Soil organic N supply from the perspective of a root - A microdialysis approach

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How much N is available for plant uptake?

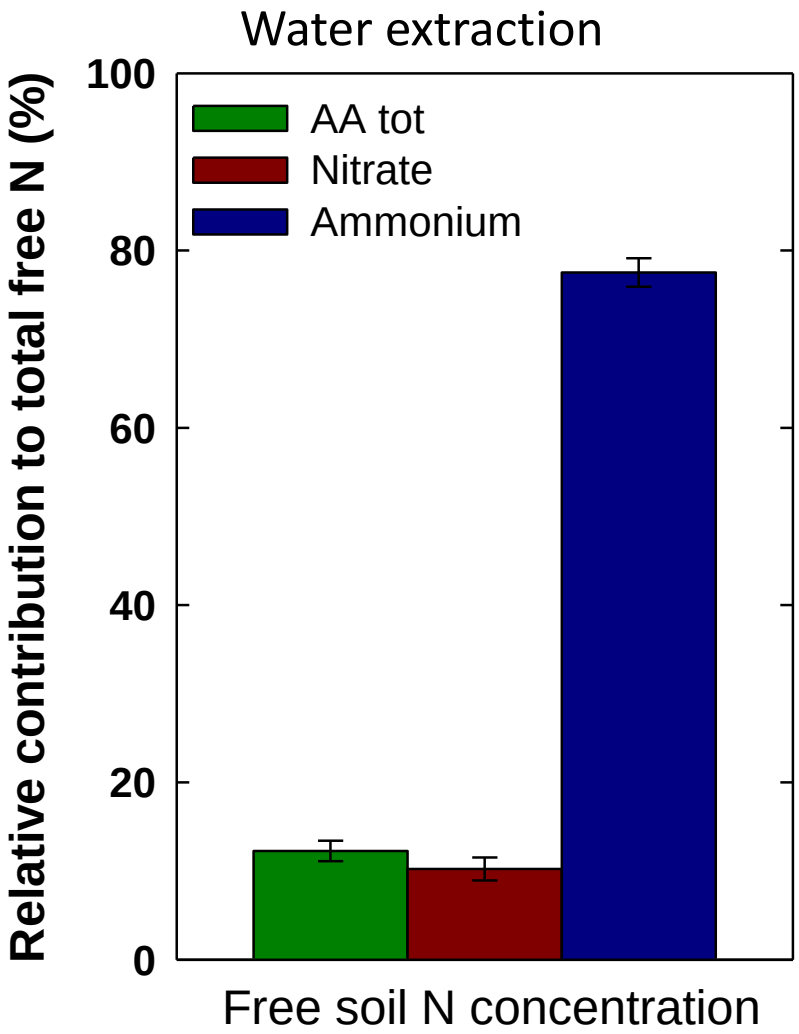
How much **inorganic and amino acid N** in the soil?

How much of this N is in contact with **root surface**?

Is N **replenished** at root surfaces after uptake?

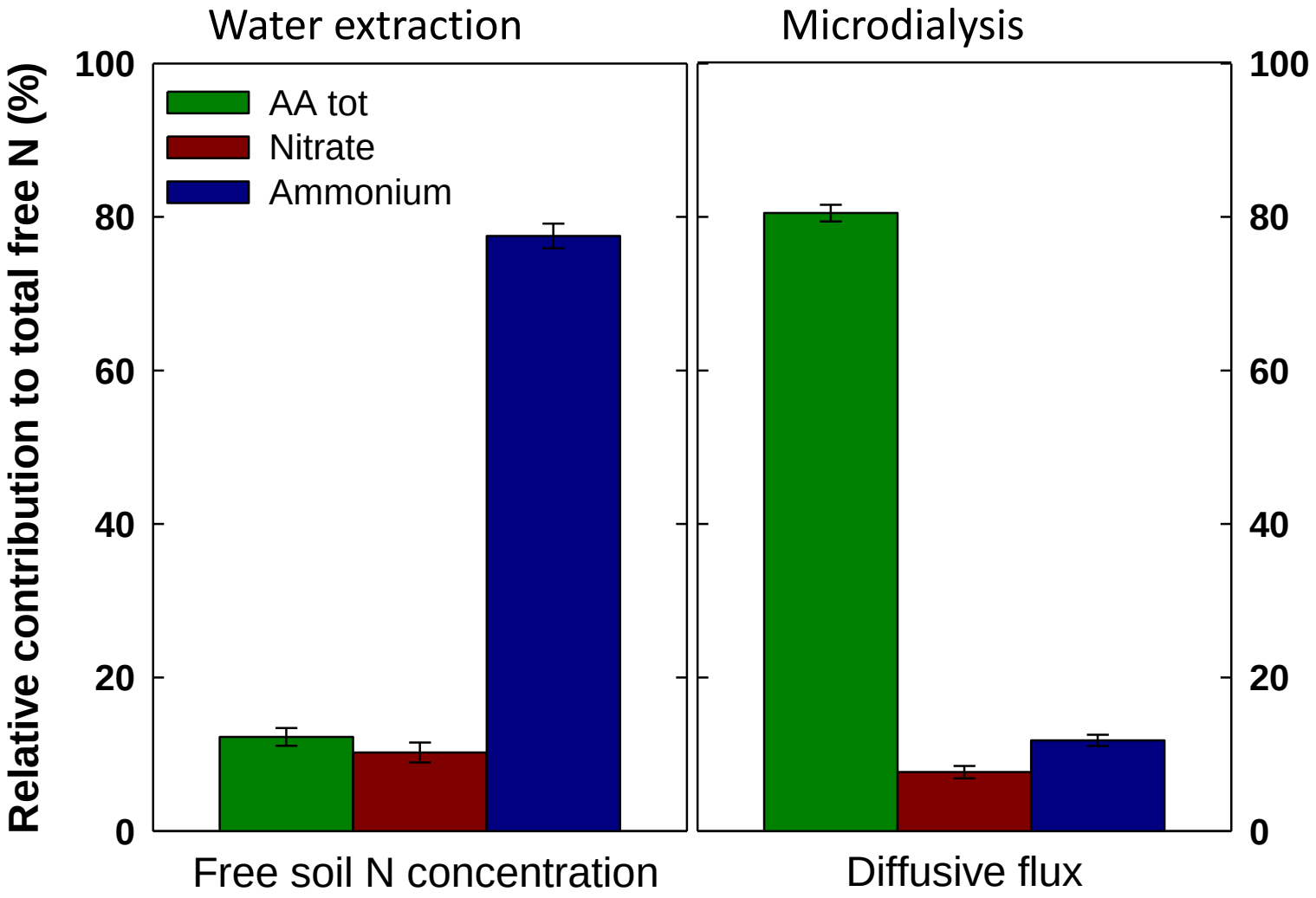
How to answer these questions?

Soil N pools: Choice of sampling method important



Inselsbacher & Näsholm (2012) New Phytologist 195, 329-334

Soil N pools: Choice of sampling method important



Why are the results so different?

