Soil & Crop Nitrogen: some considerations related to cropping, fertilization and management practices

Bob Hutmacher, Cooperative Extension Specialist

University of California

Univ. CA West Side REC and Univ. CA Davis Plant Sciences Dept.

Common "threads" in efforts to reduce N waste, improve efficiencies

- ✓ Base N applications on yield goals (use cultivar and yield goal appropriate information on crop response, uptake, return and removal if possible)
- ✓ Evaluate and improve irrigation practices and measure soil water storage status when irrigating or fertilizing
- ✓ Measure and adjust for carry-over, residual N - think about all available N sources)
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Considerations for a Nitrogen Management "Decision Plan"

- **Evaluate N needs based on a realistic yield goal**
  - Are yields limited by soil properties & hard to change?
  - Realistic long-term averages helpful, adjust for current year or improving conditions or capabilities
  - Consider and evaluate if newer cultivars and higher yield goals impact estimates of N responses and needs

Changes in yield potential of crops change over time with new cultivars, improved practices, etc.

Considerations for a Nitrogen Management "Decision Plan"

⦿ Consider a "credit" based on prior crop residues

- Vegetable, field crop, alfalfa will differ, and potential organic N contributions will not fully show up in soil test nitrate evaluations
- Some of the impacts of crops in the rotation are from incorporation of crop residues, and some are associated with synthetic fertilizer, compost or manure applications and the degree to which crops intercept and utilize these N sources
- Mineralizable N tests improving, but still are time-consuming and typically too expensive and variable to provide answers for management decision-making

How deal with great diversity in crop rotations in annual crop fields – *Is California different?*

- Vegetable crop / agronomic crop rotations with large differences in applied N associated with high yields
- Rotations that shift between shallow-rooted crops and deeper-rooted crops (affects ability to "capture" nitrogen in different parts of soil profile)
- Legume crop N additions in non-legume crop rotations (some current FREP studies trying to better quantify estimates)
- Recognize that markets, price, and some years irrigation water supplies can be the primary driver in choice of crop (as opposed to optimum choice for best N management)

Crop rotations and upper soil N *(a few examples)*

Rotations likely to produce higher soil N during year cotton grown:

Cotton grown in rotation with:

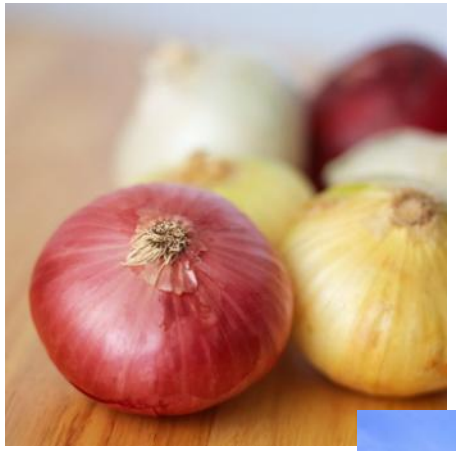
- **Shallow-rooted vegetable crops**
- **Garlic, processing tomatoes, field corn**
- **First year after alfalfa**

Rotations likely to produce lower soil N during year cotton grown:

Cotton grown in rotation with:

- **Several prior years of cotton in many cases**
- **Small grains**
- **Safflower, sugar beets**

Very broad range of crops, timing of production of crops and varieties to consider and fine tune



IRRIGATION MANAGEMENT IMPACTS IN SEMI-ARID AREAS – *it isn't just fertilizer mgmt that counts*

- **How well you control leaching losses can be affected just as much (or more) by irrigation practices** as by improved placement, timing and choice of supplemental N with fertilizer or amendment materials. Important considerations include:

  A) design, application uniformity

  B) match of irrigation practices, mgmt. with soil condition, intake characteristics

  C) lack of consideration of whether or not you are applying water in excess of soil water holding capacity in root zone?

  Affected large pre-irrigations, but also can be true with in-season irrigation management and particularly irrigations made to set transplants, germinate crops, etc. when we often are more focused on getting the plants established well and less focused on prevention of leaching losses.

