University of California

Nitrogen Management Training

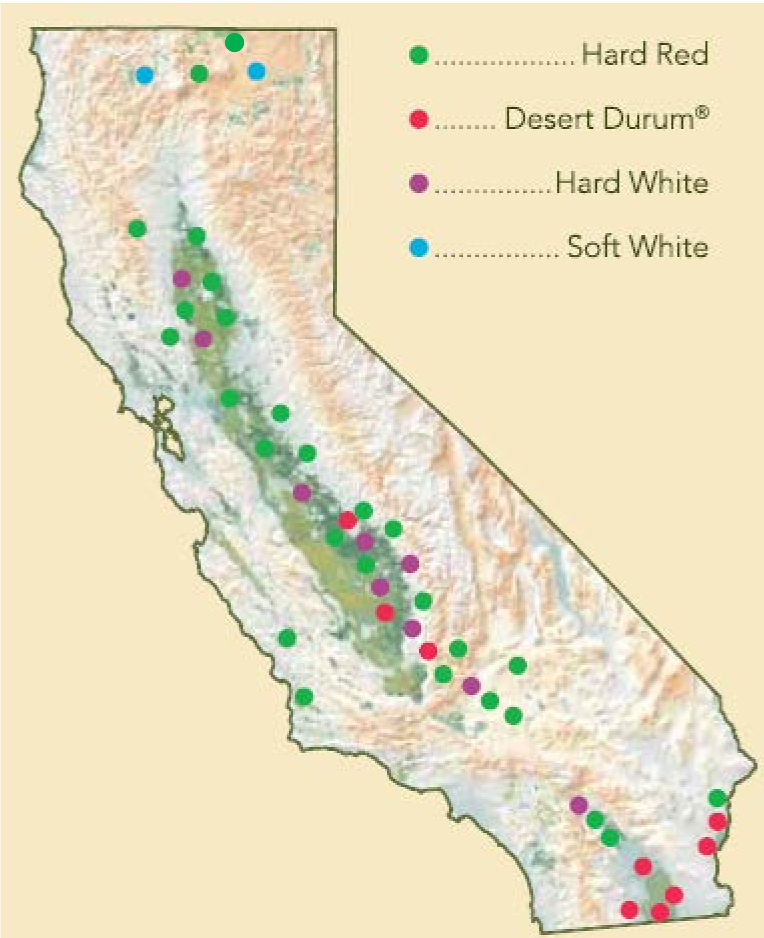
for Certified Crop Advisers

Nitrogen Management in Wheat

UC Cooperative Extension | University of California Agriculture and Natural Resources

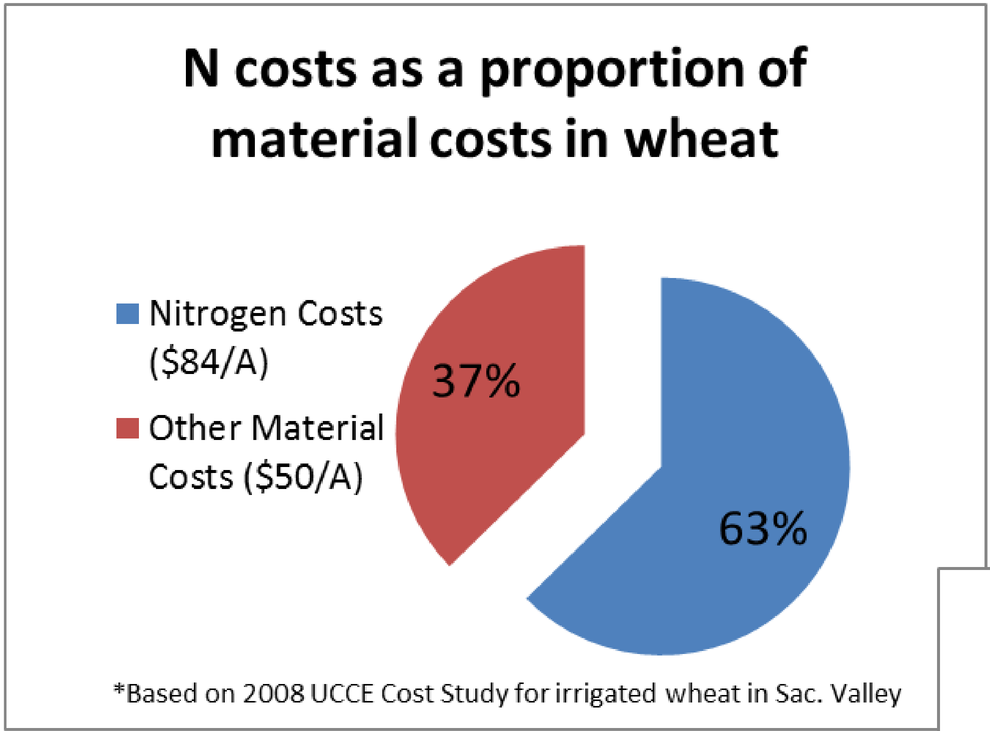
Regulatory and Agronomic Background

Spring Wheat Production in California:



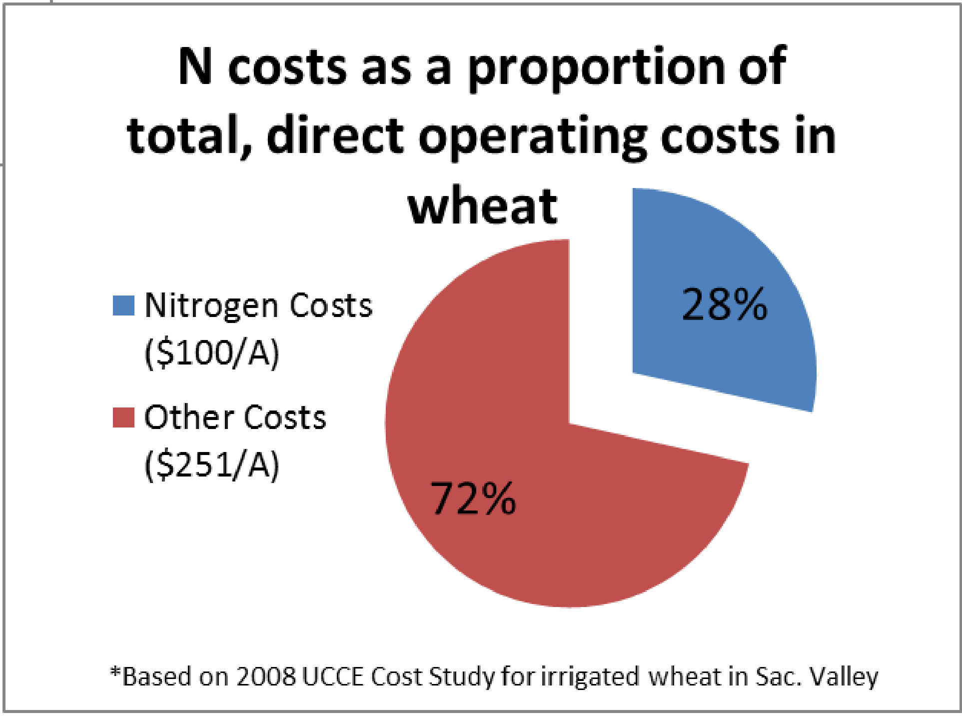
- Acreage :
  ≈ 500,000 ac yr^{-1} hard red/white;
  ≈ 50,000 ac yr^{-1} durum
- 50% grown for grain, grain growers paid for quantity & quality
- Yields ≈ 5500-6000 lb ac^{-1}
- Protein standard in CA markets is 13%
- Average rates of N application = 150-175 lbs $acre^{-1}$

N Costs and Regulations:



Optimizing the rate, timing of N application:

- Improves fertilizer use efficiency
- Increases the value of the crop



Growth and N Demand in Wheat

Wheat N Demand Depends On:

- Growth and N uptake by the crop
- Realistic expected yields (given limits of planting date, growing season length, irrigation water availability)
- Class of wheat being grown:
  - Desirability of higher protein % in durums, hard wheat classes
  - Lower protein levels for soft wheats
- Soil characteristics impacting N release/supply

Wheat N Demand: Yield and Protein Content

•Across the west, **amount of N (soil residual, mineralizable + fertilizer N) to reach peak yields** reported ranges from **3.3 to 5** lbs/100 lbs of grain under various conditions

