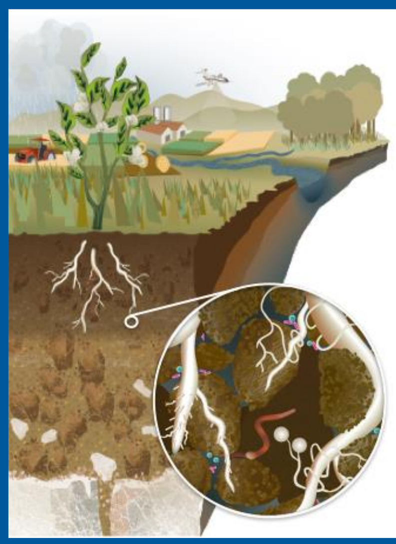

Dynamics of Nitrogen Species in Soil and their Relevance for Root System Morphology – What Have We Learned from Drew?

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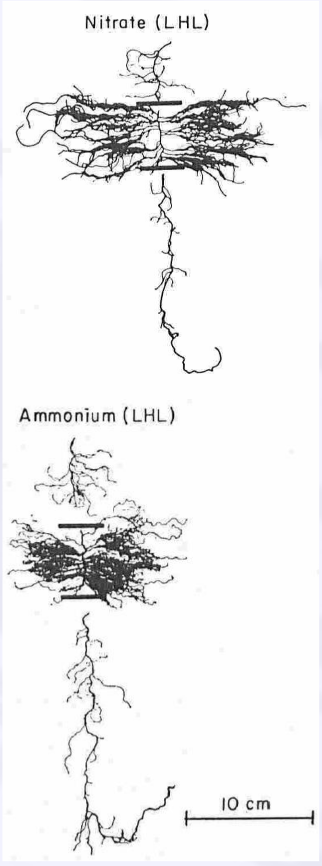
1 Introduction and Background

- Only **30-50%** of applied nitrogen (N) fertilizers are captured by crops. Therefore increasing **N-use efficiency** and **crop production** is a major challenge for **sustainable agriculture**.
- **Urea** is the most widely used N fertilizer worldwide and undergoes rapid hydrolization in soil, after which the **ammonium is oxidized to nitrate**.
- Due to the use of **nitrification inhibitors**, the importance of **NH_4^+ as N source** for plant nutrition has increased.
- Because fertilizer is applied as **granules**, nutrient rich **patches** with high concentrations of **local N** are created in the soil.
- **Systemic repression** of lateral root (LR) growth by **high N status** of the plant and **local stimulation** or **inhibition** of LR growth by availability of **NO_3** and **NH_4** are typically found.
- These responses have been shown in **sand** substrate with continuous **nutrient inflow, gel & hydroponic** systems, and are controlled by **external & internal signals**, associated with local & systemic **signalling pathways** in the plant.

...Drew?

from Drew (1975):



2 Aims

- **Combination** of *in situ* analysis of **root system development** in the **soil** with **soil chemical studies** (e.g. pH & N-dynamics in **soil solution**).
- Increase understanding of **temporal and spatial** dynamics of **root response** to **non-uniform** supply of N in the soil for 3 different plant species: **faba bean** (*Vicia faba*), **barley** (*Hordeum vulgare*) & **corn** (*Zea Mays*).

