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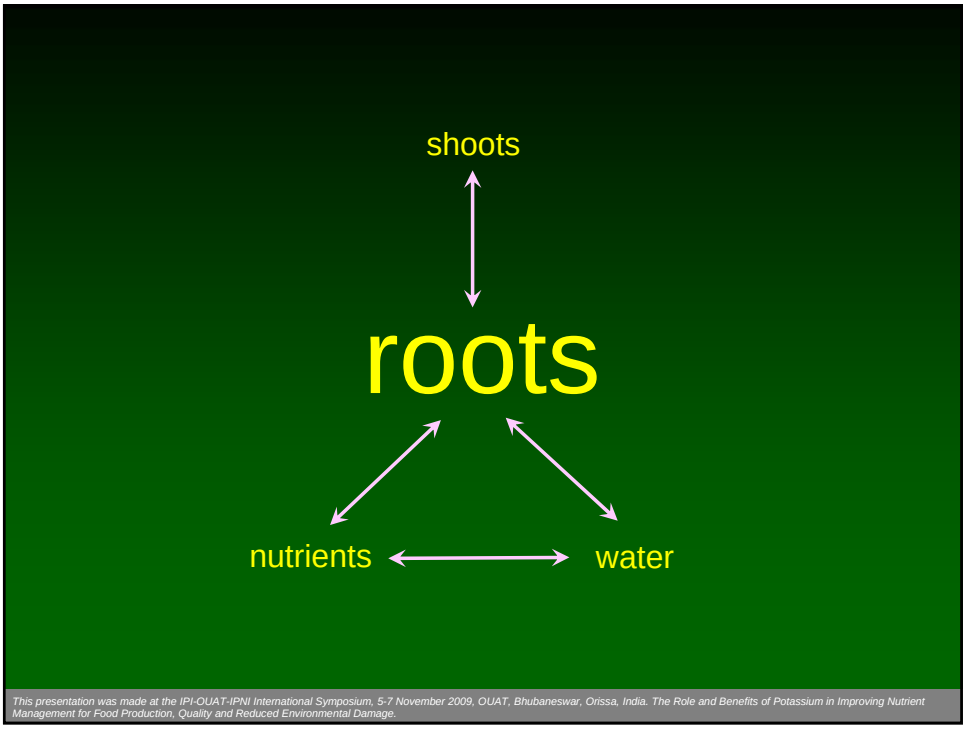
Achieving International Excellence

Mineral nutrition of drought-stressed plants

Zed Rengel

University of Western Australia
Perth

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.



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1) Water: climate change and variability

2) Nutrient supply

Fertilisers

Crop residues and other organic matter

3) Root capacity to acquire nutrients

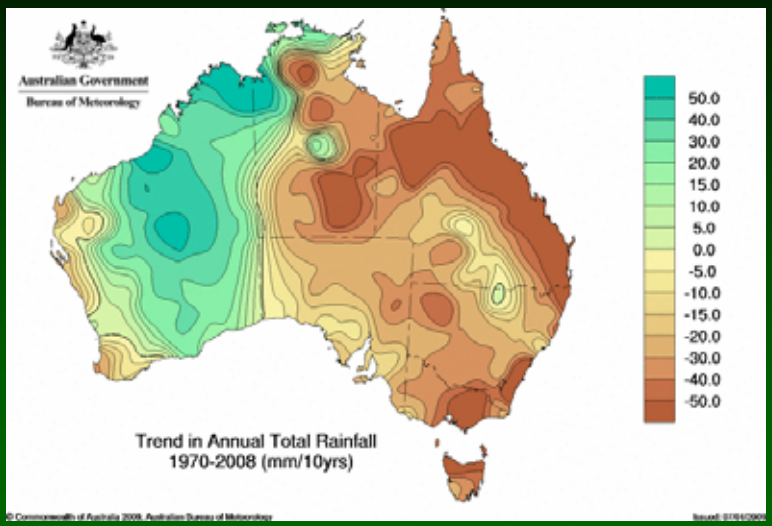
Spatial dilemma:

- nutrient reserves in topsoil
- water reserves in subsoil

Root architecture:

