Nutrient management strategies for organic vegetable production

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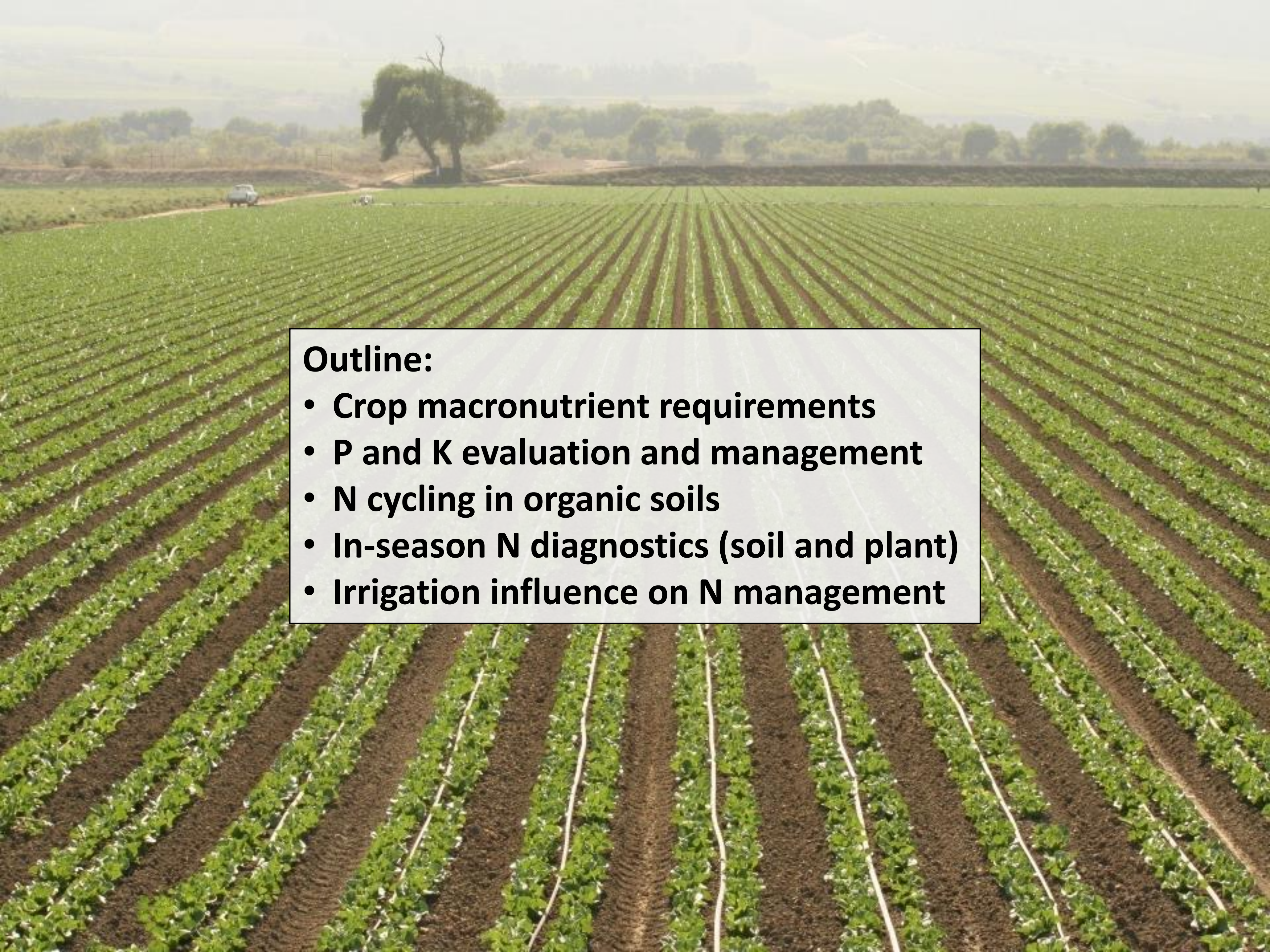


Outline:

- Crop macronutrient requirements
- P and K evaluation and management
- N cycling in organic soils
- In-season N diagnostics (soil and plant)
- Irrigation influence on N management

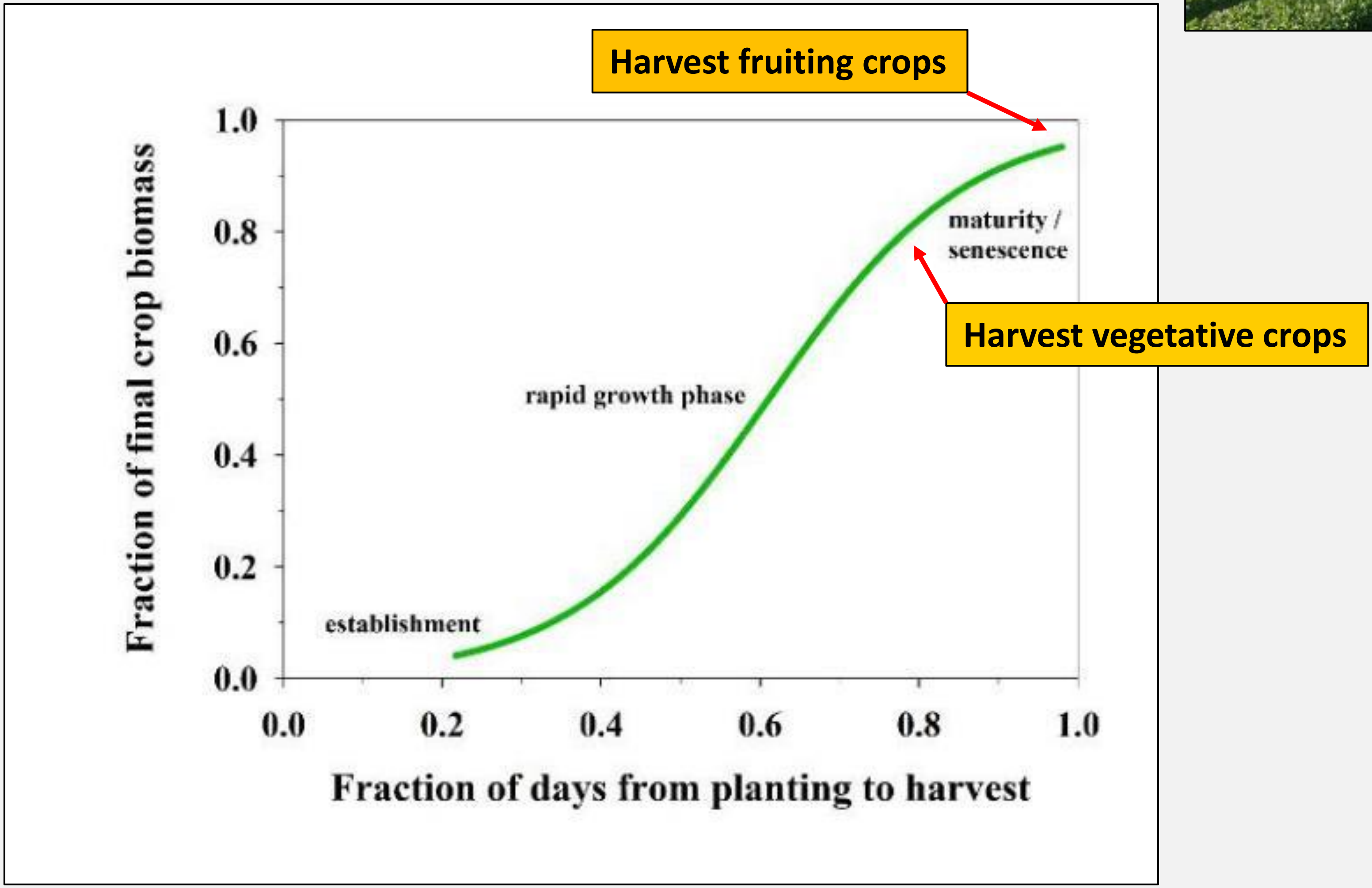
How much N/P/K do vegetable crops need?

Typical seasonal nutrient uptake of conventionally grown, high-yield vegetable crops in California:

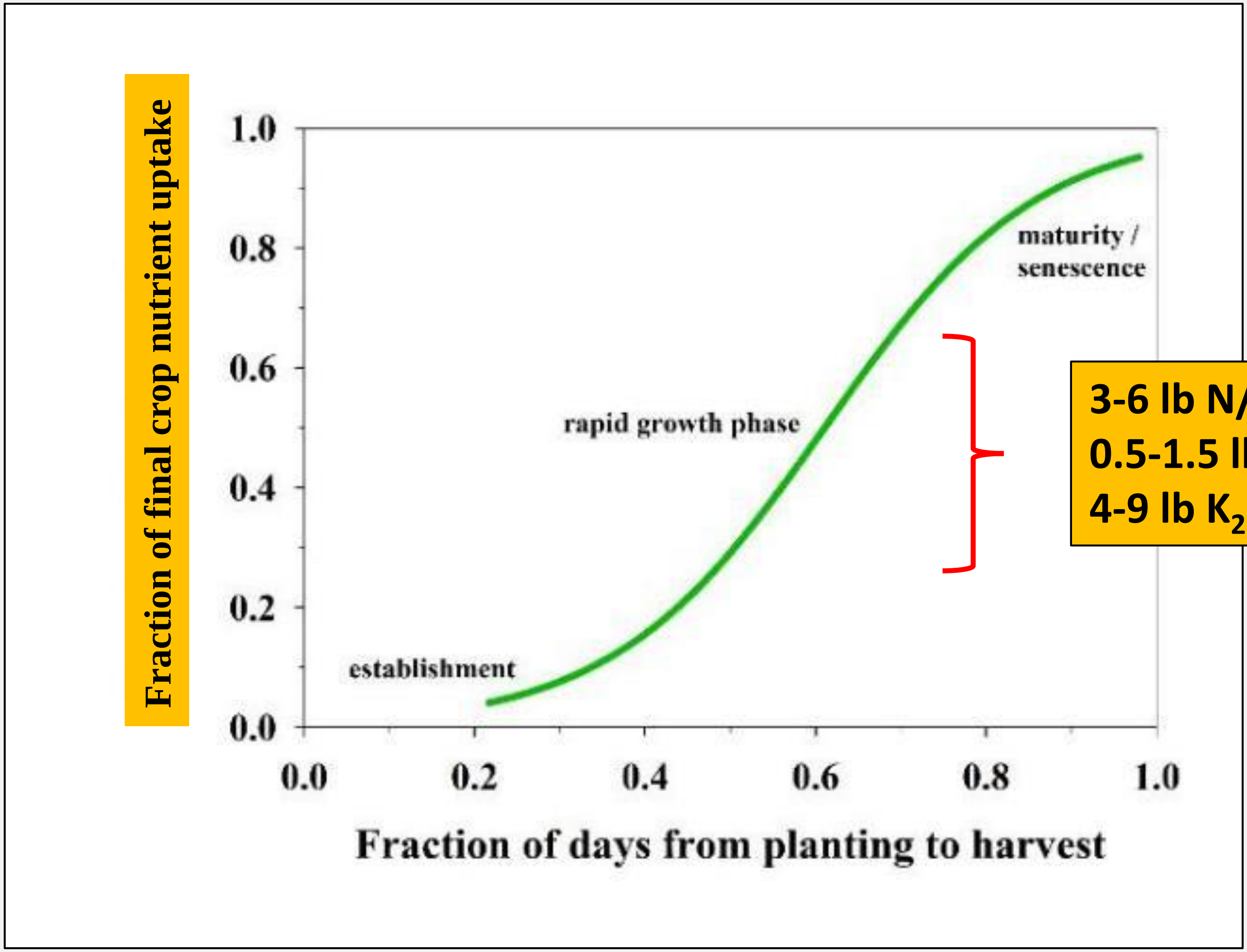
Crop	Seasonal crop uptake (lb/acre)			% nutrient removal with harvest
	N	P	K	
broccoli	250-350	40-50	280-380	25-35
Brussels sprouts	350-500	40-60	300-500	30-50
cabbage	280-380	40-50	300-400	50-60
cantaloupe	150-200	15-25	170-250	50-65
carrot	150-220	25-40	200-300	60-70
cauliflower	250-300	40-45	250-300	25-35
celery	200-300	40-60	300-500	50-65
head or romaine lettuce	120-160	12-16	150-200	50-60
baby lettuce	60-70	5-7	80-100	65-75
onion	150-180	25-35	200-260	60-75
pepper (bell)	240-350	25-50	300-450	65-75
potato	170-250	30-40	250-300	65-75
processing tomato	220-320	35-45	300-400	60-70
spinach	90-130	12-18	150-200	65-75