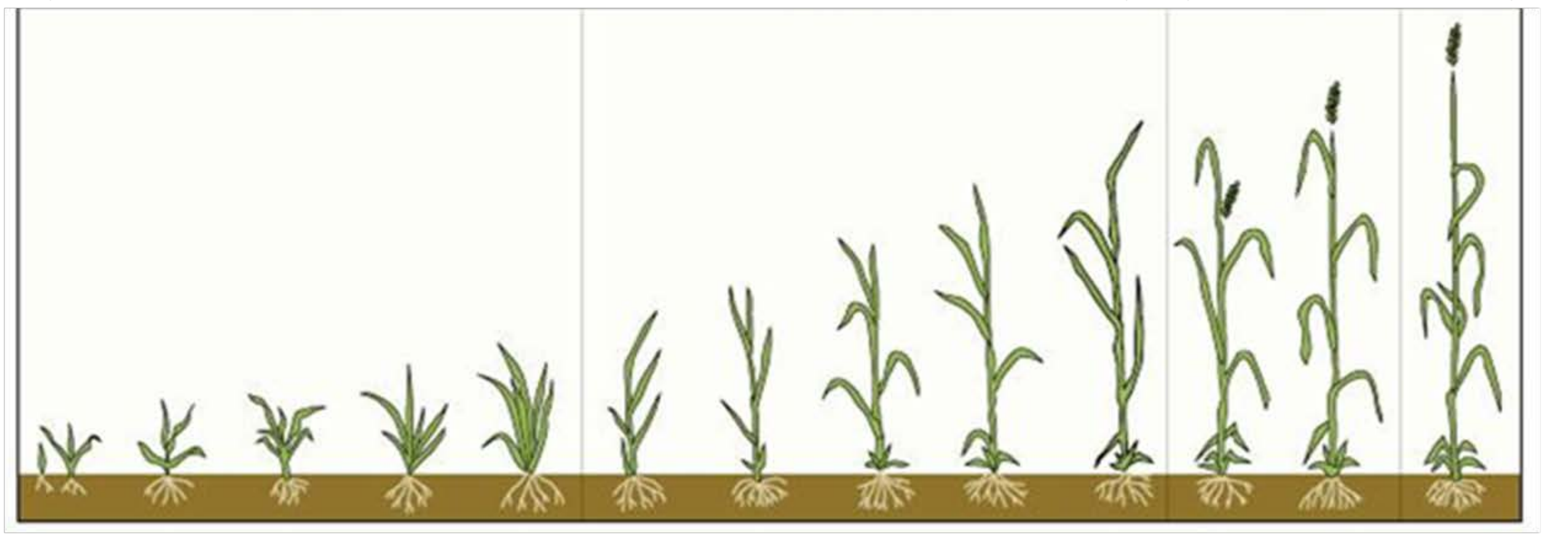
•In the northwest, grain yields were maximized with **3.2-3.5** lbs N/100lb grain, but **requirements increased to 4.6-5.3 lbs N/100 lbs grain to reach 14% protein** in hard wheats & durums

Wheat N Demand: Timing Impacts Yield and Protein Content

Fertilizer N effects on yield and protein at various growth stages

YIELD: ↑ number of tillers and kernels per head ↑ kernel weight

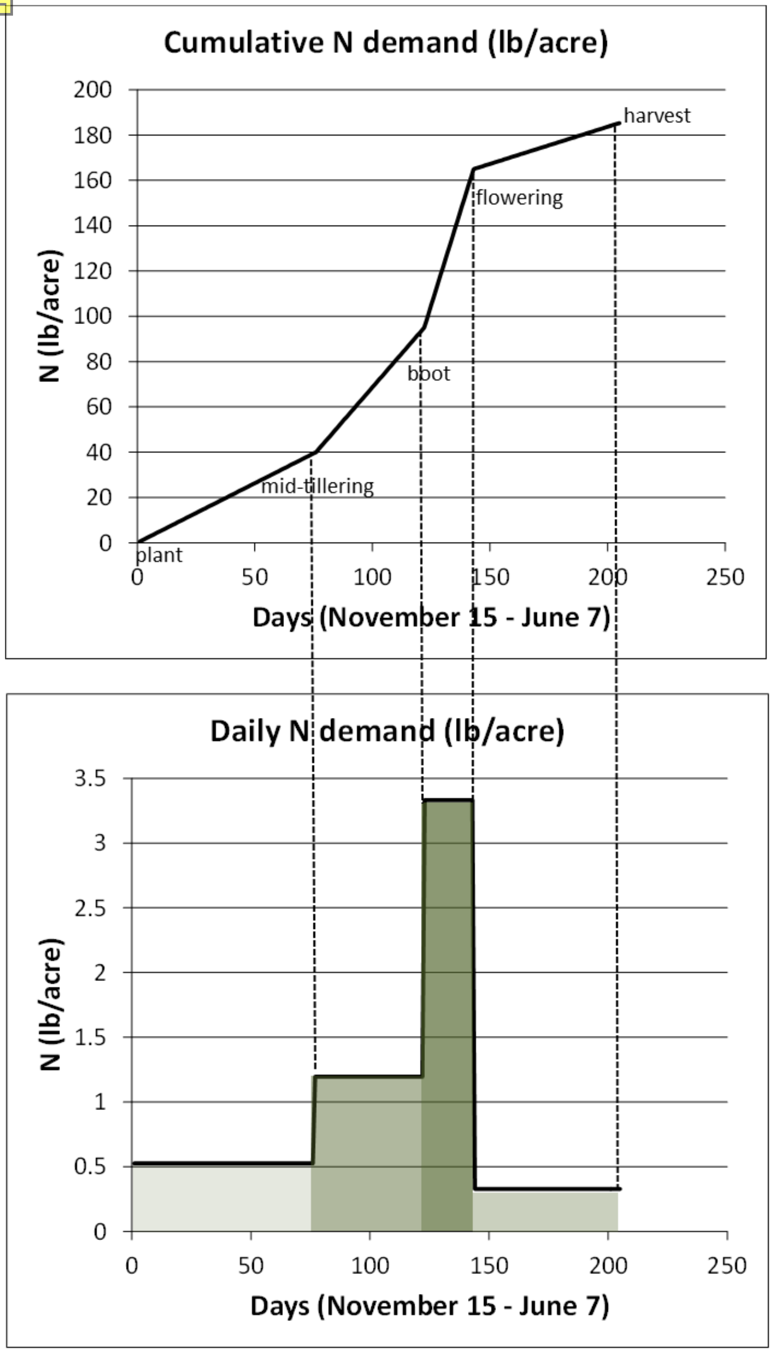
PROTEIN: ↑ biomass N for remobilization during grain fill ↑ remobilization rate, direct



Growth Stage

Image courtesy: U. Kentucky

Early Leaf Tillering Stem Elongation (jointing to boot) Heading to Maturation



Yield = 7500 lb acre^{-1} ; Protein = 11.5%

Wheat N Demand: Timing

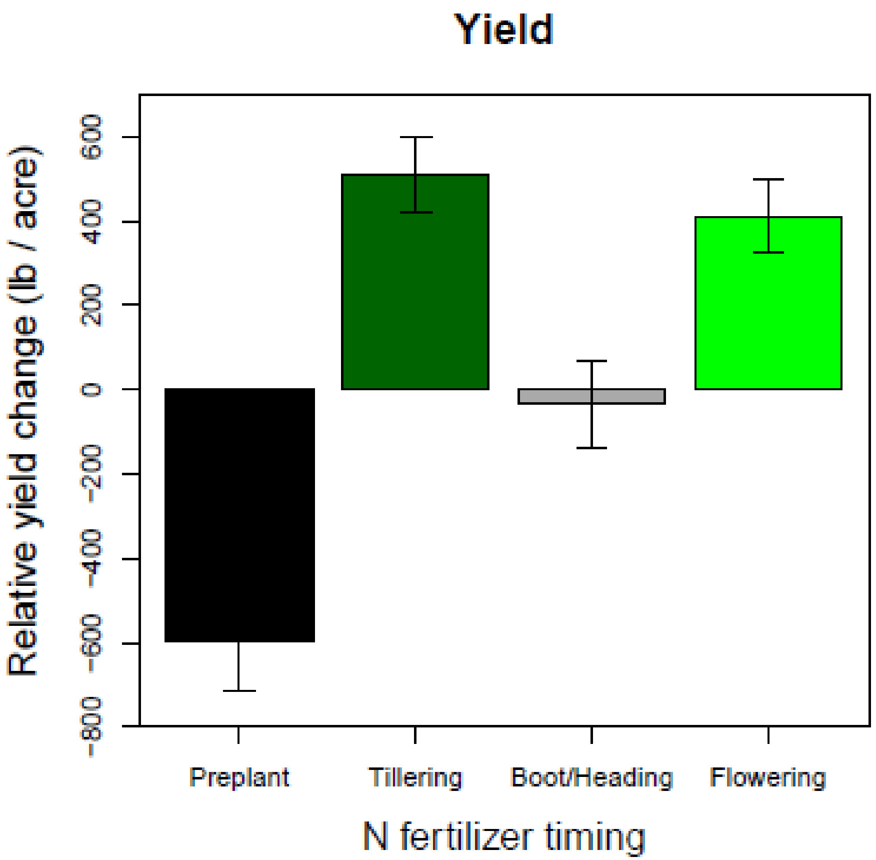
- Fertilizer N demand varies across the growing season
- Total fertilizer N demand varies according to crop's protein yield potential- importance of a reasonable yield expectation

