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

Cover Crop	Herbicide
Radish	Winter kills. If survives, use same herbicides as rapeseed.
Cereal rye	Glyphosate, Gramoxone, corn herbicides
Hairy vetch	2,4-D; no glyphosate!
Annual ryegrass	Glyphosate, done correctly, 2x Gramoxone
Clover	Glyphosate, 2,4-D
Rapeseed	Glyphosate,2,4-D; dicamba, corn herbicides
Spring oats	Winter kills
Triticale	same as cereal rye

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

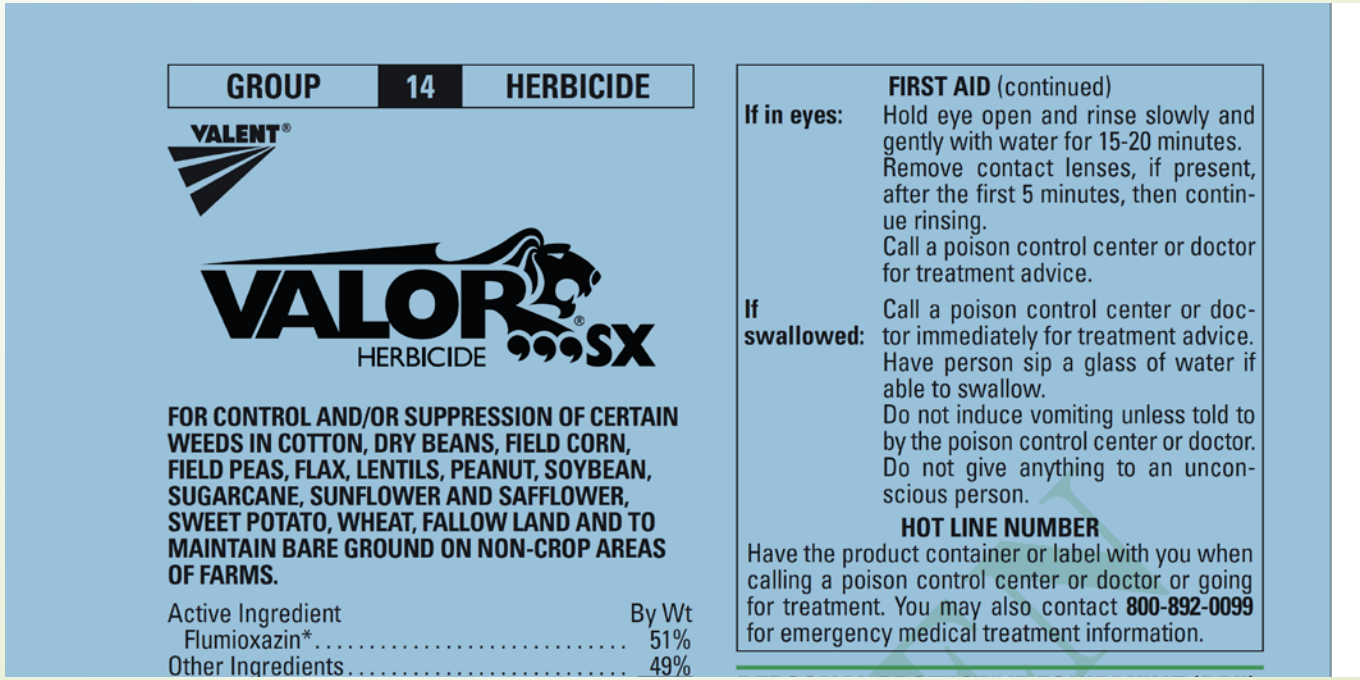
- Weather conditions affect both efficacy of burndown herbicide on cover crop and on potential carryover from herbicides in previous crop onto cover crop establishment
- Most herbicides work well when plants are vigorously growing.
- Cool, cloudy conditions slow the rate that herbicides kill plants.
  - 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

VALENT®

VALOR® SX

HERBICIDE

FOR CONTROL AND/OR SUPPRESSION OF CERTAIN WEEDS IN COTTON, DRY BEANS, FIELD CORN, FIELD PEAS, FLAX, LENTILS, PEANUT, SOYBEAN, SUGARCANE, SUNFLOWER AND SAFFLOWER, SWEET POTATO, WHEAT, FALLOW LAND AND TO MAINTAIN BARE GROUND ON NON-CROP AREAS OF FARMS.

Active Ingredient	By Wt
Flumioxazin*	51%
Other Ingredients	49%

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.