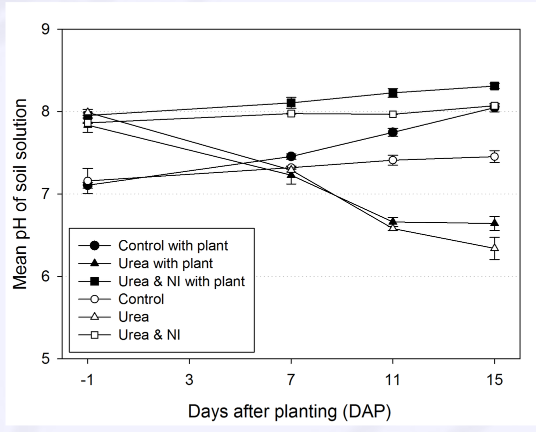
3 Methods

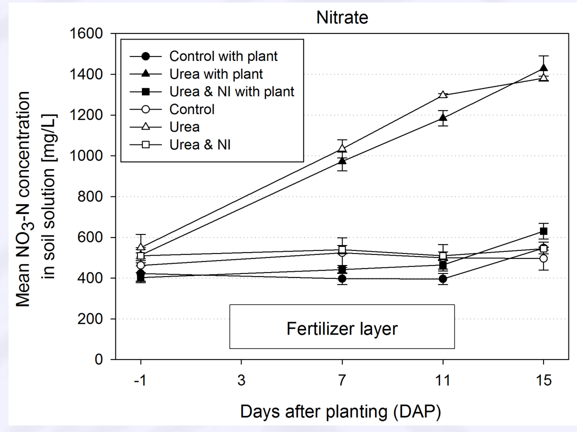
- Use of **urea granules** with and without nitrification **inhibitor** (NI) to create different **ratios of NO_3:NH_4** in **soil and soil solution.**
- **Visualization** and **characterization** of **root system development** *in situ* by X-ray computer tomography (CT) for faba bean, or several harvests over time for barley and corn.
- Monitoring of **soil solution composition** with micro **suction cups.**
- **N_{min} extraction** of unplanted control samples → **N-distribution** in the soil
- Analysis of plant **biomass** production and **N-uptake.**

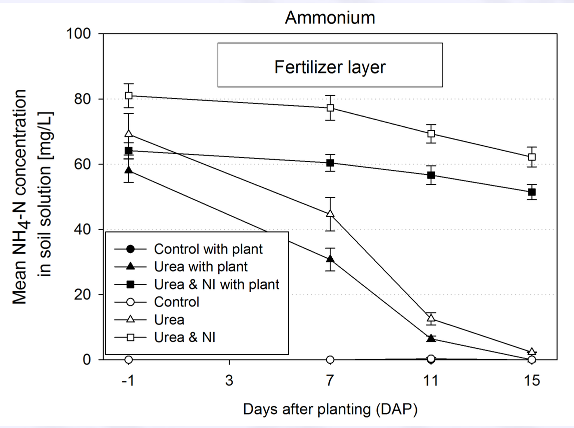
4 Results: N-dynamics in soil & soil solution, root and plant growth response

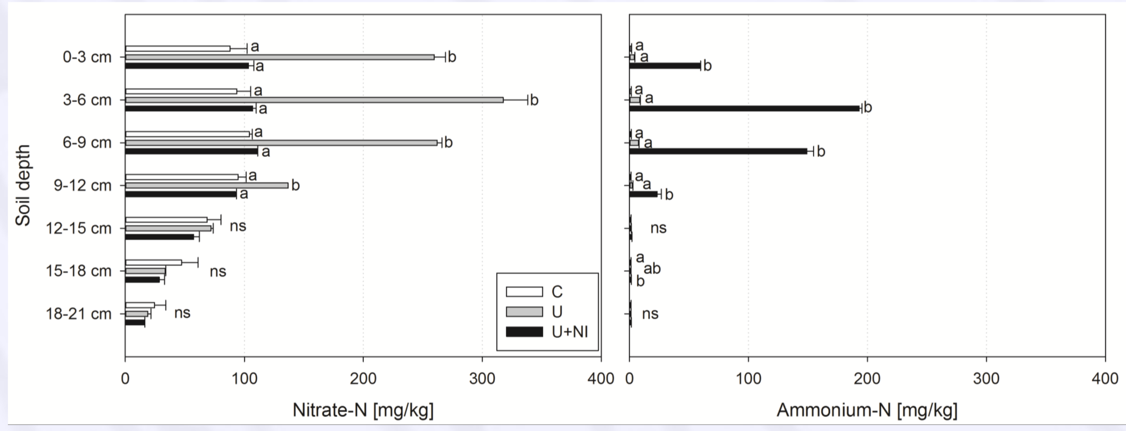
Soil chemistry & N-dynamics:

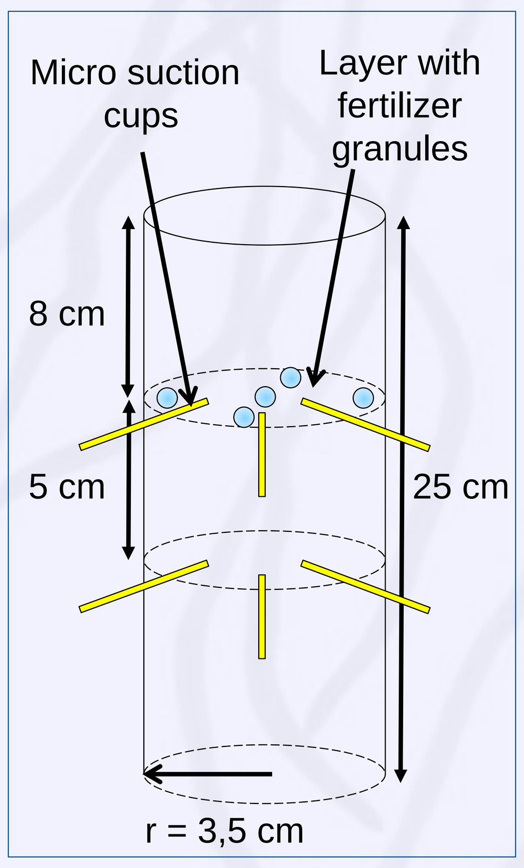
- pH reflects **N turnover** and **plant nutrient uptake**
- NO_3 & NH_4 differ in **concentration & proportion**
- N_{min} extraction (1 M KCl) of unplanted soil samples shows **absorption of NH_4**

