Exploring Cover Crop Establishment and Termination Timing for Increased Cash Crop Performance

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Education
Ph.D., Agronomy/Weed Science, University of Illinois, 1990
M.S., Agronomy/Weed Science, Washington State University, 1985
B.S., Agronomy, Colorado State University, 1982

Responsibilities and Interests:
Bill is a Professor in the Department of Crop and Soil Sciences and has been a member of the faculty since 1990. Dr. Curran has an extension-research split and has statewide responsibilities for weed management in agronomic crops. Bill's extension education program focuses on providing his ag constituents with the latest weed management information. Bill conducts research on basic weed biology, integrated weed management, weed management in conservation tillage systems including managing cover crops and most recently, he has focused on opportunities for managing weeds in organic crop production systems. Dr. Curran is active regionally and nationally in several scientific societies. He's an active member in the Weed Science Society of America, the Northeast Weed Science Society, Northeast Sustainable Ag Research and Education (SARE), and the Pennsylvania Agronomic Education Society.
Regional perspective

- Important watershed
- Diverse agricultural systems
- High density of animal agriculture
- No-till enthusiasm
- Lots of interest in cover crops
- Incentive programs
- Interest in sustainable and organic agriculture
Pennsylvania Ag

No-till (Nat’l Ag Stats, 2014)

- Corn – 66%
- Soybean – 73%
- Wheat – 70%
Cover crops – can be a valuable part of the cropping system

- Hairy Vetch
- Cereal Rye
- Oats
- Red Clover
- Forage Radish
- Winter Wheat
Benefits from cover crops
Cover crop projects - Curran

- Using high biomass cover crops to suppress weeds in organic cropping systems – 2005
  - USDA-NESARE, USDA-NEIPM, USDA-OREI
- Integrating cover crops to diversify herbicide resistant weed management – 2010
  - USDA-NESARE, USDA-CPPM, PA Soybean Board
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• Impact of cover crop termination timing on soil health, pest control, and crop performance – 2015
  • USDA-NESARE
Many Collaborators

- Mary Barbercheck, PSU
- Ryan Bates, Pioneer
- Katherine Caswell, PSU
- Sjoerd Duiker, PSU
- Mark Dempsey, former PSU
- Rob Gallagher, former PSU
- Eric Galladt, Maine
- Ron Hoover, PSU
- Heather Karsten, PSU
- Clair Keene, PSU
- Dwight Lingenfelter, PSU
- Glenna Malcolm, PSU
- Rachel Milliron, PSU
- Ruth Mischler, former PSU
- Dave Mortensen, PSU
- Eric Nord, Greenville College
- Chris Reberg-Horton, NCSU
- Matt Ryan, Cornell
- Eli Snyder, former PSU
- Steven Mirsky, USDA-ARS
- John Teasdale, USDA-ARS
- Jeff Moyer, Rodale Institute
- Meredith Ward, Elmira College
- Dave Wilson, Kings Agra-seed
- Lots of other help
Reducing tillage in organic grain crops is difficult yet desirable

- Difficult
  - Reliance on soil disturbance to control annual weeds
  - Perennial weed control

- Desirable
  - Protect soil against erosion/loss in quality
  - Reduce labor and energy use
  - Save $$
Suppressing Weeds Using Cover Crops in Pennsylvania

Cover crops provide important benefits to Pennsylvania’s croplands, including soil and water conservation. Some growers are also finding that cover crops can help reduce weed problems. Which cover crops are most suitable, and how should they be managed to enhance weed suppression?

Penn State Ag Publications
Catalog No. UC210

http://pubs.cas.psu.edu/FreePubs/PDFs/uc210.pdf
This figure demonstrates some of the ways that cover crops can suppress weeds at different stages of a weed’s life cycle. Different cover crops are more effective at different stages, and weeds vary in susceptibility of different stages.
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winter cover crops can help reduce winter annual weeds
Summer, 2004
The Rodale Institute,
Kutztown, PA
Rollers/Crimpers

• Have been used by some growers in different forms for a number of years

• Controls some reproductive annual cover crops
  • Not effective on perennials and less effective on legumes
  • Most effective on winter annuals when flowering
  • May delay planting of cash crop for effective control

