Making the Most of Cover Crop Mixtures

Mitch Hunter
PhD Candidate in Agronomy
Penn State University

March 29, 2016
NESARE Professional Development Workshop
Many thanks to...

Charlie White
Crop Management Extension Team
Many thanks to...

Cover Crop Cocktails Project Team

Mary Barbercheck  Denise Finney  Nancy Ellen Kiernan  Meagan Schipanski
Brosi Bradley  Scott Harkcom  Dawn Luthe  Brian Snyder
Mac Burgess  Abbe Hamilton  Dave Mortensen  Dayton Spackman
Sarah Cornelisse  Dave Hartman  Ebony Murrell  Alexandra Stone
Dan DeTurk  Mena Hautau  Jeff Moyer  Charlie White
Tianna DuPont  Jermaine Hinds  Christy Mullen  Dave Wilson
Katie Ellis  Shan Jin  Puneet Randhawa  Leslie Zuck
Wade Esbenshade  Jason Kaye  Rebecca Robertson  Bucky Ziegler

This material is based upon work supported by the National Science Foundation under Grant No. DGE1255832. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.
Why Mixtures?

Mixing species can diversify the benefits provided by a cover crop.
Quantifying cover crop benefits

- Yield
- Weed control
- Soil organic matter
- Soil biology
- Nitrogen retention
- Nitrogen supply

Slide credit: Denise Finney
Monoculture multifunctionality

Rye
- Yield
- Weed control
- Nitrogen retention
- Soil organic matter
- Soil biology
- Nitrogen supply

Pea
- Yield
- Soil organic matter
- Soil biology
- Nitrogen retention
- Nitrogen supply

Slide credit: Denise Finney
Mixture multifunctionality???
Mixture multifunctionality – diverse benefits

- Yield
- Weed control
- Soil organic matter
- Soil biology
- Nitrogen retention
- Nitrogen supply

- Rye
- Pea
- 3SppN

Mixture multifunctionality:
- Diverse benefits

Slide credit: Denise Finney
Are Researchers Crazy?

• Not Crazy Enough!
  • Have to simplify
  • Focus on measurable benefits – soil health?
  • Interested in determining, costs, benefits, and tradeoffs
  • Limited number of species (2-8)

• To translate research results to more diverse mixes:
  • Species = functional groups
Five Steps to Success!

1. Understand your context
2. Identify your goals
3. Select complementary species
4. Follow the fundamentals of establishing mixtures
5. Farm-tune your mix
Context is critical!

Same 4-species mix, same year, different farms:

Berks County

Montour County

- red clover
- pea
- canola
- cereal rye
Context questions

Climate?
Soil?
Planting window?
Previous cash crop?
Following cash crop?
Budget?
Planting equipment?

What are the key points of context on your farm(s)?
Identify your (diverse) goals

What are the needs on the farm?
  – Alleviate compaction
  – Improve soil structure
  – Nitrogen fixation
  – Nitrogen retention
  – Weed suppression
  – Lasting surface mulch
  – Beneficial insects
  – Fall and/or spring forage production
Pick a target C:N ratio

**C:N sets the parameters of what to plant and when to terminate**

[Image of Red Bull and a glass of beer]

OR

[Image of a glass of Guinness]

www.obsev.com

www.guinness.com
Low C:N ratio associated with high cash crop yield

\[ y = 1.4 - 6.3 \times 10^{-2}x \]

\[ R^2 = 0.55 \]

Finney et al. 16, Agron. J. 108
Low C:N ratio associated with low weed suppression.

\[ y = -2.1 + 1.2e^{-1}x \text{ if } x \leq 20.7 \]
\[ y = 0.5 \text{ if } x > 20.7 \]
\[ R^2 = 0.27 \]
Low C:N ratio associated with low N retention

\[ y = -1.9 + 9.9 \times 10^{-2}x \quad \text{if } x < 27.8 \]
\[ y = 0.8 \quad \text{if } x > 27.8 \]
\[ R^2 = 0.50 \]
Use dominant species and maturity to estimate C:N

