Aquatic Weed Control Techniques

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Nonindigenous vs. Native Community

*Alternanthera philoxeroides*
Alligatorweed

*Nelumbo lutea*
American lotus
Getting a Good Plant ID:

• This is first step in Management:
  • Publication Guides
  • Online Keys

• Experts - Send Photos or Live plant

• A number of people can identify aquatic plants in your region
  • Your Extension agent or specialist likely knows who they are

Applicator preparing to treat a storm water retention pond overgrown with water lettuce
Getting a Good Plant ID:

• Live Plant
  • Wrap in damp paper towel
  • Place in Ziploc bag
  • Ship on ice overnight to MSU

• Sending good quality digital photos are best way to get a good ID
  • Flower
  • Close-Up
  • Habitat
Getting a Good Plant ID:

• Proper identification is critical to selecting the correct herbicide
  • E.g., Aquathol K (endothall) is excellent for egeria, good for hydrilla, poor for elodea
  • They are in the same family

• Proper identification will also indicate if there is an invasive problem or a localized native nuisance
Growth Form:

- Growth form is key step in plant ID

- Littoral zone is that area of lakebed that receives enough sunlight for aquatic plants to grow

- Changes seasonally as water clarity changes
  - 3X Secchi Depth
  - Free-floating plants and algae not restricted to littoral zone
How Big is Your Problem?

- For emergent and floating leaf plants, the AREA is the critical calculation needed (with a few exceptions)

- For submersed plants and algae, water VOLUME is the critical calculation needed (some exceptions)

- Software can help with this
  - Google Earth Pro
How Big is Your Problem?

• Spend the time to take 20 or so depth soundings with a rod or sonar across the surface area of a pond
  • Or infested area

• Average these measurements for the avg depth

• Volume = area x avg. depth
  • Ac-ft.
Develop a Management Plan

• Identify problem

• Define management goals

• Select management technique
  • Assess logistics and budget
  • Identify alternatives

• Monitor...monitor some more

• Switch tactics if needed
Develop a Management Plan

- Useful metrics (Collect every 3-4 months):
  - Littoral depth
  - Water temperature
  - Water hardness/alkalinity
  - Plant community
    - %-cover or relative abundance of each spp.
  - Fish harvest/stocking rates
  - Fish feeding rates

- Start collecting before management begins
Aquatic Plant Management Approaches:

• Prevention is Best!

• Biological Control

• Mechanical Control

• Physical Control

• Chemical Control

• Integrated Control

Photo credit: G. Turnage.
Invasion Process:

- **Lag Phase**
  - Plants may go unnoticed
  - Eradication possible

- **Exponential Growth Phase**
  - Usually when management begins
  - Maintenance Management is target

- **Carrying Capacity**
  - Invasive spp. start to form large monocultures

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Logistic Growth

- Carrying Capacity
- Exponential Growth Phase
- Lag Phase

Image Credit: G. Turnage
Prevention:

- Prevention is the best plant control technique

- Multiple vectors for invasion
  - Boats and boat trailers
  - Hunting gear (duck decoy rigging)
  - Fishing gear
  - Bait buckets

- Know what's coming into and leaving your pond
  - Inspect gear
Biological Control:

- Purpose is to maintain plant population below nuisance levels
  - Not an elimination technique

- In MS, specific biocontrol agents released for:
  - Alligatorweed
  - Giant salvinia

- General biocontrol agent (grass carp) released for numerous species
Biological Control:

- Grass carp effective on some species
  - Hydrilla
  - Southern naiad
  - Leafy pondweed

- Natural feeding preference
  - “All or none” effect
  - Tends to roam downstream

- Must be restocked after 4-5 yrs.
Mechanical Control:

• Purpose is physical destruction or removal of plants

• Destruction
  • Cutting
  • Rotovating

• Removal
  • Hand Pulling
  • Harvesting
  • Diver-operated suction harvesting
Physical Control:

- Purpose is environmental alteration
- Dredging – also mechanical control
- Drawdown
  - Total ecosystem “reset”
- Benthic barrier and dyes
  - Shading
- Nutrient inactivation

