
- Bob Hutmacher (UC West Side REC, UCD Plant Sci. Dept.)
- Steve Wright; Dan Munk; Brian Marsh; Ron Vargas, Bill Weir, Doug Munier (UCCE Tulare and Kings, Fresno, Kern, Madera, Merced and Glenn Counties); Felix Fritschi (UCD Plant Sci. Dept. – now Univ. of Missouri)
- Bob Travis and Bill Rains (emeritus, UCD Plant Science Dept.)
- Bruce Roberts (formerly UCCE, Kings Co.–now CSU Fresno)
- CA Dept. of Food & Agriculture – FREP program
- Cotton Incorporated
- CA Crop Improvement Association
Need for improvements in Fertilizer management in cotton – *emphasis on Nitrogen management*

- Avoiding waste in inputs & associated costs
- N impacts on:
  - balance between vegetative & reproductive growth
  - potential interaction with insects (aphids, lygus, SLWF)
  - preparation for defoliation
- Delays in harvest & impacts on quality
- Environmental concerns regarding fate of applied materials
  - potential for leaching losses (NO₃, others)
  - changes in rotations and ability of other crops to retrieve N?
FACTORS influencing N management decisions for cotton? *(tools & flexibility needed)*

**CROP N USE / DEMANDS**

1. plant N uptake highest when leaf area rapidly increasing and when bolls, seeds developing
2. relate N needs to yield potential *(generally about 55 to 60 lbs N needed per bale of lint)*
3. consider fertilizer, residual soil N and water N as potential sources

**IF YIELD POTENTIAL CHANGES, N NEEDS MIGHT ALSO CHANGE**

1. if *good boll retention* and vegetative growth under control, might need supplemental N
2. if *poor retention*, rank growth a possibility or irrigation water high in N, may need to reduce/limit applied N
Components in Approach for Improvements in Nitrogen Management in Cotton

- Prior 5-year experiments confirmed that cotton crop needs about 50-60 lbs. N / bale of lint from all sources, applied plus soil available N
- Soil nitrate tests are available to growers and relatively inexpensive (upper 2 feet good, deeper sampling better) - Applied N rates should be adjusted for apparent available soil N (using soil NO₃)
- Petiole nitrate status and yield potential estimate?
- Consider possibility of reduced or split applications (via side-dress or water-run)
### N fertilizer recommendations for SJV cotton

**based on prior 5-year Nitrogen Mgmt studies- CA**

<table>
<thead>
<tr>
<th>Soil Residual Nitrate Levels-Upper 2 feet soil - <em>Spring pre-plant or soon after</em></th>
<th>Recommendations for N fertilizer applications/year</th>
<th>Additional Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 55 lbs N as NO₃-N</td>
<td>125 to 175 lbs</td>
<td>Less if low yields predicted due to late planting, field history</td>
</tr>
<tr>
<td>55 to 100 lbs N</td>
<td>100 to 125 lbs</td>
<td>Use plant mapping, petiole nitrate to assess yield, N status</td>
</tr>
<tr>
<td>&gt; 100 lbs N</td>
<td>75 lbs or less</td>
<td>Use mapping, petiole nitrate to assess yield potential, likely response</td>
</tr>
</tbody>
</table>
Some questions:

- Can we typically reduce N application amounts in nearly all situations?
- Is there a yield risk with reduced N applications?
Second Phase N Management Trials - cotton

Test Plot Conditions – N Plots

- 3-year field trials in grower fields plus Research Ctrs.
- 2 REC locations plus 2 grower sites per year
- Range of soil types (sandy loam, silt loam, clay loam)

- Initial (spring) soil NO$_3$-N evaluated in upper 4 feet
- 110-125 lb and 150-180 lbs N/acre treatments established
  \( \text{application amount} = \text{treatment level} - \text{tested residual in upper 2 feet of soil profile} \)
- Also tested for PO$_4$-P and exch-K / applied if needed
Experiment Treatments - years 1, 2 & 3