• May allow no-till production

Without herbicides
2005 - Penn State - Orange Crush

• Front or rear mounted
• 10.5 feet in length
• 20 inch diameter well casing (0.125 inch thickness)
• Approx. 3350 lb dry weight
• Can add ~ 1400 lb H₂O
Cover Crop Rollers for Northeastern Grain Production

W. Curran and M. Ryan, Penn State University and S. Mirsky, USDA-ARS

Background
Cover crop rollers have been used for decades in Brazil, Argentina, and Paraguay to successfully manage cover crops and their residues (Dersch et al. 1991; Ashford and Reeves, 2003). Farmers adopted these tools to manage large amounts of cover crop residue for more successful cash crop establishment in no-till systems. This “high-residue conservation tillage” system involves producing large amounts of cover crop residue and using it to suppress weeds, protect the soil from erosion, and conserve soil moisture. In the last several years, farmers in the northeast and other regions of the US have shown interest in using cover crop rollers for high residue conservation tillage. Much of the interest in the Northeast comes from organic grain and vegetable farmers who would like to reduce frequency or intensity of tillage in their rotation.

Description and potential use
Cover crop rollers have come in various designs, but are generally made from a hollow steel drum or cylinder 1 to 2 ft in diameter. The roller/crimpers used today generally have blunt blades or knives arranged on the cylinder that crimp or crush the stems of the living cover crop, which then kills it. Rollers flatten and crimp susceptible cover crops leaving an intact mat of soil protective mulch oriented in the direction of planting. This undirectional mulch can help facilitate planting and improve seed to soil contract and ultimately cash crop emergence. In contrast to mowing the cover crop, there is less risk of cover crop regrowth when it is rolled, the intact residue decomposes slower, and weed suppression is better from the uniform surface residue.

Several designs have been tested (long-straight blades vs. curved blades vs. other designs) for cover crop control and vibration reduction (Kornecki et al. 2006; Raper et al. 2004). A common design used today has metal blades welded onto a cylinder in a chevron pattern that allows for smooth operation (Ashford and Reeves, 2003). This design was further refined by The Rodale institute (www.rodaleinstitute.org). Cover crop rollers vary in width but are generally between 5 and 30 feet wide weighing at least 1000 lbs or more. Larger units are used by some farmers that employ several cylinders linked together to cover large areas more quickly. Many designs allow more weight by filling the metal drum with water. The energy required to operate...
How can we manipulate cover crops to improve weed suppression?

Consider **competitiveness** while the cover crop is living and the **physical suppression** once it is terminated.
### Potential Crops – Rolling

<table>
<thead>
<tr>
<th>Suitable</th>
<th>Not suitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cereal rye</td>
<td>• Red clover</td>
</tr>
<tr>
<td>• Wheat</td>
<td>• White clover</td>
</tr>
<tr>
<td>• Barley</td>
<td>• Sub clover?</td>
</tr>
<tr>
<td>• Triticale</td>
<td>• Sweet clover?</td>
</tr>
<tr>
<td>• Oats</td>
<td>• Alfalfa</td>
</tr>
<tr>
<td>• Hairy vetch</td>
<td>• Ann. Ryegrass</td>
</tr>
<tr>
<td>• Crimson clover</td>
<td>• Canola</td>
</tr>
<tr>
<td>• Field pea</td>
<td>• Others?</td>
</tr>
<tr>
<td>• Austrian winter pea</td>
<td></td>
</tr>
<tr>
<td>• Certain brassica’s?</td>
<td></td>
</tr>
<tr>
<td>• Others?</td>
<td></td>
</tr>
</tbody>
</table>
Hairy Vetch

*Vicia villosa*
No-till Corn into Hairy Vetch-Triticale
Effects of Planting and Termination Date on Cover Crop Biomass and Subsequent Weed Suppression Using Roller/Crimper Technology. 2005

S. Mirsky, W. Curran and M. Ryan, The Pennsylvania State University
Ground cover on April 1 across rye planting dates

Aug 25

Sept 5

Sept 15

Sept 25

Oct 5

Oct 15
Planting and termination date affects cereal rye biomass

Cereal rye biomass (lb/acre)

