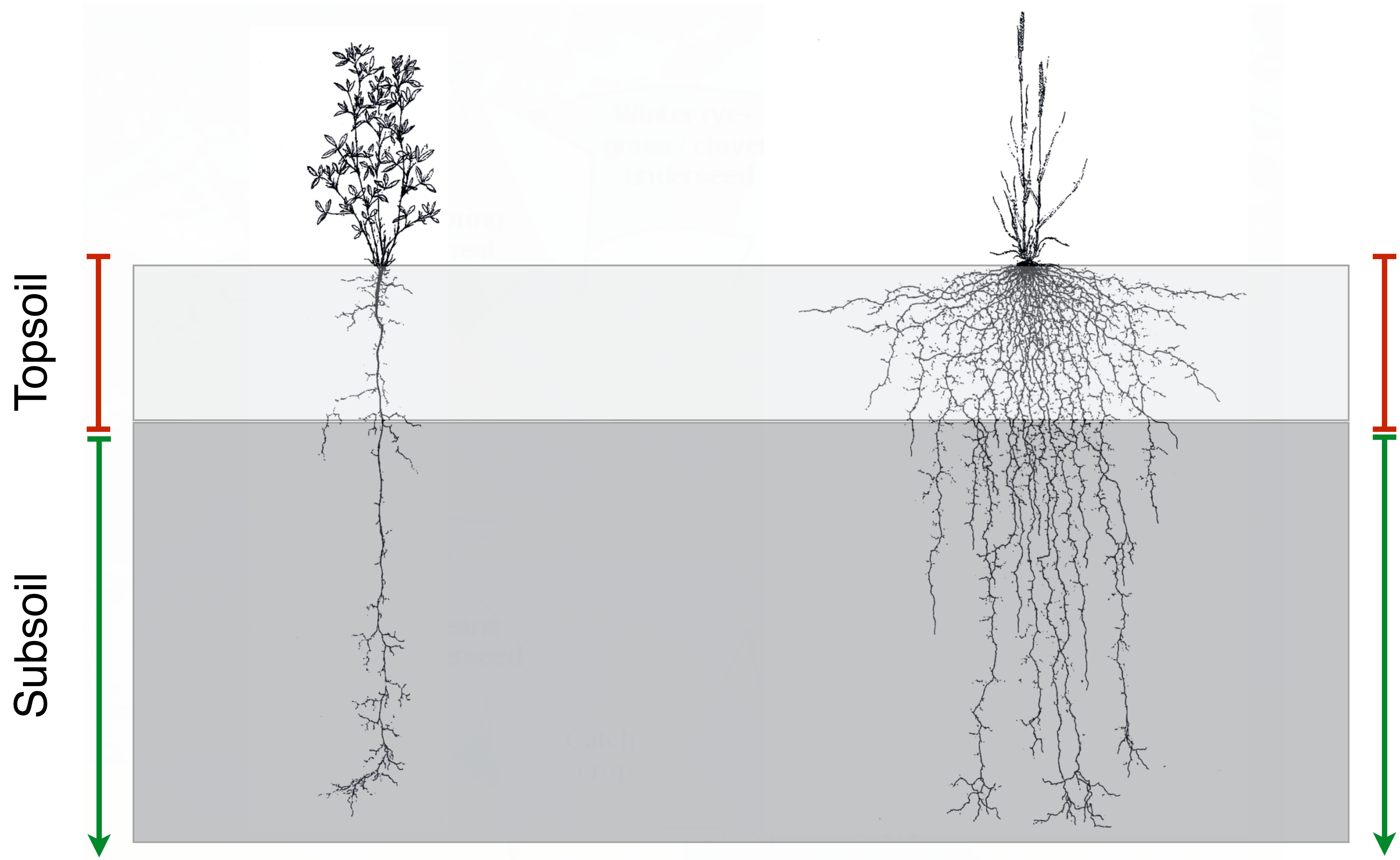
"In relation to nutrient management, we have to consider that in contrast to conventional agriculture management in organic agriculture has to deal with scarcity of nutrients."
(Köpke 1995)

Source: Han & Li, in Prep

Scale of precrop effects

"In relation to nutrient management, we have to consider that in contrast to conventional agriculture management in organic agriculture has to deal with scarcity of nutrients."
(Köpke 1995)

Scale of precrop effects



> "In relation to nutrient management, we have to consider that in contrast to conventional agriculture management in organic agriculture has to deal with scarcity of nutrients."
> (Köpke 1995)

Importance of subsoil

Beneath tilled layers
(Kautz et al. 2013a)

Below 20-30 cm of soil depth
(Kuhlmann et al. 1991; Guo et al. 2014)

Source: Eusun Han

N uptake: 47-82 %
(Kuhlmann et al. 1989)

P uptake: 37-85 %
(Kuhlmann and Baumgärtel 1991)

K uptake: 52 %
(Kuhlmann et al. 1985)

How to promote deep roots in arable land?

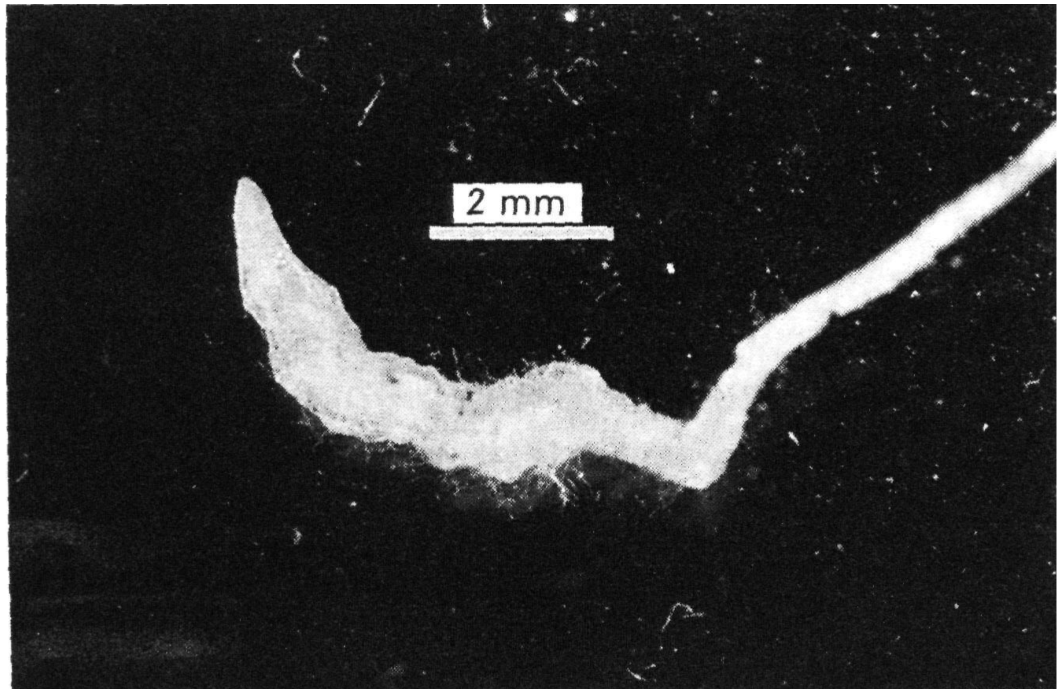
Utilization of soil structure

Plant and Environmental Sciences

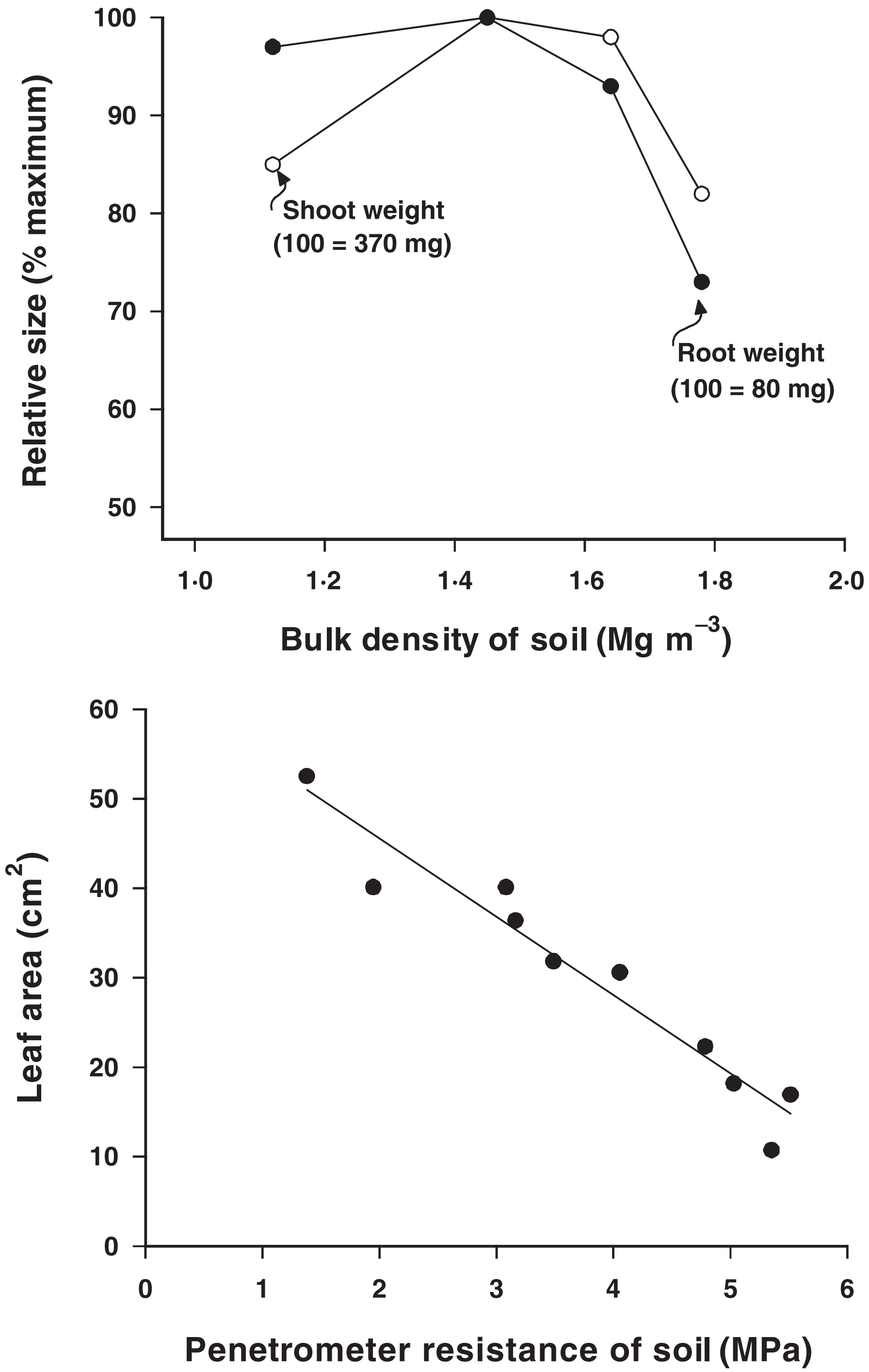
Identification of deep-rooting crops

Soil biopores

Mechanical resistance



Source: Atwell (1988)

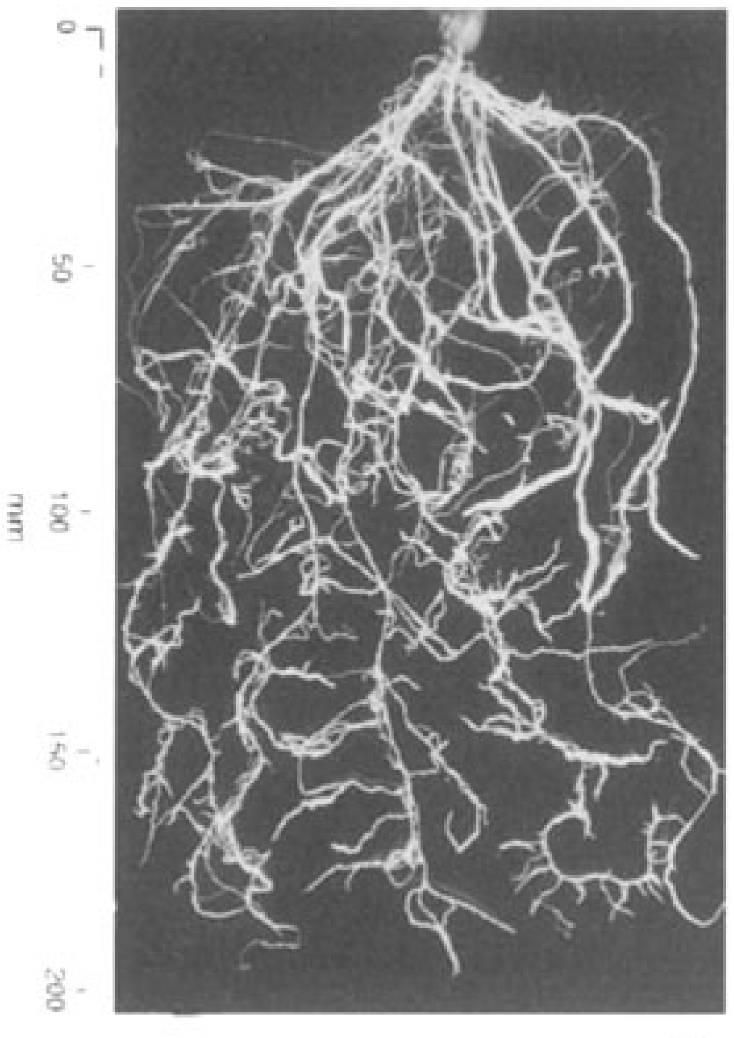


Source: Passioura (2002)