- **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 application with 2nd irrigation as water-run OR dry sidedress (generally timing within 7-14 days after 1st bloom)
- **T5** = no applied supplemental N
## Actual N Application Amounts (lbs N/ac)

<table>
<thead>
<tr>
<th>Year 1</th>
<th>A Kern</th>
<th>B SREC</th>
<th>C Fresno</th>
<th>D WSREC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual NO3-N in upper 2 feet for site</td>
<td>69</td>
<td>41</td>
<td>113</td>
<td>58</td>
</tr>
<tr>
<td>T1 (115)</td>
<td>46</td>
<td>74</td>
<td>7</td>
<td>57</td>
</tr>
<tr>
<td>T2 (175)</td>
<td>106</td>
<td>134</td>
<td>67</td>
<td>117</td>
</tr>
<tr>
<td>T3 (115+)</td>
<td>101</td>
<td>129</td>
<td>62</td>
<td>112</td>
</tr>
<tr>
<td>T4 (175+)</td>
<td>161</td>
<td>189</td>
<td>122</td>
<td>172</td>
</tr>
<tr>
<td>T5 (0)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
## Actual N Application Amounts (lbs N/acre)

<table>
<thead>
<tr>
<th>Year 2</th>
<th>A Fresno</th>
<th>B SREC</th>
<th>C WSREC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual NO3-N in upper 2 ft for site</td>
<td>44</td>
<td>92</td>
<td>60</td>
</tr>
<tr>
<td>T1 (115)</td>
<td>71</td>
<td>23</td>
<td>55</td>
</tr>
<tr>
<td>T2 (175)</td>
<td>131</td>
<td>83</td>
<td>115</td>
</tr>
<tr>
<td>T3 (115+)</td>
<td>131</td>
<td>83</td>
<td>115</td>
</tr>
<tr>
<td>T4 (175+)</td>
<td>191</td>
<td>143</td>
<td>175</td>
</tr>
<tr>
<td>T5 (0)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Year 3</td>
<td>A Kern</td>
<td>B SREC</td>
<td>C WSREC</td>
</tr>
<tr>
<td>-------</td>
<td>--------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>Residual NO3-N in upper 2 ft for site</td>
<td>41</td>
<td>58</td>
<td>45</td>
</tr>
<tr>
<td>T1 (115)</td>
<td>74</td>
<td>57</td>
<td>70</td>
</tr>
<tr>
<td>T2 (175)</td>
<td>134</td>
<td>117</td>
<td>130</td>
</tr>
<tr>
<td>T3 (115+)</td>
<td>134</td>
<td>117</td>
<td>130</td>
</tr>
<tr>
<td>T4 (175+)</td>
<td>194</td>
<td>177</td>
<td>190</td>
</tr>
<tr>
<td>T5 (0)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Year</td>
<td>Kern</td>
<td>Shafter</td>
<td>Fresno</td>
</tr>
<tr>
<td>------</td>
<td>-------</td>
<td>---------</td>
<td>--------</td>
</tr>
<tr>
<td>1</td>
<td>19-23</td>
<td>11-13</td>
<td>16-18</td>
</tr>
<tr>
<td>2</td>
<td>11-13</td>
<td>17-22</td>
<td>7-9</td>
</tr>
<tr>
<td>3</td>
<td>11-13</td>
<td>7-9</td>
<td></td>
</tr>
</tbody>
</table>

*Range of total yearly N (lbs/ac) contributed with irrigation water*
Lint Yield versus Applied N (by trt) – year 1

**Residual N03-N top 2 feet**

- A = 69 lbs
- B = 51 lbs
- C = 113 lbs
- D = 58 lbs
Lint Yields in **year 1** Trial Sites

A = Kern Co.     B = Shafter REC

<table>
<thead>
<tr>
<th>NITROGEN TRTS</th>
<th>Site A</th>
<th>Site B</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 (115)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T2 (175)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T3 (115+)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T4 (175+)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A = 46 to 161 lbs APPLIED N/acre
B = 74 to 189 lbs APPLIED N/acre

