Energizing your Crop Rotation!

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Agroecoregion map from (Glen) Padbury et al. 2002 Agron. J.
What are the important energy angles for dryland wheat systems?

- Tillage
  - Fallow vs continuous crop
    - In fallow, embedded energy
Energy angles for dryland cropping systems

- Tillage
- Nitrogen (= Pulses?)
Energy Use in U.S. Wheat Production

- N Fertilizer: 47%
- Diesel & Gasoline: 30%
- Seed: 8%
- P & K Fertilizer: 5%
- Other (electricity, embodied energy in buildings, machinery etc.): 10%

Figure from Mac Burgess

Reevaluation of Energy Use in Wheat Production in the United States
Gerhard Piringer, Laura J. Steinberg
Journal of Industrial Ecology 2006 10:1-2, 149-167
What can we do about nitrogen?

• Reduce rates?
  – Leaving money on the table in average to wet years; protein especially

• Build up soil N > legume crops?
  – Then could back off on N fertilizer
On-Farm Combine yield sensor & GPS

<table>
<thead>
<tr>
<th>Wheat after Wheat</th>
<th>Wheat after Pea</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 Bu/acre</td>
<td>23 Bu/acre</td>
</tr>
<tr>
<td>Test weight = 53</td>
<td>Test weight = 57</td>
</tr>
<tr>
<td>18% protein</td>
<td>16% protein</td>
</tr>
</tbody>
</table>


Key aspect: Long-term management
Embodied Energy to grow crops (data from 14 MT farms)

What about pulse credits?

• Who takes a pulse credit for N when figuring fertilizer rate?
Evidence from Crop Diversity Rotation Study at Bozeman

Winter Wheat - Yield

Even though a 20-lb pea N credit was assumed.

28% greater on pea stubble.
Evidence from Two Rotation Studies at Bozeman

Spring Wheat - Yield

Even though a 20-lb pea N credit was assumed.

22% greater on pea stubble
Can you make a pulse credit disappear?
Textbook N vs Non-N Rotational Benefit

Beckie and Brandt 1997

Barley Yield (bu/ac)

Nitrogen (lb/ac)

Wheat
Canola
Pea

Stubble

**Wheat after Wheat**
17 Bu/acre
Test weight = 53
18% protein

**Wheat after Pea**
23 Bu/acre
Test weight = 57
16% protein

Key aspect: Long-term management
Energy Intensity required to grow the crop

- Pea
- Lentil
- Wheat
- Wheat after Wheat
- Wheat after Pulse

--- Year 1 ---

--- Year 2 ---

Net Energy Yield

![Graph showing Net Energy Yield for different crops: Pea, Lentil, Wheat, Wheat after Wheat, Wheat after Pulse. The graph compares the energy yield between Year 1 and Year 2. Pea has the highest yield in Year 1, while Wheat after Pulse has the highest yield in Year 2.](image)

North Central aka ‘Golden Triangle’
- Very Dry (250-300 mm ppt)
- Summer Fallow-Winter Wheat
- 40+% of cropland fallow every year

NE Montana
- Less Dry (300-350mm)
- More Summer Rain
- Spring Wheat and Pulses

Gallatin Valley MSU-Bozeman
- Wet Winter, Dry Summer
Summerfallow is disappearing
AB, MT, ND, SK, SD & WY. 1926 - 2007

Modern Varieties
NT Production
Diversification!

Fallow being replaced by pulse crops (Pea, Lentil) in **NE Montana**
But, not in North-central Montana (too dry)
Adaptation Challenge

• What would have to happen to push pulse production into warmer, drier areas?
  – Winter pea, lentil?
  – Biggest challenges are:
    1. Wheat stubble provides too cool microclimate in late Fall and early spring.
    2. Seedling disease in the early spring

Mozart spring pea vs winter pea
Winter pea forage and grain protein superior to spring pea

Arvika spring pea
June 10, 2003

Melrose winter pea
June 10, 2003
Winter pea fixes more N than spring pea under dry conditions

Winter lentil

Toni winter lentil
seed increase
July 18, 2008
Bozeman, MT
What about pulses as cover crops in semiarid NGP?

“green manures should not be used for the production of spring or winter wheat in the Brown soil zone… This conclusion, however, would probably be altered if a management practice can be devised which… favorably influences the water balance of the crop”

Crop available water to 0.9 m (mm)

Havre, MT - April, 2000

With early termination, legumes grow with little net water use.
Water drove grain yield

Havre, MT - 2000

Wheat Grain kg ha\(^{-1}\)

Grain
Grain + res
Forage
Green Manure

Previous Crop

Wheat
Pea
Fallow

Grain
Grain + res
Forage
Green Manure

Havre, MT - 2000

Wheat Grain kg ha\(^{-1}\)
Legume green manures as ‘bioenergy’ crops?

