Optimizing fertilization practices in almond

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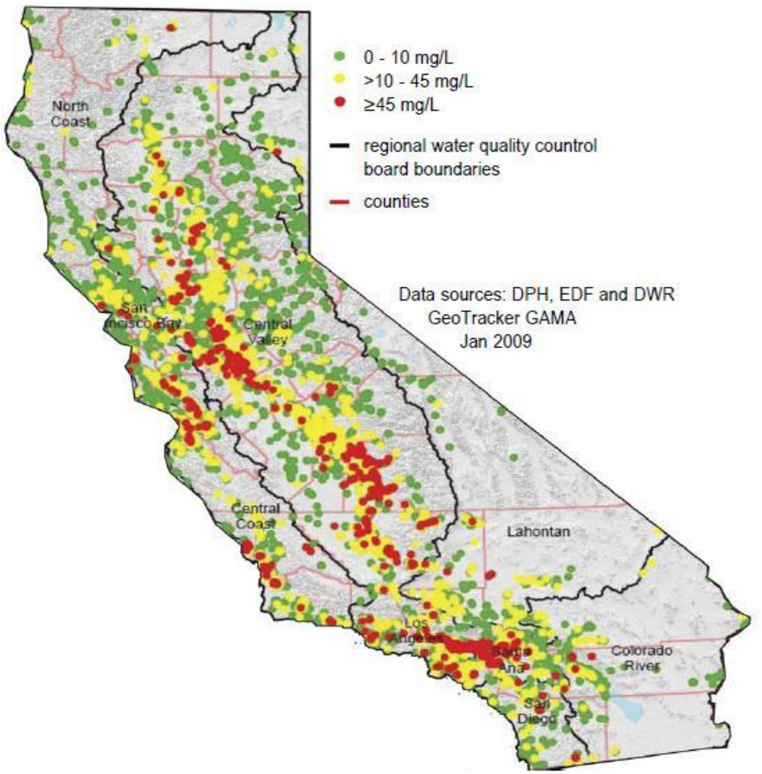
Improving the Efficiency of Nitrogen use will Reduce Production Costs and Reduce the Environmental Impact of Nitrogen

- Nitrate concentration in many California wells exceeds state drinking water standards.
- Orchards contribute significantly to nitrate in groundwater

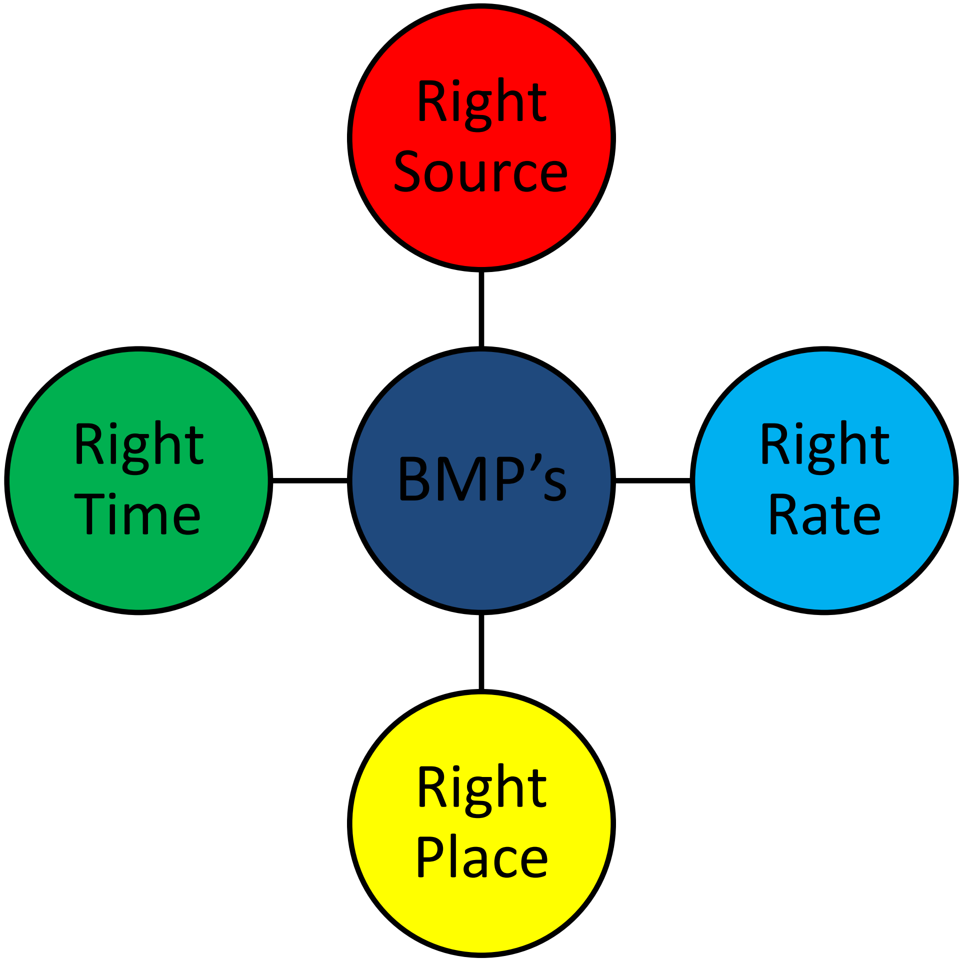
Approaches to improve N use efficiency in Almond:

- Improve orchard sampling and monitoring techniques
- Match fertilizer rate and application timing with tree specific demand (annual, daily, hourly).
- Develop nitrate monitoring practices that allow growers to adapt and adjust *(budgeting, soil and water soil sampling….)*



(Ekdahl and others, 2009; Harter Report, 2012)

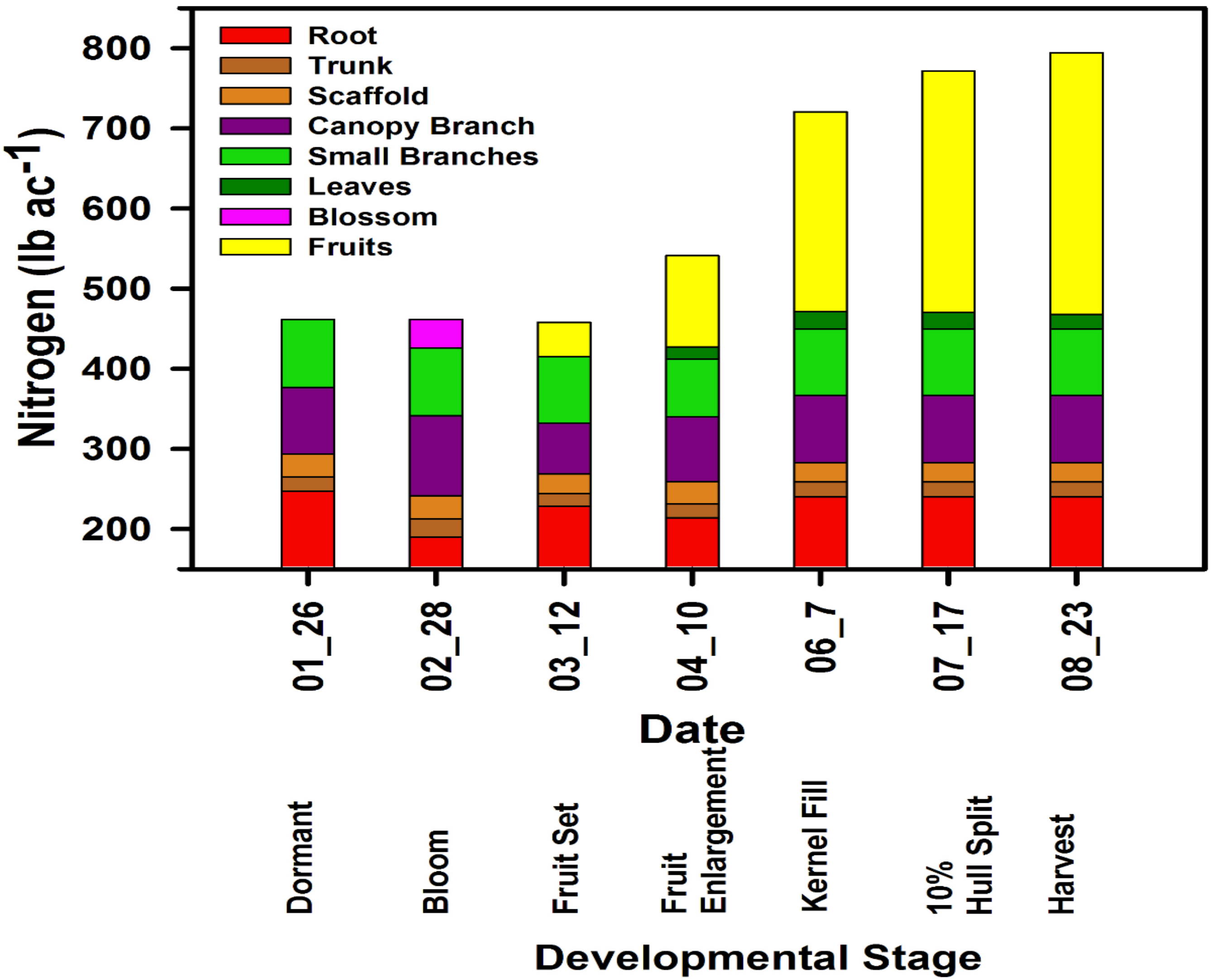
Optimal Fertilization Practices



I.F.A., 2007

Main goal = Match supply with demand

Total and Annual Dynamics of N in Mature Almond Tree (data from 12 year old trees)