Inselsbacher & Näsholm (2012) New Phytologist 195, 329-334

Soil extraction (water or salt solutions):

- Advantages: easy handling, large sample volumes, lots of replicates, no special infrastructure needed, independent of soil water status
- **BUT: Severe manipulation of the natural soil structure**

Destructive sampling

Sieving

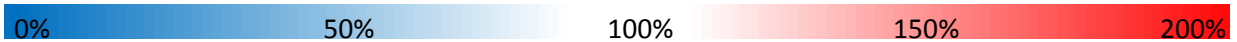
Homogenizing/storing

Extracting

Effect of sieving and extracting

NH_4^+ NO_3^- Amino acids N_{tot}

KCl (2 M)	NH_4^+	NO_3^-	pro	glu	asp	val	asn	ser	ile	gln	gly	ala	arg	Tot
Forest 0 kg	351*	98	91	79**	71***	85*	78**	76**	73***	75**	74***	70***	94	101
Forest 50 kg	228*	124***	97	75*	76*	91	87	88	83	83	88	88	86	99
Forest 100 kg	266*	99	88**	72***	63***	77***	74***	69***	64***	71***	69***	61***	87**	89
Forest 5yr	282*	117***	96	80***	75***	82***	75***	76***	70***	80***	75***	70***	86**	97
Forest 15yr	152***	115**	90	68***	66***	82**	73***	81**	65***	82**	84**	74***	83	86
Agriculture 1	137*	181*	69*	53***	48***	76*	70***	73**	47***	66**	70**	73*	67**	79
Agriculture 2	137**	171*	74***	51***	49***	76**	69***	71***	77**	68***	70***	67***	66***	80
Grassland 1	269**	91*	90	88	82	104	87	87	83	79	87	88	90	102
Grassland 2	222*	90**	104	100	98	108	99	101	86	92	99	101	103	108



Relative recovery of added standard

Inselsbacher (2014) Soil Biology & Biochemistry 71, 76-86

Effect of sieving and extracting

Water NH_4^+ NO_3^- Amino acids N_{tot}

KCl (2 M)	NH_4^+	NO_3^-	pro	glu	asp	val	asn	ser	ile	gln	gly	ala	arg	Tot
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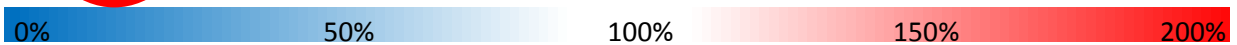
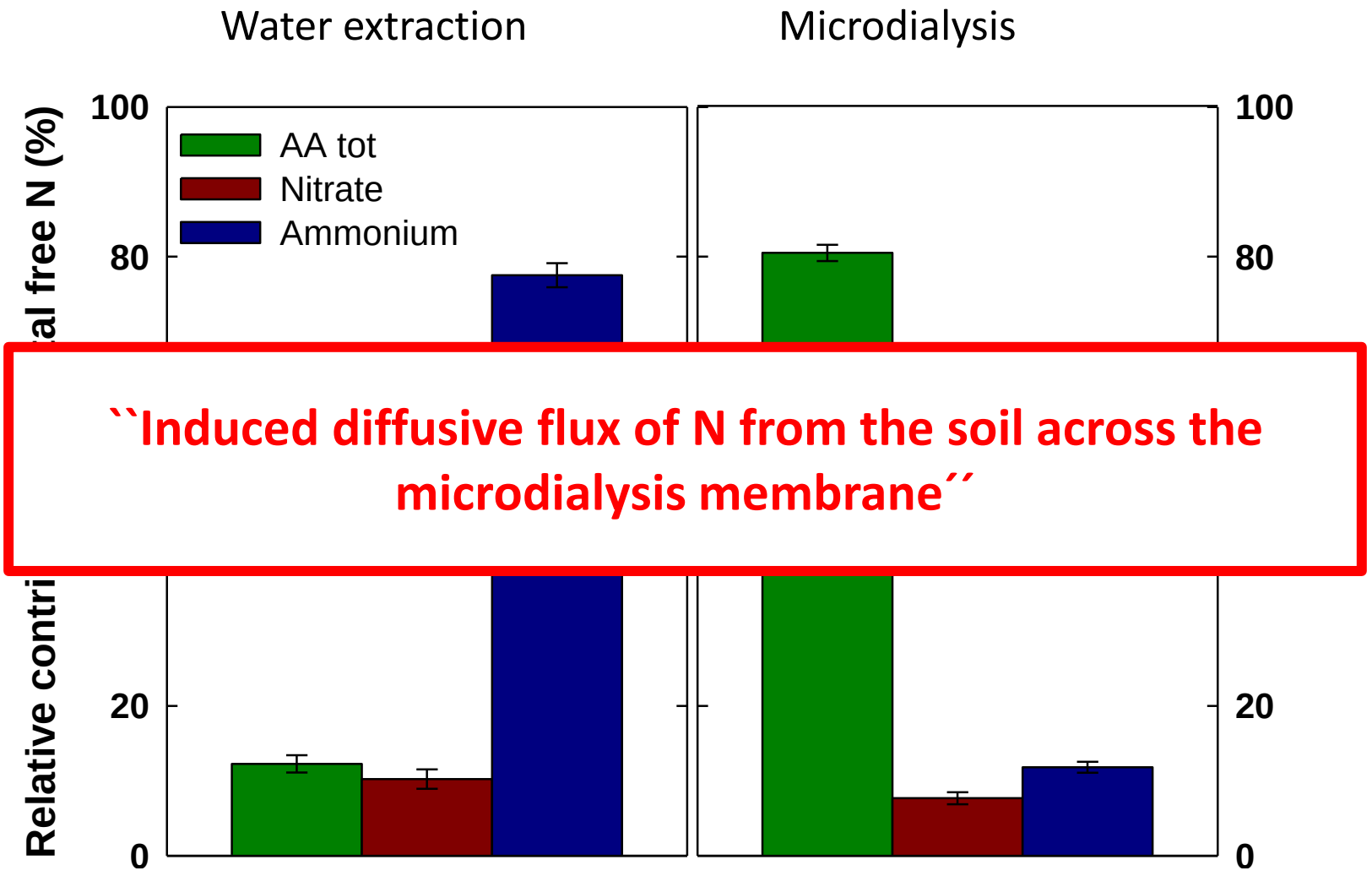


Relative recovery of added standard

- Increase of inorganic N
- Decrease of amino acid N

Inselsbacher (2014) Soil Biology & Biochemistry 71, 76-86



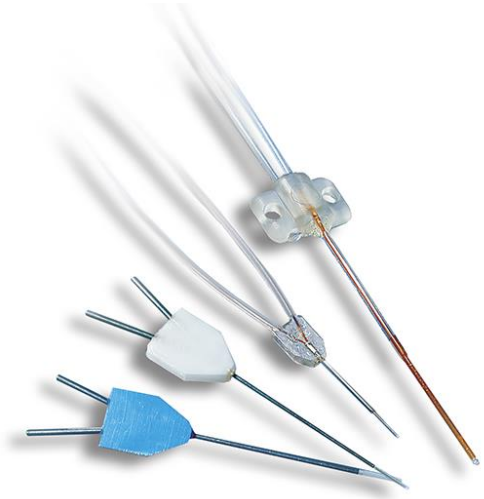
``Induced diffusive flux of N from the soil across the microdialysis membrane´´

Inselsbacher & Näsholm (2012) New Phytologist 195, 329-334

Principles of microdialysis

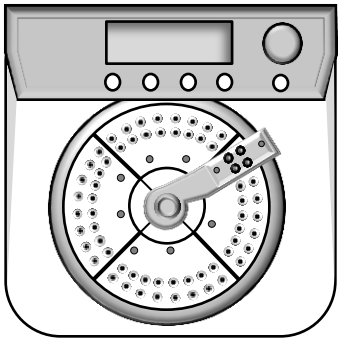
Pump

Autosampler

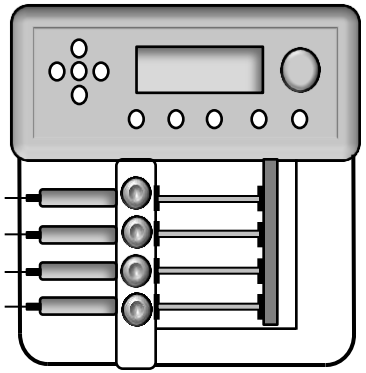


Probe

CMA Microdialysis AB, Sweden



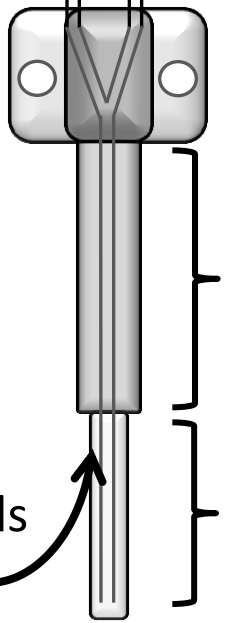
Autosampler



Pump

Outflow
(dialysate)

