Department of Plant and Environmental Sciences

Combining agronomic and breeding approaches for improved nutrient use efficiency

Kristian Thorup-Kristensen
24 September 2013

Background in agronomy

Nitrogen: Agricultural resource and environmental problem

- Cover crops
- Cropping systems and rotations
- Root growth and nitrogen utilization
- Modelling
- Analysing strengths and weaknesses of crops and rotations
- Now working also on genotypic differences in root growth as input to breeding, mainly in wheat

Topics

- NUE is not well defined, what do we want to achieve?
- Agronomic approaches give much bigger effects – but need to be repeated every year in every field
- Plant traits needed for high NUE depend on a range of factors, such as N vs. P, leaching environment etc.
- With my background I talk about plant physiology traits rather than candidate genes, QTLs etc.

NUE crop or cropping system?

- This meeting deal with nutrient use efficient genotypes
- Farmers and society need NUE cropping systems
- Need to develop genotypes designed for the system where they will be grown
  - Need to adapt the system for them
- NUE is not a trait of the plant/genotype
  - NUE is a ”trait” of the system, combining genotype, environment and agricultural management
- G*E*M

Nutrients from soil and fertilizer

- Water: ”More crop per drop”
- Same for plant nutrients
  - ➢ But we need some nutrient in the harvest product for quality

- Optimal efficiency in theory
  - ➢ Can produce high yields at limited nutrient availability
  - ➢ Maximize the biomass production per unit nutrient available
  - ➢ Harvest and remove as little as possible of the nutrient
    - – Leave it in the field to be used by succeeding crops

Nitrogen and Phosphorus

- The two most important nutrients to work with
  - ➢ Very different in almost any respect
  - ➢ But we need to deal with both

- Nitrogen very dynamic – (P almost opposite)
  - ➢ Availability changes fast
  - ➢ Large losses can occur within days/weeks/months
  - ➢ N is mobile in the soil and root zone

Nitrogen and Phosphorus

- For both we need plants with high produciton per unit nutrient
- Efficent use of resources from the soil
  - P, in order to thrive at low P
  - N, in order to deplete the soil resource
- Very different requirements for the root system
  - P, dense, superficial roots with long root hairs
  - N, Fast and extensive spread of the root system, rooting depth

Nitrogen and Phosphorus

- The value of unused N in the soil very variable
  - Match supply to demand
  - Use as much as possible
  - Manage what is left (fertilizer planning, cover crops, rotation…)
- P left in the soil will mostly stay there
  - Do not harvest and remove more than necessary
  - Need crops wich can grow well at low P availability
    - Losses caused by erosion and highly dependent on soil P content
    - Reduce need for this limited ressource
- K, much is taken up, but in seed crops little is harvested

Genotypes vs. management

- Management give larger effects (per hectare and year)
- But require yearly attention by the farmer

- Fertilizer management
- Rotation and cover crops
- Species effects
  - Root growth
  - Nutrient harvest and efficiency

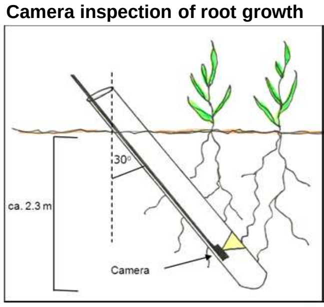
Field studies of root growth

Wheat plots in the field with 3 m long rhizotrons for root observation installed.

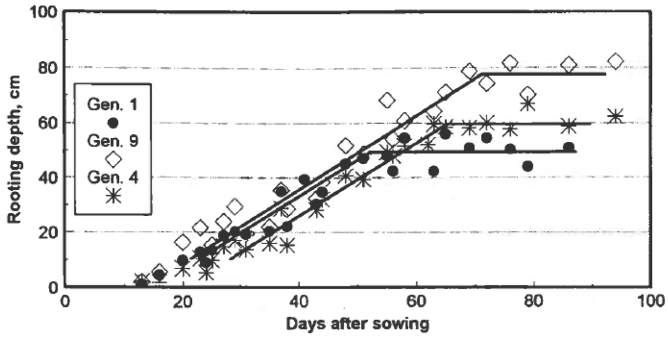
Drilling equipment for insertionn of 3 m long minirhizotrons