- observations and measurements
- modelling

Australian mean rainfall



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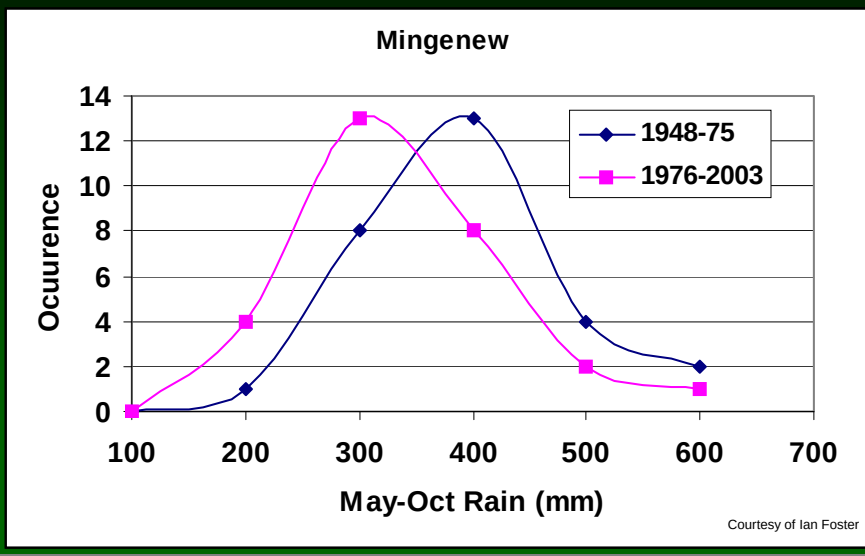
Western Australian wheatbelt



Courtesy of Ian Foster

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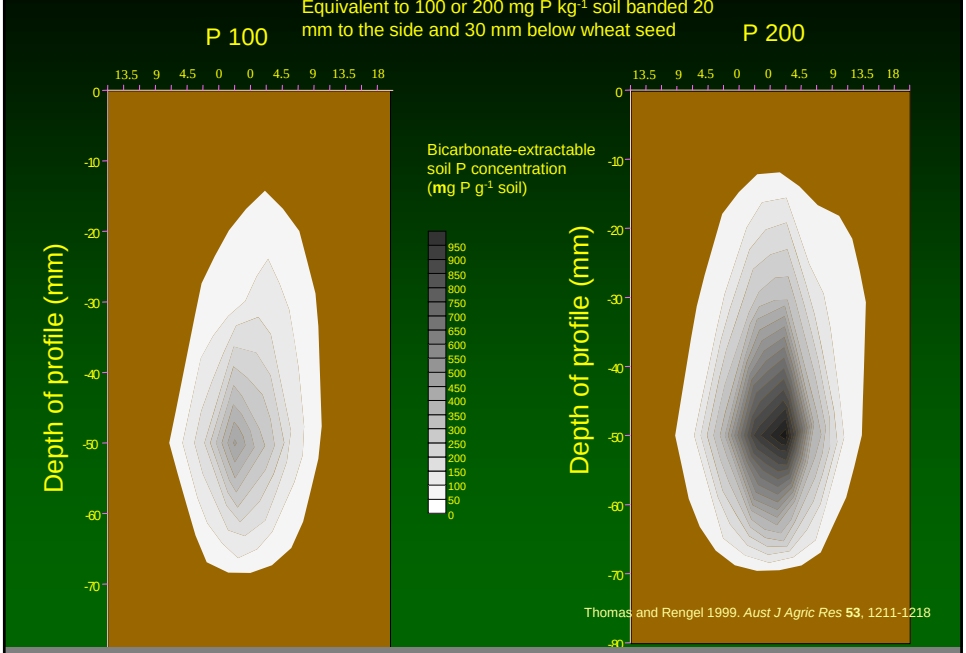
Equivalent to 100 or 200 mg P kg^{-1} soil banded 20 mm to the side and 30 mm below wheat seed