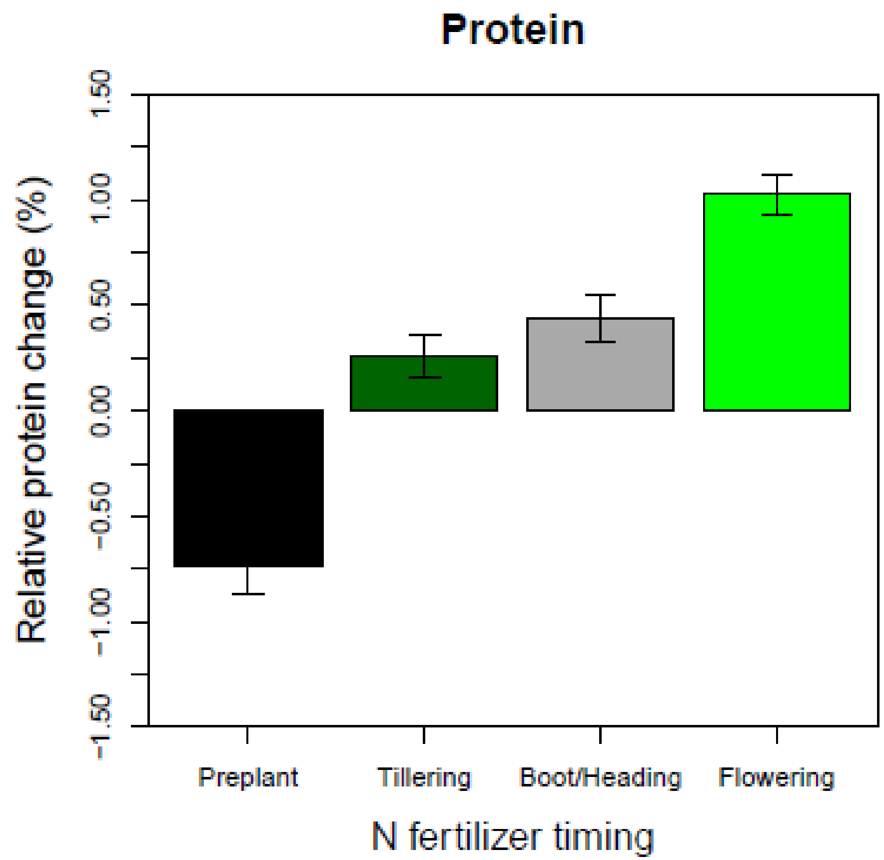
↓

Water is more limiting than N

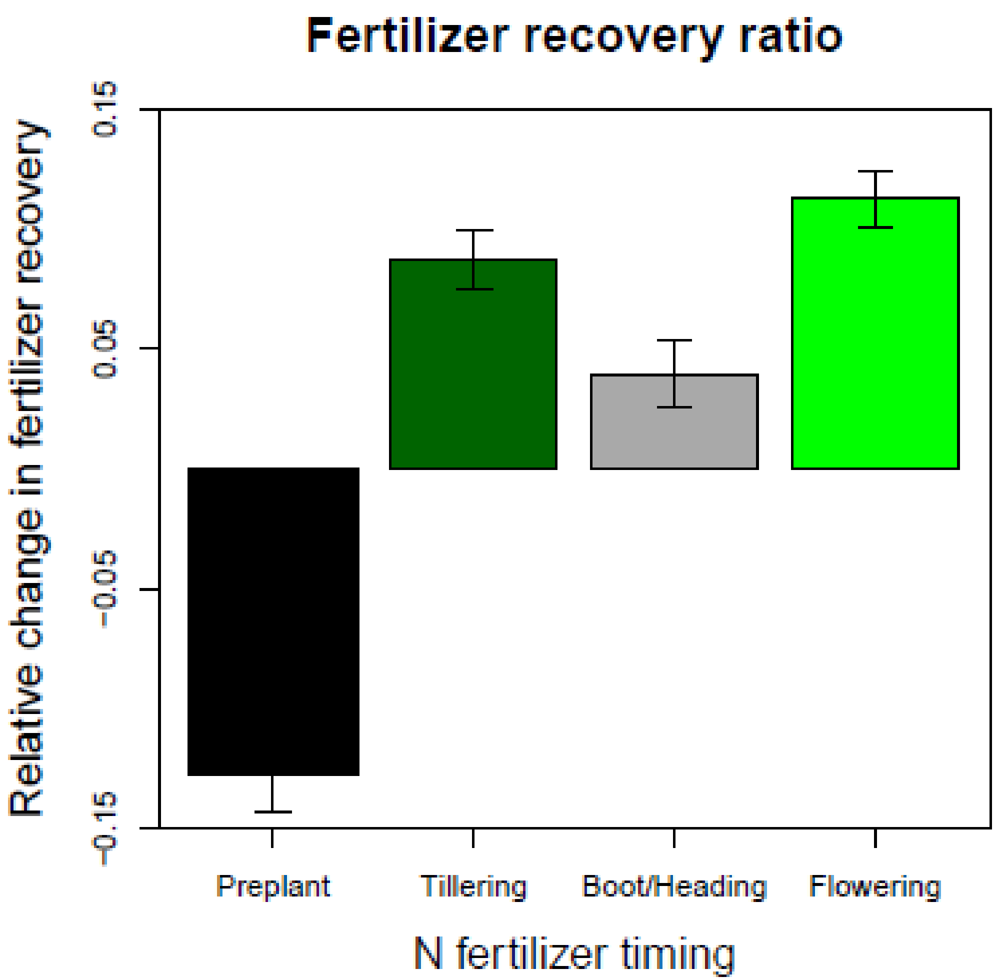
- Soil supplies a large portion of N to the crop.

