COVER CROPS AND SOIL HEALTH

MT Farm Bureau Federation
Missoula
November 9, 2015

Clain Jones (994-6076; clainj@montana.edu)
Dept. Land Resources & Environmental Sciences

MSU Soil Fertility Extension
Cover crops:

A. Teach us how to use clickers
B. Can keep you warm at night
C. Build strong worms
D. Are yummy if you are a cow
What brings you to the workshop today?

A. Farm management (mainly cash crops on 100+ acres)
B. Ranch management (mainly livestock on 100+ acres)
C. Small acreage farm/ranch management (<100 ac)
D. Job with state or federal government
E. Job as crop adviser
F. Interested citizen

A. 44%
B. 44%
C. 6%
D. 6%
E. 0%
F. 0%
Today’s goals

• Present potential benefits of cover crops
• Discuss cover crop effects on
  ▪ Nitrogen
  ▪ Soil organic matter
  ▪ Temperature, aggregate stability, microbial activity
  ▪ Following crop yield and protein
  ▪ Economics
• Present management considerations with cover crops
The Summerfallow Challenge

PROS:
Soil moisture recharge
N benefit

CONS:
Loss of organic matter
Increased soil erosion
saline seeps
N leaching
Decreased soil structure
water holding capacity
soil biological activity

Alternatives?
• No-Till
• Cover crops
Do you, or have you grown cover crops, or advise people who grow cover crops?

A. Yes
B. No

63% Yes
38% No
Have you heard of MSU’s cover crop studies?

A. Yes
B. No

53% Yes
47% No
If you’ve heard of our studies, have they changed your understanding of cover crops?

A. Yes  
B. No
If you’ve heard of MSU’s cover crop studies, how has your management changed, if at all?

A. Not at all  
B. More likely to make a change  
C. Already made a change

- Not at all: 0%
- More likely to...: 66%
- Already made ...: 34%
Benefits and challenges of cover crops

Equipment

Biomass

Management challenges

TIME

$N, P, K, S$
Soil Quality vs Soil Health

Soil Quality = properties that change little, if at all, with land use management practices
- Texture
- pH
- Cation Exchange Capacity

Soil Health = dynamic properties which may be subjective to measure
- Aggregation
- Microbial activity
- Tilth
- Nutrient availability
- Water holding capacity
- Compaction

Which is more likely to be influenced by cover crops?
What we have found with MT research trials
MSU single species cover crop research since 1999 has found higher grain yields and/or protein after cover crops when:

1. Seeding winter legumes (vs spring legumes)
2. Seeding spring cover crops early (vs late)
3. Terminating at first bloom (vs pod)
4. Tilling cover crop (vs spraying)

Why?

- More N fixed (1)
- More time for soil water to be recharged and N to become released from residue (1, 2, 3)
- Faster N release and fewer N losses (4)
Our MT studies confirmed early Saskatchewan studies that termination timing is key

WHY?

Terminating legume cover crop at early bloom produced higher organic wheat yields the following year than terminating at flat pod in 2006-2007 (Miller et al. 2011)

Similar results for advantage of bloom over pod in conventional systems
Plot Study No-till and Till: Design

3 Crop Treatments × Tillage Treatments

- Spring Pea Manure
- Spring Lentil Manure
- Fallow

- Green manures terminated at first flower
- Spring wheat planted at 4 N rates following year
- Gallatin Valley, ~14 inch annual precip.
Effect of lentil and pea cover crop on spring wheat yield & protein

Take home:
- Early-terminated spring cover crop did not hurt wheat yield or protein.
- Pea cover crop only increased yield at low N rates when tilled.
- Pea increased grain protein at all N rates and both NT and T.
- Lentil cover crop did not benefit yield or protein (likely N contribution too low)
Questions?
Cover Crop Cocktails Plot Study

1. Compare crop and soil response to fallow, single species pea CC, and multi-species mixtures
   • Cover crop and wheat: Biomass, biomass quality, yield
   • Soil:
     ▪ Microbial biomass
     ▪ Soil enzyme activity
     ▪ Soil temperature
     ▪ Aggregate stability
     ▪ Compaction
     ▪ Soil water, nitrate, and Olsen P
     ▪ Mycorrhizal colonization
     ▪ Potentially mineralizable nitrogen

