Using Plants to Manage Soil Health

With an emphasis on cover crops

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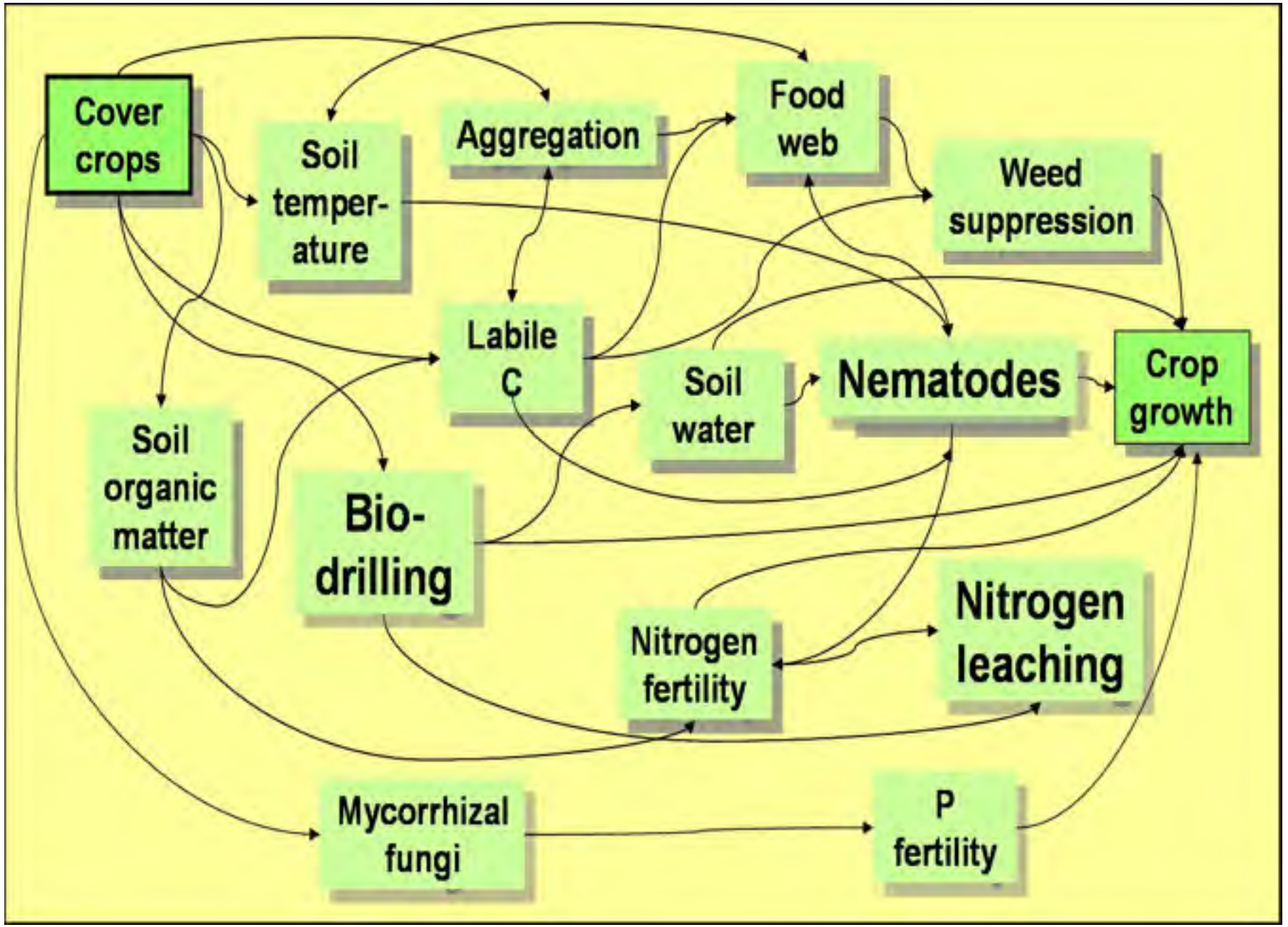
“Cover crop” or “green manure”

- Grown mainly for soil improvement…rather than for harvest (but may graze).
- Ideally grown in time and space where grains and other cash crops are not possible.

Adding cover crops to a rotation can have complex effects



Adding a cover crop can make a measurable difference to your soil and crop growth

	Cover Crop Treatment		
Crop or Soil Parameter	**No Rye**		**Rye**
Bean Drymatter kg ha^{-1}	5275.5	**	5995.1
Soybean yield kg ha^{-1}	2704.8	*	3054.9
Active C mg kg^{-1}	624.2	**	661.7
C respired in 2 days mg kg^{-1}	213.1	**	255.0
Total organic C g kg^{-1}	17.90	ns	19.06
Mineralizable N mg kg^{-1}	82.01	**	101.81
Stable aggregates %	60.40	**	69.40

Overall Means of 6 sites in MD and PA with 2 to 6 years of rye cover crop in corn –soybean rotation.

Soil Quality Indicators

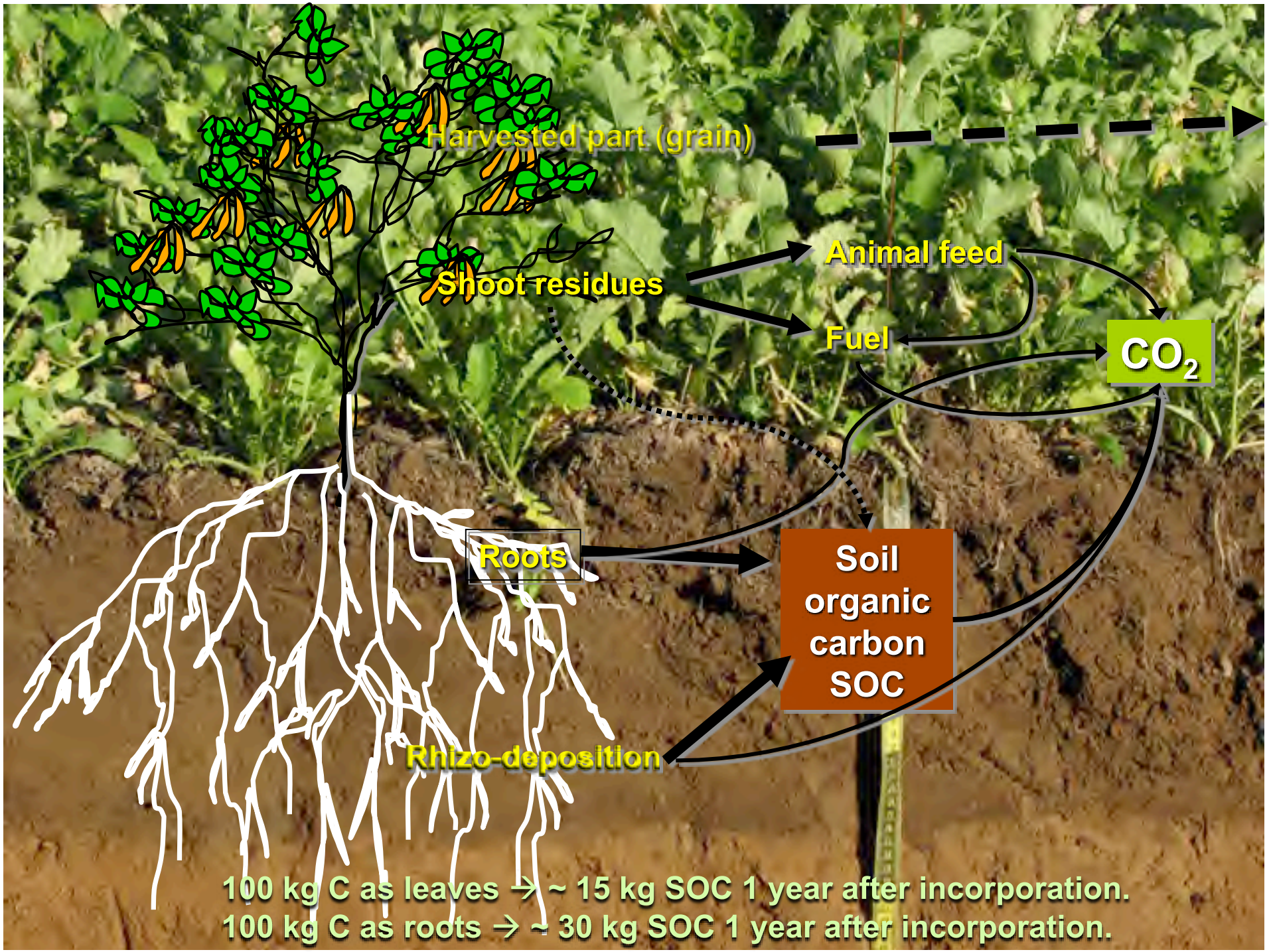
Some properties that may respond to cover crop management over a time span of a few years

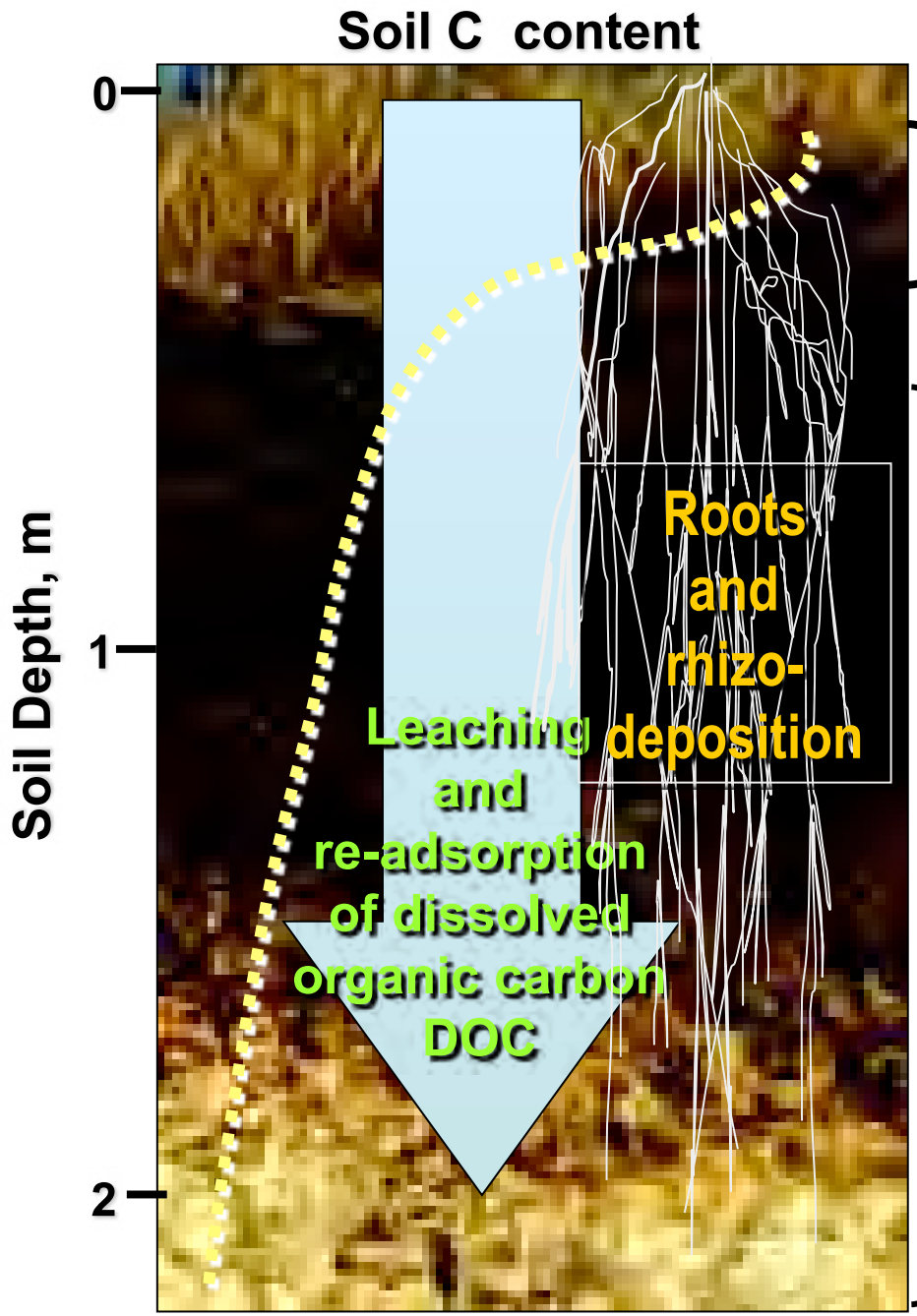
- **Active carbon**
- **Microbial biomass**
- **Total organic matter**
- **Aggregate stability**
- **Strength when wet**
- **Infiltration rate**
- **Disease suppression**
- **Mineralizable N**
- **Biological diversity**

Cover crops can increase the quality and productive capacity of the soil while decreasing greenhouse gases.

- Add organic carbon to soil.
- Add fixed nitrogen (if legume).
- Recover nutrients from subsoil.
- Improve nutrient availability & use efficiency
- Enhance soil physical, chemical and biological properties


Key differences are in the roots!


Harvested part (grain)
Shoot residues
Animal feed
Fuel
CO_2
Roots
Soil organic carbon SOC
Rhizo-deposition
100 kg C as leaves → ~ 15 kg SOC 1 year after incorporation.
100 kg C as roots → ~ 30 kg SOC 1 year after incorporation.