- **The high end of these ranges represents the main season production, the lower end represents less favorable conditions**
- **Organic crops are likely to be lower yield, and lower nutrient concentration; seasonal organic nutrient uptake perhaps 20-25% less than these tabled values??**

What is the timing of crop nutrient uptake?



What is the timing of crop nutrient uptake?



3-6 lb N/acre/day
0.5-1.5 lb P_2O_5/acre/day
4-9 lb K_2O/acre/day

P and K management:

- Soil supply is ‘buffered’, and tends not to change quickly over time
- Therefore, the foundation of effective management is soil testing and appropriate preplant application

Phosphorus test methods:

- Olsen (bicarbonate)
- Bray
- Mehlich

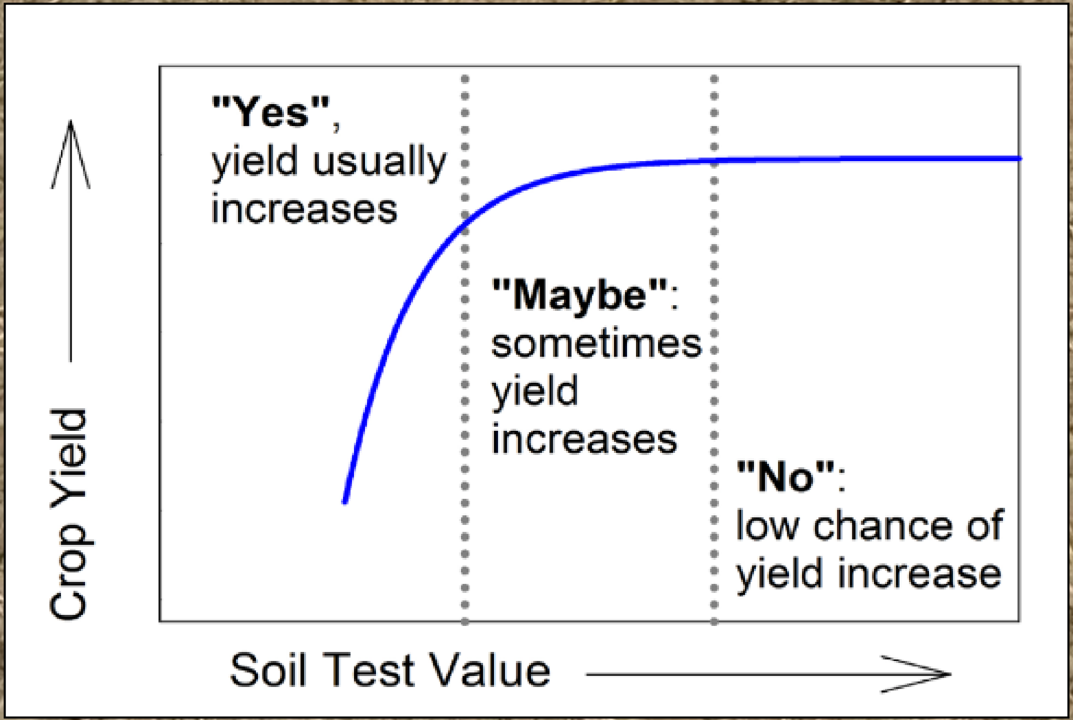
These methods give very different values, and are not well correlated

Potassium test methods (‘exchangeable K’)

- Ammonium acetate
- Mehlich

Both methods give similar values

Interpreting soil tests:



P and K sufficiency levels (the level above which fertilization will not increase crop yield) *varies widely among crops*…

Interpreting soil P test results*:

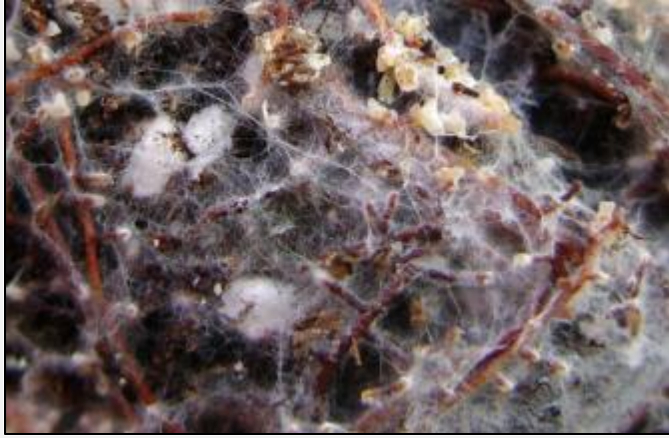
Crop	Olsen P (ppm)		
	crop response likely*	response possible**	response unlikely*
lettuce and celery	< 40	40 - 60	> 60
other cool-season vegetables	<25	25 - 35	> 35
warm-season vegetables (tomato, pepper, potato, cucurbits)	< 15	15 - 25	> 25

*regardless of soil temperature
** response more likely in soils < 60 ºF

Interpreting soil K test results*:

Crop	Exchangeable K (ppm)		
	crop response likely	response possible	response unlikely
celery	< 150	150-200	> 200
other cool-season vegetables	<100	100-150	> 150
potato, tomato, pepper	<150	150-200	> 200
cucurbits	< 80	80-120	> 120

*High-yield conventional production



Don’t organic soils provide more P and K than conventional soils at the same soil test level?

- higher degree of mycorrhizal association increases P availability
- better soil structure may increase rooting density, which increases both P and K availability

These effects are modest, and most important at marginal levels of soil fertility; most growers are uncomfortable managing on the margins …

Preplant application of P and K is generally advised; is there any justification for in-season application?

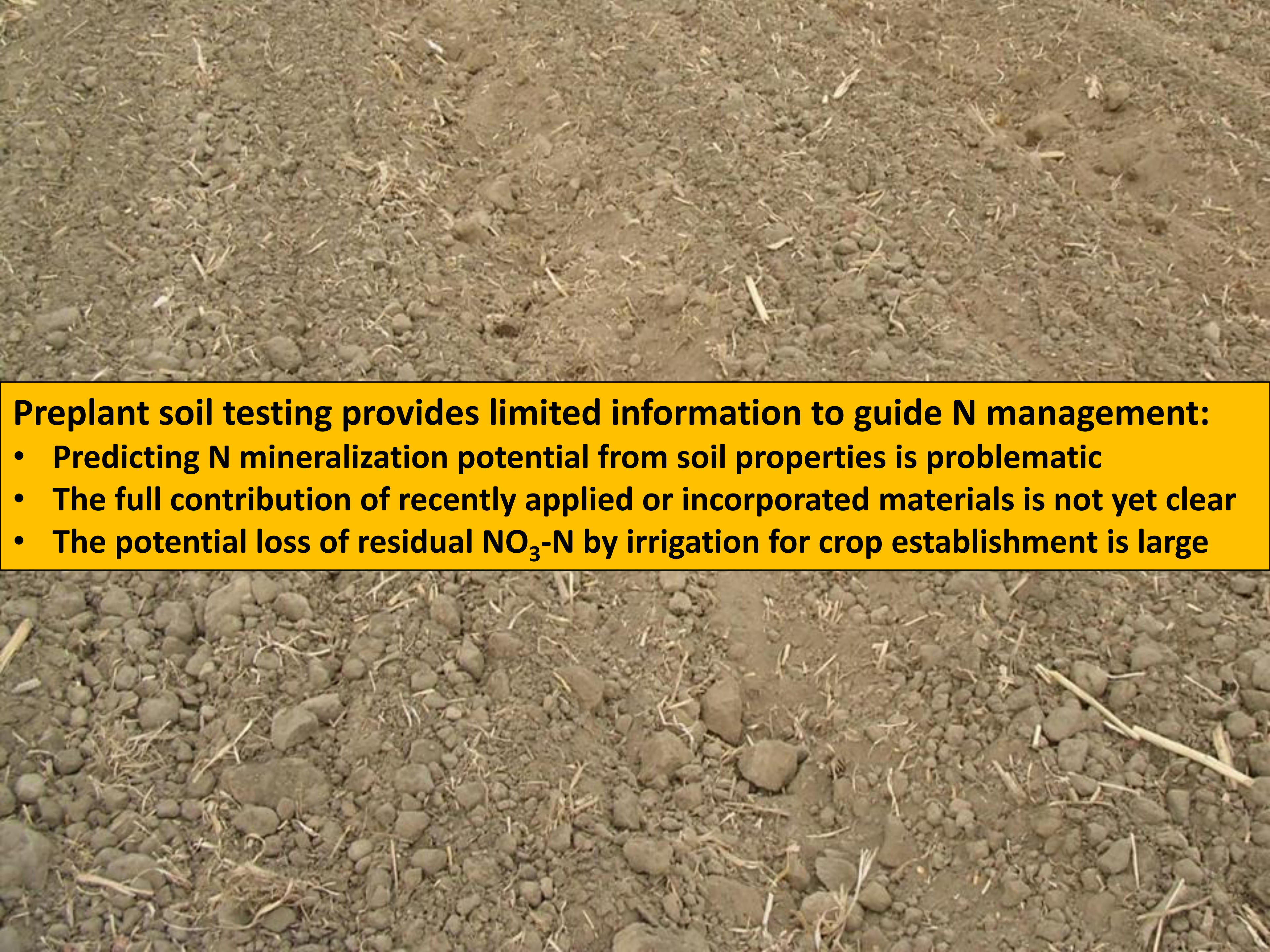
- **Probably not for P**
- **K sidedressing or fertigation may be appropriate for K-fixing soils (rare on the coast, common in the Central Valley), or in *very* sandy soils**