2. Determine the specific effects of 4 plant functional groups

3. 2 sites in Triangle, 2 in Gallatin Valley
Plant functional groups — planted individually and in groups

**Nitrogen Fixers**
- Spring Pea
- Common Vetch
- Lentil

**Fibrous Root**
- Oats
- Italian ryegrass
- Proso millet

**Tap Root**
- Purple top turnip
- Safflower

**Brassica**
- Daikon radish
- Winter canola
- Camelina

*Increase nitrogen*

*Add soil carbon*

*Reduce compaction, move nutrients upward*

*Potential disease control*
Lessons learned about plantings

• Early weed control essential
• Common vetch difficult to terminate w/ glyphosate
• Camelina, Italian ryegrass, and lentil not competitive
• Radish bolts in late spring
• Millet not competitive in mid-spring mix
• Possible biological control benefits of wheat-stem sawfly with oat and radish

Photo: Susan Tallman
Cover Crop Biomass – depends on moisture

Amsterdam 0.4 ton/acre  2012  Conrad 0.2 ton/acre

Amsterdam 1.4 ton/acre  2014  Conrad 1.0 ton/acre

Photo: Steve Spence

Photo: Meg Housman
2013 Cover Crop Biomass – wet year

Bozeman  \( p<0.001 \)

Dutton  \( p=0.81 \)
Effect of cover crop treatment on spring wheat grain yield at Dutton (2014)

Housman et al., unpub. data, Dutton

Cover Crop Mix

Spring Wheat Yield (bu/acre)

Fallow  Pea  N fixer  Brass  Fibr root  Tap root  No brass  No fibr  No N fix  No tap  All 8 spp

Averaged over 0, 60, 120 lb N/acre
Spring wheat yield at Dutton vs previous year total biomass (cc + weed)

\[ SW \text{ yield} = (-7.25 \times CC\text{biomass}) + 46.4 \]

\[ R^2 = 0.72 \]

Housman, Tallman, et al., unpub data, Dutton

What about soil health?
Potentially Mineralizable Nitrogen – 1st year

Tallman, Housman, et al., unpub data
Microbial Biomass – 1\textsuperscript{st} year

Tallman, Housman, et al., unpub data
Soil temperature at 2” deep much higher under fallow than cover crops (but no differences between pea and full)

Soils were cooler under cover crop than fallow for over a month. Benefit?

Jones, Miller, et al. unpublished
### Summary after FIRST full rotation

<table>
<thead>
<tr>
<th></th>
<th>Amsterdam</th>
<th>Conrad</th>
<th>Dutton</th>
<th>Bozeman</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC Biomass</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Biomass C:N</td>
<td>8 spec&gt;Pea</td>
<td>ns</td>
<td>8 spec&gt;Pea</td>
<td>ns</td>
</tr>
<tr>
<td>Microbial Biomass</td>
<td>ns</td>
<td>ns</td>
<td>CC&gt;fallow</td>
<td>CC&gt;fallow</td>
</tr>
<tr>
<td>PMN</td>
<td>CC&gt;fallow</td>
<td>Pea&gt;6 spec</td>
<td>CC&gt;fallow</td>
<td>ns</td>
</tr>
<tr>
<td>Olsen P</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Temp at 2”</td>
<td>--</td>
<td>--</td>
<td>CC&lt;fallow</td>
<td>CC&lt;fallow</td>
</tr>
<tr>
<td>Aggregate stability</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

*ns – no significant difference (95% confidence) among any treatments (meaning pea vs 8 spec OR fallow vs cover crops)*
### Summary after SECOND full rotation

<table>
<thead>
<tr>
<th></th>
<th>Amsterdam</th>
<th>Conrad</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cover crop biomass</strong></td>
<td>6 spp. &gt; 2 spp.</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Microbial Biomass</strong></td>
<td>CC&gt;fallow</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Microbial Enzymes (5)</strong></td>
<td>CC&gt;fallow</td>
<td>ns</td>
</tr>
<tr>
<td><strong>PMN</strong></td>
<td>CC&gt;fallow</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Olsen P</strong></td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Temp at 2”</strong></td>
<td>CC&lt;fallow</td>
<td>CC&lt;fallow</td>
</tr>
<tr>
<td><strong>Aggregate stability</strong></td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