Continuing changes in irrigation systems (Are fertilizer practices changed with systems? Often "YES"):

- MI / drip dominant in newer plantings for trees, vines, some vegetables, even agronomic crops
- More interest in pivots, linears, improved sprinklers
- Pre-plant irrigations reduced, practices changed
- Shorter-run lengths with furrow, flood considered, more monitoring
- MORE interest in sensor use (ET, irrig. system, plant & soil sensors)
- **Some changes in systems made to improve N mgmt. options, but seldom the primary motive (may change in future)*

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Timing of Applications / Reducing Potential Nitrogen Losses below the Root Zone

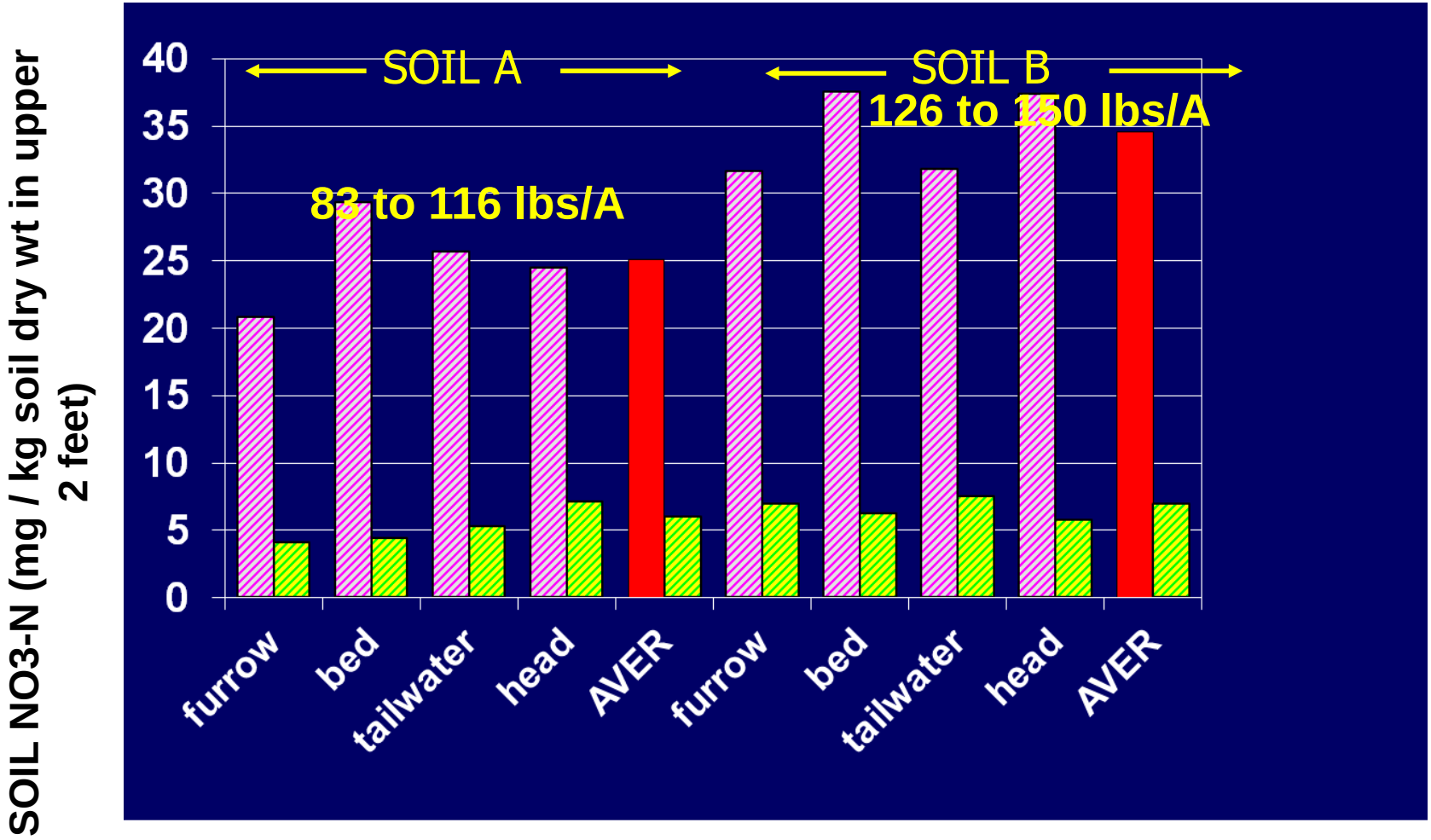
- **Avoid large winter pre-irrigations** (especially in combination with large front-end N fertilizer applications) – largely a thing of the past
- **Fall or winter application for a spring-planted crop**
  - Past work suggests with typical winter rain & temperatures, N fertilizer applied in ammonia forms would be converted to nitrate by planting time for spring crops – major reason why fall-early winter applications generally not recommended for these crops
- **Spring or late-winter applications for spring-planted crop**
  - Potential for losses affected by factors including:
    - Amount of nitrate in soil (affected by form of fertilizer applied, rate and timing of application, use of nitrification inhibitor)
    - Amount of water moving through soil (rainfall + irrigations) either on purpose (leaching) or naturally due to lack of storage capacity
    - Duration of periods of saturation of portions of soil profile - Leaching and soil saturation can be variable across fields, so makes it harder to predict