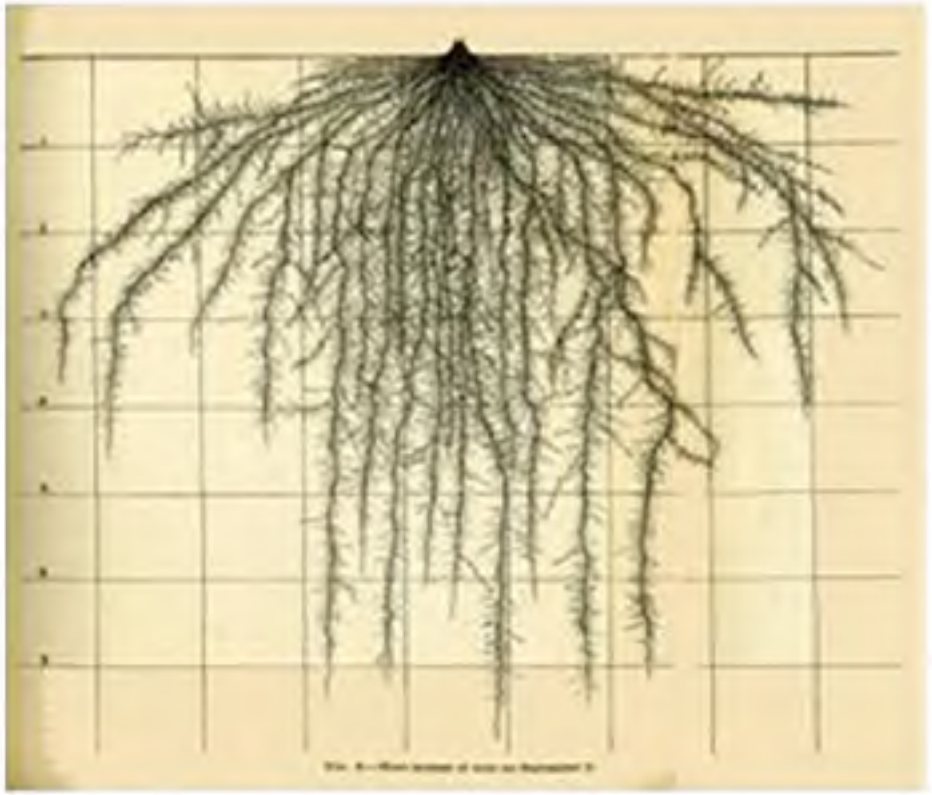
> 90% of the data is here.

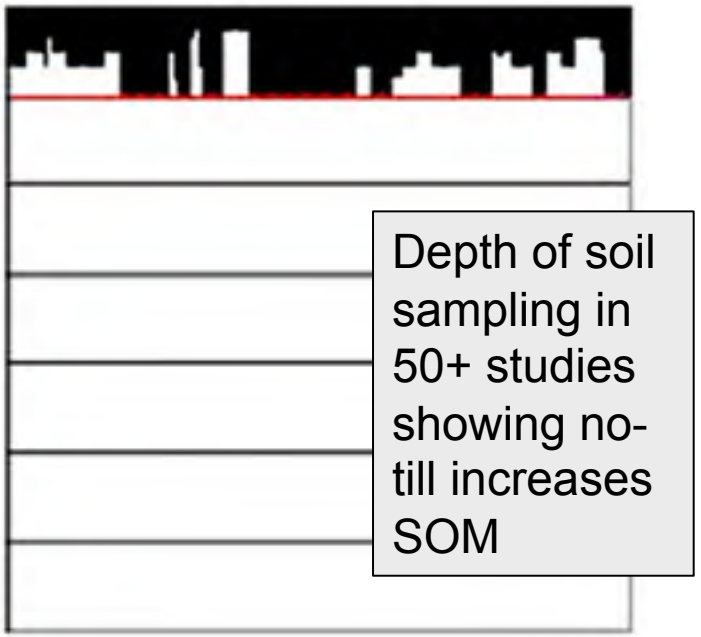
Much more effort is needed to study deep soil C

> 60% of the carbon is here.

SOC in deep layers tends to have low C/N and slow turnover times.

No-till increases SOC in surface 5 to 15 cm, but may decrease it in deeper soil layers.





Root system of a corn plant (field excavation by Weaver 1929) and the sampling depths used in 140 comparative studies of tillage impacts on soil carbon. Scale in feet.

Baker, J.M., T.E. Ochsner, R.T. Venterea, and T.J. Griffis. 2007. Tillage and soil carbon sequestration--what do we really know? Agriculture, Ecosystems & Environment 118:1-5.

Root/shoot ratio effects

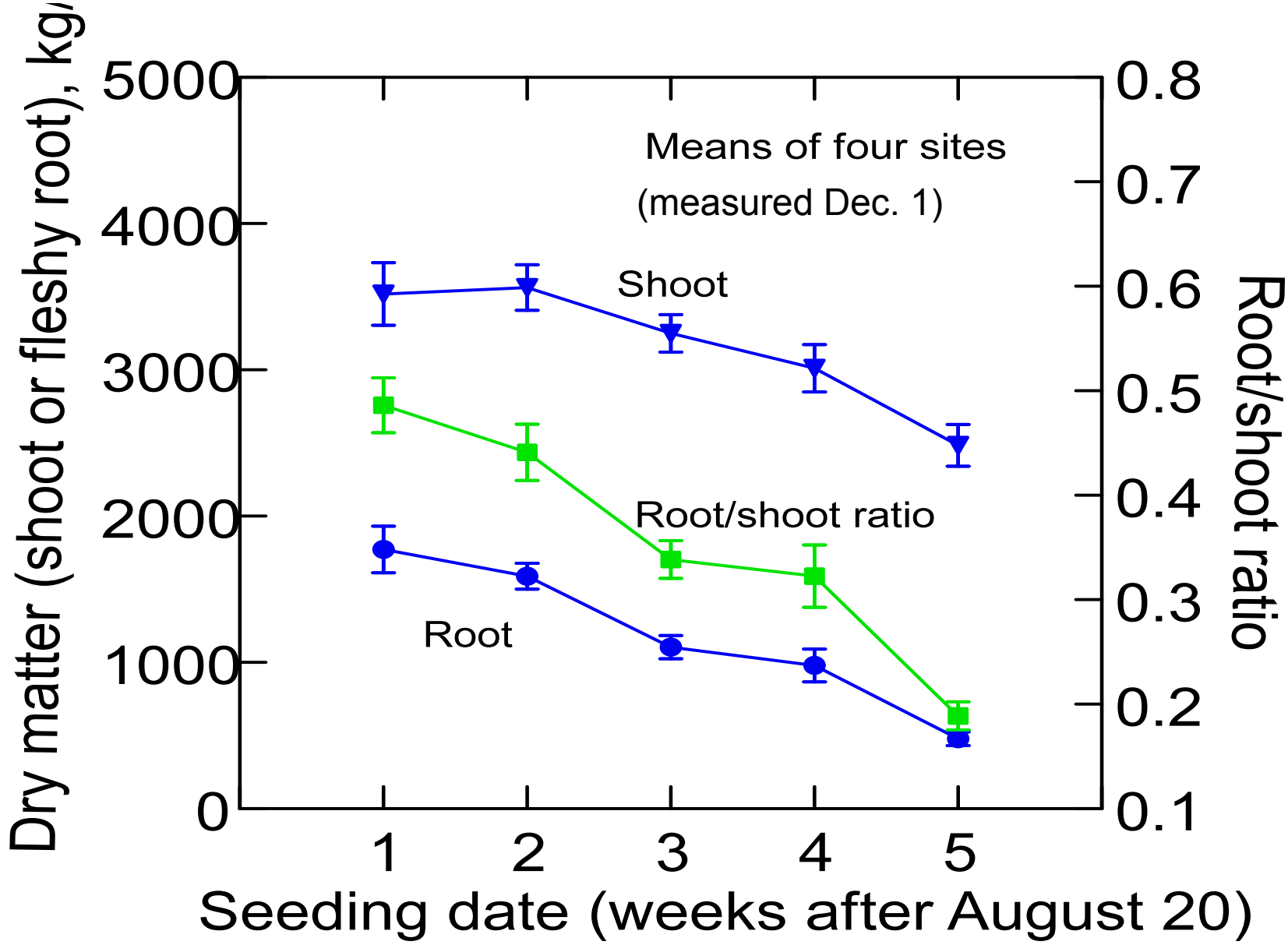
1. If conditions above ground are limiting, the roots will suffer most.

   e.g. late planting (above ground limit) decreases root/shoot ratio.

2. If conditions below ground are limiting, the shoots will suffer most.

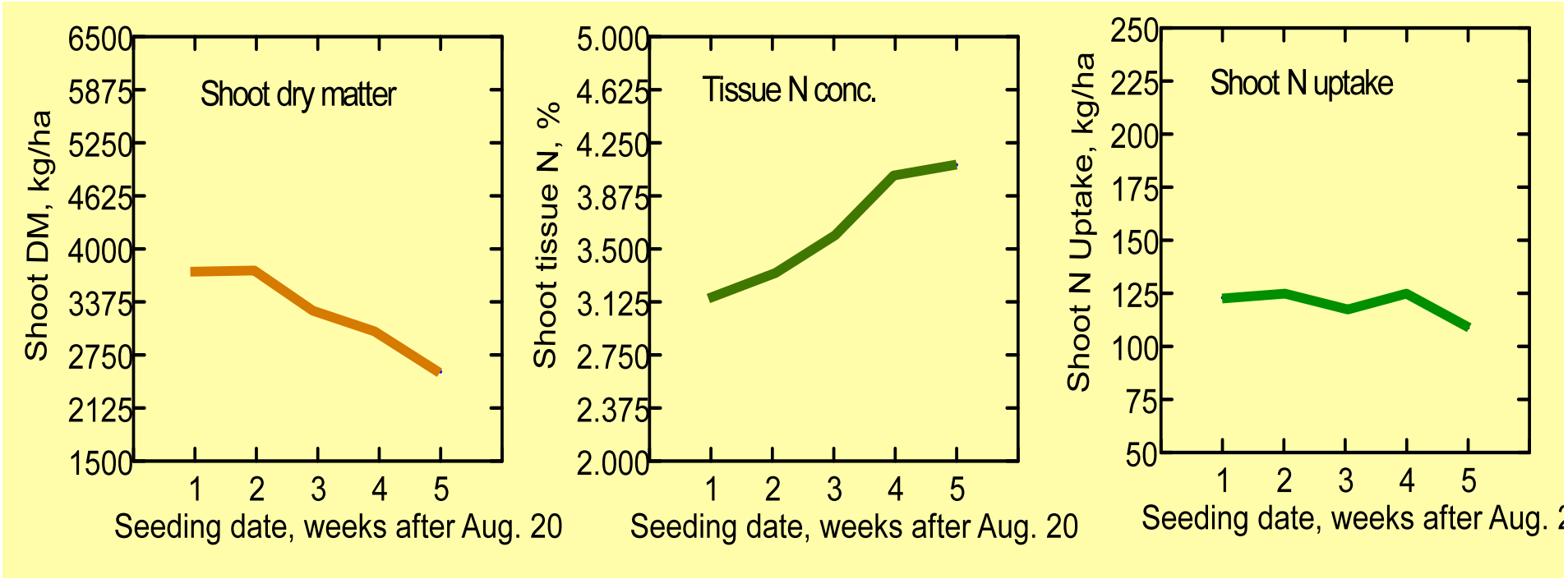
   e.g. N deficiency (soil limit) increase root/shoot ratio

Effect of seeding date on forage radish root & shoot just before frostkill

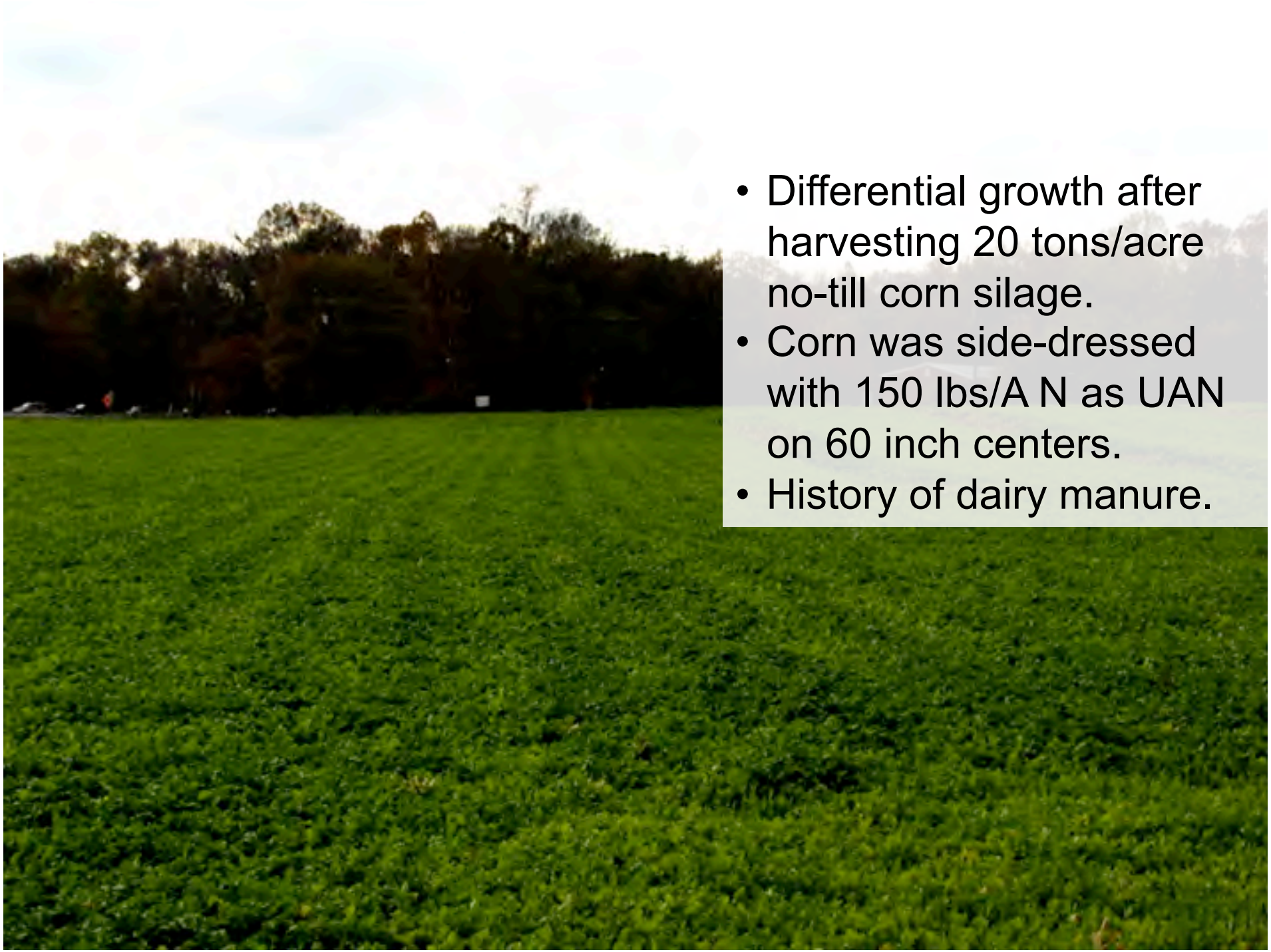


A few weeks later planting reduces weed suppression and biodrilling but not nitrogen capture.