Annual accumulation

Nuts = 90%
Leaves = 2%
Bloom = 4%
Perennial = 5%

Nutrient Demand is Determined by Yield

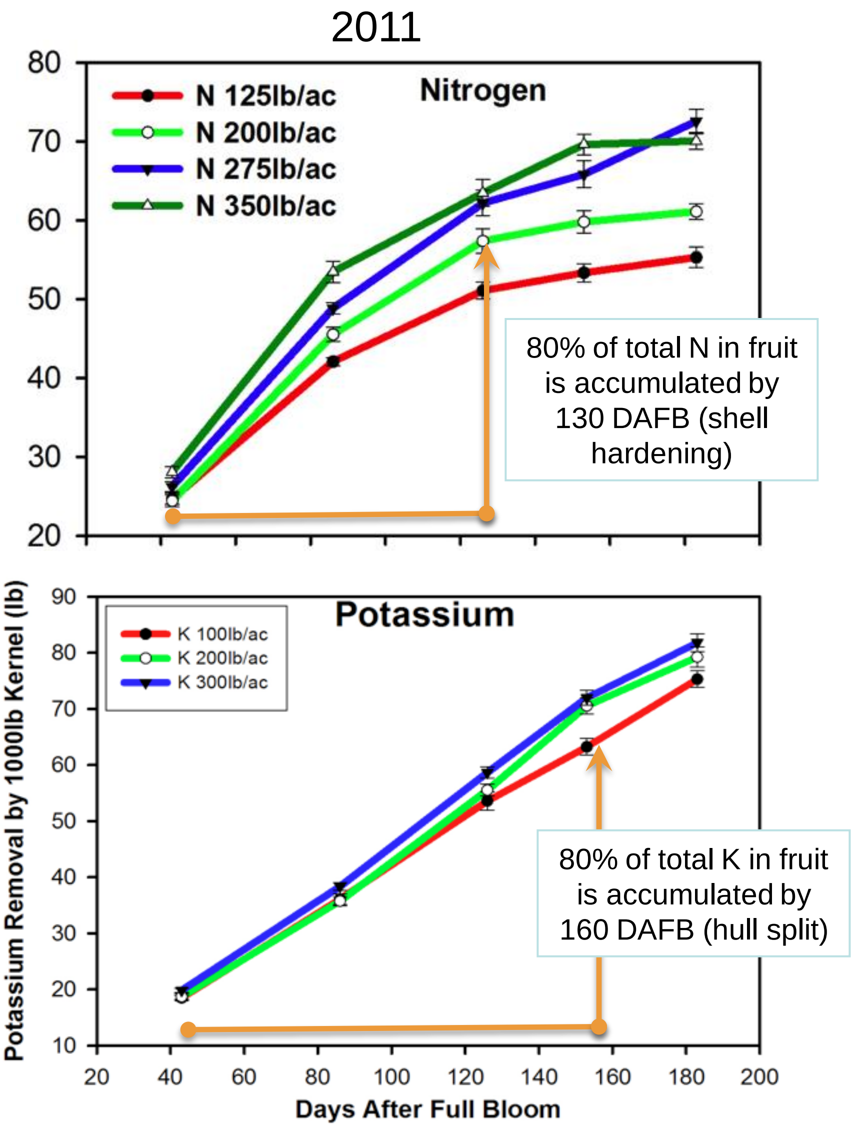
Nutrient removal Per 1000 lb
(Almond =Kernel equivalent)

Nonpareil

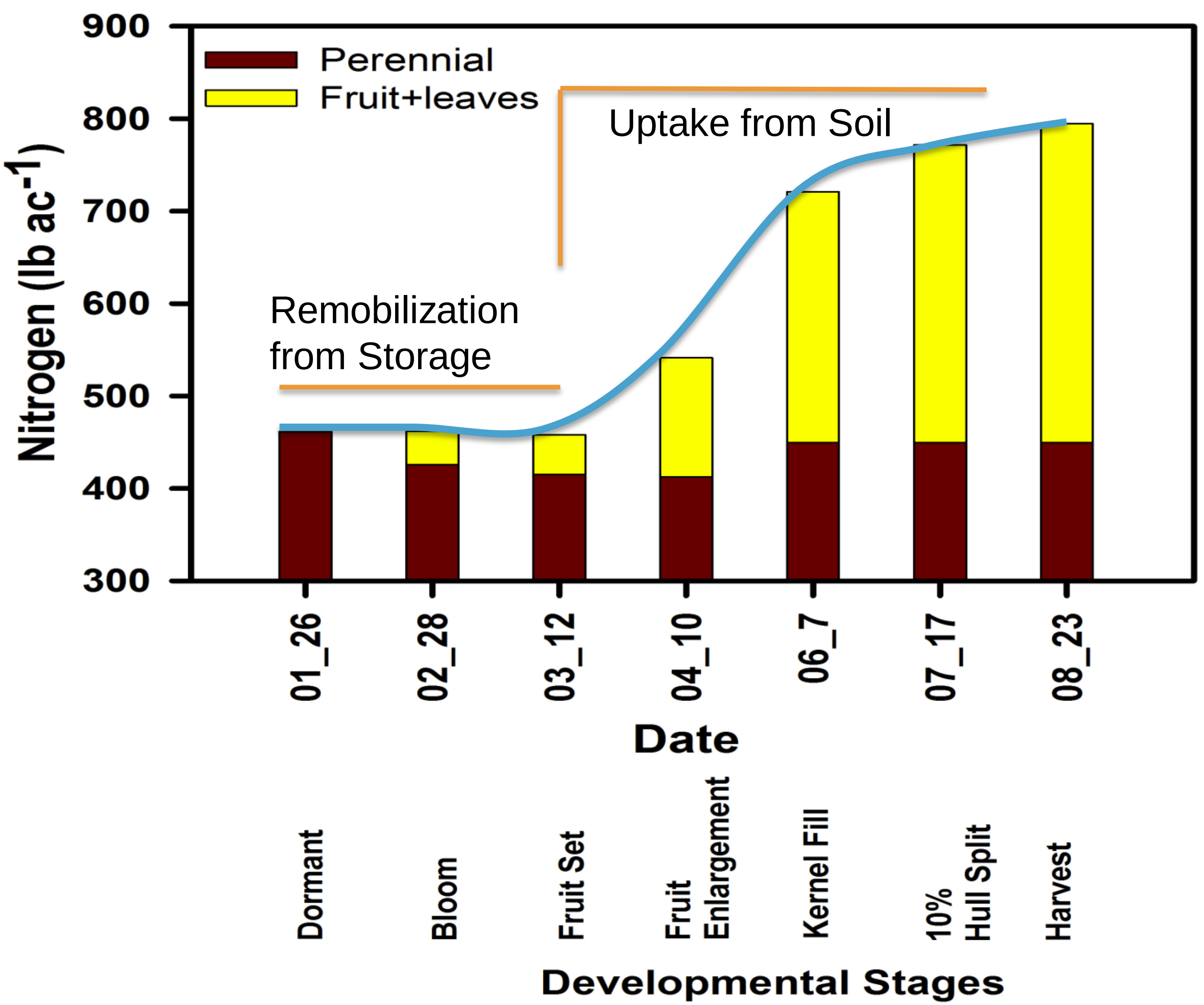
- N removal 68 lb per 1000
- K removal 80 lb per 1000
- P removal 8 lb per 1000

Monterrey

- N removal 65 lb per 1000
- K removal 76 lb per 1000
- P removal 7 lb per 1000



Total and Annual Dynamics of N in Mature Almond (data from 12 year old trees)



From dormancy to mid-March there is very little N uptake.

Uptake commences at mid-leaf out and is essentially complete by hull split.

Recommended Split:

20% Leaf Out-Fruit Enlargement
30% Fruit E

Unknowns

Relationship of N uptake to Root Growth

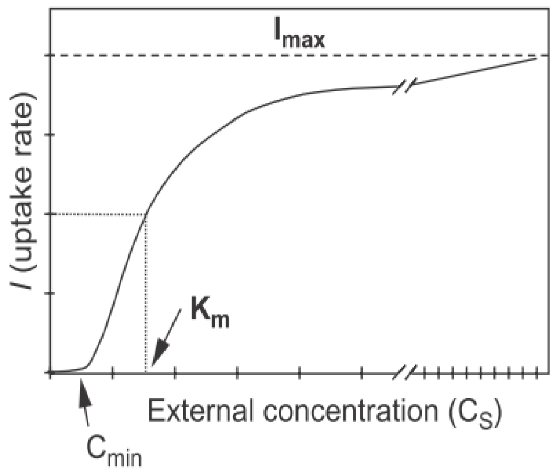
- Uptake during periods of limited above ground accumulation (Storage)

Fertilizer/Fertigation Management

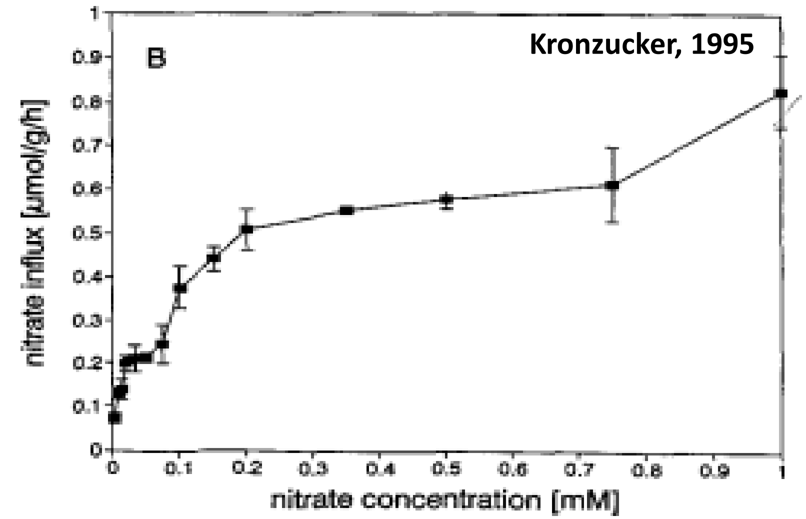
- Effects of N status (tree) on N uptake
- Influence of N concentration in soil on N uptake and N loss
- Patterns of N uptake at the weed/day/hourly time scale
- Choice of fertilizer source