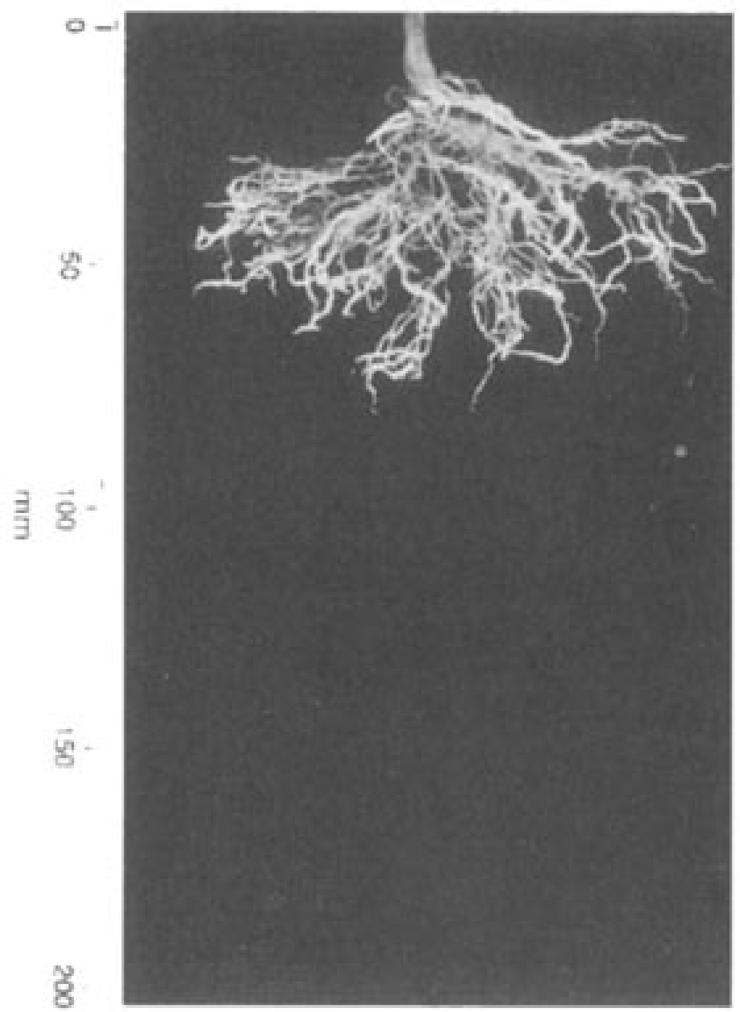
Soil biopores

Mechanical resistance

1.50 Mg m^{-3}



1.77 Mg m^{-3}



Source: Stirzaker et al. (1996)

Soil biopores

Mechanical resistance

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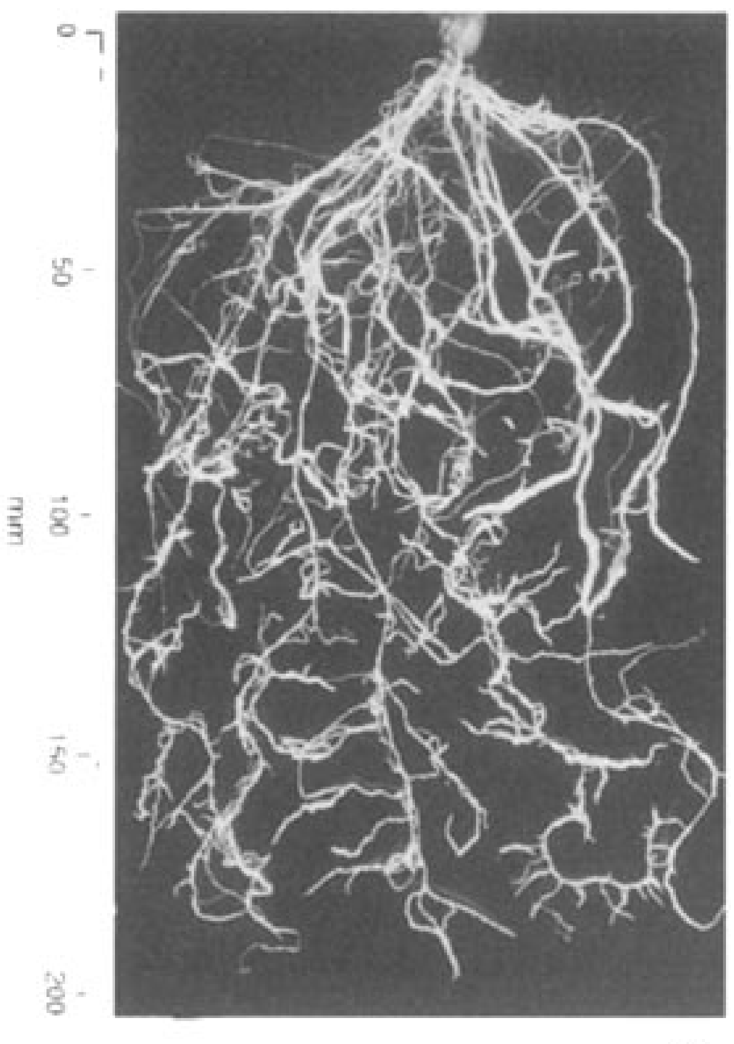
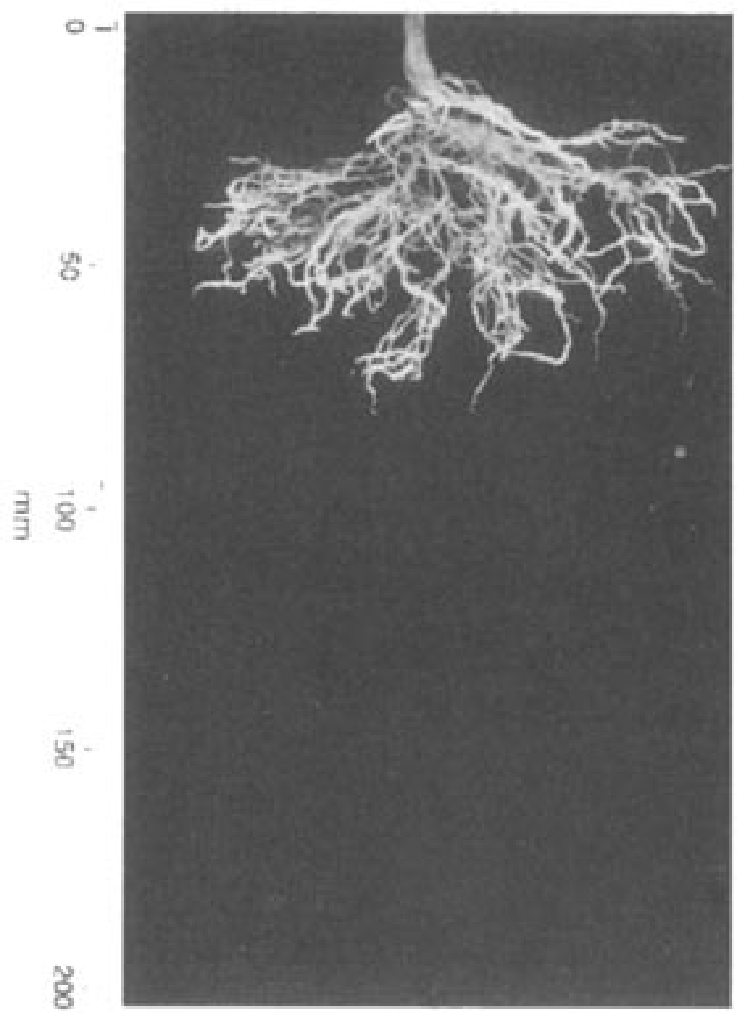
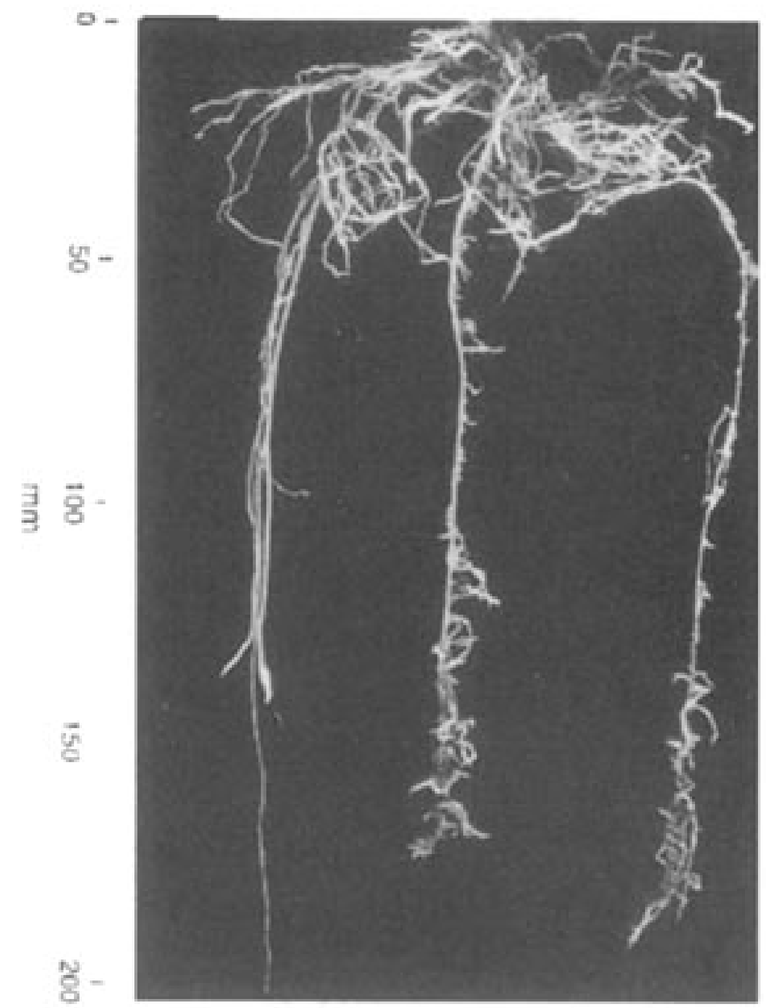


1.77 Mg m^{-3}



1.77 Mg m^{-3} with biopores



Source: Stirzaker et al. (1996)

Soil biopores

Preferential pathways

"The round voids in the soil formed by biological activity"

(Kautz 2015)

Biopores

Source: Eusun Han

Soil biopores

Preferential pathways

“The round voids in the soil formed by biological activity”
(Kautz 2015)

Biopores

Root penetration

Earthworm movement

Source: Eusun Han

Project structure

DFG-FOR 1320 (2009-2012)

Crop sequence and nutrient acquisition from the subsoil

DFG-PAK 888 (2014-present)