Wheat N Demand: Timing Impacts Yield and Protein Content



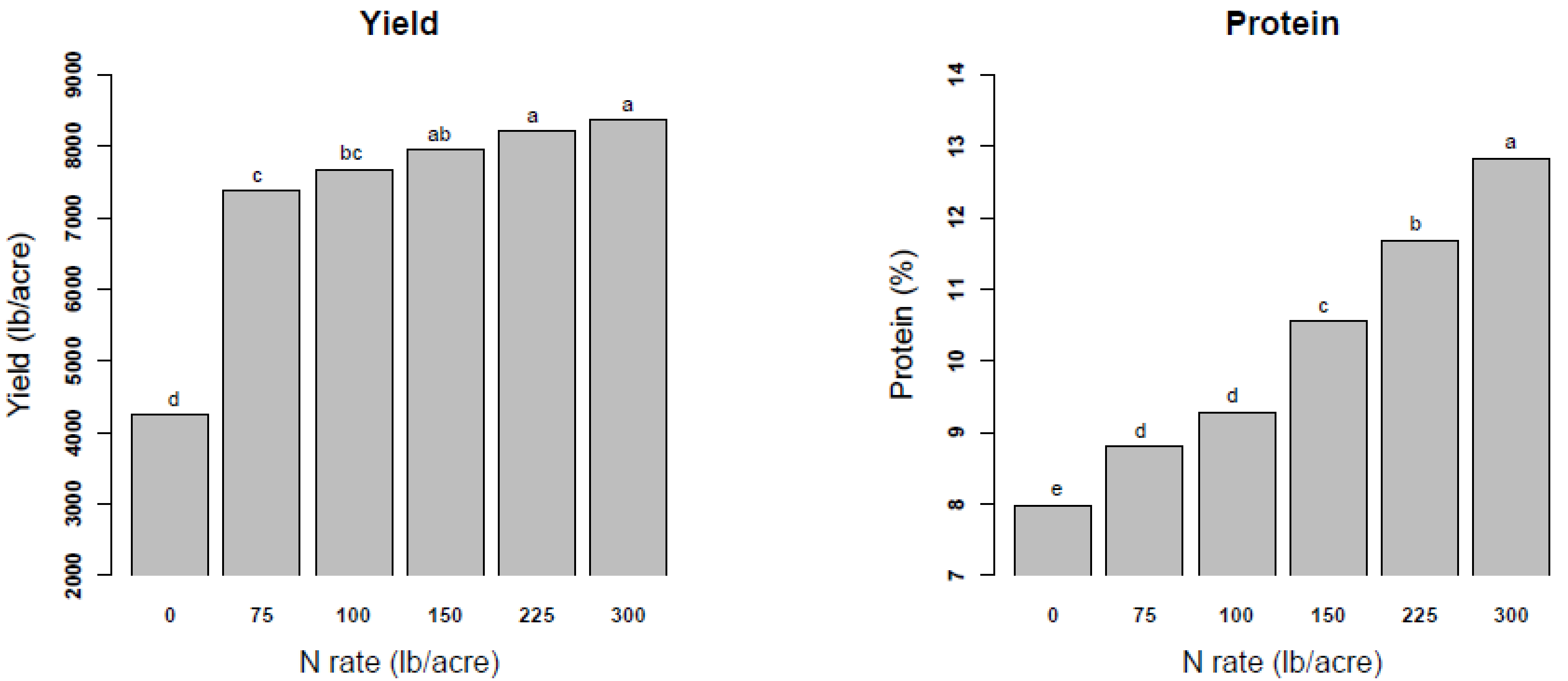


Wheat N Demand: Overall Fertilizer Use Efficiency



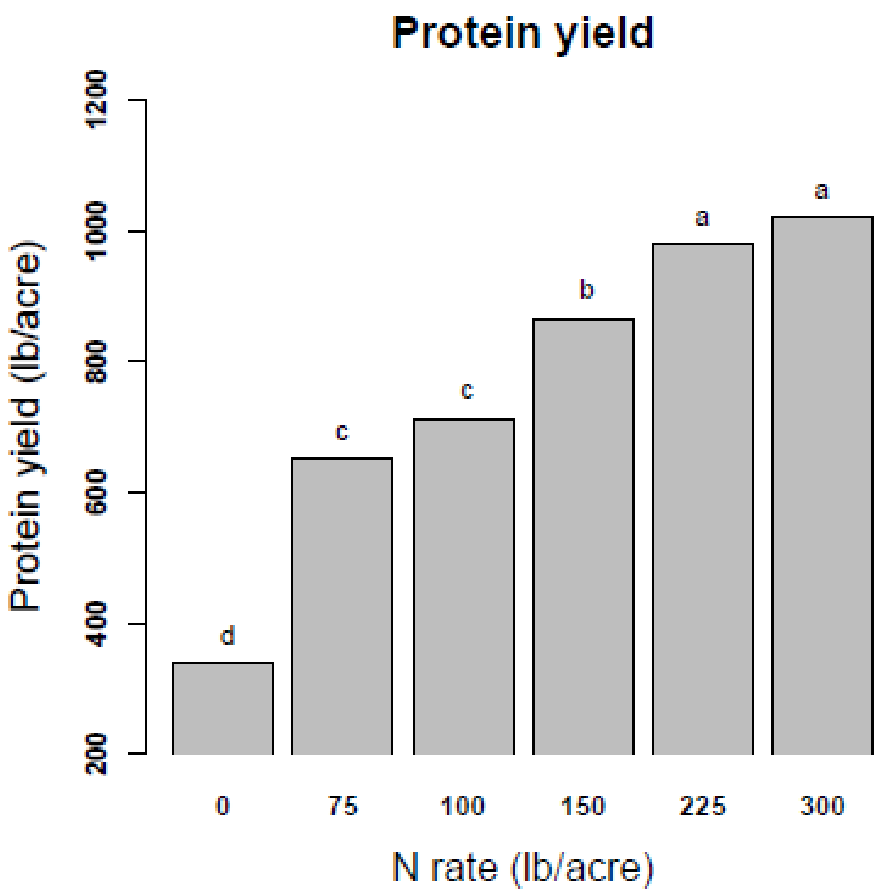
- Applications of N at Tillering and Flowering boost grain fertilizer use efficiency relative to other application timings
  - Dependent on water availability & timing
  - Large range of possibilities (0.3 – 0.65)

Wheat N Demand: Irrigated Wheat



Timing: preplant - tillering

Wheat N Demand: Irrigated Wheat



- Fertilizer N demand:

  960 lb ac^{-1} – 360 lb ac^{-1} = 600 lb ac^{-1}

  600 lb ac^{-1} / 5.7 = 105 lb ac^{-1}

  105 lb ac^{-1} / 0.5 (apparent N recovery in grain ≈ 63% overall NUE) = 210 lb ac^{-1}

  2.6 lb N / 100 lb grain

- Fertilizer N demand:

  960 lb ac^{-1} – 360 lb ac^{-1} = 600 lb ac^{-1}

  600 lb ac^{-1} / 5.7 = 105 lb ac^{-1}

  105 lb ac^{-1} / 0.4 (apparent N recovery in grain ≈ 50% overall NUE) = 263 lb ac^{-1}

  3.7 lb N / 100 lb grain

Wheat N Demand: Supplementally Irrigated Wheat

5500 lb acre^{-1}; 11% protein

- protein yield = 605 lb ac^{-1}

2500 lb acre^{-1}; 8% protein

- protein yield = 200 lb ac^{-1}

- Fertilizer N demand:
  605 lb ac^{-1} – 200 lb ac^{-1} = 405 lb ac^{-1}
  405 lb ac^{-1} / 5.7 = 71 lb ac^{-1}
  71 lb ac^{-1} / 0.5 = 142 lb ac^{-1}

  2.6 lb N / 100 lb grain

- Fertilizer N demand:
  605 lb ac^{-1} – 200 lb ac^{-1} = 405 lb ac^{-1}
  405 lb ac^{-1} / 5.7 = 71 lb ac^{-1}
  71 lb ac^{-1} / 0.4 = 178 lb ac^{-1}

  3.2 lb N / 100 lb grain

Wheat N Demand: Rainfed Wheat

4200 lb acre^{-1}; 12.5% protein

- protein yield = 525 lb ac^{-1}

2500 lb acre^{-1}; 8% protein

- protein yield = 200 lb ac^{-1}

Range of grain N demand:

114 – 263 lb ac^{-1}

- depending on:

  water

  fertilizer use efficiency

- Fertilizer N demand:

  525 lb ac^{-1} – 200 lb ac^{-1} = 325 lb ac^{-1}

  325 lb ac^{-1} / 5.7 = 57 lb ac^{-1}

  57 lb ac^{-1} / 0.5 = 114 lb ac^{-1}

  2.6 lb N / 100 lb grain

- Fertilizer N demand:

  525 lb ac^{-1} – 200 lb ac^{-1} = 325 lb ac^{-1}

  325 lb ac^{-1} / 5.7 = 57 lb ac^{-1}

  57 lb ac^{-1} / 0.4 = 143 lb ac^{-1}

  3.4 lb N / 100 lb grain

Wheat N Demand: Yield and Protein Content

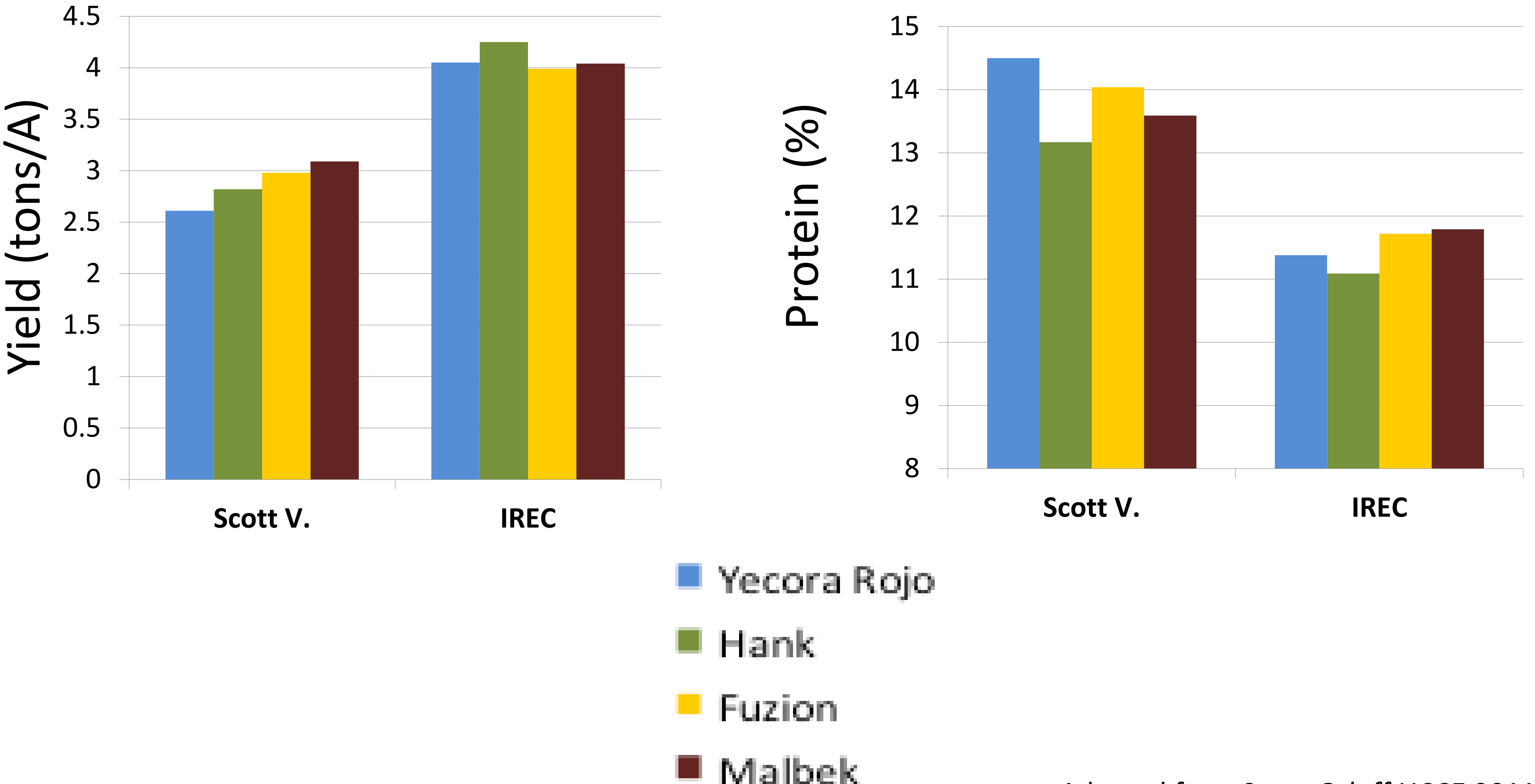
Effect of late season nitrogen at flowering (coupled with an irrigation) on yield, protein, and nitrogen status:

Site	Flowering N (lbs/acre)	Yield (lbs/acre)	Protein %
1	0	8180	11.9
	40	8681	12.8
2	0	8067	13.3
	40	7986	14.1
3	0	5242	14.9
	40	5418	15.1

Variety: Yecora Rojo

UCCE Kings County- 1988-1989, K. Cassman, B. Lindquist, S. Wuest, L. Hawe, L. Jackson, & A. Fulton

Effect of Wheat Cultivar and location on Yield and Protein Content



Adapted from Steve Orloff UCCE 2011

Crediting Non-Fertilizer N Sources

Crediting Soil Nitrate-N:

- Method 1: Top 1 foot
  - ppm NO3-N x 4 or 5
    - Example: 12ppm NO3-N x 4 or 5 ≈ 48 – 60 lb ac^{-1}

- Method 2: T op 2 feet
  - ppm NO3-N x 3.8 ≈ lb N ac^{-1} ft^{-1} of soil
    - Example: 12 ppm (1^{st} ft)x3.8 ≈ 46 lbs; 7 ppm (2^{nd} ft)x3.8 ≈ 27 lbs
      - Total ≈ 73 lb ac^{-1}
      - Or: 73 lb ac^{-1} x 0.75 ≈ 54 lb ac^{-1}
- Prior Crop:
  - Tomato residue estimated at 50 lb ac^{-1} returned, but probably reflected in soil nitrate test
  - Alfalfa contribution ≈ 100 lb ac^{-1} +

Crediting Organic N:

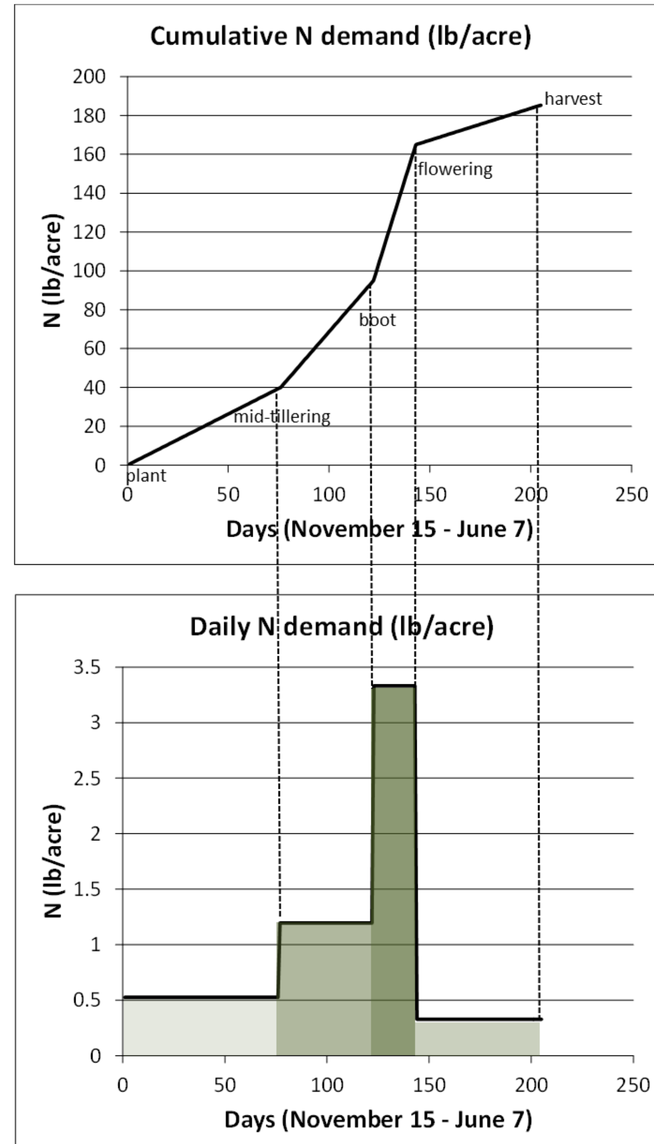
Multiple ways to estimate, many things to estimate…

- In-season soil organic matter N mineralization:
  - 0.8% OM % x 30 lb N / % OM ≈ 24 lb ac^{-1}

- Manure:
  - Example: For 5 tons dry manure/acre with 1.8% N:
    - 10,000 lbs x .018

      = 180 lbs N/acre/year
    - Estimate 10% mineralization per season

      =18 lbs/acre/year available



Yield = 7500 lb $acre^{-1}$; Protein = 11.5%

Crediting Irrigation Water N:

For 3.0 ppm NO_3^--N:

- Method 1: NO_3^--N x 2.7/ft of applied water

  -For 14 inches of water:

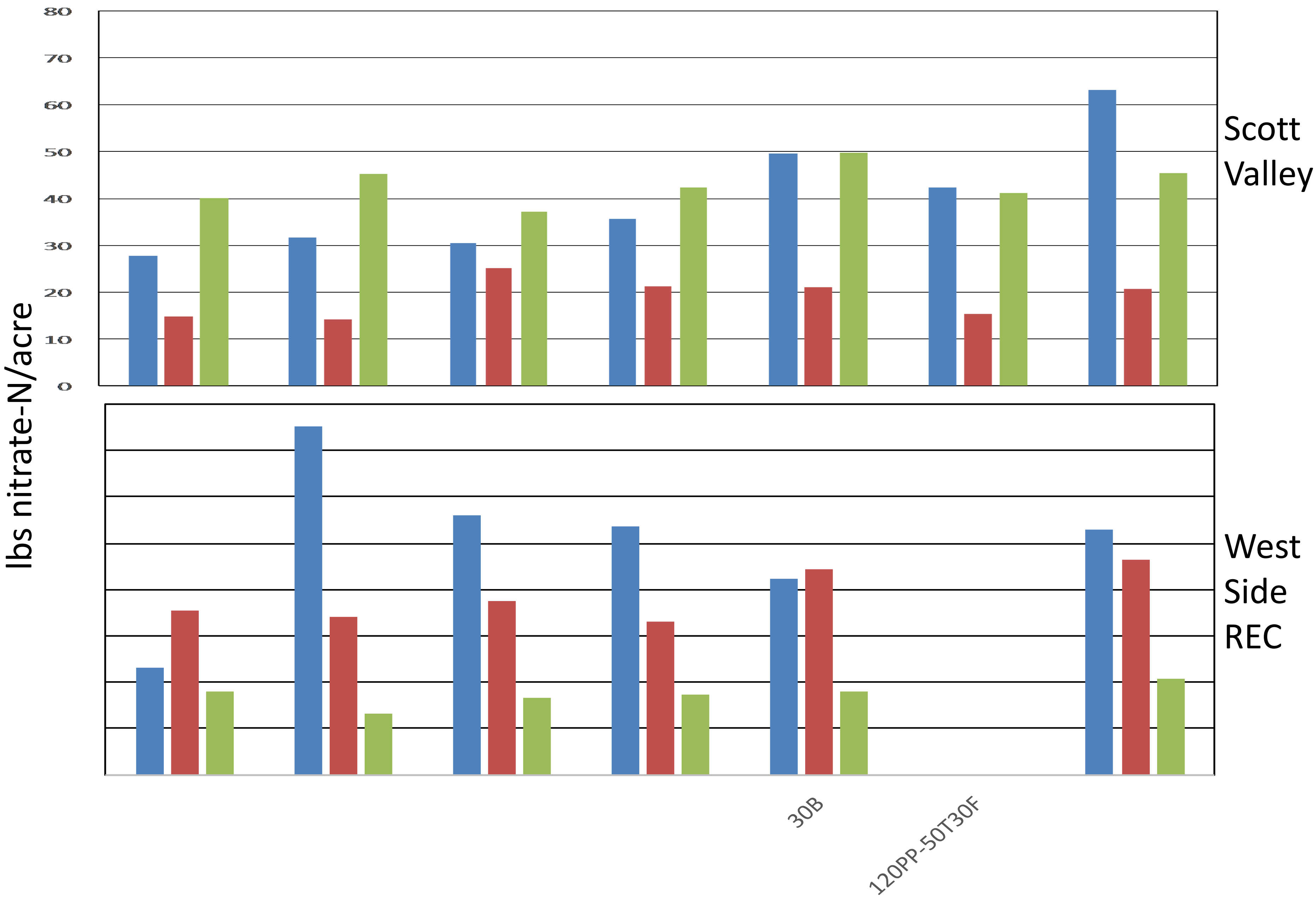
  3.0 x 2.7 x 14/12 = 9.45 lb N / acre / yr

- Method 2 : NO_3^--N x 0.23/inch of applied water

  -For 14 inches of water:

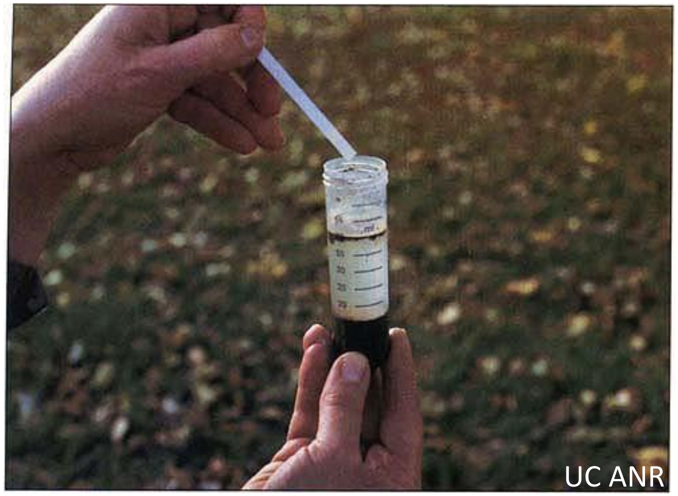
  3.0 x 0.23 x 14 = 9.66 lb N / acre / yr

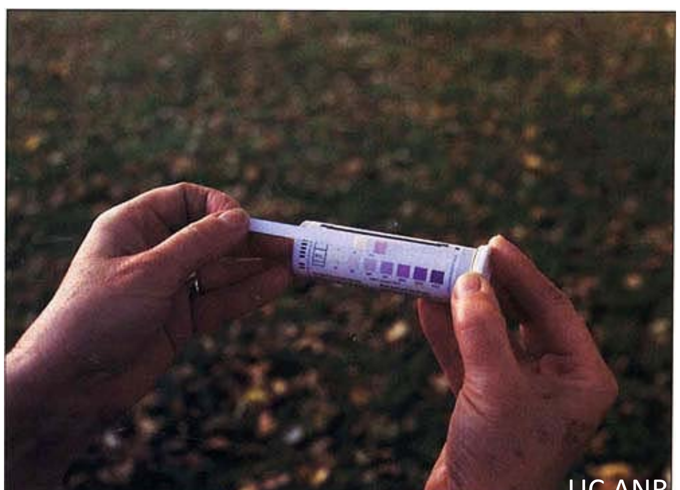
Nitrate Remaining in Soil After Harvest: Example



N Management Tools

Soil Nitrate Quick Test:





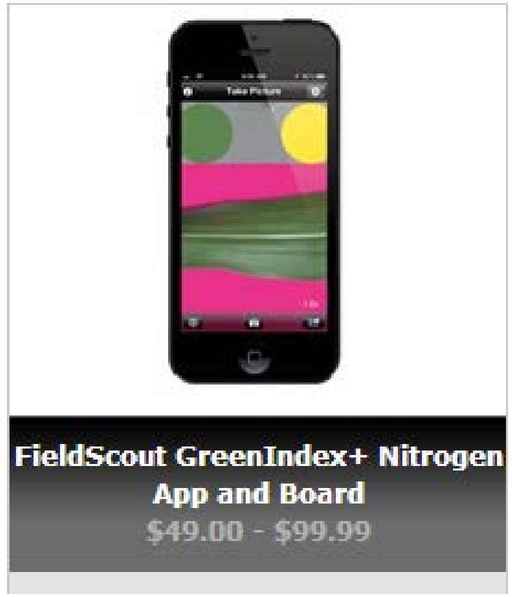
The Basic SOLVITA® Soil Response Color System

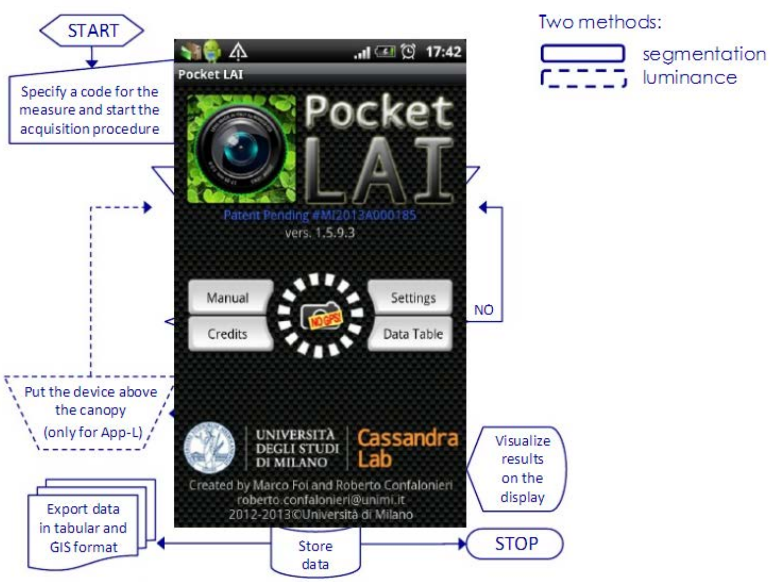
The patented gel-technology system indicates CO_2-respiration over a color range of 0 to 5 (see chart). In CO_2-Burst mode this corresponds to a range of 5 to 160 ppm CO_2-C. In BASAL mode it corresponds to a range of 0 – 55 ppm or 1 – 25 kg m²/year as CO_2.

All Solvita kits work with a basic visual color system, as shown below. By using the Solvita Digital Color Reader (DCR) the soil test values can be more accurately and precisely determined.