Thomas and Rengel 1999. *Aust J Agric Res* **53**, 1211-1218

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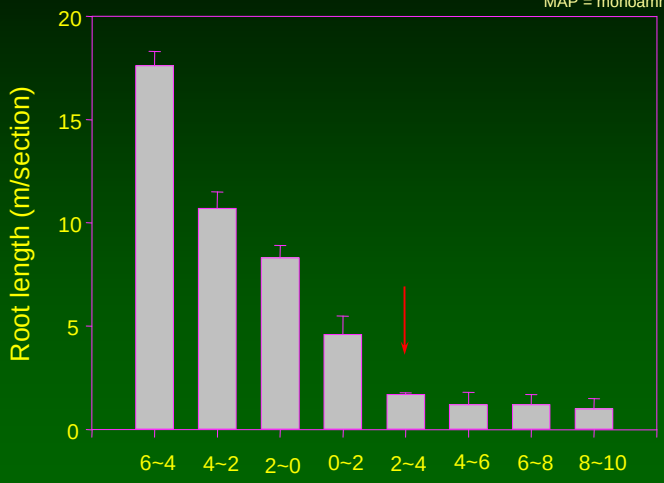
Root growth gradients around MAP fertiliser granules

MAP = monoammonium phosphate



Fertiliser band positioning

Zhang and Rengel 1999. *Aust J Agric Res* **50**, 365-373

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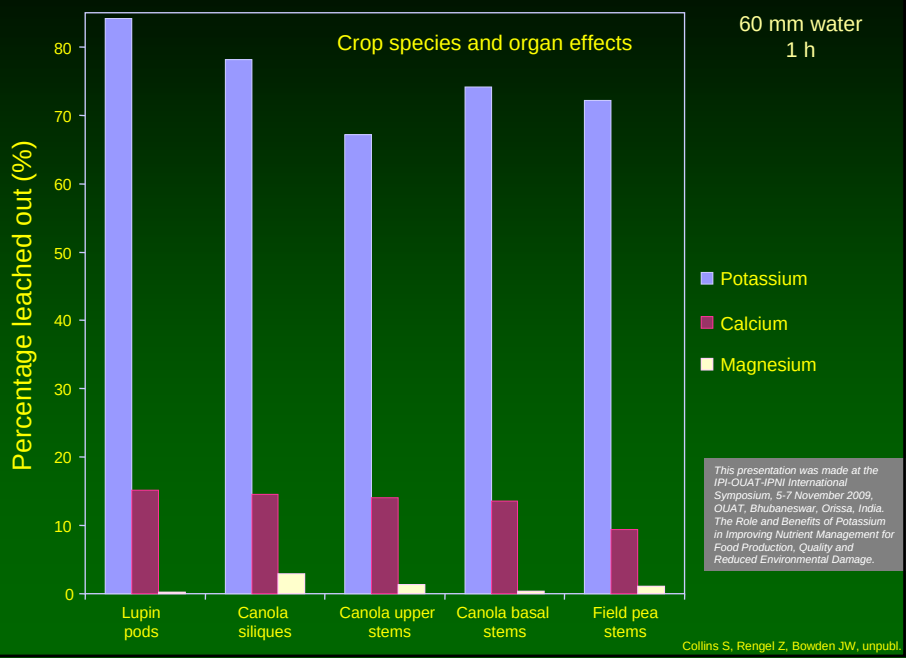
Leaching of nutrients out of crop residues



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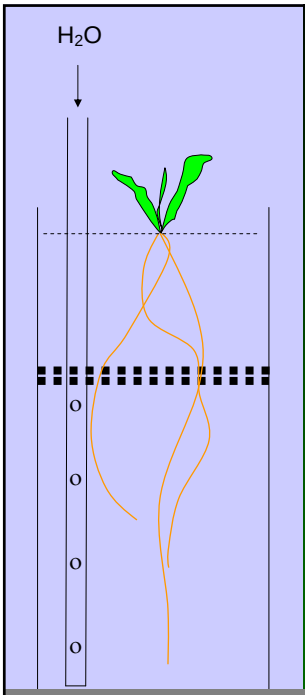
Collins S, Rengel Z, Bowden JW, unpubl.