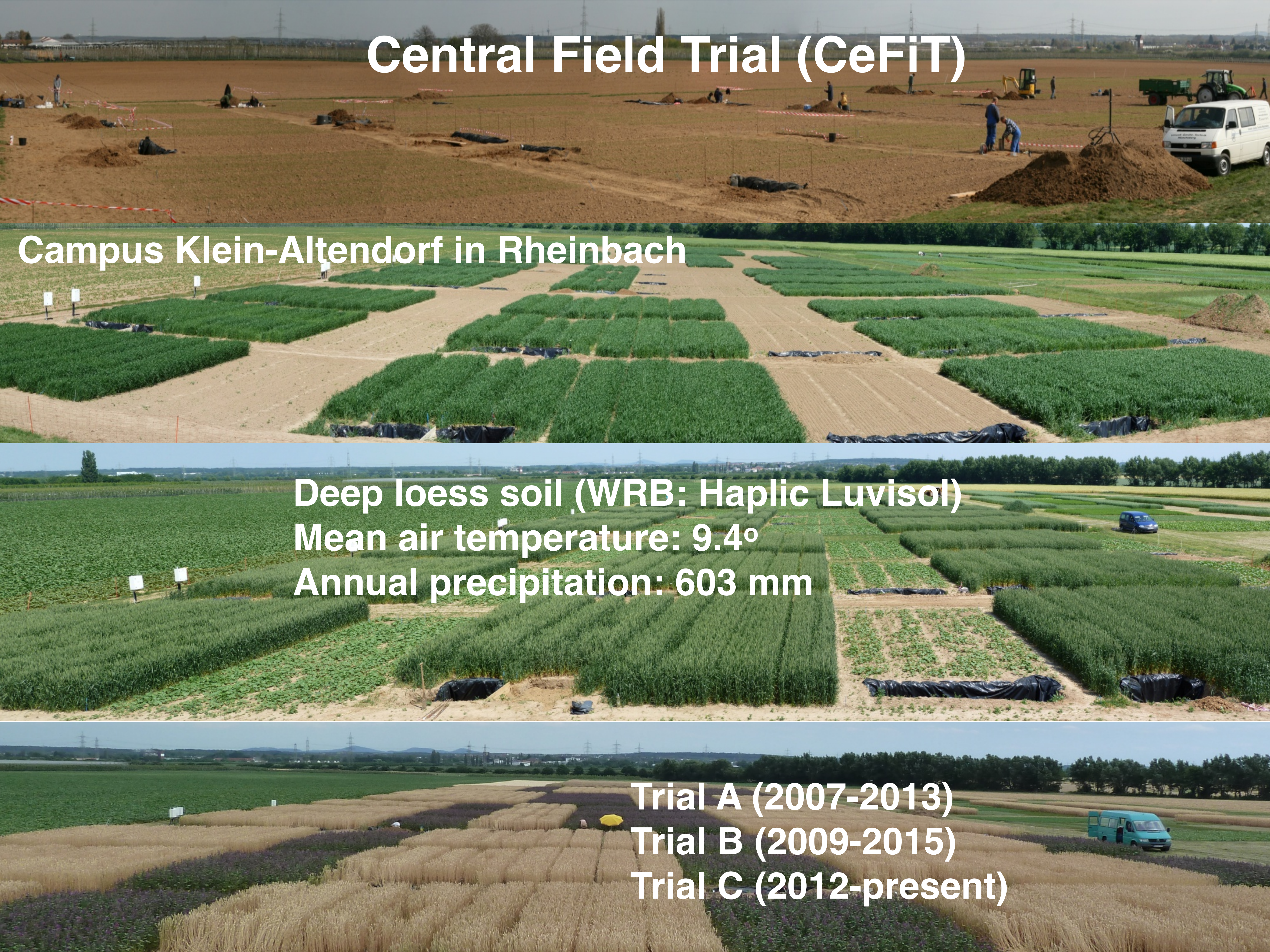
Biopores as hotspots for nutrient acquisition from the subsoil

Biopore genesis
Root growth
Shoot growth

DFG – FOR 1320

Biopore utilization
Drilosphere property
Anecic earthworm

Optimization of research methods
Investigation on relevant factors
Suggestion on future research
(2012-2015)



Central Field Trial (CeFiT)
Campus Klein-Altendorf in Rheinbach
Deep loess soil (WRB: Haplic Luvisol)
Mean air temperature: 9.4º
Annual precipitation: 603 mm
Trial A (2007-2013)
Trial B (2009-2015)
Trial C (2012-present)

Findings

- **Biopore genesis under perennial fodder cropping**
- Root morphology as affected by soil biopore systems
- **Biopore-root-shoot relationship**

Biopore genesis under perennial fodder cropping

Han, E., Kautz, T., Perkons, U., Lüsebrink, M., Pude, R., & Köpke, U. (2015). Quantification of soil biopore density after perennial fodder cropping. Plant and Soil, 394(1-2), 73–85.

Findings

Biopore genesis

1, 2 and 3 years of fodder cropping with;

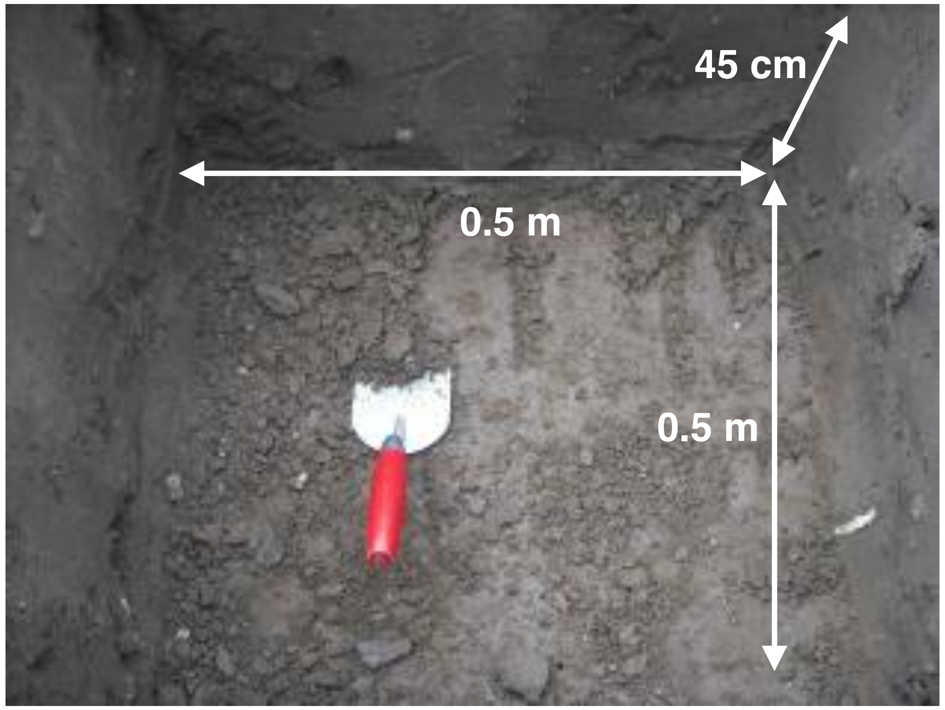
Lucerne (Luzerne)

Chicory (Wegwarte)

Tall fescue (Rohrschwingel)

Source: Wikipedia

Biopore genesis



Source: Eusun Han

Findings

Biopore genesis

2010 in Trial A (TA)
2012 in Trial B (TB)

Coarse-sized BP (BP_{cor}): >5 mm
Medium-sized BP (BP_{med}): 2-5 mm
Total BP (BP_{tot}): >2 mm

Two-year fallow

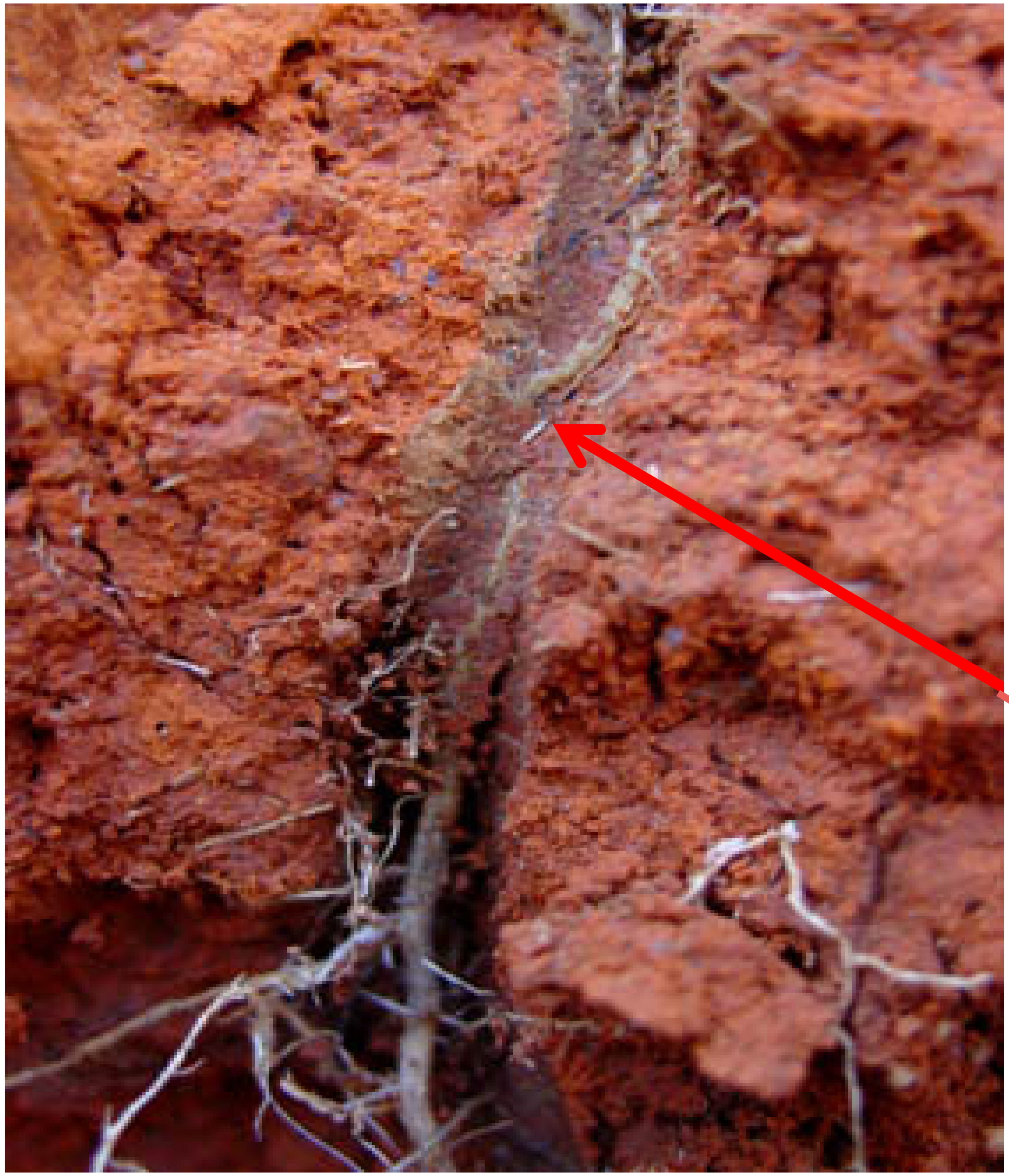
Source: Eusun Han

universitätbonn
Rheinische Landwirtschaftliche
Friedrich-Wilhelms-Fakultät der
Universität Bonn Universität Bonn