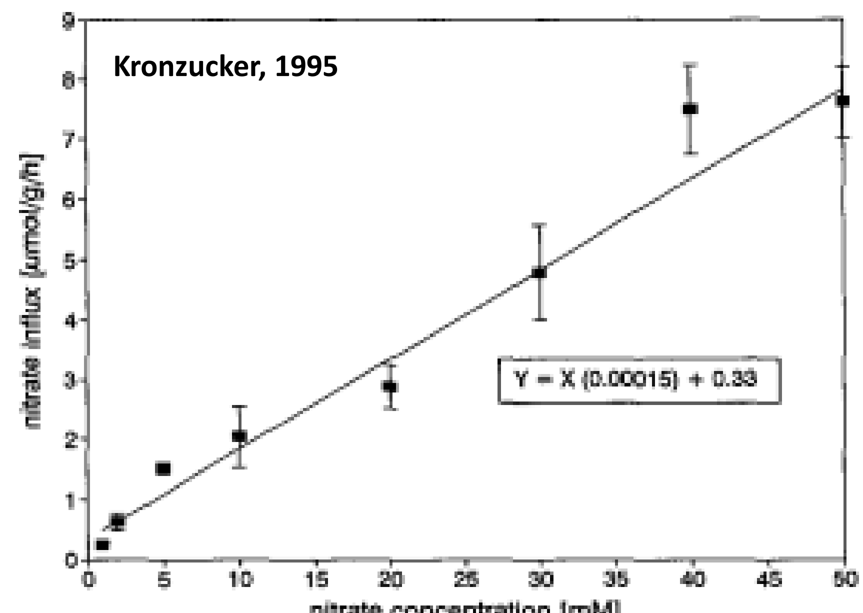
Short Term (hours/days) NO_3 Uptake

Marschner, 1995



$$I = \frac{I_{max}(C_s - C_{min})}{K_m + (C_s - C_{min})}$$

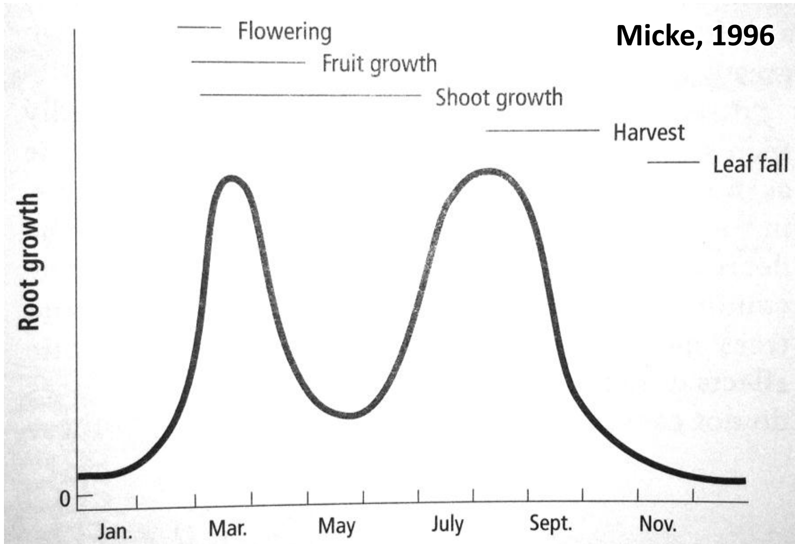




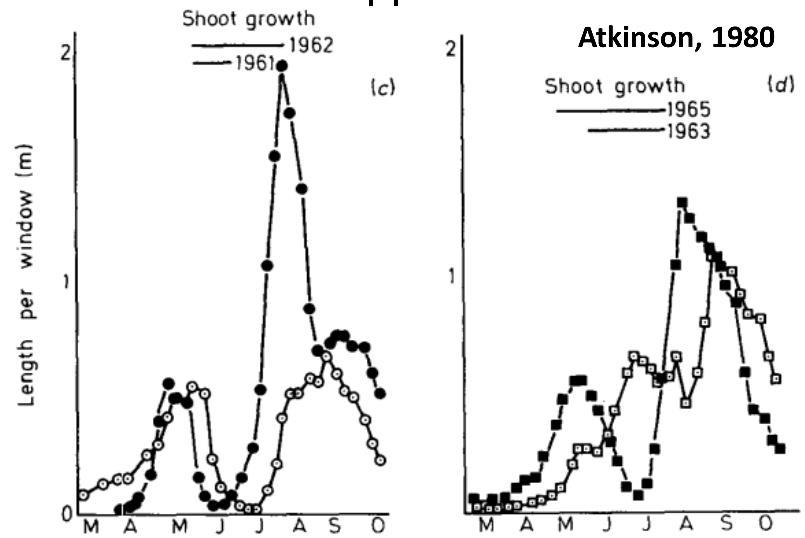
- I = Influx
- I_{max} = Maximum influx
- C_s = Soil solution concentration
- C_{min} = Minimum concentration
- K_m = Michaelis-Menten constant

What is the pattern of root growth?

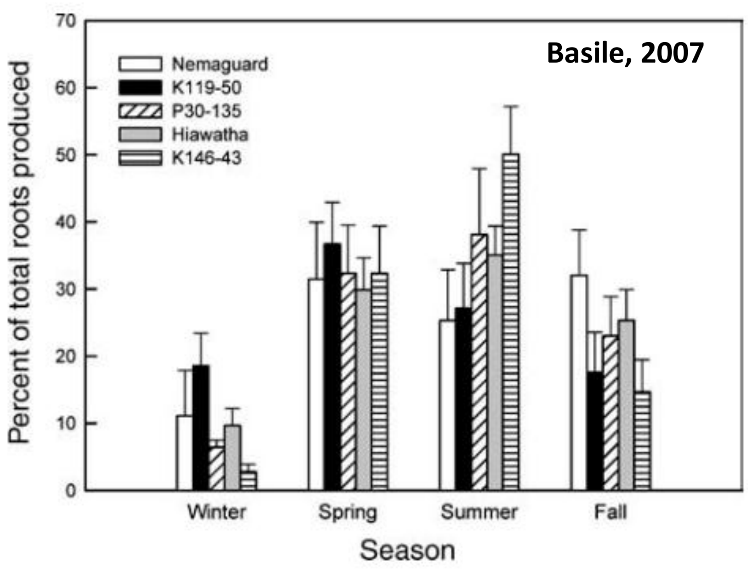
Almonds



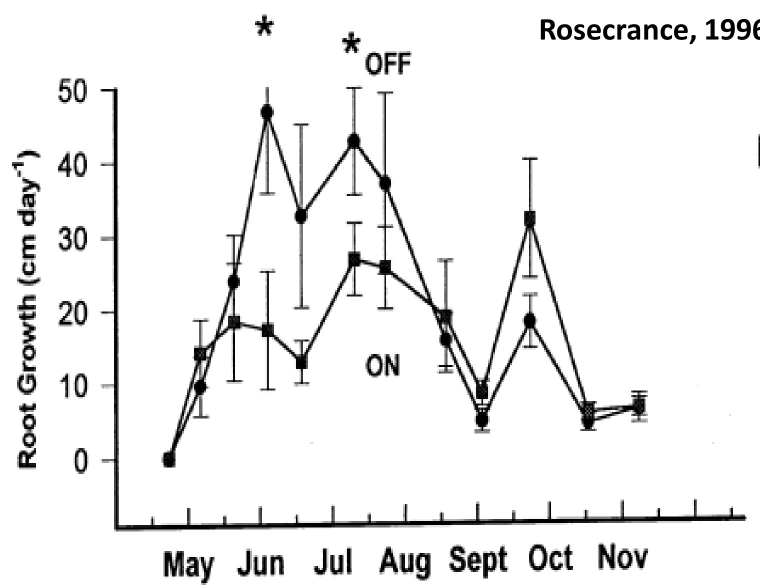
Apples



Peach



Pistachios



Objectives

- Determine almond root growth and phenology and characterize root distribution and activity as influenced by tree nitrogen status.
- Determination of the patterns and biological dynamics (K_m, V_{max}, C_{min}) of root nitrogen uptake and the relationship to tree phenology and demand.
- Integrate root phenology and uptake data into the HYDRUS 2D model to help interpret and extend findings to a wider range of soils, irrigation and demand scenarios.[1]
- Contrast tree performance and tree response to various N and K fertigation regimes (PNA project)
- Introduce and validate the concept of continuous nutrient feeding in Californian Almond production

[1]To be conducted collaboratively under leadership of Jan Hopmans and Maziar Kandelous

Rate Experiment

- 4 N rates treatments
- Fanjet irrigation system
- 4 fertigation events during the season
- Located in data trees from ongoing projects (Nutrient budget, water and nitrate optimization)

Treatment	N source	N amount (lbs/ac)
A	UAN32	125
B	UAN32	200
C	UAN32	275
D	UAN32	350

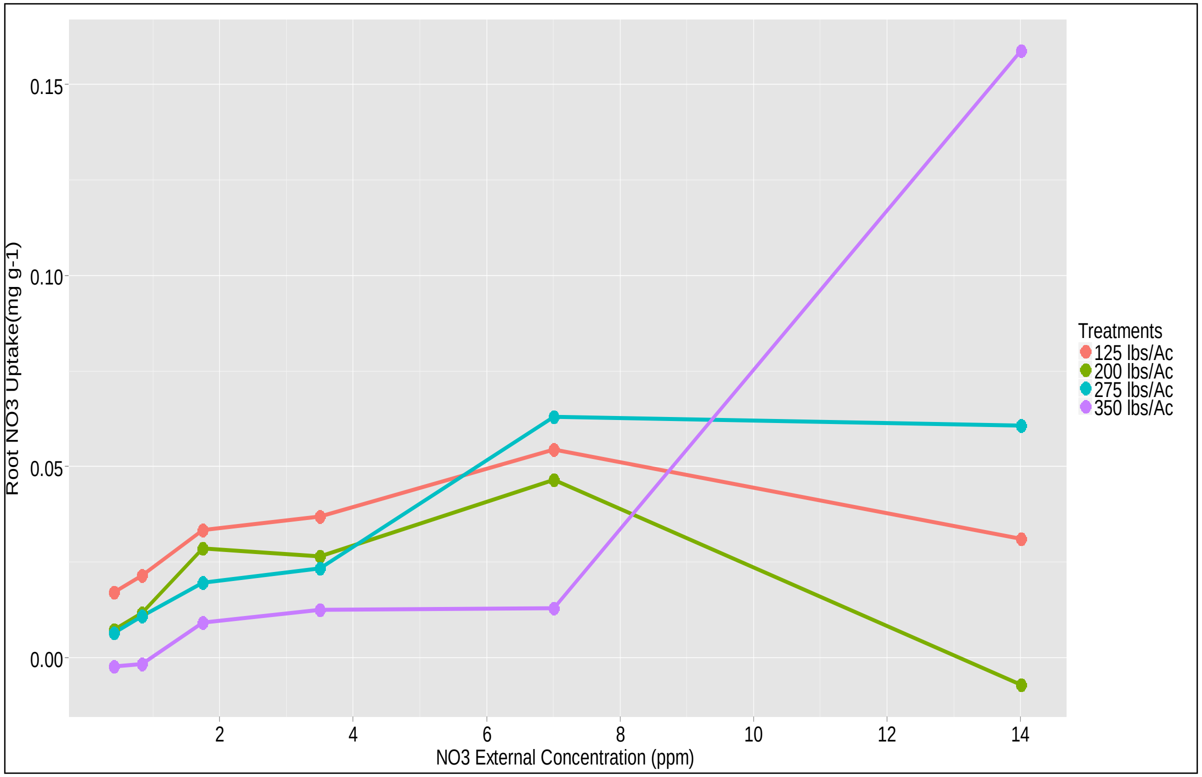
Root Physiology: Root nutrient uptake

Root Isolation

Root bags were filled with a substrate into which an excavated root was inserted and then reburied.
After a period, root bags were excavated and fine roots were used in the incubation process