Insertion of a minirhizotron

Camera inspection of root growth



Root growth of green pea genotypes

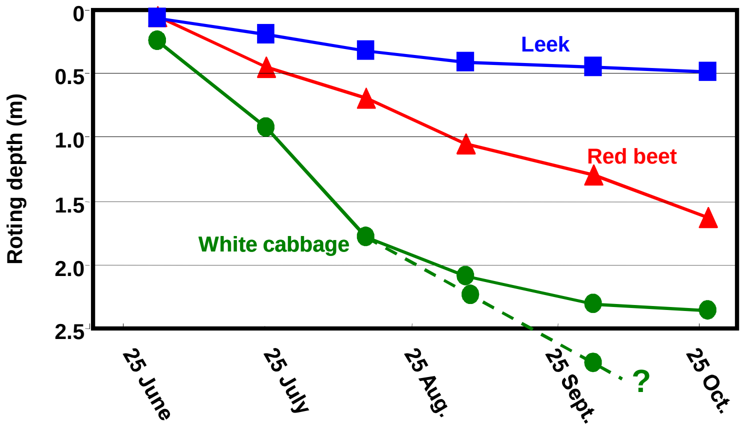


Larger depth mainly due to:

- **Larger seeds –** ***fast initiation of root growth***
- **Late harvest time –** ***longer duration of root growth***

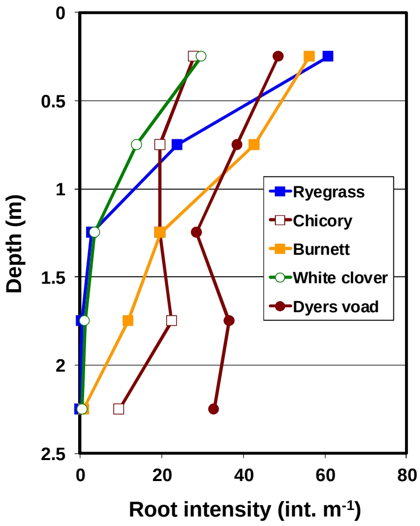
Characteristics which are optimized for other reasons

Development of rooting depth of three vegetable crops



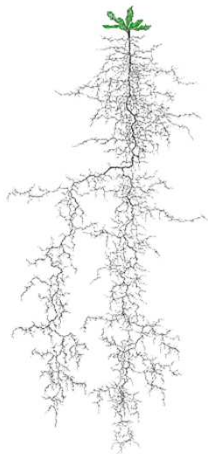
Alternative cover crops with deep rooting

Root density in November



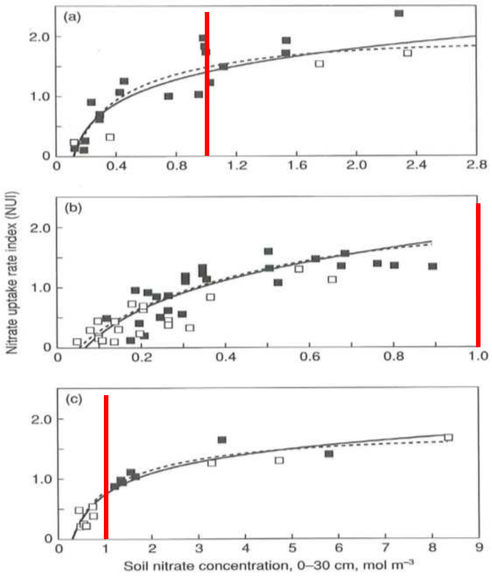
Rooting depth development rates

mm day degree^{-1}



0.2 mm	Onion, leek, celeriac
0.7-0.8 mm	Carrot, pea, potato, clovers
0.9-1.2 mm	Cereals and grasses, sugar beet, early cabbages
1.2-1.5 mm	Head cabbage, lettuce, chicory, zucchini
1.5-3 mm	Crucifer cover crops