Findings

Biopore genesis

IOL
Institut für Organischen Landbau
Universität Bonn
DFG – FOR 1320

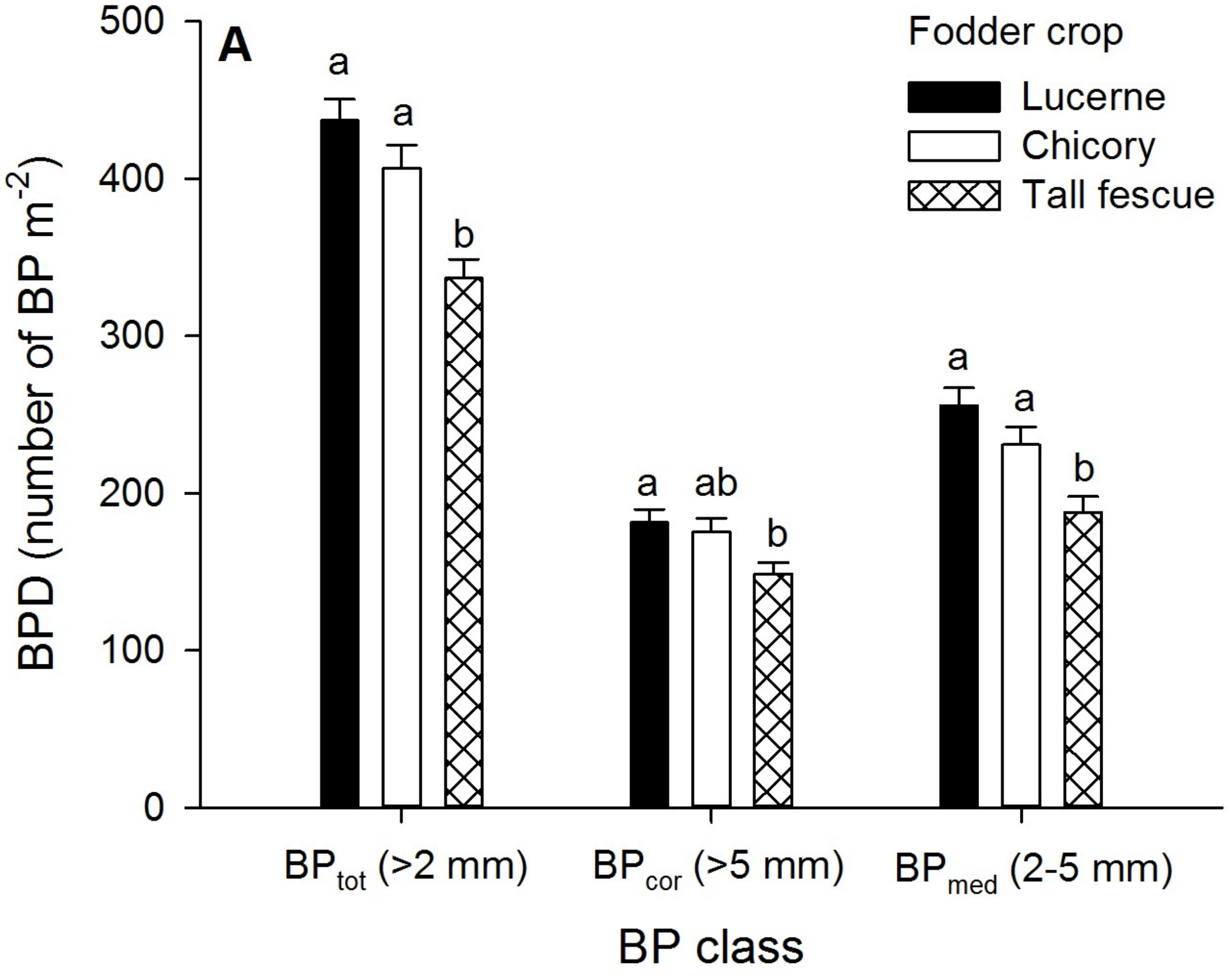


Decomposed roots

Source: John Kirkegaard

Findings

Biopore genesis

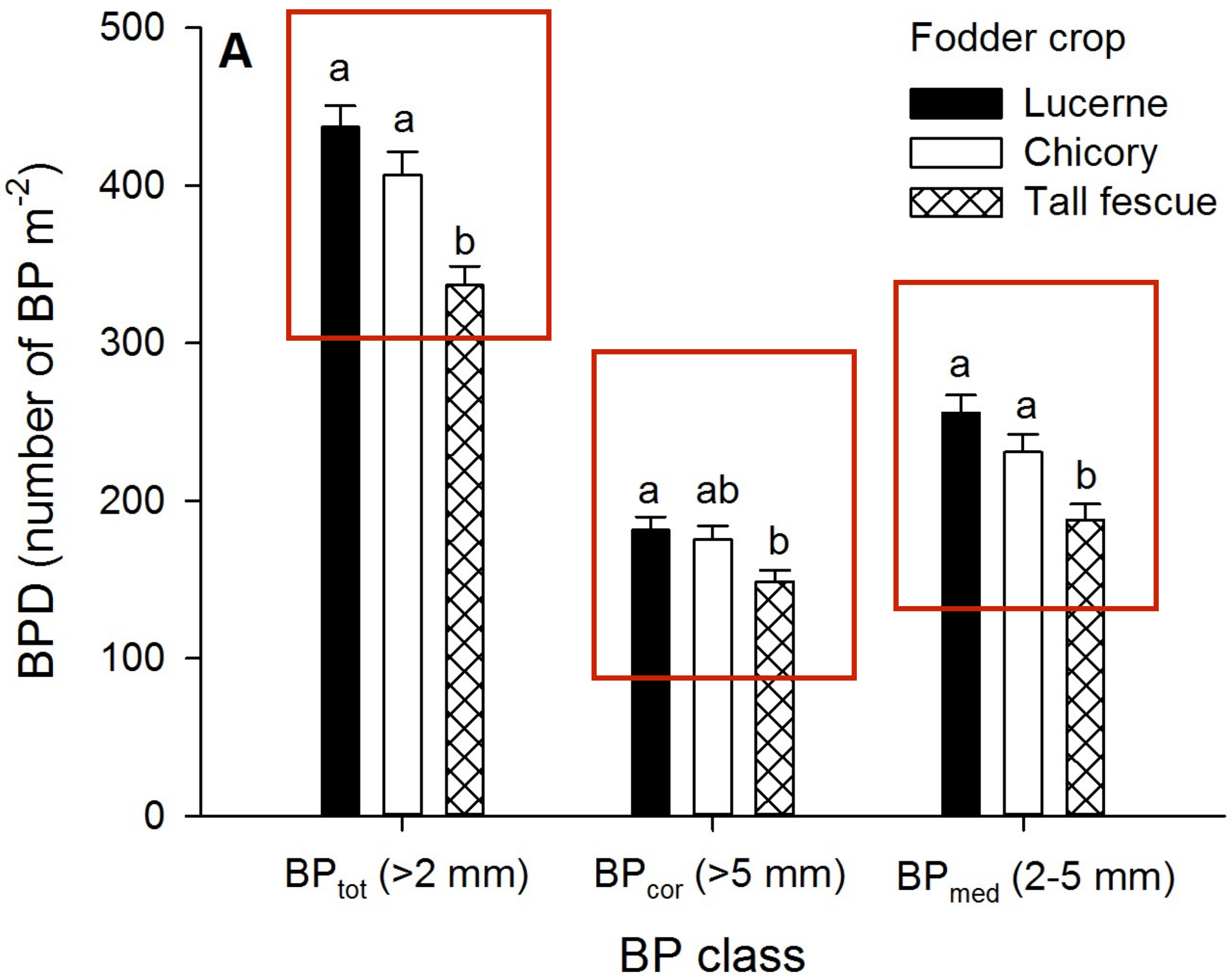


Biopore density (BPD; mean ± one SE) of all size classes (BP_{tot}: >2 mm), coarse-sized (BP_{cor}: >5 mm) and medium-sized (BP_{med}: 2-5 mm) affected by fodder crops (A: lucerne, chicory and tall fescue). Small letters indicate significant differences between the treatments within BP class (Tukey's HSD, $P \leq 0.05$). Differences are not significant without indication.

Source: Han et al. (2015a)

Findings

Biopore genesis



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Source: Han et al. (2015a)


Biopore-root-shoot relationship

Han, E., Kautz, T., Perkons, U., Uteau, D., Peth, S., Huang, N., Horn, R., & Köpke, U. (2015). Root growth dynamics inside and outside of soil biopores as affected by crop sequence determined with the profile wall method. Biology and Fertility of Soils, 51, 847–856.

Biopore-root-shoot

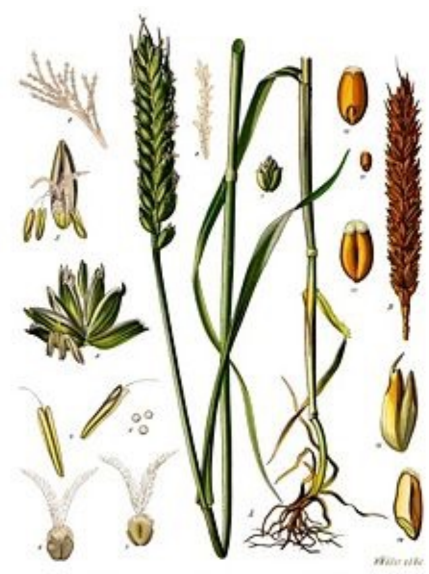
2010 | 2011 | 2012

Chicory(Chi)

Chicory(Chi)

Tall fescue (Fes)

Tall fescue (Fes)



Spring wheat (SW)

→ Treatments
Chi-Chi-SW
Fes-Fes-SW

Source: Wikipedia

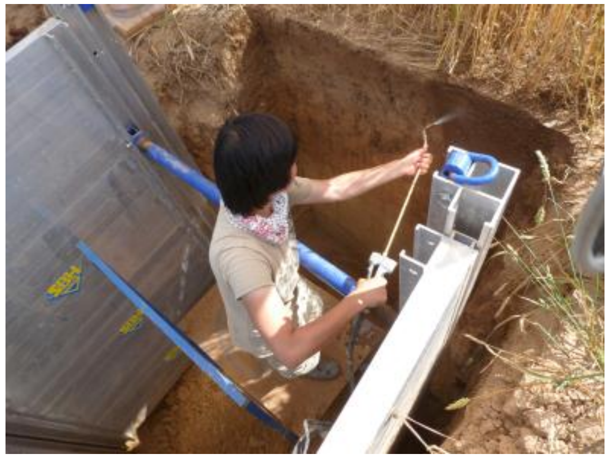
Findings

Biopore-root-shoot

Preparation of the profile wall





Source: Eusun Han

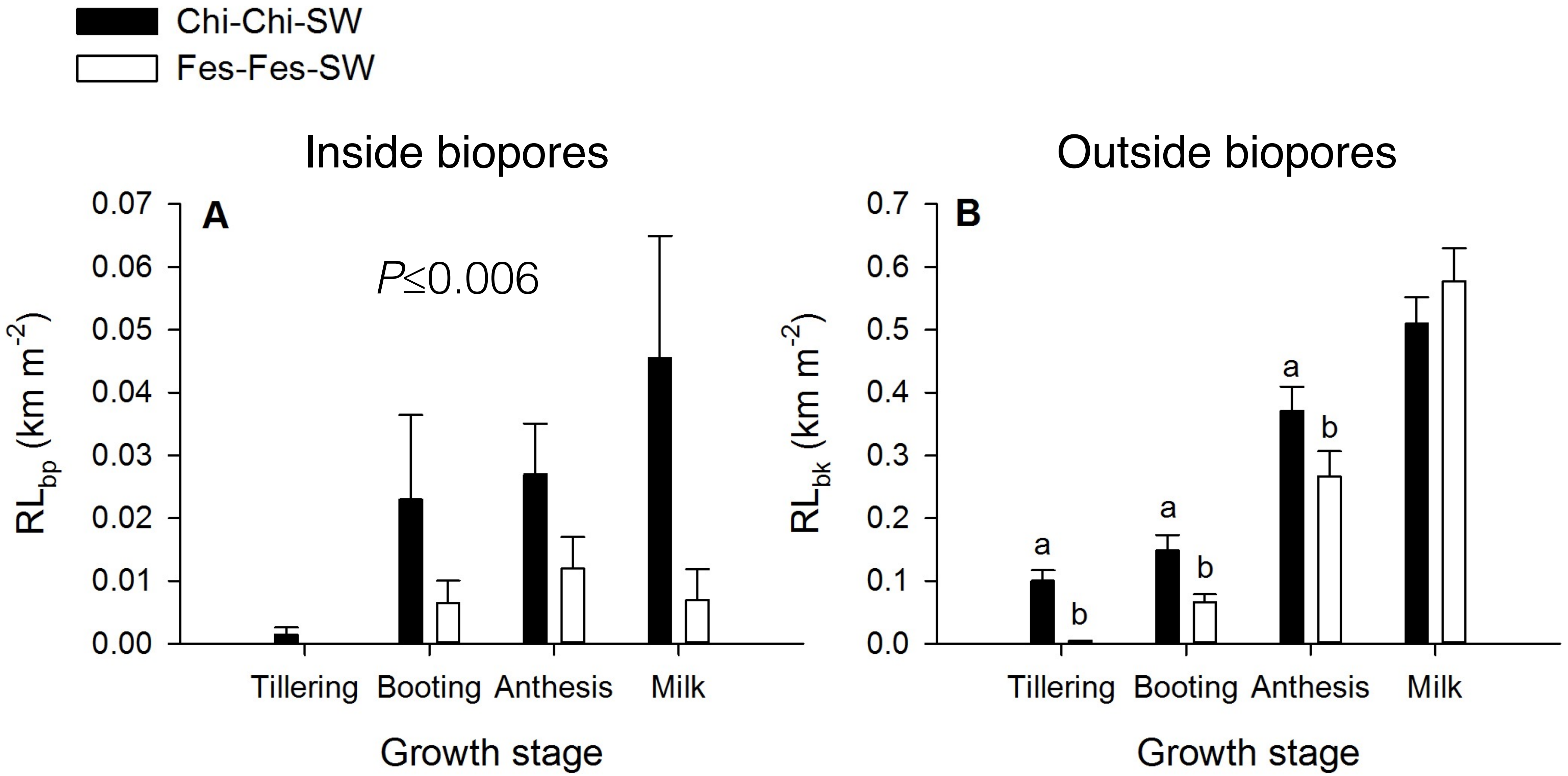
Recording the Root Length Unit (1 RLU=5 mm)