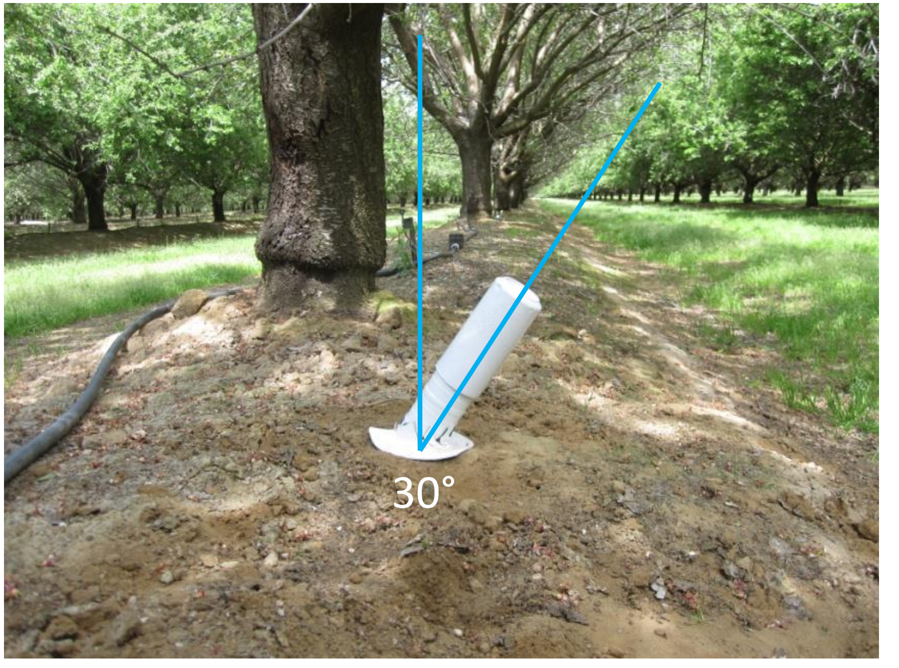
Root Physiology: Root nutrient uptake

Root Uptake
Isolated roots were placed in a solution of known concentrations for 30 minutes of incubation period and the nutrient content in the solution was then analyzed for nitrogen concentration (Depletion technique)



Differences in root NO3 uptake among N Rate treatments

Root Phenology:Minirhizotron Observations



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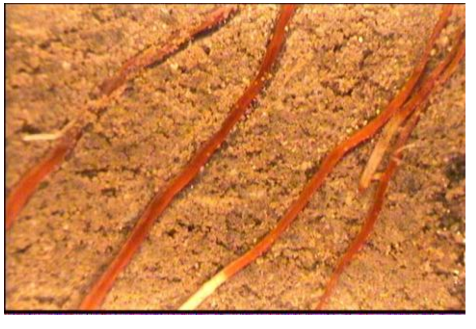

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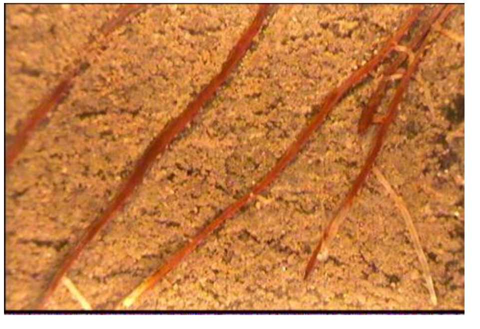


06/01

06/14

Fertigation Practice Experiment

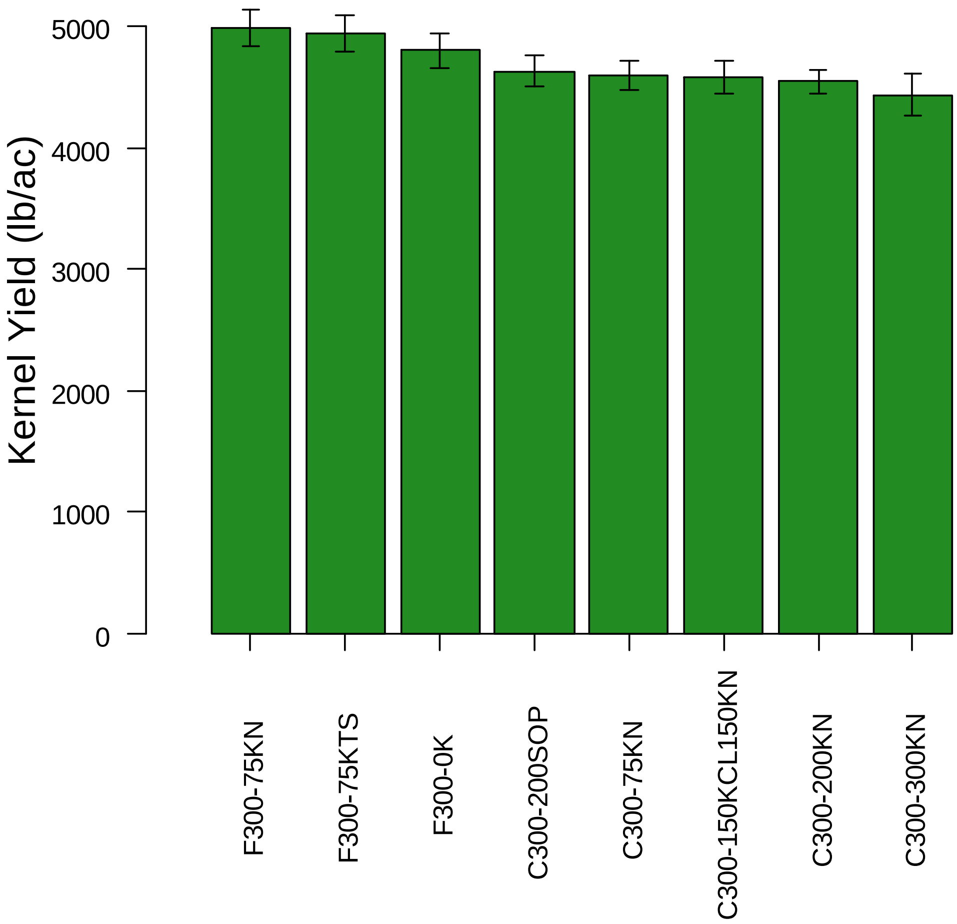
- 8 fertigation treatments (K Source, pulsed, continuous)
- 2 irrigation systems (Drip, microspinkler)

Treatment	K Source (%)				N Source (%)		Fertigation Method
	SOP	KNO_3	KCl	KTS	KNO_3	UAN	
F300-0	0	0	0	0	0	100	Standard Practice (4 fertigation events/Year)
F300-75KTS-125 SOP	62.5	0	0	37.5	0	100	Standard Practice
F300-75KN-125 SOP	62.5	37.5	0	0	9	91	Standard Practice
C300-200SOP	100	0	0	0	0	100	Continuous (fertilization in each irrigation)
C300-75KN	32.5	37.5	0	0	9	91	Continuous
C300-200KN	0	100	0	0	36	64	Continuous
C300-300KN	0	100	0	0	57	43	Continuous
C300-150 KCl-150 KNO3	0	50	50	0	17	83	Continuous

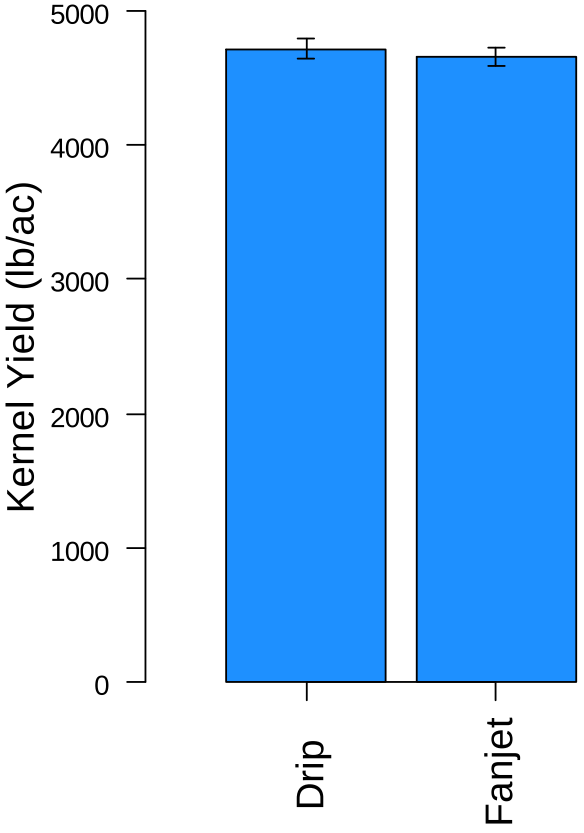
Two years data collection (2011, 2012).