Field Variability – *experiences with irrigation water uniformity, yield variability & problem areas of fields*

- Can argue that one of the more valuable sets of knowledge producers / managers /consultants have is an understanding of:
  - weak areas of fields,
  - how the fields take in irrigation water,
  - inherent differences in factors such as infiltration rates and variability in soil water intake
  - big potential to also impact nutrient uptake versus movement below root zones

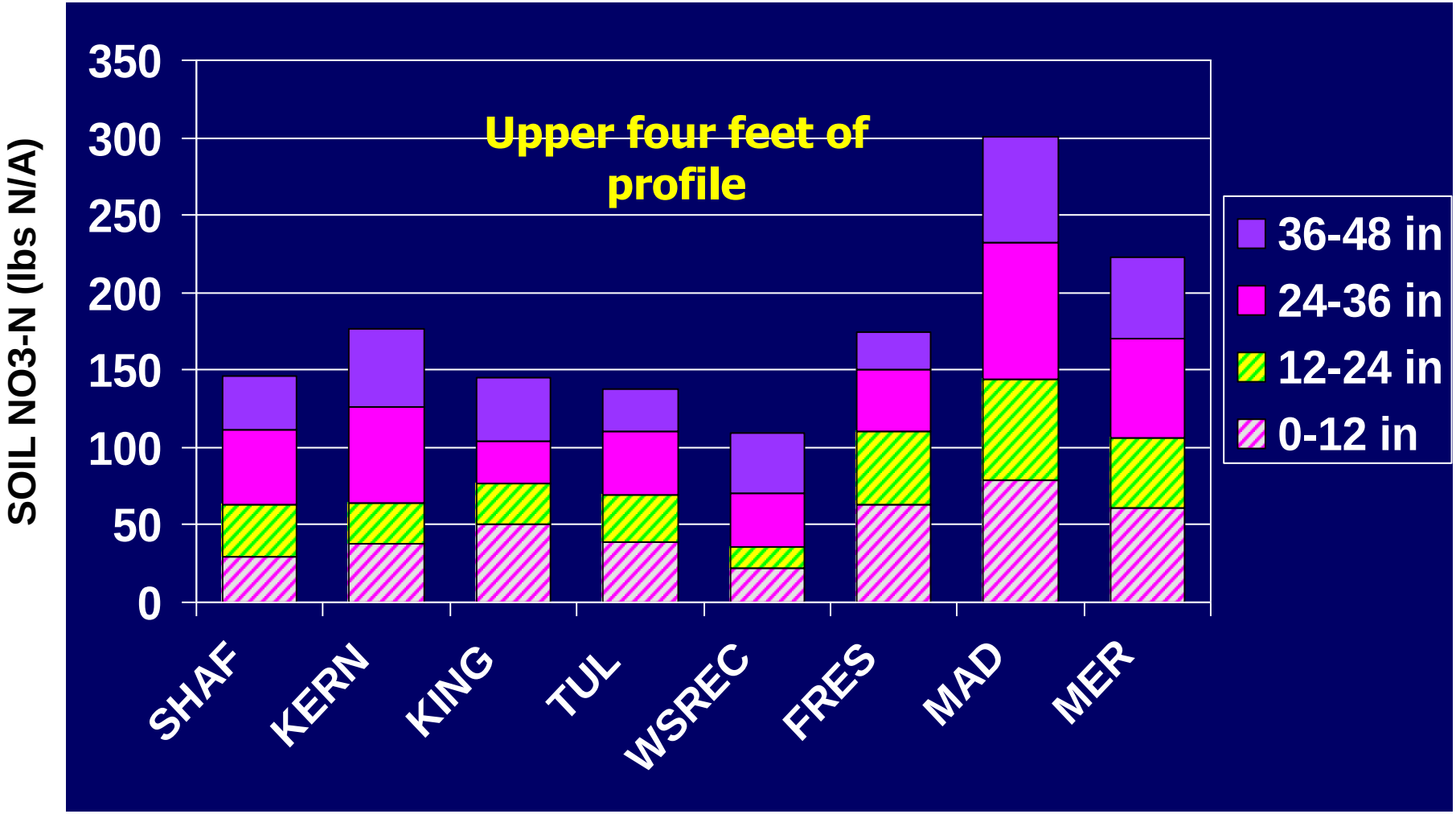
Variability in soil nitrate-N within fields *spring*

(upper 2 ft, pre-fertilize, 2 clay loam soils)



Nitrogen Project - Soil N by location

spring (pre-fertilize, near planting time data)



Fertilizer N losses – multiple factors influence potential losses?