Source: Eusun Han

Recording the Root Length Unit (1 RLU=5 mm)

Source: Eusun Han

Biopore-root-shoot

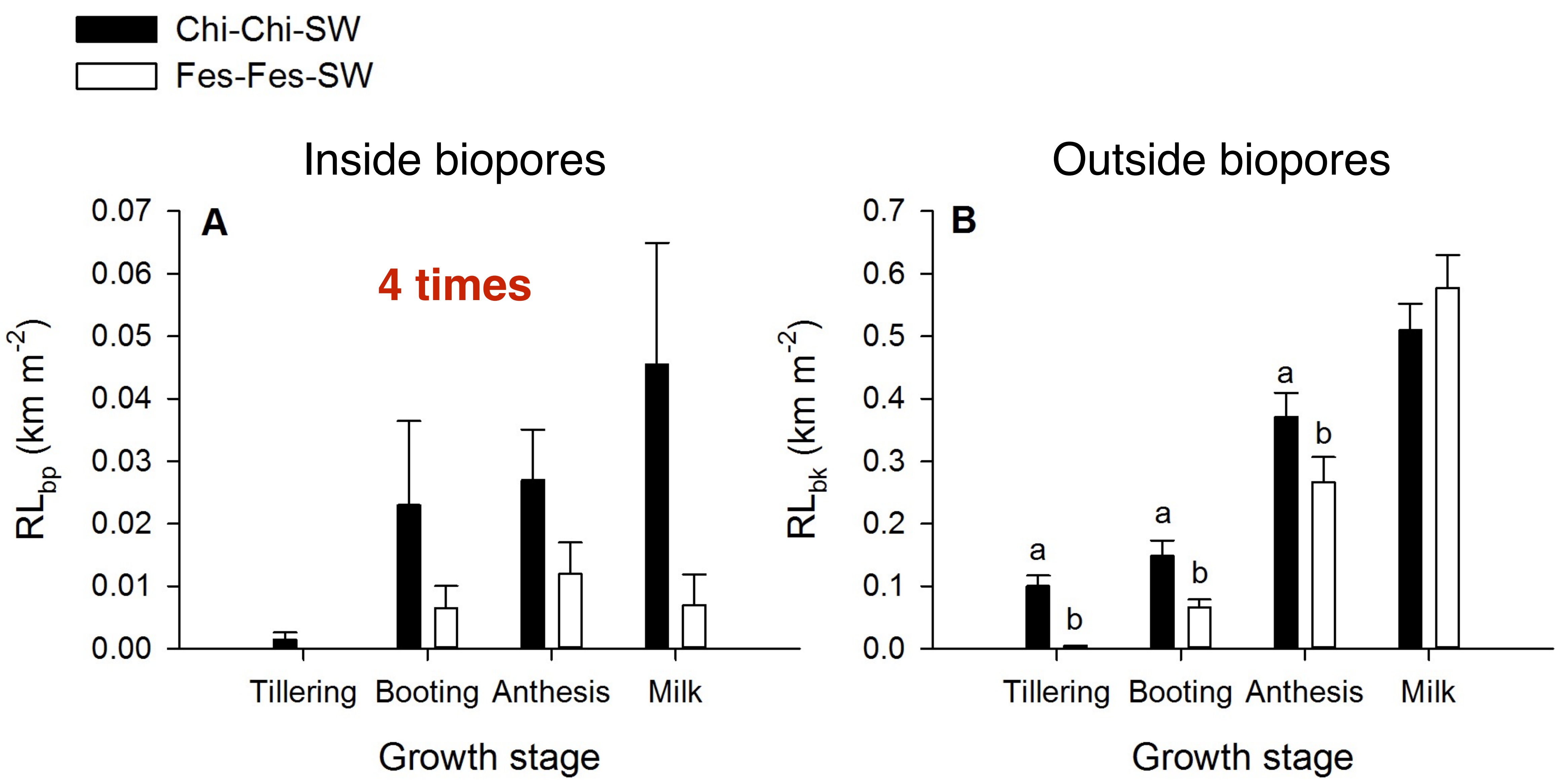


Root length (km m^{-2}) of SW outside BP (A; RL_{bk}) and inside BP (B; RL_{bp}) beneath 45 cm of soil depth affected by crop sequence (Chi-Chi-SW and Fes-Fes-SW) and growth stage (tillering, booting, anthesis and milk) in 2012. Small letters indicate significant differences between crop sequence within growth stage (pair-wise t-test, $P \leq 0.05$).

Source: Han et al. (2015b)

Findings

Biopore-root-shoot



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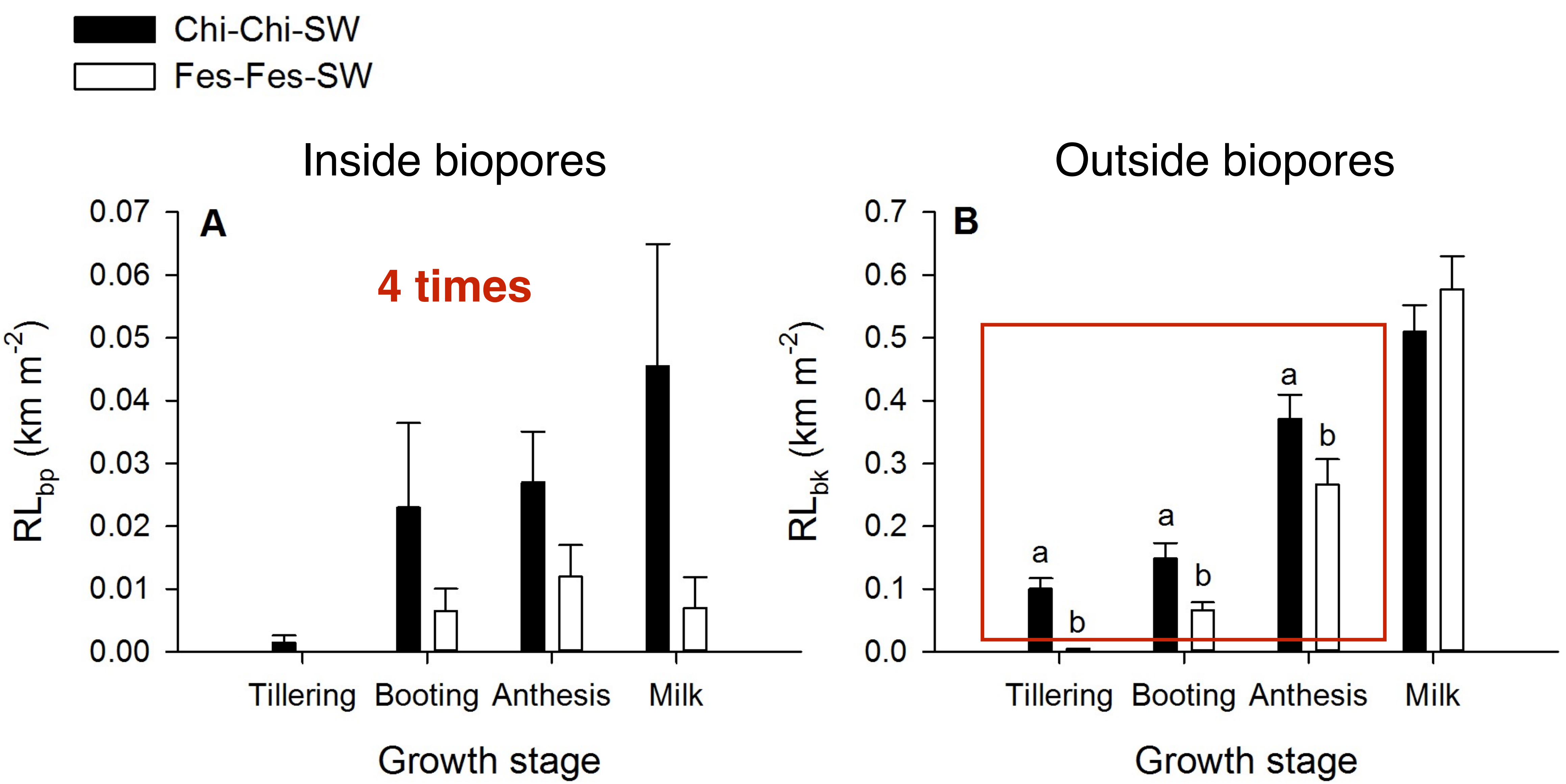
Biopore-root-shoot



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Source: Han et al. (2015b)

Biopore-root-shoot

Inside biopores

Source: Huang et al. in Prep

Re-entry to bulk soil

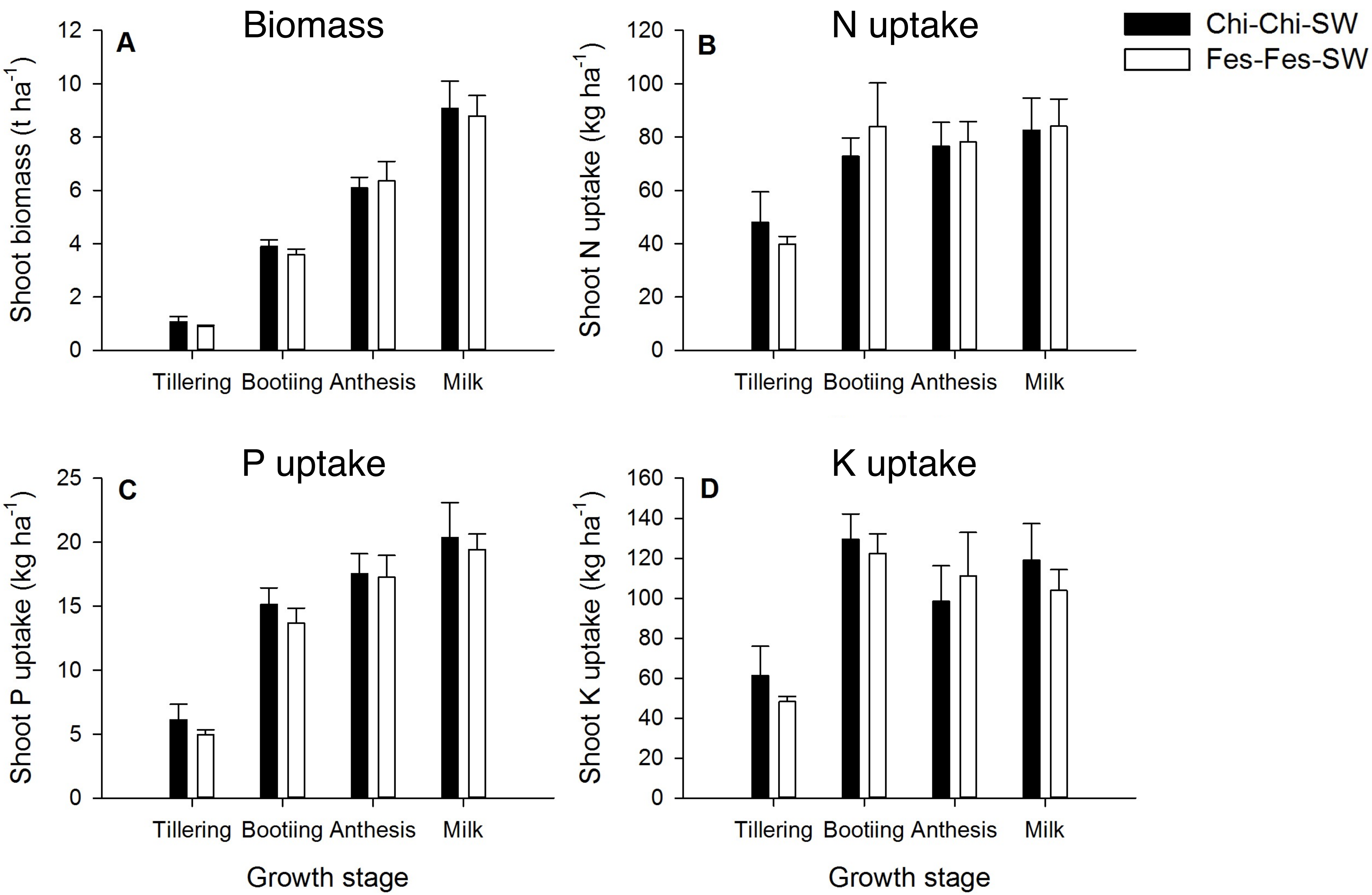
Source: Athmann et al. (2011)

Root length (km m-2) of SW outside BP (A; RL_{bk}) and inside BP (B; RL_{bp}) beneath 45 cm of soil depth affected by crop sequence (Chi-Chi-SW and Fes-Fes-SW) and growth stage (tillering, booting, anthesis and milk) in 2012. Small letters indicate significant differences between crop sequence within growth stage (pair-wise t-test, $P \leq 0.05$).