Planting dates

Termination dates

Mirsky et al. 2009
30 days in fall was roughly equal to 10 days in the spring (~2000 lbs/a)

Mirsky et al. 2009
Effect of rye planting date (and increasing rye biomass) on common lambsquarters density (4 WAT May 1)

Similar letters indicate no significant difference between treatments (Tukey’s HSD p <0.05)

Mirsky et al. 2009
Effect of rye mulch biomass on weed seedling density
(Mohler and Teasdale, 1993)
ROSE
Reduced-tillage Organic Systems Experiment

- Organic 3-year crop rotation relying predominantly on rolled cover crops for weed control
- Initiated in 2010
- Three sites (PA, MD, DE)
- Weed and insect pest management
- On-farm trials in PA, MD, and NC

Research funding provided by USDA OREI Award No. 2009-51300-05656
USDA-NIFA-ICGP-002796
Cover crops substituting for tillage

- Cover crop-based organic rotational no-till
  - Terminate cover crops with roller-crimper to form mulch
    - Cover crop must be susceptible to mechanical control
  - No-till plant cash crops
  - Rely on mulch for early season weed control
    - Need at least 6,000 lbs A\(^{-1}\)
    - Even more farther south
Maximizing Cover Crop Mulches

- Successful weed suppression with cover crops requires 4000 to 11,000 lb/acre dry matter

Biomass production at each site

**Cereal rye**
- DE: 6,700-10,800 lb/acre
- MD: 5,000-11,200 lb/acre
- PA: 4,500-8,600 lb/acre

**Hairy vetch/triticale**
- DE: 4,000-7,000 lb/acre
- MD: 4,500-6,000 lb/acre
- PA: 5,500-6,500 lb/acre
Key findings – ROSE 1.0

• Multiple passes with a roller-crimper may be necessary to control cover crops

• Equipment modifications are needed when dealing with heavy residue

• Insects: beneficial insects respond positively to organic management and increase pest-suppression services

• Weeds: perennials did not become a problem in 3 years but supplemental control necessary where annual weed density is high
  • Starting with a clean field will maximize the probability of being able to maintain good annual weed control
New management constrains
Greater cover crop biomass constrains crop establishment
Planting Green

- Planting Green is a term used for the practice of planting crops into actively growing cover crop in a no-till system.
- Allows for maximum above and below ground biomass
  - Higher C:N ratio covers will persist longer
- Can help manage excess spring soil moisture (kill early in dry years)
- May reduce certain pest problems (e.g. slugs)
- Can require specialized planting equipment
  - Farmers adjust cover crop seeding rates to avoid too much residue (0.5 to 1 bu/acre)
- Want high turgor cover crops to enable slicing with coulters/disk openers
Improving Crop Establishment

- Planters more effective than drills
  - Too much steel in the field
- Soil moisture content
- Weight
- Residue quality
  - (Plant at rolling vs. delayed planting)
  - Coulter type (wavy, straight, straight and bubbled)
- Closing wheels (solid rubber or cast, spoked, posi)
Improving Crop Establishment

- Coulters (wavy, straight, straight and bubbled)
- Closing wheel (solid rubber or cast, spoked, posi)
ZRX – zone till - developed by Charles Martin, PA farmer and now being sold by Dawn Equipment
ROLLING SOLUTION. To help plant through such daunting residue, Criswell worked with Charles Martin to attach his custom helical cover-crop residue rollers to the front of his planter. The rollers are divided by solid-disc row cleaners that divide the heavy residue and clear a nice path for planting.
Special Herbicide Considerations for Planting Green

- Glyphosate – cover seed and use Roundup Ready if crop emerging
-Paraquat – cover seed and apply before crop emergence
- PGR herbicides - Some injury potential – timing important
-Other herbicides – Product specific – could be preplant or crop emergence issues
EPP – 5/8/15 – 1779 lb/acre
PRE – 5/15/15 – 4462 lb/acre
PLTGRN – 5/21/15 – 5446 lb/acre

Applied 140 lb N on 5/15
Effect of planting timing on corn population (2015, Rock Springs)
Effect of planting timing on corn yield
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Cover Cropping Barriers

• Following grain harvest or even silage in some areas there is limited opportunity for establishment

• Cost of establishment and benefits of late planted cover crops are concerns
2013-2014
COVER CROP SURVEY
REPORT

A SYNOPSIS OF THE INFORMATION COLLECTED DURING THE 2013-2014 COVER CROP SURVEY.