N uptake by wheat, oilseed rape and maize
- effect of soil nitrate content



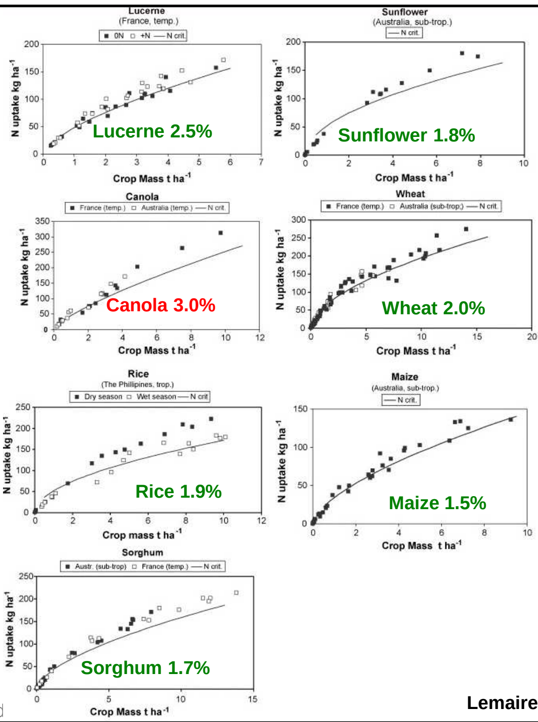
Wheat

Oilseed rape

1 mol m^{-3} = 42 kg N/ha (0-30 cm)

Maize

Breeding a



Crop N content at increasing DM

and %N at 10 Mg DM ha^{-1}

Lemaire *et al.* (2007)

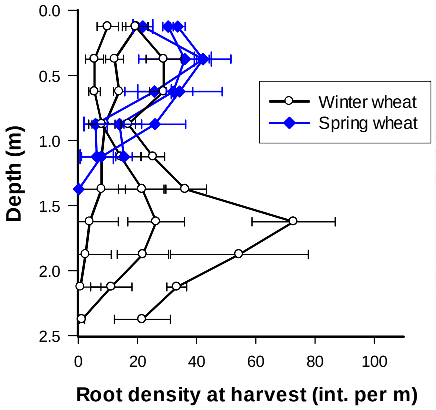
Breed

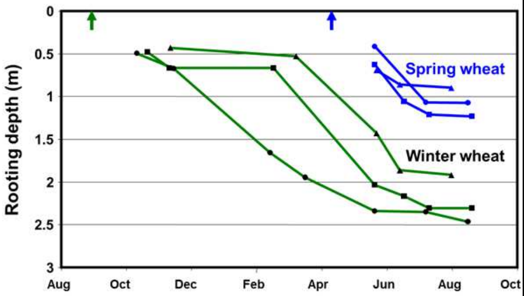
N in Canola compared to other crops

	%N in DM at 10 Mg ha^{-1}	SLN (g N m^{-2} leaf)	Stem N at LAI 4
Canola	**3.0**	**2.4**	**100**
Sunflower	1.8	2.0	60
Wheat	2.0	1.6	31
Maize	1.5	1.7	85
Sorghum	1.7	1.5	36
Lucerne	2.5		

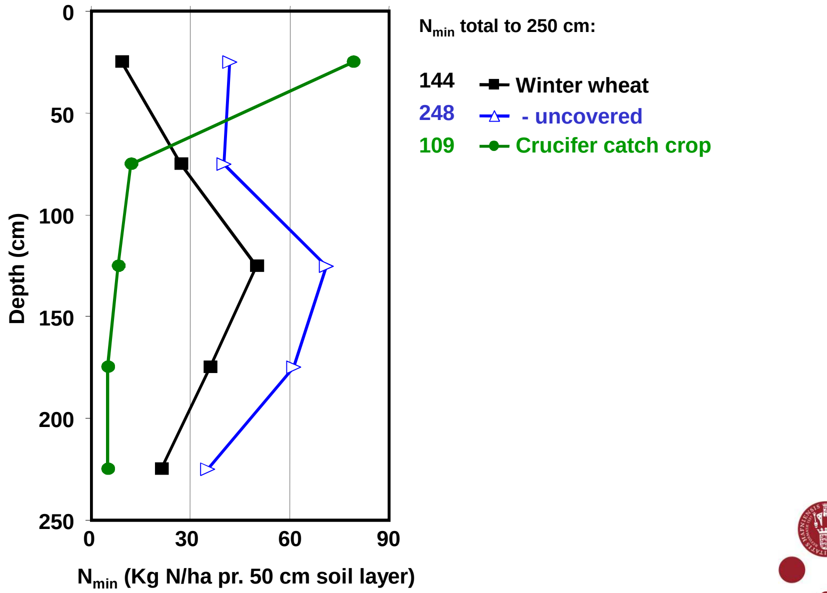
from
Lemaire *et al.* (2008)
Lemaire *et al.* (2007)