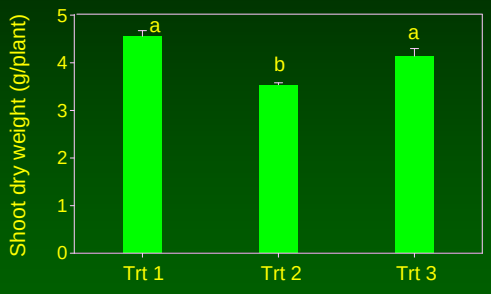


Nutrients in topsoil, water in subsoil

Nutrients in topsoil, water in subsoil

Paul Damon

Spatial separation of nutrient and water supply



Topsoil
Trt 1: +P, +H_2O
Trt 2: –P, +H_2O
Trt 3: +P, –H_2O

Subsoil
+K, +H_2O

Ma, Rengel & Bowden 2007. *Plant & Soil* 291, 301-309

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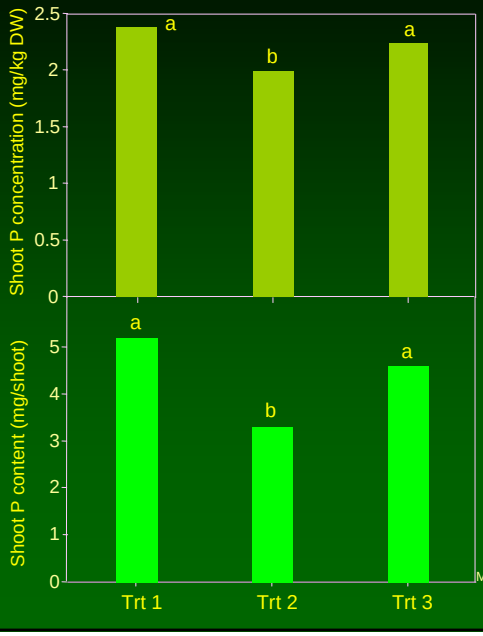

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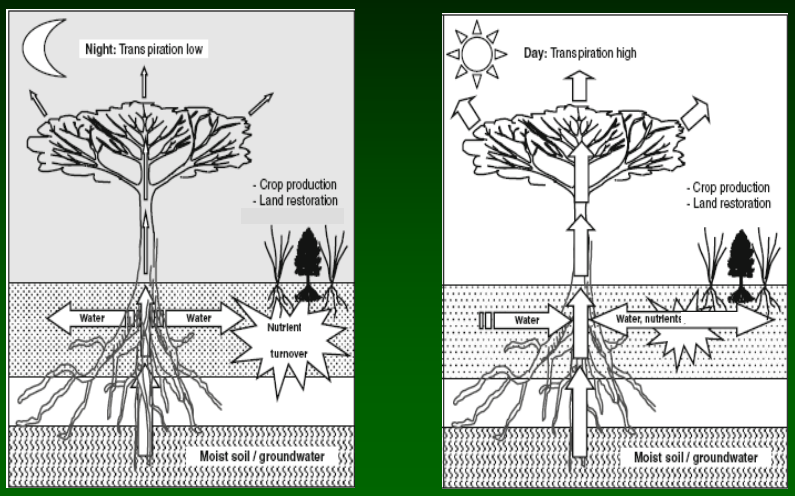
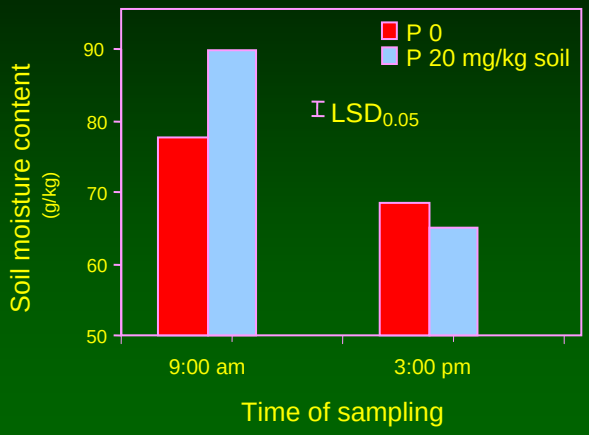
Hydraulic lift