N FORM IN THE SOIL – what happens after fertilize?

- IF applied fertilizer N or mineralized OM N stayed in the form of ammonium ions (NH4+), it would be attached to the negatively charged soil particles and residue, and in that ammonium form:
  - It would be much less prone to loss through leaching, and wouldn't be lost by denitrification (microbial conversion to N gas in saturated soils)
- However, the microbial process of nitrification (ammonia converted to nitrate) can readily occur over weeks, resulting in much of applied N converted to a form more susceptible to leaching.
  - Once in nitrate form, denitrification (also a microbe dependent process) can convert nitrate to N gas, also subject to losses
  - Nitrification: temperature has important effects (warmer=faster)
  - Denitrification: temperature, soil water content (accelerates when saturated, anaerobic conditions exist)

Considerations in Nitrogen management "Decision Plans"

- **Consider complexity of N sources and fates in the soils and production systems you have**
  - Plants can take up both ammonium and nitrate forms of N, but in most agricultural soil conditions, nitrate is typically present in greater quantities than ammonium, so often the focus and recommendations are on measuring nitrate in soils
  - Where this may be a less accurate assumption (nitrate more prevalent than ammonium) could be when you are evaluating organic production fields, fields incorporating green cover crops or high levels of organic matter, or with true slow-release specialty fertilizers. Under these circumstances, nitrate recommendations & guidelines developed under more conventional synthetic N fertilizer practices may be less accurate and less useful.

Some fertilizer N characteristics with potential to impact handling, timing of use and losses

General Considerations:

- The rate at which different N fertilizers convert from their initial composition into nitrate (and then be more susceptible for losses) can be considered along with price, handling characteristics, etc.

- In no-till or limited till situations, even lower volatilization potential N fertilizers should be placed in contact with soil and below the bulk of the plant residue if possible

- When making applications of fertilizer, consider the physical impacts of soil moisture conditions, application method (shanked in, etc.), & timing of application on soil compaction, other issues that could affect plant uptake, use and growth

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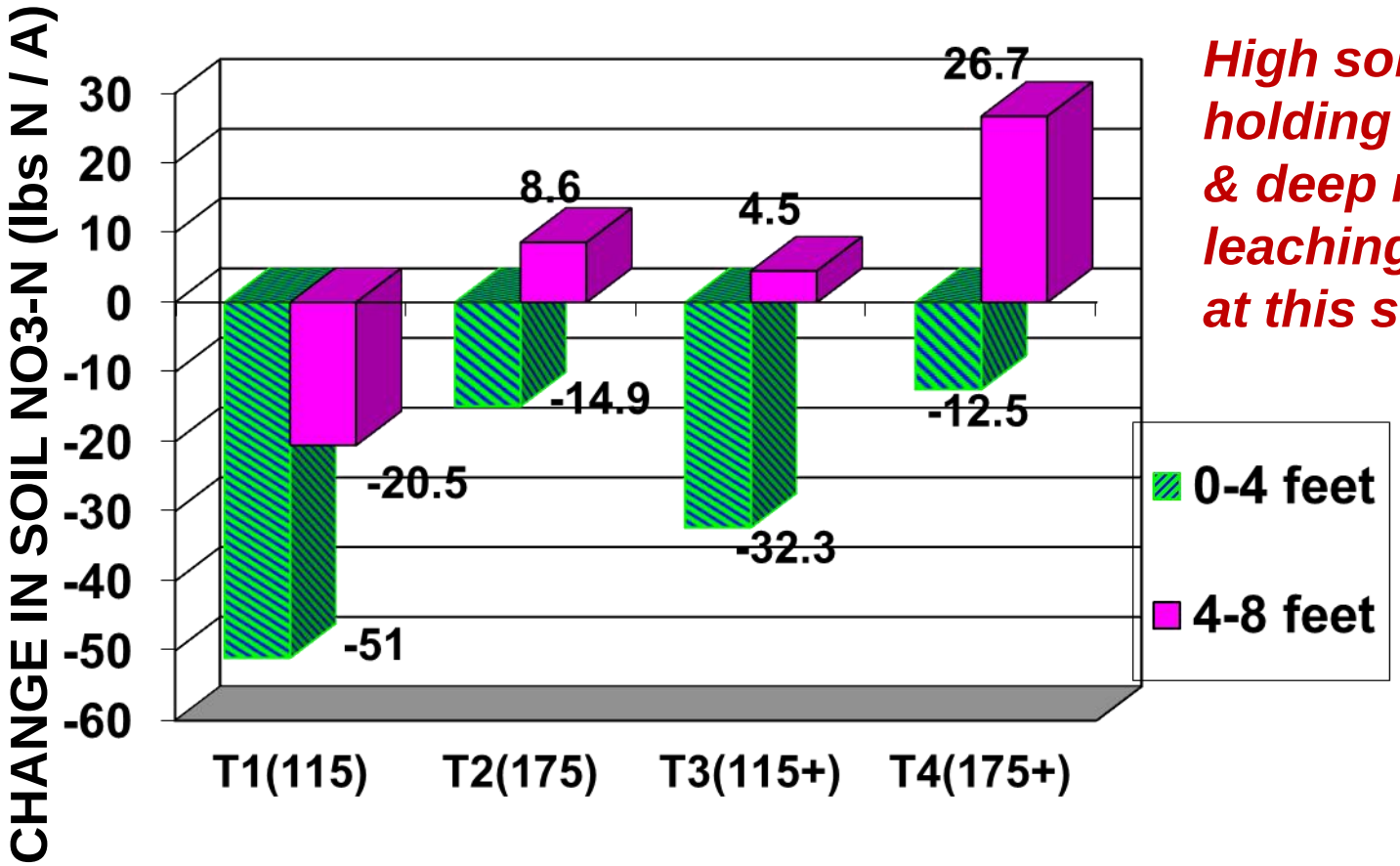
Split N application treatments - Examples