P and K application vs. crop nutrient uptake:

- Crop uptake ratio of N : P_2O_5 is typically between 3:1 and 5:1
- Crop uptake ratio of N : K_2O is typically between 1:1.2 to 1:1.5
- Ratios of *available* N:P:K in organic nutrient sources are often far out of balance

In manure-based material:

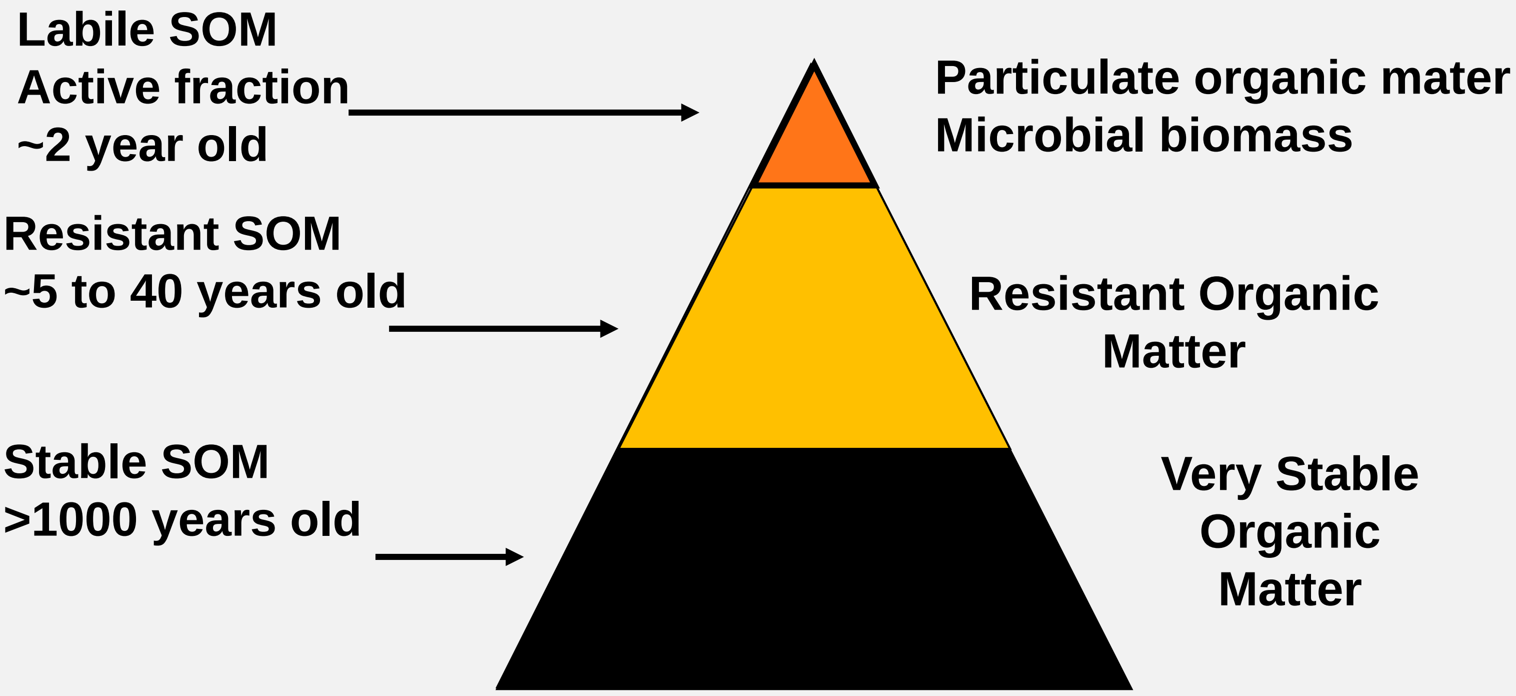
- ‘available’ N:P_2O_5 ratio often < 1:2
- ‘available’ N:K_2O ratio often > 1:3



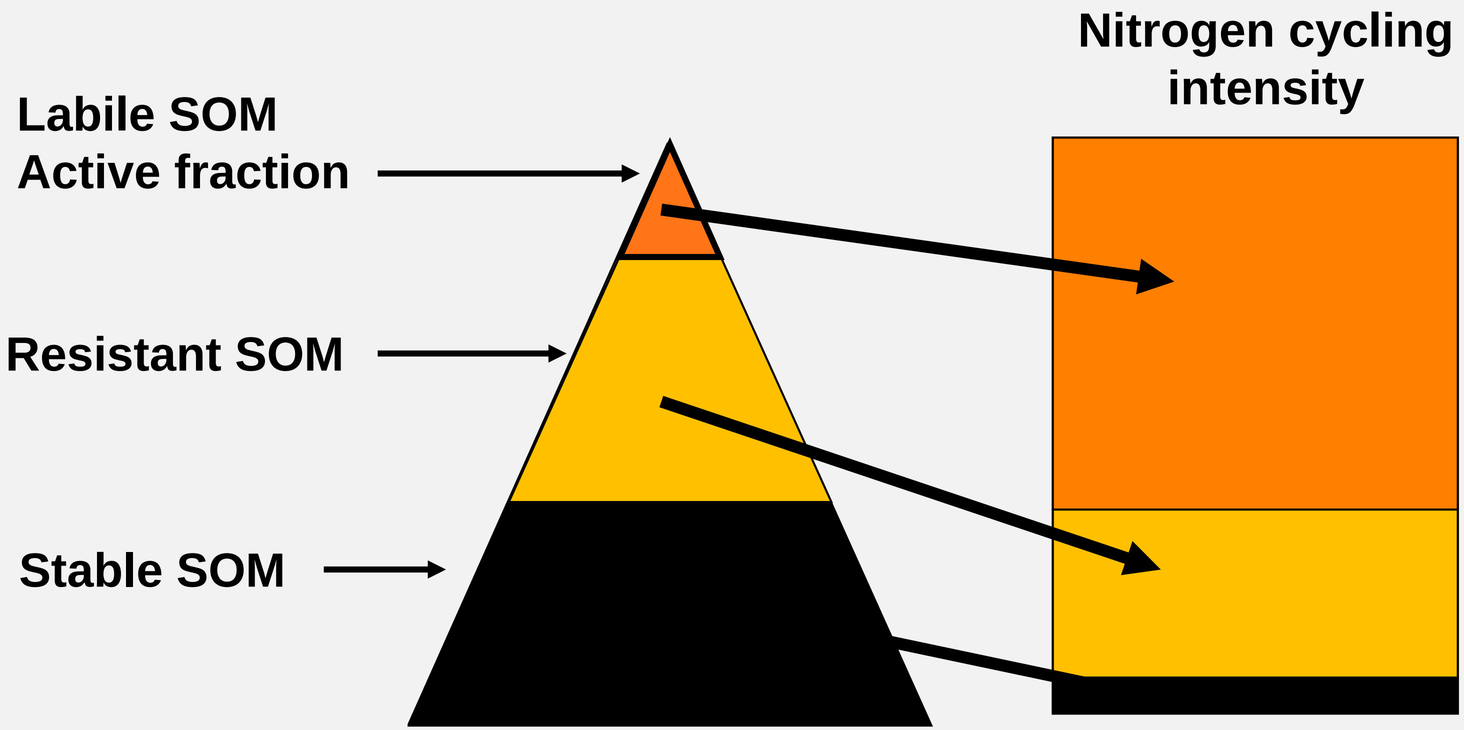
Preplant soil testing provides limited information to guide N management:

- **Predicting N mineralization potential from soil properties is problematic**
- **The full contribution of recently applied or incorporated materials is not yet clear**
- **The potential loss of residual NO_3-N by irrigation for crop establishment is large**

Effective organic N management requires an understanding of N cycling through soil organic matter (SOM)



Contribution of soil organic pools to nitrogen availability

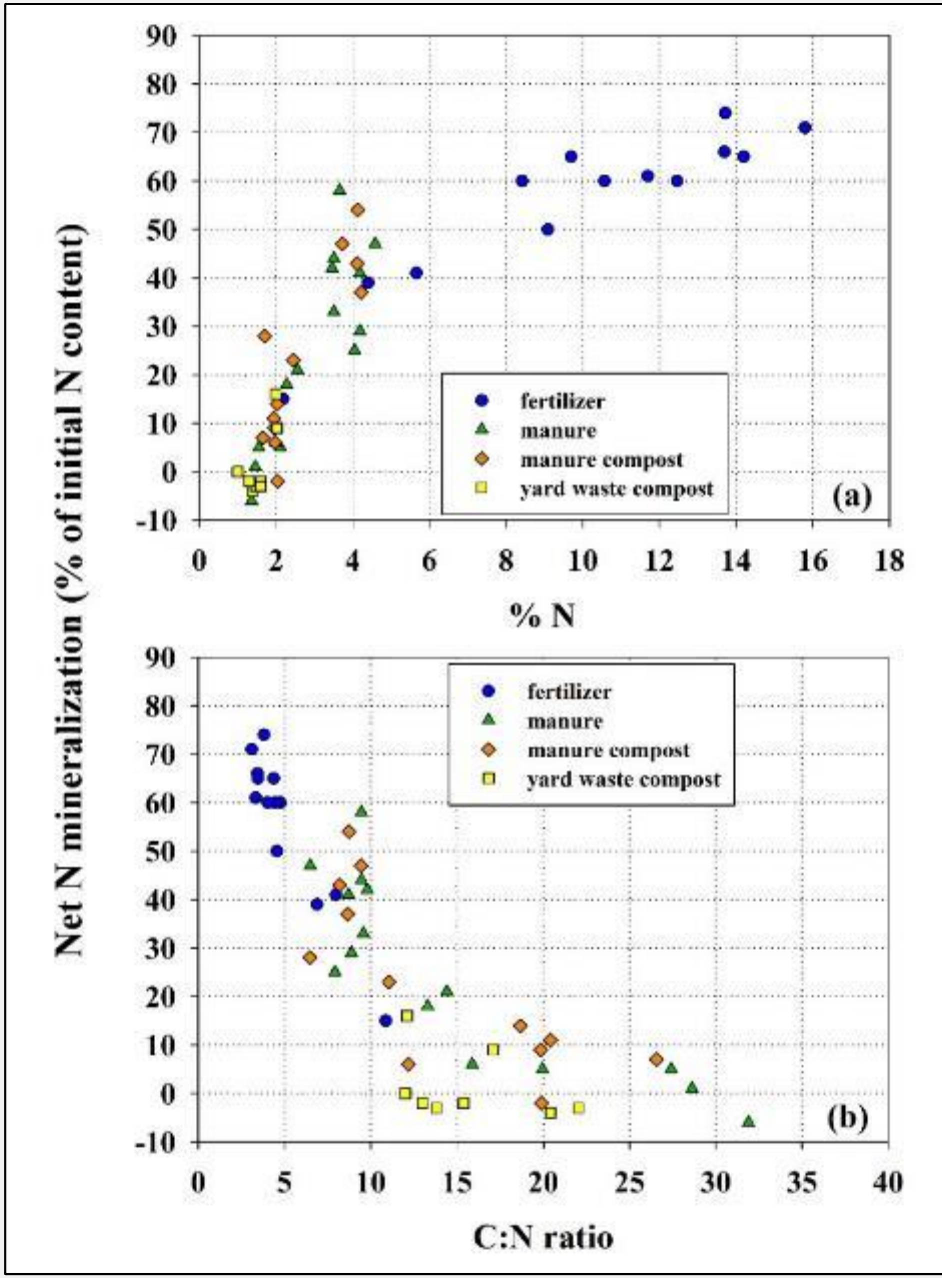


- **Increasing labile SOM through organic matter additions increases N mineralization potential (N_{min})**

