Soil Health and Soil Fertility: 
&
A Few Comments on Exports 

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A few announcements:

- **Western Alfalfa & Forage Symposium**
  - Reno, Nevada — Nov. 19-20-21, 2019

- **Sign Up for the ‘Alfalfa Blog’**
  - Recent articles on Exports, Grazing, weed management, Lorsban insecticide
  - Just Google ‘Alfalfa Blog’ and it usually comes up.
  - 1x or 2x per month
  - Sign up for notices
What about Exports?

Arizona hay grown for Export, Nov. '17
In the past 10 years, exports have gone from a minor to a major component of production in some regions (Western US, Spain).
Global Exports Alfalfa & Grass (2001-2017 – ITC)

Increase of +266,000 MT/year

\[ y = 266043x + 4E+06 \]
\[ R^2 = 0.8762 \]
Figure 2. Global Exports of Alfalfa and Grass Hays by Country Share of Quantity and Value, 2017 (Source: ITC Trade Map)
US Alfalfa Exports:

Total 2007 Exports = 930,000 MTs

- Japan: 631
- Korea: 156
- UAE: 33
- Rest of World: 43
- Taiwan: 67

Total 2017 Exports = 2.9 million MTs

- China: 1,210
- Japan: 702
- UAE: 250
- Saudi Arabia: 361
- Korea: 239
- Rest of World: 71
- Taiwan: 67

Figure 5: Volume of US alfalfa Exports by Destination 2007 and 2017. Total grass and alfalfa exports exceeded 5 MMTs (2017).
% of Western state’s Hay Exported (7 states)
# Export Product Mix

<table>
<thead>
<tr>
<th>Product</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>50%</td>
</tr>
<tr>
<td>Timothy</td>
<td>11%</td>
</tr>
<tr>
<td>Perennial Ryegrass</td>
<td>7%</td>
</tr>
<tr>
<td>Annual Ryegrass</td>
<td>2%</td>
</tr>
<tr>
<td>Fescue</td>
<td>11%</td>
</tr>
<tr>
<td>Orchardgrass</td>
<td>1%</td>
</tr>
<tr>
<td>Bentgrass</td>
<td>1%</td>
</tr>
<tr>
<td>Klein</td>
<td>4%</td>
</tr>
<tr>
<td>Sudangrass</td>
<td>9%</td>
</tr>
<tr>
<td>Bermuda</td>
<td>4%</td>
</tr>
</tbody>
</table>

(Source: USFEC, Bill Plourd)
A few problems can occur
Key Problem Issues

- Importers have world perspective
  - Can reject from one area, favor another (play games)
- Cost/price squeeze
- Distance from farm to port
- Dock Strike, slowdown (2014)
- Maintaining, defining quality
- GMO sensitivity
  - Rejection of loads with low level detection (China)
- Trade Wars
Potential Impact of Trade War with China (D. Sumner, Ag Issues Center)

- 25% tariff + 7% tax = 32% tax (2018)
- Total US Production – 16,900,000 MT
- Western States price ($297/MT)
- Quantity to China (1,181,000 MT)
- Value $351 million
- Estimated Price decline 7.5%
- Estimated Revenue loss: $377 million/year
- (conservative estimate)
Late 2018- Early 2019

- October, 2018 volume of exports to China was about 50% of those earlier in year. 30% of those of 2017 max.
- Increase in Saudi demand makes up for some of this.
- Low acreage (<700,000 in CA) helps.
- USDA-FAS (Foreign Ag. Service) indicates alfalfa hay GMO acceptance in China is high priority.
Soil Health and Soil Fertility in Alfalfa

Alfalfa Production Imperial Valley
Are soils:

A. An inert mineral matrix mostly useful to support roots?
B. A place to put fertilizers
C. A complex living, breathing ‘organism’ that provides plant nutrients and supports all life on earth?
D. Something that gets your clothes dirty?
What is Soil Health?

Kate Scow, UC Davis
What is soil health?

- Soil health, also referred to as soil quality, is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.

- This definition speaks to the importance of managing soils so they are sustainable for future generations.

-- NRCS
Soil Degradation
Soil food web: creators and beneficiaries of soil health
Organic matter and microbes in create aggregate structure: fueled by carbon inputs

Kate Scow, UC Davis
Brady and Weil, 2010 from Tisdall and Oades
Soil structure for water movement and gas exchange

Kate Scow, UC Davis
Soil Structure

Kate Scow, UC Davis
Don’t Treat Your Soil LIKE DIRT
How is this relevant to forages?