- **High Nitrogen Concentration**
  - 5:1: Clovers, Peas
  - 10:1: Radish
  - 15:1: Canola
  - 20:1: Cereal Rye, Triticale
  - 30:1: Annual Ryegrass
  - 40:1: Oats, Sorghum sudangrass

- **Low Nitrogen Concentration**
Many benefits increase with greater cover crop biomass

- Nitrogen retention
- Nitrogen supply
- Weed suppression
- Erosion control
- Soil organic matter

To increase biomass, select complementary species
Complementary growth periods

- **Winter-killed** crops:
  - Oats
  - Sorghum-Sudangrass
  - Sunnhemp
  - Fava Beans
  - Soybeans

- **Winter Hardy** crops:
  - Cereal Rye
  - Annual Ryegrass
  - Red Clover
  - Triticale
  - Canola

- **Wheat** in June-August
- **Winter-killed Cover Crop** from December to April
- **Winter Hardy Cover Crop** from April to June-August
- **Corn** in June-August
Complementary Growth Periods

Sorghum sudangrass + annual ryegrass + crimson clover
Complementary Maturation in Spring

- Cereal rye matures too early compared to legumes
- Consider triticale or annual ryegrass instead

Hairy vetch + triticale

Annual ryegrass + crimson clover
Complementary growth forms

- Mix tall-open species with low-dense species and vining species
- Don’t plant any of the species too densely
Complementary growth forms

30 lbs/ac Sorghum-Sudan grass was too dense!
Lack of complementarity increases competition

12 lbs/ac Red Clover

12 lbs/ac Red Clover + 10 lbs/ac Ann. Ryegr.

Only one layer of the canopy is being used
Complementary nutrient acquisition strategies

- Oats + Crimson Clover
- Forage Radish + Oats + Austrian Winter Pea
Beyond Biomass: Benefits from specific species

- Flowering species for pollinator resources
- Alleviating compaction with forage radish roots
- High forage quality from annual ryegrass or triticale

How much of the species do we need to achieve the benefit?

Canola monoculture

Canola in mixture
# Extension Fact Sheet: Making the Most of Mixtures

Table 1. Characteristics, ability to provide various services, and recommended planting date windows for nonlegume winter cover crops commonly used in temperate cropping systems.

<table>
<thead>
<tr>
<th>Species</th>
<th>Optimum Termination Timing</th>
<th>Growth Form</th>
<th>Nitrogen Retention</th>
<th>Nitrogen Supply</th>
<th>Erosion Control</th>
<th>Allelate Subsoil Compaction</th>
<th>Weed Suppression</th>
<th>Resources for Beneficial Insects</th>
<th>Habitat for Beneficial Insects</th>
<th>Forage Production</th>
<th>Planting Date Window, Weeks before First Killing Frost</th>
<th>Potential Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal Rye (<em>Secale cereale</em>)</td>
<td>ES to MS</td>
<td>SD to T0</td>
<td>▶️</td>
<td>▼</td>
<td>▶️</td>
<td>▶️</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>4 weeks prior to 6 weeks after</td>
<td>Narrow window for spring management due to rapid maturity progression in spring; mature residues can immobilize nitrogen</td>
</tr>
<tr>
<td>Triticale (x <em>Triticosecale</em>)</td>
<td>MS</td>
<td>SD to T0</td>
<td>▶️</td>
<td>▼</td>
<td>▶️</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>4 weeks prior to 6 weeks after</td>
<td>Mature residues can immobilize nitrogen</td>
</tr>
<tr>
<td>Wheat (<em>Triticum aestivum</em>)</td>
<td>MS to LS</td>
<td>SD to T0</td>
<td>▶️</td>
<td>▼</td>
<td>▶️</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>4 weeks prior to 3 weeks after</td>
<td>Mature residues can immobilize nitrogen</td>
</tr>
<tr>
<td>Spelt (<em>Triticum spelta</em>)</td>
<td>MS to LS</td>
<td>SD to T0</td>
<td>▶️</td>
<td>▼</td>
<td>▶️</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>4 weeks prior to 6 weeks after</td>
<td>Mature residues can immobilize nitrogen</td>
</tr>
<tr>
<td>Annual Ryegrass (<em>Lolium multiflorum</em>)</td>
<td>MS</td>
<td>SD</td>
<td>▶️</td>
<td>▼</td>
<td>▶️</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>3 to 10</td>
<td>Mature residues can immobilize nitrogen</td>
</tr>
<tr>
<td>Oats (<em>Avena sativa</em>)</td>
<td>WK-25*</td>
<td>SD</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>3 to 10</td>
<td>Highly competitive against other species in the mix</td>
</tr>
<tr>
<td>Sorghum-sudangrass (<em>Sorghum bicolor x S. bicolor var. sudanese</em>)</td>
<td>WK-32*</td>
<td>T0</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>8 to 12</td>
<td>Highly competitive against other species in the mix; high carbon residues can immobilize nitrogen</td>
</tr>
<tr>
<td>Forage Radish (<em>Raphanus sativus var. longipinnatus</em>)</td>
<td>WK-25*</td>
<td>SD</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>3 to 10</td>
<td>Highly competitive against other species in the mix</td>
</tr>
<tr>
<td>Canola (<em>Brassica rapa</em>)</td>
<td>ES to MS</td>
<td>SD to T0</td>
<td>▶️</td>
<td>▼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>3 to 10</td>
<td>Highly competitive against other species in the mix; can host pests of brassicaceeous cash crops</td>
</tr>
<tr>
<td>Sunflower (<em>Helianthus annuus</em>)</td>
<td>WK-32*</td>
<td>T0</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>◼</td>
<td>10 to 14</td>
<td></td>
</tr>
</tbody>
</table>
Cover Crop Mixtures: Establishment Details