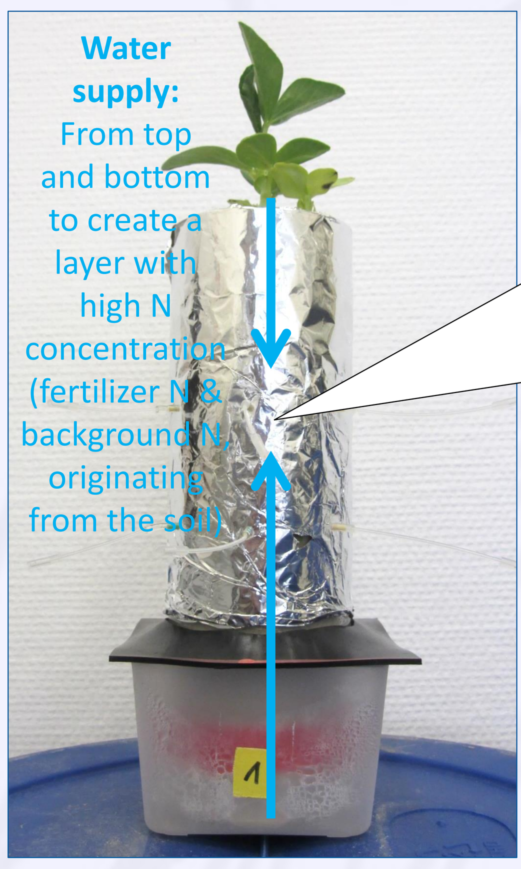










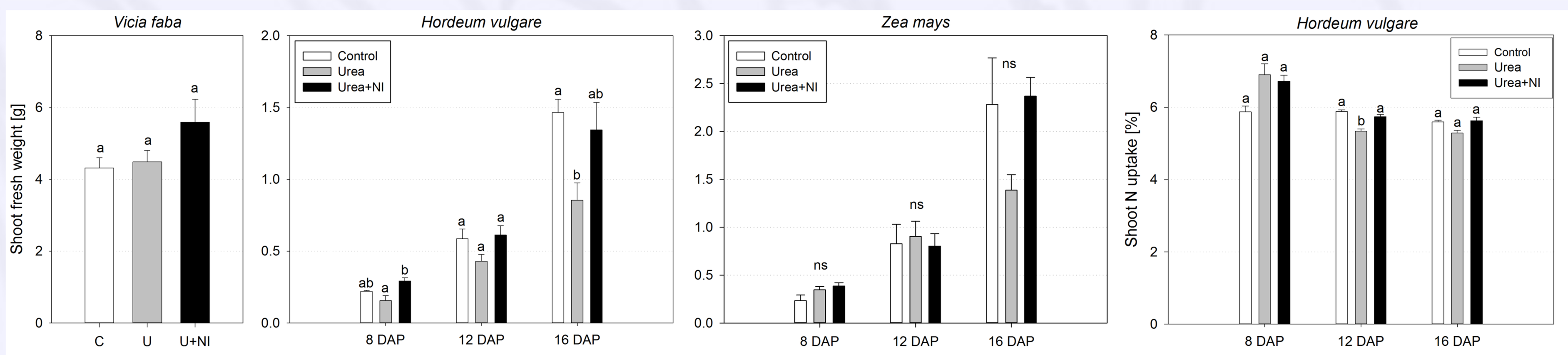


Soil:
Haplic Luvisol
Bt horizon
Sieved & homogenized
Silty clay loam
(4% sand, 68% silt, 28% clay)
Aggregated texture
Low background-N

X-ray CT:

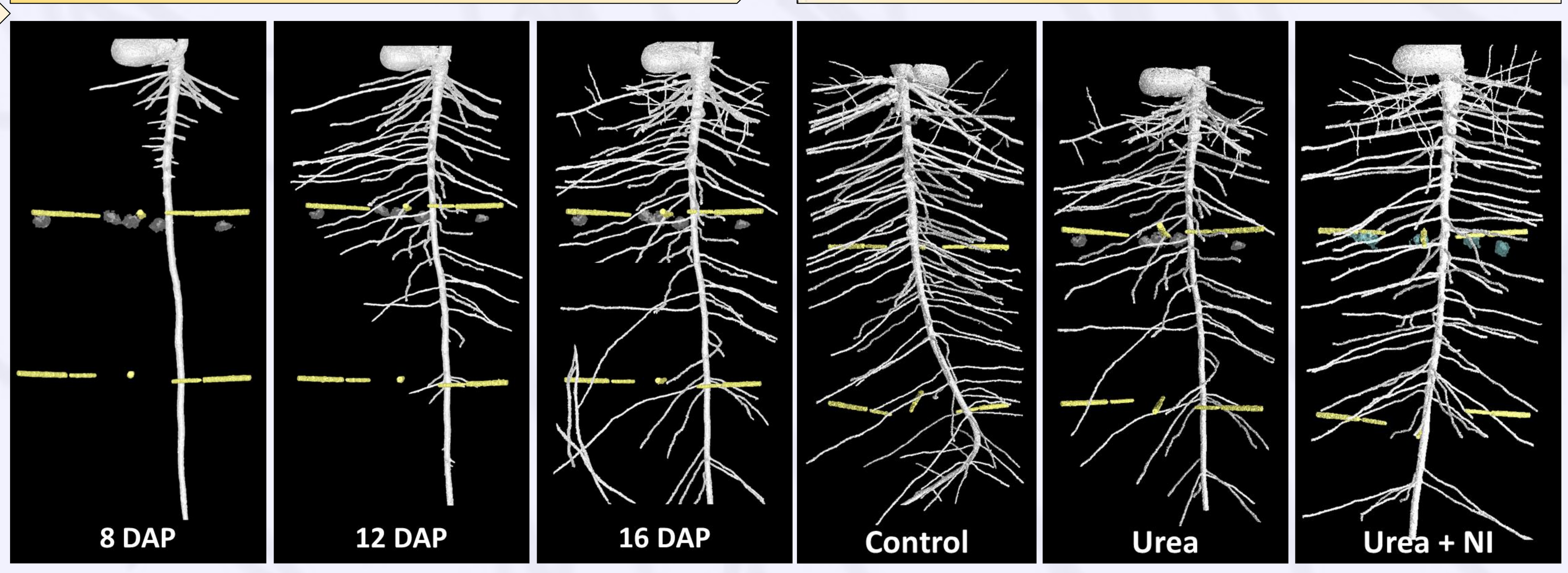
- Visualization & characterization of **faba bean root growth**
- 3 applications (**8, 12 & 16 DAP**)
- 140 kV, 286 µA, **40 µm resolution**
- 0.5 mm Cu filter, 1000 projections
- Estimated cumulative dose per plant **< 4 Gy**

