Cover Crop Termination: Considerations When Selecting Herbicides and the Potential for Resistance

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Objectives

- Factors to consider
- Herbicides used to terminate cover crops
  - Mode of action
  - Environmental effects
  - Potential for resistance
  - Potential for carryover
Factors to consider when terminating cover crops

- 1. The cover crop species
- 2. The cover crop growth stage
- 3. Other weed species present
- 4. The production crop to be planted
- 5. The weather conditions at application
## Cover Crop Species

<table>
<thead>
<tr>
<th>Cover Crop</th>
<th>Herbicide</th>
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<tbody>
<tr>
<td>Radish</td>
<td>Winter kills. If survives, use same herbicides as rapeseed.</td>
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<tr>
<td>Cereal rye</td>
<td>Glyphosate, Gramoxone, corn herbicides</td>
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<tr>
<td>Hairy vetch</td>
<td>2,4-D; no glyphosate!</td>
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<tr>
<td>Annual ryegrass</td>
<td>Glyphosate, done correctly, 2x Gramoxone</td>
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<tr>
<td>Clover</td>
<td>Glyphosate, 2,4-D</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>Glyphosate, 2,4-D; dicamba, corn herbicides</td>
</tr>
<tr>
<td>Spring oats</td>
<td>Winter kills</td>
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<tr>
<td>Triticale</td>
<td>same as cereal rye</td>
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</tbody>
</table>
The cover crop growth stage

- Be able to spray when needed!!
- Smaller plants are more susceptible than larger plants
- Plants in the reproductive stage will be difficult to control.
- Allow enough time between spraying the cover crop and planting the production crop.
Other weed species present

- Be aware of the presence of other weeds in the cover crop
- Certain weeds are highly resistant to glyphosate, ALS inhibitors, ACCase inhibitors and Triazines
  - Marestail-Glyphosate and ALS inhibitors
  - Annual ryegrass-ACCase inhibitors, Glyphosate, ALS inhibitors
The production crop to be planted

- Many herbicides will have residual activity that can affect production crop
- Only use herbicides that are labelled for pre-plant burndown for the production crop
- Make sure the time interval is correct between application of burndown herbicide and production crop
  - 2,4-D and dicamba have a 14-28 day restriction for planting soybeans after application. The new 2,4-D or dicamba resistant soybeans would not have this restriction.
  - Atrazine has a 10 month restriction for soybeans
  - Canopy EX®, and Cloak EX® have a 7 to 14 day restriction on soybeans and 10 month restriction on corn.
  - Sharpen® at greater than 1 oz/a has a 14 day restriction before soybeans.
The weather conditions at application

- Weather conditions affect both efficacy of bumdown herbicide on cover crop and on potential carryover from herbicides in previous crop onto cover crop establishment.
- Most herbicides work well when plants are vigorously growing.
- Cool, cloudy conditions slow the rate that herbicides kill plants.
  - Particularly important for translocated herbicides
    - Glyphosate
    - ALS inhibitors
    - 2,4-D, dicamba
    - Grass herbicides
    - HPPD inhibitors
- Dry conditions will reduce efficacy and increase carryover from previous herbicides.
Resistance Management

- Resistance is selected by depending on one mode of action of herbicide to control weeds.
- Glyphosate resistance was selected due to the widespread adoption of resistant crops and the sole use of glyphosate.
- Always use multiple MOAs within the same crop.
- Can determine MOA for the label.
Resistance Management

- Most labels show the MOA classification of a herbicide

**GROUP 14 HERBICIDE**

**FIRST AID (continued)**

If in eyes:
Hold eye open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing.

Call a poison control center or doctor for treatment advice.

If swallowed:
Call a poison control center or doctor immediately for treatment advice. Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to by the poison control center or doctor. Do not give anything to an unconscious person.

**HOT LINE NUMBER**
Have the product container or label with you when calling a poison control center or doctor or going for treatment. You may also contact 800-852-0099 for emergency medical treatment information.
Resistance Management

- Most labels show the MOA classification of a herbicide
Resistance Management

- Keep a log on what herbicides are being used in each field
- Make sure that there are multiple MOAs being used every year.
Herbicides used to terminate cover crops

- **Glyphosate (Group 9):** Kills plants by inhibiting synthesis of aromatic amino acids.

