**Mode of Action: Photosynthesis Inhibitors**

**Site of Action:** D-1 quinone-binding protein of photosynthetic electron transport chain (aka: photosystem II inhibitors)

**Mobile Photosynthesis Inhibitors**
- Herbicide families
  - triazine
  - triazinone
  - phenylcarbamates
  - phenylurea

**Herbicide Injury Symptoms (Mobile)**
- Initially yellowing of leaf margins or tips
- Interveinal chlorosis follows
- Yellowing or browning of older leaves, then death

**Nonmobile Photosynthesis Inhibitors**
- benzothiadiazole
- nitrile

**Herbicide Injury Symptoms (Nonmobile)**
- Foliage that is contacted by the herbicide will become yellow or bronze, turn brown and die
Photosynthesis inhibitors

- **Mobile**
  - Triazine, group 5
    - atrazine, simazine
  - Triazinone, group 5
    - metribuzin
  - Phenylurea, group 7
    - linuron, diuron
  - Phenylcarbamates, group 5
    - desmedipham, phenmedipham

- **Nonmobile**
  - Benzothiadiazole, group 6
    - bentazon
  - Nitrile, group 6
    - bromoxynil

Herbicide Family: Triazines

**Site of action:** Photosystem II inhibitor (PSII)

**Mode of action:** Photosynthesis inhibitor

Herbicide family: Triazine

- Characterized by substitutions on a triazine ring

- insoluble in water and low solubility in organic solvents, so formulated as WP, WDG, F, or SC.

Biological properties

- Primarily PRE products
- Controls most annual broadleaf weeds and many annual grasses
- Generally more phytotoxic on higher pH soils
- Triazine resistant weeds fairly common
  - 50 + species worldwide
  - In North Dakota:
    - Kochia
    - Infests one location ~ 50 acres

Atrazine

- Trade name: AAtrex, Atrazine (many companies)
- Cost: $4.00/lb
- Rates: 0.38-1 lb/A
- Time applied: PRE, POST in corn
  - translocated

Weeds controlled (high rate)

- Most annual grass and broadleaf weeds
  - grasses are the first to escape, better on broadleaves
  - downy brome, G-E
  - Foxtails, P
  - Vol. cereals, G-E
  - Wild oat, G-E
  - Most WCG broadleaf weeds listed as: G-(E)
    - Except:
      - Horseweed, F
      - Canada thistle, N
Crops labeled

- Corn, grain sorghum, sweet corn, popcorn
- chemical fallow
  - long residual
- turf and sod production
- some established tree fruits and nuts
- conifers
- sugarcane

Other comments

- Restricted Use Pesticide
- due to ground and surface water concerns (runoff and leachability)
  - must limit rates on erodible soil
  - 50 ft buffer from wells while mixing and loading
  - 66 ft buffer from field runoff sites
  - 200 ft buffer from streams and lakes
- Some POST activity with COC in corn

Other comments

- Residues of atrazine frequently carryover to affect sensitive crops the following growing season
- Most tolerant >>> most susceptible
  - millet > flax > soybean > barley > wheat > oat > sunflower > sugarbeet > mustards
- Corn rapidly metabolizes atrazine
  - breaks it down and makes it inactive

Other comments

- Soil persistence, long in ND (pH, weather, temperature)
  - From Weed Control Guide (WCG)
  “Atrazine applied PPI or PRE or at rates greater than 0.75 lb ai/acre is not recommended in ND.”
  - 0.38 lb ai/A standard recommended rate in ND
  - Excellent supplement to many herbicides
  - Atrazine is available in several premixes that require excessive atrazine rates for normal crop rotation in ND

Atrazine soil persistence

- Atrazine and most triazines are mainly degraded by acid hydrolysis
  - Need moisture
  - Need lower pH for adsorption to soil or OM
  - Need warm soil
- Acid hydrolysis, herbicide + water = inactive
  - happens in acid soil conditions pH < 7 + water
- In ND more herbicide is in solution instead of held in place for degradation (soil pH basic)

Simazine

- Tradename: Princep (4L or Caliber 90)
- Cost: $5.50/lb
- Rates: 2-4 lb/A
- Time applied: PRE
- Weeds controlled: most annual grass and broadleaf weeds
Crops labeled

- Trees (conifers) and perennial hort crops
  - Listed in the WCG for Shelterbelt Weed Control
  - Trees should be at least 3 years old
- Fruit and nut crops
  - Apples, peaches, pears, avocados, oranges
  - Raspberries, blueberries, grapes
- Soil Sterilant – longer residual than atrazine
- Non-crop areas
  
  Note: Not RUP because less water soluble than atrazine

Metribuzin

- Herbicide group: Triazinone
- Tradename: Sencor, Tri-Cor [4F or 75 DF]
- Cost: $25-28/lb
- Time applied: PRE/PPI or POST
- Rates: 1.2-6 oz/A

Weeds controlled

- PPI
  - downy brome, F-G
  - foxtails, F
  - vol cereals, G
  - wild buckwheat, F
  - kochia, G
  - mustards, E
  - pigweeds, E
  - common ragweed, E
  - Canada thistle, N
  - c. lambsquarters, F
- POST
  - downy brome, N
  - foxtails, F
  - vol. cereals, P
  - wild buckwheat, G
  - kochia, F-G
  - mustards, E
  - pigweeds, G
  - common ragweed, E
  - Canada thistle, N
  - c. lambsquarters, E

