



Characterizing N Fertilizer Requirements of Crops Following Alfalfa

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See: <http://alfalfa.ucdavis.edu>

Alfalfa – A Cash and Rotation Crop

- ❑ 19 million acres US – 1 million CA
- ❑ 4th largest economic crop in US
- ❑ \$1.3 billion in CA – largest acreage crop
- ❑ Grown in rotation with:
 - Corn/small grains (US)
 - Corn/grains/tomato/cotton/vegetables (CA)
- ❑ Life of stand typically 4-6 years
- ❑ ~150-200 K acres rotated annually (CA)



Alfalfa - Wisconsin



Alfalfa-Pennsylvania



Alfalfa – New York State



Alfalfa - Idaho



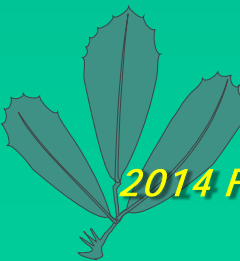
Alfalfa South Dakota



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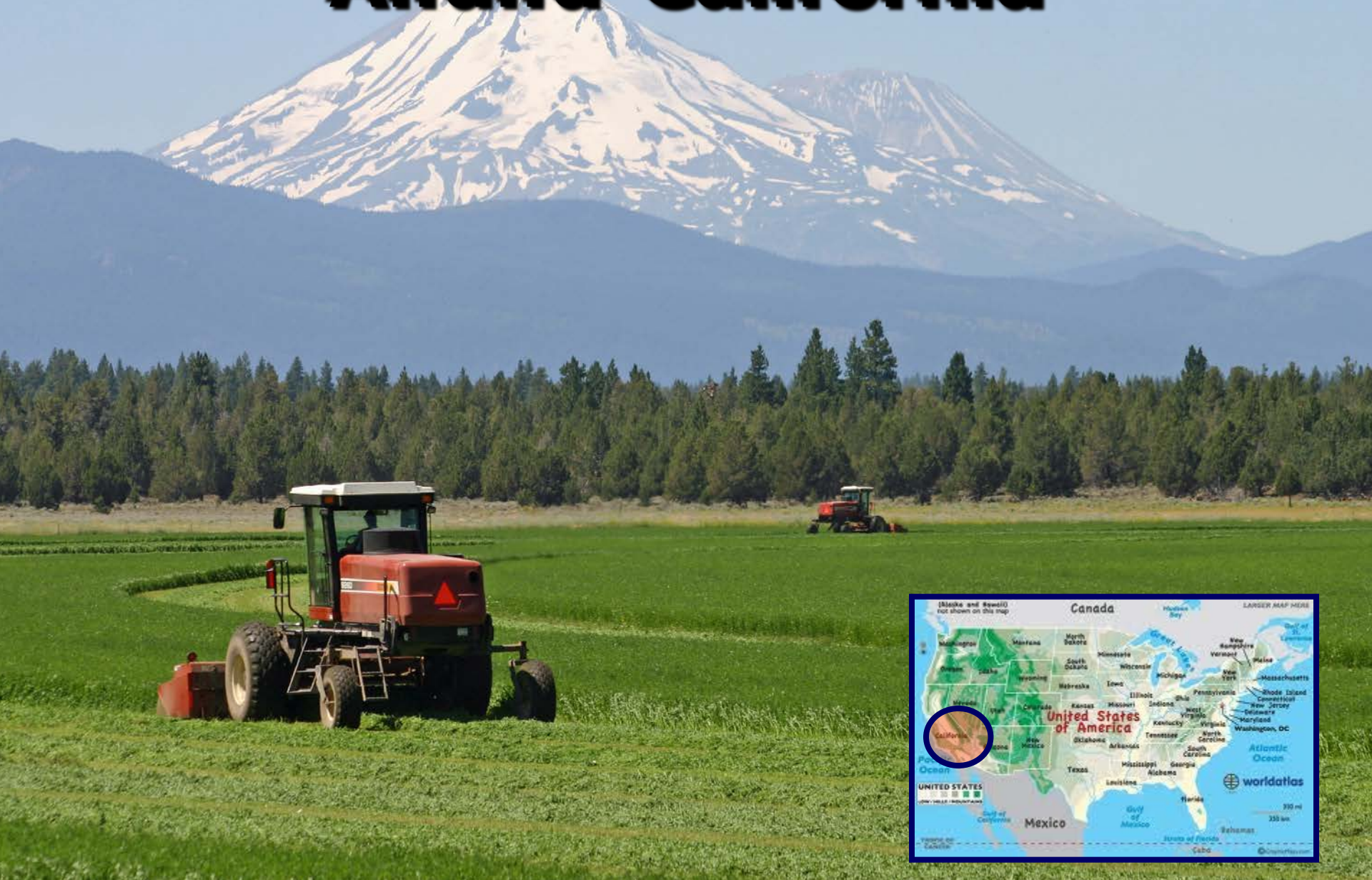
Arizona



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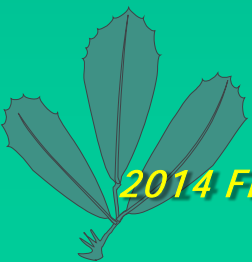
Alfalfa-California



Alfalfa fixes atmospheric N₂ and can contribute N to the soil



Source: http://commons.wikimedia.org/wiki/File:Medicago_sativa_root_nodules.JPG

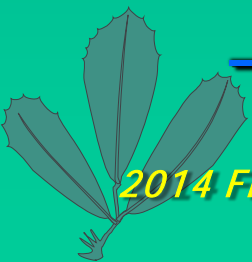


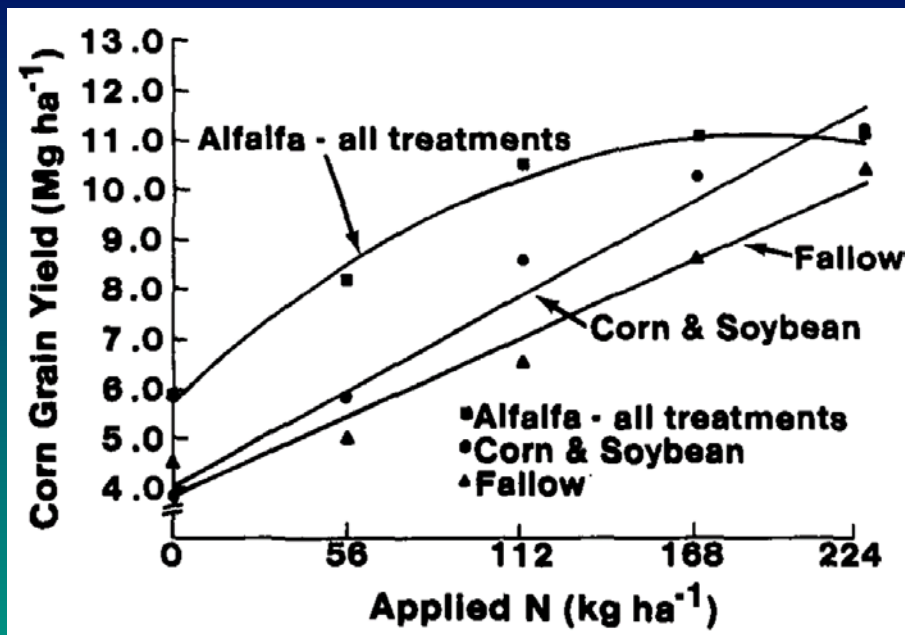
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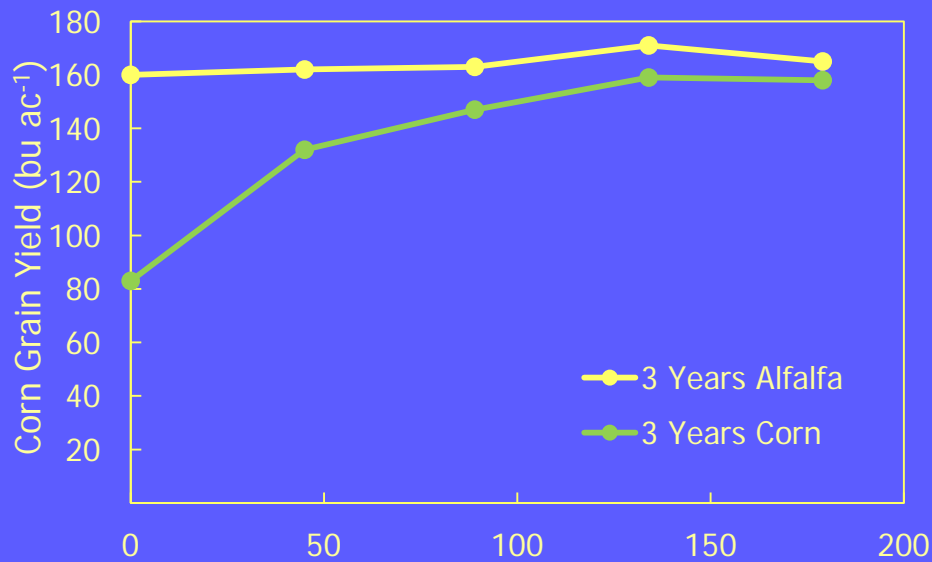
Key Issues with N in alfalfa

- How much of the N needs of the plant are satisfied by N_2 fixation?
 - 70-90% (no fertilizers recommended)
- Will the crop take up nitrate from the soil?
 - Yes, effective nitrate scrubber
- What is the contribution of alfalfa N_2 fixation to subsequent crops?
 - It depends