Estimating N mineralization potential of manures, composts and fertilizers

Net N mineralization in 8-10 weeks at 70-75 °F:

- N concentration is the best predictor of N availability because N concentration drives the C:N ratio
- Materials < 2% N provide little, if any, N
- High N materials (feather meal, blood meal, guano, fishery wastes) mineralize > 50% of their N

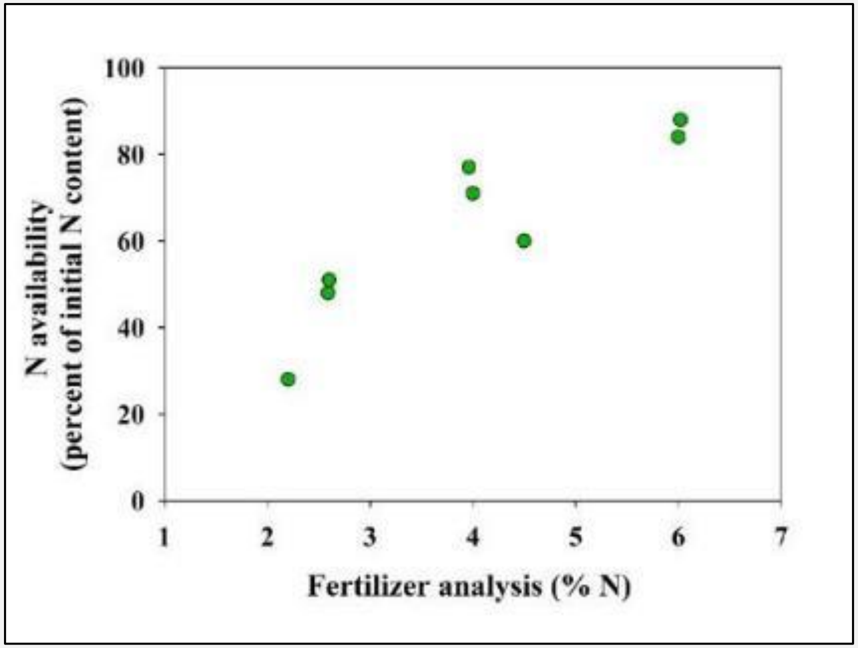


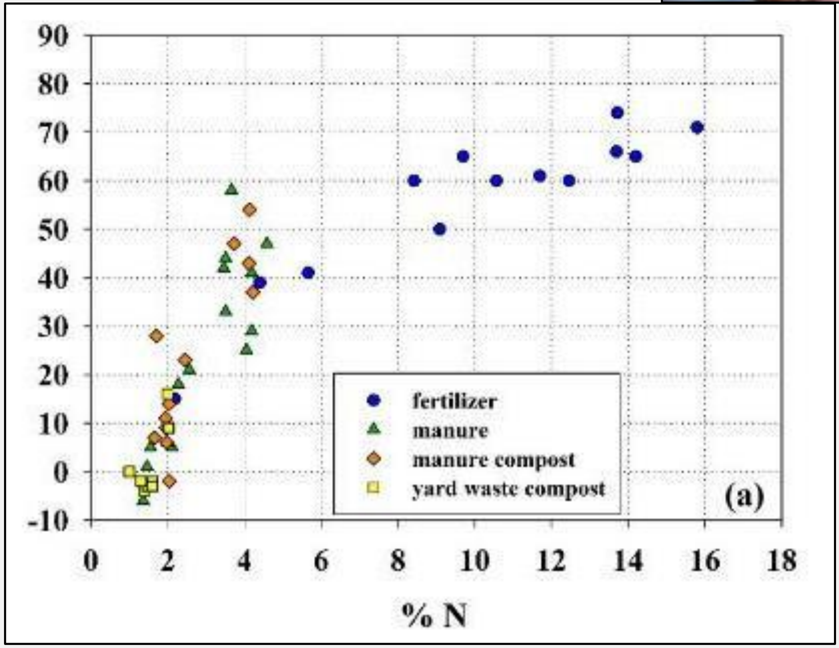
Data adapted from:
Castellanos and Pratt, 1981. Soil. Sci. Soc. Amer. J. 45:354-357
Gale et al., 2006. J. Environ. Qual. 35:2321-2332
Hartz and Johnstone, 2006. HortTechnology 16:39-42

Liquid organic fertilizers, and ‘blended’ fertilizers, have faster N_{min} than their % N suggest:

- The N concentration of the feedstock material is diluted with water or other material

N_{min} of liquid organic fertilizers over a 4 week incubation:

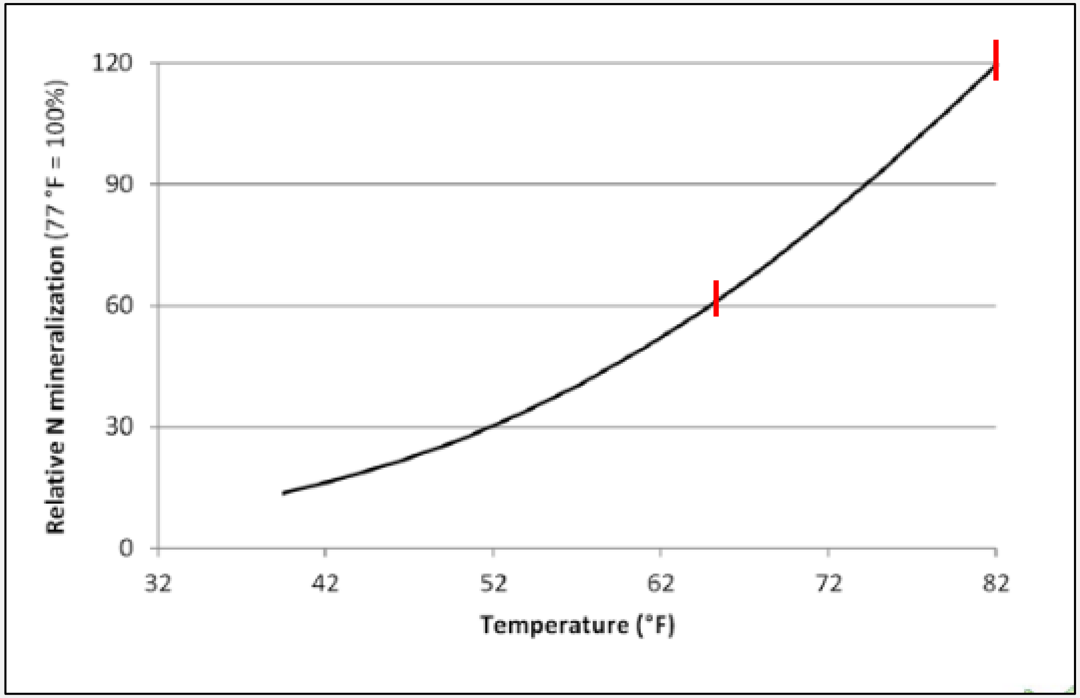




Hartz, unpublished data

How does soil temperature affect N mineralization of amendments and fertilizers?

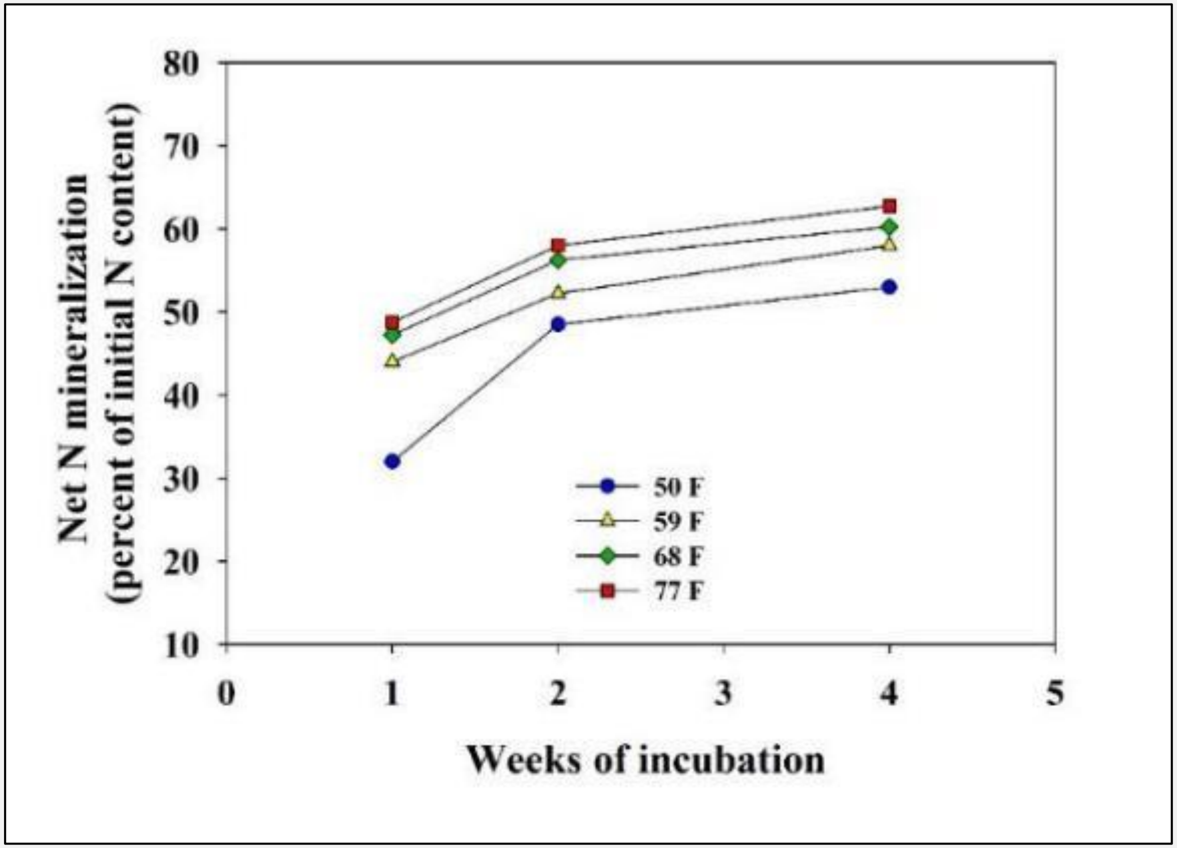
- lower temperature does slow microbial processes; general rule of thumb is that the rate of microbial processes double with each 18 ºF rise in temperature



- however, since organic materials contain both labile and resistance N compounds, the effect of temperature on N_{min} is not this great

How does soil temperature affect N mineralization of amendments and fertilizers?