Drawn down lake; kayaker is in central lake channel, surrounding sediment is normally underwater.
Chemical Control:

- **Purpose** is induction of phytotoxic effects for plant death

- **Only use** EPA approved herbicides with aquatic use language on the label
  - THE LABEL IS THE LAW
  - Only use aquatic approved additives
    - NIS, MSO, & COC

- **Off label use is illegal!!**
  - Buyer beware when talking to county co-ops

- **Systemic:**
  - 2,4-D (Amine)
  - Bispyribac-sodium
  - Fluridone
  - Glyphosate
  - Imazamox
  - Imazapyr
  - Penoxsulam
  - Triclopyr
  - Topramezone
  - Florpyrauxifen-benzyl

- **Contact:**
  - Carfentrazone-ethyl
  - Copper
  - Diquat
  - Endothall
  - Flumioxazin

- **Algae Specific:**
  - Peroxidases
Chemical Control:

- Foliar Applications
  - Emergent and Floating Plants

- Calculate the area of the infestation, not the area of the waterbody

- Application to leaves above the surface of the water

- Use aquatic-approved surfactant
Chemical Control:

- Submersed Applications

- Herbicides are applied to water, and plants take up herbicide from water

- Water movement, residence time, and concentration are critical for effective treatment
  - Water flow
  - Tides
  - Wind
  - Temperature
  - Herbicide formulation
Chemical Control:

• Submersed Applications

• Concentration-Exposure Time Relationships critical for herbicide selection in moving water

• Higher rate = less contact time needed

• Dyes study usually done first
Chemical Control:

- Herbicide Issues
  - Selectivity and activity
  - Use restrictions
  - Herbicide resistance
  - Herbicide stewardship
  - Regulation—NPDES

- Tank Mixes often used to avoid/mitigate issues above

- Use appropriate rates
  - Don’t cut corners on rate calculations

Figure 2. Mean and standard deviations obtained from laboratory assays of the β-carotene content of hydrilla shoot apices following a 14-day exposure to fluridone concentrations ranging from 0 to 91 nM. Phenotypes: ●: susceptible (179 lakes); ○: low resistance (8 lakes); ▼: intermediate resistance (7 lakes); ▽: high resistance (5 lakes) (reprinted with permission of Blackwell Publishing from Michel et al.®).
Integrated Control:

- Combines techniques from 4 control categories
  - Can be cheaper but not always

- Usually attain better, longer lasting control
  - Plant is stressed from multiple directions

- Not always needed or appropriate
Chemical Control:

• Herbicide Selection

• See the most recent Weed Control guidelines for your state

• Herbicide formulation and rate can affect control efficacy

• Plants may not respond immediately
  • Learn time of symptomology
  • Ask Extension specialist if not sure
Intro to Chemical Control:

- Rivers and Harbors Act – 1890’S
  - Water hyacinth

- 2,4-D – 1940’s

- 16 general use herbicides in aquatics
  - 1 is a dye
  - Peroxides - algae

- 100’S of terrestrial use herbicides - 2023
Intro to Chemical Control:

- Herbicide Physico-Chemical Properties Differ
- pH sensitive
- Turbidity
- Temperature sensitive
- Systemic vs. contact
- Short vs. long CET
- Foliar vs. submersed activity
Intro to Chemical Control:

- Systemic Herbicides:
  - 2,4-D
  - Bispyribac sodium
  - Florpyrauxifen-benzyl
  - Fluridone
  - Glyphosate
  - Imazamox
  - Imazapyr
  - Penoxsulam
  - Topramezone
  - Triclopyr

- Contact Herbicides:
  - Carfentrazone-ethyl
  - Copper
  - Diquat
  - Endothall
  - Flumioxazin

- Dyes

- Peroxides (algae)

- Adjuvants:
  - Non-ionic surfactants (NIS)
  - Buffering agents
  - Stickers
  - Sinkers
  - Methylated seed oils (MSO)
  - Crop oil concentrate (COC)
  - Markers
  - De-foamers
Environmental Fate:

• Environmental Fate – life cycle of a chemical (herbicide) or pollutant after release.

