SITE OF ACTION:
A. PHOTOSYSTEM I (PS₁) INHIBITORS
B. PROTOPORPHRYIN OXIDASE (PPO) INHIBITORS
Herbicide injury symptoms - $PS_I$

- Limp water-soaked appearance, followed by necrosis

Herbicide injury symptoms - PS₁

- Limp water-soaked appearance, followed by necrosis

Drift injury: localized
Herbicide injury symptoms - PPO

- Plants may turn yellow, then turn brown and die

Herbicide Groups classified as CMD’s

- **PS$_T$s**
  - Bipyridylium
    - Paraquat, Diquat

- **PPOs**
  - Diphenylether
    - Acifluorfen, lactofen, fomesafen, oxyfluorfen
  - $N$-phenylthalamide
    - flumiclorac, flumioxazin
  - Oxadiazole
    - oxadiazon
  - Tiazolinone
    - Carfentrazone, sulfentrazone
Biological properties of action

- CMDs are photodynamic
  - they act independently of photosynthesis, but require light for activity

- PS$_I$s
  - PS energy is diverted from normal pathway and leads to production of toxic species and cell membrane destruction

- PPOs
  - inhibit PPO causing an accumulation of Proto, damaging membranes, causing “leaks” (water soaked appearance)
Site of action: PS₁
Herbicide family: bipyridilium

- Herbicide: paraquat
- Trade name: Gramoxone Inteon, Cyclone Star
- Cost: $17/lb
- Rates: 0.33-0.67 lb/A
- Time applied: POST, contact
  - Action is very fast, a few hours to 2 days
RESTRICTED USE PESTICIDE
DUE TO ACUTE TOXICITY
FOR RETAIL SALE TO AND USE ONLY BY CERTIFIED APPLICATORS OR PERSONS UNDER THEIR DIRECT SUPERVISION AND ONLY FOR THOSE USES COVERED BY THE CERTIFIED APPLICATOR’S CERTIFICATION.

Gramoxone
Inteon

Herbicide
A Weed, Grass, and Harvest Aid Desiccant/Defoliant Herbicide

Active Ingredient:
Paraquat dichloride (1,1'-dimethyl-4,4'-bipyridinium dichloride) .................... 30.1%
Other Ingredients: .......................... 69.9%
Total: .......................................... 100.0%

Contains 2.0 pounds paraquat cation per gallon as 2.762 pounds salt per gallon. Contains alerting agent (odor), emetic, dye and Inteon Technology.

KEEP OUT OF REACH OF CHILDREN.

DANGER/PELIGRO POISON

• NEVER PUT INTO FOOD, DRINK OR OTHER CONTAINERS.
• IF SWALLOWED, TAKE IMMEDIATE ACTION AS PRESCRIBED IN FIRST AID STATEMENT. SYMPTOMS ARE PROLONGED AND PAINFUL.
• DO NOT USE OR STORE IN OR AROUND THE HOME.
• DO NOT REMOVE CONTENTS EXCEPT FOR IMMEDIATE USE.
• THE ODOR OF THIS PRODUCT IS FROM THE ALERTING AGENT WHICH HAS BEEN ADDED, NOT FROM PARAQUAT.
Weeds controlled

- Non-selective, most annual grass and broadleaf weeds
- Some resistance has occurred worldwide when paraquat is used repeatedly for 8 or 9 years
- Burns of the tops off perennials
  - like mowing, weeds just comeback
- Similar to glyphosate, but not translocated
Crops labeled

- Preplant or prior to crop emergence:
  - Many agronomic crops
  - Many horticultural crops
  - Corn: directed application
    - drop nozzles only in the lower 3 inches of the corn crop
- Desiccant: Product used to kill the above ground growth.
  - Promotes dehydration of plant tissue and may lower moisture level of seeds to facilitate harvest (speed up drying).
- Crops desiccated
  - soybean, drybean, lentil, sunflower (oil-type only)
  - potato (only fresh market, there is a little movement within the potato plant)
- Chemical fallow

Zimdahl, 2007
Other comments

- Restricted use pesticide
  - ORAL TOXICITY
- Not translocated in the plant (contact)
- requires a non-ionic surfactant
  - aids in more thorough coverage
- Immediately inactivated by contact with soil
  - no soil activity
Ways to avert people from drinking paraquat

- Stench
- Induces vomiting (emetic)
- Purgative
- Acid induced gel alginate (turns into gel)

**THESE PRECAUTIONS HAVE EFFECTIVELY MADE PARAQUAT TEN TIMES SAFER**
Site of action: PS₁
Herbicide Family: bipyridylium

- Herbicide: diquat
- Trade name: Reglone, Reward
- Cost: $52.50/lb
- Rates: 0.25-0.5 lb/A
- Time applied: POST, contact
Weeds controlled