ABSTRACT
This document summarizes information from farmers across the United States, both users and non-users of cover crops, who responded to a cover crop survey. The report assesses attitudes about cover crops, perceived benefits and challenges surrounding their use, and communications channels that can aid in supporting the adoption and success of cover crops.

http://www.ctic.org/media/CoverCrops/CTIC_04_Cover_Crops_report.pdf
Cover Crop Challenges - Cover Crop Users

- Time / labor required for planting and increased management: 49.6%
- Establishing cover crops: 42.5%
- Cover crop seed cost: 38.0%
- Selecting the right cover crop for my operation: 35.9%
- Cost of planting and managing cover crops: 35.3%
- Cover crop seed availability: 15.9%
- No measurable economic return: 15.8%
- Cover crop sometimes uses too much soil moisture: 14.3%
- Cover crop becomes a weed in the following year: 10.2%
- Other: 8.8%
- Increased insect potential: 7.1%
- Increases overall crop production risk: 6.2%
- Nitrogen immobilization: 6.0%
- Yield reduction in the following cash crop: 4.9%
- Increased disease potential: 2.1%

N = 1,415

http://www.ctic.org/media/CoverCrops/CTIC_04_Cover_Crops_report.pdf
Previous attempts to expand cover cropping have had limited success

- Aerial applications inconsistent
- Late drilling has little benefit in fall and later development in spring
Alternatives to post-harvest seeding

Charlie Martin’s high-boy interseeder
Penn State Interseeder Project

• First tested in 2010
• No-till machine that is multifunctional
  • Can also apply sidedress N and herbicide
• First design had in-row coulter tillage
• Broadcast seed distribution in inter-row zone
• Packing wheels to cover seed
Newest Version Design Components

- Drill units between rows
- Liquid N stream applied adjacent to corn row
- Herbicide applied under corn canopy
- Assist wheels to carry weight
- Ground drive
- Loading platform
- Conversion to Drill Unit
- Hitch for Towing
Interseeding in V5-V7 corn

Crimson clover about 4 and 8 weeks after interseeding

Red clover in the fall prior to corn harvest.

Annual ryegrass cover after corn silage harvest in the fall.
Commercialized by Interseeder Technologies, LLC - http://interseeder-tech.com/

- Currently marketing 4 and 6 row machines with various configurations
Interseeders across the US, 2016
NRCS Conservation Innovation Grant (CIG) Project – PA, MD, and NY (2012-2015)

- Evaluate new design under different on-farm conditions
- Compare different cover crop species and mixtures
- Document impact on host and subsequent crops

Curran, WS, GW Roth, R. Hoover, J. Wallace, MR Ryan, and SB Mirsky. 2012. Maximizing conservation in the Chesapeake Bay Watershed with an innovative new 3-way interseeder for early establishment of cover crops in no-till corn and soybean. NRCS CIG.
CIG Project - Five Experiments

• **Experiment 1 - On-farm protocol.** This trial is testing four or five cover crop treatments across many locations in three states (MD, NY, and PA). This trial is looking at both cover crop and corn performance the year of establishment and in rotation.

• **Experiments 2 and 3 - Species and variety experiments.** The cover crop species and annual ryegrass variety experiments were conducted at single locations in PA, MD, and NY in 2013 and 2014.

• **Experiment 4 - Interseeding in soybean.** Soybeans were planted in May or June and interseeded 4 to 6 weeks after planting. This experiment was conducted at 3 locations in 2013 and repeated in 2014 (not discussed today).