- **Symptoms**
  - Cessation of growth
  - Chlorosis
  - Takes several days to weeks for plants to die.
Glyphosate

- EPSPS is primarily in growing points. **Glyphosate has to get to growing points to be active.**
- Anything that prevents glyphosate from getting to the growing points will reduce activity.
- **Factors affecting translocation**
  - Cool, cloudy conditions reduces production and translocation of sugars in plant, which reduces translocation of glyphosate
  - Time of day of application: Glyphosate require translocation for over 4 hours before sunset after application
  - Which means no spraying after 2pm in cold weather
Glyphosate: Factors affecting translocation

- Other herbicides in tank mixes
  - Any herbicide that reduces photosynthesis or kill the plants rapidly will reduce translocation of glyphosate
  - Triazines
  - HPPD inhibitors (e.g. Calisto, Laudis, Balance Flex)
  - Paraquat
  - PPO inhibitors (e.g. Spartan, Sharpen)
Glyphosate: Factors affecting translocation

- Cover crop species
  - Tolerant cover crops
    - Vetches
    - Clovers
  - To control mix with auxenic herbicides (e.g., 2,4-D, dicamba)
Glyphosate: Resistance

- Multiple species have developed resistance.
  - Annual ryegrass
  - Waterhemp
  - Palmer amaranth
  - Giant and common ragweed
  - Marestail/Horseweed
  - Kochia
Glyphosate: Resistance

- Look out for multiple resistant weeds
  - Waterhemp:
    - 5 way resistance
      - Glyphosate
      - ALS inhibitors
      - Atrazine
      - HPPD inhibitors
      - PPO inhibitors
Herbicides used to terminate cover crops

- Auxenic herbicides (Group 4)
  - 2,4-D, MCPA
  - Dicamba
  - Fluroxapyr (Starane)
  - Clopyralid (Stinger)
  - Halauxifen-methyl (Arylex)
Auxenic Herbicides

- Auxenic herbicides kill plants by interfering with multiple metabolic processes in the plant

Symptoms
- Severe twisting of leaves and stems (epinasty)
- May take more than a week for plants to die.

- Auxenic herbicide translocate in susceptible species
- Only kill broadleaves, limited activity on grasses.
- Very effective on legume cover crops.
Auxenic Herbicides: Resistance

- Multiple species have developed resistance to auxenic herbicides
  - Kochia:
    - Multiple resistance to dicamba and glyphosate
  - Tall waterhemp
    - Multiple resistance to triazines, PPO inhibitors, ALS inhibitors, glyphosate and HPPD inhibitors
  - Wild mustard
Auxenic Herbicides: Carryover

- Soil residual activity
- 2,4-D
  - Half life in untreated soil-60 days.
  - Rate of degradation dependent on soil texture and pH
    - Degrade more slowly as OM increases
    - Degrade more slowly as pH decreases
- Apply 14 to 28 days before planting soybeans
Auxenic Herbicides: Carryover

- **Dicamba**
  - Half life ranges from 4-14 days under warm, moist conditions
  - Slower degradation under cool, dry conditions
  - Interval between pre-plant application and soybean planting dependent on rainfall
    - Low rainfall-increased interval
  - Production crop sensitivity
    - Wheat, Rice, Sorghum-15 d;
    - Soybean-14-28 d.
  - No cover crop issues
Herbicides used to terminate cover crops

- Glufosinate (Liberty) (Group 10)
- Glufosinate kills plants by interfering with ammonia recycling.
- Causes rapid inhibition of photosynthesis and other metabolic processes
  - Symptoms
    - Chlorosis
    - Leaf burning
    - Can kill within a week
- Very sensitive to environmental conditions
Glufosinate

- A contact herbicide that needs good coverage
- Activity greatly decreased in cool, cloudy conditions.
- Plants need to be actively growing.
- May not give satisfactory control in early applications.
- Only a few cases of resistance have been reported
Herbicides used to terminate cover crops

- Paraquat (Gramoxone Interon) (Group 22)
- Kills plants due to accumulation of free radicals that tear up plant membranes.