- Primarily used as a desiccant
  - dry many crops to facilitate seed harvest, ornamentals included
  - potato vine killing
    - can be used for storage potatoes
- Non-cropland, non-selective weed control
  - not restricted use
    - Still some risk (i.e. Warning)
### Search Results for *reglone*

<table>
<thead>
<tr>
<th>Product</th>
<th>Manufacturer</th>
<th>Category</th>
<th>Labels MSDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reglone® Desiccant</td>
<td>Syngenta Crop Protection, Inc.</td>
<td>Agriculture/Crop Protection</td>
<td></td>
</tr>
<tr>
<td>(Caution)</td>
<td></td>
<td>Labels &amp; MSDS - USA</td>
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</table>

- **2004**
- **2009**
Weeds controlled

- Primarily used as a desiccant
  - dry many crops to facilitate seed harvest, ornamentals included
  - potato vine killing
    - can be used for storage potatoes
- Non-cropland non-selective weed control
  - not restricted use
    - Still some risk (i.e.; Caution, Warning)
  - landscapes
  - parking lots, highways, railroads
Other comments

- Other characteristics similar to paraquat
  - contact, no soil activity, etc
  - Fast acting, requires NIS
    - Rapid action caused by diquat due to diversion of energy from PS, producing peroxide radicals, which result in rapid sell collapse and onset of phytotoxic symptoms

- Now used in some home and garden mixtures with glyphosate in a consumer targeted product
  - very small amount of product
  - claim: “makes the glyphosate work faster”
  - Fact: Visual injury does happen faster, but...

From Wehtje et al.

- **Experiment:** Applied $^{14}$C-glyphosate with and without diquat to compare absorption and translocation
  - Glyphosate applied alone: ~60% recovered on the treated leaf, 40% translocated
  - Glyphosate with diquat: ~80% recovered on the treated leaf, and only 6.1% translocated
  - Diquat antagonized the glyphosate! **The claim is misleading.**
    - The rapid tissue death from the diquat prevented glyphosate entry into the vascular tissues for translocation
  - To overcome antagonism, higher glyphosate rates must be used
  - These rates are excessive though for the actual need if the consumer would be patient.
Site of Action: PPO inhibitor
Mode of action: Cell membrane disruptor

- Herbicide group: Diphenylether
- Herbicide: acifluorfen
- Trade name: Ultra Blazer
- Cost: $35/lb
- Rates: 0.25-0.5 lb/A
- Time applied: POST, contact

Ultra Blazer®
Herbicide
Weeds controlled

- many broadleaf weeds
  - nightshades, G-E
  - common lambsquarters, G
  - wild mustard, E
  - redroot pigweed, E
  - annual smartweeds, E
  - common ragweed, F-G
  - Russian thistle, G
  - Canada thistle, N
  - foxtails, P-F
Crops labeled

- Soybean
- peanut
- rice
- strawberry
Other comments

- No soil residual
- Daytime temperatures should exceed 70 F, but not exceed 85 F
  - If too hot, crop injury
- Adjuvant needed (NIS, PO/COC, AMS, UAN)
  - Temp + RH =155 is benchmark for crop injury concern
  - Adjuvant selection
  - Adjuvant rate
- Mixed with bentazon for broadspectrum control
  - bentazon + acifluorfen = Storm
Site of action: PPO Inhibitor
Mode of action: Cell Membrane Disruptor

- Herbicide family: Diphenylether
- Herbicide: lactofen
- Trade name: Cobra, Phoenix
- Cost: $80/lb, $90/lb
- Rates: 1.5-3.2 oz/A
- Time applied: POST, contact
Weeds controlled

- Many broadleaf weeds
  - common cocklebur, G
  - wild mustard, E
  - redroot pigweed, E
  - nightshades, G
  - common ragweed, G-E
  - annual smartweeds, G
  - foxtails, P-F
Crops labeled

• Soybean

Other comments

• Soil residual activity minimal, may last 2-3 wk under moist soils
• Application to soybean at the first bloom has resulted in some white mold (sclerotinia) suppression
• Cobra requires adjuvant, Phoenix has built-in
• Herbicide “burns” soybeans, outgrow in 3 wk
Site of action: PPO Inhibitor
Mode of Action: CMD

- Herbicide family: Diphenylether
- Herbicide: fomesafen
- Trade name: Flexstar, Reflex
- Cost: $66.50/lb
- Rates: 0.12-0.24 lb/A
- Time applied: POST, contact
Weeds controlled

- G-E control of most broadleaf weeds listed in the WCG except
  - wild buckwheat, P
  - horseweed, N-P
  - common lambsquarters, P-F
  - hairy nightshade, F-G
  - biennial wormwood, P
  - Canada thistle, N