Source: Han et al. (2015b)

Findings

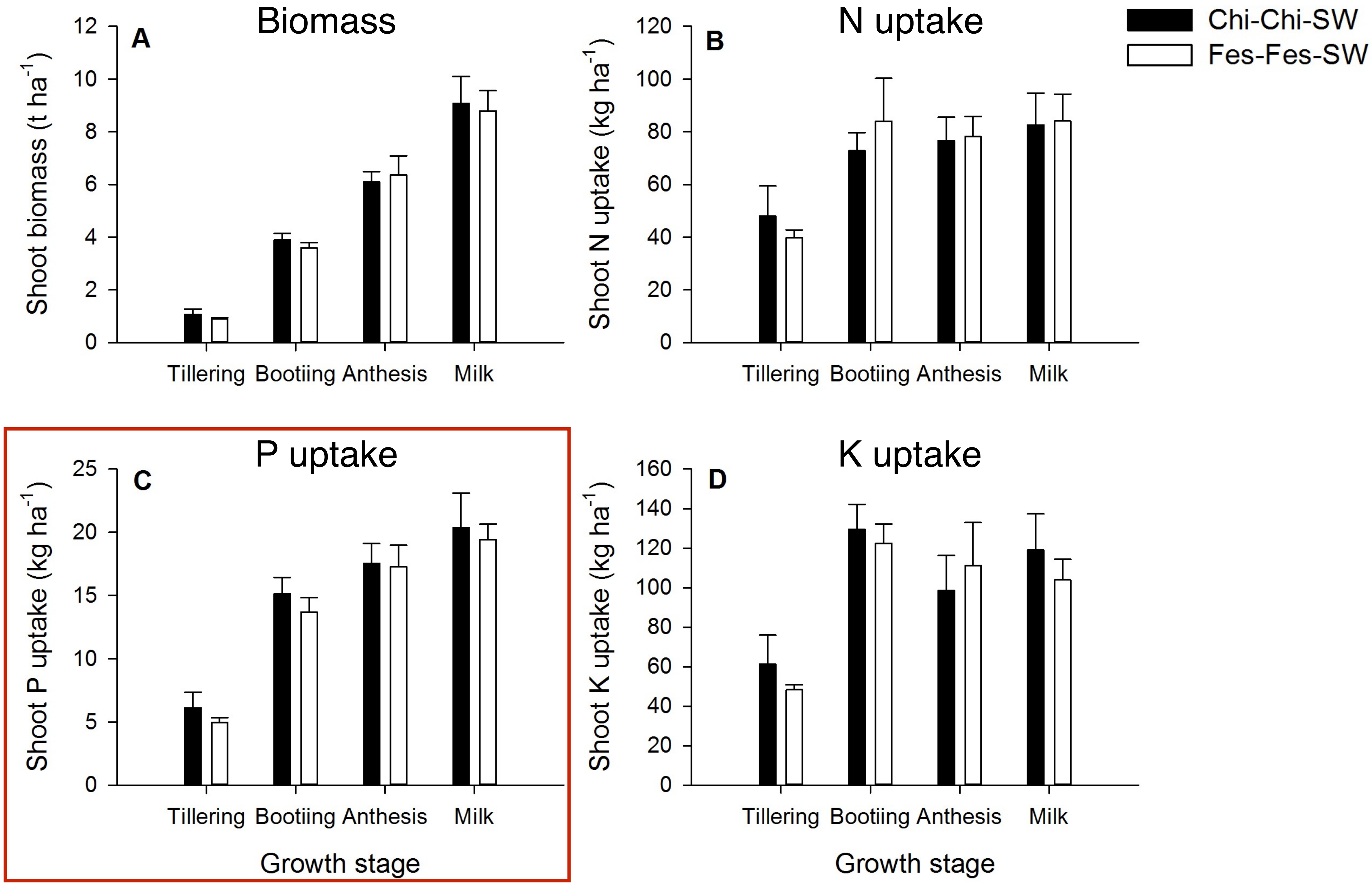
Biopore-root-shoot



Shoot biomass (A; t ha^{-1}), N (B; kg ha^{-1}), P (C) and K uptake (D) of spring wheat affected by crop sequence (Chi-Chi-SW and Fes-Fes-SW) and growth stage (tillering, booting, anthesis and milk) in 2012.

Source: Han et al. (2015b)

Biopore-root-shoot



$P \leq 0.003$

Shoot biomass (A; t ha^{-1}), N (B; kg ha^{-1}), P (C) and K uptake (D) of spring wheat affected by crop sequence (Chi-Chi-SW and Fes-Fes-SW) and growth stage (tillering, booting, anthesis and milk) in 2012.

Source: Han et al. (2015b)

How to promote deep roots in arable land?

Utilization of soil structure

Plant and Environmental Sciences

Identification of deep-rooting crops

DeepFrontier

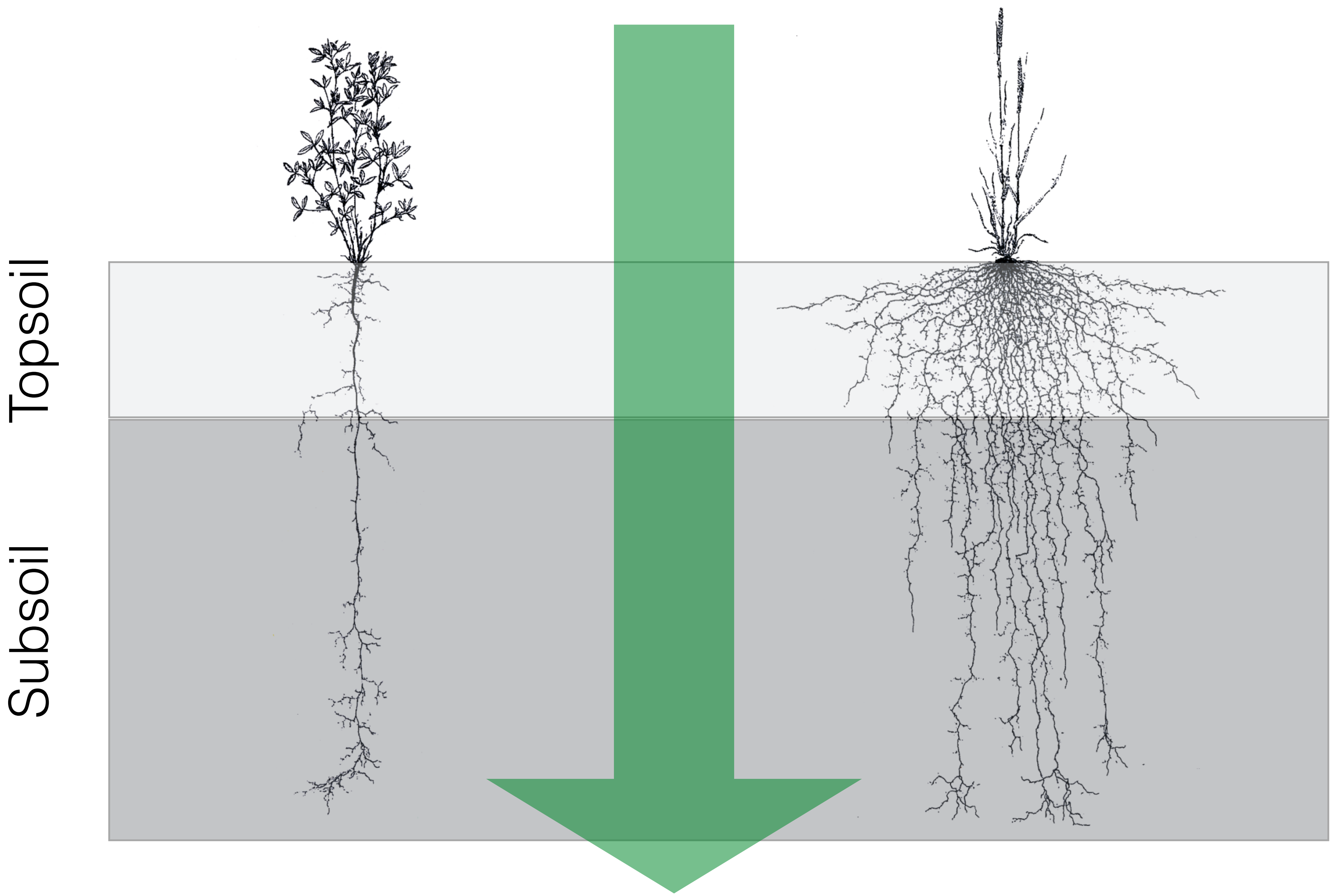
Department of Plant and Environmental Sciences,
University of Copenhagen