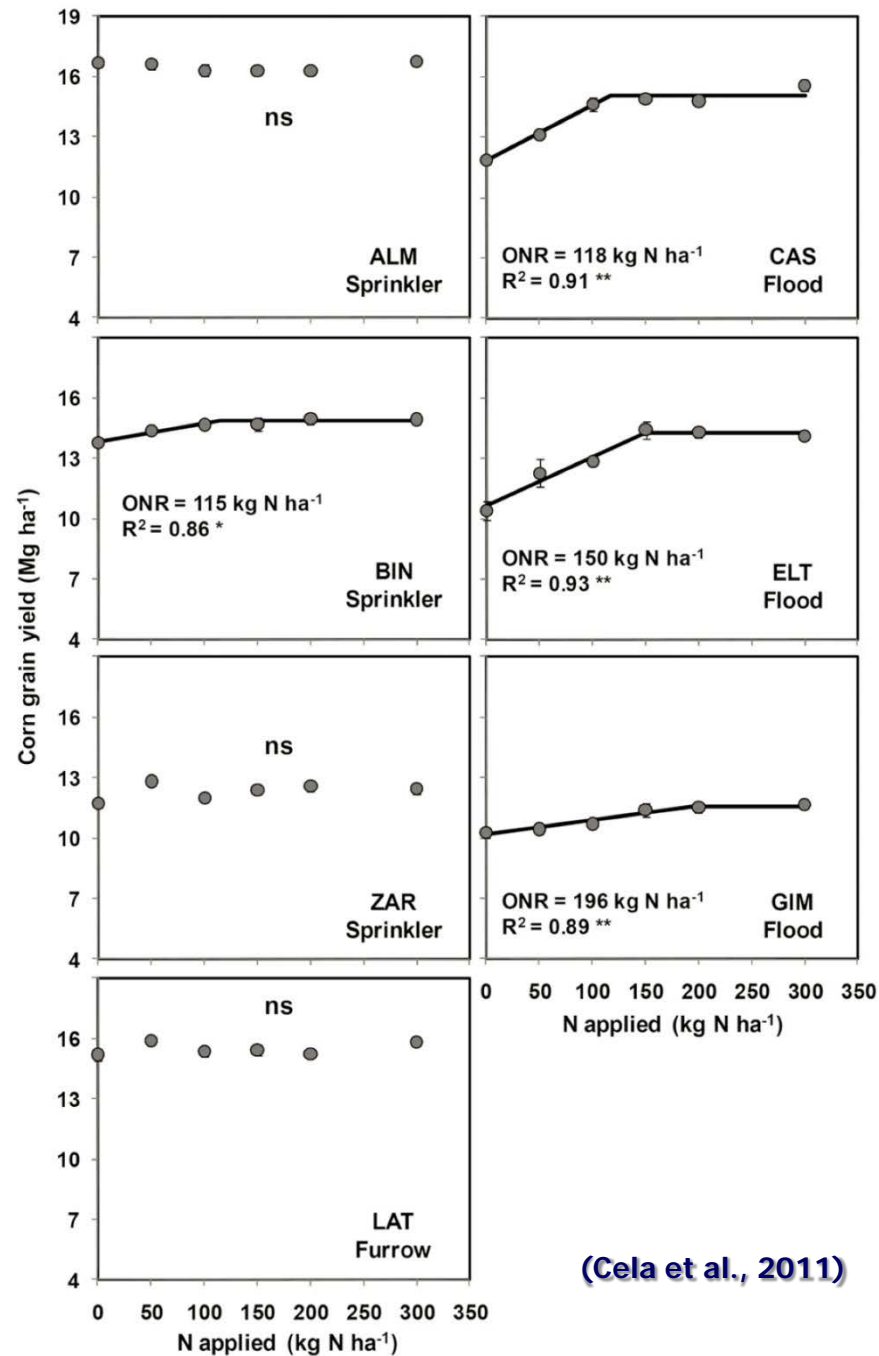




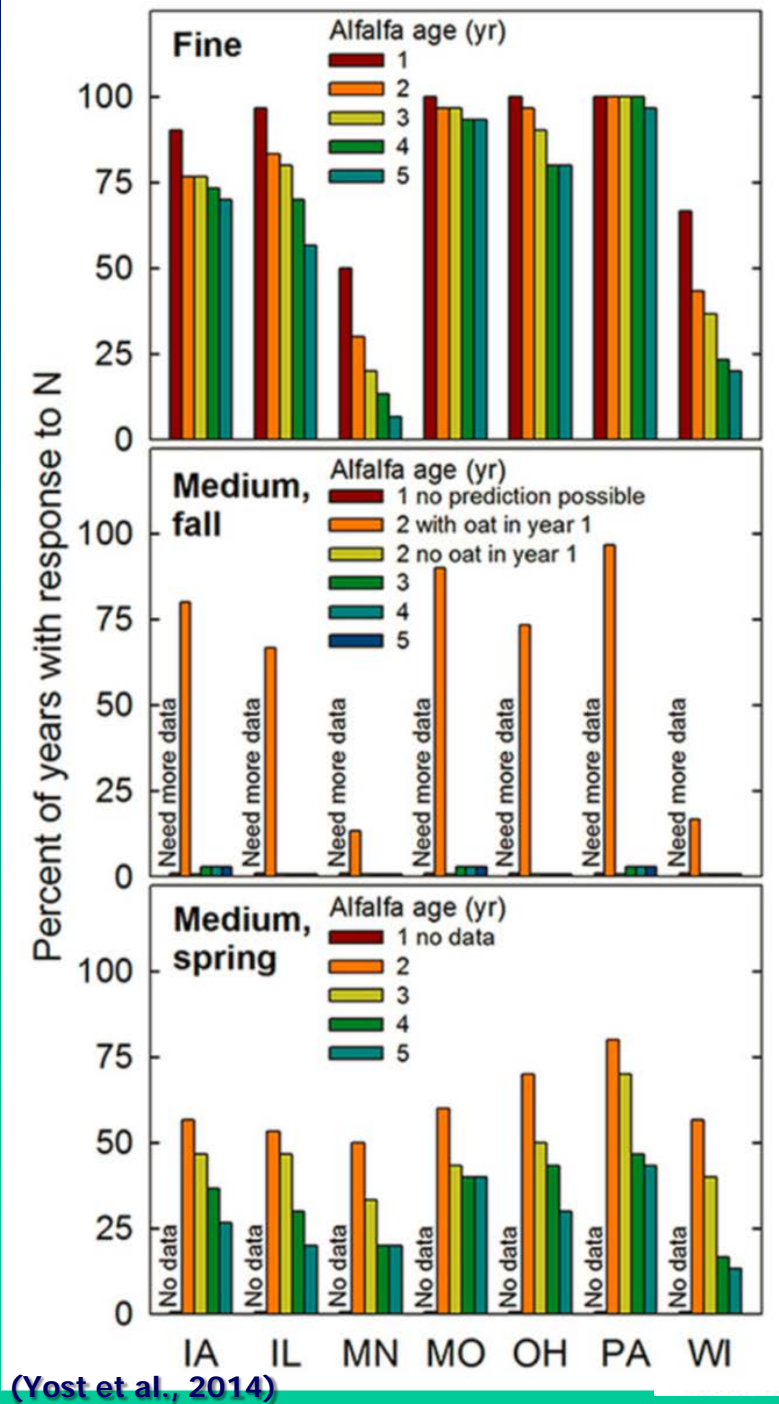
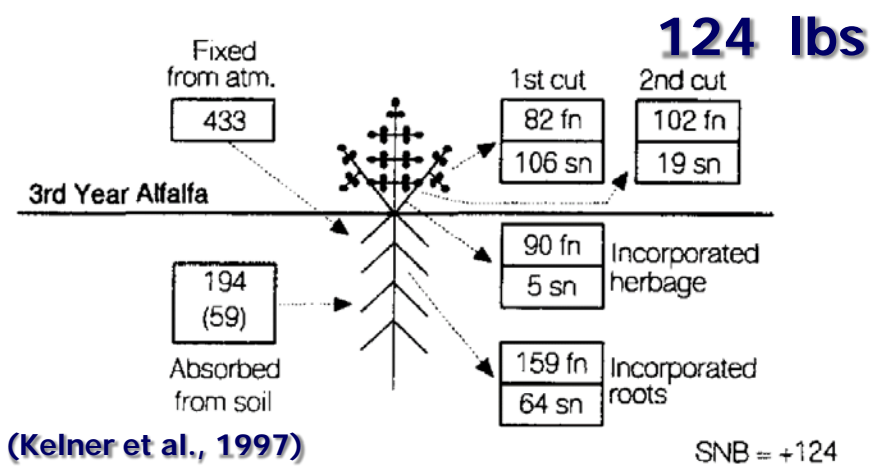
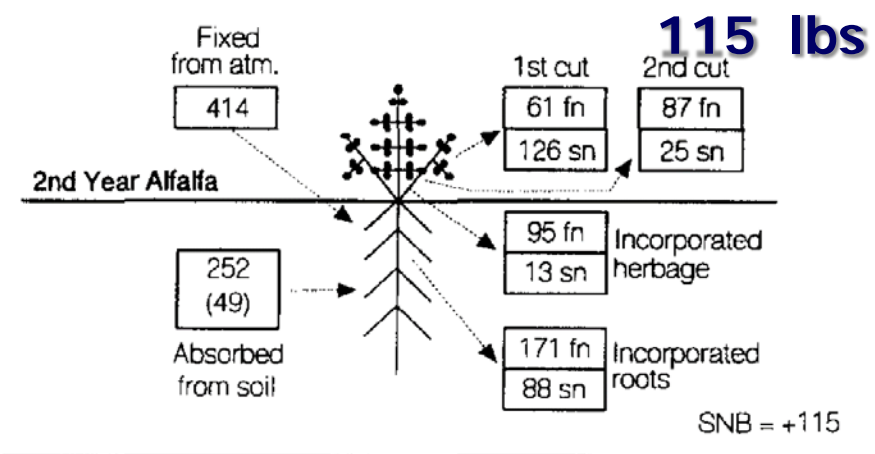
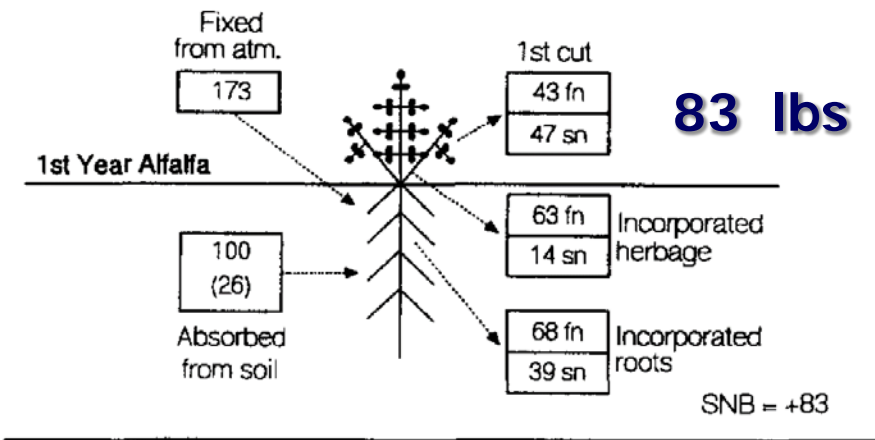
(Hesterman et al., 1986)