- **Soil Fertility: Satisfying the needs of crop production**
  - Alfalfa, Other forage crops

- **Long-term building of ‘soil health’**
  - Soil Fertility (over time)
  - Optimizing soil condition (drainage, salinity, structure), organic matter
  - Sustain soils for other crops, future

- **Forages have a lot of positives**
  - But we can ‘mine’ soils as well!
Rotation Study Treatments
5 Years – N Treatments in Wheat following Alfalfa vs. Grains

Tulelake

Kearney

(Davis site not pictured)
Wheat Yields – Effect of Crop Rotation

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

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

Davis
Tulelake
Alfalfa rotation benefits wheat grain protein content.

Fertilization helped increase protein content, even at high N fertilization rates.
Good Soil Fertility and Stewardship

- Is highly compatible with high yields, quality, and profitability
- Resists ‘extractive’ soil management practices
Yield is limited by the most deficient plant nutrient. If one of the essential plant nutrients is deficient, plant growth will be poor even when all the other nutrients are abundant.
In California....

- P and K are the most frequently limiting nutrients for alfalfa
- Growers often do not monitor adequately either soil or plant
- Typically under-applied on deficient soils
- P and K uptake/removal levels are high
- Perennial plant, thus a multi-year question
Differences in Harvest Index

95%

40%
Alfalfa removes nutrients...

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Forage Yield Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 t/a</td>
</tr>
<tr>
<td>P (P2O5)</td>
<td>21(47)</td>
</tr>
<tr>
<td>K (K2O)</td>
<td>160(192)</td>
</tr>
</tbody>
</table>

(Adapted from Meyer et al., 2007)

In 4 years, CA alfalfa removes an average of:
- 168 lbs P (288 max)
- 1280 lbs K (2240 max)
How (and when) do you know whether a mineral is limiting?
Potassium Deficiency
Phosphorus
Molybdenum
Nitrogen
Sulfur Deficiency
Over Irrigation

- Visual symptoms not always reliable
- Yield loss occurs before visual symptoms apparent
# Nutrient Deficiencies in Alfalfa

<table>
<thead>
<tr>
<th>Element</th>
<th>Deficiency Symptom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>Generally yellow, stunted plants</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Stunted Plants with small leaves, plants are sometimes dark blue-green or reddish</td>
</tr>
<tr>
<td>Potassium</td>
<td>Pin-spots on leaf margins, on more mature leaves, turning yellow to brown leaf tips and edges</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Generally yellow, stunted plants</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Generally yellow, stunted plants</td>
</tr>
</tbody>
</table>
Diagnosing Nutrient Deficiencies in Alfalfa

- Visual Observation
  - Too late...?
- Soil Testing
  - Pre-Plant Diagnostics
- Plant Sampling
  - In-Season Diagnostics
- Fertilizer Strips in Field
  - Confirm Diagnosis
Soil Sampling

- Highly recommended during establishment.
Permanent markers (trees, telephone or electric poles, fence posts)

290 ft.

250 ft.

50 x 50 foot permanent benchmark areas
Soil Sampling

- Several areas of field
- To rooting depth (3-4’)
- Anticipate 2-3 years replacement supply
# Understand your soil status

## Interpretation of Soil Test Results for alfalfa production

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Extract</th>
<th>Deficient</th>
<th>Marginal</th>
<th>Adequate</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus</td>
<td>Olsen P</td>
<td>&lt;5</td>
<td>5-10</td>
<td>10-20</td>
<td>&gt;20</td>
</tr>
<tr>
<td>Potassium</td>
<td>NH$_4$ acetate</td>
<td>&lt;40</td>
<td>40-80</td>
<td>80-125</td>
<td>&gt;125</td>
</tr>
<tr>
<td>Expect response?</td>
<td></td>
<td>Likely</td>
<td>Frequently</td>
<td>Sometimes</td>
<td>Rarely</td>
</tr>
</tbody>
</table>

Soil Value (ppm)
Early availability of P important to nurture ‘baby’ to strong, deep-rooted plant

Dr. Mohammad Akmal, Illustration
But, Where are the Roots?
Soil Sampling and Lab Methods:

- Rooting Depth?
- Phosphorus Fixation Issues with clays?
- Extraction methods?
Soil samples are very useful but….