Liste and White 2008. *Plant & Soil* **313**, 1-17

Daily fluctuations in water content in dry topsoil

- wheat -



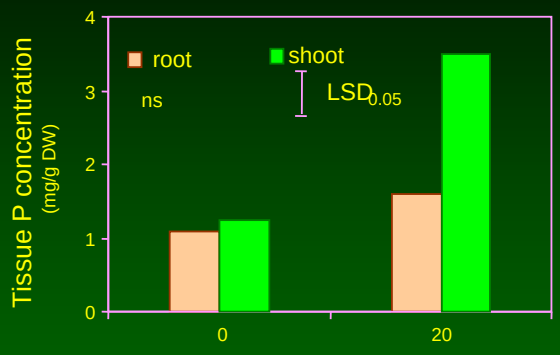
Topsoil dry, water supplied to subsoil

P fertiliser was banded in dry topsoil

Valizadeh, Rengel and Rate 2003 . *Aust J Agric Res* **54**, 59-65

Uptake of P from dry topsoil

- wheat -



Shoot DW (g/plant)	
P 0	0.39
P (20 mg/kg)	0.59
$LSD_{0.05}$	0.08

Topsoil dry, water supplied to subsoil

P fertiliser was banded in dry topsoil

Valizadeh, Rengel and Rate 2003 . *Aust J Agric Res* **54**, 59-65

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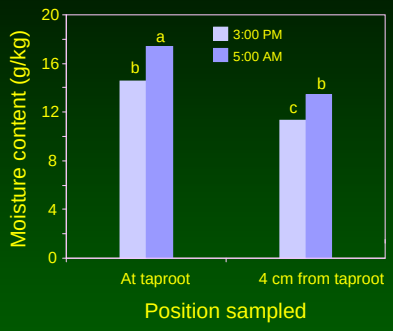
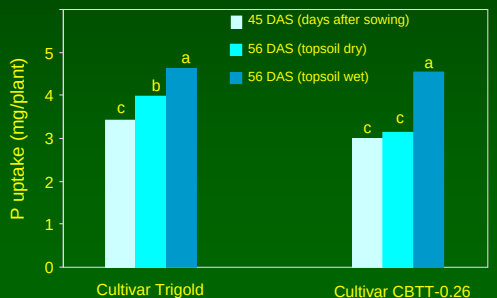
Hydraulic lift and P uptake from dry topsoil

- canola -



P applied only to the topsoil

Wet/dry topsoil treatments imposed on d 45



Rose et al 2008. *Aust J Agric Res* **59**, 38-45

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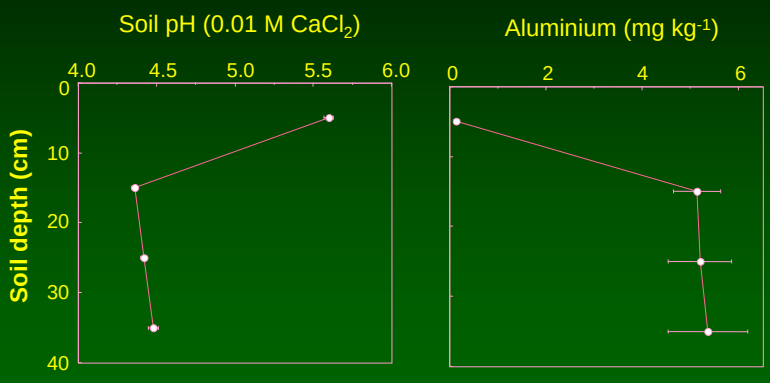
Water in subsoil, but subsoil is hostile

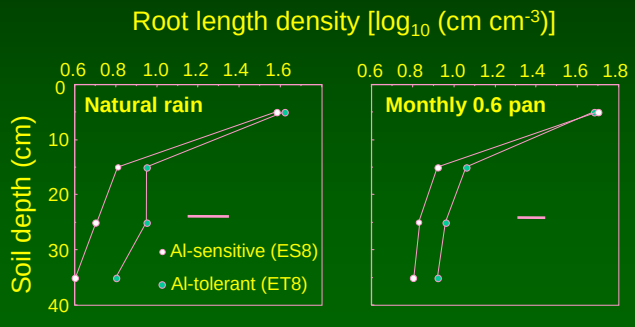
Field experiment in Merredin, Western Australia



Tang, Rengel, Abrecht and Tennant 2002. *Field Crops Res* 78, 93-103.