Inflow
(perfusate)

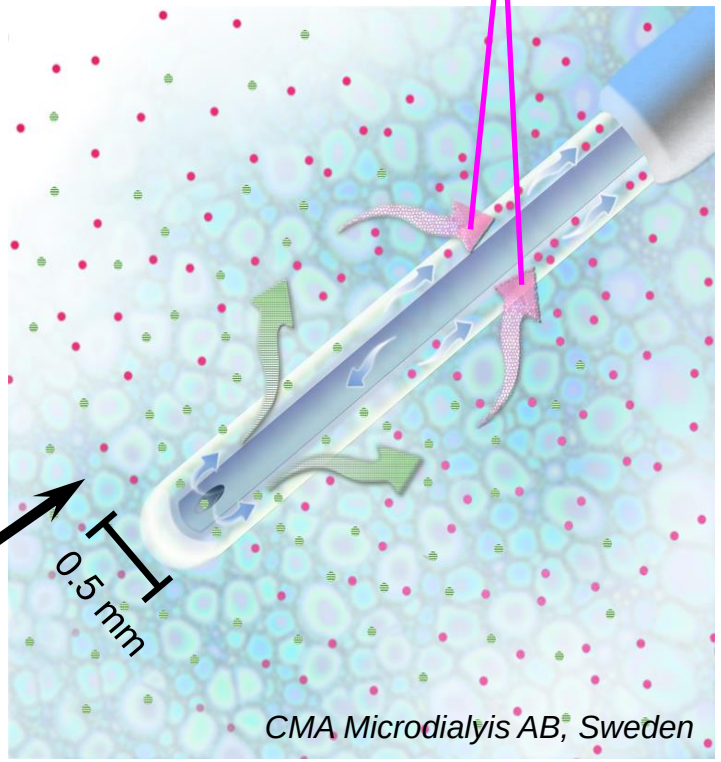


Flexile shaft

Target
compounds

Membrane

Target compounds



Inselsbacher et al. (2011) Soil Biology & Biochemistry 43, 1321-1332

Advantages of microdialysis:

- Not disturbing natural system
- No soil water is removed
- No enzymatic breakdown in samples
- No additional sample cleaning necessary
- High spatial resolution (*Inselsbacher et al. (2011) Soil Biology & Biochemistry 43, 1321-1332)*
- High temporal resolution (*Inselsbacher et al. (2014), Soil Biology & Biochemistry 74, 167-176)*
- Direct estimation of diffusion and mass flow *(Oyewole et al. (2014), New Phytologist 201, 1056-1064)*
- Direct comparison between soil fluxes and root uptake

Differences between microdialysis probes and plant roots:

- Microdialysis is passive and unselective
- Microdialysis probes installed at fixed positions
- Microdialysis does not account for ion-exchange (root exudation)

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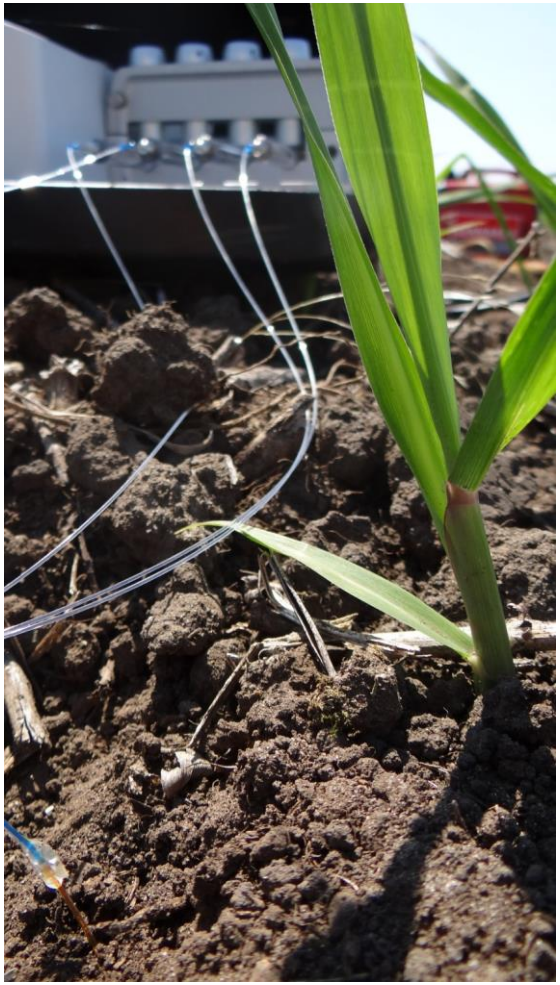
Similarities:

- Design and geometry (zylindrical, small dimensions)
- Microsites in virtually undisturbed soil are explored
- N at the surface is depleted (by induced diffusion or root uptake)
- Diffusion across membranes and root uptake of N depends on constant replenishment at surface

In-situ monitoring of soil N fluxes

(nmol N cm^{-2} h^{-1})



Combination with ^{15}N root uptake studies

Can be directly related to soil N fluxes

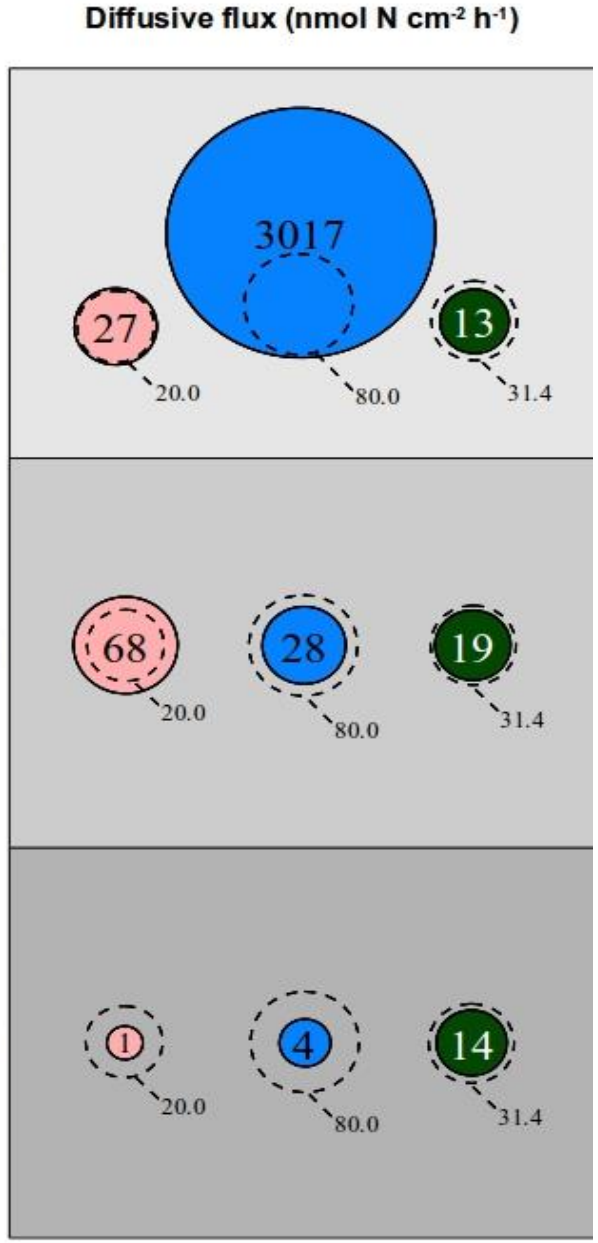
(nmol N cm^{-2} h^{-1})

Combination with ^{15}N root uptake studies

Diffusive fluxes similar to max. root uptake rates

NH_4^+ fluxes in urea fertilized fields exceed max root uptake rates

→ Significant losses of fertilizer (ammonia volatilization!)



