COVER CROPS AND SOIL HEALTH

MT Organic Association
Bozeman
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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
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
Do you, or have you grown cover crops?

A. Yes
B. No
When have you used cover crops? Select all that apply.

A. As a late summer to fall cover 25%
B. As a winter crop 25%
C. As a spring-summer crop 25%
D. Other 25%
How familiar are you with cover crop mixtures?

A. Never heard of them  20%
B. Minimal knowledge    20%
C. Quite familiar but never tried         20%
D. Tried but not likely to use again     20%
E. Tried and will continue to use         20%
What is the average number of species in your cover crop?

A. 1
B. 2 – 3
C. 4 – 5
D. 6 – 7
E. 8 or more
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

Which is more likely to be influenced by cover crops?

**Soil Health** = dynamic properties which may be subjective to measure

- Aggregation
- Microbial activity
- Tilth
- Nutrient availability
- Water holding capacity
- Compaction
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)
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).

WHY?

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WHY?
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

*Increase nitrogen*

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

*Add soil carbon*

*Reduce compaction, move nutrients upward*

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

*Potential disease control*

**Brassica**
- Daikon radish
- Winter canola
- Camelina
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 2012
0.4 ton/acre

Conrad
0.2 ton/acre

Amsterdam 2014
1.4 ton/acre

Conrad
1.0 ton/acre

Photo: Steve Spence

Photo: Meg Housman
Spring wheat yield at Dutton vs previous year total biomass (cc + weed)

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

\[ R^2 = 0.72 \]

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

What about soil health?
Potentially Mineralizable Nitrogen – 1\textsuperscript{st} year

Tallman, Housman, et al., unpub data
Microbial Biomass – 1st 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?

Cover crops terminated on 5 July

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>
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<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>Pea&gt;8 spec,fall.</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>
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<tr>
<td>Aggregate stability</td>
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<td>ns</td>
<td>ns</td>
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</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>
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<tr>
<th></th>
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<tbody>
<tr>
<td>Cover crop biomass</td>
<td>6 spp. &gt; 2 spp.</td>
<td>ns</td>
</tr>
<tr>
<td>Microbial Biomass</td>
<td>CC&gt;fallow</td>
<td>ns</td>
</tr>
<tr>
<td>Microbial Enzymes (5)</td>
<td>CC&gt;fallow</td>
<td>ns</td>
</tr>
<tr>
<td>PMN</td>
<td>CC&gt;fallow</td>
<td>ns</td>
</tr>
<tr>
<td>Olsen P</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Temp at 2”</td>
<td>CC&lt;fallow</td>
<td>CC&lt;fallow</td>
</tr>
<tr>
<td>Aggregate stability</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

Soil water generally not limiting, except 2012

Wheat yield
2004 CC = Fallow
2006 CC = Fallow
2008 CC = Fallow
2010 CC > Fallow
2012 CC = Fallow
8 Year Plot Study:
Grain yield in 8\textsuperscript{th} year (2010)

@ 12\% moist
8 Year Plot Study: Grain protein in 8\textsuperscript{th} year

Pea cover crop after 4 CC-wheat rotations saved \textbf{124 lb N/acre} 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)
After 4 rotations pea GM provides same net return as fallow, with less N

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?
Cropping system effects on soil N after 6 years (MSU Post Farm)

![Graph showing Total Nitrogen 1 ft. Depth (lb N/ac) for different cropping systems.]

**ORG: LGM 1 in 2 years**

* - sig higher than tilled fallow wheat

Cropping System
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
Plant biomass to produce SOM requires nutrient inputs

From 2000 to 2012, MSU Post Farm
Organic received no inputs
Organic rotation = legume GM/Wheat/Lentil/Barley or Safflower
Approximately how many years are you willing to invest in cover crops before getting a financial return?

A. 0
B. 1
C. 2
D. 3
E. 4
F. 5+
Have your cash crop yields changed as a result of cover crop use?

A. No
B. Yes, increased
C. Yes, decreased
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
Economic options

Do 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
Questions?
From 2000 to 2012, MSU Post Farm Organic received no inputs
Organic rotation = legume GM/Wwheat/Lentil/Barley or Safflower

Nutrient losses from fields

Assorted rotations w/wheat + fertilizer
Manure

- Tilled in ~9 tons/acre aged manure prior to seeding winter wheat on one ORG plot 2009.
- = 75 lb TOTAL $P_2O_5$/acre
  ≈ 400 lb TOTAL N/acre
Effect of manure on 2010 winter wheat grain yield

Post Farm, Bozeman
Miller, unpub data

No effect on grain protein
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 likely to change, based on what we have presented today?

A. Yes

B. No

Response Counter
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