- **lower temperature does slow microbial processes**
- **however, highly labile N will be mineralized relatively quickly regardless of temperature; once highly labile N is mineralized additional N_{min} is slow, regardless of temperature**

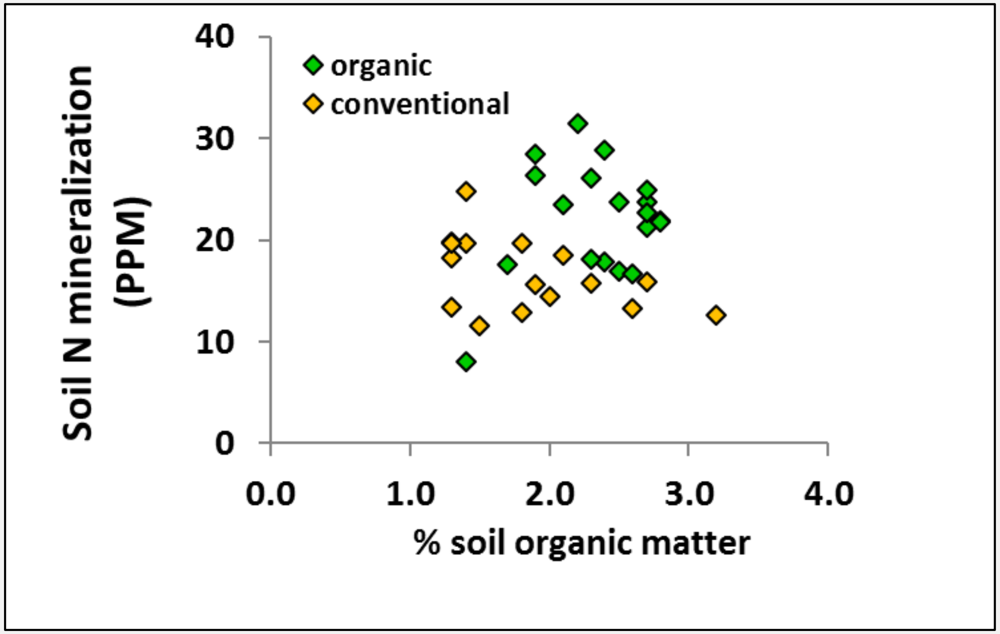


Mean of 4 high-N organic fertilizers, Hartz and Johnstone 2006. HortTechnology 16:39-42

Given current organic management practices in California, how big an increase in soil N mineralization potential is likely?

- **Measureable, but not large**

Lab incubation of Central Valley soils in vegetable rotations:

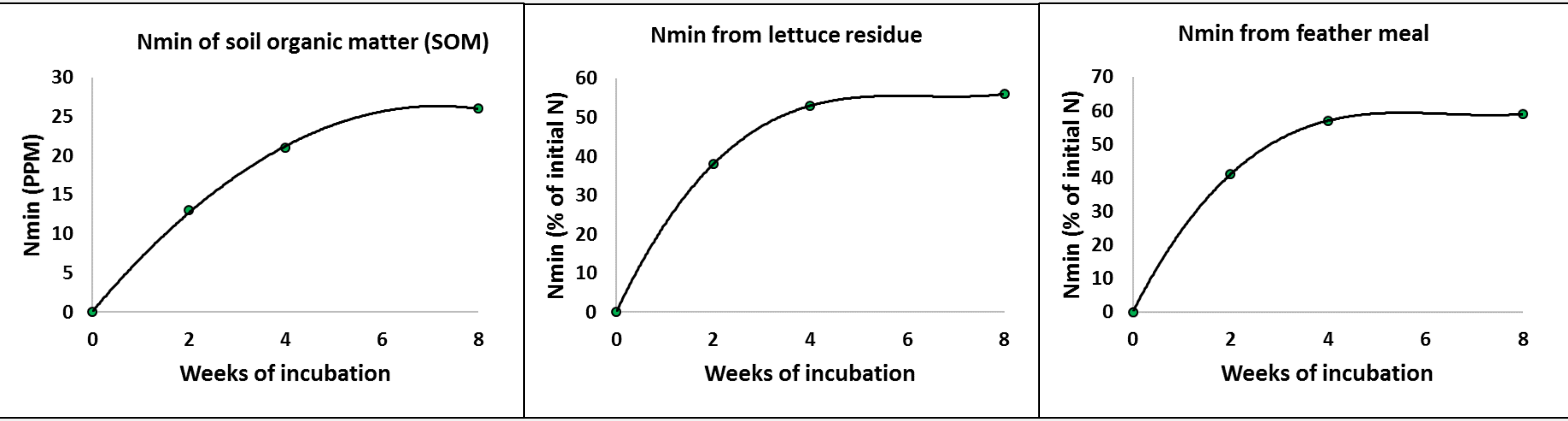


- **Organic soil averaged 1.3 lb N/A/day (2.1% of organic soil N)**
- **Conventional soil averaged 1.0 lb N/A/day (1.7% of organic soil N)**

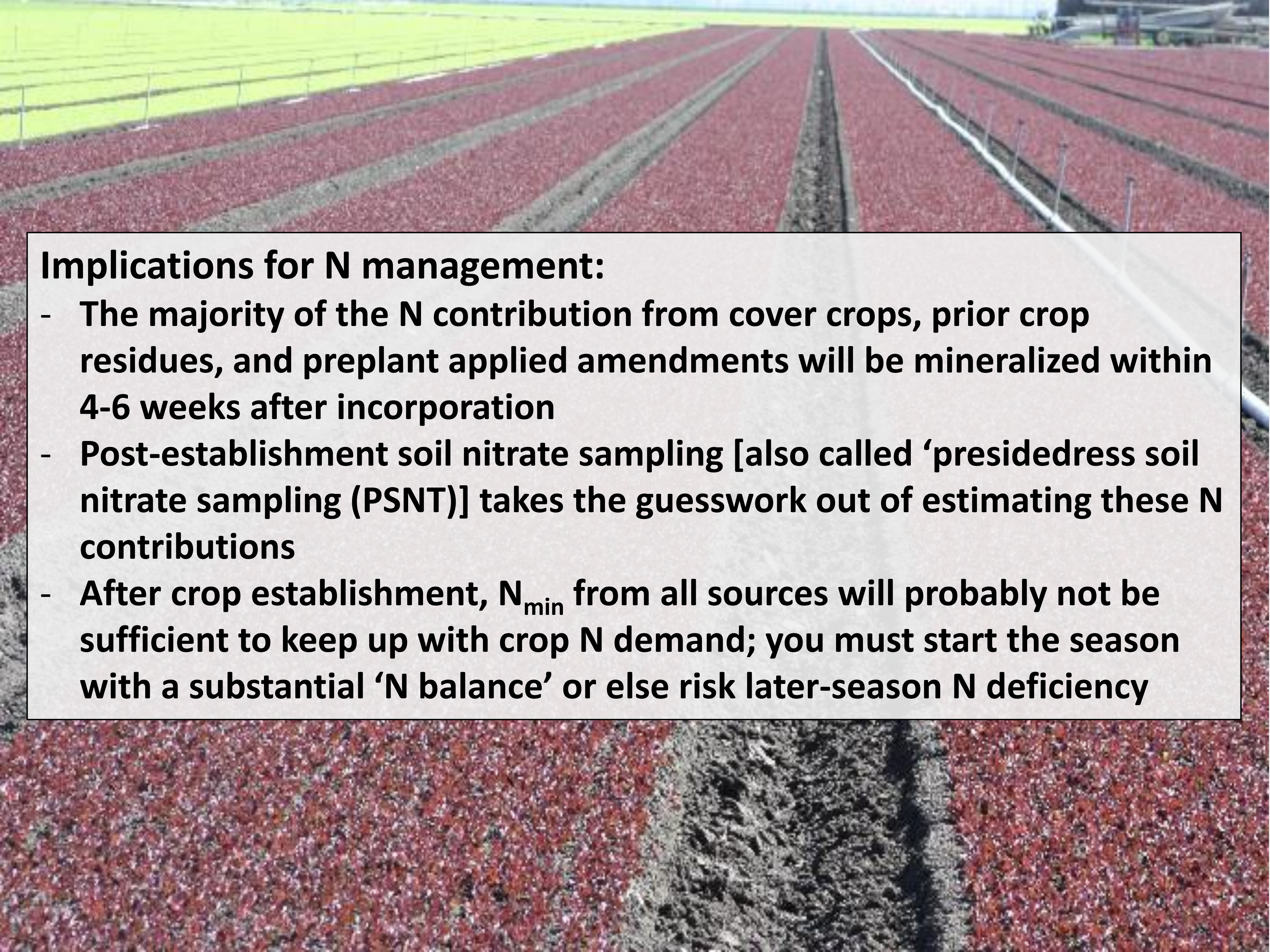
Data adapted from Castro Bustamante and Hartz, 2016. Commun. Soil Sci. Plant Anal. 47:Sup 1, 46-53.

Timing of N_{min}:

- Soil tillage, or addition of organic material, causes a burst of soil microbial activity, and N_{min}
- Within weeks the microbial activity slows, and N_{min} drops to a much lower rate



Lab incubation at 68 ^{o}F, Hartz, unpublished data



Implications for N management:

- The majority of the N contribution from cover crops, prior crop residues, and preplant applied amendments will be mineralized within 4-6 weeks after incorporation
- Post-establishment soil nitrate sampling [also called ‘presidedress soil nitrate sampling (PSNT)] takes the guesswork out of estimating these N contributions
- After crop establishment, N_{min} from all sources will probably not be sufficient to keep up with crop N demand; you must start the season with a substantial ‘N balance’ or else risk later-season N deficiency