- Soil solution has been extracted using SSAT installed at 3 depths (30 – 60 – 90 cm)
- Four sampling dates
- Leaf nutrient analysis at 2 dates
- Individual tree yields

2011 Yields

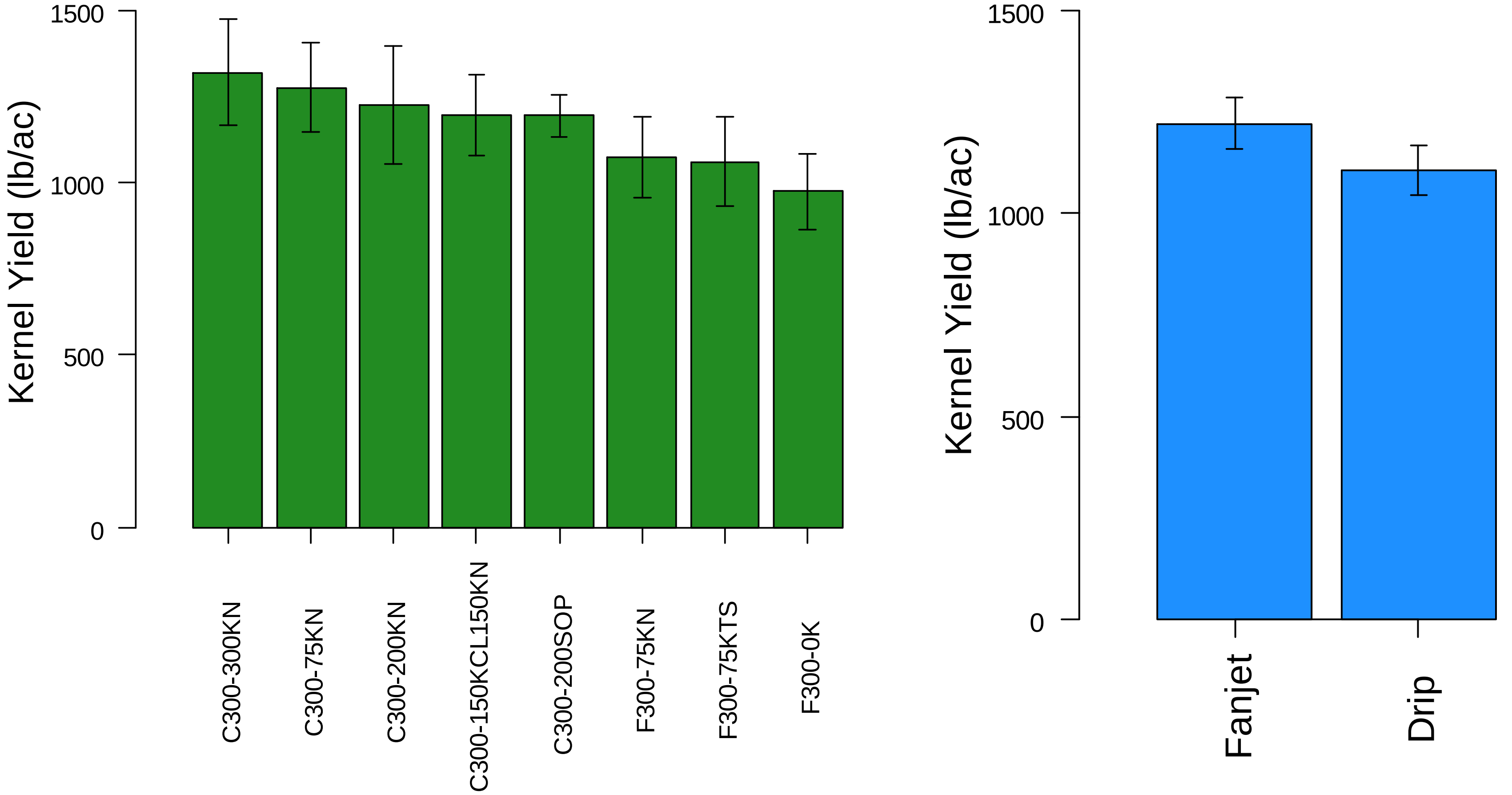


Kernel Yield (lb/ac)
5000
4000
3000
2000
1000
0
F300-75KN
F300-75KTS
F300-0K
C300-200SOP
C300-75KN
C300-150KCL150KN
C300-200KN
C300-300KN