- **T1** = 115 lbs N / acre *(applied plus residual determined as NO3-N in upper 2 ft soil profile)*
- **T2** = 170 to 180 lbs N / acre *(applied plus residual NO3-N in upper 2 ft soil profile)*
  - *1st fertilizer application made May-early June*
- **T3** = 115 lbs N / acre *(as in T1, but with supplemental N (sidedress or water-run for 55-60 added lbs N / acre)*
- **T4** = 170 to 180 lbs N / acre *(as in T3, but with higher initial application amount*
  - *Supplemental water-run application with 2nd irrigation or dry sidedress (generally within 7-14 days after 1st bloom)*

Where does soil nitrate end up? Rate & Timing Impacts

Change in Soil NO3-N (Fall minus Spring) *WSREC site – year 1*



High soil water holding capacity & deep roots limit leaching potential at this site

NITROGEN TREATMENT

Discussion issues –
Research and provision of Crop-Specific N data

In developing research projects or providing data that end up being used in regulatory programs, how do we best provide crop-specific N responses / removal and water use data?

Some questions could include:

- Best methods used to estimate crop N uptake versus removal across a range of yield potentials – how avoid over- or under-estimating these #'s since in the future some limits may be imposed based on these numbers
- Since there always will be variability associated with soils, year, climate with this kind of data, how do we provide information that considers:
  - A range of production conditions (soil types, yield potential limits or different responses based on climate, versus other production issues such as deficit irrigation, saline water use, etc.)

Discussion issues –
Research and provision of Crop-Specific N data

- Some Options or Best Practices for improved Nitrogen Management will be / could be related to minor to major <u>changes in irrigation management or changes in irrigation systems.</u> With that in mind:
- How do we provide information on components of improved practices for nitrogen management without dictating that a change in irrigation system will be required *(unless that is recommendation that we want to deliver?)*
- Consider that for some agronomic crops (lower to moderate-value crops), a change to relatively high cost irrigation systems may be difficult to rationalize as compared to coupling that change in irrigation system with shifting to a higher profit-potential crop.
- *Thanks for the opportunity to pose some questions & not provide answers.*