Shoot growth response and N uptake

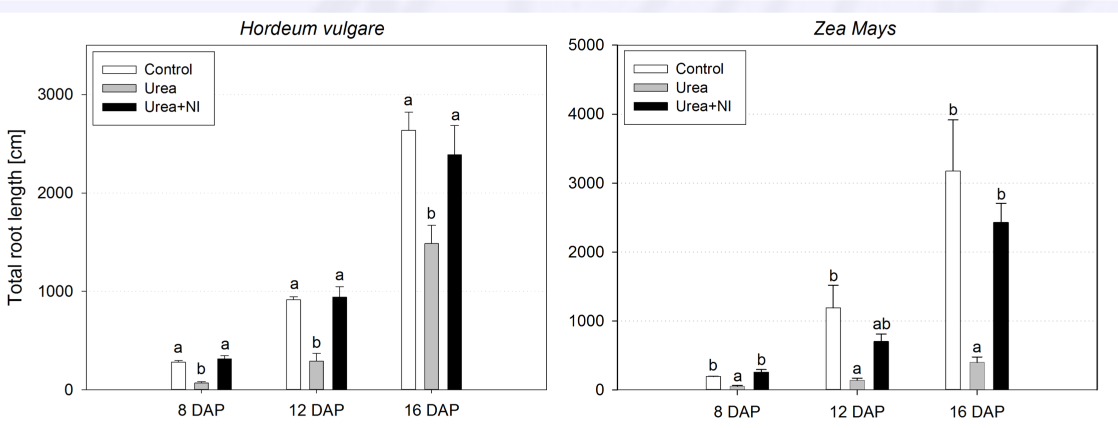


Visualization of root growth over time

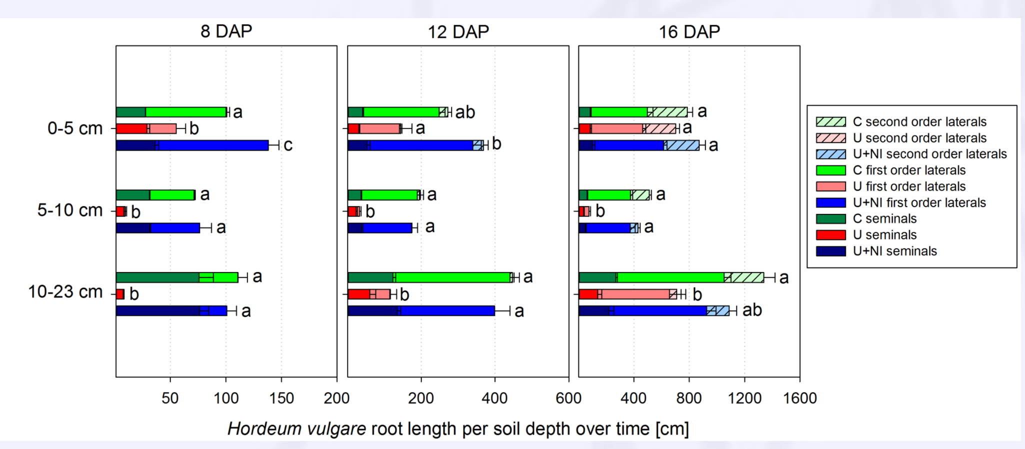
Differences in root system architecture between treatments



Root growth dynamics for *Hordeum vulgare* & *Zea mays* (WinRHIZO analysis)