• Why is this important?
  • Can affect human health
  • Paraquat & organ weakening

• Can affect microflora
  • Microbes in soil and water

• Can affect non-target plants
Environmental Fate:

• Factors affecting herbicide fate in environment
  • Water solubility
    • Solubility <-> Adsorption <-> Mobility
    • KOW – partition coefficient
      • High = hydrophobic
    • pKa – log of dissociation constant of acid
    • Microbial degradation

• Adsorptive potential
  • KOC - measure of attraction of ions/molecules to solid surface (or organic material).

• Half Life
  • Time to reach one half of original dose.
Environmental Fate:

- Factors affecting herbicide fate in environment (cont)
  - Photodecomposition
    - Latitude
    - Season
    - UV light
  - Volatility – occurs when herbicide goes from liquid to gas state.
    - Vapor pressure
    - Soil moisture (wetlands)
    - Temperature
  - Soil/water chemical properties

- Herbicide – half life of 30 min
  - After 90 min 1/8th of herbicide remains

![Diagram showing herbicide decay over time with specific half-lives and concentrations at different times]
Definitions:

- Adsorption – attraction, adhesion, or accumulation of herbicides to a substance.
- Photodegradation (photolysis) – broken down by sunlight.
- Microbial degradation – broken down by microbes (bacteria).
- Hydrolysis – broken down by interactions with water.
- Plant uptake – taken in by pores on plant tissues (roots, leaves, etc.).
- Sequestration – occurs when herbicides placed in a location (usually vacuoles) w/in plants that inhibits phytotoxicity due to herbicides.
Definitions:

- Site of Action – location in plant where herbicide acts to cause damage.

- Chlorosis (chlorotic) – loss of green color in plants (yellowing).

- Necrosis (necrotic) – death of plant cells.

- Bleaching – plants take on a white color.

- Systemic Herbicide – herbicide that translocates (moves) from the site of entry through the plant to the site of action.

- Contact Herbicide – herbicide that does not translocate, but rather affects plants at or near the site of entry into the plant.
Systemic Herbicides:

Herbicide Application

Translocation
Systemic Herbicides:

2,4-D – (2,4-dichlorophenoxy)acetic acid
- Selective for dicots, although ‘leaky.’
- Submersed or foliar applications.
- Auxin mimic.
- Acid and ester formulations:
  - Acid – root uptake better
  - Ester – foliage uptake better
- Symptomology – twisting/bending, chlorosis, necrosis, plant death.

<table>
<thead>
<tr>
<th></th>
<th>2,4-D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Use Rate (ppm)</td>
<td>0.5 – 4.0</td>
</tr>
<tr>
<td>Selectivity</td>
<td>Selective (dicots)</td>
</tr>
<tr>
<td>Degradation</td>
<td>Microbial, Photolysis</td>
</tr>
<tr>
<td>Half-Life (days)</td>
<td>7 – 48</td>
</tr>
<tr>
<td>Mode of action</td>
<td>Auxin mimic, growth regulation</td>
</tr>
<tr>
<td>Time to symptomology</td>
<td>Days to weeks</td>
</tr>
<tr>
<td>$K_{OC}$ (mL/g)</td>
<td>20 (salt), 100 (ester)</td>
</tr>
<tr>
<td>$K_{OW}$</td>
<td>NA</td>
</tr>
<tr>
<td>p$\text{Ka}$</td>
<td>2.7</td>
</tr>
</tbody>
</table>

* Check labels for herbicide use restrictions.
Systemic Herbicides:

**Bispyribac-sodium** – 2,6-bis [(4,6-dimethoxy-2-pyrimidinyl]oxy) benzoic acid

- Submersed or foliar application.
- Stable at pH 5-9.
- Symptomology: growth stops, chlorosis, necrosis, and plant death.