- What are the true Rooting Patterns?
- Does Soil Sampling = Rooting Depth?
- Does the soil release nutrients to the plant the same way as the lab extract?
- Is the plant well supplied?
- Ask the Plant!
## Relative Reliability of Soil and Plant Tissue Tests

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Soil Testing</th>
<th>Plant Tissue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus (P)</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>Very Poor</td>
<td>Excellent</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>Poor*</td>
<td>Excellent</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>Not Done</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

*Good for evaluating toxicity of boron

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How many growers currently do soil tests? Plant tissue tests?
Yield Response of Alfalfa to Phosphorus, Intermountain
(4 cuts, 2016)

\[ y = 5E-08x^3 - 5E-05x^2 + 0.0176x + 6.4238 \]
\[ R^2 = 0.8544 \]
2010

P Response – Sac. Valley

2011
The effect of phosphorus rate on alfalfa yield, Lancaster CA.

<table>
<thead>
<tr>
<th>Lbs P$_2$O$_5$/A</th>
<th>Cut 1 4/30</th>
<th>Cut 2 6/10</th>
<th>Cut 3 7/14</th>
<th>Cut 4 8/21</th>
<th>Cut 5 10/2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfertilized</td>
<td>1.56</td>
<td>1.65</td>
<td>1.57</td>
<td>1.60</td>
<td>1.13</td>
<td>7.51</td>
</tr>
<tr>
<td>100</td>
<td>1.90</td>
<td>1.84</td>
<td>1.71</td>
<td>1.74</td>
<td>1.19</td>
<td>8.38</td>
</tr>
<tr>
<td>Increase</td>
<td>0.34</td>
<td>0.19</td>
<td>0.14</td>
<td>0.14</td>
<td>0.06</td>
<td>0.87</td>
</tr>
<tr>
<td>200</td>
<td>1.94</td>
<td>1.85</td>
<td>1.76</td>
<td>1.75</td>
<td>1.27</td>
<td>8.57</td>
</tr>
<tr>
<td>Increase</td>
<td>0.38</td>
<td>0.20</td>
<td>0.19</td>
<td>0.15</td>
<td>0.14</td>
<td>1.06</td>
</tr>
</tbody>
</table>
The effect of phosphorus rate on alfalfa yield

Scott Valley, CA. (Olsen P 2.4 ppm)

<table>
<thead>
<tr>
<th>Rate (lbs $P_2O_5/A$)</th>
<th>Cut 1 6/12</th>
<th>Cut 2 7/21</th>
<th>Cut 3 8/28</th>
<th>Total</th>
<th>Increase over Unfert.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>1.94</td>
<td>1.44</td>
<td>1.25</td>
<td>4.63</td>
<td>—</td>
</tr>
<tr>
<td>40</td>
<td>2.25</td>
<td>1.79</td>
<td>1.49</td>
<td>5.53</td>
<td>0.90</td>
</tr>
<tr>
<td>80</td>
<td>2.43</td>
<td>1.75</td>
<td>1.39</td>
<td>5.56</td>
<td>0.93</td>
</tr>
<tr>
<td>120</td>
<td>2.68</td>
<td>1.79</td>
<td>1.46</td>
<td>5.93</td>
<td>1.30</td>
</tr>
<tr>
<td>160</td>
<td>2.61</td>
<td>1.81</td>
<td>1.46</td>
<td>5.88</td>
<td>1.25</td>
</tr>
</tbody>
</table>
Understand your soil status

### Recommended ranges of P & K applications for alfalfa at different soil test values

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Yield Level (t/a)</th>
<th>Deficient</th>
<th>Marginal</th>
<th>Adequate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus ($P_2O_5$)</td>
<td>8</td>
<td>120-180</td>
<td>60-90</td>
<td>0-45</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>180-270</td>
<td>90-130</td>
<td>0-60</td>
</tr>
<tr>
<td>Potassium ($K_2O$)</td>
<td>8</td>
<td>300-400</td>
<td>150-200</td>
<td>0-100</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>400-600</td>
<td>200-300</td>
<td>0-150</td>
</tr>
</tbody>
</table>
Potential Yield Increase from Fertilizer Application
Reduced Rate?

- Greatest response from initial increments of fertilizer
- Long – term build up?
What about in-season?

- Opportunity for incorporation past
- Was soil application adequate?
- Ongoing deficiency?
- Ask the plant!
## Tissue Sampling

### Interpretation of Plant Tissue Tests results – 10% bloom stage

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Plant Tissue Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deficient</td>
</tr>
<tr>
<td></td>
<td>ppm</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Mid 3&lt;sup&gt;rd&lt;/sup&gt; Stem</td>
</tr>
<tr>
<td></td>
<td>300-500</td>
</tr>
<tr>
<td>Potassium</td>
<td>Mid 3&lt;sup&gt;rd&lt;/sup&gt; Stem</td>
</tr>
<tr>
<td></td>
<td>-.40-0.65</td>
</tr>
</tbody>
</table>

(Adapted from Meyer et al., 2007)
Effect of Growth Stage on Nutrient Concentration
Effect of Maturity and Cutting on Mid-Stem PO₄-P

1st Cut

2nd Cut

2019-McArthur Winter Meeting
Maturity Effects on P Concentration (2010)