- Strong **inhibition** of root growth by **high nitrate** (urea treatment)
- Even **more pronounced for *Zea mays***
- **No effect by ammonium?**
- Root length is **not always sufficient** to describe root response!
- Differences in **number of 1st order laterals** for barley (see below)



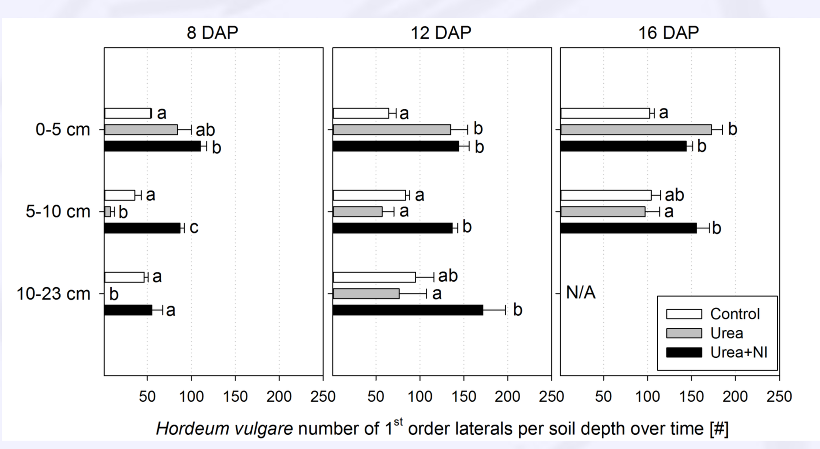
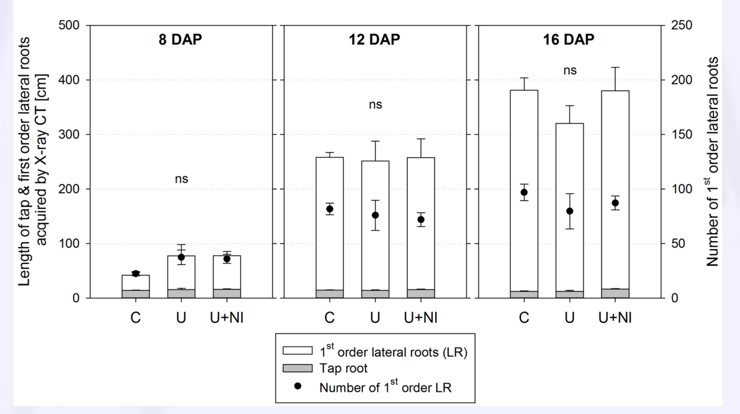
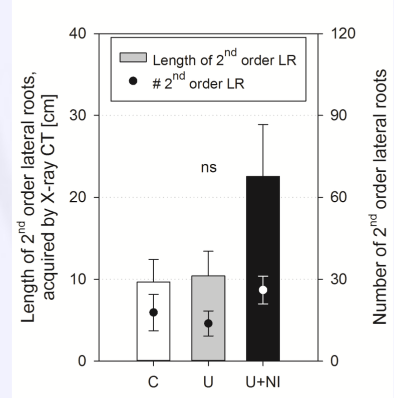


Image processing of CT data and root growth analysis for *Vicia faba*

Workflow:

- Image **stitching** of both scans
- Image **denoising (Gauss)**
- **Segmentation** of root phase **(Region growing)**
- Surface smoothing **(Median)**
- **Skeletonization**
- **Analysis** of skeleton





5 Conclusions

- This study setup is well capable to monitor **soil chemical dynamics** in relation to **urea-based N-fertilization** in the rhizosphere.
- Application of **X-ray CT** to visualize and analyze root development of **faba bean** was successful but **cannot simply be adopted for barley & corn.**
- **Roots** of faba bean, barley and corn **respond differently** to the given conditions, especially regarding the influence of **high nitrate** concentrations in the fertilizer layer. Corn and barley roots are **strongly inhibited**, while faba bean roots did **not respond significantly** to high nitrate.
- Influence of **ammonium is less pronounced** than in artificial systems but may **reflect conditions in soil** where transport, sorption, additional sources of organic matter and microbial turnover have to be taken into account.

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