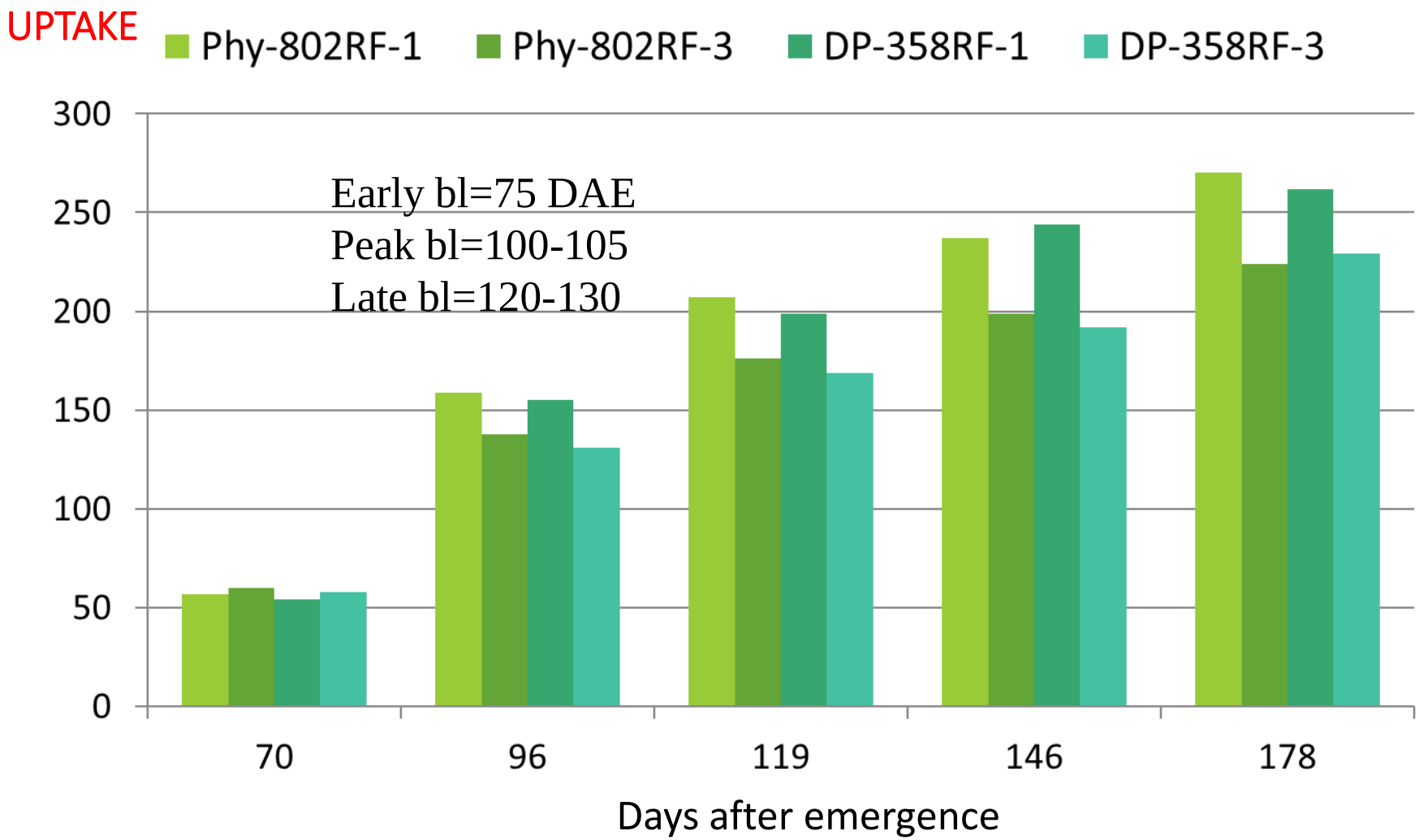
Discussion issues –
Research and provision of Crop-Specific N data

- Some questions could include:
- *Do we know for many of the major agronomic crops if there are:*
  - Cultivar differences in N uptake, removal at similar yield levels?
  - Differences in N response or uptake associated with sub-sets of major crops (ie. Pima cotton versus Upland / Acala types, different types of small grains)
  - If some of the numbers to be used in these regulatory programs are based on older data sets or data from outside California, how do we assess utility of that data for current use, or make a case for new work to re-assess N supply responses and removal?

Some examples using cotton data

NITROGEN UPTAKE above-ground plant parts (lbs/ac) as a function of days after planting – Drip Irrigated PIMA varieties – 2014 DEFICIT IRRIGATION TREATMENTS