(Fox and Piekielek, 1988)



(Cela et al., 2011)



(Yost et al., 2014)

Alfalfa forage in CA can remove 250-1000 lbs N/acre per year...

Table 1. Crop removal of Nitrogen at different alfalfa yield and protein levels. Shaded area indicates most likely range for California Central Valley locations.

	Crude Protein of Alfalfa Forage					
	16	18	20	22	24	26
Tonnage (t/a)	%Nitrogen in Forage					
	2.56%	2.88%	3.20%	3.52%	3.84%	4.16%
	Crop Removal of N					
	lbs N/acre					
5	256	288	320	352	384	416
6	307	346	384	422	461	499
7	358	403	448	493	538	582
8	410	461	512	563	614	666
9	461	518	576	634	691	749
10	512	576	640	704	768	832
11	563	634	704	774	845	915
12	614	691	768	845	922	998

Shaded area represents most likely outcome

...and most of the nitrogen comes right out of thin air!

Estimating Nitrogen Credits



Nitrogen Credits for Alfalfa and Soybean in Wisconsin

First year credit:	medium & fine textured soils		sandy soils	
	> 8 inches of regrowth	< 8 inches of regrowth	> 8 inches of regrowth	< 8 inches of regrowth
Alfalfa (stand density)	Nitrogen Credit (lb N/acre)			
Good(70-100 % alfalfa, > 4 plants/ft ²)	190	150	140	100
Fair(30-70 % alfalfa, 1.5 - 4 plants/ft ²)	160	120	110	70
Poor.....(0-30 % alfalfa, < 1.5 plants/ft ²)	130	90	80	40

Second year credit: In the second cropping year following fair and good stands on medium and fine textured soil, you can take a 50 lb N/acre credit.

Soybean

40 lb N /acre is available to crops following soybean in a rotation. No credit on sandy soils.

Nitrogen Credits around the World

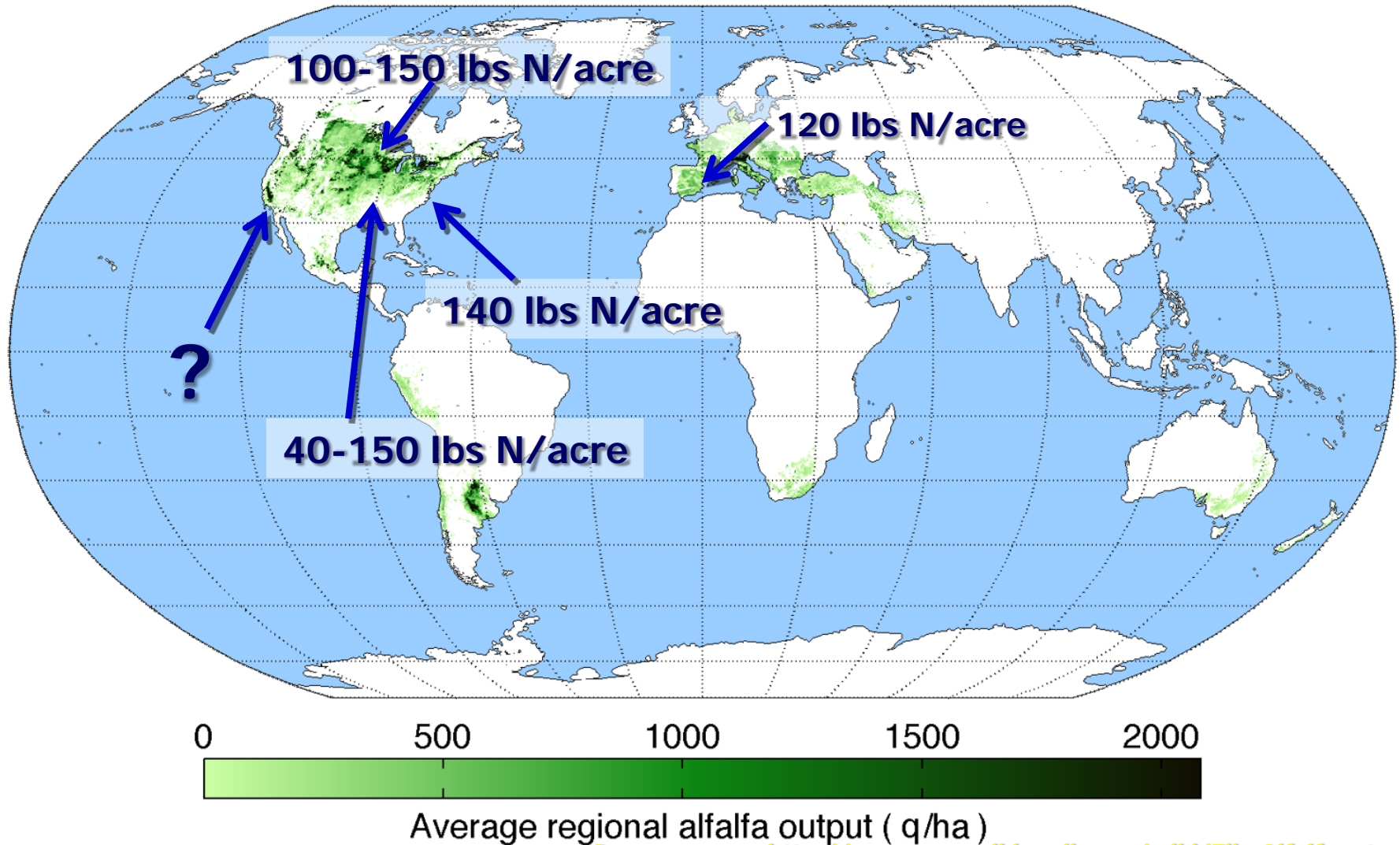


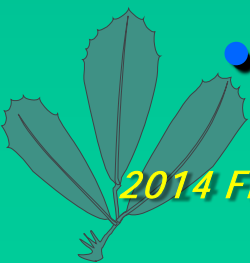
Image source: <http://commons.wikimedia.org/wiki/File:Alfalfaoutput.png>

How much N is contributed to subsequent crops?

- **Depends on:**
 - Location
 - Temperature
 - Soil moisture (irrigation)
 - Soil texture
 - Alfalfa growth, stand age, stand density
 - Mineralization rate

Developing Nitrogen Credits for California:

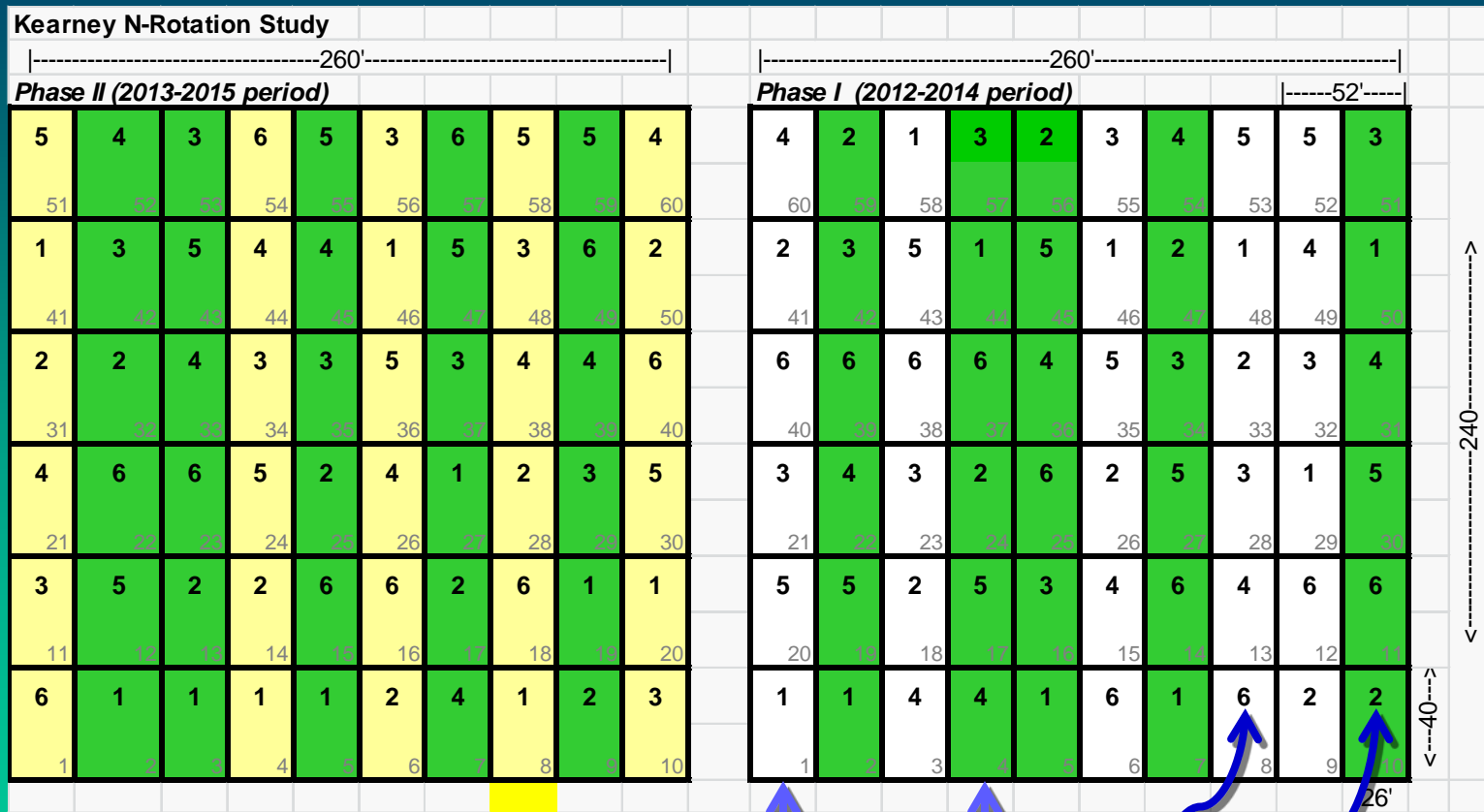
- **Two Rotation Treatments:**
 - Continuous Alfalfa (3+ years)
 - Grain Rotation (Sudangrass/Wheat) for at least 1.5 yrs
- **Three Locations:**
 - Davis (Solano County)
 - Kearney (Fresno County)
 - Tulelake (Siskiyou County)
- **Six Nitrogen Rate Treatments in Wheat:**
 - 0, 50, 100, 150, 200, 250 lbs N/acre



Field Layout (Kearney)

Phase II (2014-15)

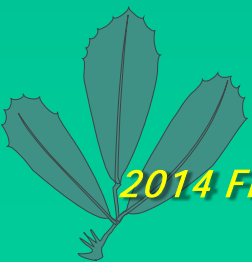
Phase I (2013-14)



Grains

Alfalfa

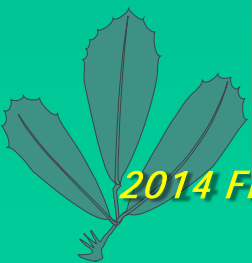
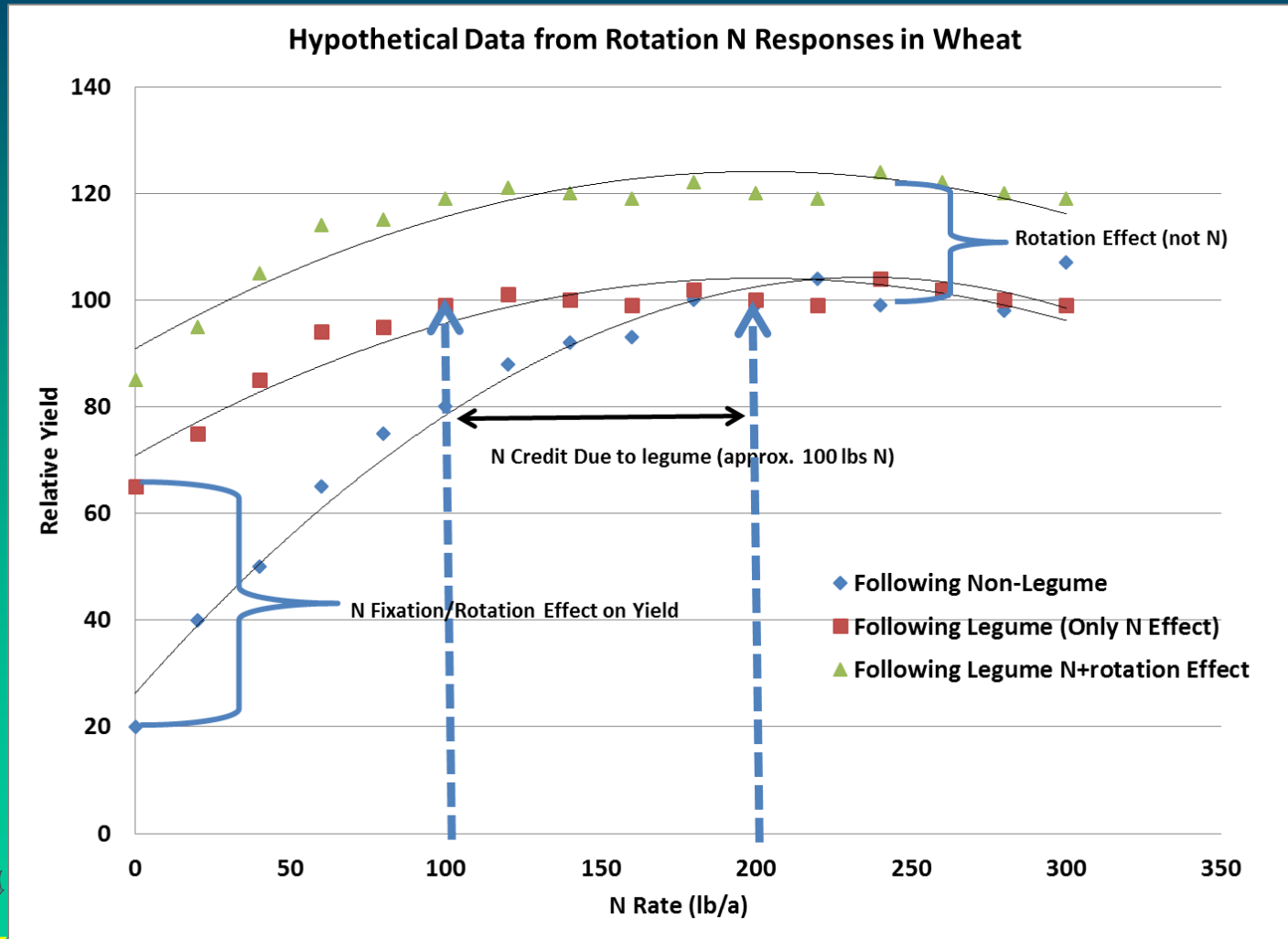
N Rates



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Developing Nitrogen Credits for California – wheat as bioassay



Rotation Study Treatments

Continuous Alfalfa and Grain Rotation

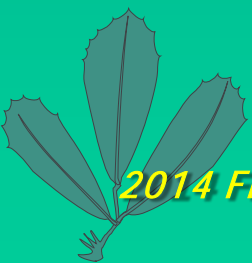


Tulelake



Davis

(Kearney site not pictured)



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Rotation Study Treatments

N Treatments in Wheat following Alfalfa and Grains

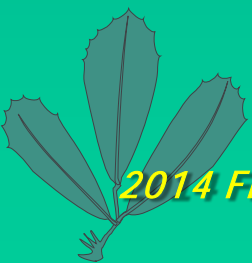


Tulelake



Kearney

(Davis site not pictured)