Site B not responsive – insects & other factors limit yield
Lint Yield versus Applied N (by trt) – year 2

Residual N03-N top 2 feet
A = 44 lbs
B = 92 lbs
C = 60 lbs
Lint Yield versus Applied N (by trt) – year 3

Residual N03-N top 2 feet
A = 41 lbs
B = 58 lbs
C = 69 (actually Tulare Co site)
D = 45 lbs
Lint Yields in **year 3** Trial Sites

A = Kern Co. B = Shafter REC

Site A: T3 petiole #'s called for N; T4 did not
Site B: T3 and T4 #'s called for N

Site B not very responsive – unclear where N comes from?

- A = 74 to 194 lbs N/acre
- B = 57 to 177 lbs N/acre

**NITROGEN TRTS**

- T1 (115)
- T2 (180)
- T3 (115+)
- T4 (180+)
- 0 N
Additional considerations
what added factors can you consider that impact your confidence in reducing applied N?

• **Soil sampling decisions**
• **petiole nitrate measurements**
• Fruit set and yield potential
Sources of observed variation in soil nitrate sampling results

- Time of sampling during winter / spring
  - *In semi-arid, irrigated mgmt, we settled on planting time sampling (either pre-plant if had access or soon after planting)*
- Prior crop and amount of fertilizer applied OR plant material incorporated
- Depth of soil sampling
- Uniformity of growth and cover with prior crop
- Location with respect to head or tail for irrigation
- Soil texture and infiltration characteristics
Crop rotations and upper soil N
Can help identify when deeper soil N may be a factor

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
Is sampling upper two feet of soil enough?

- **Depth in soil profile where**
  - fertilizer N is applied
  - Soluble N accumulates
  - Amount of leaching of soluble N occurs

  ... *Can be highly variable with soil texture, amount of fertilizer applied, soil water infiltration characteristics, prior crops and N recycling*

- At some sites, upper 2 feet gives good idea of amounts of available N & levels decline with greater depth

- At other sites, significant nitrate-N exists at depths beyond 2 feet & could greatly impact crop response
Nitrogen Project - Soil N by location

spring (pre-fertilize, near planting time data)

Upper four feet of profile

SOIL NO3-N (lbs N/A)
Variability in soil nitrate-N within fields spring (upper 2 ft, pre-fertilize, 2 clay loam soils)

SOIL NO₃-N (mg / kg soil dry wt in upper 2 feet)

- **SOIL A**: 83 to 116 lbs/A
- **SOIL B**: 126 to 150 lbs/A
Some ways we can look at fate of applied Nitrogen
Change in Soil NO3-N (Fall minus Spring) WSREC test site – year 1

High soil water holding capacity & deep roots limit leaching potential at this site
PLANT MEASUREMENTS OF NITROGEN STATUS – recent N Mgmt Studies in Cotton
Some questions relate to total plant N uptake under decent yield conditions (what is taken up by the above-ground plant? *Usually not including roots* …

Some approaches ask about N removal with harvest (what is taken off of the field in lint, trash/burs, and seed?)
NITROGEN UPTAKE and NITROGEN REMOVAL (lbs/ac) as a function of days after planting – **Drip Irrigated ACALA/UPLAND** varieties – 2013

Yields Irrig Trt 1 = 2141, 2051 lbs/ac    Irrig Trt 3 = 1834, 1858 lbs/ac

**UPTAKE**

- **Phy725RF-1**
- **Phy-725RF-3**
- **FM-2484-1**
- **FM-2484-3**

Early bl=75 DAE
Peak bl=100-105
Late bl=120-130

Days after emergence
NITROGEN UPTAKE and NITROGEN REMOVAL (lbs/ac) as a function of days after planting – Furrow-Irrigated ACALA and PIMA – 2011, 2013