<table>
<thead>
<tr>
<th><strong>Bispyribac-sodium</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Use Rate (ppm)</td>
</tr>
<tr>
<td>Selectivity</td>
</tr>
<tr>
<td>Degradation</td>
</tr>
<tr>
<td>Half-Life (days)</td>
</tr>
<tr>
<td>Mode of action</td>
</tr>
<tr>
<td>Time to symptomology</td>
</tr>
<tr>
<td>$K_{oc}$ (mL/g)</td>
</tr>
<tr>
<td>$K_{ow}$</td>
</tr>
<tr>
<td>pKa</td>
</tr>
</tbody>
</table>

* Check labels for herbicide use restrictions.
Systemic Herbicides:

Florpyrauxifen-benzyl – 2-pyridinecarboxylic acid, 4-amino-3-chloro-6-(4-chloro-2-fluoro-3-ethoxy-phenyl)-5-fluoro-, phenyl methyl ester

- Submersed or foliar application.
- SC Form: 1 PDU = 10 ppb
  - Labeled in SE states of U.S.
- Symptomology: twisting/bending, chlorosis, necrosis, plant death.

<table>
<thead>
<tr>
<th></th>
<th>Florpyrauxifen-benzyl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Use Rate (ppm)</td>
<td>0.01 – 0.05</td>
</tr>
<tr>
<td>Selectivity</td>
<td>Broad spectrum</td>
</tr>
<tr>
<td>Degradation</td>
<td>Hydrolysis (pH dependent)</td>
</tr>
<tr>
<td>Half-Life (days)</td>
<td>111 (pH 7); 1.3 (pH 9)</td>
</tr>
<tr>
<td>Mode of action</td>
<td>Auxin mimic, growth regulation</td>
</tr>
<tr>
<td>Time to symptomology</td>
<td>Days</td>
</tr>
<tr>
<td>$K_{OC}$ (mL/g)</td>
<td>34,200</td>
</tr>
<tr>
<td>$K_{OW}$</td>
<td>NA</td>
</tr>
<tr>
<td>pKa</td>
<td>NA</td>
</tr>
</tbody>
</table>

* Check labels for herbicide use restrictions.
Systemic Herbicides:

Fluridone – 1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1H)-pyridinone

- Submersed or foliar application.
- Long CET required at lower rates.
- Symptomology – bleaching, chlorotic, plant death.
  - Usually takes weeks to months to gain control of problematic species

<table>
<thead>
<tr>
<th></th>
<th>Fluridone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Use Rate (ppm)</td>
<td>0.005 – 0.030</td>
</tr>
<tr>
<td>Selectivity</td>
<td>Broad spectrum</td>
</tr>
<tr>
<td>Degradation</td>
<td>Microbial, Photolysis</td>
</tr>
<tr>
<td>Half-Life (days)</td>
<td>20+</td>
</tr>
<tr>
<td>Mode of action</td>
<td>Inhibits pigment synthesis</td>
</tr>
<tr>
<td>Time to symptomology</td>
<td>Days to weeks</td>
</tr>
<tr>
<td>$K_{OC}$ (mL/g)</td>
<td>1,000 (avg), ~250 – 2,460</td>
</tr>
<tr>
<td>$K_{OW}$</td>
<td>74</td>
</tr>
<tr>
<td>pKa</td>
<td>None</td>
</tr>
</tbody>
</table>

* Check labels for herbicide use restrictions.
Systemic Herbicides:

**Glyphosate** – N-(phosphonomethyl)glycine

- Foliar application.

- 3 formulations:
  - All salts

- Symptomology – growth stops, chlorosis, necrosis, and plant death.
  - Witch’s broom

<table>
<thead>
<tr>
<th></th>
<th>Glyphosate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Use Rate (%)</td>
<td>2 – 5</td>
</tr>
<tr>
<td>Selectivity</td>
<td>Broad spectrum</td>
</tr>
<tr>
<td>Degradation</td>
<td>Adsorption, Microbial</td>
</tr>
<tr>
<td>Half-Life (days)</td>
<td>14+</td>
</tr>
<tr>
<td>Mode of action</td>
<td>Enzyme inhibitor (ESPS)</td>
</tr>
<tr>
<td>Time to symptomology</td>
<td>Days to weeks</td>
</tr>
<tr>
<td>$K_{OC}$ (mL/g)</td>
<td>24,000</td>
</tr>
<tr>
<td>$K_{OW}$</td>
<td>0.0006 – 0.0017</td>
</tr>
<tr>
<td>$pK_a$</td>
<td>2.6, 5.6, and 10.3 (diff forms)</td>
</tr>
</tbody>
</table>

* Check labels for herbicide use restrictions.
Systemic Herbicides:

**Imazamox** – 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazole-2-yl]-5-(methoxymethyl)-3-pyridinecarboxylic acid

- Foliar or submersed application.
- Active in soil.
- Symptomology – chlorosis, necrosis, and plant death.