Crops labeled

- Legumes: Soybean, lentil, field pea
- Potato: 0.5-1 lb/A (PRE), 0.25-0.5 lb/A (POST)
- Other hort crops: Asparagus, carrot, tomato
- Corn: POST-directed application (>8” tall)
  - try to keep off the corn as much as possible with drop nozzle
- Dormant Alfalfa
- Turf

Other comments

- Used for wild mustard control in soybean
- More soybean injury on higher pH soils
  - for all crops, limited to 0.2 lb/A if pH greater than 7.5
- May carryover at higher rates
OTHER PS II inhibitors, xylem mobile (Soil active, absorbed by roots)

- Herbicide: Diuron
  - $6/lb, 1.6 to 6.4 lb/A
  - Trade name: Karmex/generics
  - Crops used: asparagus, tree fruits

- Herbicide: Linuron
  - $21-50/lb, 0.5 to 3 lb/A
  - Trade name: Lorox
  - Crops used: Carrots, asparagus

Family: Phenylcarbamate

- Desmedipham
  - Tradename: Betanex
  - Crops used: sugarbeet

- Phenmedipham
  - Tradename: Sold in as a premix
  - Betamix:
    - desmedipham + phenmedipham
    - rate: 0.06 to 0.6 lb/A
    - cost: $70/lb
  - Progress:
    - desmedipham +
    - phenmedipham +
    - ethofumesate
  - Crops used: sugarbeet

Family: Phenylcarbamate

Desmedipham and Phenmedipham

- Useful in sugarbeet microrate
  - Activity POST on very small weeds
  - Not many other options in sugarbeet for certain weeds

- Glyphosate
  - RR sugarbeet canabalized conventional market
  - Glyphosate resistance created need for alternatives
  - Limited conventional availability
  - Market adjusted

Family: Benzothiadiazoles

Site of Action: PS II
Mode of Action: PS Inhibitor

- Herbicide: Bentazon
- Trade name: Basagran
- Cost: $15-17/lb
- Rates: 0.5-1 lb/A
- Time applied: POST, contact – need good coverage

Weeds controlled

- many annual broadleaf weeds
  - weeds need to be small
  - no grasses
    - common cocklebur, G-E
    - common lambsquarters, F-G
    - mustards, E
    - annual smartweeds, E
    - common sunflower, E
    - biennial wormwood, G-E
    - Canada thistle, F-G (suppression)

Crops labeled

- Soybean
- Dry bean
- corn, including sweet corn and popcorn
- field pea
- turf
- woody plants and ornamentals
Other comments

• No soil activity
• Often band applied to reduce cost
• Control improved with oil additive
• Wild mustard controlled at 0.5 lb/A
• Often mixed with other POST broadleaf herbicides for “broad spectrum” control
  – Rezult: bentazon + sethoxydim (Copack, B & G)
  – Storm: bentazon + acifluorfen (ultra blazer)
  – Varisto: bentazon + imazamox (premix)

Weeds controlled

• Many annual broadleaf weeds
  – Wild buckwheat, G-E
  – Kochia, G-E
  – Common lambsquarters, G
  – Mustards, F-G
  – Nightshades, E
  – Pigweeds, P-F
  – Common ragweed, E
  – Canada thistle, P

Crops labeled

• Small grains (wheat, barley, oat, rye)
  – 3-leaf to prior to boot
• Corn
• Other broadleaf agronomic crops
  – Flax, alfalfa
• Hort crops
  – Onion
  • 2-leaf to 5-leaf stage

Herbicide family: Nitrile
Site of Action: PS II
Mode of Action: PS Inhibitor

• Herbicide: Bromoxynil
• Trade name: Buctril
• Cost: $90-145/lb
• Rates: 0.25-0.5 lb/A
• Time applied: POST, mostly contact

Weeds controlled

• Many annual broadleaf weeds
  – Wild buckwheat, G-E
  – Kochia, G-E
  – Common lambsquarters, G
  – Mustards, F-G
  – Nightshades, E
  – Pigweeds, P-F
  – Common ragweed, E
  – Canada thistle, P

Common purslane, P

• MICRO-RATE RESEARCH (ONION)
• Bromoxynil at 0.25-0.5 oz ai/A
• Common lambsquarters (cot-2 leaf), G-E
• Redroot pigweed (cot-2 leaf), F-G

Crops labeled

• Small grains (wheat, barley, oat, rye)
  – 3-leaf to prior to boot
• Corn
• Other broadleaf agronomic crops
  – Flax, alfalfa
• Hort crops
  – Onion
  • 2-leaf to 5-leaf stage

Other comments

• No soil activity (no residual)
• Some Bromoxynil resistant crops – BXN cotton
• Safe on cereal crops
  – Bromoxynil + MCPA = Bronate Advanced/generics
  – Bromoxynil + pyrsulfotole = Huskie
  – Brox+pyrsulfotole+thiencarbazone = Huskie Complete
  – Bromoxynil + fenoxaprop + pyrsulfotole = Wolverine
  – Bromoxynil + fluroxypyr = Starane NXT
  – Bromoxynil + fluroxypyr + MCPA = Carnivore
  – Bromoxynil + fluroxypyr + 2,4-D = Kochivore