Labeled for use in Soybean
Dry Bean
Other comments

- Rate varies with geography, due to soil residual
- Include an adjuvant (NIS or MSO)
- Can be mixed with some EC herbicides but the emulsifier may increase crop injury
- Also sold in a premix with glyphosate
  - fomesafen + glyphosate = Flexstar GT
Site of action: PPO Inhibitor
Mode of Action: CMD

- Herbicide family: Diphenylether
- Herbicide: oxyfluorfen
- Trade name: Goal (2EC), GoalTender (4ACS)
- Cost: $49.00/lb
- Rates: 1-2 lb/A
- Time applied: POST, or PRE (some soil activity)
Weeds controlled

- broadleaf weeds
  - G-E on most WCG broadleaf weeds except...
    - mustards, F
    - annual smartweed, F
    - Canada thistle, N
    - WCG grasses, P
      - Except Wild Oat, F-G
Crops Labeled

- Key horticultural crop herbicide
  - many trees
  - vegetables, broccoli, cabbage, cauliflower, onion
  - Fruit, nut, and vine crops
- Micro-rate research for weed control in onion
  - Oxyfluorfen (GoalTender):
    - 1 oz ai/A (three sequential applications)
    - Common lambsquarters, F-G
    - Redroot pigweed, E
    - Highest yielding treatment
      - controlled common purslane, E
GoalTender
Other comments

- Surface applied before transplanting of some cover crops (some soil activity)
- Usually can apply over-the-top of conifers but not over-the-top on deciduous trees
- Deciduous trees applied to soil surface after tree leaves have fully expanded
Herbicide family: *N*-pheythalamide
Herbicide: flumiclorac
Cost: $260/lb
Rate: 0.1 to 0.3 oz ai/A
Trade name: Resource
Weeds controlled: broadleaf weeds
- Limited information in ND
- Limited activity on weeds tested
Crops labeled
- corn and soybean

Site of action: PPO Inhibitor
Mode of Action: CMD

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[Chemical Structure Image]

[Logo Image]
Herbicide family: \(N\)-phenylthalamide
Herbicide: flumioxazin
Trade name: Valor, Chateau (more $, same product)
- Chateau (high value crops, more risk for company)
Cost: Valor, $11/oz; Chateau, $14/oz
Flumioxazin Uses

- Weeds controlled: small-seeded broadleaf
- Crops applied
  - Valor – cotton, bean, corn, potato
  - Chateau – grape, mint, fruit and nut crops
  - Payload – vegetation management, right-of-way
- Available in premixes
  - Fierce – flumioxazin+pyroxasulfone
  - Enlite – flumioxazin+thifensulfuron+chlorimuron
- Available in copack
  - Gangster – flumioxazin+chloransulam
Site of action: PPO Inhibitor
Mode of Action: CMD

- Herbicide family: Oxadiazole
- Herbicide: oxadiazon
- Trade name: Ronstar
- Weeds controlled: Annual grass and broadleaf weeds
Crops labeled: turf

- For use in dormant, established turf
- apply 2-3 wk prior to green-up
- if rain not expected within 4 hours, water in using irrigator
**Crops labeled: ornamentals**

**PLANT TOLERANCE:** RONSTAR 50 WSP Herbicide can be used as a directed or over-the-top spray application in a minimum of 50 gallons of water per acre on the following ornamental species:

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>VARIETIES</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Arborvitae</td>
<td>American - Smaragd, Rheingold, Giant -</td>
<td>Holly</td>
<td>Japanese - Helleri</td>
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<td></td>
<td>Zebrina</td>
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<td>Kurogane</td>
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<tr>
<td>Baby's Breath</td>
<td><em>Gypsophila paniculata</em></td>
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<td>Chinese – Parsonii</td>
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<tr>
<td>Barberry</td>
<td>Japanese</td>
<td>Ice Plant**</td>
<td>Large Leaf</td>
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<tr>
<td>Boxwood</td>
<td>Dazzler</td>
<td>Ivy**</td>
<td>English, Algerian</td>
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<tr>
<td>Cedar</td>
<td>Eastern Red</td>
<td>Juniper</td>
<td>Common - Berkshire, Effusa</td>
</tr>
<tr>
<td>Cranberry</td>
<td>American</td>
<td></td>
<td>Creeping - Blue Chip, Blue Rug, Andorra</td>
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<tr>
<td>Daisy**</td>
<td>African Trailing</td>
<td></td>
<td>Singleseed - Blue Star</td>
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<tr>
<td>Dodonaea</td>
<td>Purpurea</td>
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<td>Savin - Buffalo, Tamariscifolia</td>
</tr>
<tr>
<td>Euonymus</td>
<td>Evergreen - Golden Japanese, Gold Spot</td>
<td>Oleander</td>
<td>Common</td>
</tr>
<tr>
<td>False Cypress</td>
<td><em>Nootka - Aurea</em></td>
<td>Ophiopogon</td>
<td>Major, Minor</td>
</tr>
<tr>
<td></td>
<td>Hinoki - Graciosa, Pygmaea</td>
<td>Periwinkle**</td>
<td>Eastern White, Mugho, Scotch</td>
</tr>
<tr>
<td></td>
<td><em>Sawara - Aurea nana</em></td>
<td>Pine</td>
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<td></td>
<td>Douglas, Fraser, Grand, Noble</td>
<td>Raphiolepis</td>
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<td>Spruce*</td>
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<td>Statice</td>
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<td></td>
<td>Consult State Agricultural Experiment Station or Extension Service weed specialists for specific recommendations for local weed problems and for information on possible lower dosages.</td>
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<td></td>
<td>* Do not use in California on Fir, Hemlock, and Blue Spruce.</td>
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<tr>
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<td>** Use a maximum of 4 WS packets per acre on Daisy, Ice Plant, Ivy, and Periwinkle.</td>
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</tbody>
</table>
Herbicide Family: Triazolinone
Herbicide: carfentrazone
Trade name: Aim
Cost: $500/lb
Rates: 0.125-0.25 oz/A
Time applied: POST, contact