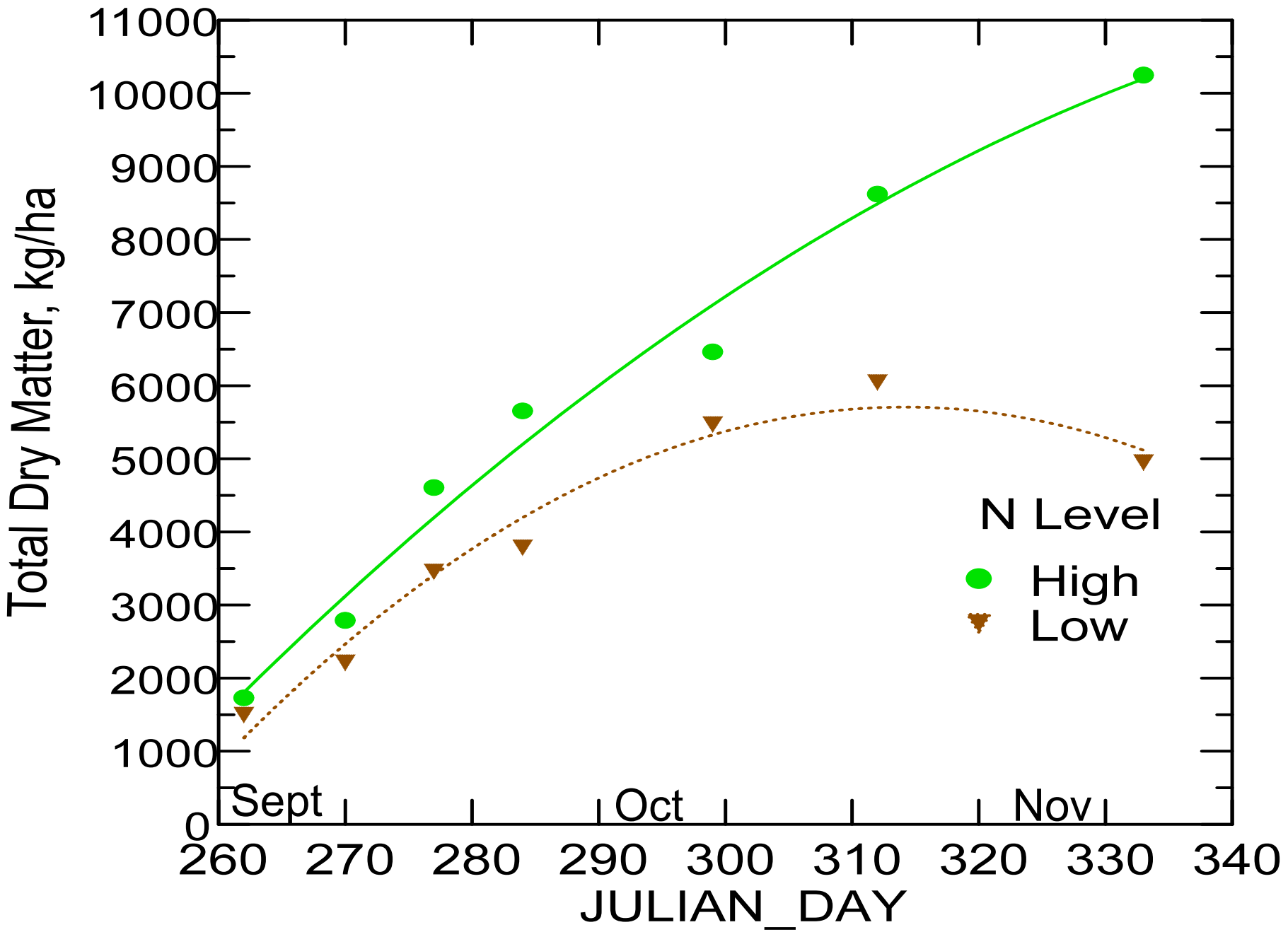
Effect of seeding date on forage radish growth & nitrogen uptake in fall



Means of 3 sites in 2007

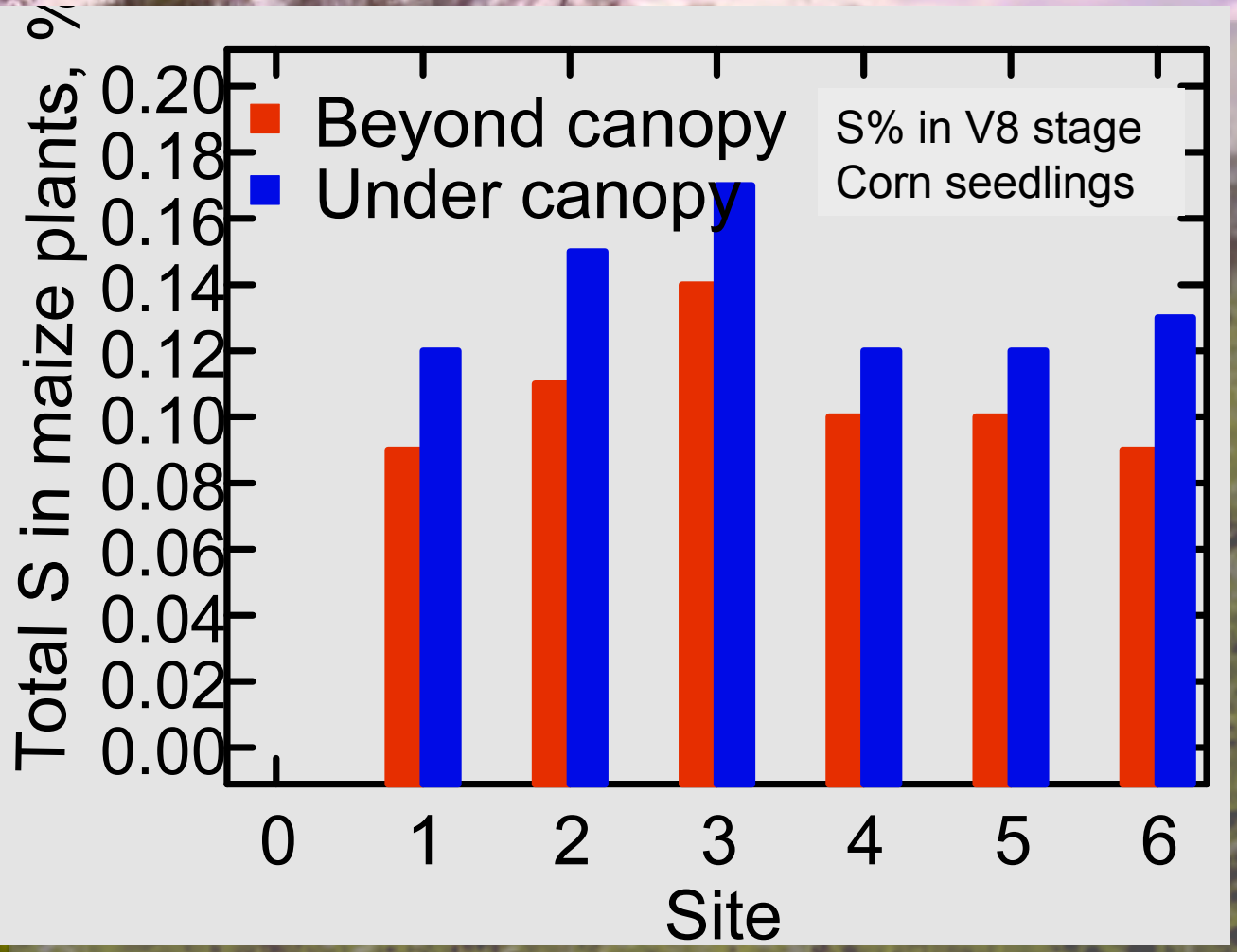


- Differential growth after harvesting 20 tons/acre no-till corn silage.
- Corn was side-dressed with 150 lbs/A N as UAN on 60 inch centers.
- History of dairy manure.


Total Dry Matter, kg/ha
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Sept
Oct
Nov
260
270
280
290
300
310
320
330
340
JULIAN_DAY
N Level
High
Low

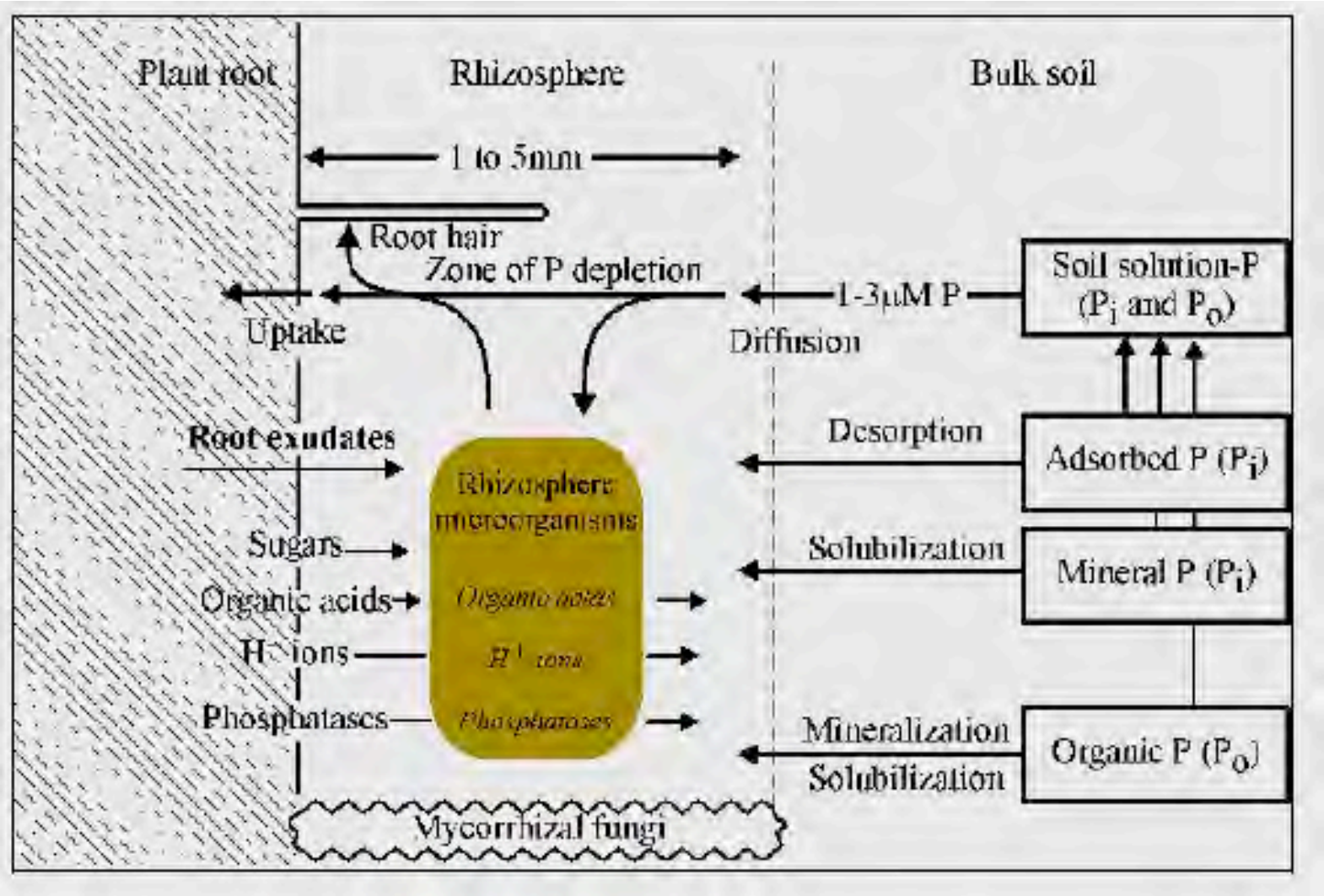
Nutrient cycling by Acacia albida (syn. Faidherbia albida) in African agroforestry systems

Example of deep root "pumping" on enhanced nutrient recovery



From Weil and Mughogho (1993)

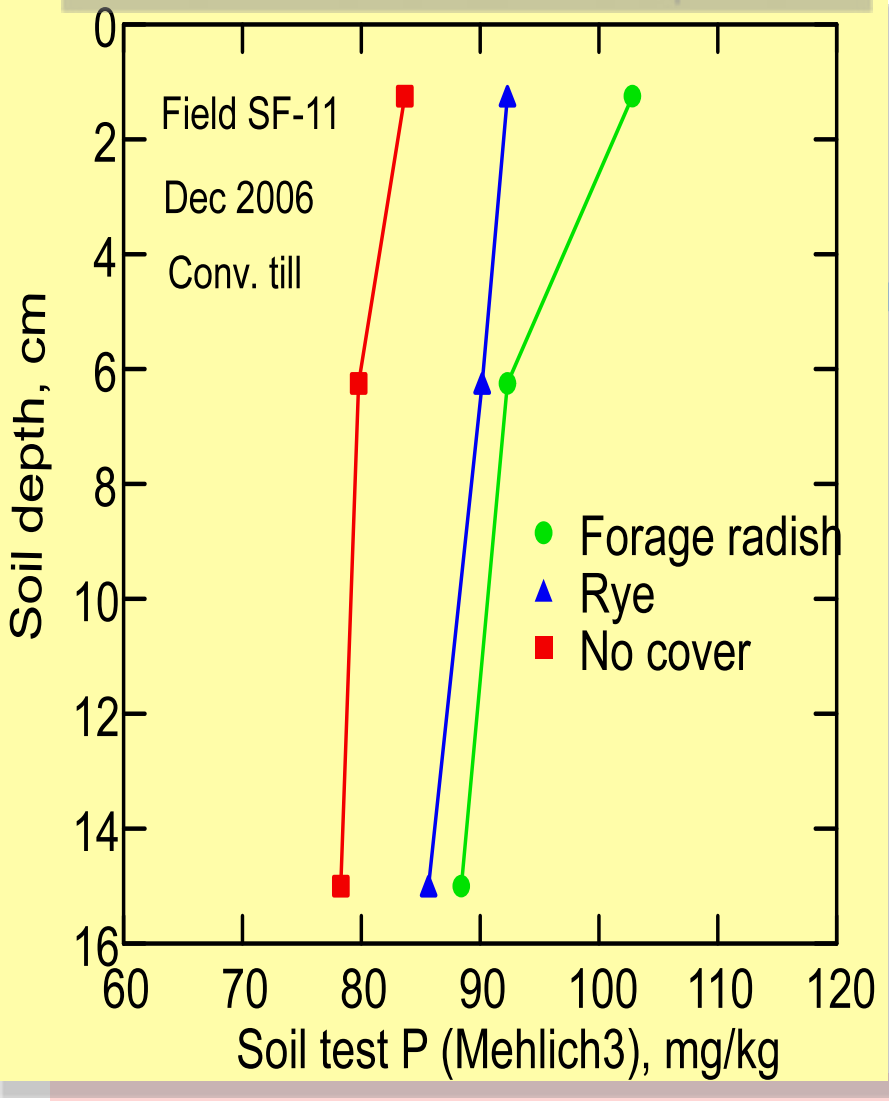
For phosphorus, root influences can be complex