Brackin et al. 2014, under review

The University of Queensland

School of Agriculture and Food Sciences

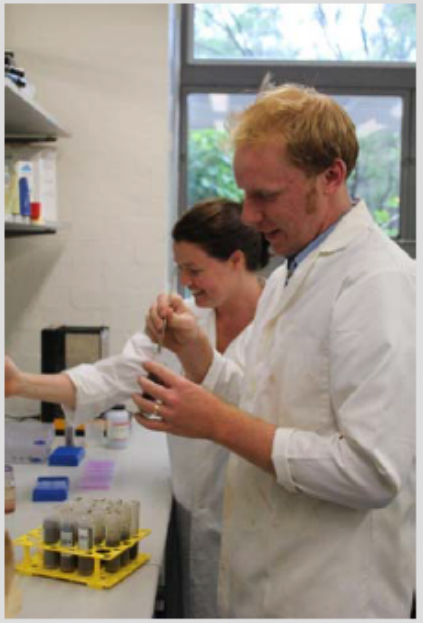
A 'quantum leap' in fertiliser up-take

A Queensland researcher whose work promises to change how canegrowers fertilise their crops has been announced the winner of the SRDC funded 2013 Young Science and Innovation Award.

University of Queensland PhD scholar Richard Brackin, aged 26, was announced the winner at the annual Australian Bureau of Agricultural Resource Economics and Sciences (ABARES) Outlook Conference in Canberra today (5 March 2013).

Richard was one of 12 award winners – each sponsored by a different agricultural commodity organisation.

Award judges said his research, into micro-dialysis soil sampling, could deliver economic, environmental and social benefits, with implications for climate change, the environment (especially the Great Barrier Reef), and grower input costs.



Source: The University of Queensland, Australia. School of Agriculture and Food Sciences. www.uq.edu.au/agriculture

Summary

- Sieving and extracting soils **alters composition of soil N**
- Microdialysis: **minimal disturbance**, useful for ***in-situ* studies**
- **Amino acids** contribute significantly to total N supply
- Plants may **rely on organic N** sources when no N fertilizer left
- Greatest potential in **combination with other methods** (e.g., ^{15}N uptake studies)

Thanks to:

Torgny Näsholm

Olusegun Ayodeji Oyewole

Sandra Jämtgård

Camila Aguetoni Cambui

Margareta Zetherström

Richard Brackin

Susanne Schmidt

Arbeitsgruppe Geoökologie

Vetenskapsrådet

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The Swedish Research Council Formas

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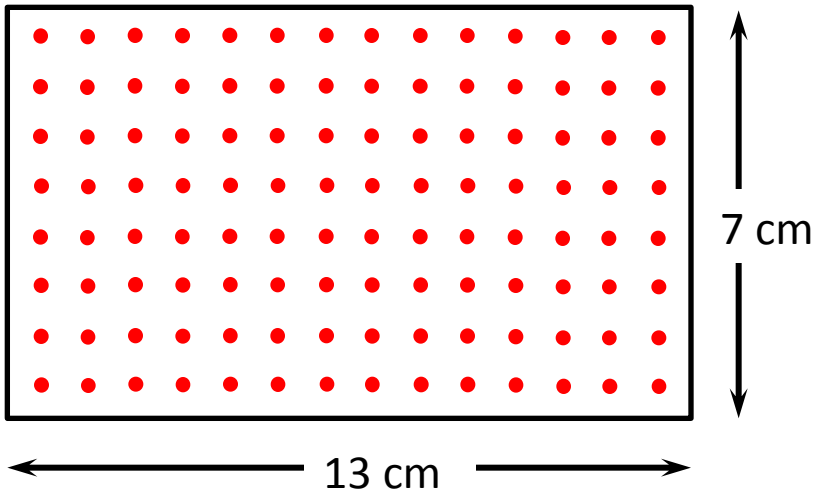
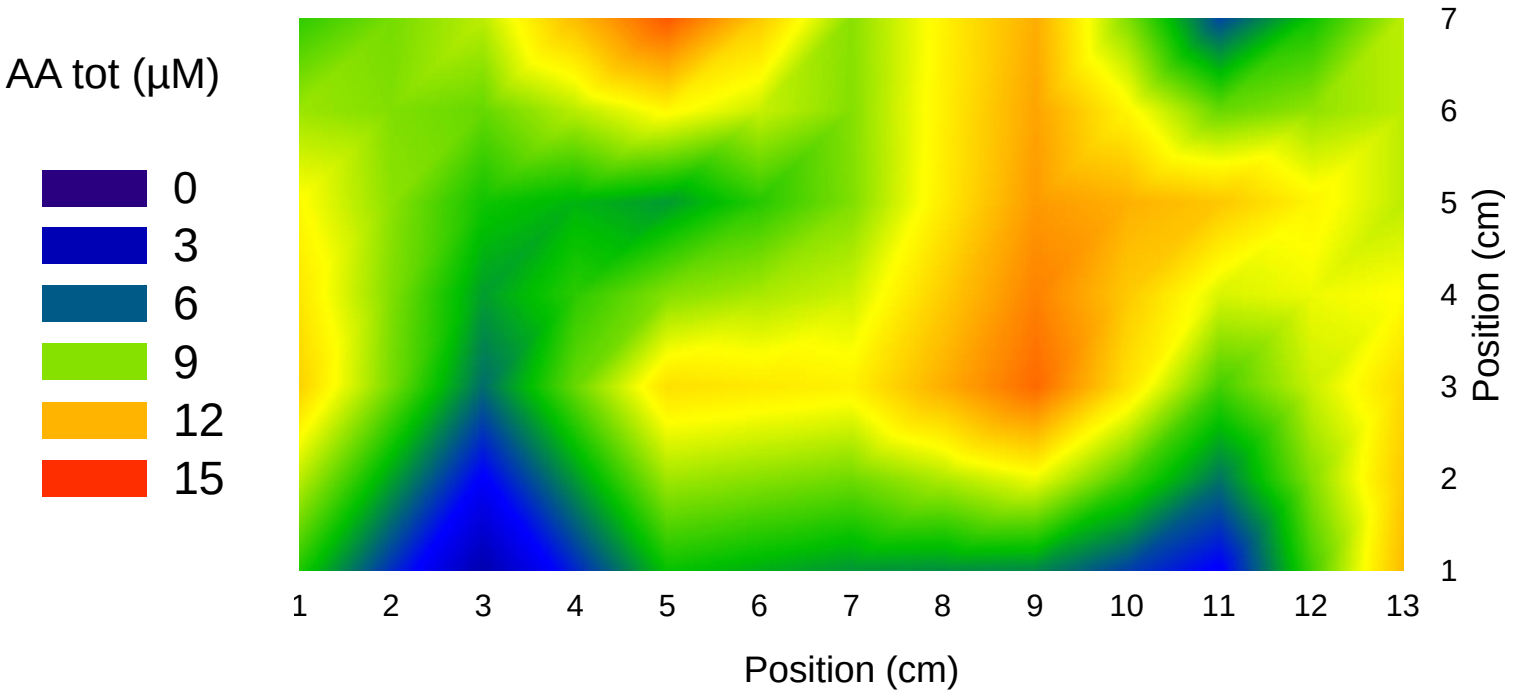
Soils are highly heterogeneous!