Yields Irrig Trt 1 = 1887, 1710 lbs/ac Irrig Trt 3 = 1940, 1679 lbs/ac



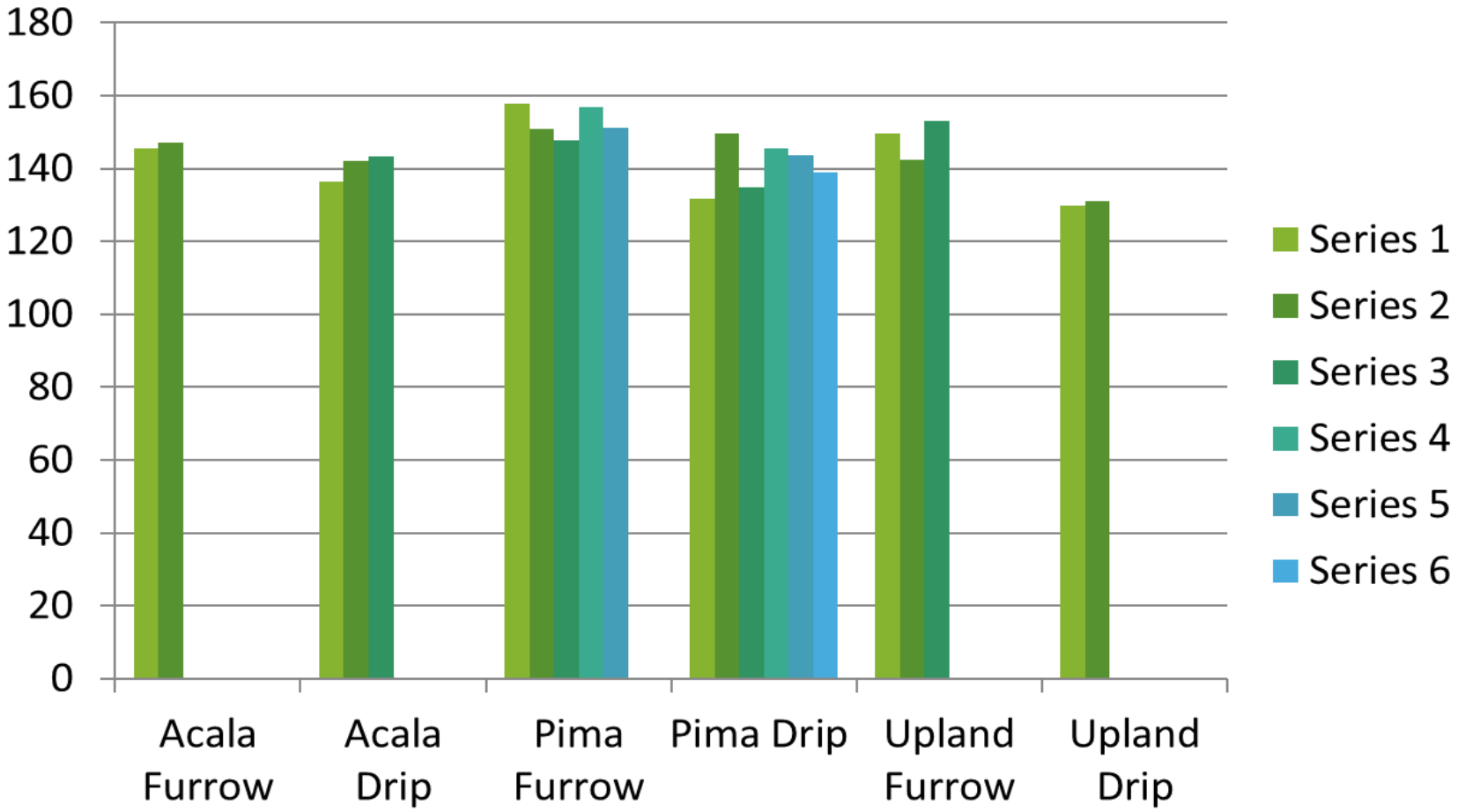
Above Ground Plant Nitrogen Uptake (kg/ha)

Cultivar / Type	Irrigation Level	Irrigation Method	Lint Yield (kg/ha)	Pre-harvest N Uptake(kg/ha)
Phy-802 Pima	Deficit	Drip	1557	202
		Furrow	1486	186
	Full	Drip	2103	298
		Furrow	1977	265
Phy-725 Acala	Deficit	Drip	1691	210
		Furrow	1555	183
	Full	Drip	1989	263
		Furrow	2380	302
FM-1830 Upl	Deficit	Drip	1685	201
		Furrow	1589	181
	Full	Drip	2258	283
		Furrow	2040	261