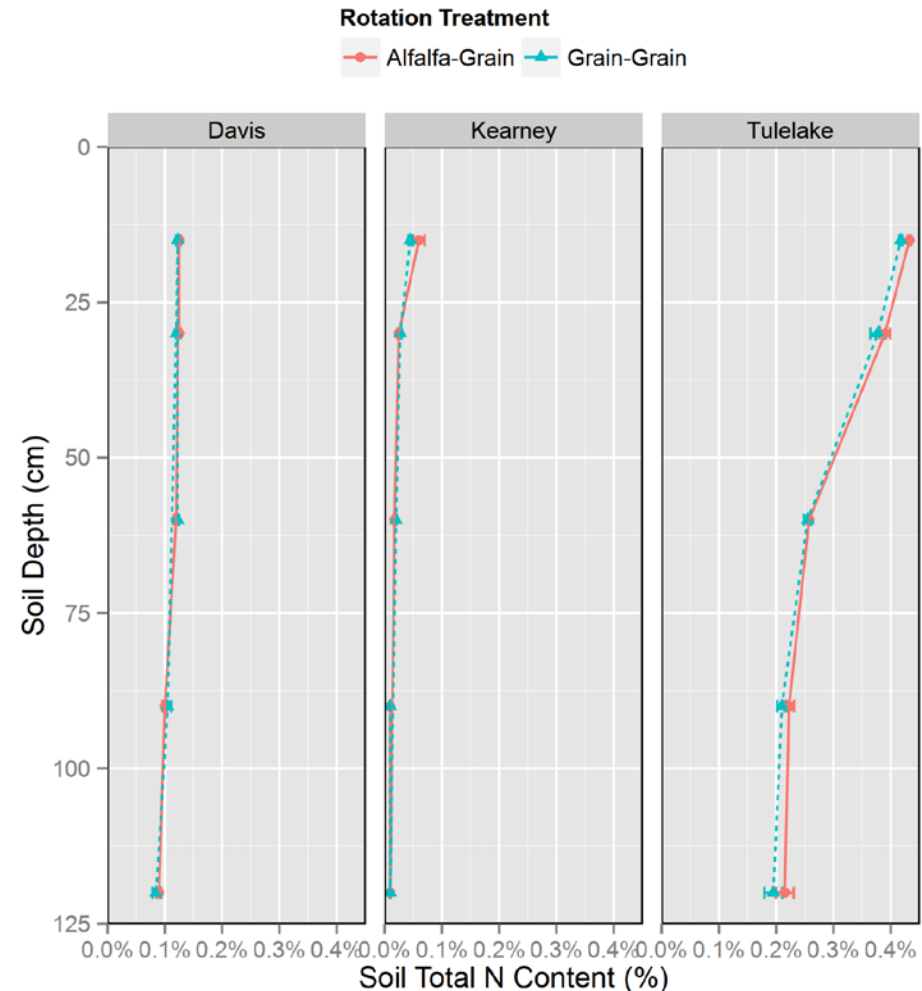
How much do soil tests say?

- Continuous alfalfa maintained relatively high soil nitrate concentrations compared to grain rotation
- Much less than 25 ppm NO_3^- optimum
- Soil total N was not significantly affected

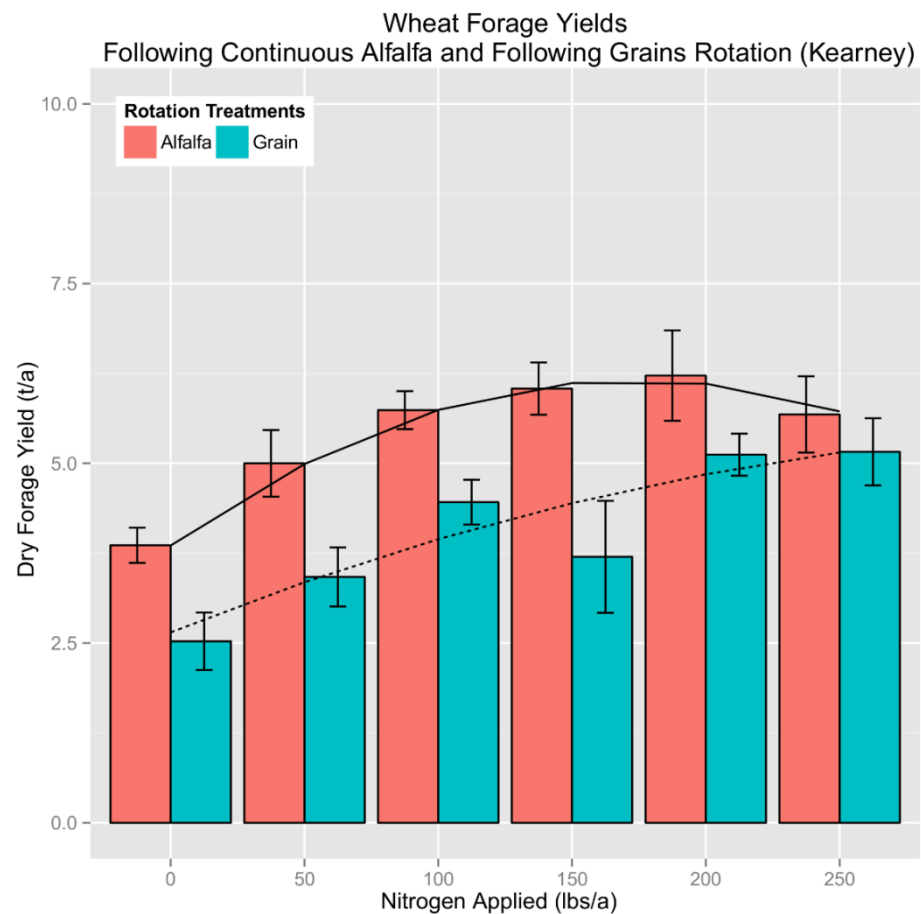
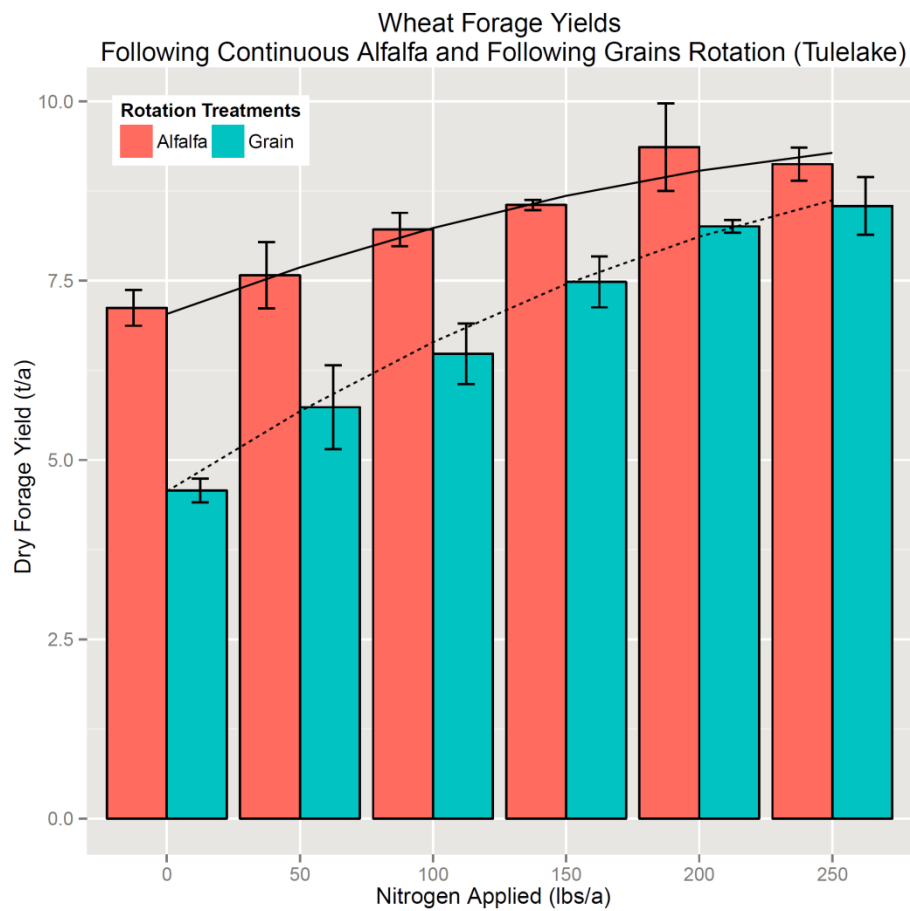
Nitrate Concentrations in Top 30 cm of Soil

Rotation Treatment	Continuous Alfalfa-Grain	Grain Rotation-Grain
Davis	6.79 ppm	2.86 ppm
Kearney	5.148 ppm	0.4925 ppm
Tulelake	6.95 ppm	3.97 ppm

Soil Total N Content by Depth
After Continuous Alfalfa and after Grains Rotation
At Davis, Kearney, and Tulelake



Wheat following alfalfa benefited from fertilization at Tulelake and Kearney



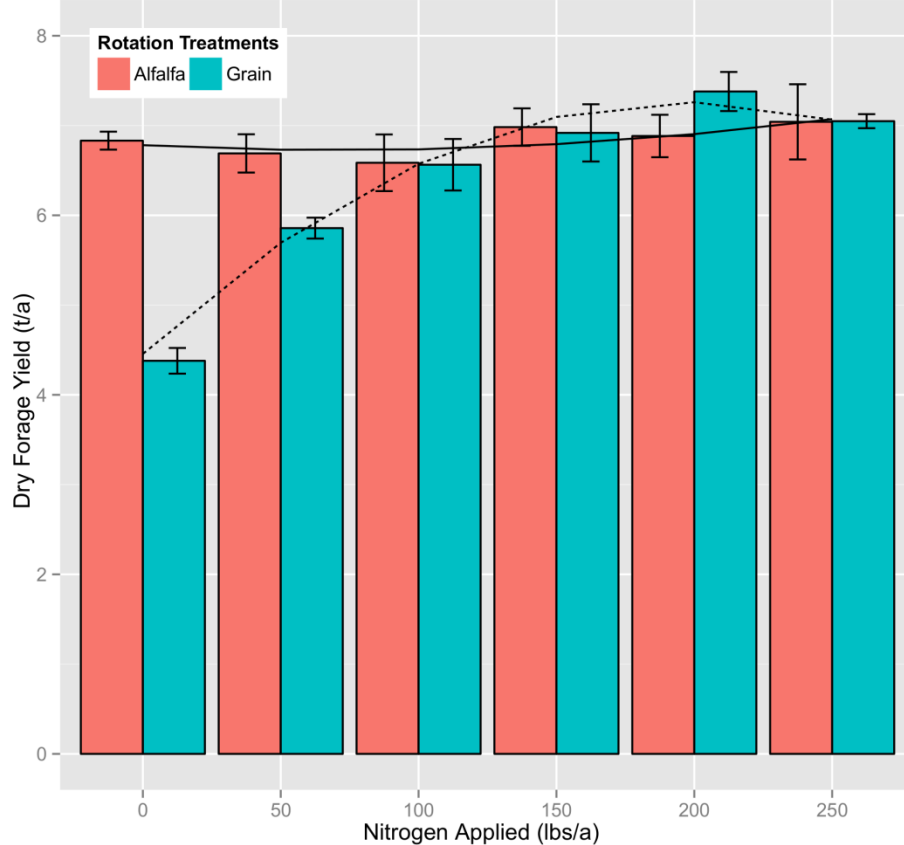
Tulelake
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Kearney