<table>
<thead>
<tr>
<th></th>
<th>Imazamox</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Use Rate (ppm)</td>
<td>0.050 – 0.075</td>
</tr>
<tr>
<td>Selectivity</td>
<td>Broad spectrum</td>
</tr>
<tr>
<td>Degradation</td>
<td>Microbial, Photolysis</td>
</tr>
<tr>
<td>Half-Life (days)</td>
<td>7 – 14</td>
</tr>
<tr>
<td>Mode of action</td>
<td>Enzyme inhibitor (ALS)</td>
</tr>
<tr>
<td>Time to symptomology</td>
<td>Days to weeks</td>
</tr>
<tr>
<td>$K_{OC}$ (mL/g)</td>
<td>Weak</td>
</tr>
<tr>
<td>$K_{OW}$</td>
<td>5.36</td>
</tr>
<tr>
<td>pKa</td>
<td>2.3, 3.3, &amp; 10.8 (pH 5-9)</td>
</tr>
</tbody>
</table>

* Check labels for herbicide use restrictions.
Systemic Herbicides:

**Imazapyr** – (±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo1H-imidazole-2-yl]-3-pyridinecarboxylic acid

- Foliar application.
- Active in soil.
- Symptomology – growth stops, chlorosis, necrosis, and plant death.

*Check labels for herbicide use restrictions.*

<table>
<thead>
<tr>
<th></th>
<th>Imazapyr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Use Rate (%)</td>
<td>2 – 5</td>
</tr>
<tr>
<td>Selectivity</td>
<td>Broad spectrum</td>
</tr>
<tr>
<td>Degradation</td>
<td>Microbial, Photolysis</td>
</tr>
<tr>
<td>Half-Life (days)</td>
<td>2 – 4</td>
</tr>
<tr>
<td>Mode of action</td>
<td>Enzyme inhibitor (ALS)</td>
</tr>
<tr>
<td>Time to symptomology</td>
<td>Days to weeks</td>
</tr>
<tr>
<td>$K_{OC}$ (mL/g)</td>
<td>Weak, reversible</td>
</tr>
<tr>
<td>$K_{OW}$</td>
<td>1.3</td>
</tr>
<tr>
<td>pKa</td>
<td>1.9 and 3.6</td>
</tr>
</tbody>
</table>
Systemic Herbicides:

Penoxsulam – 2-(2,2-difluoroethoxy)-6-(trifluoromethyl)-N-(5,8-dimethoxy[1,2,4]riazolo-[1,5c]pyrimidin-2-yl)benzenesulfonamide

- Foliar or submersed application.
- Active in soil.
- Symptomology – chlorosis (possible reddening of veins), necrosis, and plant death.

<table>
<thead>
<tr>
<th>Penoxsulam</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Use Rate (ppm)</td>
<td>0.01 – 0.04</td>
</tr>
<tr>
<td>Selectivity</td>
<td>Broad spectrum</td>
</tr>
<tr>
<td>Degradation</td>
<td>Microbial, Photolysis</td>
</tr>
<tr>
<td>Half-Life (days)</td>
<td>15+</td>
</tr>
<tr>
<td>Mode of action</td>
<td>Enzyme inhibitor (ALS)</td>
</tr>
<tr>
<td>Time to symptomology</td>
<td>Days to weeks</td>
</tr>
<tr>
<td>$K_{OC}$ (mL/g)</td>
<td>104</td>
</tr>
<tr>
<td>$K_{OW}$</td>
<td>-0.354</td>
</tr>
<tr>
<td>pKa</td>
<td>NA</td>
</tr>
</tbody>
</table>

* Check labels for herbicide use restrictions.
Topramezone – [3-(4,5-dihydro-isoxazolyl)-2-methyl-4-(methylsulfonyl) phenyl](5-hydroxyl-1-methyl-1H-pyrazol-4-yl)methanone

- Foliar or submersed application.
- Active in soil.
- Symptomology – bleaching, chlorosis, necrosis, and plant death.