Root length density of wheat genotypes in soil profiles with various irrigation treatments

Field experiment in Merredin, WA



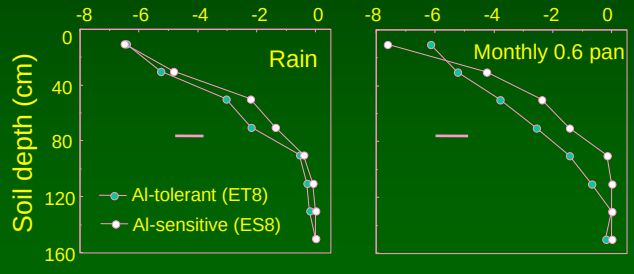
Tang, Rengel, Abrecht and Tennant 2002. *Field Crops Res* 78, 93-103.

Differential uptake of water by wheat genotypes in various irrigation treatments

(during 16 August - 11 October)

Field experiment in Merredin, WA

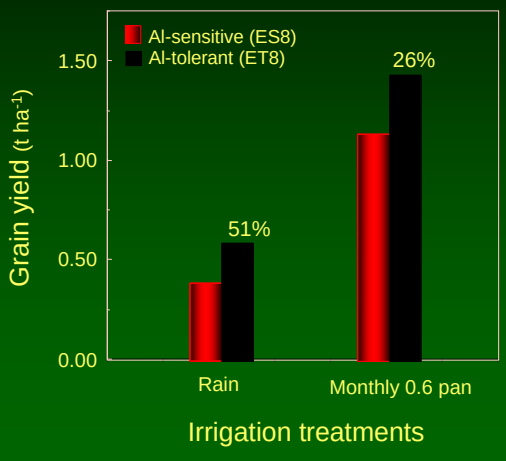
Changes in soil moisture content (%)



Tang, Rengel, Abrecht and Tennant 2002. *Field Crops Res* 78, 93-103.

Al-tolerant wheat yields higher than Al-sensitive wheat under subsoil acidity

Field experiment in Merredin, WA



Tang, Rengel, Abrecht and Tennant 2002. *Field Crops Res* 78, 93-103.

Rhizoboxes and a pin-board method

Vanessa Dunbabin

Yinglong Chen

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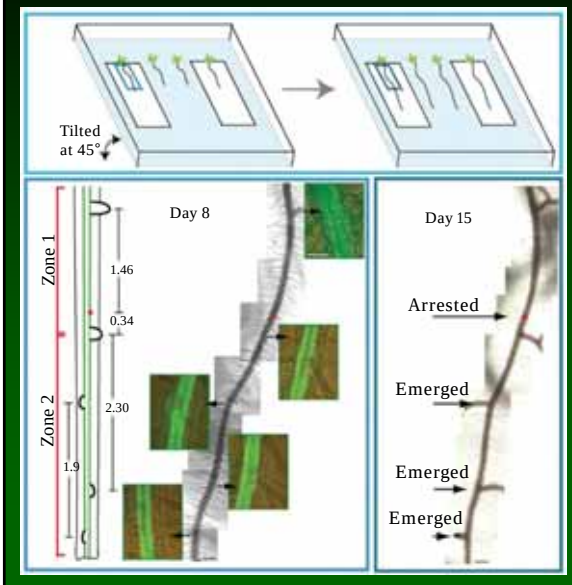
Yinglong Chen


Yinglong Chen

Each division
= 10 mm

Yinglong Chen

Imaging lateral root formation of *Arabidopsis thaliana*



mounted in 50% glycerol

- visualised under microscope using epifluorescence (green insets)
- Red dot indicates the presence of a stage I primordium

Dubrovsky et al 2006. *Ann. Bot.* **97**, 903-915

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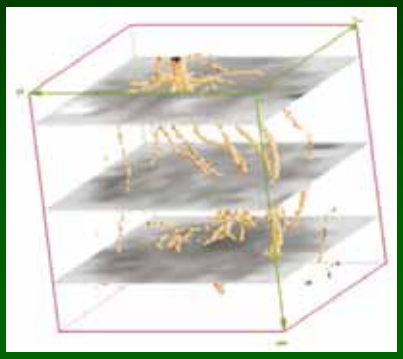
Non-invasive imaging of roots and their environment

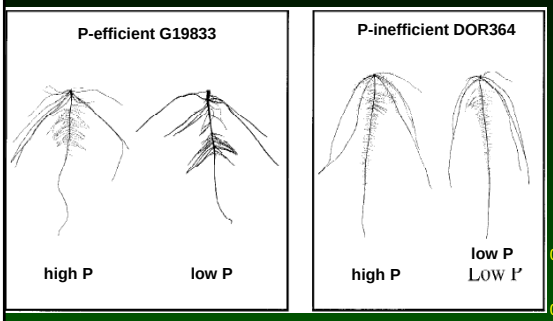
Magnetic resonance imaging (CT-MRI)
of maize roots and soil water