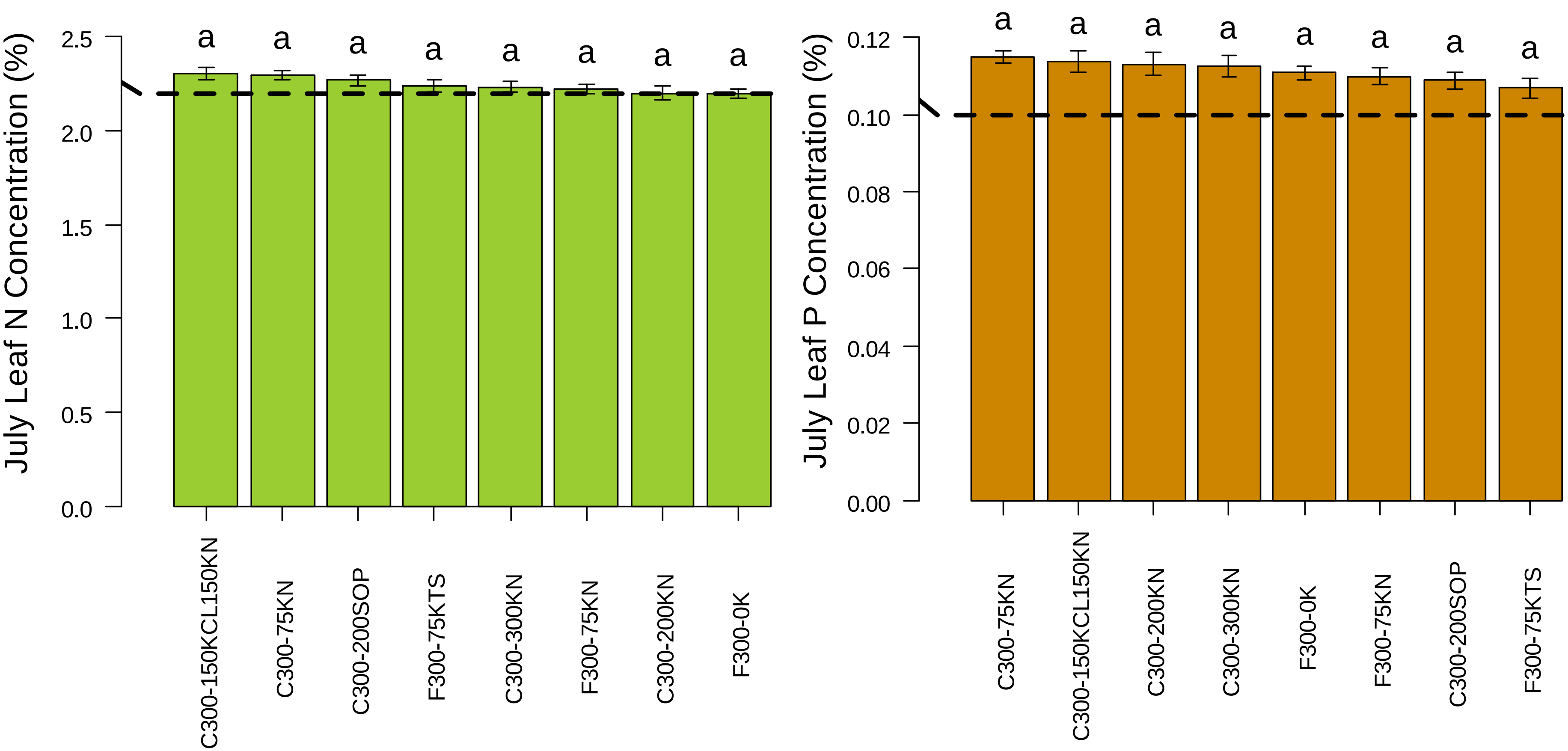


Kernel Yield (lb/ac)
5000
4000
3000
2000
1000
0
Drip
Fanjet

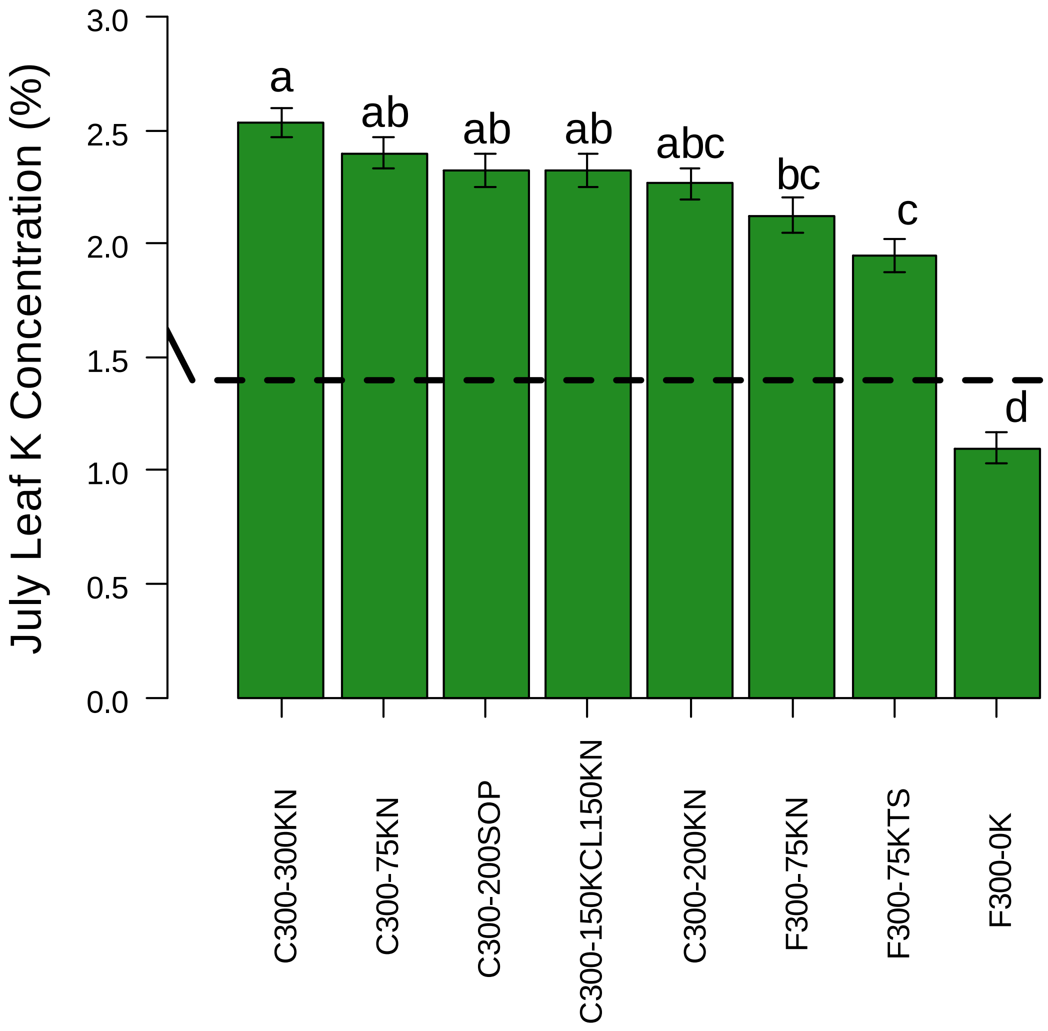
2012 Yields


Kernel Yield (lb/ac)
0
500
1000
1500
C300-300KN
C300-75KN
C300-200KN
C300-150KCL150KN
C300-200SOP
F300-75KN
F300-75KTS
F300-0K
Kernel Yield (lb/ac)
0
500
1000
1500
Fanjet
Drip

Leaf Tissue Analysis (July)



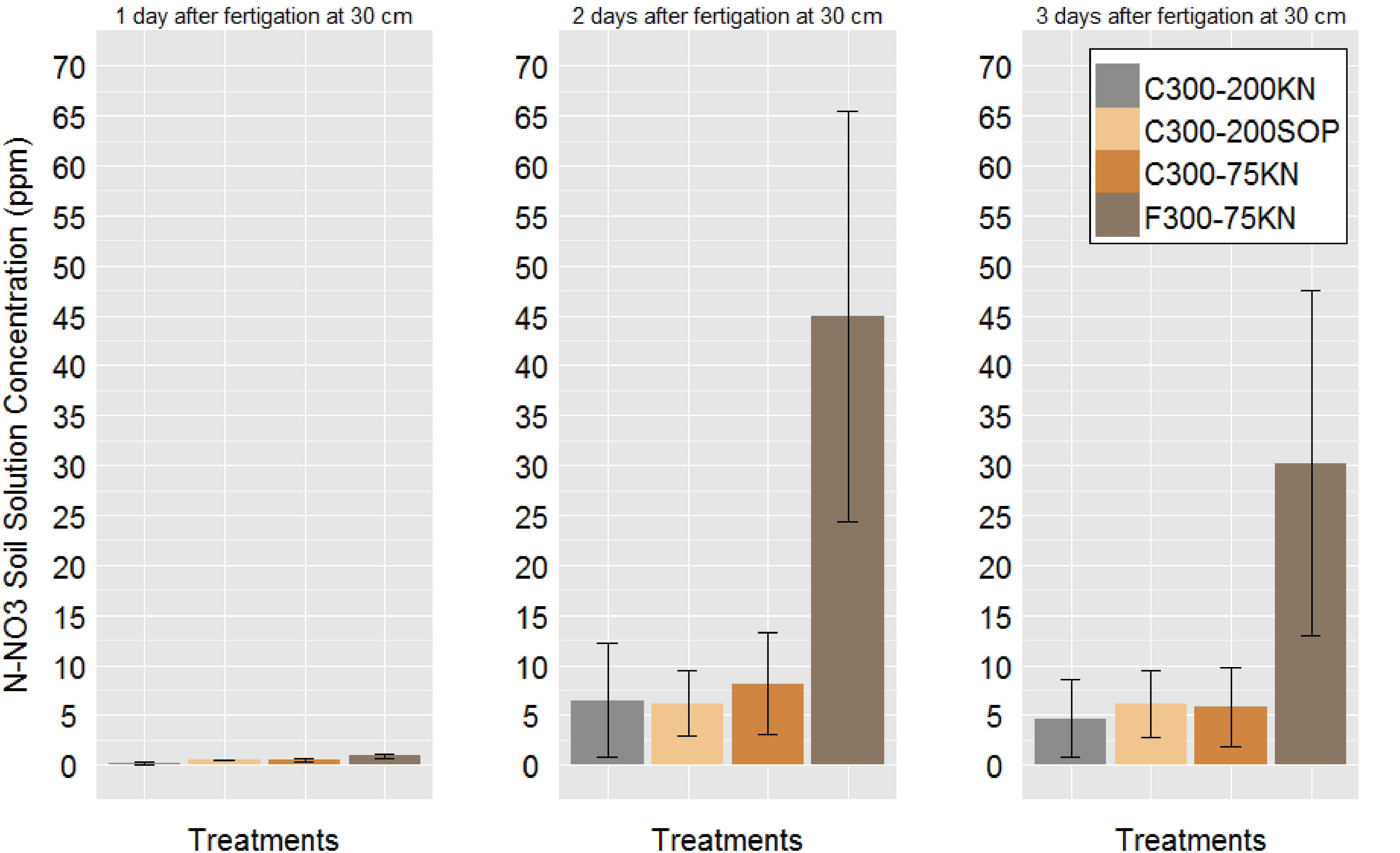
Leaf K Analysis



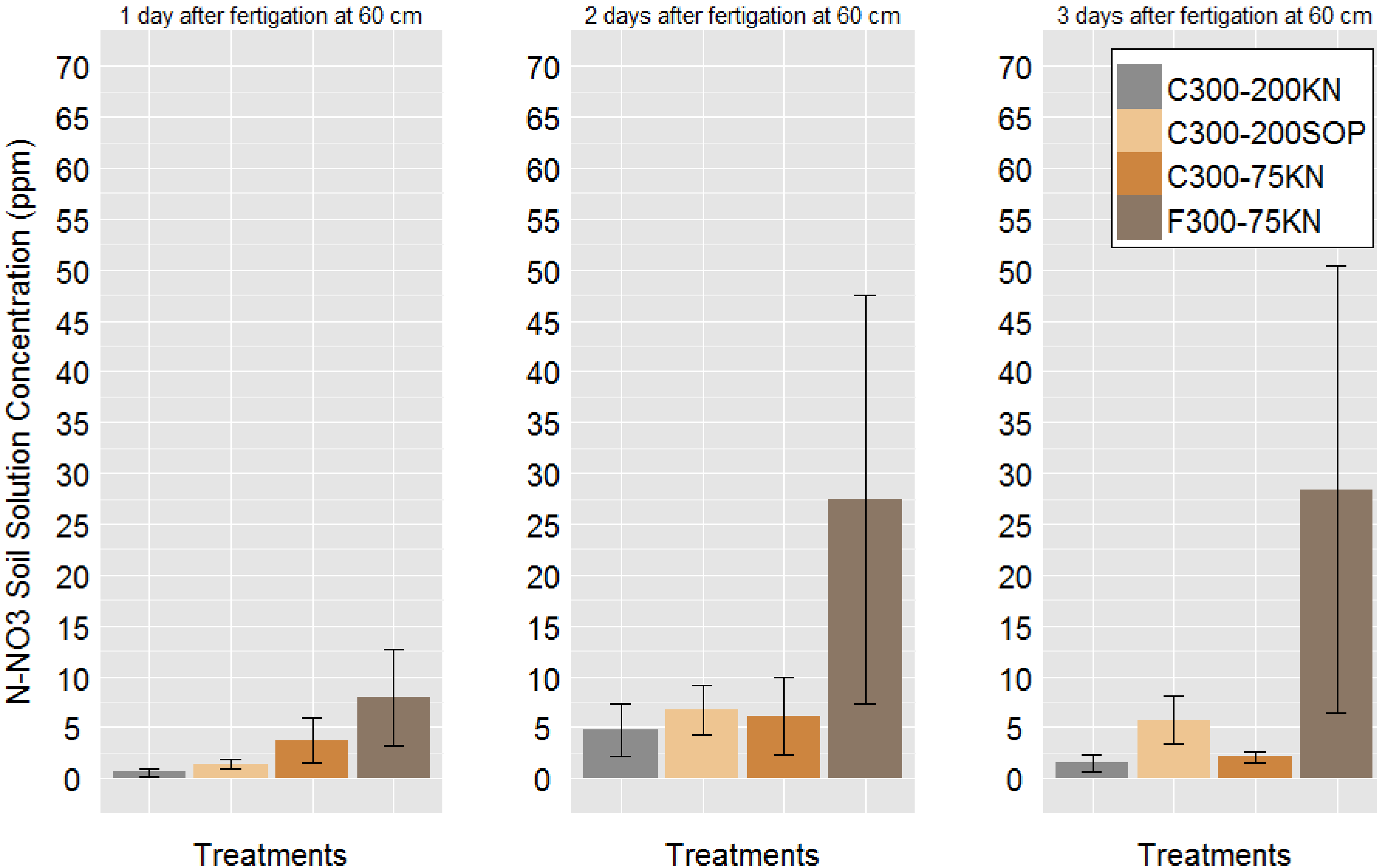
Soil Solution Access Tubes (Treatments description)

Treatments	K Source (%)				N Source (%)		Fertigation Method
	SOP	KNO3	KCl	KTS	KNO3	UAN	
C300-200KN	0	100	0	0	36	64	Continuous
C300-200SOP	100	0	0	0	0	100	Continuous
C300-75KN	32.5	37.5	0	0	9	91	Continuous
F300-75KN	62.5	37.5	0	0	9	91	Standard Practice