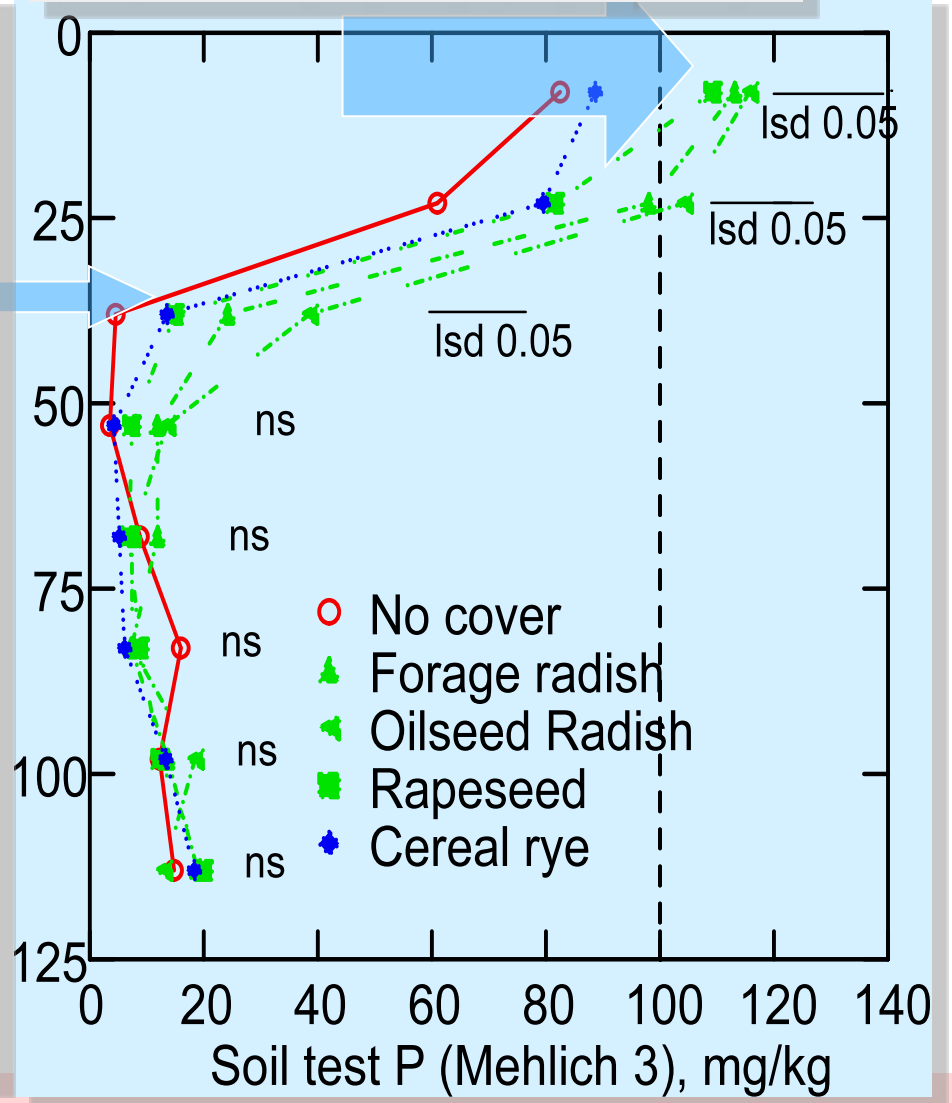
Hocking, P., P. Randall, E. Delhaize, and G. Keerthisinghe. 2000. The role of organic acids exuded from roots in phosphorus nutrition and aluminum tolerance in acidic soils, p. 61-70 Management and conservation of tropical acid soils for sustainable crop production. IAEA, Vienna, Austria.

Increased available phosphorus in surface soil horizons

Silt loam, upper 6 inches (15 cm)
In first winter of cover crop trts.

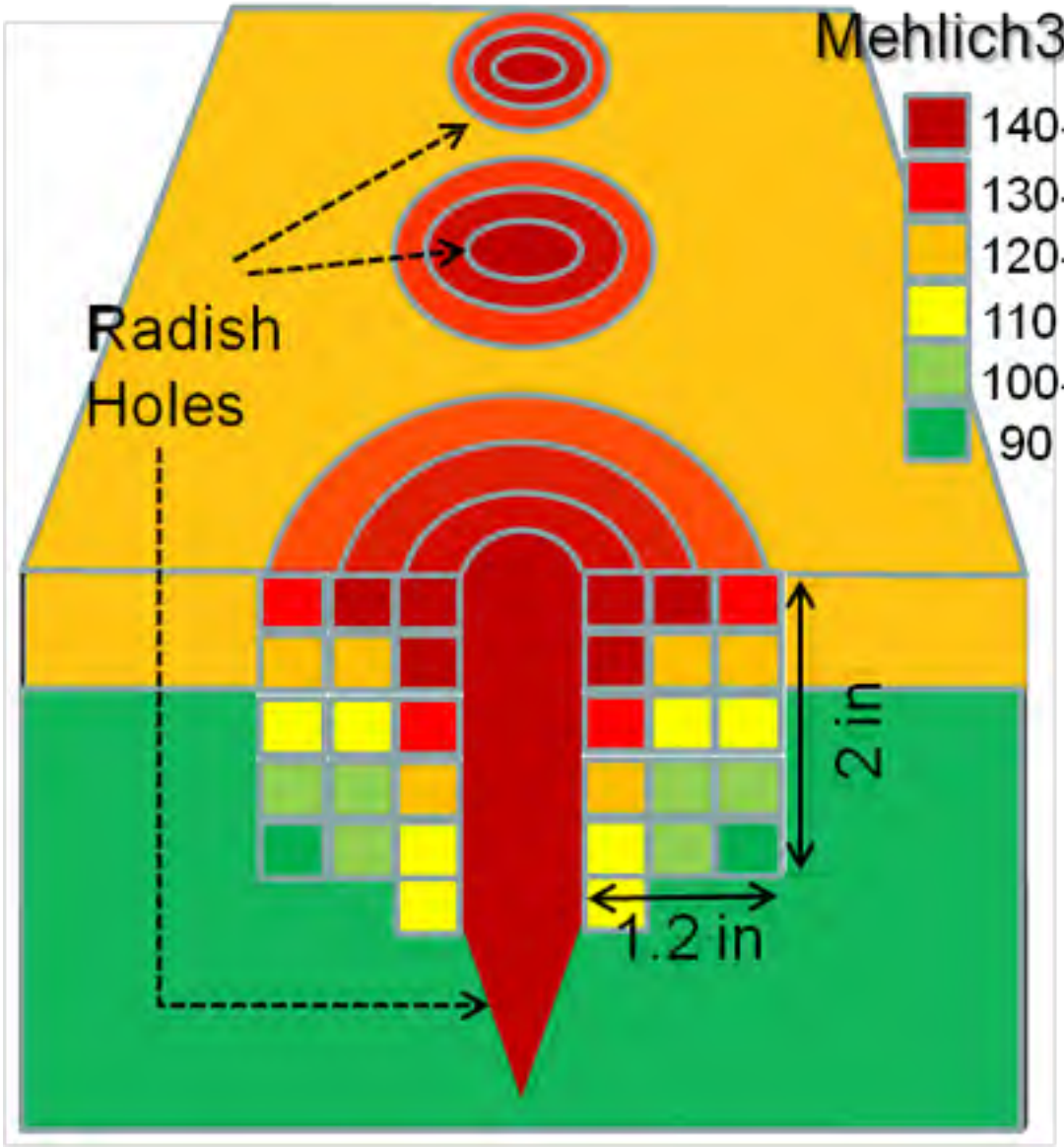


Silt loam, upper 4 feet (120 cm)
In 3rd winter of cover crop trts.

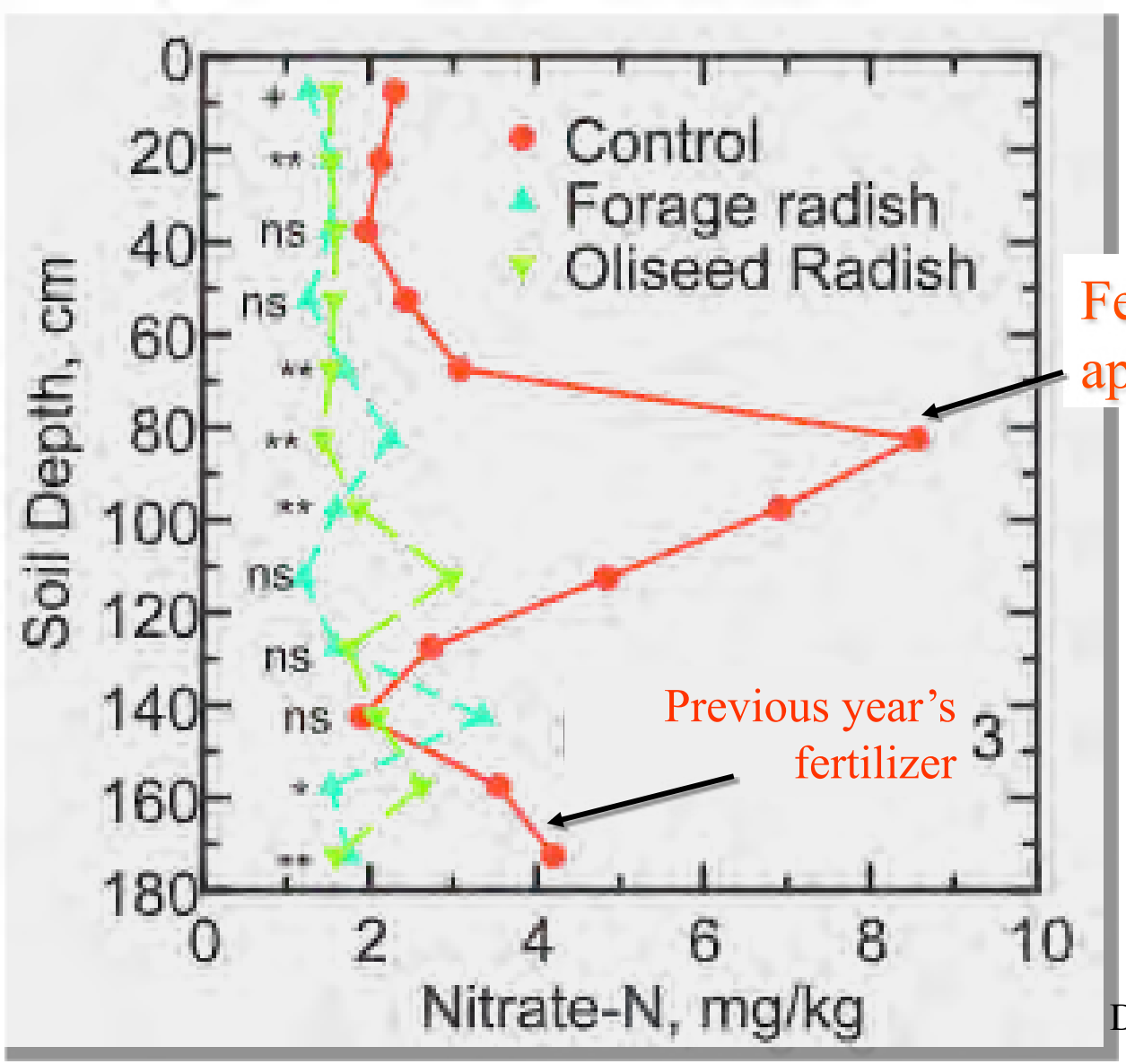


- Deep P brought to surface & bound P made available

P Concentration around radish holes



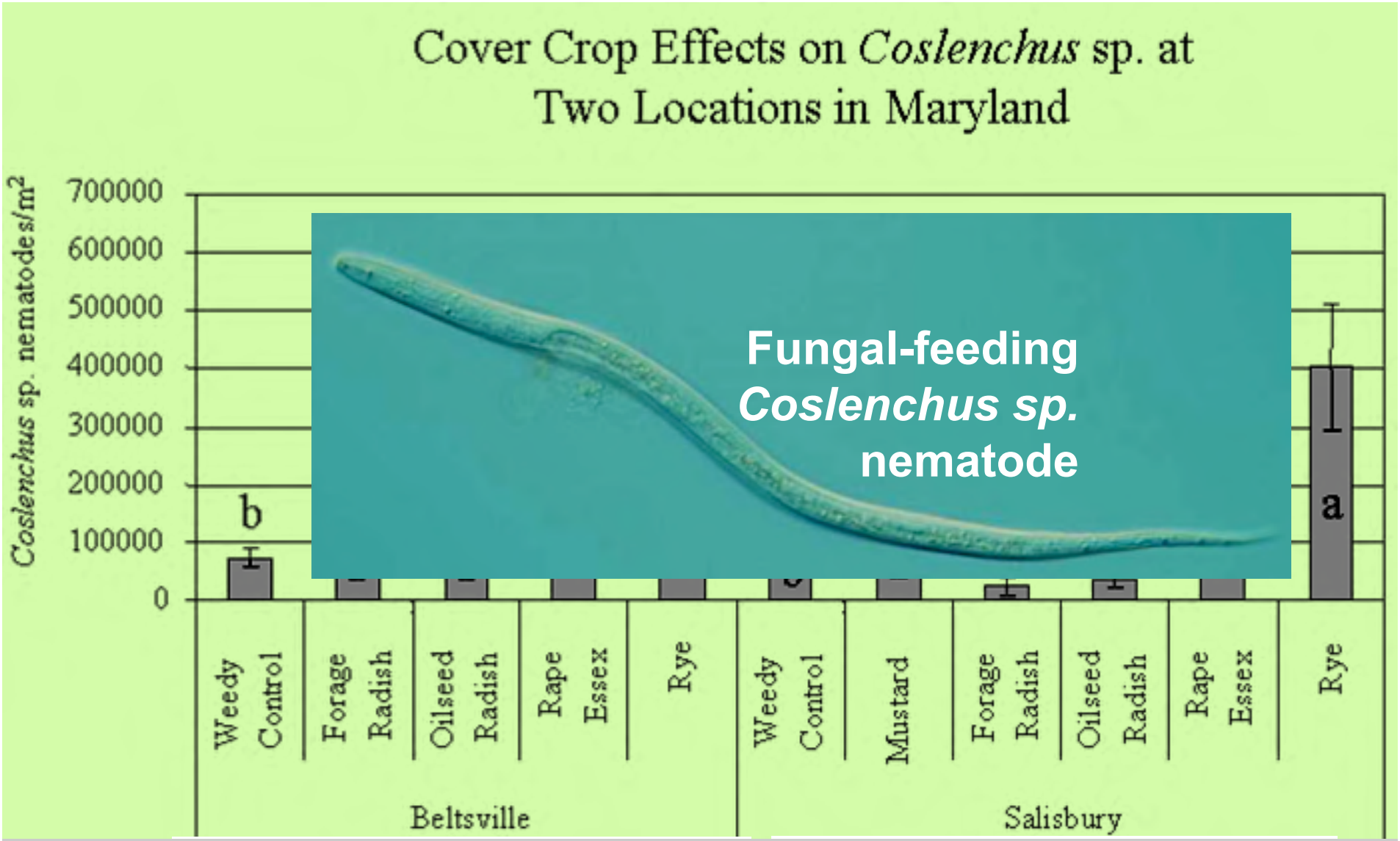
Capture of Deep Soil N After Grain Crop Harvest



Wheat was harvested in July. Cover crops grew from late August – early December

~ 150 kg N/ha taken up by cover crop from "N deficient" sandy soil.