- brown surfaces = roots
- horizontal layers = water content changes over 2 weeks

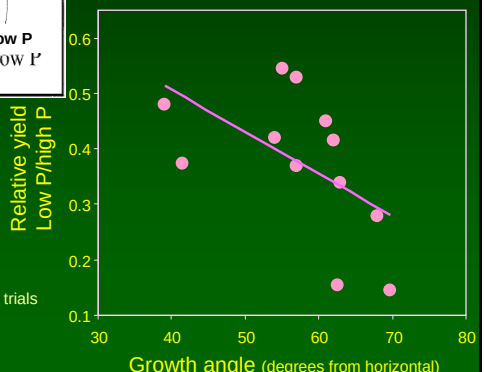


de Dorlodot et al 2007. *Trends Plant Sci.* **12**, 474-481

Root adaptation to foraging nutrients in the topsoil



6-day-old bean seedlings



Relative yield from field trials

Lynch and Brown 2001. *Plant & Soil* 237, 1-17

Modelling **hydraulic** architecture of the soil-plant system (maize)

3-D soil-water transport model

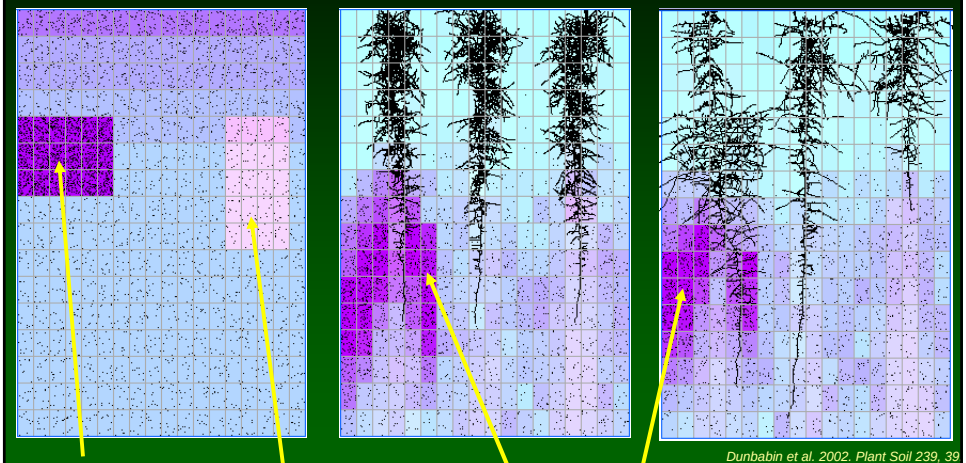
Modelled roots and initial soil-water potential

de Dorlodot et al 2007. *Trends Plant Sci.* **12**, 474-481

initial soil profile

unresponsive root systems grow according to pre-defined rules only

root systems responding to their local environment



Dunbabin et al. 2002. Plant Soil 239, 39

local high nitrate patch

local dry patch

nitrate leaching through soil profile after successive rain events

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Conclusions

Fertiliser (P/ammonium) placement may be critical for adequate nutrient supply without burning the seedlings, especially in drying soil

Nutrients (eg. K and S) can be washed out of crop residues with water

Most crops can hydraulically lift water from subsoil to topsoil, allowing nutrient uptake from dry topsoil

Conclusions

It is important to breed cultivars with root architecture appropriate for a given environment:

- shallow roots for foraging nutrients in the topsoil and
- deep roots for taking up water when topsoil dries out

3-D models simulating root growth and water and nutrient uptake have a potential to be used in breeding programs for producing cultivars with optimal root architecture for a given environment

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Terry Rose (UWA, now National Agro-environmental Institute, Tsukuba, Japan)
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Bill Porter (Western Australian Department of Agriculture and Food)
Chris Gazey (Western Australian Department of Agriculture and Food)
Bill Bowden (Western Australian Department of Agriculture and Food)
Art Diggle (Western Australian Department of Agriculture and Food)

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