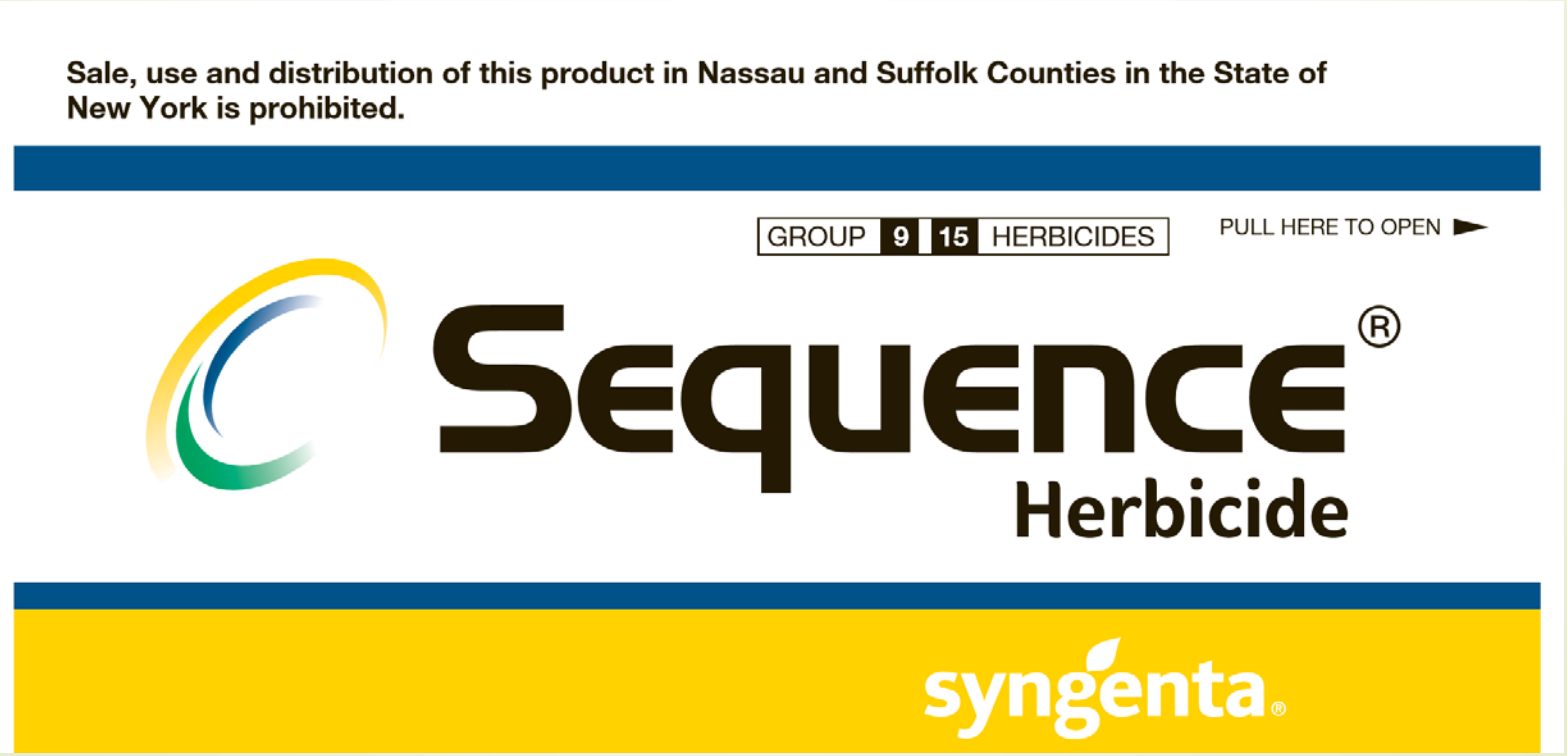
If swallowed: Call a poison control center or doctor immediately for treatment advice. Have person sip a glass of water if able to swallow.
Do not induce vomiting unless told to by the poison control center or doctor.
Do not give anything to an unconscious person.

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 **800-892-0099** 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 (eg. 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
  - Sever 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

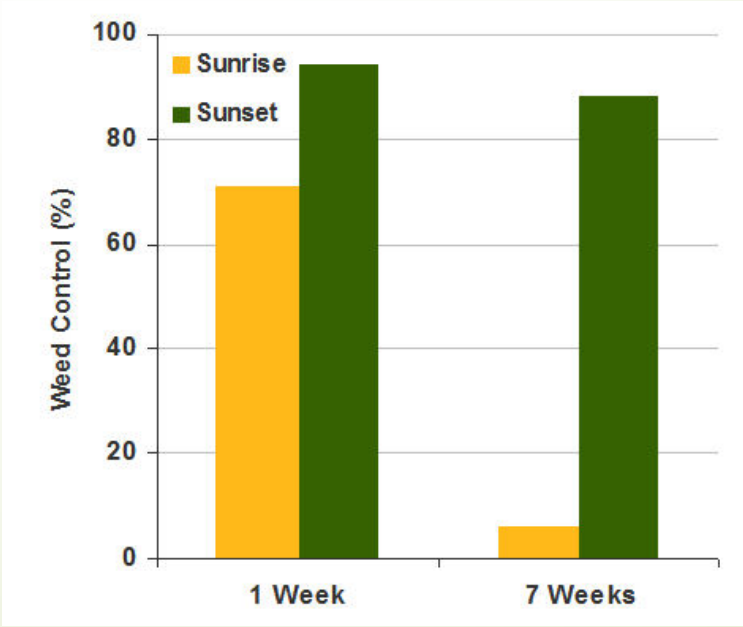
- A contact herbicide that needs good coverage
- Activity greatly decreased in cool, cloudy conditions.
- Plants need to be actively growing.
- May not give satisfactory control in early applications.
- Only a few cases of resistance have been reported

Herbicides used to terminate cover crops

- Paraquat (Gramoxone Interon) (Group 22)
- Kills plants due to accumulation of free radicles 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)
  - Triazoloyrimidines (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

Chemical family	Imidazolinone	Sulfonylurea	Triazolopyrimidines	Thiencarbazone
Example product	Raptor	Classic	FirstRate	Component of Caprino
Residual activity	Long	Variable	Long	Long
Activity extended in/under	Acidic soils	Basic soils, dry conditions	Dry conditions	
Most sensitive cover crops	Mustards		Mustards	

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 radicles 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

	Herbicide				
Property	**Sharpen**	**Valor**	**Cobra**	**Spartan**	**Reflex**
Residual Activity	Short	Short	Short	Long	Long
Most sensitive cover crops	Vetch, Wheat	Rye, Canola		Rye, Cereals, Canola	Rye, Vetch, Canola

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.