Dean and Weil, 2009



A single rape or rye crop altered soil food web from bacterial-dominated to fungal, thus influencing nutrient cycling. Gruver, Weil, Zasada, Sardanelli, and Momen (2010. J. of Applied Ecology).


Effect of cover crop rooting on soil tilth.
Rye
Forage radish

Rye roots fail to penetrate a compacted soil

“*Biodrilling*”

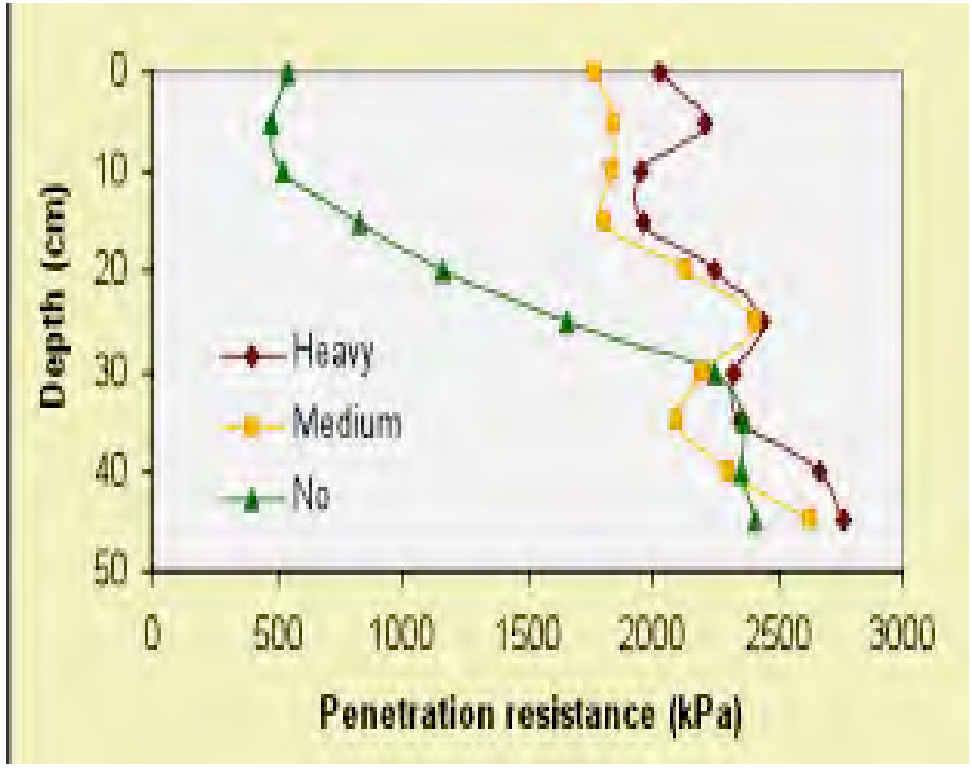
Compaction Experiment
(Don't try this on your farm!)

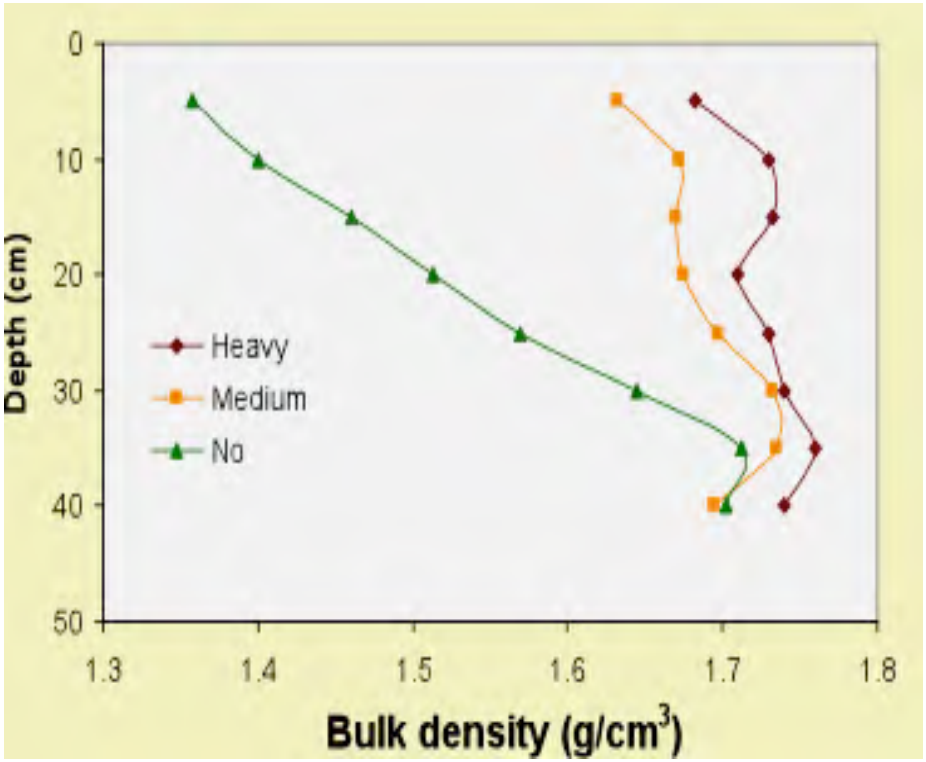
3 compaction levels:

- **No: no pass**
- **Medium: one pass**
- **Heavy: two passes**

For each pass
Wt: $1.19*10^4$ kg
contact area: 1600 cm^2 force: $7.44*10^4$ N

Soil properties after compaction treatments

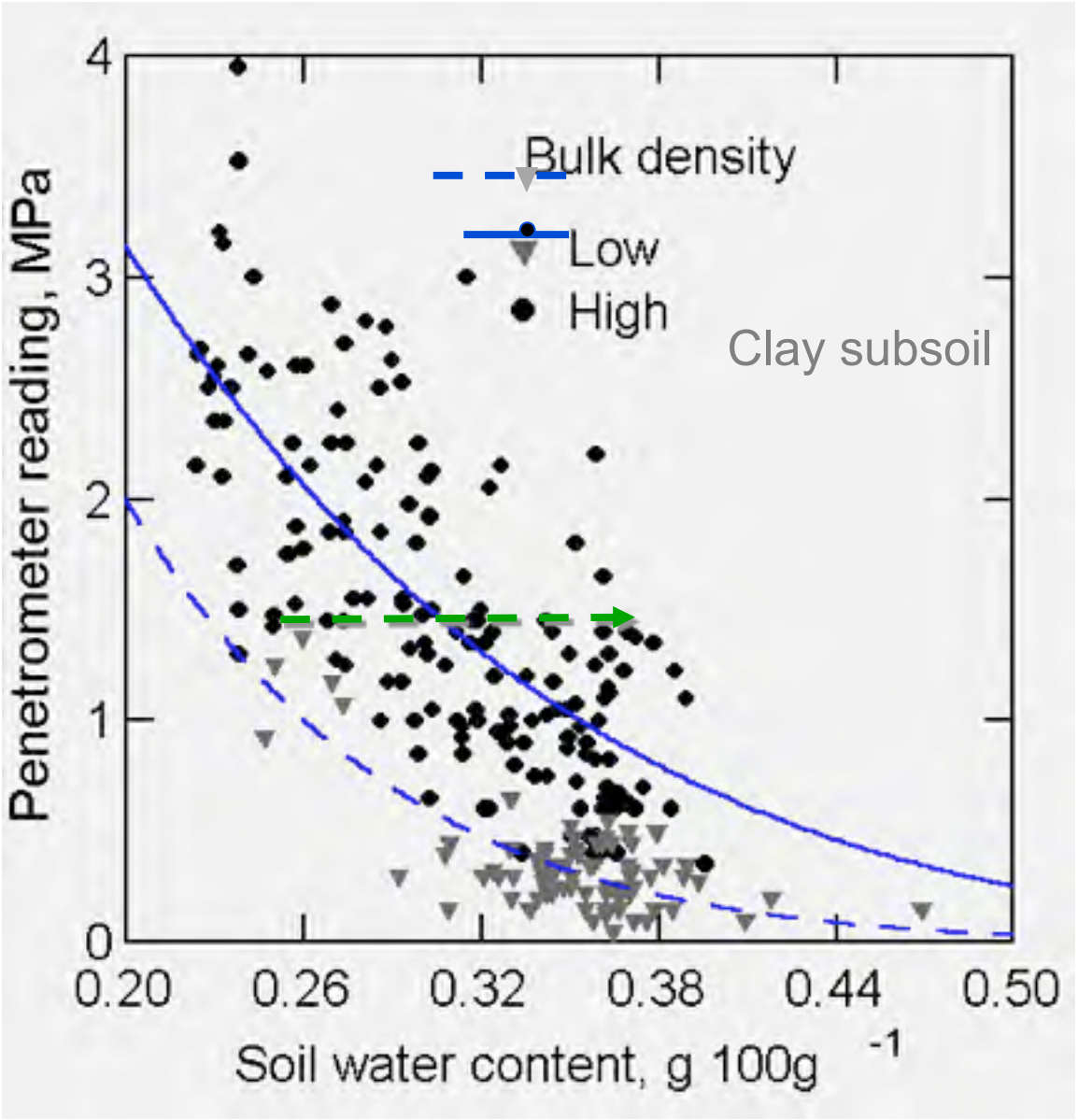




Soil strength and bulk density for different compaction levels.

Chen and Weil. 2009

Soil water content influence on soil strength



From Brady & Weil. 2002. The Nature and Properties of Soils. 13th ed. Prentice Hall.

Rye and Radish Cover Crops in Dec. after compaction

Forage Radish roots under no or heavy compaction

Note: the whole experimental site was disked to 8 cm (3 inches) to provide a suitable seedbed before planting cover crops.

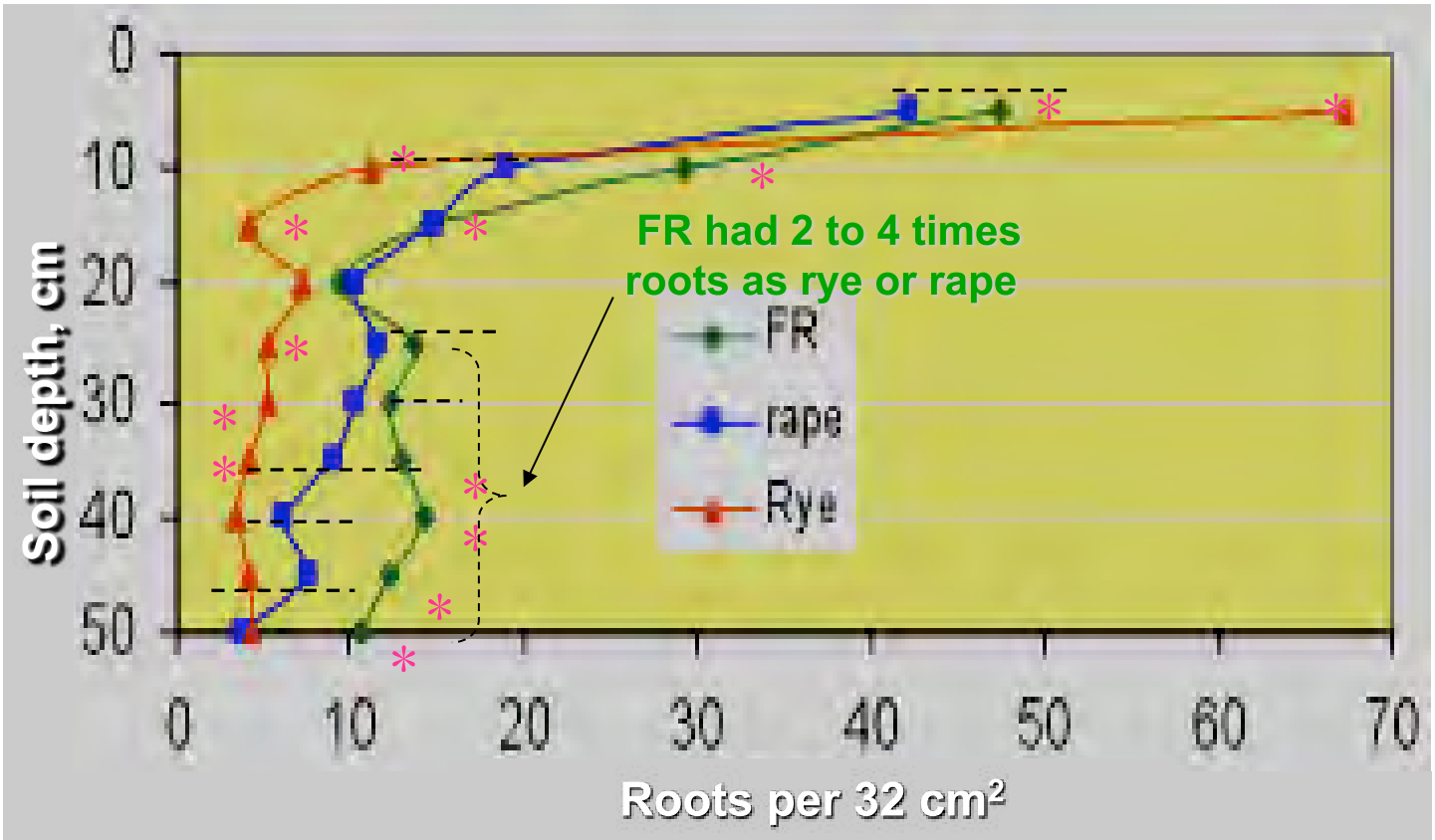
Core-break method to determine at root numbers with depth.