Symptoms
- Rapid burning of leaves
- Plants die within a few days
- Can get regrowth, particularly on grasses.
Paraquat-PSI inhibitor

- Paraquat can translocate in the plant
- Usually kills too fast to translocate very far.
- If applied in late afternoon or evening, get better activity because it can translocate further into plant.
Paraquat-PSI inhibitor

- A contact herbicide so requires good coverage.
- Works better on broadleaves
- Plants need to be vigorously growing under bright light.
- No soil activity
- To kill grasses need to apply twice
Paraquat-Resistance Management

- A few species have developed resistance to paraquat
  - Horseweed
Herbicides used to terminate cover crops

- PSII inhibitors (Group 5)
  - Atrazine
  - Simazine
  - Metribuzin (Sencor)
  - Bentazon (Basagran)
PS II Inhibitors

- PSII inhibitors kill plants by inhibiting photosynthesis.
- Stops photosynthesis and plants starve
- Excess energy is diverted to producing superoxides which also destroy plant membranes

Symptoms
- Chlorosis
- Burning of leaves, starting with the leaf margin
- Kill plants with a week.

- Translocate in xylem of plant, but not in phloem, so if applied post will not translocate to roots.
- Activity will be decreased under dry conditions.
Triazine: PSII inhibitors

- Is synergistic with paraquat and HPPD inhibitors
- Has residual activity so can carry over into production crop
  - Soybeans: 10 months
Triazine: Resistance

- Widespread resistance to triazines
  - Velvetleaf
  - Pigweeds
  - Foxtails
  - Lambsquarters
  - Horseweed
  - Kochia
Herbicides used to terminate cover crops

- Post Grass herbicides (ACCase inhibitors) (Group 1)
  - Fluazifop (Fusilade)
  - Haloxyfop (Verdict)
  - Quizalofop (Assure II)
  - Clethodim (Select)
  - Sethoxydim (Poast)
  - Tralkoxydim (Grasp)
  - Pinoxadim (Axial)
ACCase Inhibitors

- Kill grasses by inhibiting lipid biosynthesis

  Symptoms
  - Stunted plants
  - Emerging shoot easily pulled from plant with dead meristem
  - Takes 2 or more weeks for plants to die completely

- Grasses have a form of ACCase that is inhibited by the herbicide.
- Broadleaf plants have a different form of ACCase that is not inhibited.
ACCase Inhibitors

- Lack of fatty acids stops cell division and elongation leading to cell death
- Highly critical in growing points of plants
- Symptoms:
  - Cessation of growth
  - Death of meristem
- Herbicide has to get to growing point to kill plant.
ACCase Inhibitors: Factors affecting translocation

- Works best on young, rapidly growing plants
- Dry conditions
  - Reduces translocation
  - Very limited activity on droughted plants.
- Auxenic herbicides reduce efficacy of ACCase inhibitors.
- Tank mixes with PPO inhibitors reduce translocation of these herbicides.
ACCase Inhibitors: Resistance

- Resistant grasses have been selected in multiple species
  - Annual ryegrass
  - Wild oats
  - Giant and green foxtail
- Multiple resistance to ALS inhibitors is common.
Herbicides used to terminate cover crops

- ALS Inhibitors (Group 2)
  - Imidazolinones (Pursuit, Raptor)
  - Sulfonylureas (Basis, Resolve)
  - Triazolopyrimidines (FirstRate)
  - Triazolinones (part of Capreno)
ALS inhibitors

- Kill plants by inhibiting synthesis of branched chain amino acids.
- Symptoms
  - Vein reddening
  - Leaf chlorosis
  - Terminal bud necrosis
  - Slow whole plant necrosis (2-4 weeks)
- Target site only in growing tissue
- ALS inhibitors have to translocate to growing points to be active.
- Anything that inhibits transport of ALS inhibitors to growing points decreases activity.
ALS inhibitors: Factors affecting translocation

- Very similar to the factors affecting glyphosate efficacy.
- Anything that inhibits plant’s ability to photosynthesize and translocate sugars will reduce activity of ALS inhibitors
  - Cool, cloudy conditions
  - Drought
  - Other herbicides that interfere with photosynthesis
  - Auxenic herbicides
ALS inhibitors: Resistance