Cotton – UC West Side REC studies

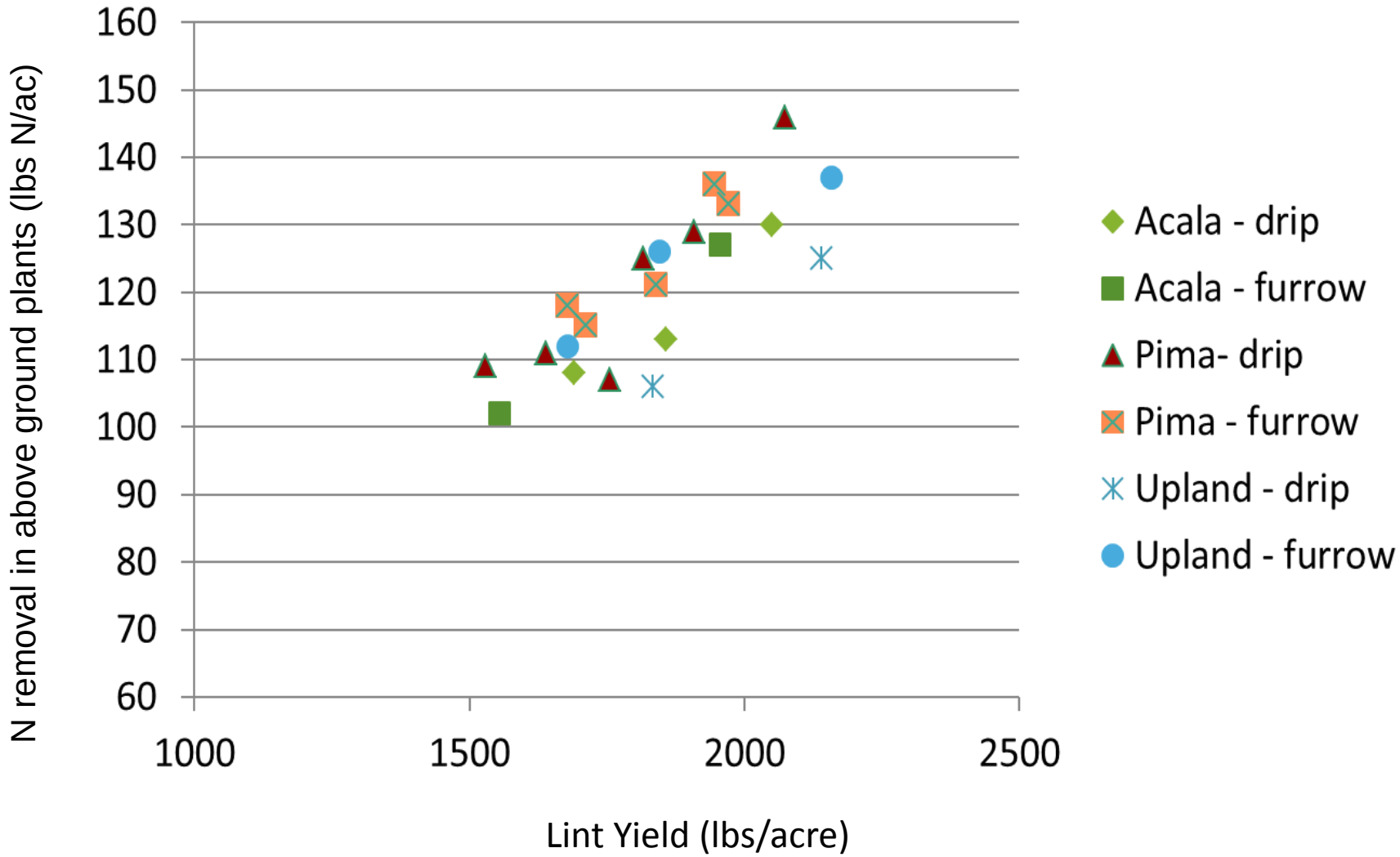
N Removal (lbs N / ton of lint yield) as a function of **cotton type** and **irrigation method**

(Acala = Phy-725RF only; Pima = Phy-802 RF and DP-358 RF only; Upland = FM 1830 GLT and FM 2484 B2RF only)



Cotton – UC WSREC studies

N Removal (lbs N/acre) as a function of lint yield, cotton type and irrigation method



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Thank you

Support for Cotton N Studies was from:

1) CA State Support Committee, Cotton incorporated
2) CDFA Fertilizer Research and Education Program (FREP)
3) University of CA West Side REC, UC Davis Plant Sci Dept
4) Shafter Research Station

University of California
Agriculture and Natural Resources

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- **Consider complexity of N sources and fates in the soils and production systems where you have:**
  - N additions come as synthetic fertilizers, crop residues, cover crops, manures and dairy lagoon water
  - N removed via crop harvest and removal, leaching & volatilization
  - N can be tied up in organic forms that only slowly become available, or in microorganisms for eventual release, which can be released through mineralization at rate impacted by many factors (microbial populations, temperature, moisture, residue amounts)
  - Soil organic matter breaks down & ammonium can be released for later transformation into nitrate (this gets us to the same point as ammonium fertilizers, where ammonium can be converted into nitrate)