Taking soil core to a depth of 2 ft (60 cm)

Three cores per plot

Counting root numbers at the breakage faces

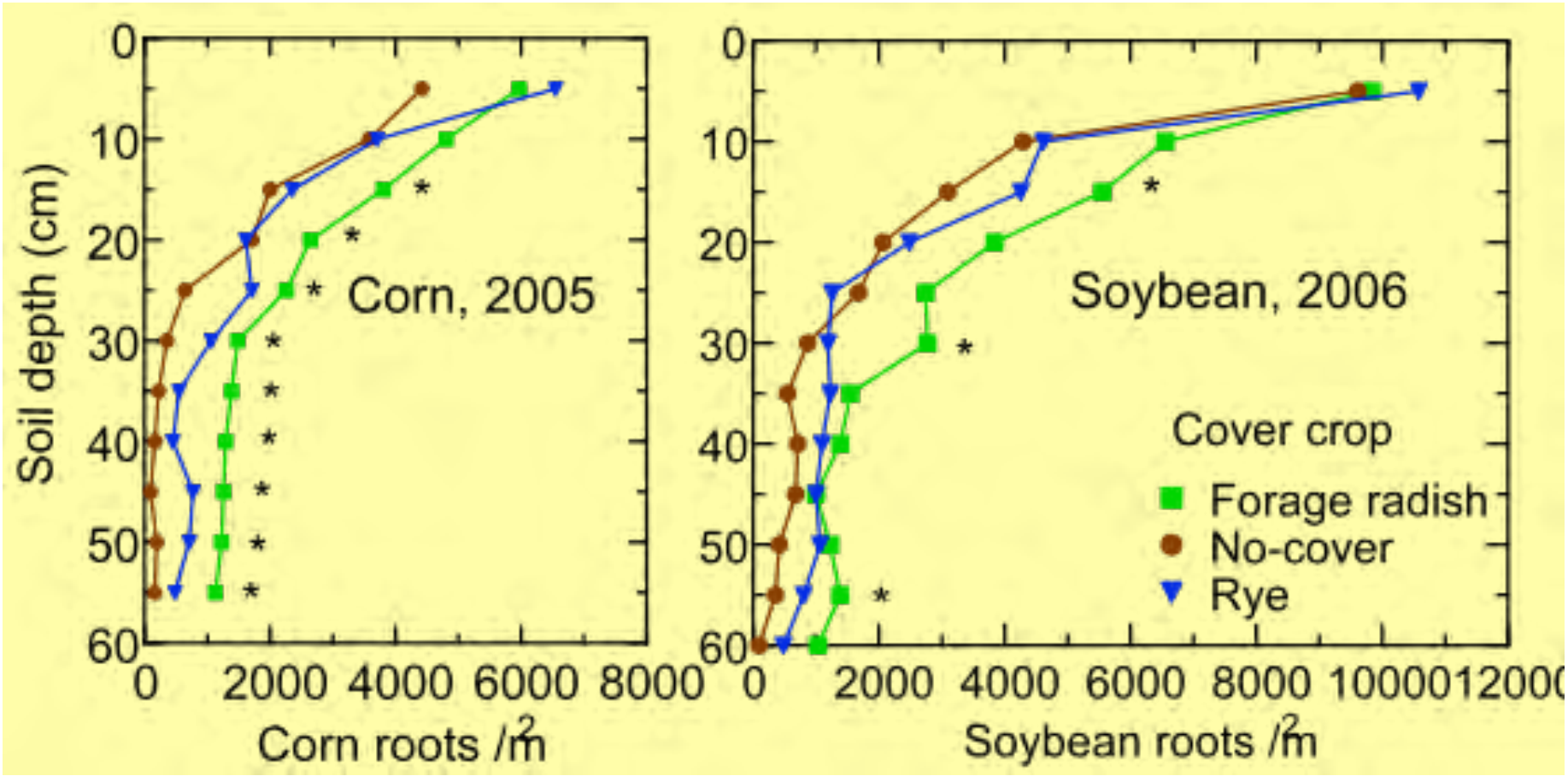
Root penetration capability of 3 cover crop growing under heavy compaction



Chen and Weil, 2009.

Differences of root numbers (per 32 cm^2) at each depth are indicated by *; student t-test, a=0.05

Fall cover crop improves vertical distribution of crop roots the following season.

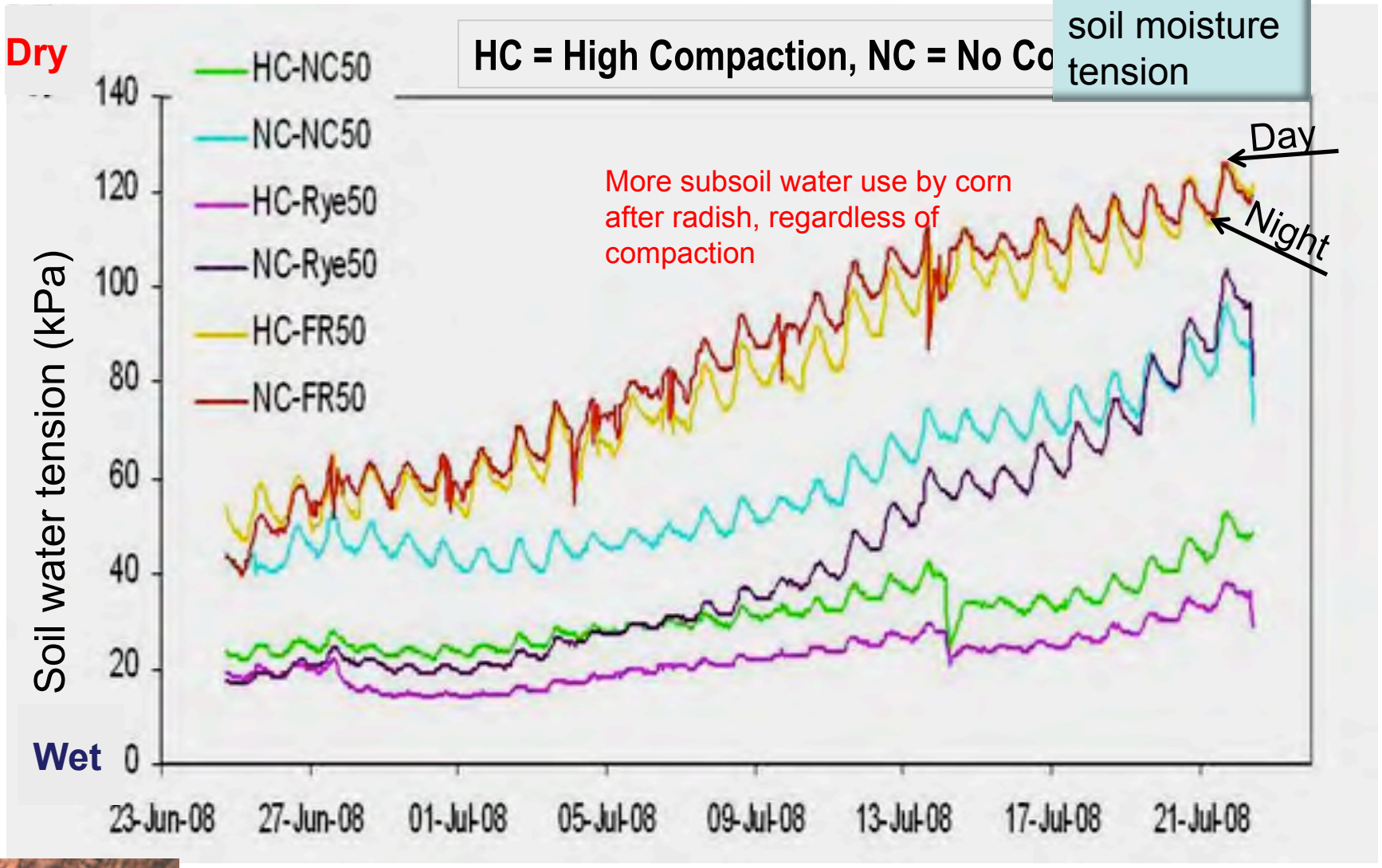


* Indicates significant differences in roots/m^2 at each (P=0.05)

Means of 12 cores (3 cores per replication) in sandy soil at Hayden farm. Weil and Chen. 2007

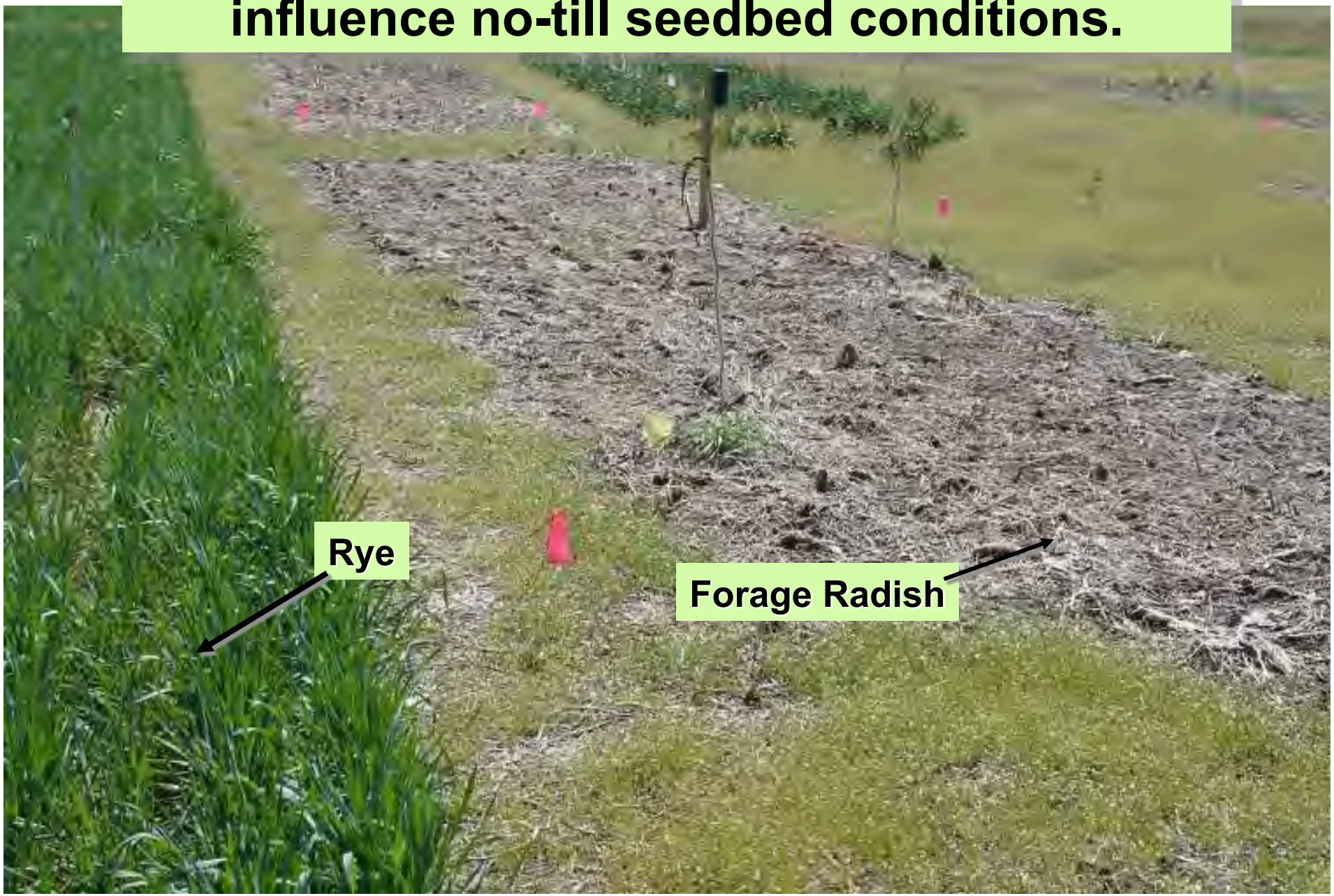
Water use in subsoil (2 ft deep) under corn in mid-summer growing seaso