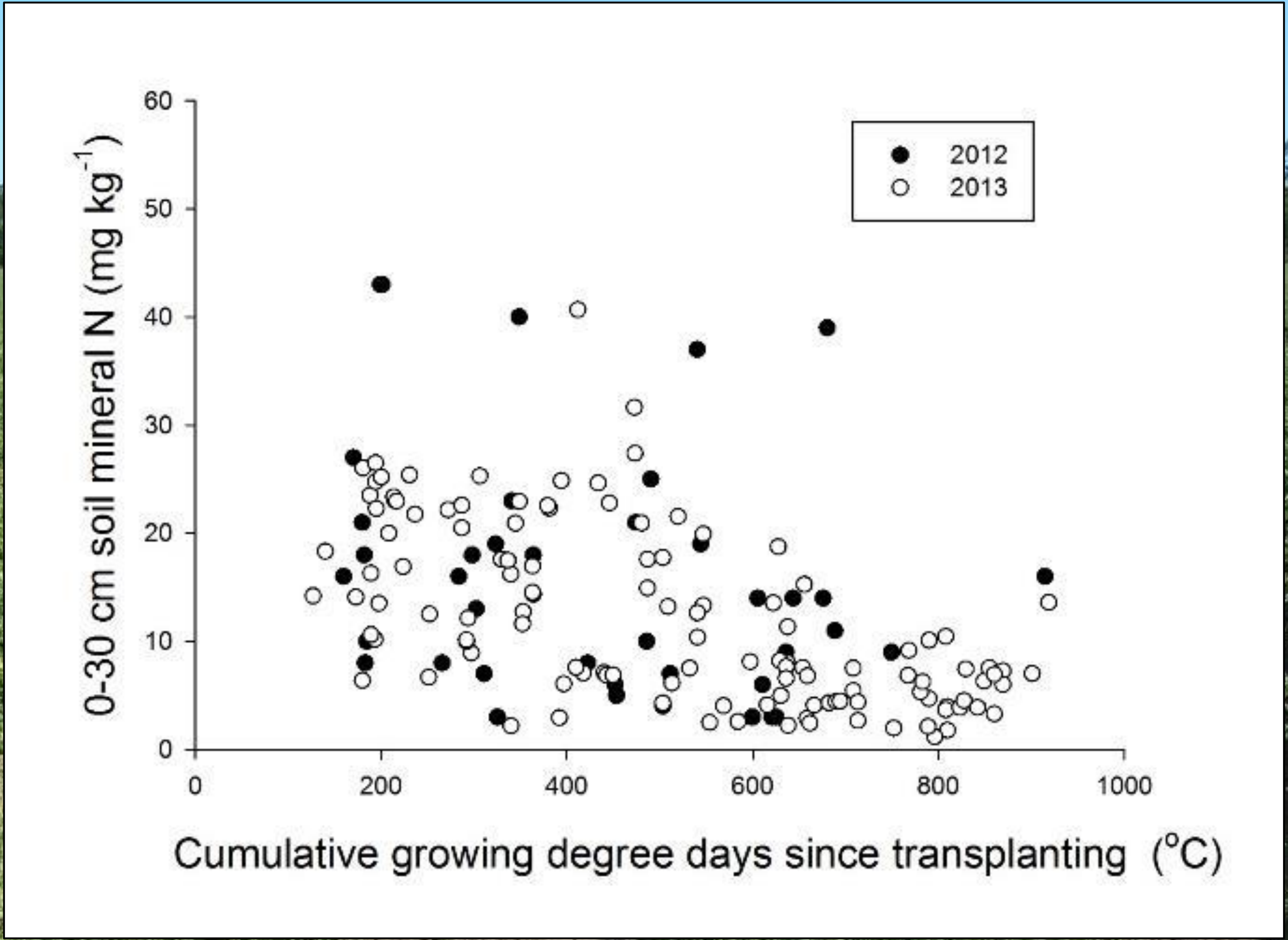
Importance of beginning the season with substantial soil NO_3-N:

In 22 organic processing tomato fields

- **Soil NO_3-N sampled every 2 weeks from 3 weeks after transplanting (WAT)**
- **Whole plant N concentration at 11 WAT measured to assess crop N sufficiency**

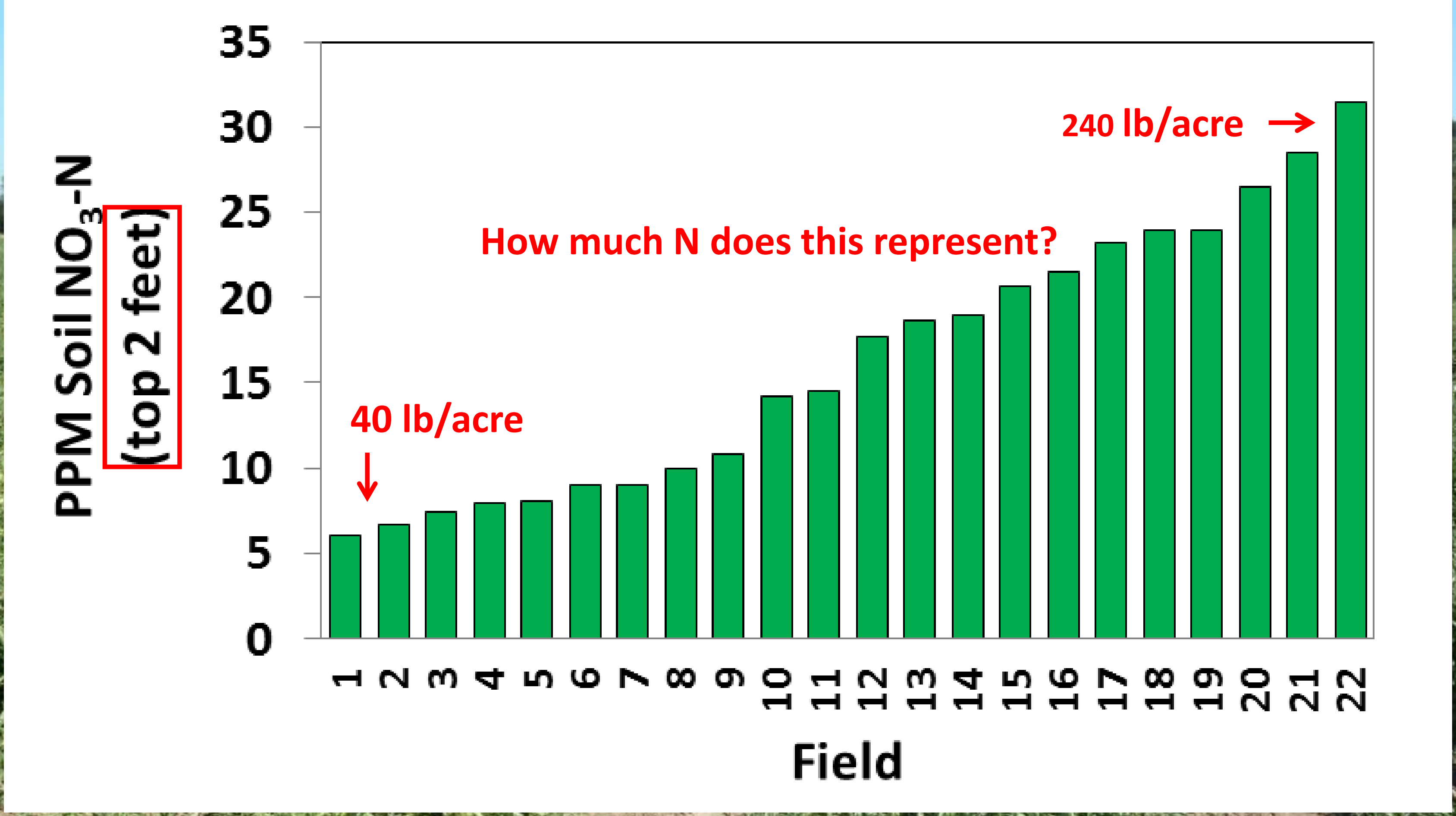
Castro Bustamante, S. and T.K. Hartz, 2015. HortScience 50:1055-1063

Soil NO_3-N highly variable among fields, declines over time:



Castro Bustamante, S. and T.K. Hartz, 2015. HortScience 50:1055-1063

Degree of variability in soil NO_3-N at 3 WAT is of agronomic significance:



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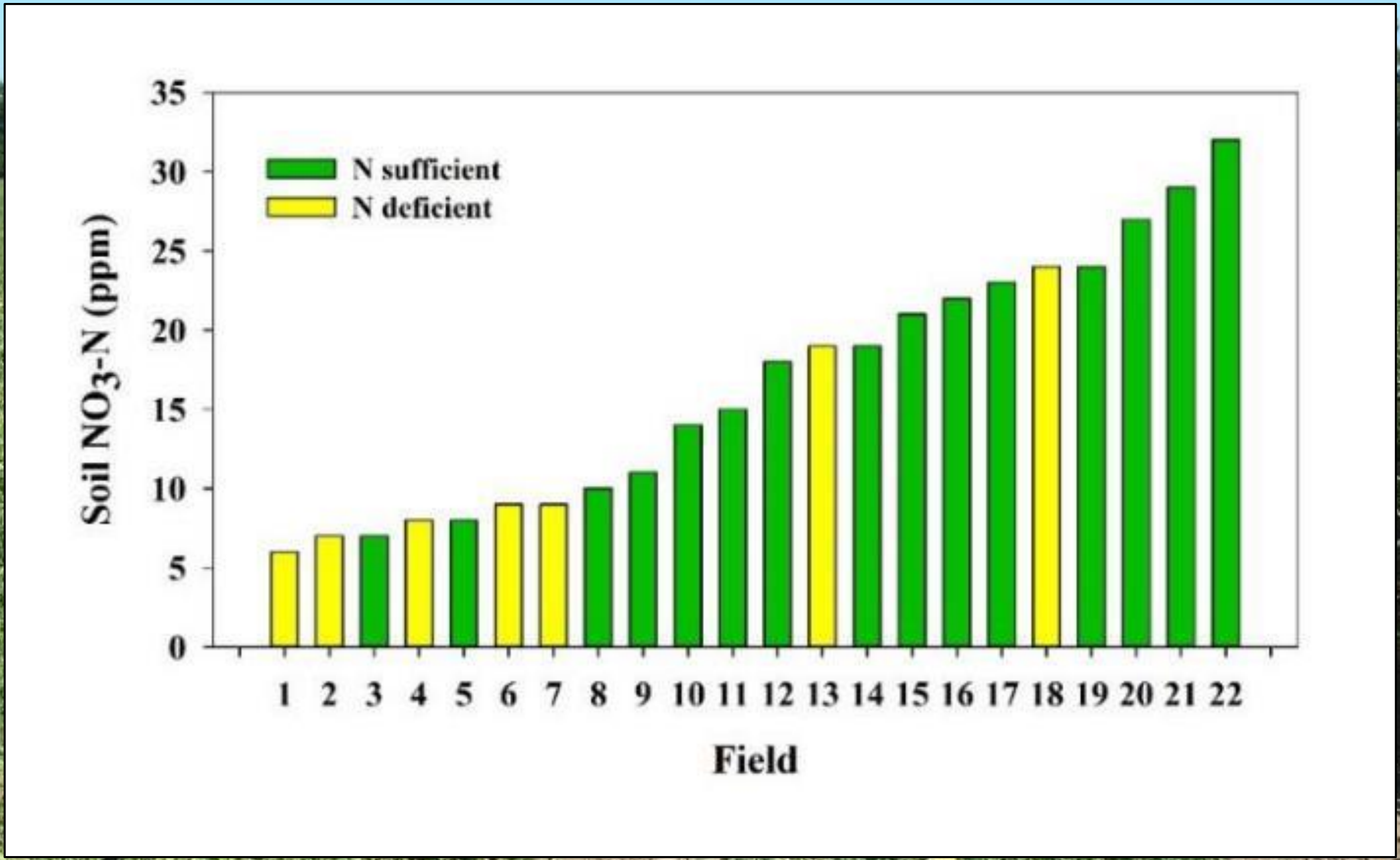
Low early-season soil NO_3-N predicted later season N deficiency:



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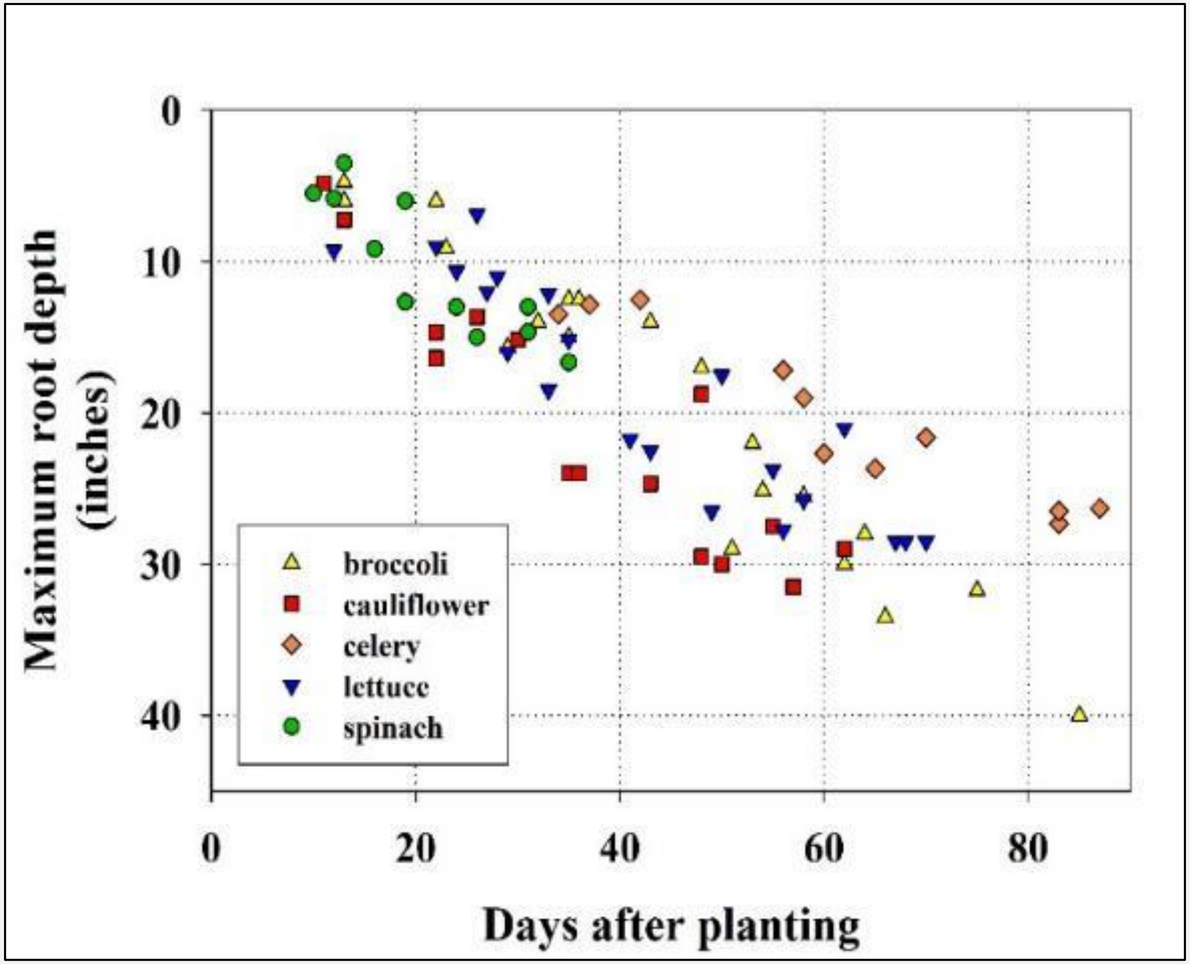
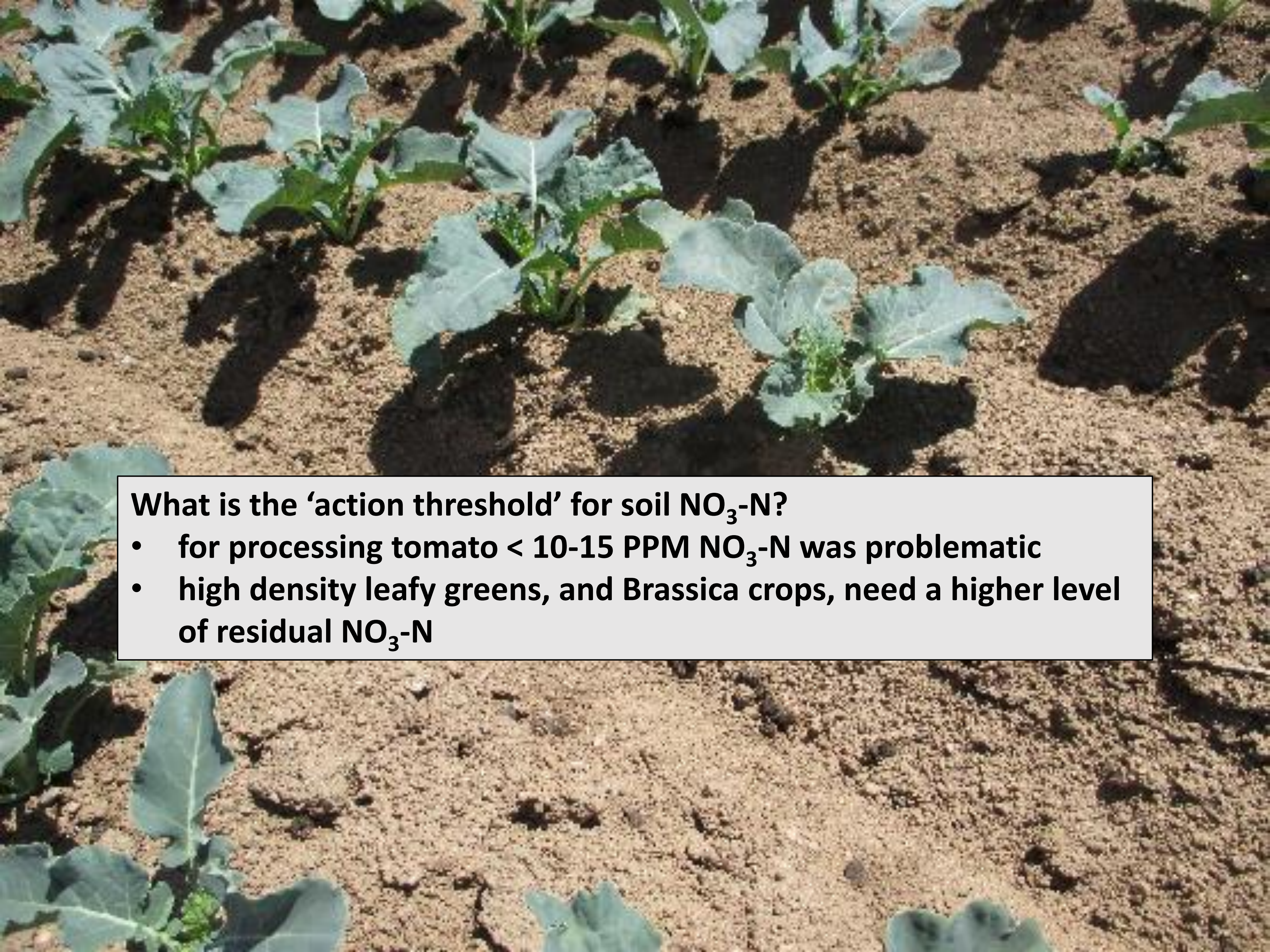
How to use early-season soil nitrate (NO_3-N) sampling in organic production?

- How deep to sample?
- What is the ‘action threshold’ for N application?
- How late in the season can organic fertilizer application be useful?

How deep to sample?



Surprisingly, there tends to be a reasonably good correlation between NO_3-N in the top foot and NO_3-N in the second foot of soil

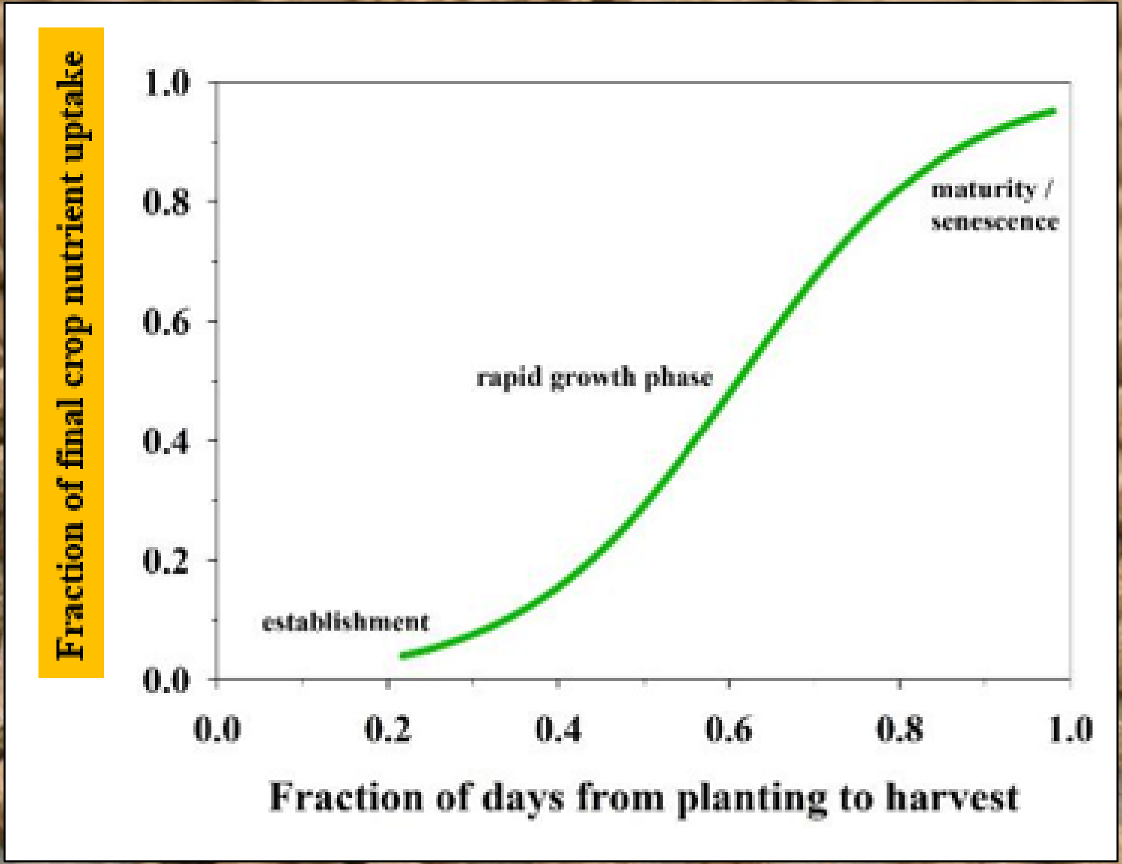


What is the 'action threshold' for soil NO_3-N?

- **for processing tomato < 10-15 PPM NO_3-N was problematic**
- **high density leafy greens, and Brassica crops, need a higher level of residual NO_3-N**

How late in the season can N fertilizer application be useful?