N concentration differs significantly in soil microsites

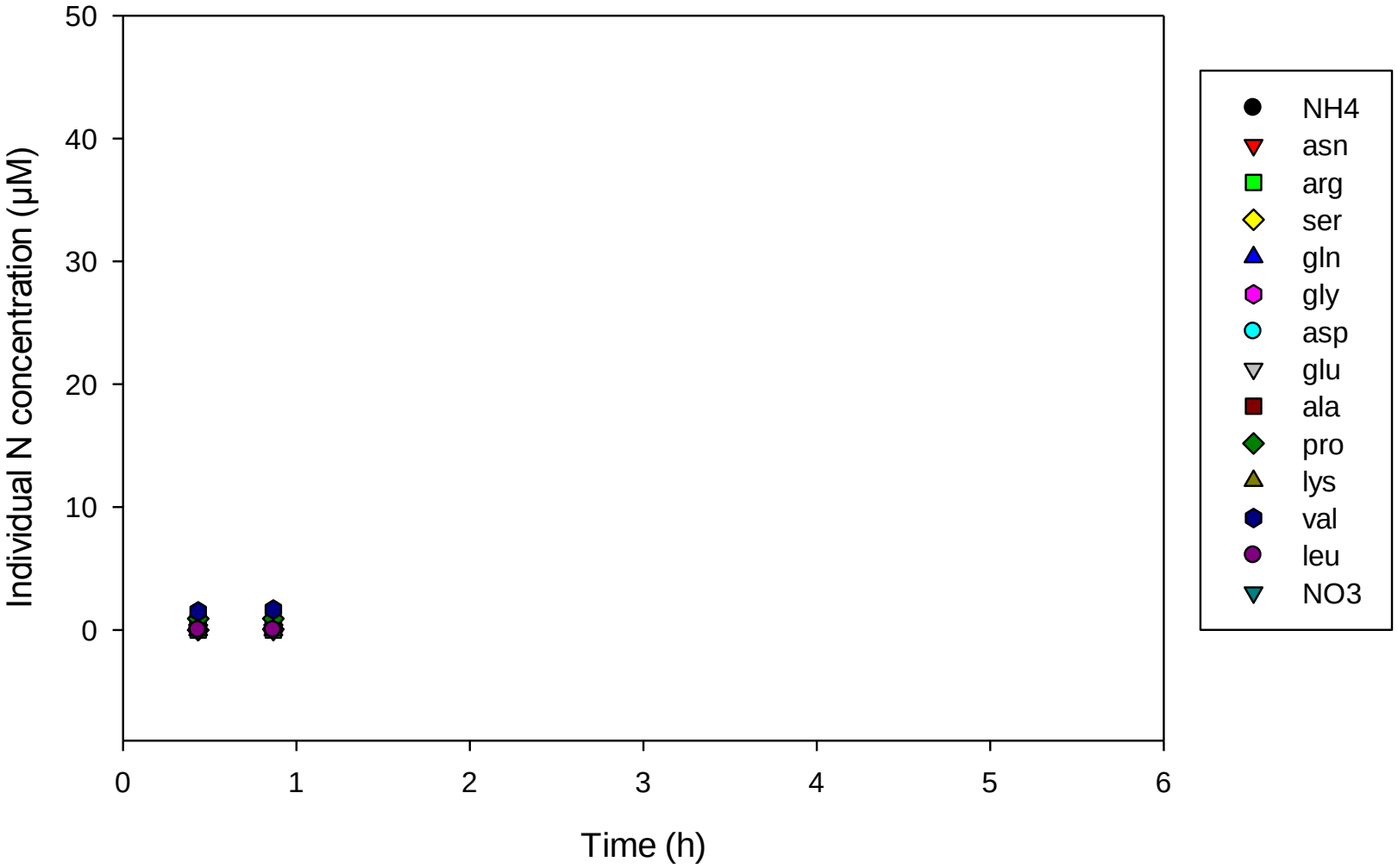


Microdialysis for monitoring N fluxes at **high spatial resolution**

(→ *Niche ecology; Rhizosphere studies*)

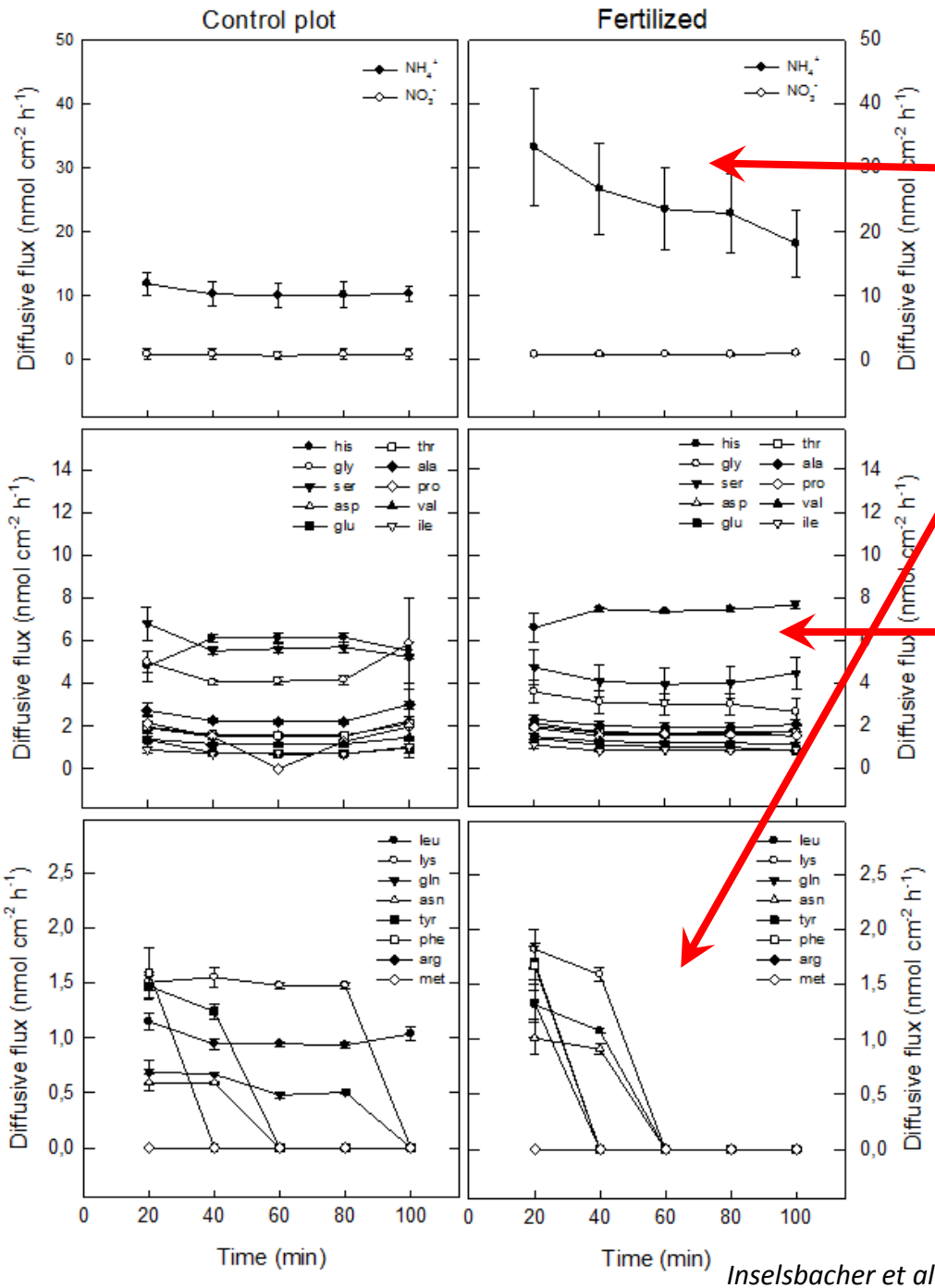
Inselsbacher et al. (2011) Soil Biology & Biochemistry 43, 1321-1332