Note daily fluctuation in soil moisture tension

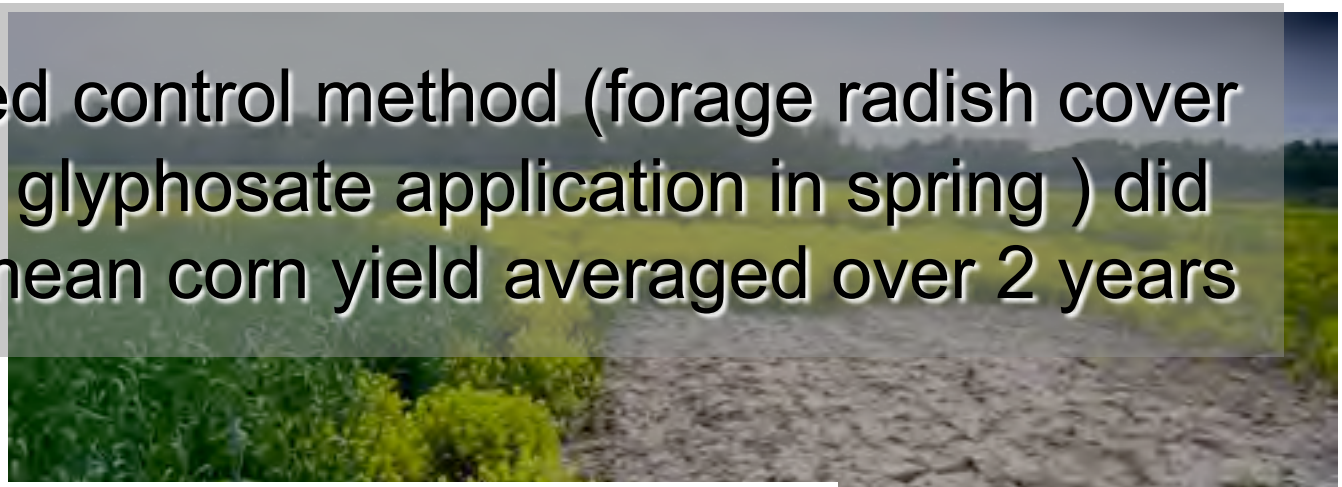


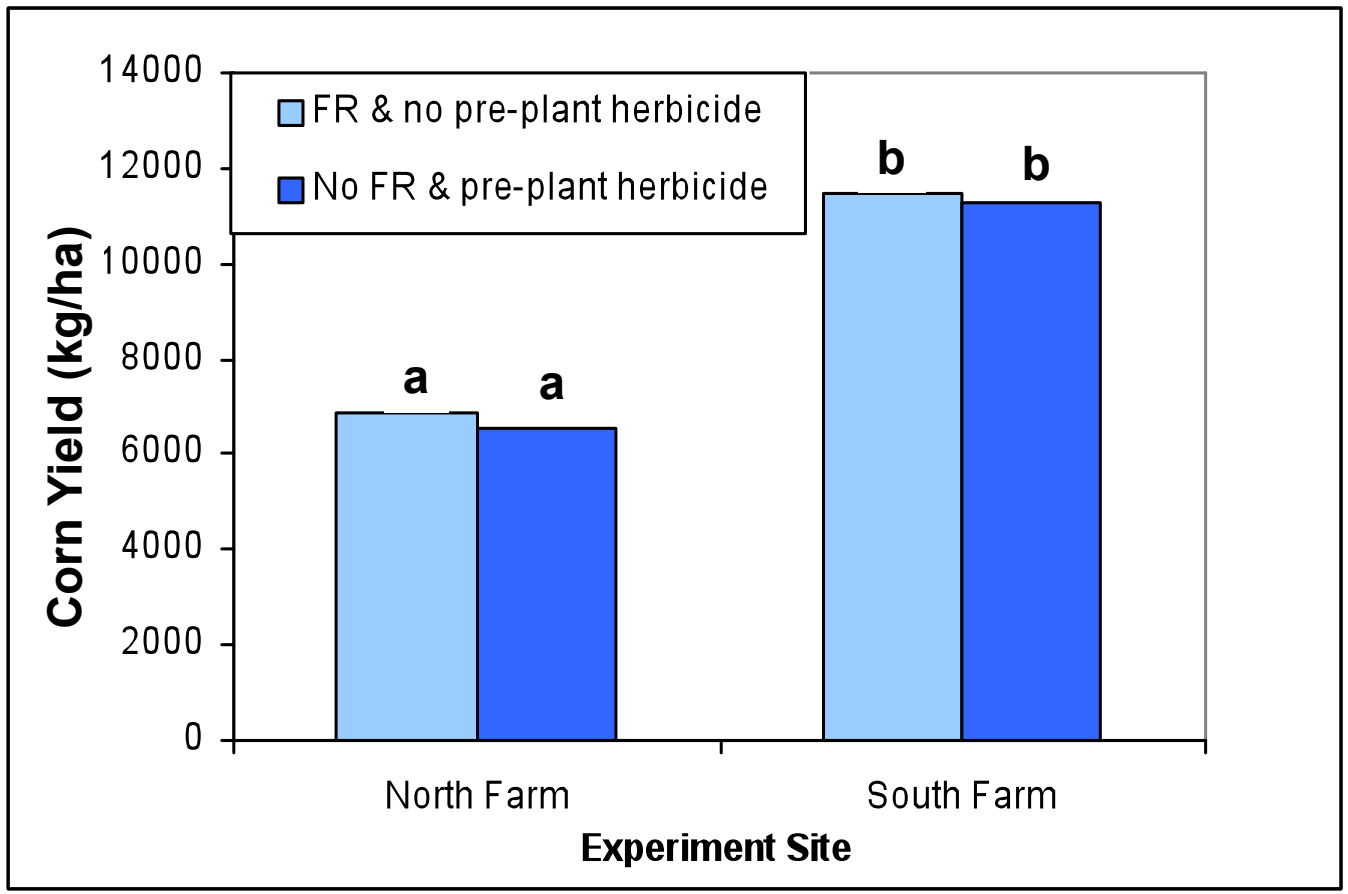
Rooting depth and access to subsoil water

Vegetation and residues dramatically influence no-till seedbed conditions.



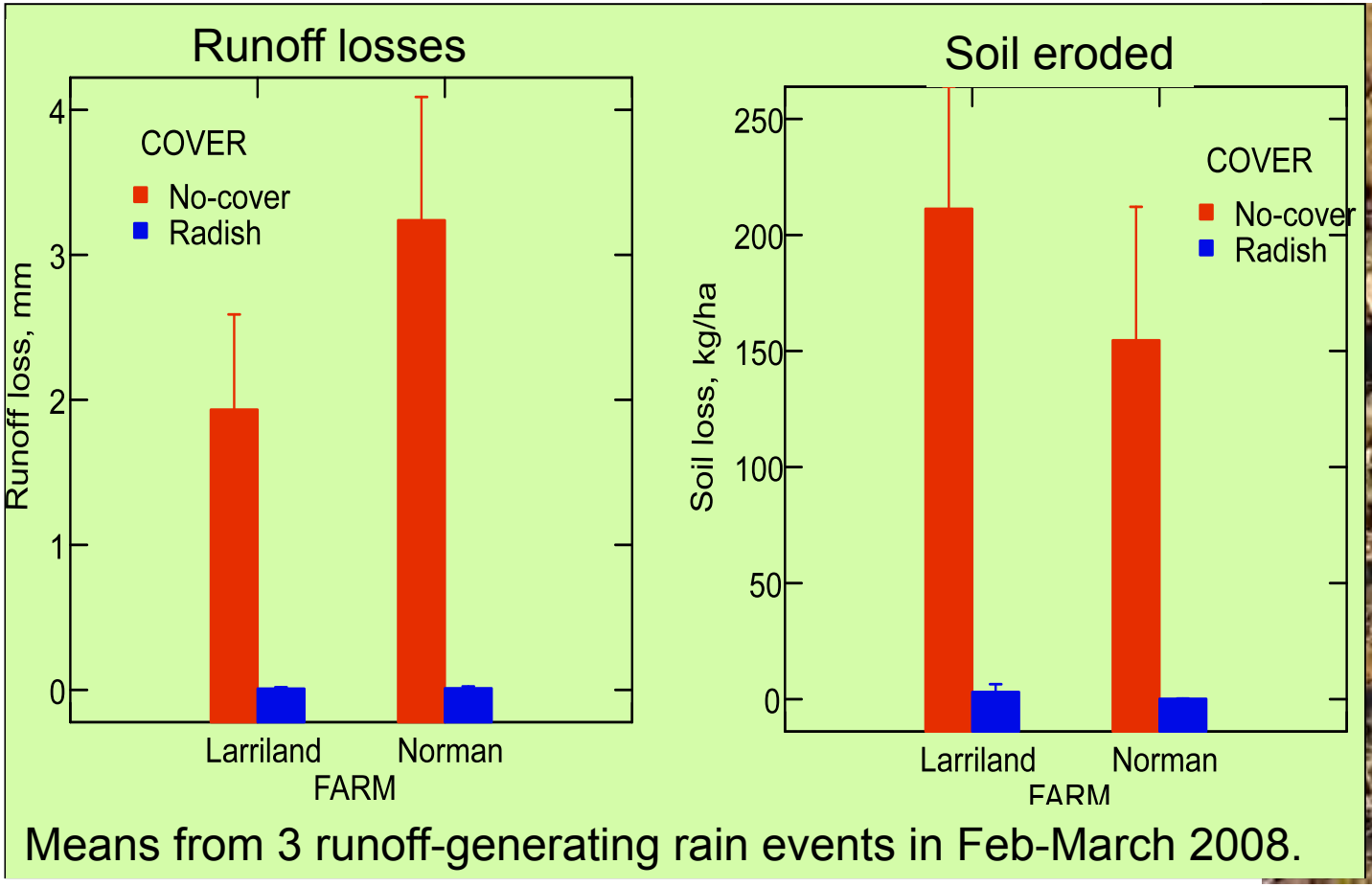
Pre-plant weed control method (forage radish cover crop in fall *v.* glyphosate application in spring) did not change mean corn yield averaged over 2 years



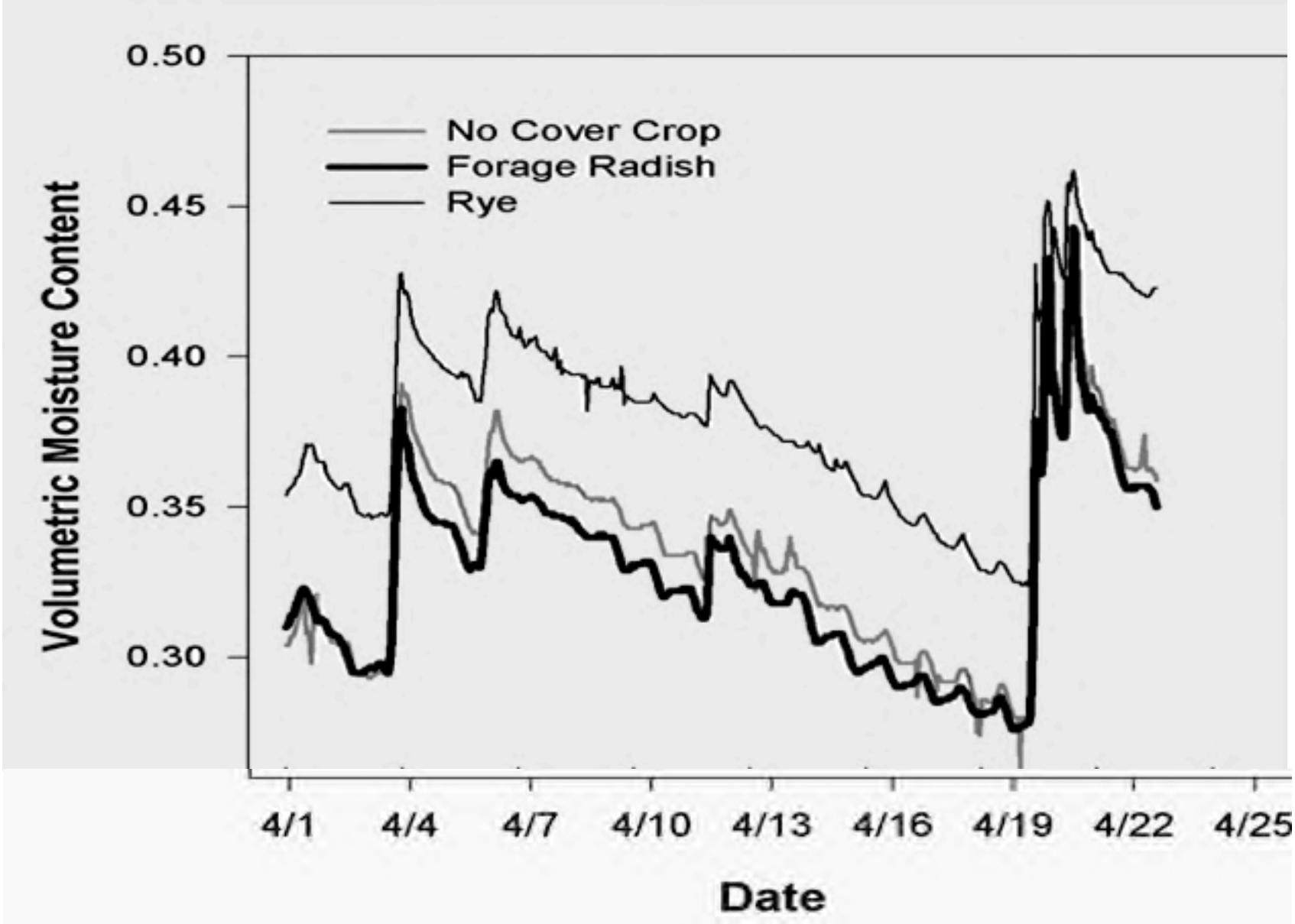


Letters within experimental site bars indicate significant difference (α=0.05)

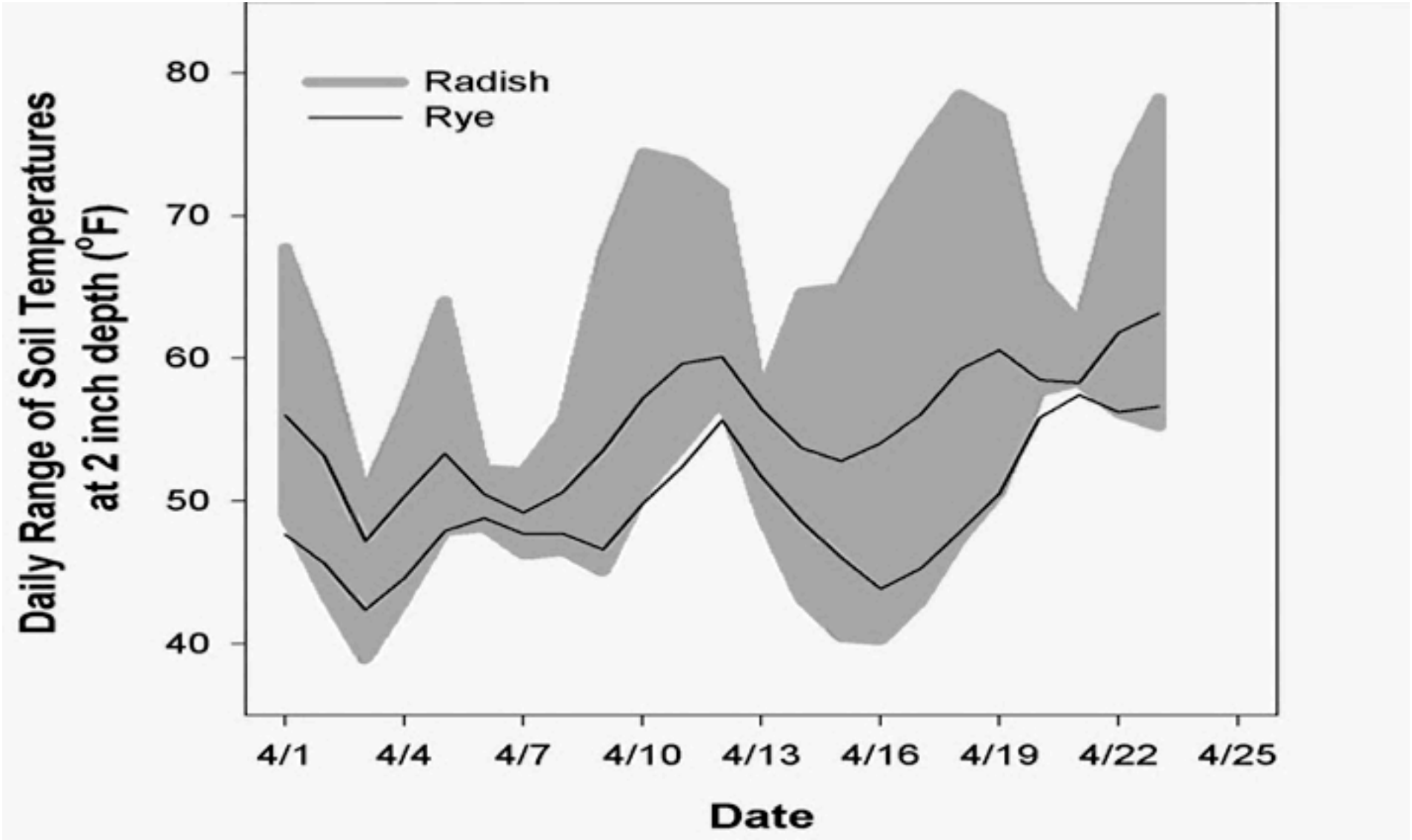
Forage radish provides soil protection despite leaving little residue by early spring.