Site of action: PPO Inhibitor
Mode of Action: CMD
Weeds controlled

- Broadleaf weeds (need to be small)
  - kochia, F-E
  - common lambsquarters, F-E
  - nightshades, G
  - redroot pigweed, G-E
  - common waterhemp, F-E
  - wild mustard, P
  - Canada thistle, N
  - field bindweed, F
  - *(suppression)*

common waterhemp, pigweed family, annual
Crops labeled

- Small grains – up to jointing stage
  - Premix with 2,4-D called Rage D-tech
- Soybean – V3 to V10 (not typically used in ND)
- Corn – up to 12 inches tall
- Turf – actively growing
  - Quicksilver
- Many other directed application labels (avoiding contact with foliage)
- Can be used PRE to kill existing weeds in more than 200 crops
Other comments

- suitable in many tank-mixes with both grass and broadleaf herbicides
- requires NIS at 0.25% v/v
- may cause some cosmetic injury (speckling and spotting) soon after treatment to crop plants, but will soon outgrow
- injury may be increased if applied during high humidity and higher moisture
- Data shows carfentrazone may be safened by ALS inhibiting herbicides
Herbicide family: Triazolinone
Herbicide: sulfentrazone
Trade name: Spartan, Blanket, generics
  Authority
  Speedzone
Cost: $162/lb
Rates: 1.5-3 oz/A
Time applied: PRE, PPI, POST (usually not in ND)
Weeds controlled

- Many annual small-seeded broadleaf weeds G-E

- PRE, PPI
  - goosefoots, E
  - pigweeds, F-G
  - nightshades, F-E
  - mustards, G-E
  - smartweeds, E
    - including wild buckwheat, F-G
  - biennial wormwood, F-G
  - horseweed, F-G
  - Grass: downy brome, F-G

- POST
  - used for grass suppression or control in sod production
    - yellow nutsedge
    - purple nutsedge
    - other sedges
Crops labeled

- soybean
- dry bean
- chickpea, field pea
- sunflower
- potato
- flax
- turf grass for sod production
  - well established root systems
  - three month harvest restriction
Other comments

- Tank-mixed with PPI/PRE herbicides registered in soybean
- Consistent weed control requires $\frac{1}{2}-\frac{3}{4}$ inch of rainfall prior to weed emergence – PRE
  - PPI has become less and less due to cropping systems
- Residual concerns
  - Crop rotation restrictions, especially greater than 1 yr for mustard crops, sugarbeet, and several horticultural crops
Herbicide family: pyrimidinedione
Herbicide: saflufenacil
Trade name: Sharpen (Verdict: saflu + dimethenamid-P)
Cost: $201.75/lb
Rates: 0.35-1.1 oz/A
Time applied: PRE (residual) and POST (burndown)
Weeds controlled: Most ND WCG broadleaf weeds, G-E
Crops labeled: PRE: small grains, corn, field pea, chickpea, soybean, sunflower (desiccant)

Site of action: PPO Inhibitor
Mode of Action: CMD

Powered by Kixor® Herbicide

BASF
The Chemical Company
Homework

- Develop a diagnostic model/tree to separate herbicide site of action by symptomology
- Include all sites from Growth Regulator through next week’s Pigment and Cellulose inhibition modes of action
- Work in groups is encouraged, turn in one form per group
- Scematics/diagrams encouraged
- Due April 23, worth 15 pts