Simulating depletion around root



Standardized soils: depletion zone around membrane

Inselsbacher et al. (2011) Soil Biology & Biochemistry 43, 1321-1332



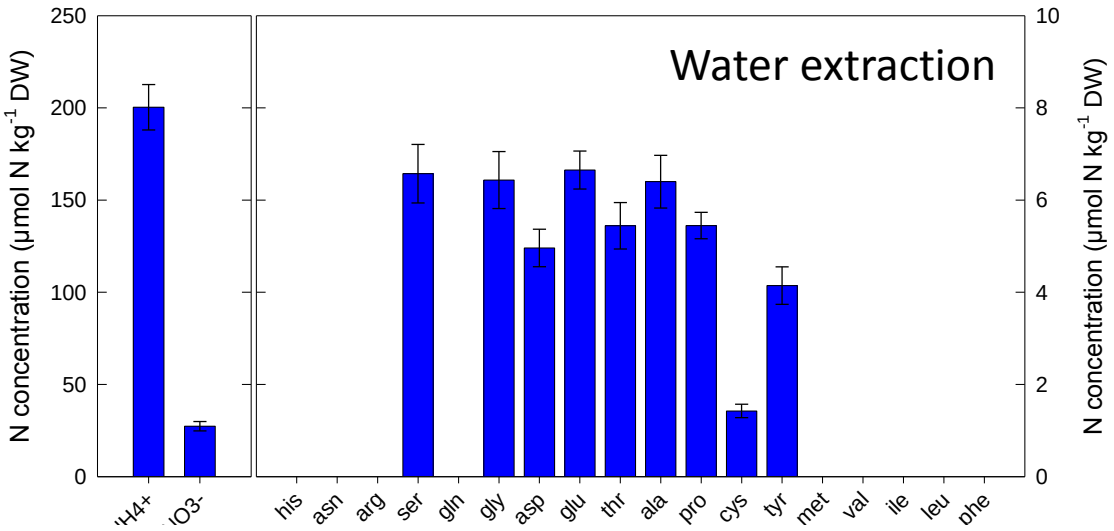
NH_4^+ depleted only in fertilized plot

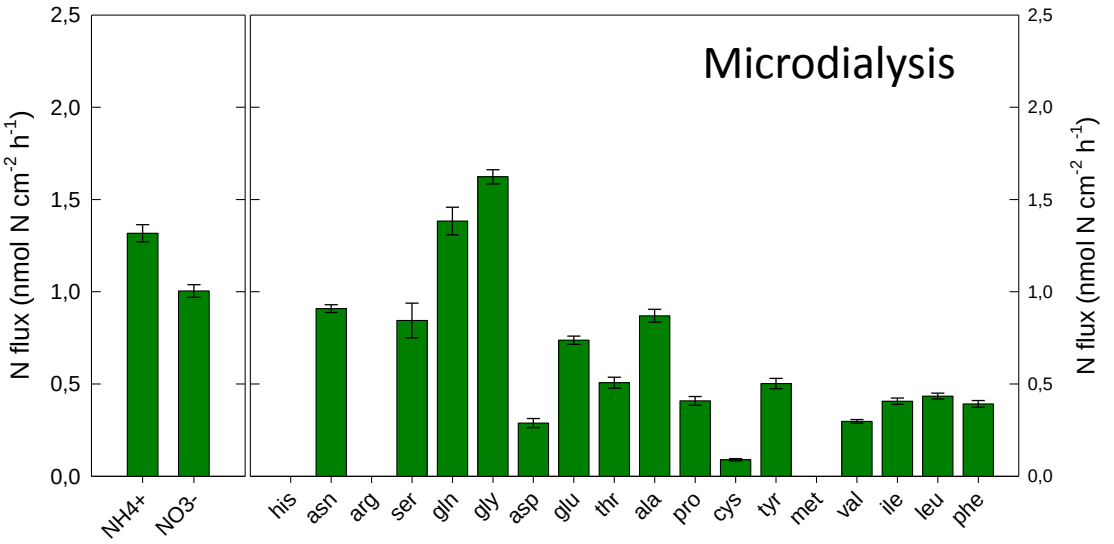
Only few amino acids are depleted

Rest of amino acids in **equilibrium**

Constant replenishment of N pools in the field!

Inselsbacher et al. (2014), Soil Biology & Biochemistry 74, 167-176





Low relative contribution of amino acids

Only half of individual amino acids available for root uptake

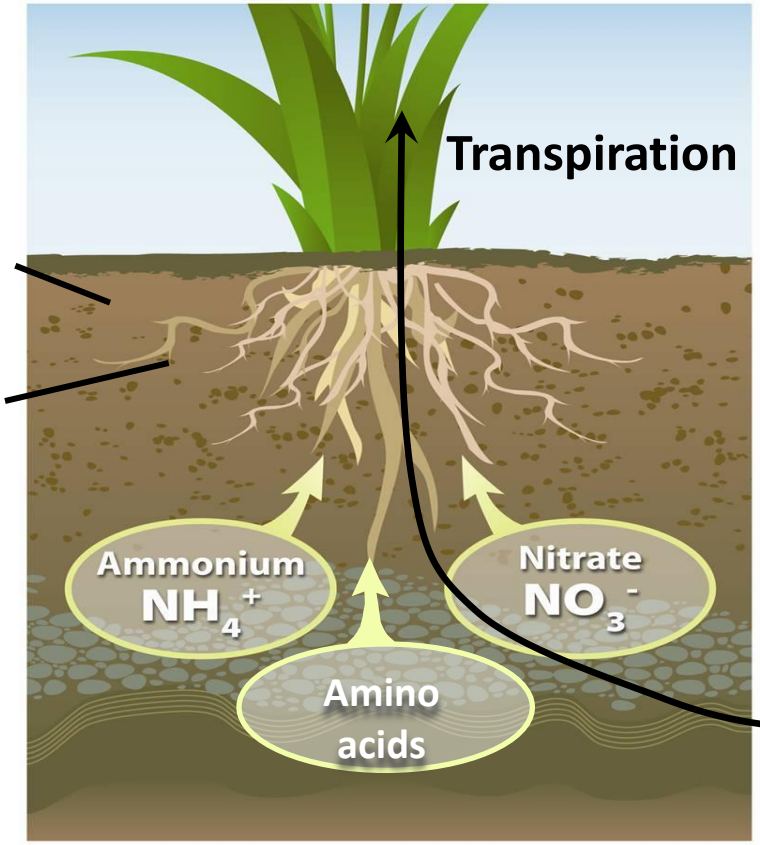
High relative contribution of amino acids

Nearly all amino acids available for root uptake

Why are the results so different?