Yields Acala = 2158, 1956 lbs/ac  Pima = 1972, 1839 lbs/ac

**UPTAKE**

- Phy-725RF
- FM 2484
- Phy-802RF
- DP-358RF

Early bl=70 -75 DAE
Peak bl=95-105
Late bl=115-130

Days after emergence

<table>
<thead>
<tr>
<th>Days</th>
<th>Phy-725RF</th>
<th>FM 2484</th>
<th>Phy-802RF</th>
<th>DP-358RF</th>
</tr>
</thead>
<tbody>
<tr>
<td>72</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>98</td>
<td></td>
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</tr>
<tr>
<td>121</td>
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<tr>
<td>148</td>
<td></td>
<td></td>
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<tr>
<td>175</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>ENTRY</td>
<td>DRIP IRRIG TRTS (2013)</td>
<td>190 DA Emerge HARVEST REMOVAL (lbs Nitrogen/acre)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>------------------------</td>
<td>--------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phy-725RF</td>
<td>Trt 1 (late stress)</td>
<td>139</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phy-725RF</td>
<td>Trt 3 (least water)</td>
<td>123</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM 2484 B2F</td>
<td>Trt 1 (late stress)</td>
<td>132</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM 2484 B2F</td>
<td>Trt 3 (least water)</td>
<td>119</td>
<td></td>
<td></td>
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<tr>
<td>ENTRY</td>
<td>FURROW IRRIGATED (2011, 2013)</td>
<td>190-200 DAE HARVEST REMOVAL (lbs Nitrogen/acre)</td>
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<td>-------------</td>
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<td></td>
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</tr>
<tr>
<td>Phy-725RF</td>
<td>Acala / Upland</td>
<td>140</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM-2484 B2F</td>
<td>Upland</td>
<td>128</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phy-802RF</td>
<td>Pima</td>
<td>145</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DP-358</td>
<td>Pima</td>
<td>135</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Petiole NO3-N Evaluations in CA
Need for Feed-back Approach

* most consistent data between late squaring & 4 weeks after 1st bloom
* With residual soil NO3-N of >60-70 lbs N/acre top 2 ft, petiole NO3 data had little sensitivity when lint yields <1200 lbs/acre
* At lower residual soil N or with yields > 1400 lbs per acre, utility of petiole data improves
* With split applications or low-rate frequent nutrient applications, lower early bloom petiole NO3-N still ok
Cotton - WSREC - 67 lbs N/A in top 4 ft with yields ranging from 1590 to 2260 lbs/A and N applications of 65, 130 or 195 lbs N/acre

Impacts of high yields on petiole nitrate sensitivity
Cotton - WSREC - 61 lbs N/A in top 4 ft with yields ranging from 1050 to 1240 lbs/A and N applications of 65, 130 or 195 lbs N/acre.

Under much lower yields, less sensitive.
Can also consider use of leaf N% measurements:
Leaf N conc (%) as affected by irrigation treatment and DAE (average across Acala/Upland entries)
<table>
<thead>
<tr>
<th>Year</th>
<th>Site/ Yield</th>
<th>Yield Response Supplemental N (yield increased (+) or decreased (-) in: Trt 3 vs. 1 and Trt 4 vs. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Trt 3 versus Trt 1 (Trt 3 supplemented)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trt 4 versus Trt 2 (Trt 4 supplemented)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Petiole NO3 status of Trt 1 from 1st to peak bloom</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Petiole NO3 status of Trt 2 from 1st to peak bloom</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Defic. border</td>
</tr>
<tr>
<td>ONE</td>
<td>A – 1620</td>
<td>+98 NS</td>
</tr>
<tr>
<td></td>
<td>B – 1230</td>
<td>-64 NS</td>
</tr>
<tr>
<td></td>
<td>C – 1730</td>
<td>+299</td>
</tr>
<tr>
<td></td>
<td>D – 1900</td>
<td>+89</td>
</tr>
</tbody>
</table>
# Yield Responses to Supplemental N – YEARS 2, 3