- High-N fertilizers (> 6% N) are likely to mineralize 50% or more of their N content in 2-3 weeks after incorporation



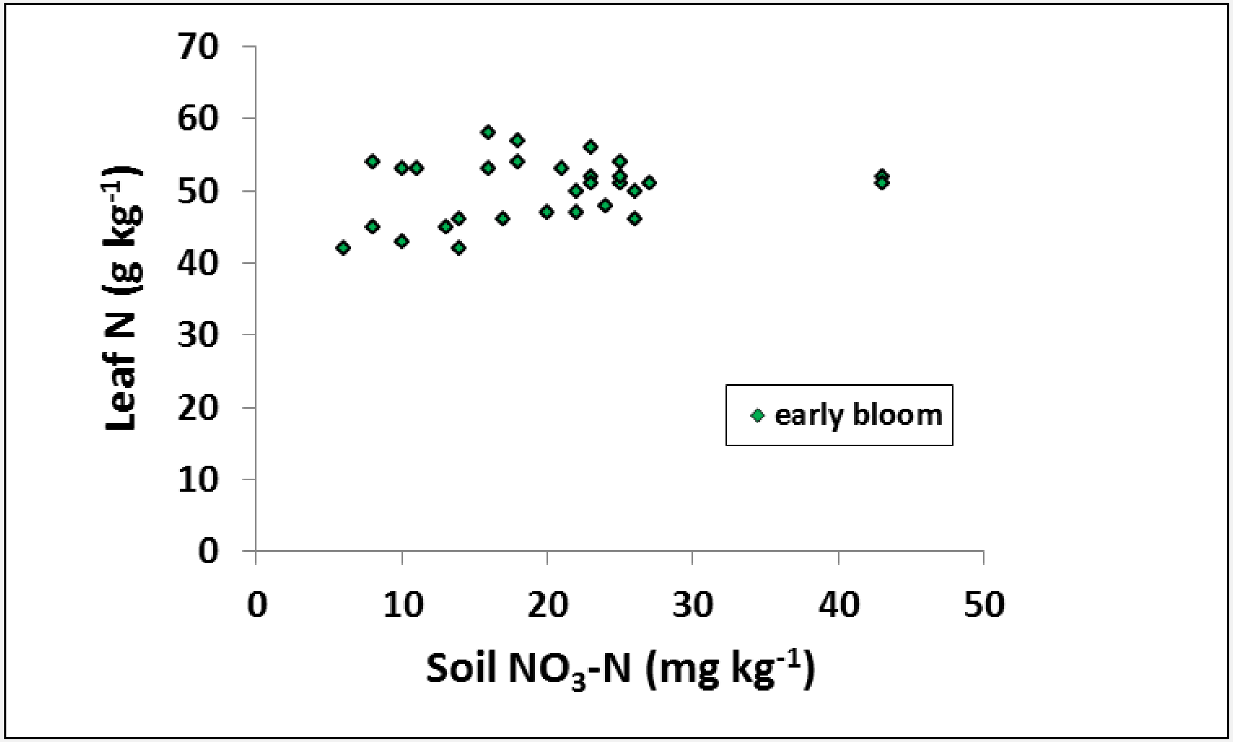
Lab analysis is more accurate, but there is an on-farm 'Nitrate Quick Test' that can *semi-quantitatively* estimate soil NO_3-N

https://vric.ucdavis.edu/pdf/fertilization/fertilization_UsingthePre-SidedressingSoilNitrateQuickTesttoGuideNFertilizerManagement.pdf

http://cemonterey.ucdavis.edu/files/153199.pdf

Leaf analysis is of limited value in fine-tuning fertilizer application:

- Correlation between soil NO_3-N and leaf N is poor until the crop N uptake rate is high



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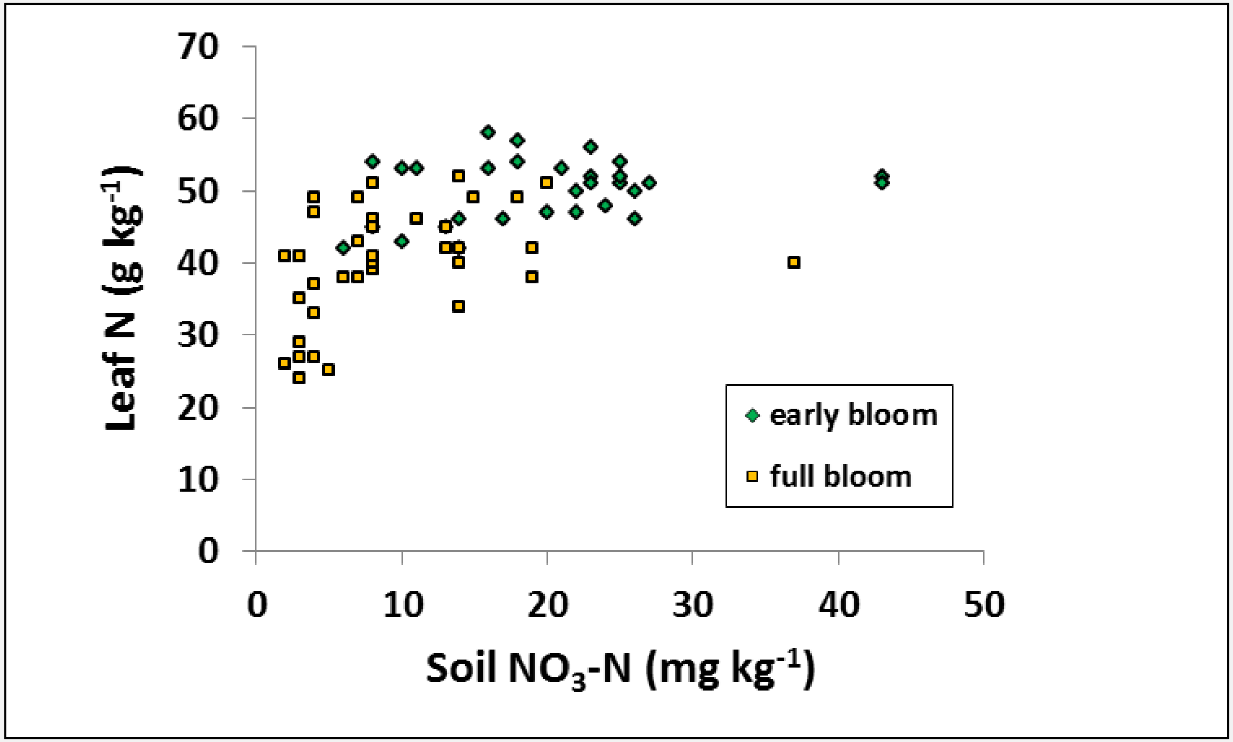

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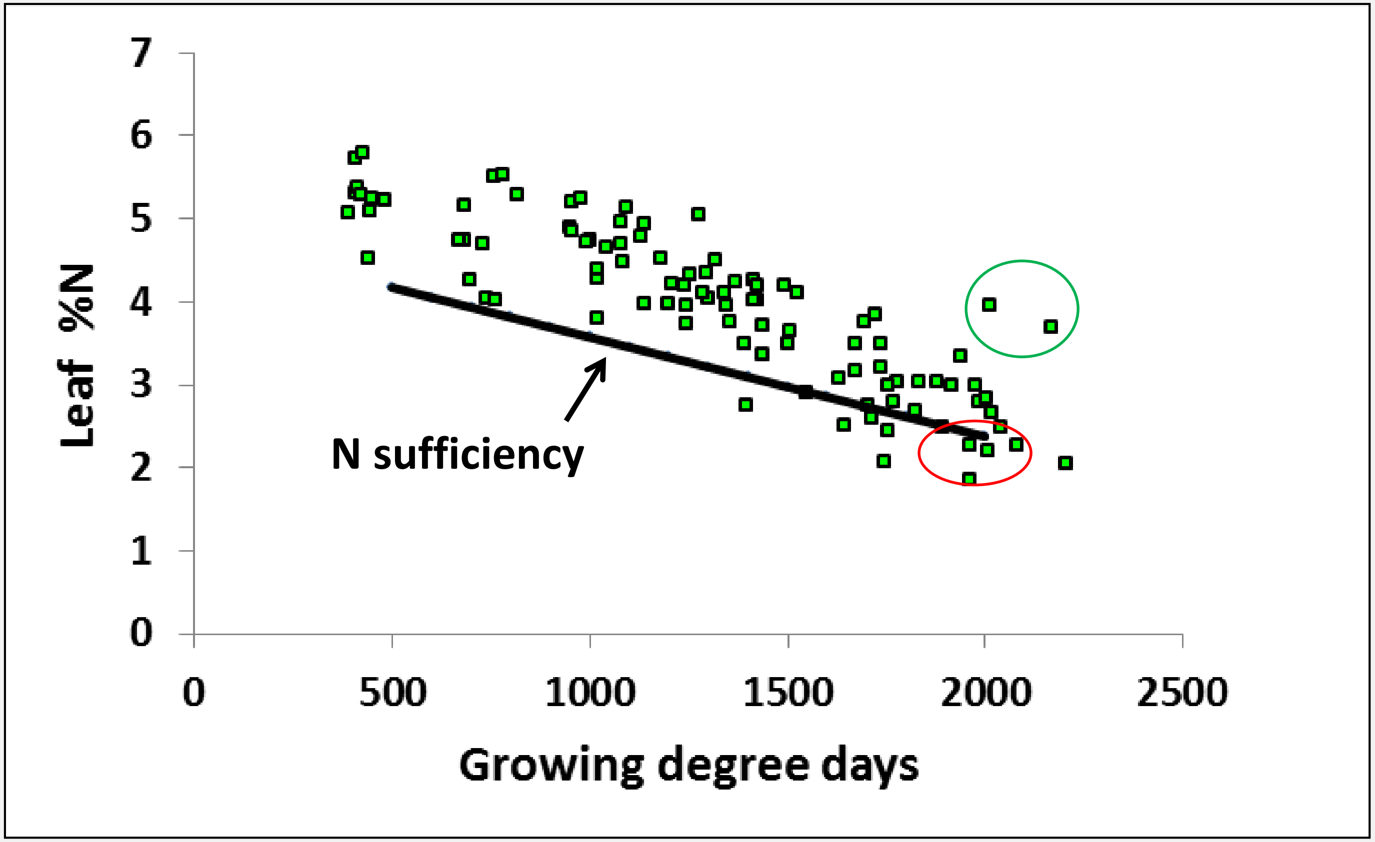
End-of-season tissue sampling can provide guidance for next season :

Processing tomato leaf N from 20 commercial fields :



What about petiole NO_3-N analysis?

- Very low petiole NO_3-N at 3-4 weeks post-establishment may be a useful predictor of future N deficiency; unfortunately, a 'sufficient' NO_3-N level does not confirm soil N sufficiency
- later season petiole NO_3-N generally not useful, as organic systems often have very low values, even where N is sufficient



Irrigation management can make or break organic N management

- **Each acre inch of leaching will commonly carry at least 10 lb of NO_3-N below the root zone; loss potential is greatest in the early part of the crop cycle**


Questions?