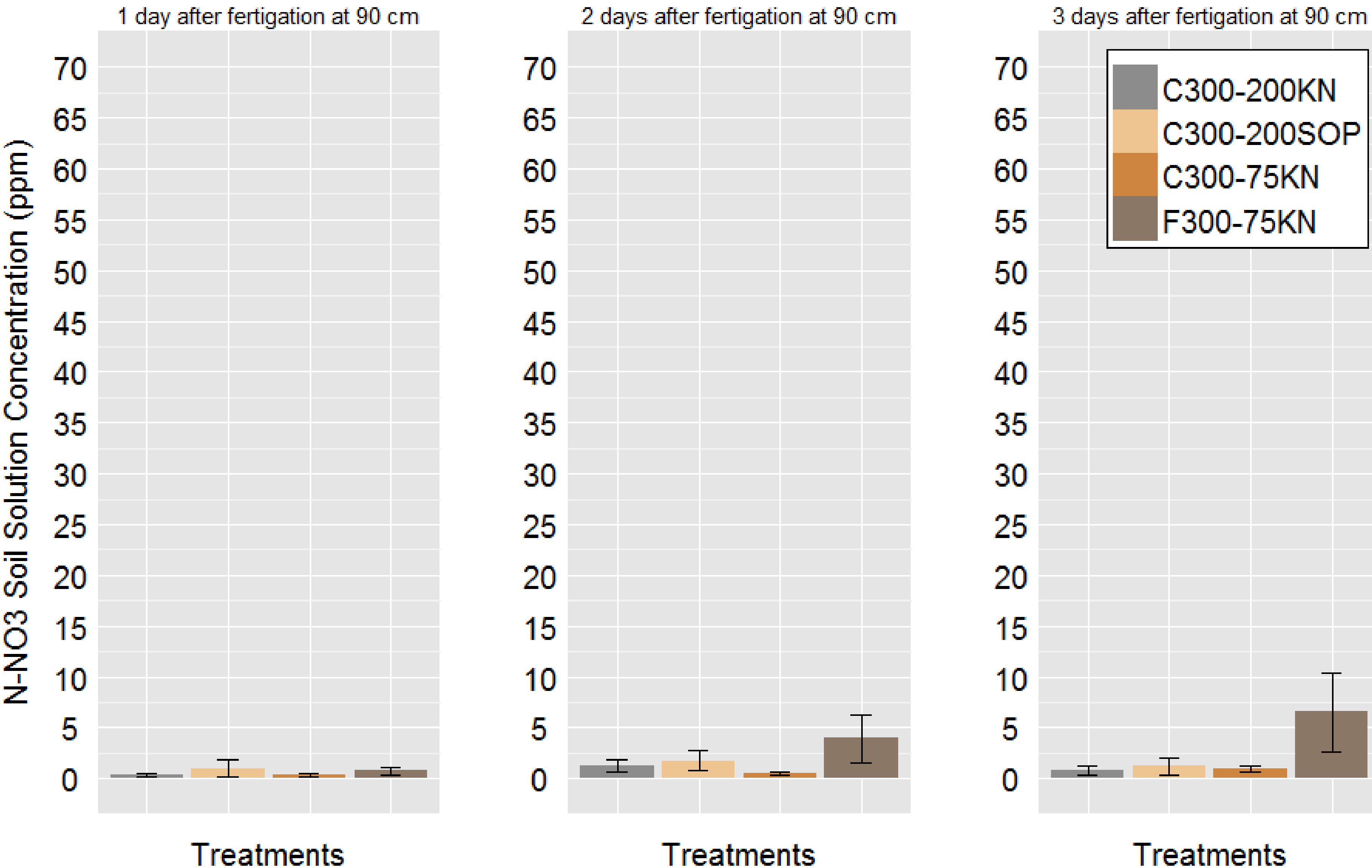
First Fertigation at 30 cm



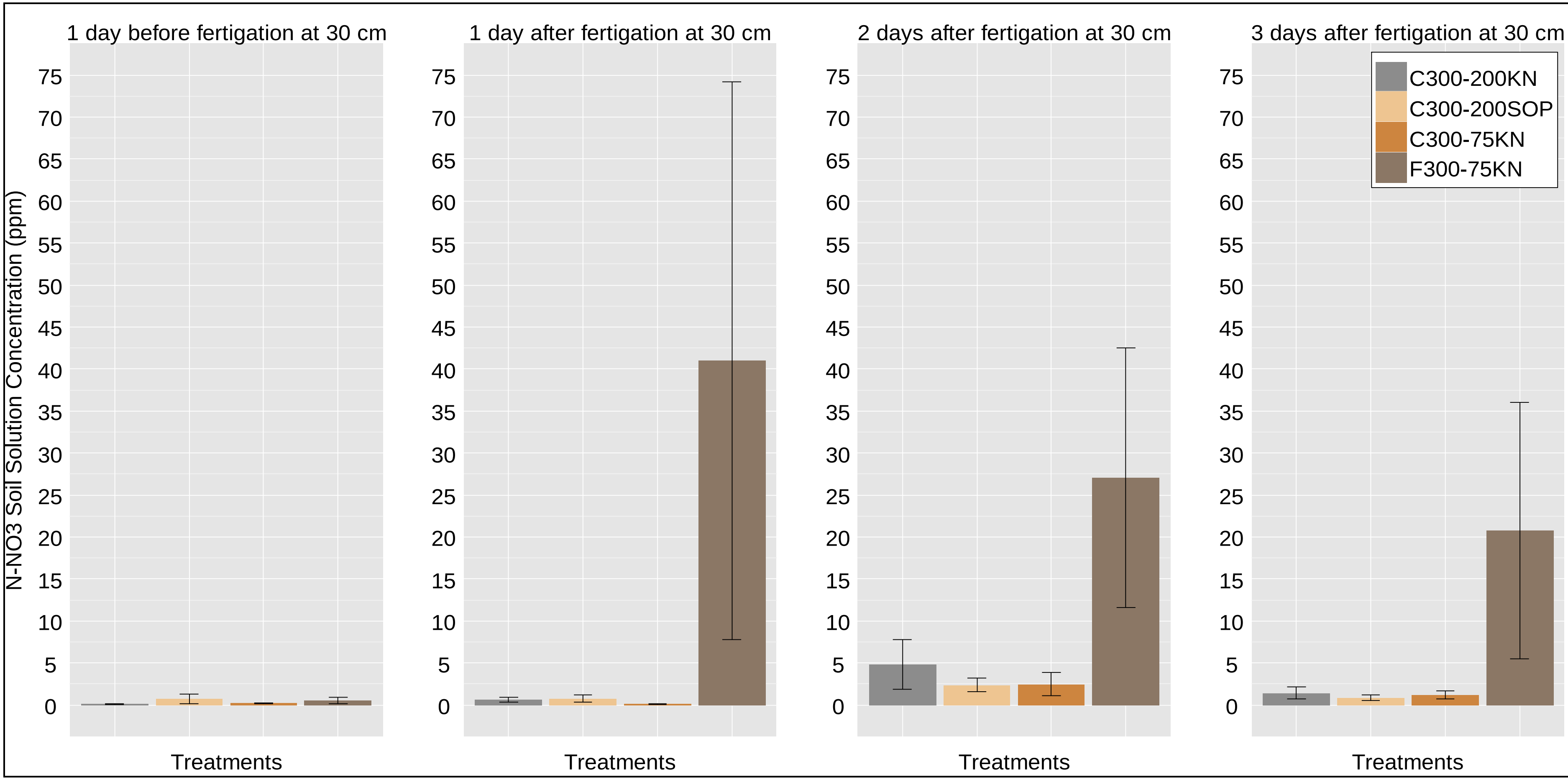
First Fertigation at 60 cm



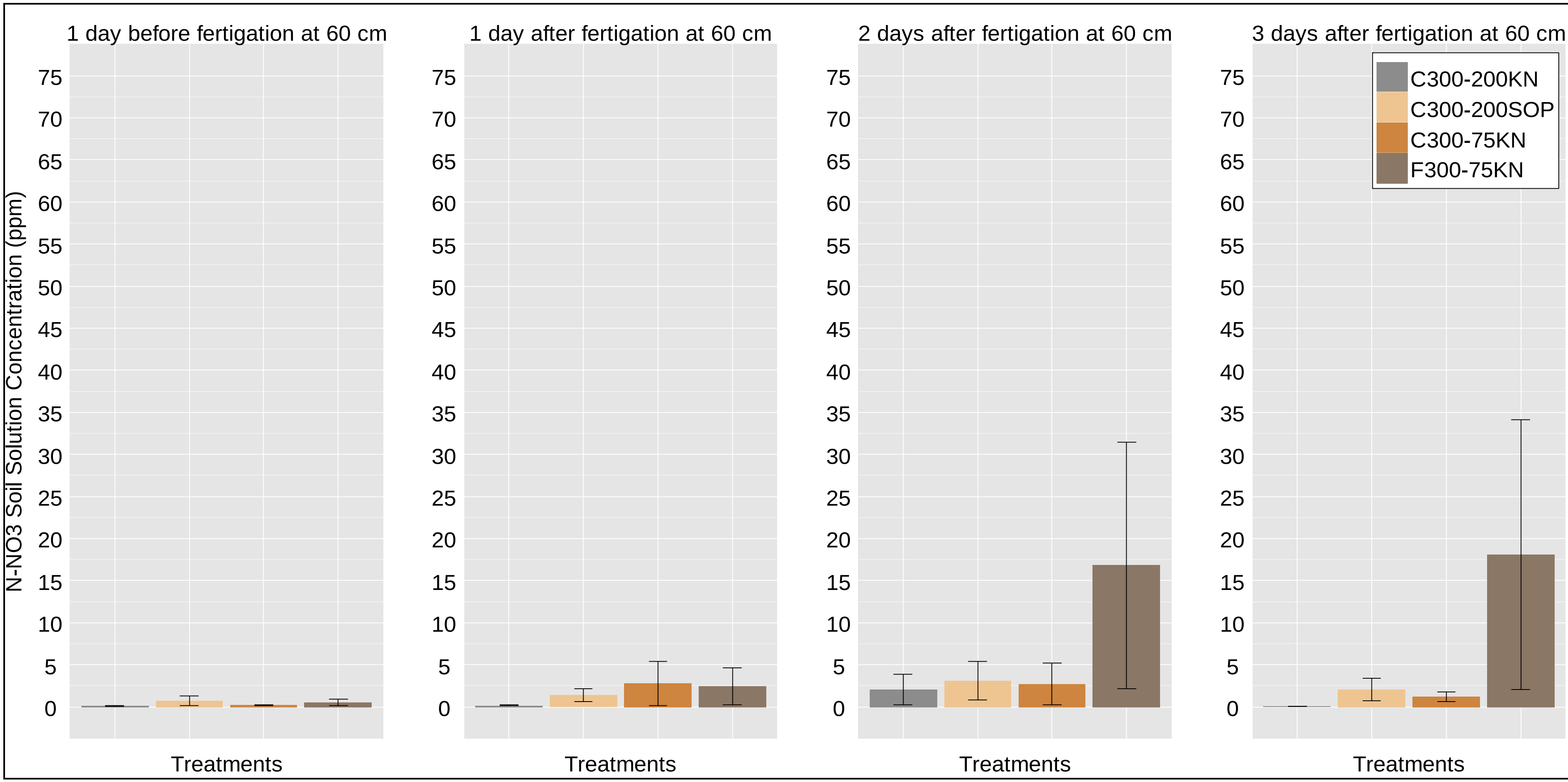
First Fertigation at 90 cm



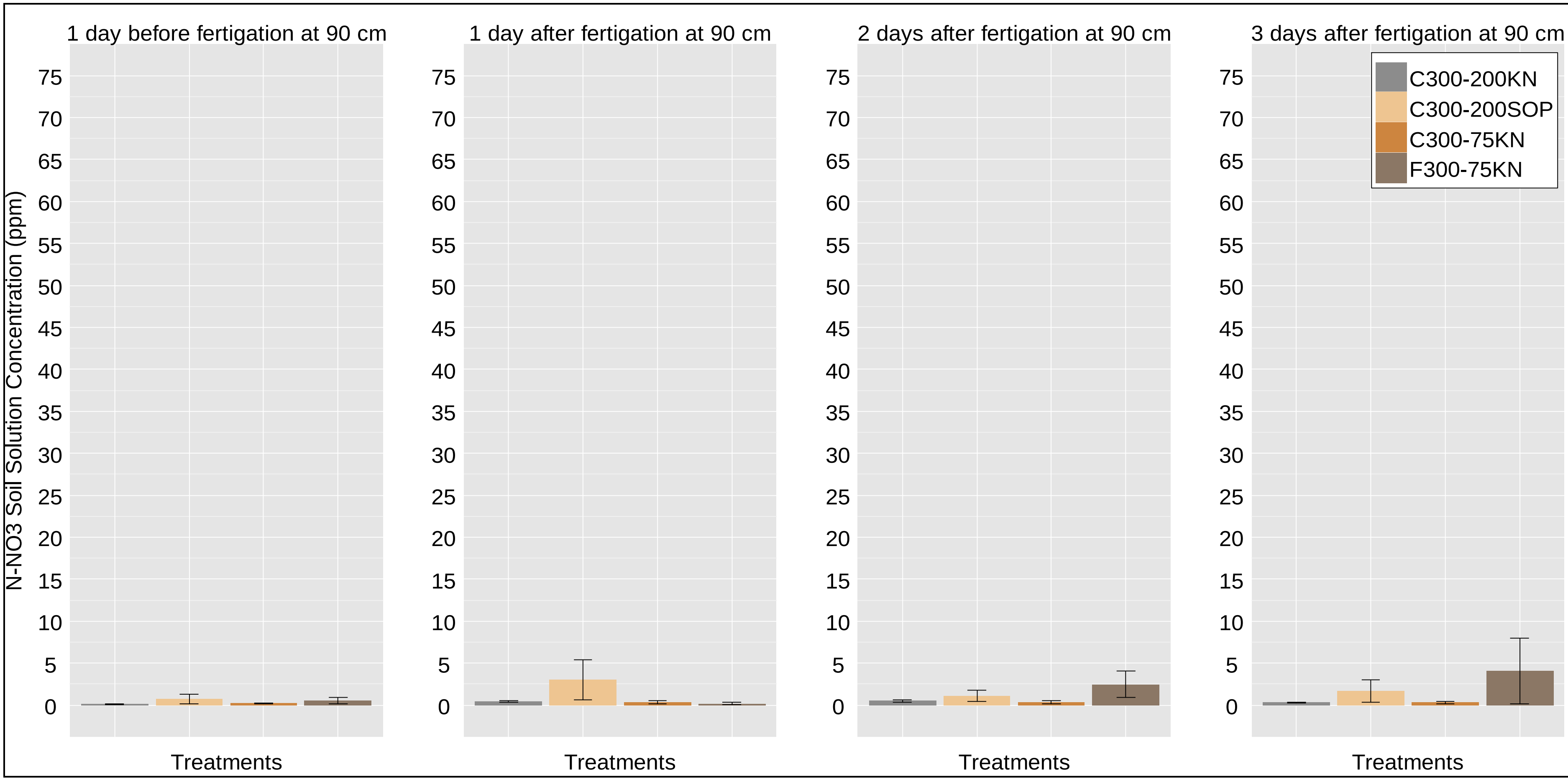
Second Fertigation at 30 cm



Second Fertigation at 60 cm



Second Fertigation at 90 cm



Conclusions from SSAT

- There is a large variability in NO_3 concentration within the treatment.
- Continuous treatments can reduce NO_3 concentration at depths.
- Due to rapid soil water depletion it is only possible to take samples early in the season.
- A new approach is needed for the extraction of soil solution samples

Modifications: A new approach to extract soil solution samples

- Two additional SSAT will be installed in each treatment/block combination- deeper in the soil profile: 150 cm and 250 cms
- Calculation of the potential NO_3 leaching in different treatments
- Sampling will be more frequent
- Data will be used in subsequent validations and simulations by Hydrus.

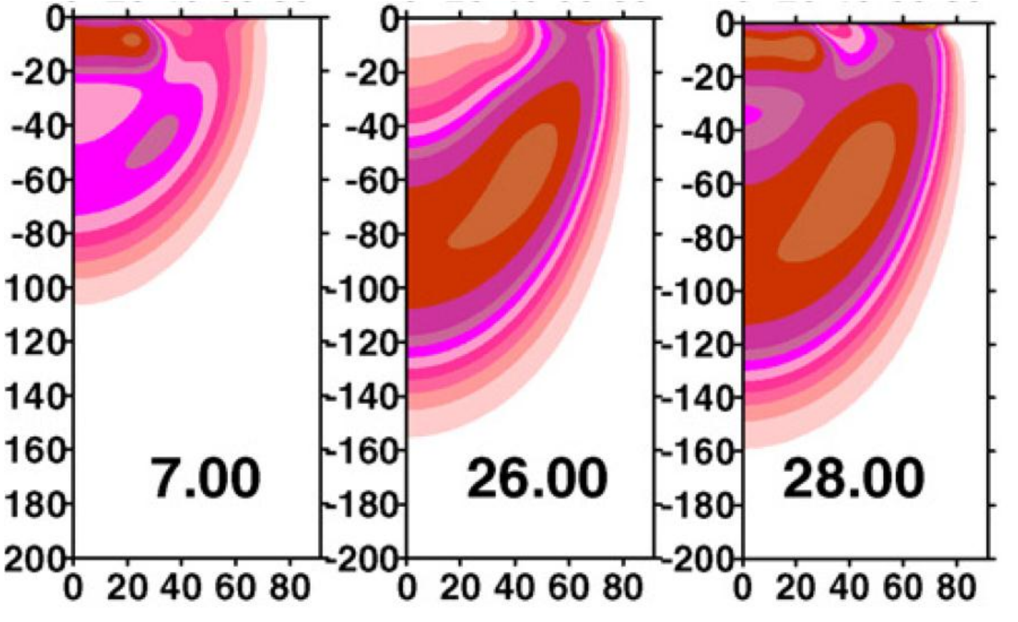
Conclusions

- A field method to measure root nutrient uptake was successfully tested and may give a good approximation of uptake at the root scale level.

- To date there is no differences in crop performance among fertigation practices (continuous, standard); however, continuous fertigation may reduce NO_3 leaching.