Means from 3 runoff-generating rain events in Feb-March 2008.



Effect of soil cover (living rye v decayed forage radish) on soil water at 2 inch depth in April in Md.

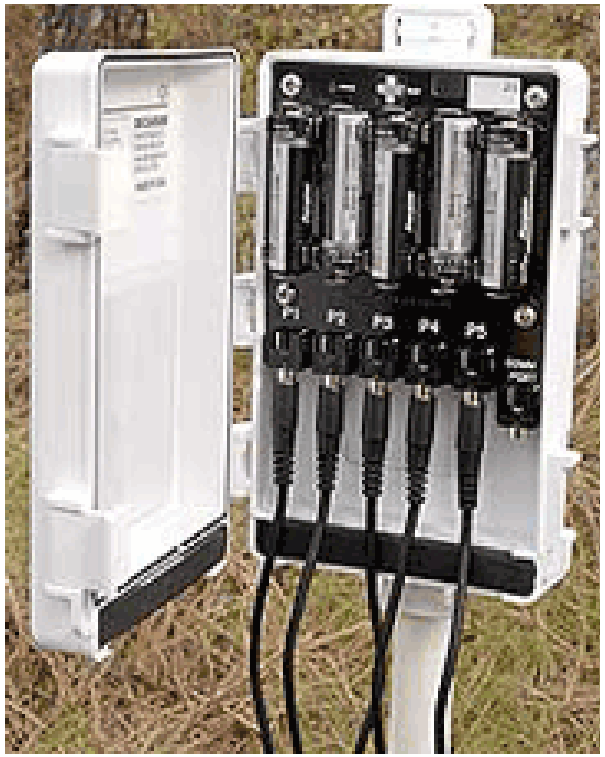


Effect of soil cover (living rye v decayed forage radish) on soil temperature at 2 inch depth in April in Md.

Alternate drill rows of rye and radish

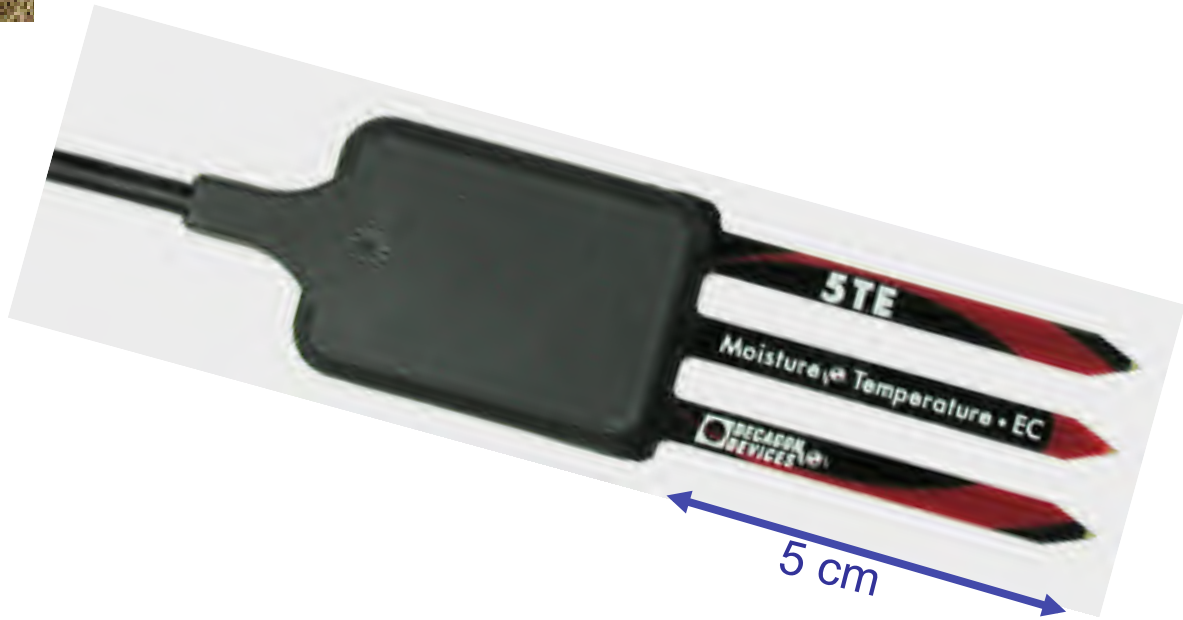
Pure radish

Alternate drill rows of Sudex and radish

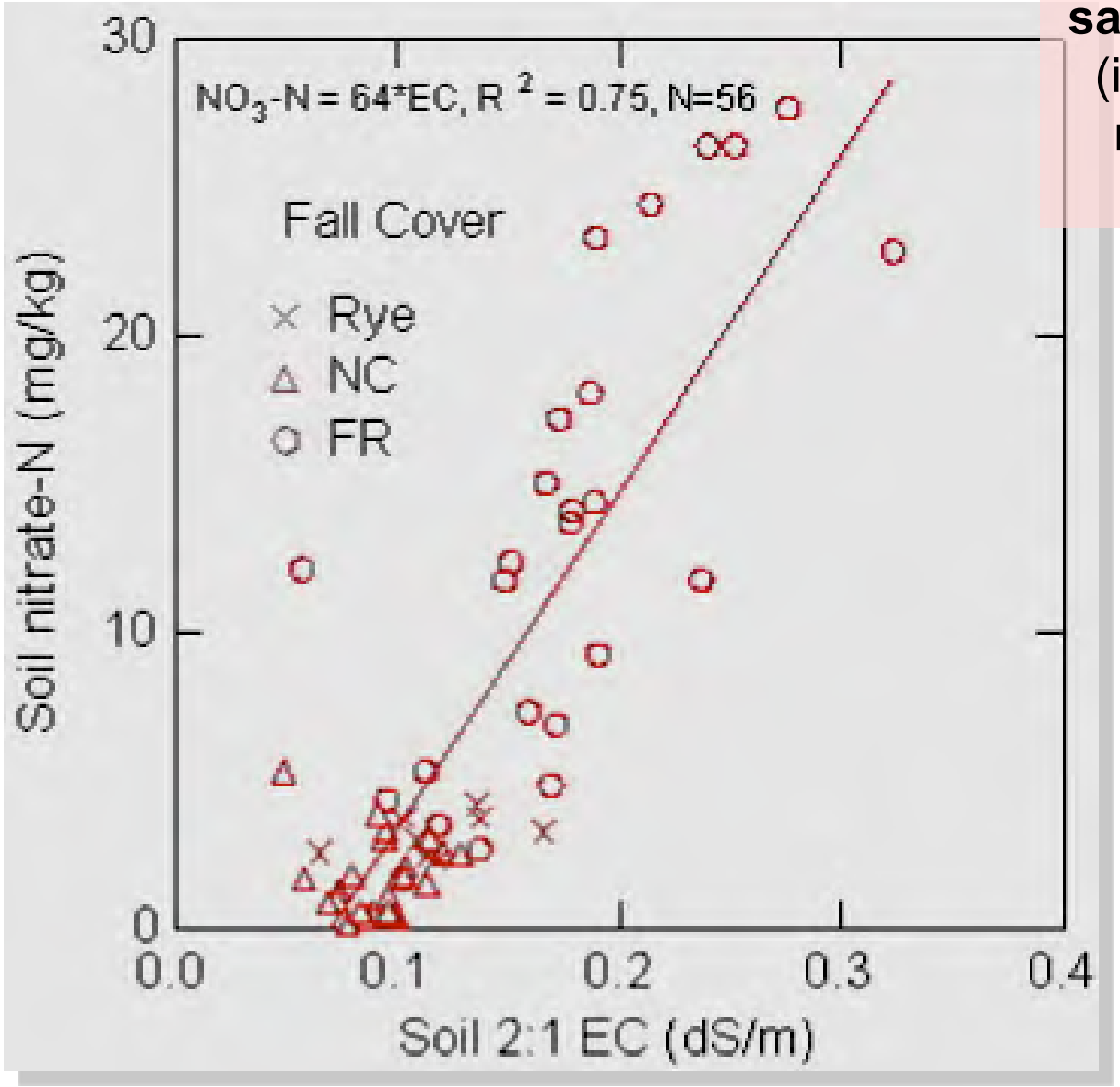


5TE sensor (Decagon, Inc.) measures

1. **Volumetric water content (using capacitance/frequency domain technology)**
2. **Soil temperature**
3. **Bulk soil electrical conductivity**

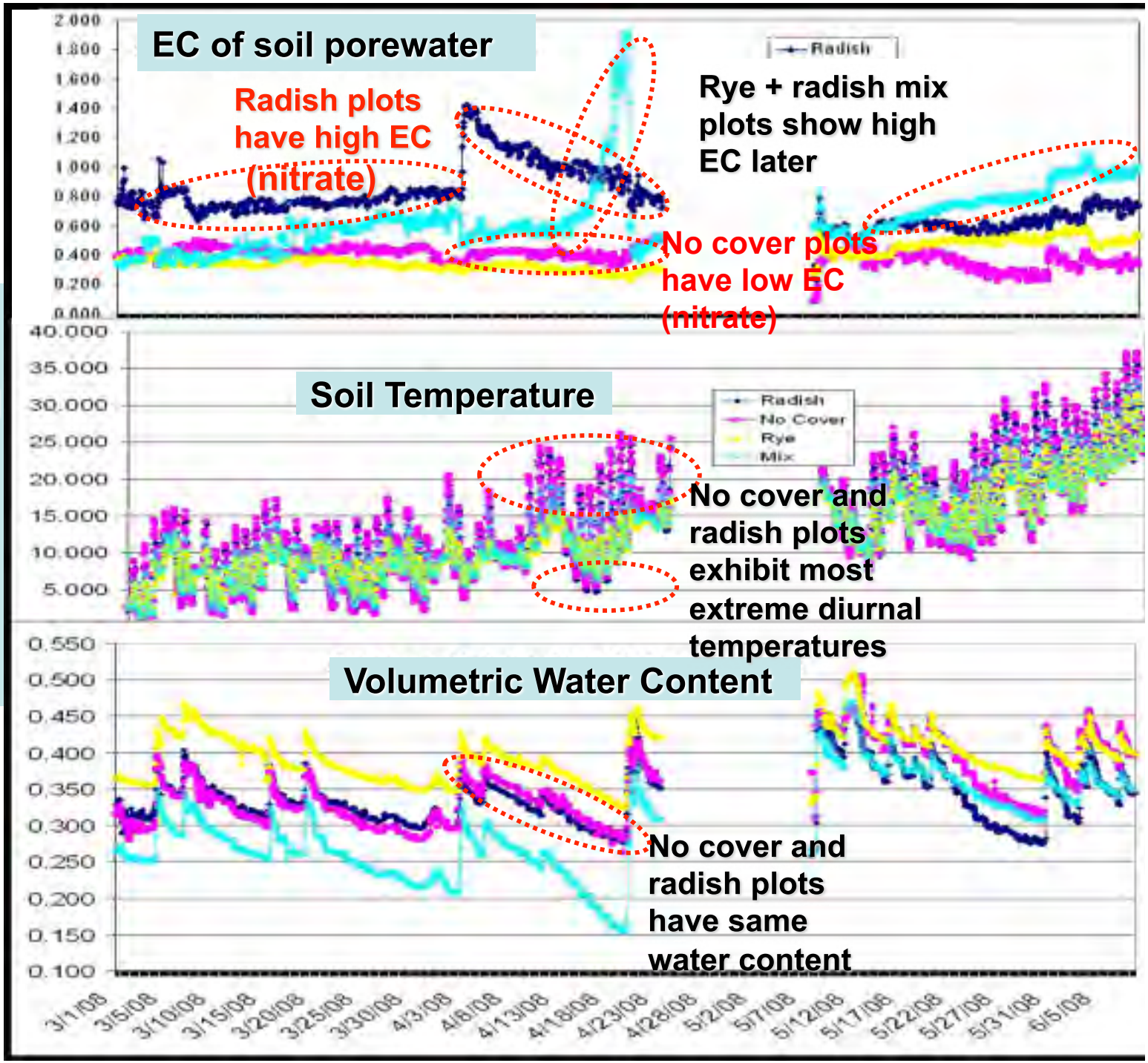


Nitrate is the main salt affecting soil EC (in most non-saline, non-alkaline, non-calcareous soils).



Cover crop effects on bio-chemical and physical properties monitored with capacitance sensors.

Sensors at 7.5 cm (3in) in this example



Forage radish can pay for itself by...

- alleviating soil compaction via bio-drilling root channels.*
- eliminating need for spring burn down herbicide or seedbed tillage.*
- capturing 100 to 150 lbs./A of N from deep in the soil.
- releasing available N for spring planting.
- increasing water infiltration and reducing runoff.

*** Biodrilling and weed suppression require planting by Sept. 15.**

Think about…

Managing plants to improve soils