Root growth of spring and winter wheat
- three years experiment

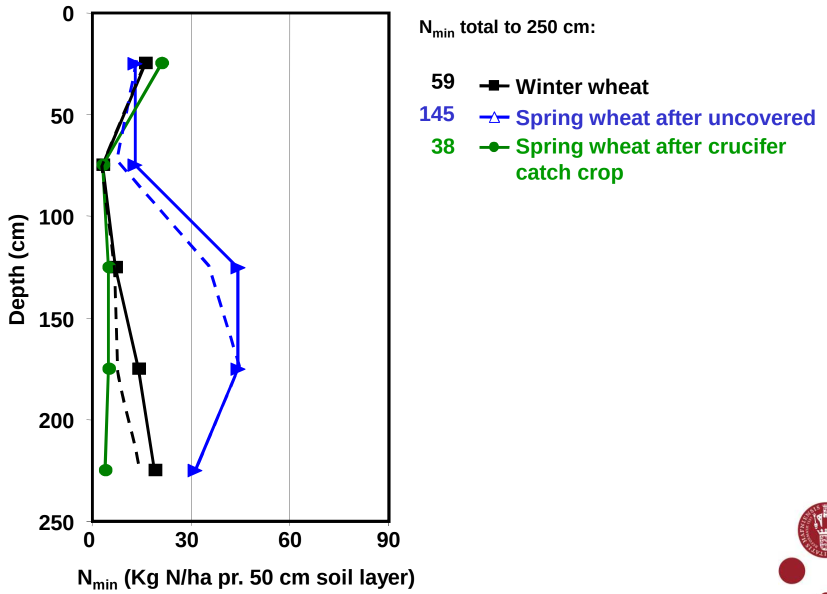




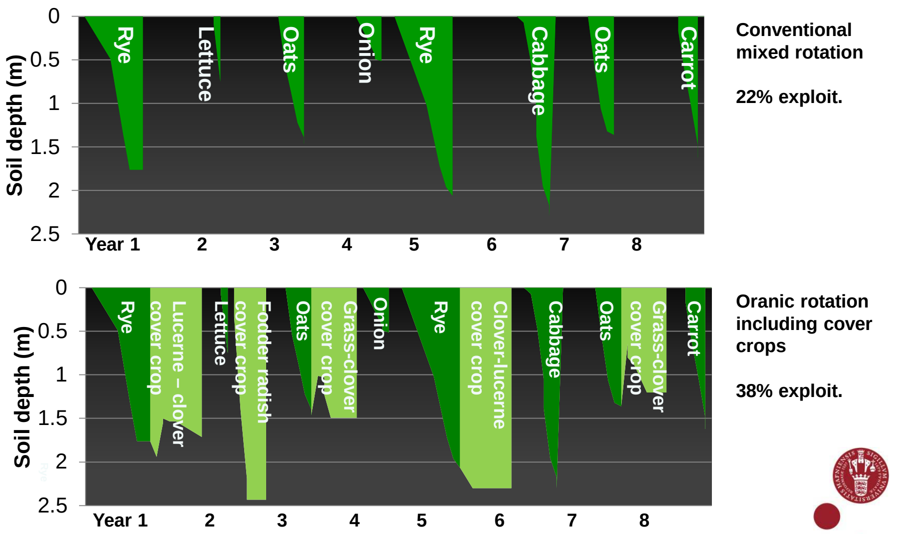
N_{min} April under wheat, catch crop or no cover