- Wide spread resistance in multiple species
  - 159 different species world wide
  - In Midwest states, 7 to 27 different species depending on the state
- Widespread resistance
  - Tall Waterhemp
  - Kochia
  - Palmer amaranth
  - Ragweeds
  - Horseweed
  - Ryegrass
  - Foxtails
# ALS inhibitors: Carry over

<table>
<thead>
<tr>
<th>Chemical family</th>
<th>Imidazolinone</th>
<th>Sulfonyleurea</th>
<th>Triazolopyrimidines</th>
<th>Thiencarbazone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example product</td>
<td>Raptor</td>
<td>Classic</td>
<td>FirstRate</td>
<td>Component of Caprino</td>
</tr>
<tr>
<td>Residual activity</td>
<td>Long</td>
<td>Variable</td>
<td>Long</td>
<td>Long</td>
</tr>
<tr>
<td>Activity extended in/under</td>
<td>Acidic soils</td>
<td>Basic soils, dry conditions</td>
<td>Dry conditions</td>
<td></td>
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<tr>
<td>Most sensitive cover crops</td>
<td>Mustards</td>
<td></td>
<td>Mustards</td>
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Herbicides used to terminate cover crops

- PPO inhibitors (Group 14)
  - Sharpen
  - Valor
  - Spartan
  - Resource
  - Cobra
  - Reflex
PPO inhibitors

- PPO inhibitors stop the biosynthesis of chlorophyll and other pigments,

- Produce free radicals which destroy cell membranes

- Symptoms
  - Rapid burning of leaves and stem
  - Plants die within a week.

- PPO inhibitors require light

- Most do not translocated in plants very well.
PPO inhibitors: Factors affecting efficacy

- Contact herbicides, so require very good coverage.
- More active on broadleaves than grasses
- May burn out tops, but can be regrowth.
PPO inhibitors: Resistance

- Resistance has been selected in the Midwest
  - Tall waterhemp
  - Palmer amaranth
  - Common ragweed
- Most are already resistant to ALS inhibitors
# PPO inhibitors: Carry over

<table>
<thead>
<tr>
<th>Residual Activity</th>
<th>Property</th>
<th>Sharpen</th>
<th>Valor</th>
<th>Cobra</th>
<th>Spartan</th>
<th>Reflex</th>
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<tbody>
<tr>
<td>Short</td>
<td>Vetch, Wheat</td>
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<td>Long</td>
<td>Rye, Cereals,</td>
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<td>Canola</td>
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</table>
Herbicides used to terminate cover crops

- HPPD inhibitors (Group 27)
  - Balance Flex
  - Calisto
  - Impact
  - Laudis
HPPD Inhibitors

- HPPD inhibitors kill plants by inhibiting biosynthesis of carotenoids and plastoquinones.
- Loss of carotenoids results in loss of protection of chlorophyll from destruction in light. Thus, plants turn white.
- Plastoquinones are also key part of photosynthesis
- Explains synergy between PS II inhibitors and HPPD inhibitors
HPPD Inhibitors

- HPPD inhibitors are mobile in plant:
  - **Site of action in the growing points**
  - **Translocated to growing points**
  - See chlorosis in the emerging shoot.
  - Always applied with atrazine to give maximum activity.
HPPD Inhibitors-Resistance

- Resistance has been selected in multiple species
  - Tall waterhemp
  - Palmer amaranth
- Most of these biotypes show multiple resistance to other MOA
  - ALS inhibitors
  - Glyphosate
HPPD Inhibitors-Carryover

- Weak acid-soil binding depends on pH and soil OM
- Short residual soil herbicides but can carryover into soybeans
  - Carryover can occur in sandy soils with low pH and very dry conditions.
- Most sensitive cover crops
  - Small legumes
  - Mustards
Annual ryegrass as a cover crop

- Very aggressive grass that can be difficult to control.
  - Widespread resistance
  - Seed can carryover into crop
- Guidelines (Purdue University)
  - Buy pure seed
  - Kill before setting seed (4-6”)
  - Combine glyphosate (1.25 lb/a) with Sharpen (1 oz/a) for most consistent results.
  - Combine Gramoxone with metribuzin and 2,4-D or dicamba
    - Works well under cooler conditions.