Plant and Environmental Sciences

ICROFS
International Centre for Research
in Organic Food Systems

AARHUS UNIVERSITY

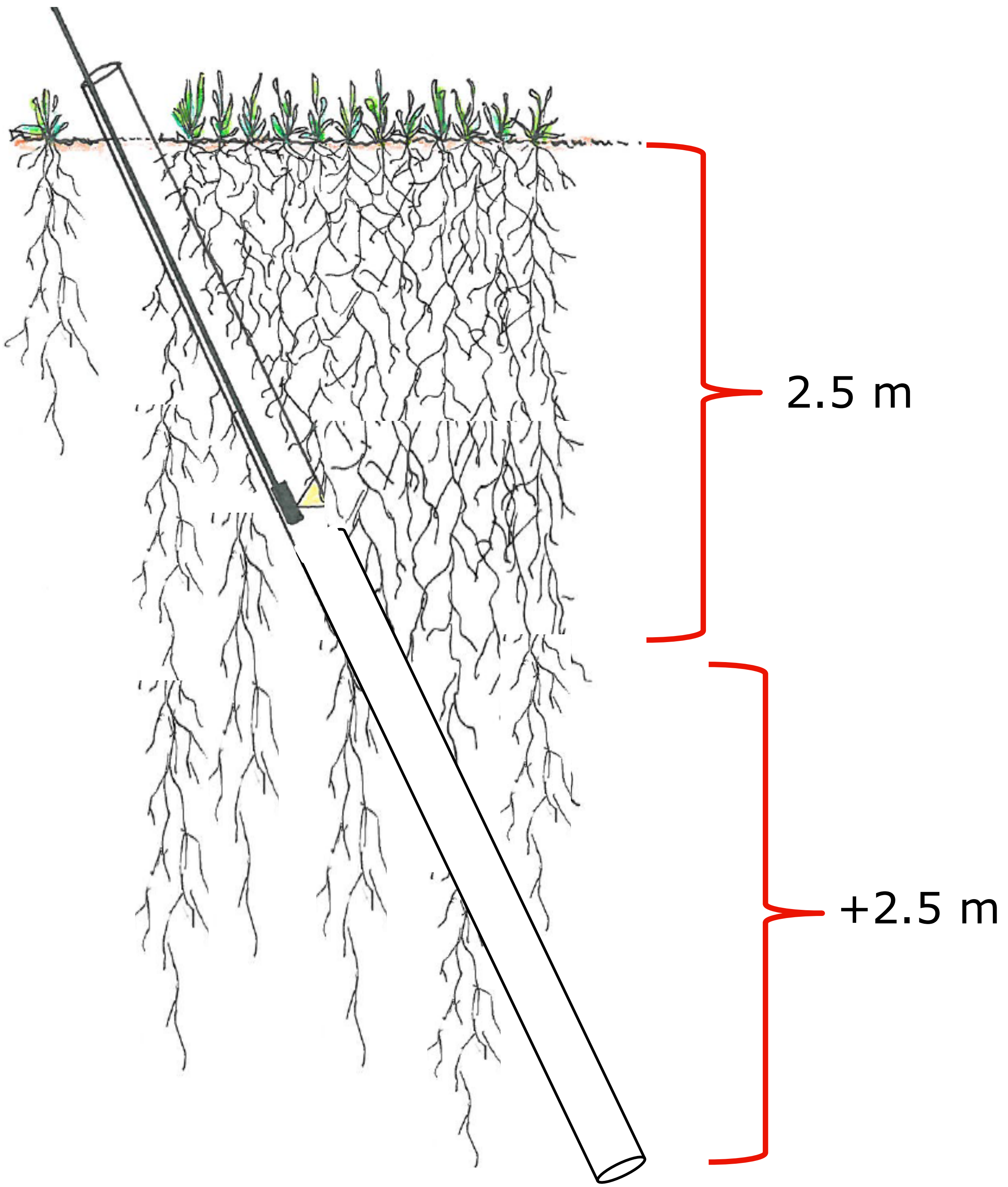
Down to 5 m

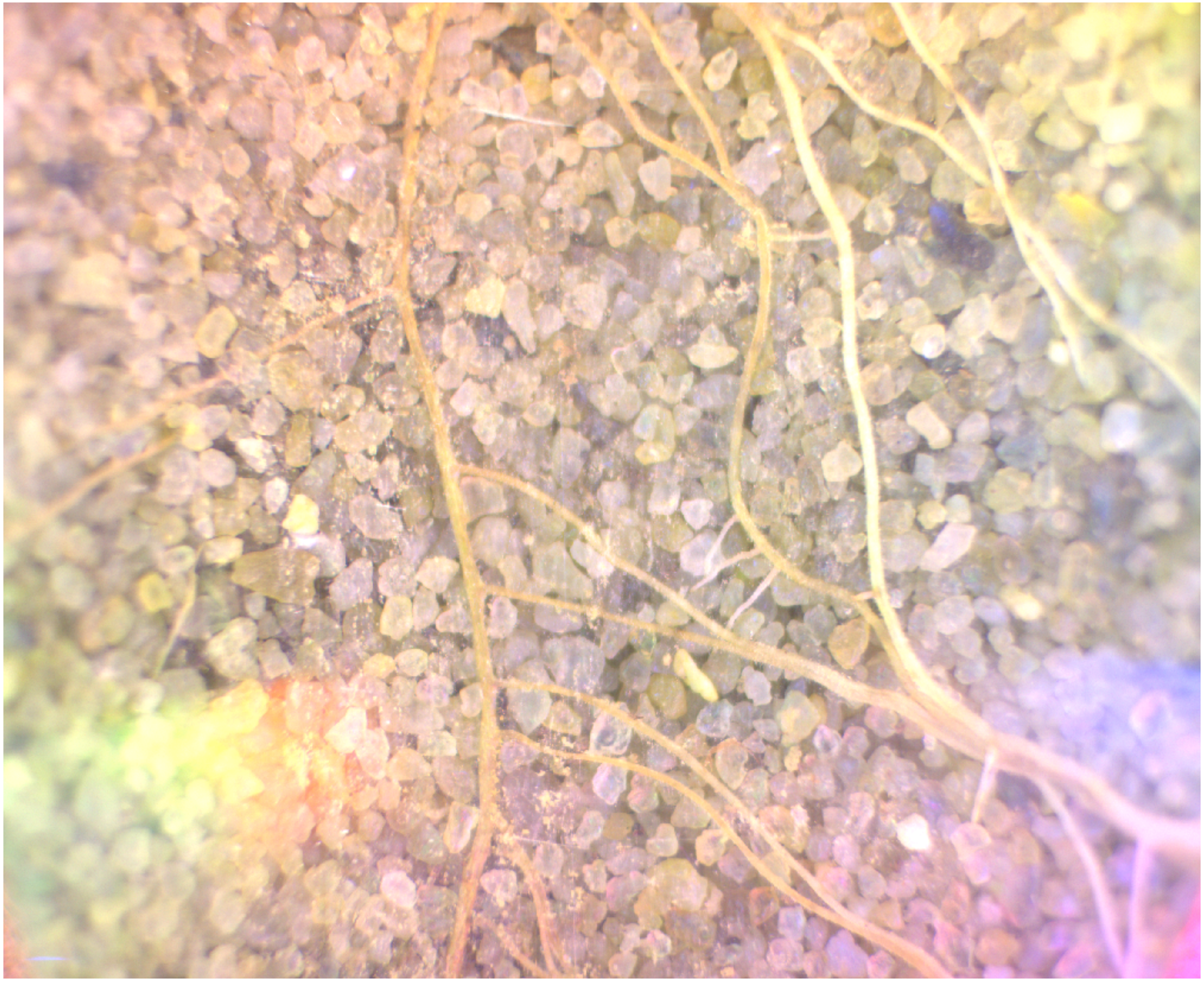


DeepRootLab

Source: ICROFS

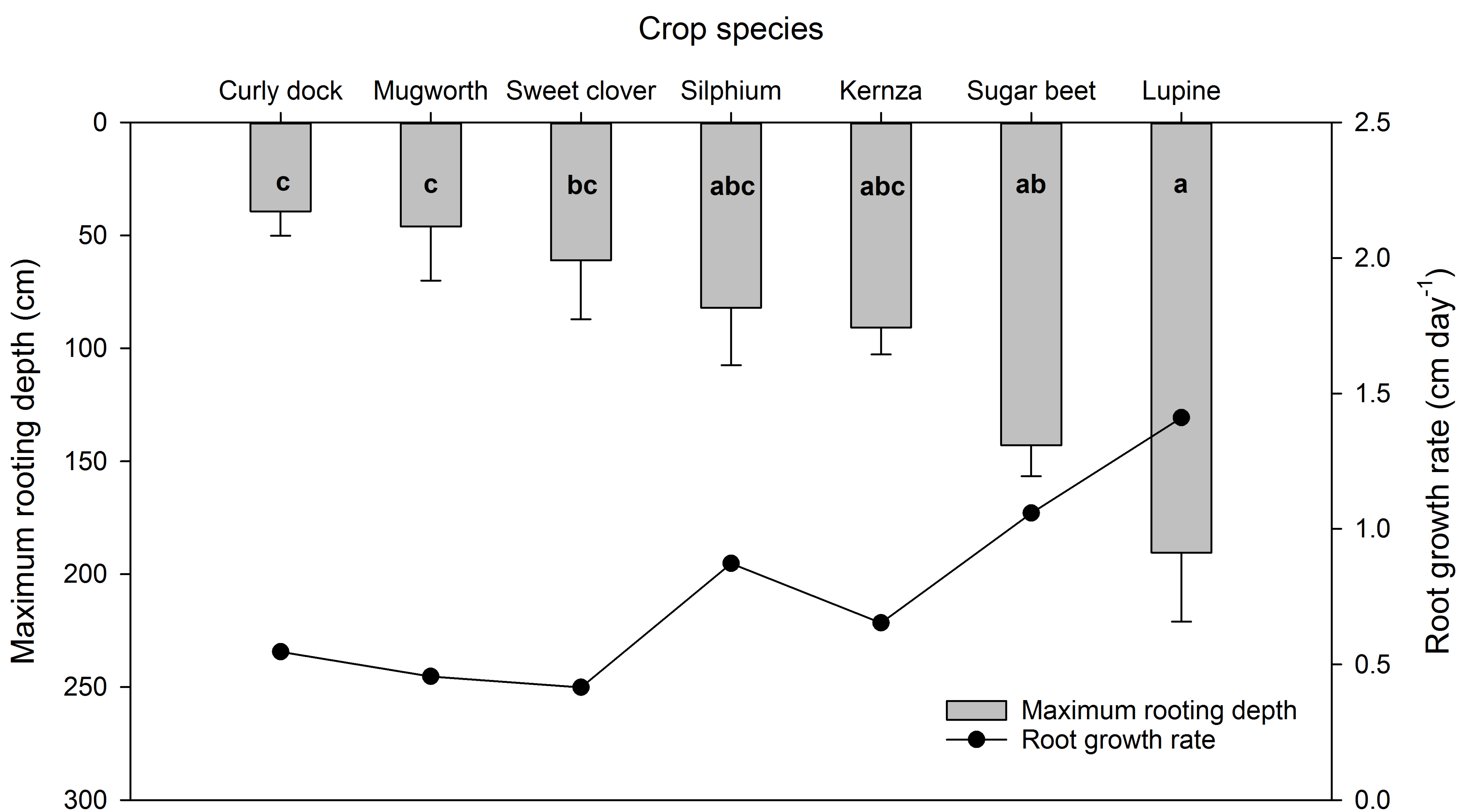
Minirhizotron method





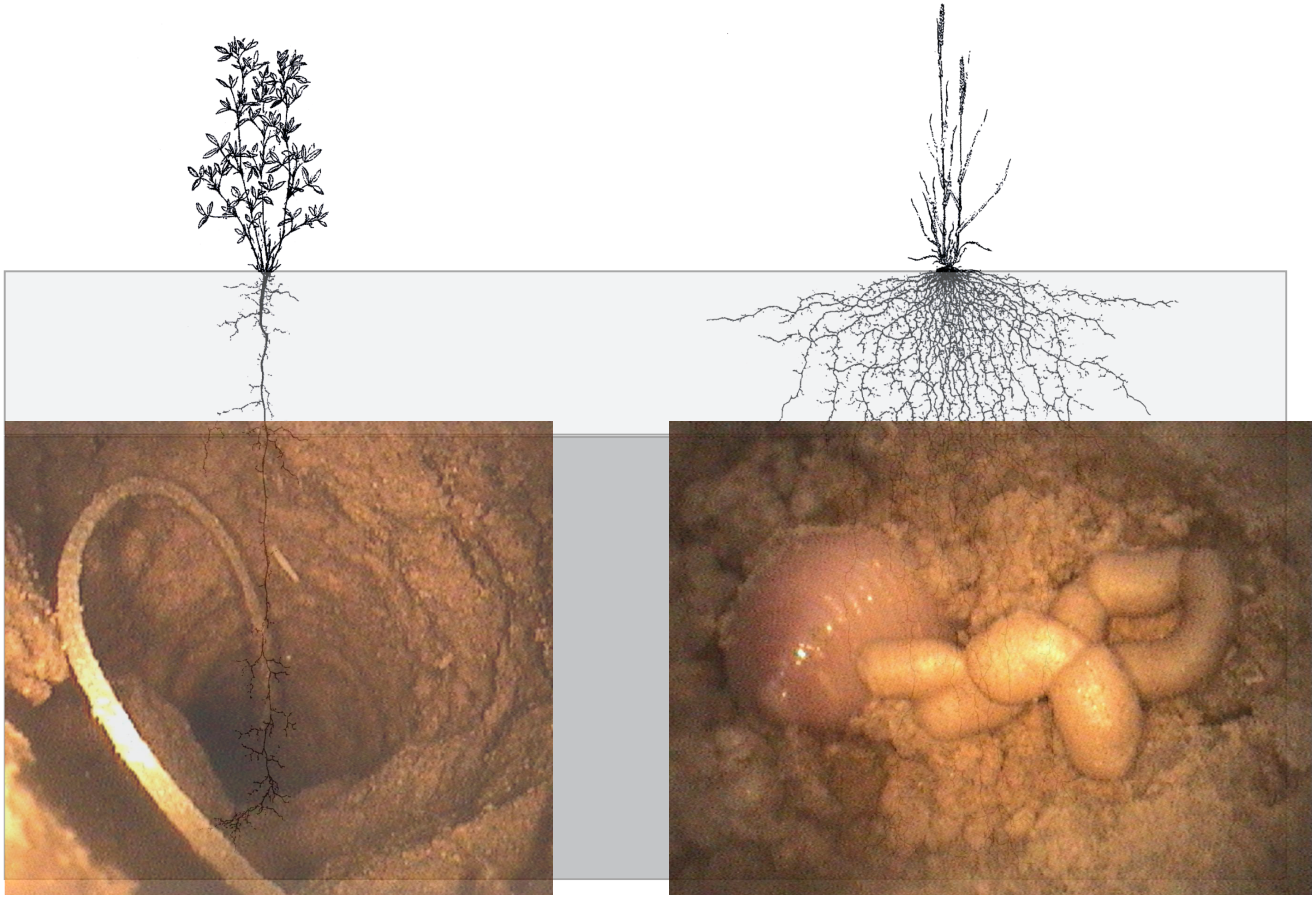
Source: Han et al. submitted

Deep-rooting crops



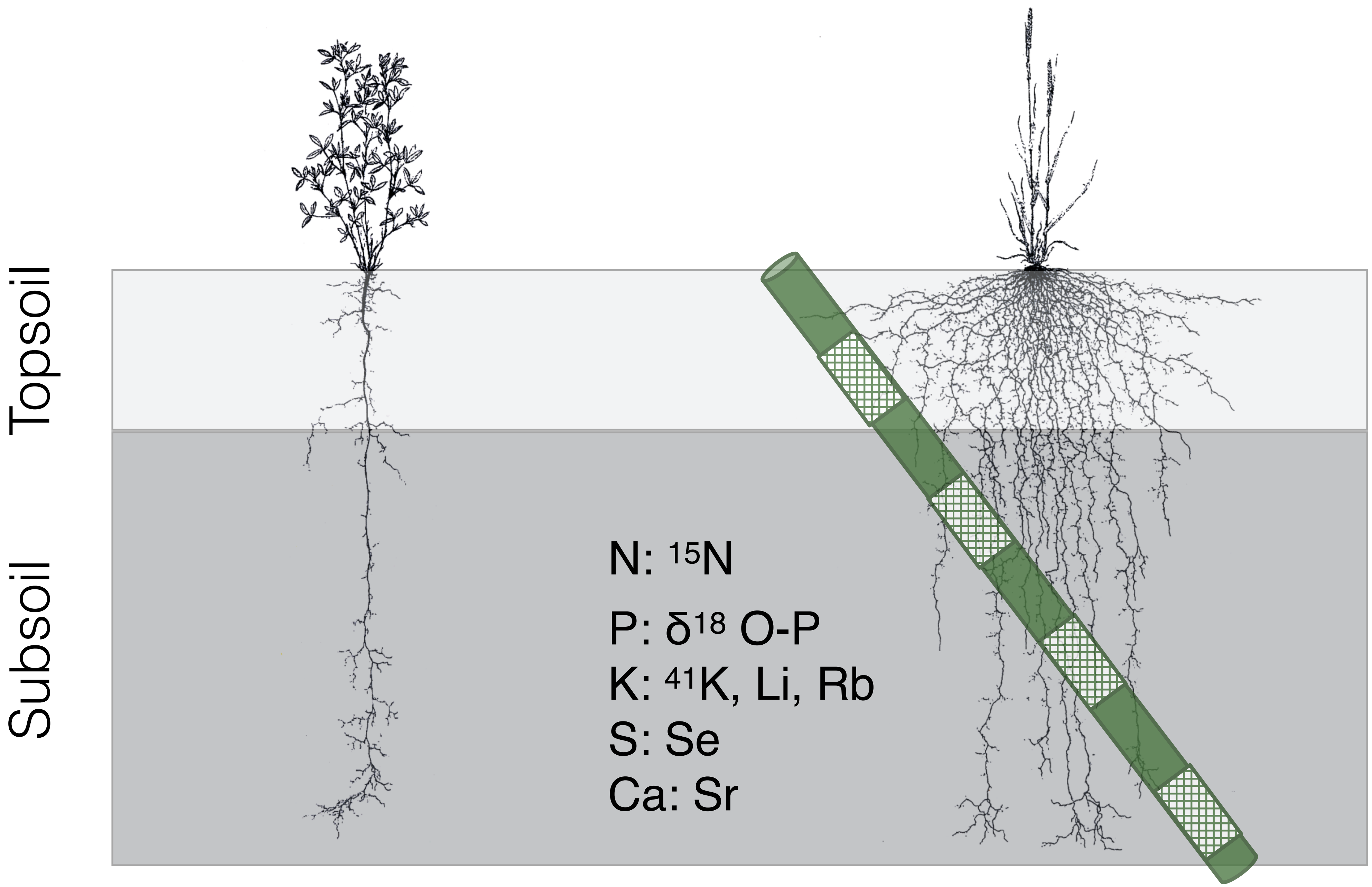
Source: Han et al. submitted

Biopore genesis to biopore utilization

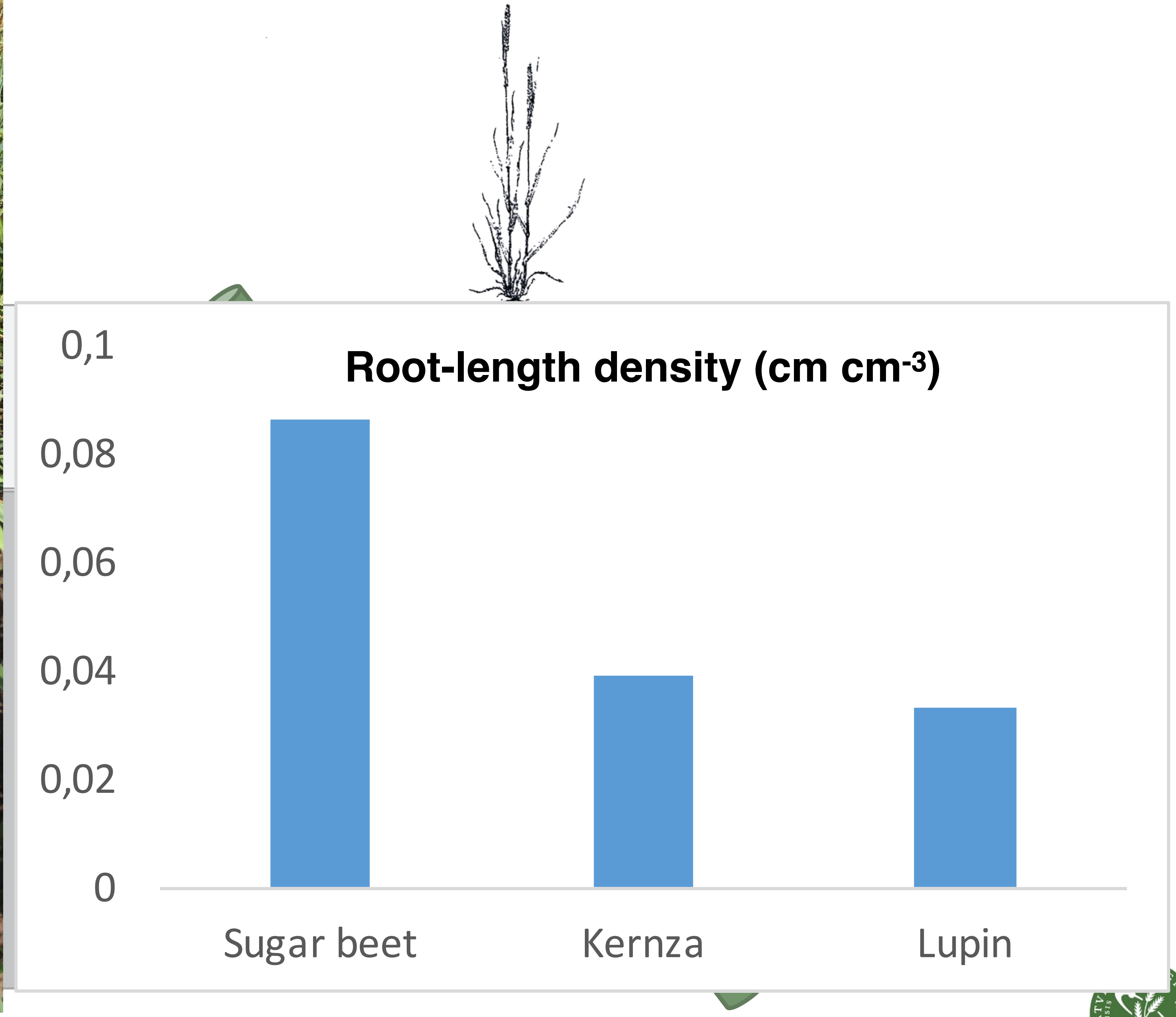


Source: Huang et al. in Prep

Quantification of plant resource uptake



Quantification of plant resource uptake




Research must go on.

What about Asian deep roots?

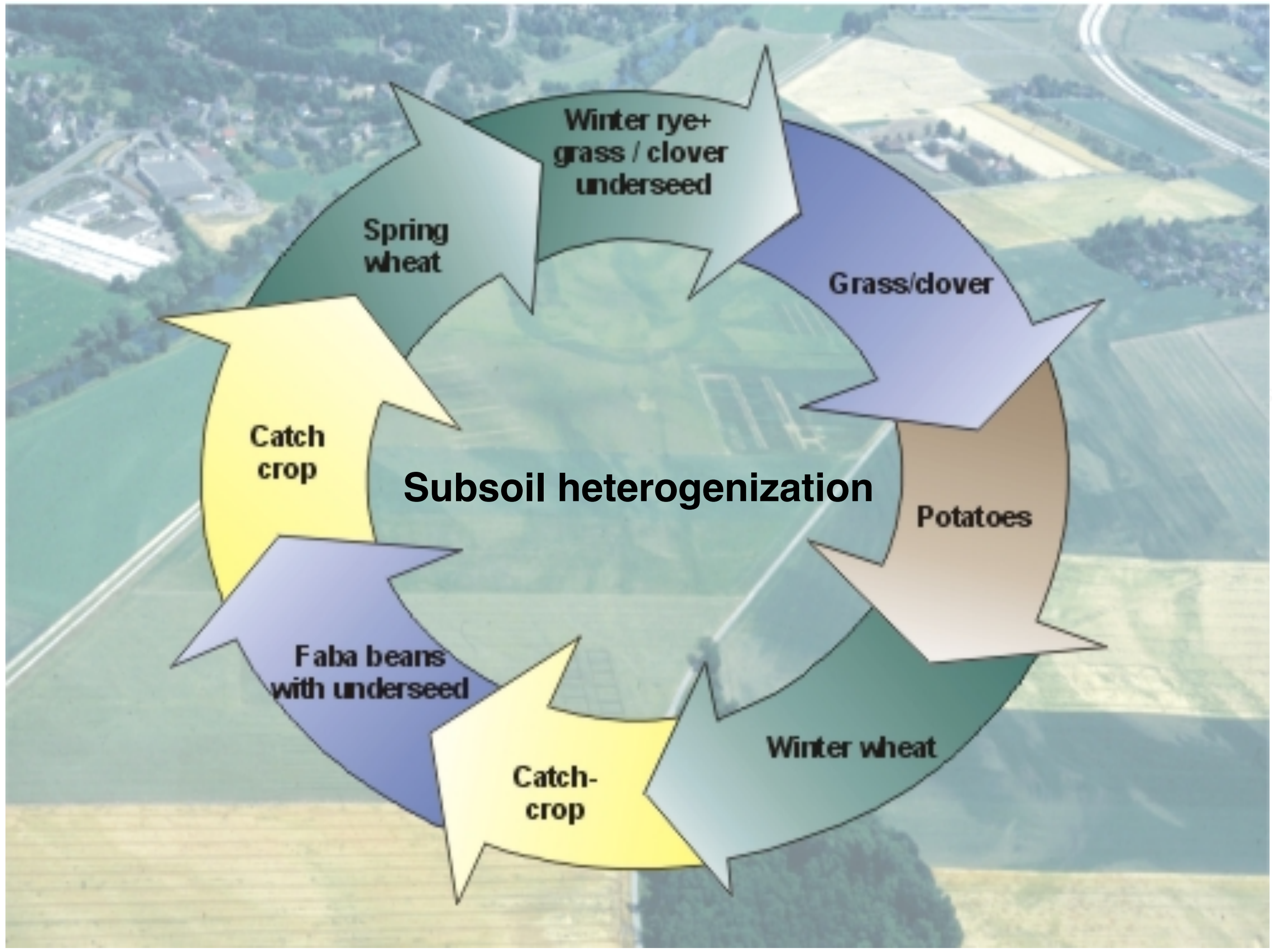
Organic agriculture and deep roots

Köpke, U., **Han, E. et al.** (2015). Optimising cropping techniques for nutrient and environmental management in Organic Agriculture. Sustainable Agriculture Research, 4(3), 15–11.

Role of deep roots in organic agriculture

"Organic Agriculture is designed to derive large parts of nutrients from the solid phase."

Diversification of cropping system



↓

- Enhanced access to the subsoil
- Improved nutrient status of **drilosphere**

Acknowledgements

The first farm
IFOAM Asia

and,

Acknowledgements

The first farm
IFOAM Asia

and,

Dr. Zejiang Zhou

Plant and Environmental Sciences

“We should cherish and grow young organic leaders.”

Department of Plant and Environmental Sciences

Thank you

For your attention