- **Phosphorus %**
  - **Early Bud**
  - **Late bud**
  - **10% Bloom**

- **Maturity**

- **Whole tops**
- **Top 15 cm**
- **Mid stems**
Maturity Effects on P Concentration (2011)

![Graph showing maturity effects on P concentration](image)
Maturity Effects on K Concentration (2010)

Potassium %

Early Bud  Late bud  10% Bloom

Maturity

whole tops

- top 15 cm

mid stems
Maturity Effects on K Concentration (2011)
# Values to Interpret Cored Bale Samples

<table>
<thead>
<tr>
<th>NUTRIENT</th>
<th>UNIT</th>
<th>DEFICIENT</th>
<th>MARGINAL</th>
<th>ADEQUATE</th>
<th>HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus</td>
<td></td>
<td>&lt;0.26</td>
<td>0.27–0.29</td>
<td>0.30–0.39</td>
<td>&gt;0.39</td>
</tr>
<tr>
<td>Early bud</td>
<td>%</td>
<td>&lt;0.23</td>
<td>0.24–0.25</td>
<td>0.26–0.34</td>
<td>&gt;0.34</td>
</tr>
<tr>
<td>Late bud</td>
<td>%</td>
<td>&lt;0.20</td>
<td>0.21–0.22</td>
<td>0.23–0.30</td>
<td>&gt;0.30</td>
</tr>
<tr>
<td>10% bloom</td>
<td>%</td>
<td>&lt;0.23</td>
<td>0.24–0.25</td>
<td>0.26–0.34</td>
<td>&gt;0.34</td>
</tr>
<tr>
<td>10% bloom</td>
<td>%</td>
<td>&lt;0.20</td>
<td>0.21–0.22</td>
<td>0.23–0.30</td>
<td>&gt;0.30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Potassium</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Early bud</td>
<td>%</td>
<td>&lt;0.91</td>
<td>0.92–1.24</td>
<td>1.25–1.60</td>
<td>1.60–3.42</td>
</tr>
<tr>
<td>Late bud</td>
<td>%</td>
<td>&lt;0.87</td>
<td>0.88–1.19</td>
<td>1.20–1.53</td>
<td>1.53–3.27</td>
</tr>
<tr>
<td>10% bloom</td>
<td>%</td>
<td>&lt;0.80</td>
<td>0.81–1.09</td>
<td>1.10–1.40</td>
<td>1.40–3.00</td>
</tr>
</tbody>
</table>
Soil samples taken along each windrow (15 to 20 cores)

- Compare results from fractionated tops, whole tops, cored bales, soil samples

I went to school for this?
Whole Plant vs. Bale P

\[ y = 1.0655x - 0.0162 \]
\[ R^2 = 0.9497 \]
Whole Plant vs. Bale K

\[ y = 1.0331x - 0.105 \]

\[ R^2 = 0.9431 \]
Mid-Stem PO$_4$-P vs. Bale Total P

\[ y = 0.0001x + 0.097 \]

\[ R^2 = 0.8764 \]
**Bale vs. Mid Stem K**

\[ y = 0.8726x + 0.2373 \]

\[ R^2 = 0.8316 \]
Interpreting soil or tissue test values

Recommended ranges of P & K applications for alfalfa at different soil or tissue test values

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Yield Level (t/a)</th>
<th>Deficient</th>
<th>Marginal</th>
<th>Adequate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus (P₂O₅)</td>
<td>8</td>
<td>120-180</td>
<td>60-90</td>
<td>0-45</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>180-270</td>
<td>90-130</td>
<td>0-60</td>
</tr>
<tr>
<td>Potassium (K₂O)</td>
<td>8</td>
<td>300-400</td>
<td>150-200</td>
<td>0-100</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>400-600</td>
<td>200-300</td>
<td>0-150</td>
</tr>
</tbody>
</table>
**Approaches to Soil Fertility:**

- **“Recipe” Approach:** (NO)
  - Applying a Fixed Amount ‘cookbook’
  - Eventually results in over- or under-fertilization

- **“Prescription” Approach:** (YES)
  - Diagnosis – visual & lab
  - Soil or plant tissue analysis
  - Tailored to needs of the field

- **“Soil Health” Approach:** (YES)
  - Envision limitations to soils improving over time.
  - Not just N-P-K, but organic matter, soil biology, Soil Structure
  - Soil and cropping systems management to improve soils

Cannot overstate importance of soil testing or plant tissue testing to determine fertility status
Summary

- Soil Health is multi-dimensional!
- Long term ‘health’ is the goal
- Soil analysis good for pre-plant assessment
  - pH, salinity, P and K
- Use Plant tissue analysis in season
  - Evaluate most limiting nutrient then fertilize and resample
  - Leave untreated strips to assess effectiveness
- Bale sampling for tissue testing practical