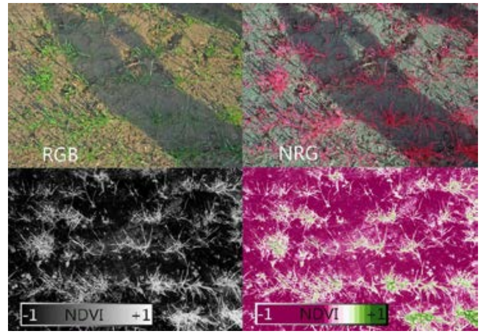
Sequence of Typical Soil Solvita Test Results:

Greenness Test:





Spectral Sensors:



atLEAF chlorophyll meter

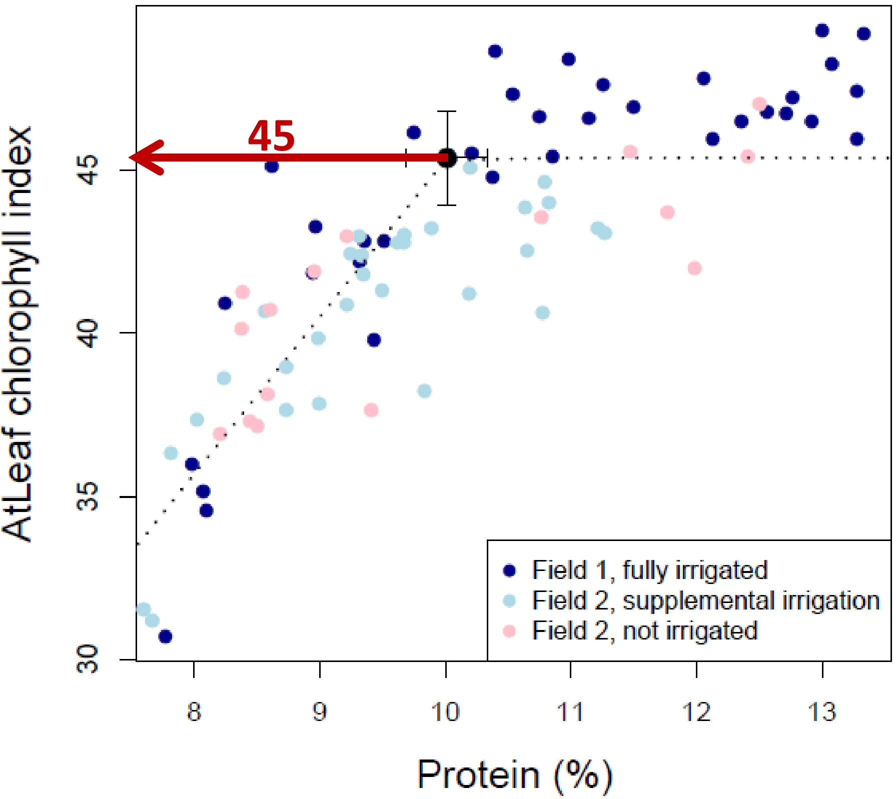
- SPAD proxy (660 and 940 nm)
- proxy for yield leaf N concentration
- Retail: ≈ \$250

Trimble Greenseeker handheld

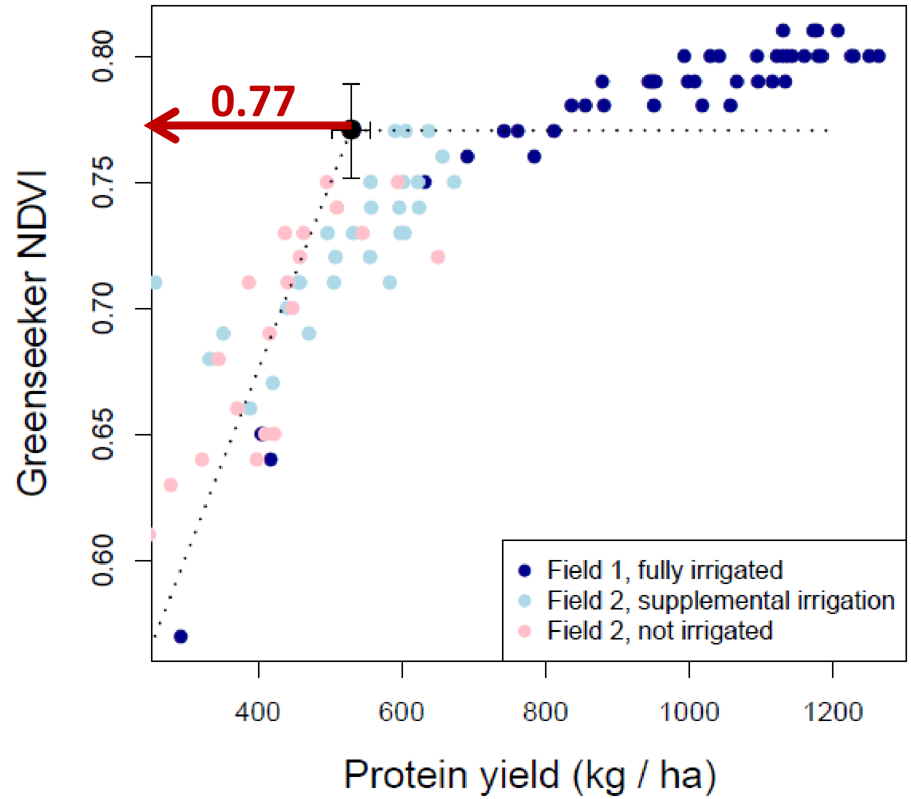
- NDVI (660 and 770 nm)
- Suitable proxy for yield potential?
- Retail: ≈ \$500