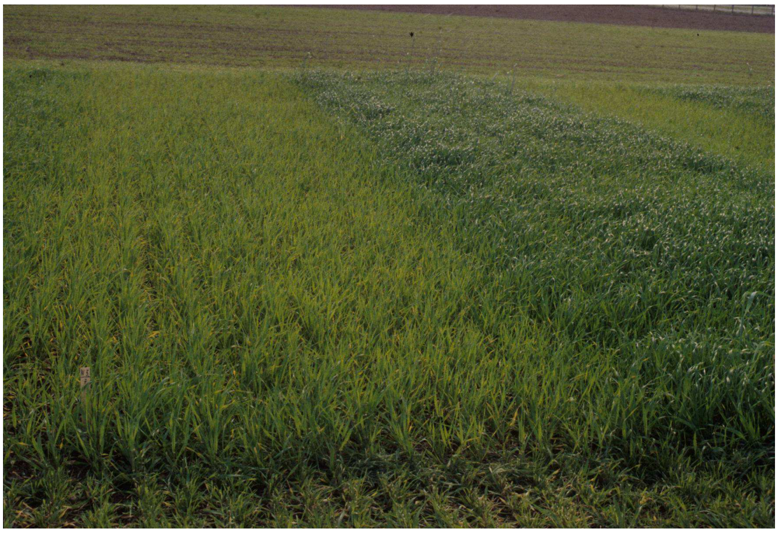
N_{min} after harvest of winter or spring wheat

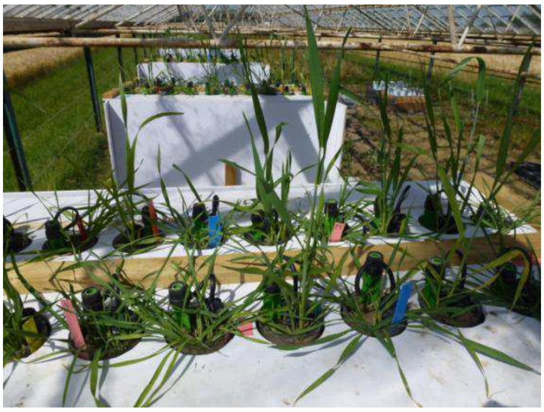


Root exploitation dynamics of rotation



Nitrogen ”carry over” effect of a cover crop






The ”N task” of a crop

- example oilseed rape – is it a highly NUE crop??

- Help use what is left from last years crop and from soil
- Use its N for efficient production
- Create little loss risk

- **Oilseed rape:**
- Deep root growth and very efficient N uptake
- N productivity moderate, litter loss and high N concentration
- Substantial mineralization after harvest

The great ”National Danish N reduction experiment”

- Strict N regulations through more than 20 years
- N quotas for farmers
  - In theory 10% below economic optimum
  - In reality probably more
  - N fertilization often 30% below what is used in neighbour countries
- Farmers unhappy but breeders happy!!
- Danish breed cultivars developed under these conditions now dominate the Danish market

NUE is not well defined!
- what do we actually want?

- High uptake of applied nutrients
  - Or of soil nutrients?
- High concentration of nutrients in harvesed product (protein in grain)
  - High relative harvest of nutrients (NHI)
- High biomass production per unit nutrient taken up
- High biomass produciton per unit nutrient available
- High biomass production per unit nutrient harvested
- Crop can cope with low soil fertility

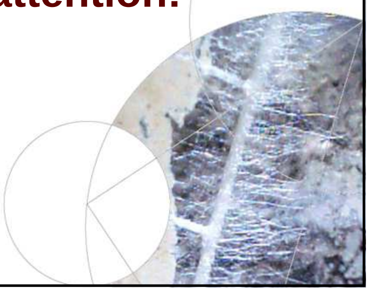
Systems we need to breed for?

- High input systems
  - Aim for very high production
  - High yield per unit nutrient put in
- Low input conventional systems
  - Accept some yield reduction (e.g. the Danish N system)
  - Maximize utilization of fertilizer, manure and soil resources
  - But not very basically different from the high input systems
- Organic farming systems
  - In general low nutrient availability
  - Difference in timing, source, etc.
  - High variability, - not all fields fertilized

Department of Plant and Environmental Sciences

Combining agronomic and breeding approaches for improved nutrient use efficiency

Thank you for your attention!



Kristian Thorup-Kristensen
24 September 2013