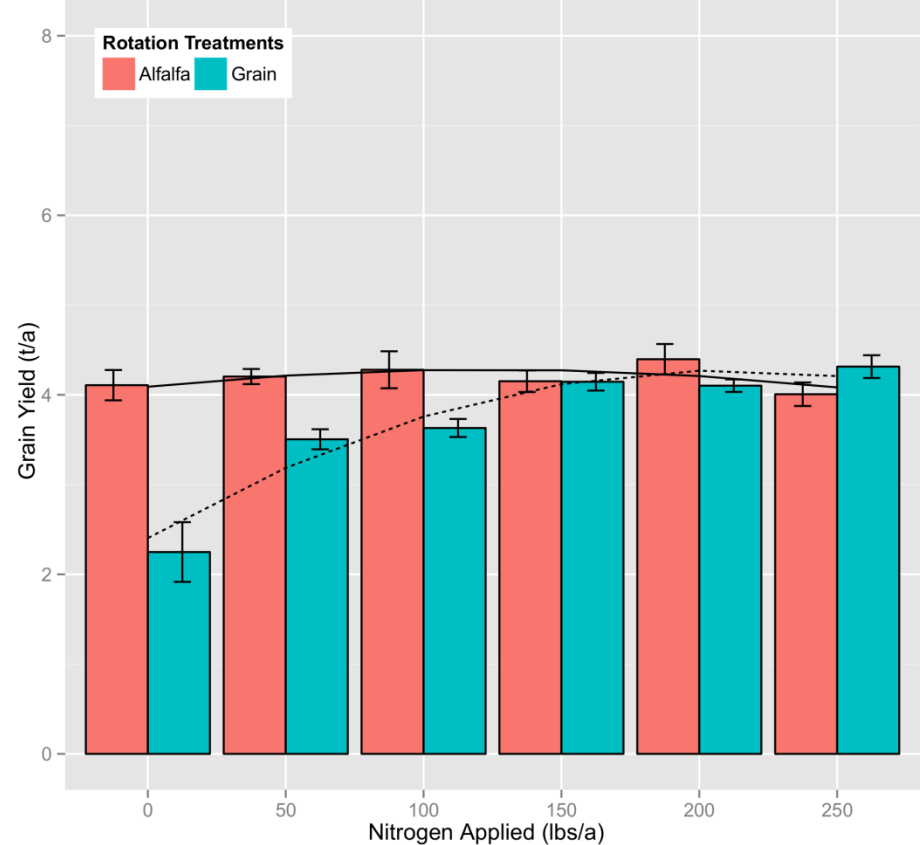


Wheat following alfalfa did not respond to N fertilization at Davis

Wheat Forage Yields
Following Continuous Alfalfa and Following Grains Rotation (Davis)

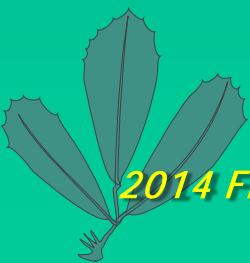
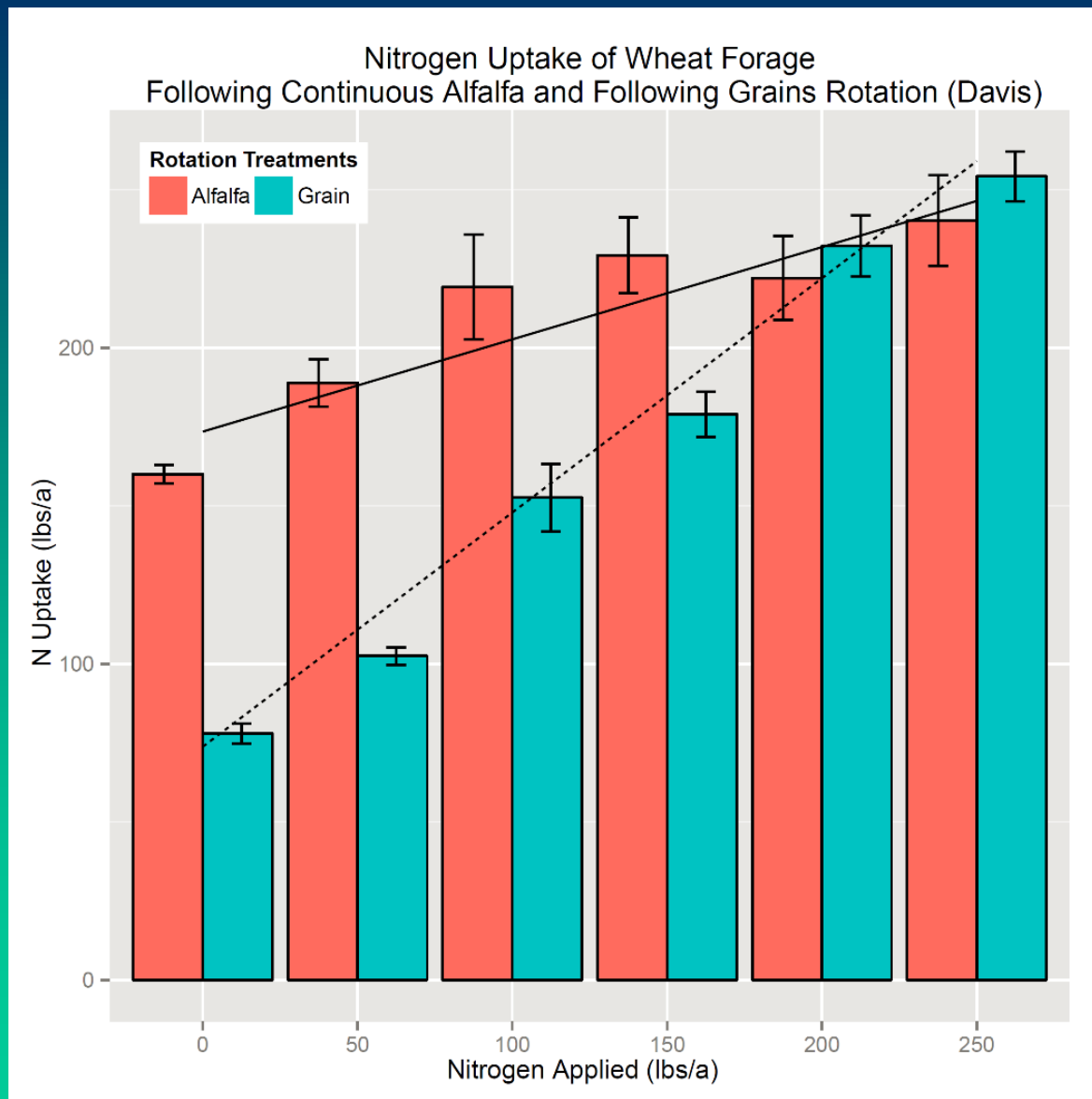


Wheat Grain Yields
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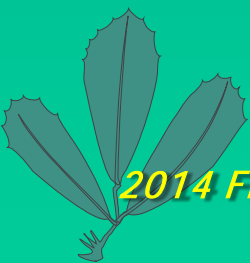
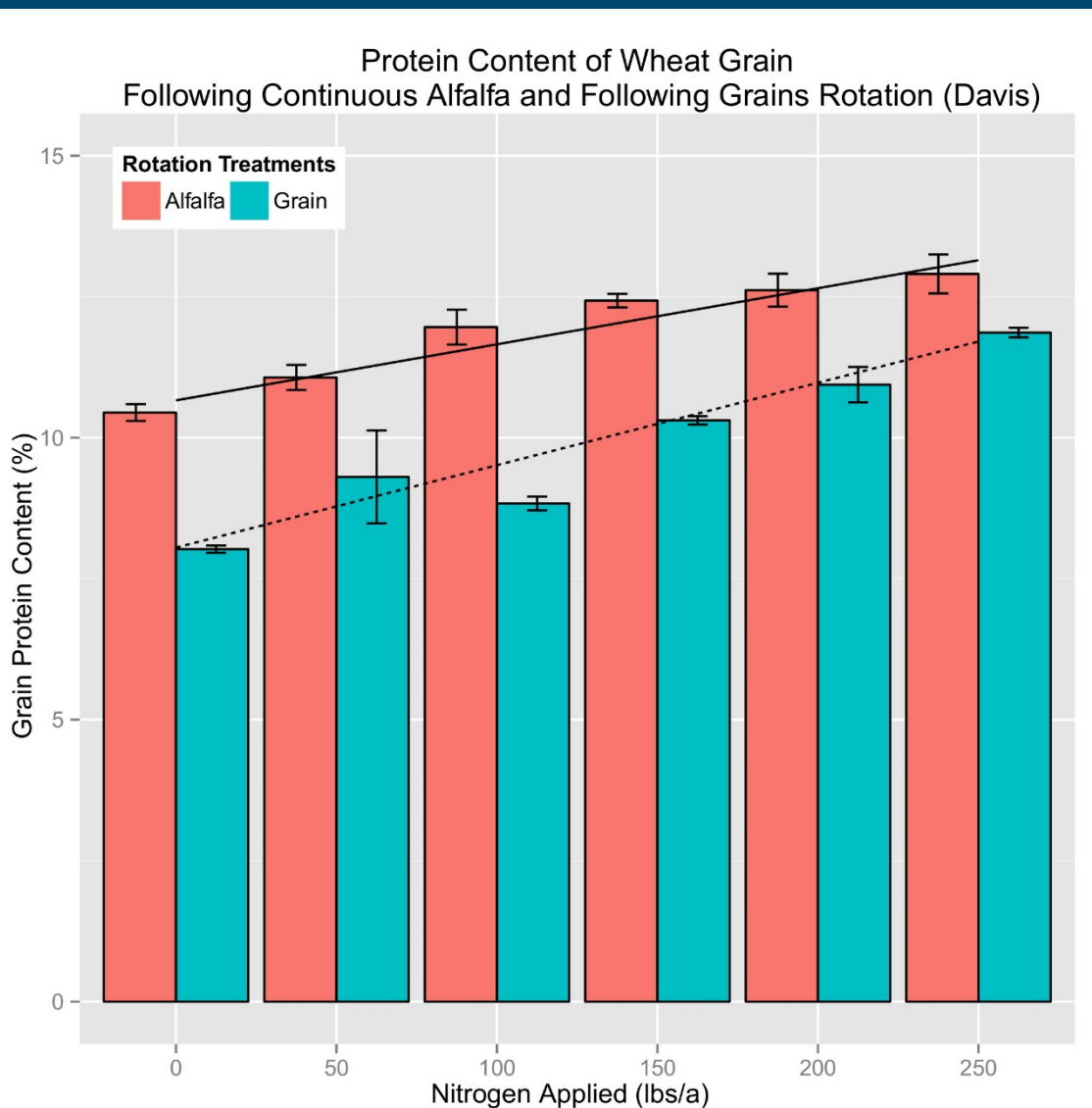
What about N uptake at Davis?