Trt 3 (extra N) versus Trt 1  
Trt 4 (extra N) versus Trt 2

<table>
<thead>
<tr>
<th>Year</th>
<th>Site/ Yield</th>
<th>Yield Response Supplemental N (yield increased (+) or decreased (-) in: Trt 3 vs. 1 and Trt 4 vs. 2</th>
</tr>
</thead>
</table>
|      |             | Trt 3 versus Trt 1  
Petiole NO3 status of Trt 1 from 1st to peak bloom |
|      |             | Trt 4 versus Trt 2  
Petiole NO3 status of Trt 2 from 1st to peak bloom |
|      |             | Defic. border | Adeq. | Excess | Defic. border | Adeq. | Excess |
| 2    | A – 1780    | +44 NS         |       |        |          | +23 NS        |        |        |
|      | B – 2040    | +752           |       |        |          | -35 NS        |        |        |
|      | C – 2000    | +315           |       |        |          | -10 NS        |        |        |
| 3    | A – 1490    | +333           |       |        |          | +56 NS        |        |        |
|      | B – 1560    | +42 NS         |       |        |          | -38 NS        |        |        |
|      | C – 1770    | -101           |       |        |          | -49 NS        |        |        |
|      | D – 1410    | +152           |       |        |          | -85 NS        |        |        |
How account for YIELD POTENTIAL differences?

*Suggested use of plant map data*

**also evaluated top-5 retention at FB1 and FB6**

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>Bottom 5 Fruit Branch 1st position retention (%)</th>
<th>Height:Main Stem Node# Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Timing of measurement (FP1 flower)</td>
<td>Timing of measurement (FP1 flower)</td>
</tr>
<tr>
<td>Fruiting branch</td>
<td>FB1</td>
<td>FB6</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>Points</td>
</tr>
<tr>
<td>LOW</td>
<td>&lt;40</td>
<td>-2</td>
</tr>
<tr>
<td>MOD.</td>
<td>40-70</td>
<td>-1</td>
</tr>
<tr>
<td>HIGH</td>
<td>&gt;70</td>
<td>0</td>
</tr>
</tbody>
</table>

*More pluses (+) indicate incr. chance positive response to more applied N*

*More negatives (-) suggest less chance positive response to more N*
Summary:

Approach for Improvements in Nitrogen Management in Acala Cotton

- Crop needs about **50-60 lbs. N / bale of lint** from all sources, applied plus soil-available N

- In semi-arid irrigated production, soil nitrate tests available to growers are relatively inexpensive and, in our tests were useful (upper 2 feet good, deeper better)

- Applied N rates can be **adjusted for apparent available soil N** (estimate using residual soil NO3 at/near planting)

- Consider use of **plant map and petiole data** when feasible to provide additional information about possible crop responses to and the utility of supplemental N applications (via side-dress or water-run)
NISSN OGEN MANAGEMENT
for Cotton (mid- to late-season)

Even with this approach ... consider that there will be CONDITIONS WHERE N MANAGEMENT BECOMES MORE DIFFICULT including:

1. poor fruit retention / particularly if combined with vigorous vegetative growth
2. late-planted, re-planted cotton fields with a tendency toward vegetative growth
3. previous crops heavily fertilized, with high residual N
4. high irrigation water NO3-N
5. Reduced early fertilizer N application with subsequent very good fruit set

6. All these situations promote need for more feedback info to do good N mgmt ... not less feedback
Components of an N application
“Decision Plan”

- Consider that side-dress applications within season are likely a little more directed, better positioned to be intercepted by the root system than applications of N made pre-plant or just after planting
  - may consider a 5 to 10% lower rate based on this efficiency

- Try hard to resist tendency to apply “just a little more” than what you have calculated as necessary for the yield goal
  - This “risk mitigation” or insurance approach in many years could increase the chance of losses below the root zone
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
4) Shafter Research Station