*ns – no significant difference (95% confidence) among any treatments (meaning pea vs 8 spec OR fallow vs cover crops)*
Cover Crop Cocktails Plot Study: Take home messages on yield and soil quality

- After one cycle, spring wheat grain yields higher after pea and N fixers than most other mixes.
- Higher cover crop biomass correlated with lower spring wheat yield, likely b/c of more water and N use.
- Relatively few soil health differences between pea and 8-species mix after one cycle; not unexpected.
- After two cycles, no soil health differences between pea and 8-species mix, but CCs increased microbial activity.
Questions?
Cover Crop Cocktails Farm Study: Spring wheat yield after mixed CC, Gallatin Valley

Why was protein so much lower after mixed cover crops?
Percent legume and termination timing affects plant available N (PAN)

**Take home:** Legume % less than 50 can result in low available N esp if terminated late

Willamette Valley, Oregon

Sullivan and Andrews, 2012
Cover Crop Cocktail Farm Study: 1 rotation of mixed CC reduced grain yield in 4 of 6 production years

Yield less after mixed cover crops on farmers’ fields, likely due to late termination and high water & N use by CCrop
Cover Crop Cocktail Farm Study: 1 rotation of mixed CC produced varied grain protein results

- Signif difference with 90% probability

P. Miller
unpub data
Cover Crop Cocktails Farm Study: Take home messages on yield and protein

- Spring wheat grain yield was lower after CC than fallow in four of six field-scale studies, and protein results were mixed.
- High water use from late termination was likely cause of yield differences.
- Low N availability from late termination & low legume % was likely cause of protein differences.
Questions or Comments?
Not a stellar outlook for cover crops in short term, what about long term? 8-year plot study

Legume or fallow year

Wheat year
8-year Plot Study

- Long-term effects of no-till pea forage/legume cover crop-wheat vs. fallow-wheat
- ~16” annual precip on deep soils & ability to recharge soils
- Pea forage grown in 2003, 05, 07 and pea CC grown in 2009, terminated at full pod
- Spring or winter wheat planted in even years. 2010 was wettest of wheat years, 2012 record drought.
- 2 N rates: Full (3 lb available N/bu) and ½ N
- NO differences in wheat yield following CC and following fallow in 2004, 2006, 2008, and 2012, and large benefit of CC in 2010
8 Year Plot Study: Grain yield in 8th year (2010)

Grain yield (bu/ac)

@ 12% moist
8 Year Plot Study:
Grain protein in 8th year

Pea cover crop after 4 CC-wheat rotations saved **124 lb N/ac** compared to fallow.
Potentially mineralizable N (PMN)
Cover crop-wheat vs fallow-wheat (April of 8\textsuperscript{th} yr)

This equates to an 80 lb N/ac benefit of CC in just top 6 inches!

O’Dea et al. (2015)
Economics: 8-year Plot Study (2009-2012)

Miller et al., 2015
8-year Plot Study: Take home messages

• In the first 3 cycles, wheat grain yield was not higher after legume than after fallow.
• After 4 two-year cycles, wheat grain yield and protein were higher after legume CC than after fallow.
• Higher than normal precipitation in 2010 likely 1) increased release of available N from an increased organic N pool, and 2) made N limiting to growth.
• Over 100 lb N/ac was saved in 2010 following legume cover crop compared to fallow!
• Economic returns were more stable with cover crop (less dependent on N rate)
Questions?
N credit from pulse/legumes

- N Credit = The amount of fertilizer N to back off from a standard recommendation (e.g., lb N/bu of yield goal) when previous crop is a legume, based on spring soil sampling.
- Adjust yield goal — will be lower after legumes than fallow due to water use, but higher than after small grain
Estimated N credit from pulse/legume

- Legume cover crop grown once: 20-30 lb N/acre (higher if moist)
- Legume cover crop grown 3 or more times: 30-50 lb N/acre
- If fall soil test (rather than spring), increase all of above by 10 lb N/acre (due to overwinter N mineralization)
## Example N rate calculation (based on Big Sandy study results)