- Same yield, but different N uptake and forage protein content
- Forage protein content was between 6% and 11%

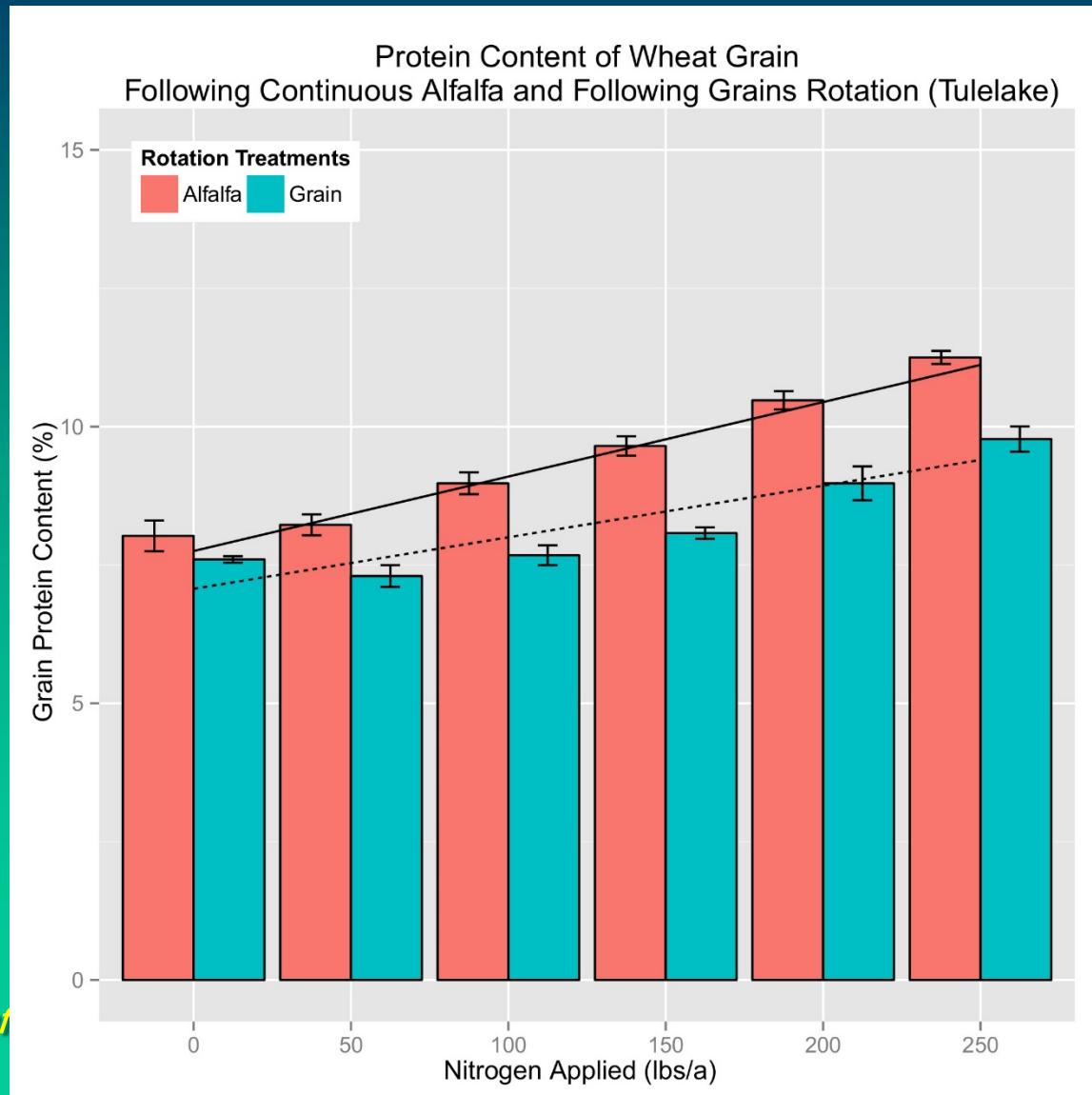


Continuous alfalfa treatment benefited grain protein content at Davis

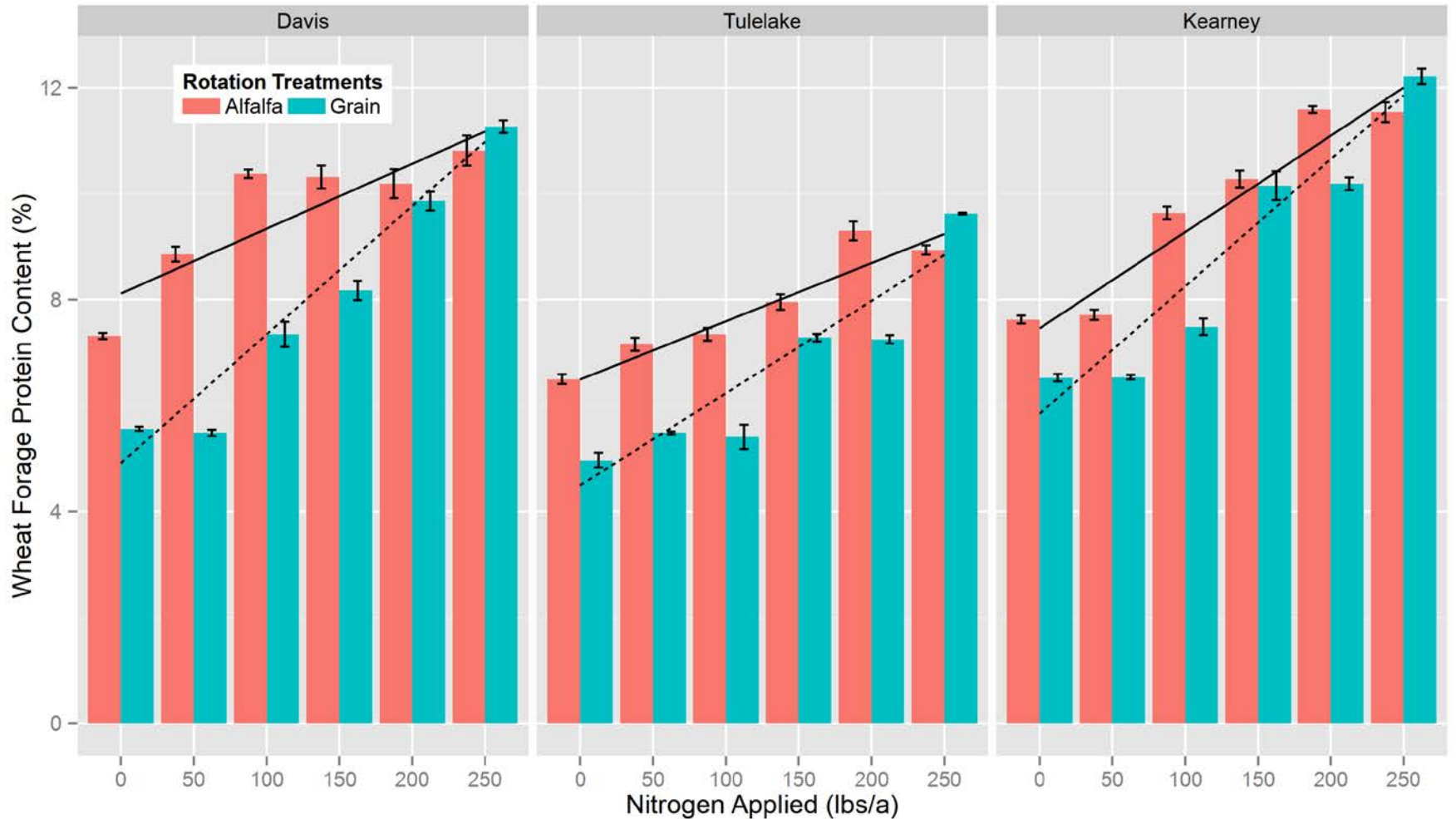
Fertilization helped increase protein content, so N from alfalfa satisfied N needs for high yields.