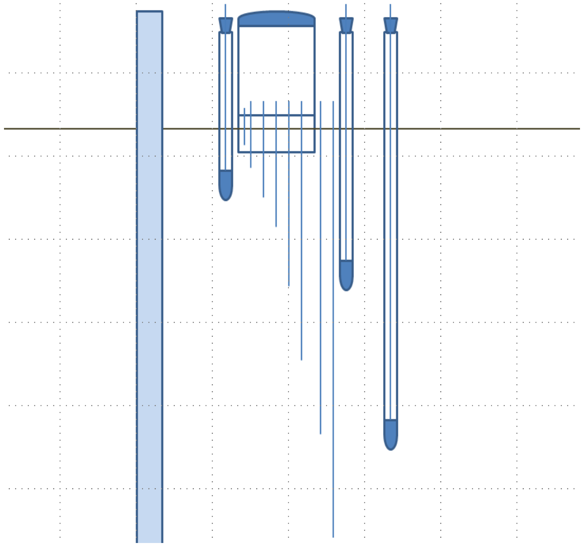
Project Synergies: Validation of Hydrus model (Hopmans Lab)

- **Monitor soil water and nitrate movement for 2 micro irrigation systems (Drip and Fanjet).**
- **Perform simulations to determine:**
  - **Almond tree root distribution**
  - **Soil water movement and nitrate transport**
  - **Root water/nitrate uptake.**
- **Minimize nitrate leaching**



Project Synergies: Effects of Fertigation Frequency & N Source on N_2O in a Soil Profile (Smart Lab)

- Measure differences in overall N_2O emissions attributable to continuous vs. conventional fertigation .
- Describe corresponding effects of UAN concentration on N_2O concentration by depth.
- Measure differences in overall N_2O emissions attributable to UAN vs. KNO_3 fertigation.
- Correlate observed emissions with soil profile concentrations measured, accounting for soil moisture.
- Prepare a data set suitable for testing the equations included in the Hydrus 2D/3D.



Future Plans

- Fine tuning of the root uptake method. Concentration ranges will be increased up to levels in the soil post fertigation.
- Analysis of minirhizotron images for the rate and the fertigation experiments
- Data integration for Hydrus model to determine best fertigation practices for almond context
- Determination of a potential NO3 leaching for different fertigation practices