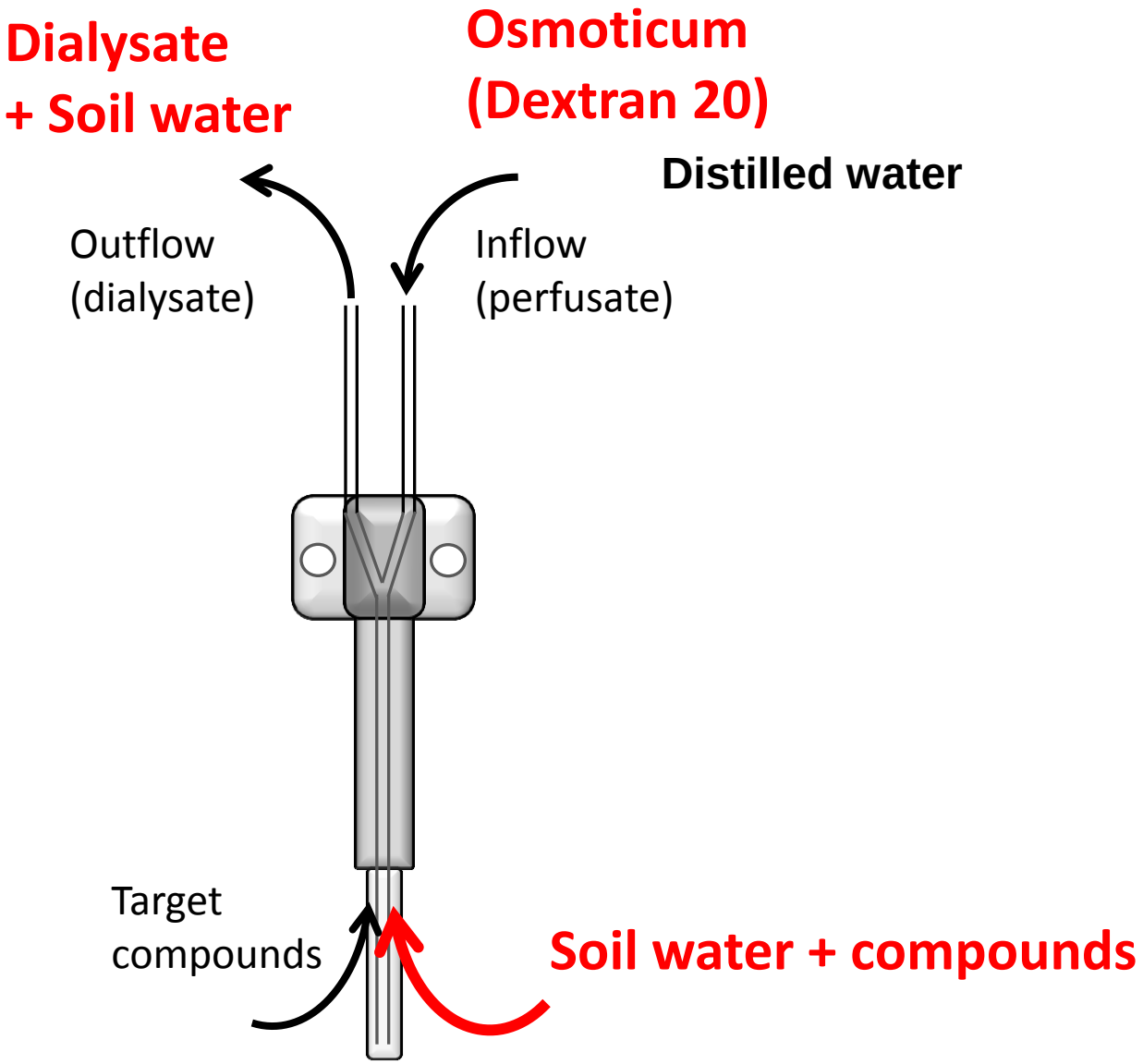
Inselsbacher & Näsholm (2012) New Phytologist 195, 329-334

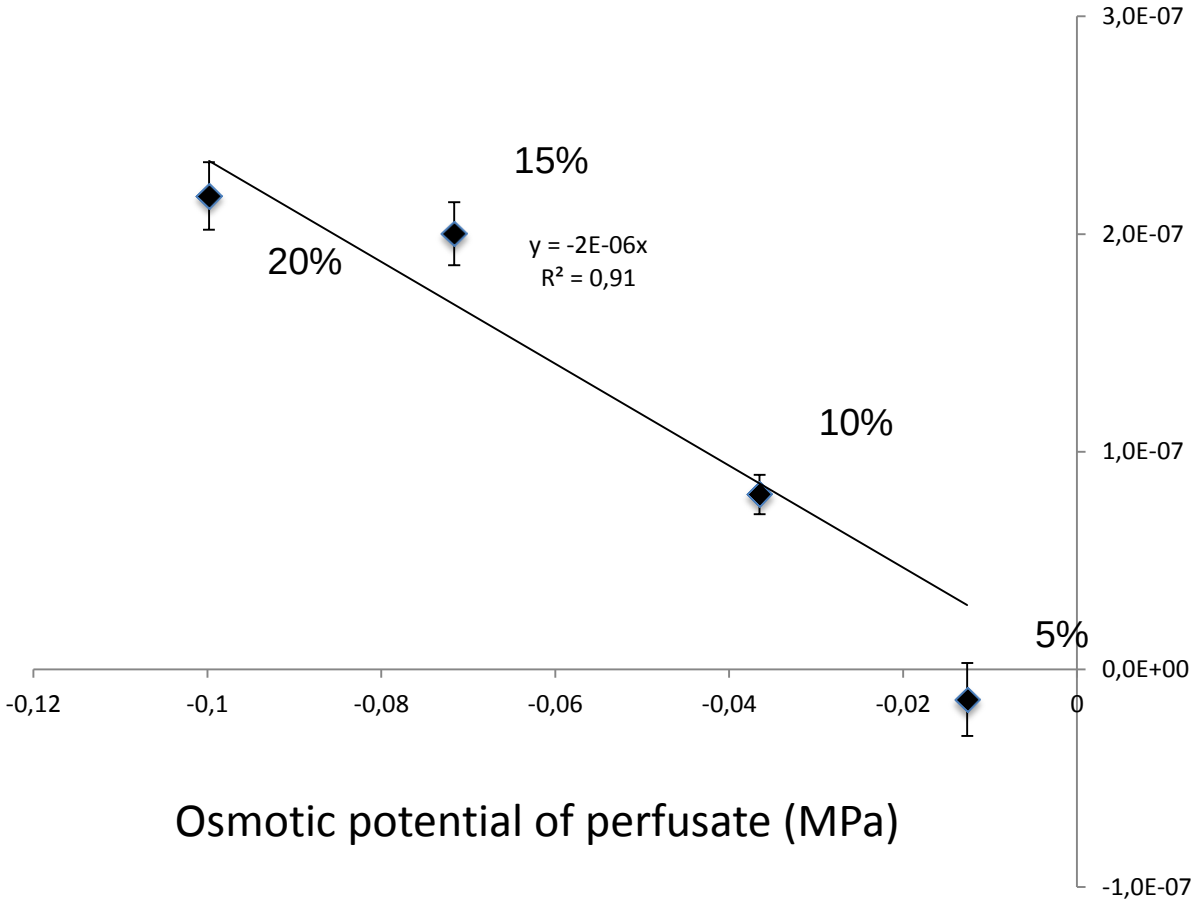
The roles of diffusion and mass flow



Diffusion: Movement of molecules or ions along a concentration gradient

Mass flow: Movement of dissolved nutrients to the root surface in flowing soil water