**Lentil**
- Cheaper seed (discounted feed grade)
- Easier stubble management

**Pea**
- Faster initial growth
- More N fixation
- Better weed competition
Does tillage affect N release from legume green manure? (yes, but can be at expense of water)

NT = 0 tillage
T-NT = 1 tillage
NT-T = 2 tillage
T = 3 tillage
June 17, 2007 – Perry tilling green manure


No-till green manure – Aug 6, 2007

Tillled green manure - Aug 6, 2007
On Farm Trial 2010-2011

Grain Protein, LGM vs. Fallow

Grain Protein (g kg⁻¹) at 12% moist.

Error bars = 1 SE mean

LGM: 3.5 bu/ac lower…
Summary of Short Term LGM Results

• With early termination, we can prevent yield loss from soil water depletion

• N cycling is limited, or delayed, without tillage
  – Rarely find increased soil N at seeding

• Short term N benefits are elusive
  – Winter pea has been exception but it’s survival has been elusive!

• Economics are marginal at best
  – And dependent on finding low-cost seed
What about long-term system results?

• Long-term tilled lentil green manure studies appeared to be improving soil fertility economically
  – Zentner et al. 2004 (Swift Current) and various (Froid, MT)
  – These studies operating independently but simultaneously in same agroecoregion reached similar conclusions … profound soil changes about the 6-yr mark

• We initiated a long-term trial at Bozeman, using pea and no-till
Positive economic net returns from green fallow compared with tilled fallow (Swift Current, SK; Zentner et al. 2004)

Economic Wow! moment

2nd 6-yr cycle

Changed to 2-3 wk earlier termination of lentil
Pea green manure increased spring soil nitrate after 4 appearances in 7 yr?
Long-term effects of LGM? (after 7 yr)

Vida spr wheat yield 2010 GGRS

Pea manure fertilized least, biggest yield

0 N applied
2010 Net Returns/acre – Spring wheat

LSD0.10 = $33

1. Full rate of fertilizer very valuable for yield AND protein.
2. Pea green manure effect was shocking! Long-term response??
Net returns after 2-yr sequence

LSD 0.10 = $35
Can we make this happen in much drier conditions?

- **2 locations in Triangle**
  - Dutton (clay) and Big Sandy (silt loam)
  - Run for 6 years!
- **4 Water Risk Strategies**
  - Fallow, Legume Green Manure, Pulse Crop, Cont. Wheat
- **4 N Fertilizer Strategies**
  - 0, ½ $X$, 1 $X$, 1 ½ $X$
  - $X = 3$ lb N per bushel of targeted yield
Winter wheat yield – 2012, Dutton

Producer’s yield target was 60 bu on fallow; 40 on stubble. Drought capped yield. Not very N responsive.
Winter wheat yield – 2012, Dutton

Protein story. Full rate of N was more than enough to meet yield goal in all situations.
Winter wheat return$ – 2012, Dutton

Early story. Fallow paid in a dry year. Long-term?

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<th>Previous crop and N fertilizer rate</th>
<th>marginal return to winter wheat ($/ac)</th>
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<tbody>
<tr>
<td>Fallow</td>
<td>0 0.5X 1X 1.5X</td>
</tr>
<tr>
<td>Pea manure</td>
<td>0 0.5X 1X 1.5X</td>
</tr>
<tr>
<td>Pea grain</td>
<td>0 0.5X 1X 1.5X</td>
</tr>
<tr>
<td>Spr wheat</td>
<td>0 0.5X 1X 1.5X</td>
</tr>
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Winter wheat 2 yr return$ – 2011-2012, Dutton

Pulse crop strategy competitive with fallow. Long term?

Previous crop and N fertilizer rate

- Fallow
- Pea manure
- Pea grain
- Spr wheat
Really long-term question:

– Can N fixation be overdone?
FIGURE 3. Nitrate-N distribution in soil profile showing long-term leaching losses under W, W-L, and F-W systems. (Adapted from Campbell et al. 1993b)
$W-L$ minus Cont. Wheat, Old Rotation, Swift Current, SK 1985 - 2005
(Campbell et al. CJSS)
Conclusions

1. Bioenergy role is tied both to N fertilizer replacement AND positive rotational benefits to cereal crops.
2. It may be wise to examine environmental sustainability of soil nitrogen cycling related to long-term pulse production.
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Too many pulse producers to name

NIFA - AFRI- Managed Ecosystems