Achieving the right seeding depth

• Mix the seeds and shoot for the middle - ~0.75 to 1”
  - Sometimes leads to poor stands

• Separate seeds by size into different drill boxes
  - Most reliable, need the right equipment

• Can also make separate trips
  (eg. drill, then broadcast/cultipack)
Cover Crop Mixtures: Establishment Details

Preventing seed separating and settling

- Rarely a problem
- Worst case is large round and small round seeds
  - (eg. Austrian winter pea + Canola)
- Seeds of different shapes and sizes mixed together create a stable packing arrangement
Cover Crop Mixtures: Establishment Details

Selecting row configurations

Forage radish and hairy vetch in alternating 15” rows

August

November
Cover Crop Mixtures: Establishment Details

Selecting row configurations

Forage radish and cereal rye in alternating pairs of 7.5” rows

November

March
Cover Crop Mixtures: Establishment Details

Selecting row configurations

In a drill with two seed boxes:

- Tape over alternating openers in the desired configuration

Other options:

- Cardboard baffles
- Split row planters
Cover Crop Mixtures: Establishment Details

Finding the right seeding rates

• Start with an educated guess, plant a small acreage, observe results, adjust as needed

For a grass-legume mix

• Reduce grass seeding rate to between ½ and ¼ the monoculture rate
• Keep legumes near monoculture rates

Limit seeding rates for highly competitive species

• Forage radish – 2 to 3 lbs/acre
• Canola – 3 to 4 lbs/acre
• Sorghum-sudangrass – 15 to 20 lbs/acre
• Oats – 20 to 40 lbs/acre
Accounting for redundancy

- When species share the same growth period, growth form, and nutrient acquisition strategy, divide seeding rate by the number of species in the group.

[Image: 3X / acre = 1X / ac 1X / ac 1X / ac]
So you’ve planted a diverse cover crop mixture...