<table>
<thead>
<tr>
<th></th>
<th>Fallow</th>
<th>Grain pulse grown 1x</th>
<th>Legume cover crop grown 1x</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW yield goal (bu/ac)</td>
<td>45</td>
<td>35</td>
<td>45</td>
</tr>
<tr>
<td>Spring soil N (lb/ac)</td>
<td>80</td>
<td>55</td>
<td>65</td>
</tr>
<tr>
<td>Total soil N recommended (bu/ac x 2.6 lb/bu)</td>
<td>45 x 2.6 = 117</td>
<td>35 x 2.6 = 91</td>
<td>45 x 2.6 = 117</td>
</tr>
<tr>
<td>N credit (lb/ac)</td>
<td>0</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>Fertilizer N (lb/ac)</td>
<td>117-80-0=47</td>
<td>91-55-10=26</td>
<td>117-65-25=27</td>
</tr>
</tbody>
</table>
SOM input = a function of biomass input

- Residue decomposition rate varies with climate, tillage, soil type, etc.
- Potential SOM input depends on biomass produced regardless of soil and site conditions

Fisher et al., 2007, Australia irrigated systems
Decomposition of plant residue to SOM

Wet year and climate
Bozeman, 2013
3300 lb/acre

Dry year and climate
Conrad, 2012, 360 lb/acre

CO₂
50%
1650 lb/acre
Soil Organic Matter
180 lb/acre
SOM addition to soil

2% SOM in top 6”
40,000 lb SOM/acre

Wet year and climate
1650 lb SOM/acre

\[
\frac{1650}{40,000} = 0.04 \rightarrow 2.08\% \text{ SOM}
\]
After 3 cycles = 2.24%

Dry year and climate
180 lb SOM/acre

\[
\frac{180}{40,000} = 0.0045 \rightarrow 2.01\% \text{ SOM}
\]
So why try?

The journey of a thousand miles begins with one step. ... Martin Luther King, Jr.

Small increases in SOM lead to potentially large improvement in soil structure.

Fisher et al., 2007
Australia, irrigated, variety of soil types
SOM after 10 years cropping systems (2012)

![Bar chart showing SOM in top foot of soil across different cropping systems and tillage practices.

SOM in 2002 is indicated by a dashed line. Bar heights represent SOM in 2012.

F-W: 23 (e)
W-W: 29 (ab)
Pgrain-W: 29 (ab)
Pforage-W: 28 (cd)
CC-W: 28 (bcd)
CRP: 30 (a)

Engel, unpub data, MSU Post Farm]
Legume cover crops: They take time to influence subsequent wheat yield

Allen et al., 2011, Culbertson
Pulse/legume rotations benefit protein before yields

Allen et al., 2011, Culbertson
Questions?
Economic options

Do you, or would you, graze cover crops?

A. Yes

B. No

- Grazing may provide more immediate economic return and increase the rate of change in soil health. Currently under study at MSU-Northern.
- NRCS provides incentives for growing cover crops
Conclusions

- In short term (1 CC-cycle studies), grain yield and protein are generally equal or less than after fallow.
- Early termination (by ~ first pea bloom) is key to preventing yield and protein losses.
- In short term studies, there does not appear to be yield or soil quality advantages of multiple species mixes over pea.
- In long term (4+ cycles), yield, protein, and net revenue can be higher after cover crops than fallow, especially at low N rates, likely from more available N.
- Cover crops provide resilience to uncontrollable factors such as weather and markets
- Cover crop value to soil health, subsequent crops, and possibly land value is expected to increase over time.
Is your management, or management recommendations, likely to change, based on what we have presented today?

A. Yes
B. No
Acknowledgments

- USDA – AFRI
- USDA – WSARE
- NRCS – CIG
- Montana Fertilizer Advisory Committee
- Montana Wheat and Barley Committee
- Numerous landowners
- Ann McCauley
- Jeff Holmes
- Anton Bekkerman
- Mac Burgess
For a pdf version of this presentation and additional information on cover crops and soil fertility, see http://landresources.montana.edu/soilfertility