• **Experiment 5 - Herbicide safety.** The safety of herbicides was examined in Pennsylvania in 2013 and in three states in 2014.
USDA-CIG Multi-State Project (n=15) (MD, PA, NY - 2013-2015)

**On-farm: All Site-Years (n=15)**

**Fall Biomass (lbs/a)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Fall Biomass (lbs/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>ac</td>
</tr>
<tr>
<td>Annual ryegrass</td>
<td>c</td>
</tr>
<tr>
<td>Legume-mix</td>
<td>ab</td>
</tr>
<tr>
<td>Grass-legume mix</td>
<td>bc</td>
</tr>
<tr>
<td>Radish (NY only)</td>
<td>a</td>
</tr>
</tbody>
</table>

**Corn Grain Yield (bu/a)**

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<tr>
<td>Grass-radish mix..</td>
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<thead>
<tr>
<th></th>
<th>numDF</th>
<th>denDF</th>
<th>F-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>4</td>
<td>143</td>
<td>9.9125&lt;0.0001</td>
<td>0.591</td>
</tr>
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<td>Site-Year</td>
<td>14</td>
<td>36</td>
<td>22.1353&lt;0.0001</td>
<td>0.00650</td>
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<th>numDF</th>
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<tbody>
<tr>
<td>Treatment</td>
<td>5</td>
<td>196</td>
<td>0.591</td>
<td>0.70650</td>
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<tr>
<td>Site-Year</td>
<td>14</td>
<td>36</td>
<td>28.942&lt;0.0001</td>
<td>0.00650</td>
</tr>
</tbody>
</table>
Spring cover crop biomass at Rock Springs in 2014 was unusually low due to the severe winter. Crimson clover did not survive the winter and spring growth was delayed with other cover crops.

Standard error of the mean (SE) bars presented. Significant differences in sites and cover crops.
Erie County PA 2015: Interseeded mix

- Short season, NW PA
- 3rd year of interseeding
- Corn silage and shelled high moisture corn
- 6 lbs Annual ryegrass, 6 lb Red Clover and 1 pound of radish

Retain manure nutrients/build soil health.
Clinton County PA : Corn/SB Fall 2015

Build soil health.
Reduce the impact of tillage.
South Dakota

- Radish, ryegrass, red clover
- 229 bushels/acre
- Green cover with living roots after corn
- Winter cover when wheat is not in rotation

Build soil health. Retain unused N.
Grazing Interseeded Ryegrass/clover

Retain nutrients, provide needed forage. Give pastures a rest.
We have had failures:

• Seeded too deep
• Feeding by slugs, earthworms, other
• Mid/late-summer drought
• Competitive cash crops
• Herbicides

Lancaster, 2013
Evaluating Tolerance of Interseeded Cover Crops to Pre-Emergent Herbicides for Corn Production in the Mid-Atlantic

J Wallace¹, W Curran¹, S Mirsky², M Ryan³, D Lingenfelter¹

¹Penn State University, ²USDA-BARC, ³Cornell University
## Summary For Corn Herbicides
Preliminary Recommendations for the Northeast

<table>
<thead>
<tr>
<th>Grass Herbicides</th>
<th>Active Ingredient</th>
<th>Broadleaf Products</th>
<th>Active Ingredient</th>
</tr>
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<tbody>
<tr>
<td><strong>Injury Possible</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Dual II Magnum 7.64 EC</td>
<td>s-metolachlor*</td>
<td>Callisto 4 SC</td>
<td>mesotrione*</td>
</tr>
<tr>
<td>Zidua 85 WG</td>
<td>pyroxasulfone*</td>
<td>Impact 2.8 SC</td>
<td>topramezone*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Balance Flexx 2 SC</td>
<td>isoxaflutole*</td>
</tr>
<tr>
<td><strong>Potentially Safe Products</strong></td>
<td></td>
<td>Resolve 25 WG</td>
<td>rimsulfuron</td>
</tr>
<tr>
<td>Prowl H2O 3.8 CS</td>
<td>pendimethalin</td>
<td>Atrazine 4 L</td>
<td>atrazine (&lt;1.12 kg)*</td>
</tr>
<tr>
<td>Outlook 6 EC</td>
<td>dimethenamid-P*</td>
<td>Sharpen 2.85 SC</td>
<td>saflufenacil*</td>
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<tr>
<td>Harness 7 EC</td>
<td>acetoxychlor*</td>
<td></td>
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</tr>
</tbody>
</table>

*Premixed products also contain many of these active ingredients*
Management needed for success

• Timing of interseeding
• Species selection
• Herbicide management
• Cash crop variety selection
• Local research/testing is needed to determine fit
Thank you for your attention  Questions/Discussion?

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