...what will you get?
A diverse mixture can adapt to different soil fertility levels

**Low Nitrogen Level**

- 25 lbs/ac cereal rye
- 39 lbs/ac Austrian winter pea
- 6 lbs/ac canola
- 6 lbs/acre red clover

**High Nitrogen Level**
The same “4 Species Mix” varied widely by farm

<table>
<thead>
<tr>
<th>Research Station</th>
<th>Farm 1</th>
<th>Farm 2</th>
<th>Farm 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rye dominated</td>
<td>Canola dominated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low N</td>
<td>High N</td>
<td>High N</td>
</tr>
</tbody>
</table>

- Rye dominated: Farm 1
- Canola dominated: Farm 2
- Low N: Farm 3
- High N: Farm 1 and Farm 2
- Moderate N: Farm 3

Legend:
- red clover
- pea
- canola
- cereal rye
Next Challenge: Farm-Tuning Cover Crop Mixtures
Conclusions

- Research is showing that mixtures can **diversify** benefits over monocultures

- Five steps to success:
  1. Understand your context
  2. Identify your goals
     - C:N ratio is key
  3. Select complementary species
     - Growth form / Growth period / Nutrient acquisition
  4. Follow basic management recommendations for establishment and seeding rates
  5. Farm-tune the mix: Observe results and make adjustments as necessary
Thank You!

Feel free to contact us for more information:
Mitch Hunter - mchunter@psu.edu - 814-865-9021
Charlie White - cmw29@psu.edu - 814-863-9922
Making the Most of Mixtures: Considerations for Winter Cover Crops in Temperate Climates

Organic Agriculture  May 18, 2015
Authors:
Charles White, Penn State University; Mary Barbercheck, Penn State University; Tianna DuPont, Penn State University; Denise Finney, Penn State University; Abbe Hamilton, Penn State University; Dave Hartman, Penn State University; Mana Hautau, Penn State University; Jermaine Hinds, Penn State University; Mitch Hunter, Penn State University; Jason Keye, Penn State University; Jim La Chance, Penn State University

extension.org
Mixtures webinar – 71186
Making mixtures guide – 72973
Seeding Rates in Cover Crop Cocktails (CCC) Experiment, Penn State 2015-2016

<table>
<thead>
<tr>
<th>Cover Crop</th>
<th>Seeding Rates (lbs/acre)</th>
<th>Seed Cost / acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crimson Clover</td>
<td>34</td>
<td>$67</td>
</tr>
<tr>
<td>Canola</td>
<td>18</td>
<td>$55</td>
</tr>
<tr>
<td>Radish</td>
<td>8</td>
<td>$41</td>
</tr>
<tr>
<td>Triticale</td>
<td>124</td>
<td>$71</td>
</tr>
<tr>
<td>Oat</td>
<td>87</td>
<td>$23</td>
</tr>
<tr>
<td>Winter Pea</td>
<td>65</td>
<td>$62</td>
</tr>
<tr>
<td>Biculuture</td>
<td>Triticale (29), Winter Pea (50)</td>
<td>$62</td>
</tr>
<tr>
<td>3 spp mix, Nitrogen</td>
<td>Crimson Clover (13), Triticale (29), Winter Pea (25)</td>
<td>$66</td>
</tr>
<tr>
<td>3 spp mix, Management</td>
<td>Radish (1), Oat (17), Winter Pea (41)</td>
<td>$50</td>
</tr>
<tr>
<td>5 spp mix</td>
<td>Crimson Clover (8), Canola (3), Triticale (24), Winter Pea (14), Red Clover (3)</td>
<td>$58</td>
</tr>
<tr>
<td>6 spp mix</td>
<td>Crimson Clover (11), Canola (1), Radish (1), Triticale (11), Oat (8), Winter Pea (50)</td>
<td>$62</td>
</tr>
</tbody>
</table>
Can mixtures achieve multiple goals?

Yes – but make a plan

Guidelines:

1. **Weeds**: Have 1-2 species that provide fast ground-cover in the fall, then add species to achieve other goals

2. **Insects**: To support beneficial insects for pollination or biological control, manage mixtures to include flowers

3. **Nitrogen**: Combine a well-adapted legume with a low seeding rate of a winterhardy grass or brassica

4. **Overall**: Aim for balanced biomass from all species in the mix to benefit from a range of functions
Nitrogen Management with Cover Crop Mixtures Rule of Thumb

To balance N retention and supply, combine a well-adapted legume with a low seeding rate of a winterhardy grass or brassica.

![Bar chart showing corn silage yield (T/acre) for different crops and mixtures.](chart.png)