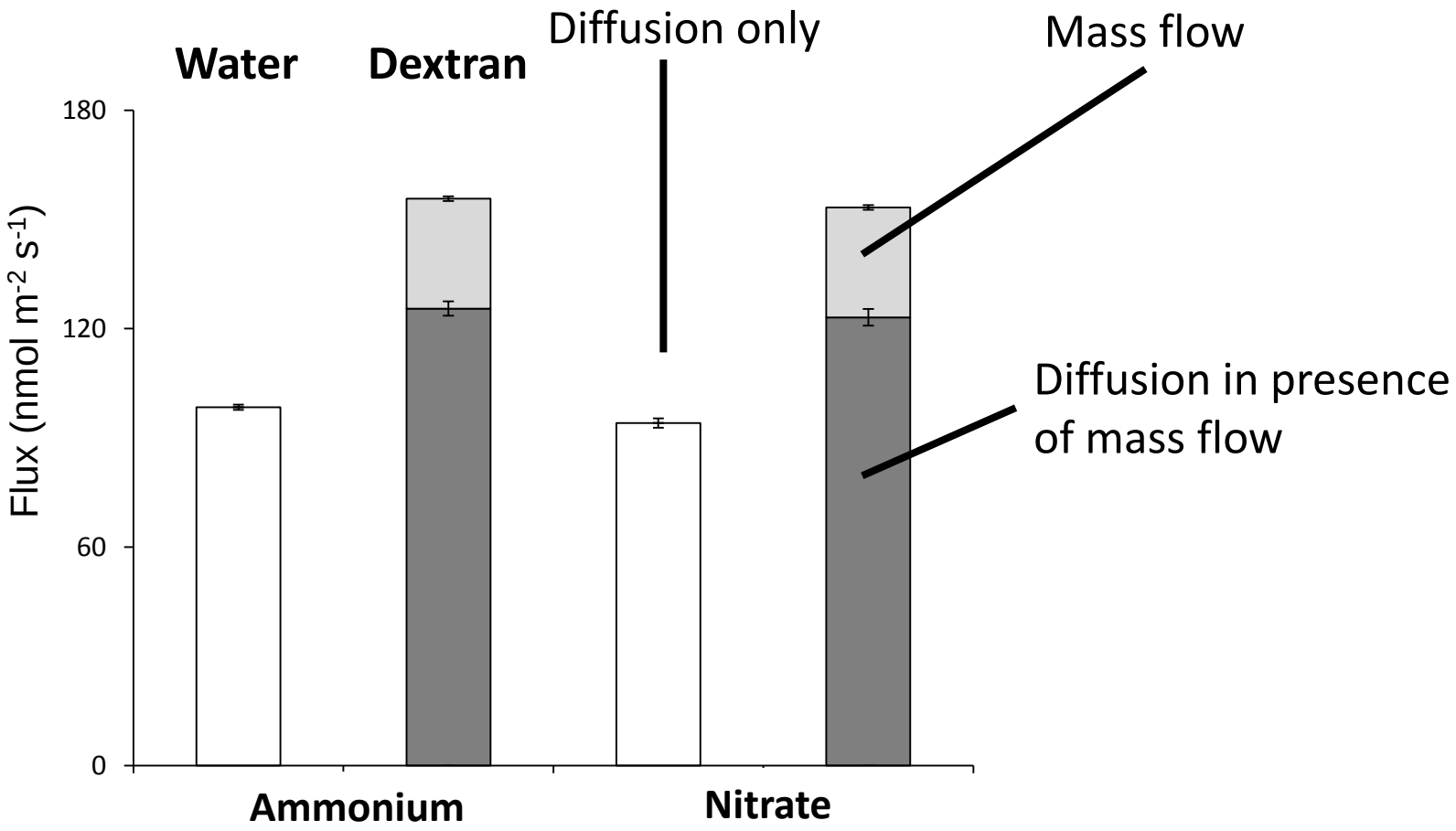

Dialysate
+ Soil water
Osmoticum
(Dextran 20)
Distilled water
Outflow
(dialysate)
Inflow
(perfusate)
Target
compounds
Soil water + compounds



Change in osmotic potential of perfusate leads to change in water flux

➡ **different rates of induced mass flow possible**

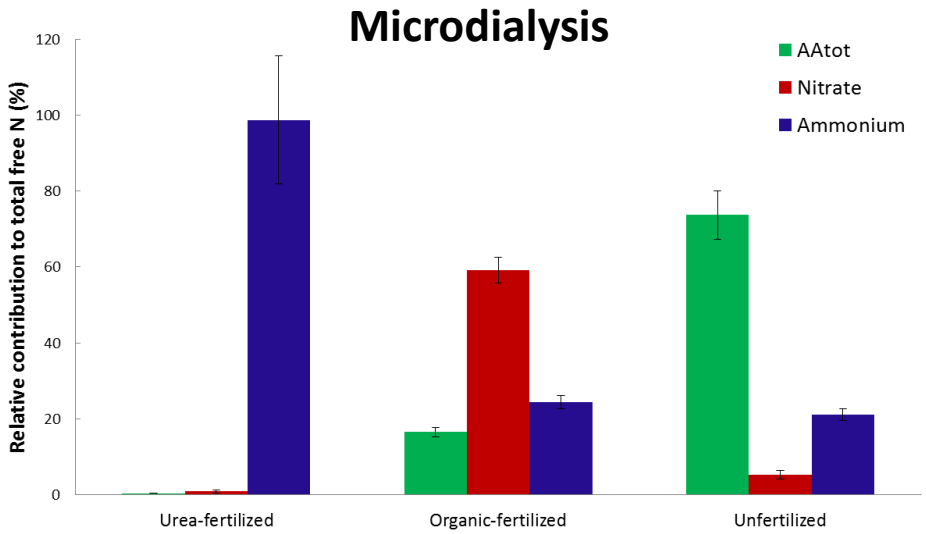
Oyewole et al. (2014) New Phytologist 201, 1056-1064

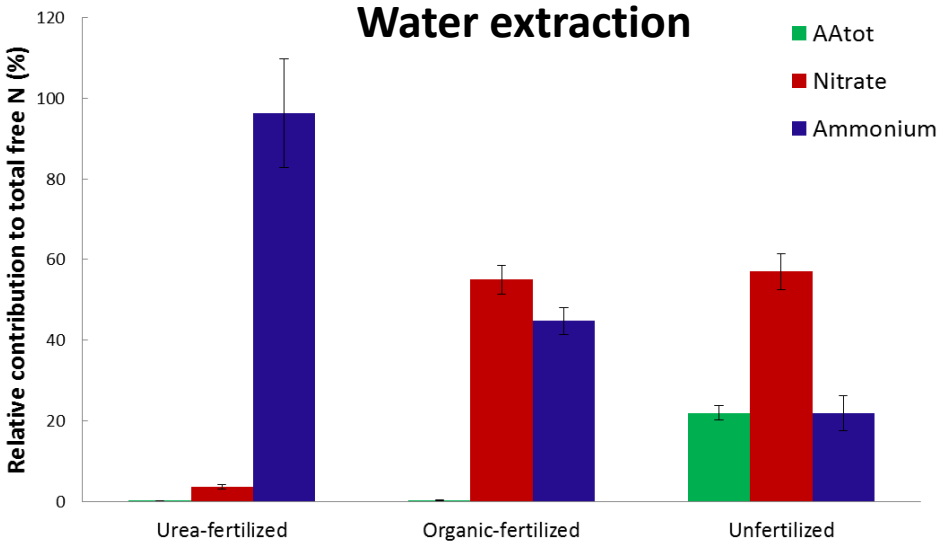


Direct effect of mass flow: direct supply of N in water

Indirect effect of mass flow: increase of diffusion rates

Oyewole et al. (2014) New Phytologist 201, 1056-1064





- Differences less pronounced in fertilized systems
- Amino acids dominate N fluxes in unfertilized soils
- ~ 9 months/year state of unfertilized field

➡ amino acids more important than previously assumed

Brackin et al. 2014, under review