Spectral Sensors: Calibration

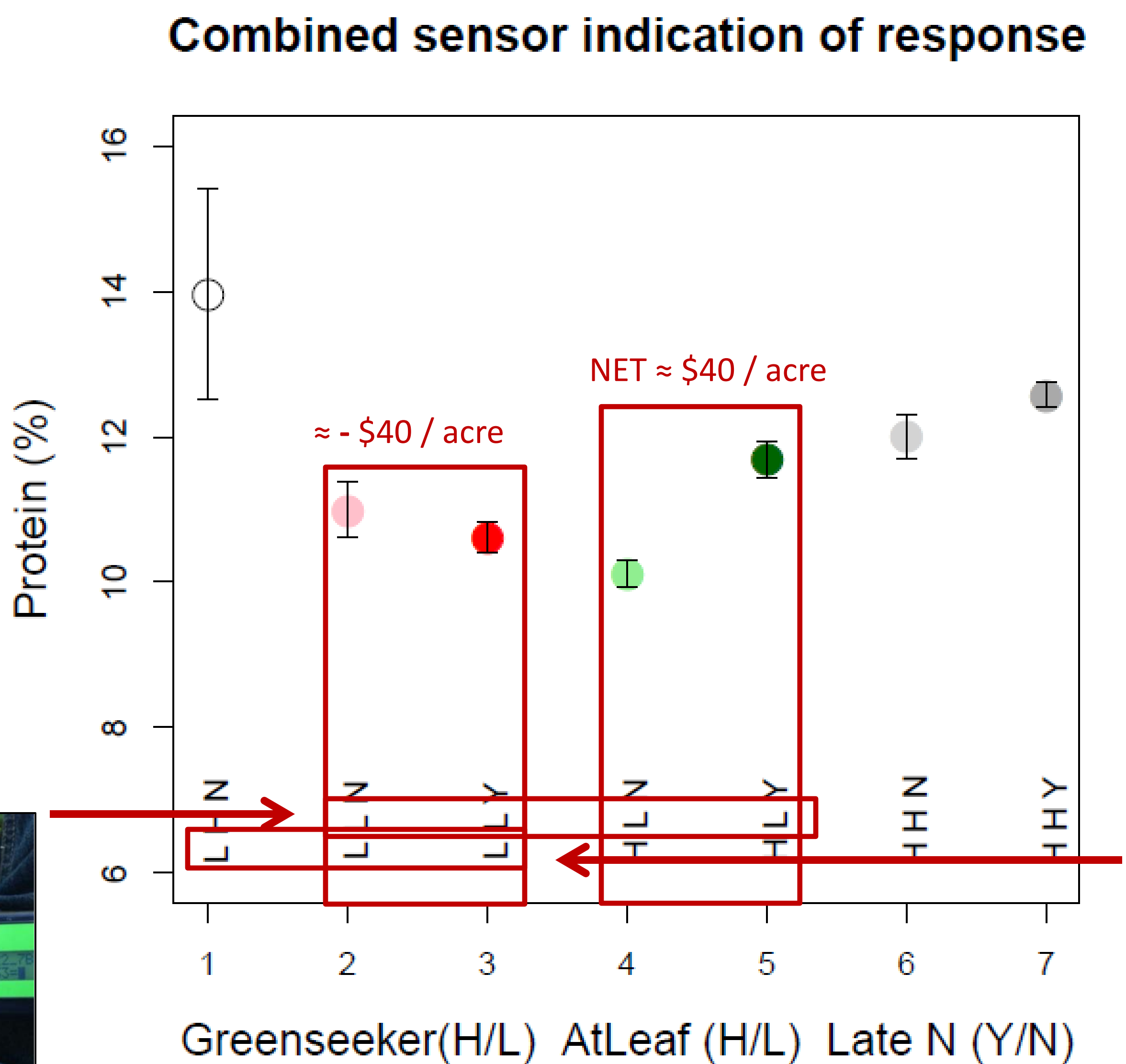
Flowering reading and protein outcome

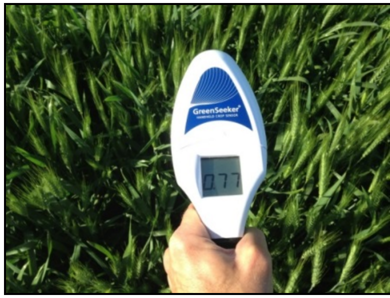


Flowering reading and protein outcome



Spectral Sensors: Decision Support





*For 4 ton crop with a $0.50 / cwt premium/discount per % above or below target (11%).

Spectral Sensors: Do-It-Yourself Calibration?

Image courtesy: Oklahoma State University

N Management Strategies

Split Application:

						Blanca Grande (HWW)515		Summit 515 (HRW)	
Pre-Plant	50 lbs N Tillering	50 lbs N Joint	50 lbs N Boot	50 lbs N Flowering	Total lb N/Acre	Protein %	Yield Tons/A	Protein %	Yield Tons/A
80R					80	**10.9**	**3.70**	**10.3**	**3.37**
80R	✶				130	**11.4**	**3.89**	**11.0**	**3.96**
80R	✶		✶		180	**11.7**	**4.17**	**11.4**	**4.05**
80R	✶			✶	180	**13.8**	**3.88**	**12.8**	**4.16**
80R			✶	✶	180	**13.5**	**3.45**	**12.4**	**3.77**
80R + 50 lb N	✶		✶		230	**13.3**	**3.99**	**12.7**	**4.34**
80R + 50 lb N	✶			✶	230	**13.6**	**4.35**	**13.5**	**4.22**
80R		✶	✶	✶	230	**13.6**	**3.94**	**12.7**	**4.14**
80R + 200 lb N					280	**13.3**	**4.20**	**12.8**	**4.00**
80R + 50 lb N	✶	✶		✶	280	**13.7**	**4.53**	**13.5**	**4.25**
80R + 50 lb N	✶		✶	✶	280	**13.5**	**4.21**	**13.4**	**4.08**
80R	✶	✶	✶	✶	280	**13.3**	**4.51**	**13.1**	**4.33**
80R + 120 lb N	✶	✶			300	**13.4**	**4.22**	**13.0**	**4.40**
80R + 120 lb N	✶		✶		300	**13.2**	**4.40**	**13.0**	**4.24**
80R + 50 lb N	✶	✶	✶	✶	330	**13.6**	**4.57**	**13.5**	**4.51**
LSD						**0.60**	**0.43**	**0.57**	**0.41**
CV						**3.20**	**7.25**	**3.19**	**6.93**

Split Application: Results Cont'd.

Volante (Durum)

Pre-Plant	50 lbs N Tillering	50 lbs N Joint	50 lbs N Boot	50 lbs N Flowering	Total lb N/Acre	Protein %	Yield Tons/A
80R					80	**9.5**	**3.84**
80R	✶				130	**10.9**	**4.20**
80R	✶		✶		180	**9.9**	**4.07**
80R	✶			✶	180	**12.2**	**4.77**
80R			✶	✶	180	**11.9**	**4.12**
80R + 50 lb N	✶		✶		230	**12.1**	**4.04**
80R + 50 lb N	✶			✶	230	**12.8**	**4.31**
80R		✶	✶	✶	230	**12.2**	**4.44**
80R + 200 lb N					280	**12.4**	**4.32**
80R + 50 lb N	✶	✶		✶	280	**12.7**	**4.35**
80R + 50 lb N	✶		✶	✶	280	**12.8**	**4.36**
80R	✶	✶	✶	✶	280	**12.8**	**4.33**
80R + 120 lb N	✶	✶			300	**12.4**	**4.10**
80R + 120 lb N	✶		✶		300	**12.5**	**4.29**
80R + 50 lb N	✶	✶	✶	✶	330	**13.0**	**4.37**
LSD						**0.69**	**0.31**
CV						**4.02**	**5.13**

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N Planning Worksheet: Example

5500 lb $acre^{-1}$; 11% protein

- N Demand:
  3.2 lb N / 100 lb grain
  ≈ 176 lb N x 1.25 (straw)
  ≈ 220 lb N

- N Credit:
  Irrigation NO3-N
  = 3.5 ppm
  Irrigate 4”, 2 times
  = 8” x 0.23 x 3.5
  ≈ 6 lb N

NITROGEN MANAGEMENT PLAN WORKSHEET

NMP Management Unit: __________

1. Crop Year (Harvested): __________

r ID# __________

3. Name:

4. APN(s):	5. Field(s) ID	Acres

CROP NITROGEN MANAGEMENT PLANNING	
6. Crop	wheat
7. Production Unit	
8. Projected Yield (Units/Acre)	5500 lb/ac
9. N Recommended (lbs/ac)	
10. Acres	
Post Production Actuals	
11. Actual Yield (Units/Acre)	
12. Total N Applied (lbs/ac)	
13. ** N Removed (lbs N/ac)	
14. Notes:	

N APPLICATIONS/CREDITS	15. Recommended/ Planned N	16. Actual N
17. Nitrogen Fertilizers		
18. Dry/Liquid N (lbs/ac)	150 lb/ac	
19. Foliar N (lbs/ac)		
20. Organic Material N		
21. Available N in Manure/Compost (lbs/ac estimate)		
22. Total Available N Applied (lbs per acre)	150 lb/ac	
23. Nitrogen Credits (est)		
24. Available N carryover in soil; (annualized lbs/acre)	64 lb/ac	
25. N in Irrigation water (annualized, lbs/ac)	6 lb/ac	
26. Total N Credits (lbs per acre)	70 lb/ac	
27. Total N Applied & Available	220 lb/ac	

Other Small Grains:

- Barley and Oats require substantially less N
  - Optimal yields can be achieved between 50 and 120 lb N / acre

- Durum wheat may require 130% N to achieve quality targets
  - Good timing can help

Components of N Application Decision Plan:

- Evaluate N needs based on realistic yield goal
  - Realistic, long-term averages adjusted for changing conditions or capabilities
- Consider credits from prior crops, amendments, irrigation water NO_3^--N
  - Estimate organic N contribution from crop residue, which varies and will not fully show up in soil tests
- Resist tendency to apply "just a little more" than necessary for yield goal
  - Consider a 5-10% lower rate based on efficiency gained from split applications at appropriate growth stages

Summary Improved N Management Approach:

Emphasize split applications to better impact yield & protein:

- Lower application rates pre-plant
  - Avoid losses from slow initial growth, earlier rain/irrigations
  - Initial higher infiltration rates allow more water and soluble nutrients to move
- Split applications better matched to periods of:
  - Higher plant uptake
  - Critical growth stages
  - Reduced soil water infiltration rates
- Late season N applications
  - Evaluate impacts on grain protein
  - Evaluate potential for losses below root zone with deep soil sampling

Summary Improved N Management Approach:

Reduce fallow period / pre-plant N applications

- Inefficient because separate from periods of plant uptake
- Avoid losses during pre-plant or early growth period, when soil water storage capacity can be limited with rainfall

In-field sensors for real-time protein-yield info

- Multiple sensors for improved predictability

Soil Nitrate-N testing

- Not all soil N is in nitrate form, but under most conditions, much of readily available N is in nitrate form
- N mineralization can supply about 5-40% of needs
- Soil testing can help:
  - Give confidence in making better use of stored soil N
  - Limit waste
  - Protect against leaching losses

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