Continuous alfalfa also benefited grain protein content at Tulelake

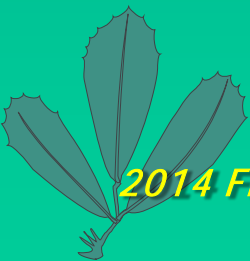
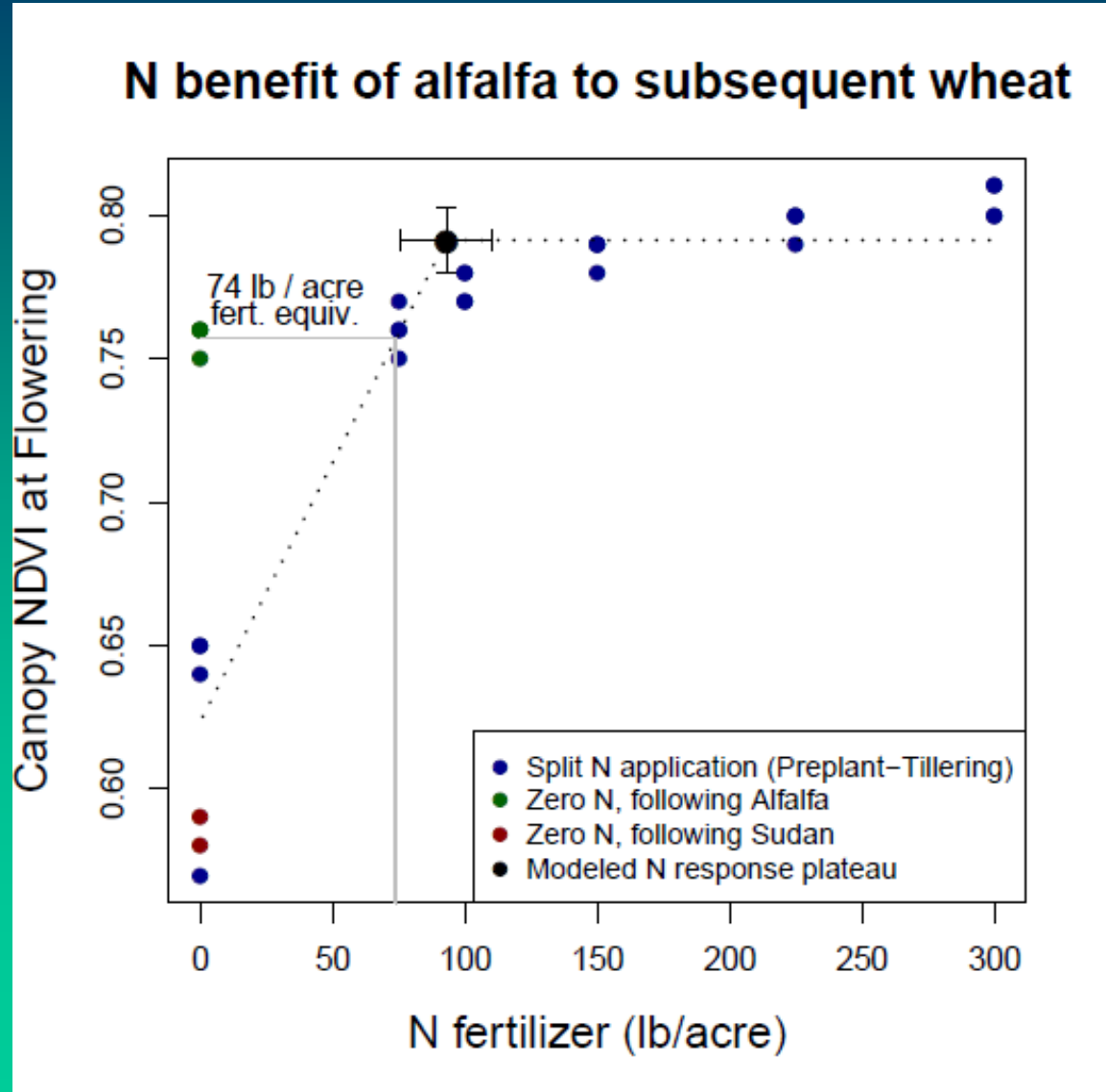


Wheat forage protein content was likely only affected by alfalfa's N contribution



Utilizing Plant Samples to estimate rotation value:

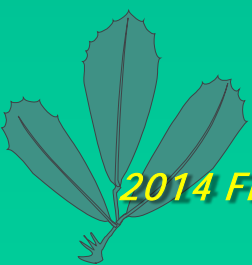
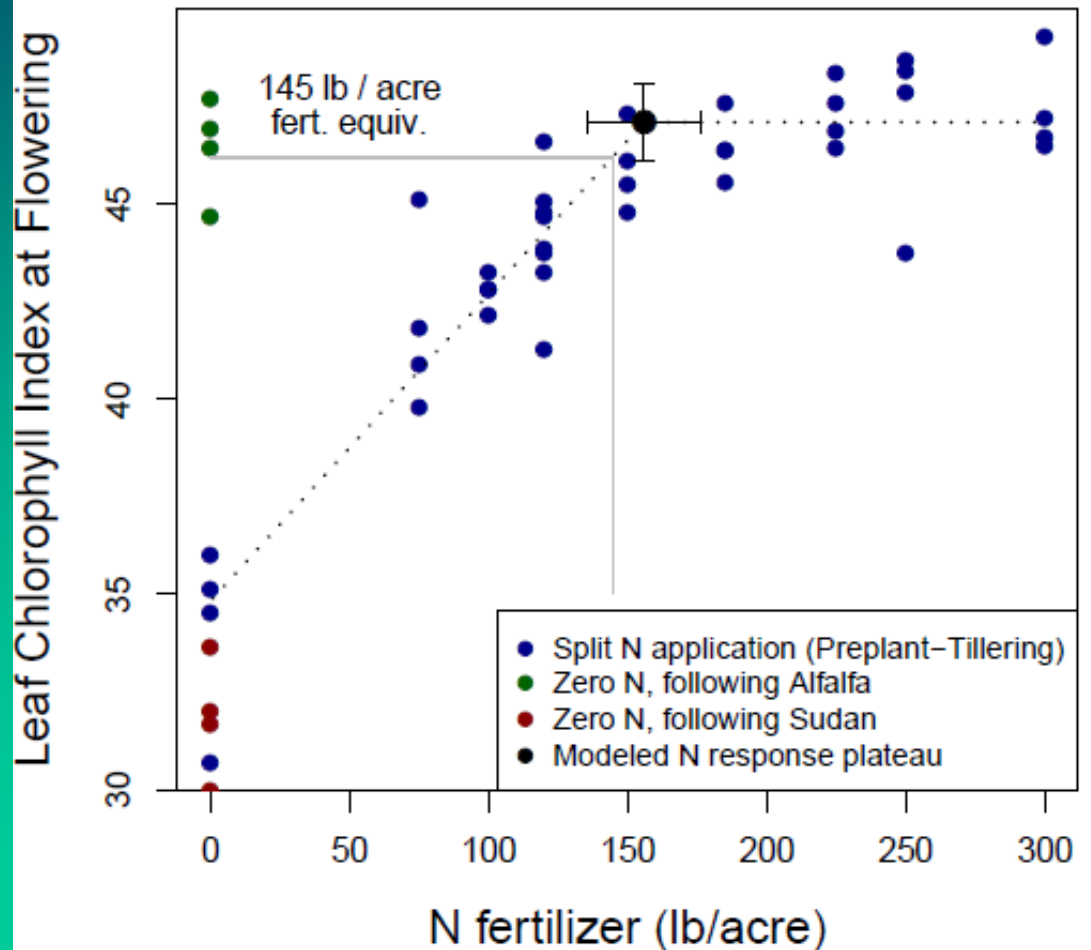
□ NDVI prediction



Utilizing Plant Samples to estimate rotation value:

Leaf Chlorophyll Index

N benefit of alfalfa to subsequent wheat



Conclusions

- **Based on forage yields, without considering economic N rates, alfalfa's N contribution was:**
 - **80-100 lbs N/acre at Kearney (Coarse Soil)**
 - **100-150 lbs N/acre at Tulelake (Medium-Textured Soil)**
 - **100-150 lbs N/acre at Davis (Medium-Textured Soil)**
- **Alfalfa provided enough N to satisfy wheat crop at Davis.**
- **Benefits to grain protein - More N increased grain protein content.**
- **Non-N rotation effects may have been at play at Tulelake and Kearney**

Further Work

- ❑ **Phase II: Replications – Year effects.**
- ❑ **Predictability of Soil Residual N?**
- ❑ **Predictability of early plant measurements?**
- ❑ **Generalized (integrated) recommendation for California's rotations which consider stand, other factors**



Many thanks!



References

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- ❑ Yost, M.A., Russelle, M.P., Coulter, J.A., 2014. Field-specific fertilizer nitrogen requirements for first-year corn following alfalfa. *Agronomy Journal* 106, 645. doi:10.2134/agronj2013.0416