<table>
<thead>
<tr>
<th>Topramezone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Use Rate (ppm)</td>
</tr>
<tr>
<td>Selectivity</td>
</tr>
<tr>
<td>Degradation</td>
</tr>
<tr>
<td>Half-Life (days)</td>
</tr>
<tr>
<td>Mode of action</td>
</tr>
<tr>
<td>Time to symptomology</td>
</tr>
<tr>
<td>K_{OC} (mL/g)</td>
</tr>
<tr>
<td>K_{OW}</td>
</tr>
<tr>
<td>pKa</td>
</tr>
</tbody>
</table>

* Check labels for herbicide use restrictions.
Systemic Herbicides:

**Triclopyr** – [(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid

- Foliar or submersed application.
- Active on woody vegetation.
- Symptomology – twisting & bending, growth stops, chlorosis, necrosis, and plant death.

<table>
<thead>
<tr>
<th>Triclopyr</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Use Rate (ppm)</td>
<td>0.75 – 2.5</td>
</tr>
<tr>
<td>Selectivity</td>
<td>Selective (dicots)</td>
</tr>
<tr>
<td>Degradation</td>
<td>Microbial, Photolysis</td>
</tr>
<tr>
<td>Half-Life (days)</td>
<td>0.5 – 3</td>
</tr>
<tr>
<td>Mode of action</td>
<td>Auxin mimic, growth regulation</td>
</tr>
<tr>
<td>Time to symptomology</td>
<td>Days to weeks</td>
</tr>
<tr>
<td>$K_{OC}$ (mL/g)</td>
<td>20</td>
</tr>
<tr>
<td>$K_{ow}$</td>
<td>2.64, 0.36, &amp; 0.11 (pH 5, 7, 9)</td>
</tr>
<tr>
<td>pKa</td>
<td>2.68</td>
</tr>
</tbody>
</table>

* Check labels for herbicide use restrictions.
Contact Herbicides:

Herbicide Application

No Translocation
Contact Herbicides:

Carfentrazone-ethyl – ethyl 2-chloro-3-[2-chloro-4-fluoro-5-[4-(difluoromethyl)-4,5-diydro-3-methyl-5-oxo-1h-1,2,4-trizol-1-yl]phenyl]propanoate

- Foliar or submersed application.
- Early morning applications better.
- Symptomology – necrosis and plant death.

**Carfentrazone-ethyl**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Use Rate (ppm)</td>
<td>0.2</td>
</tr>
<tr>
<td>Selectivity</td>
<td>Broad Spectrum</td>
</tr>
<tr>
<td>Degradation</td>
<td>Microbial, Photolysis</td>
</tr>
<tr>
<td>Half-Life (days)</td>
<td>3 – 8 (pH dependent)</td>
</tr>
<tr>
<td>Mode of action</td>
<td>Enzyme inhibitor (PPO)</td>
</tr>
<tr>
<td>Time to symptomology</td>
<td>Days</td>
</tr>
<tr>
<td>(K_{OC}) (mL/g)</td>
<td>750</td>
</tr>
<tr>
<td>(K_{OW})</td>
<td>3.36</td>
</tr>
<tr>
<td>pKa</td>
<td>None</td>
</tr>
</tbody>
</table>

* Check labels for herbicide use restrictions.
Contact Herbicides:

**Copper** – copper chelate or sulfate

- Foliar or submersed application.
  - Chelates active longer in water
  - Only use in water alkalinity >50 ppm

- Many formulations.

- Symptomology – cells become chlorotic, plant/algal death.
  - Commonly used as an algaecide.

<table>
<thead>
<tr>
<th></th>
<th>Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Use Rate (ppm)</td>
<td>0.2 – 1.0</td>
</tr>
<tr>
<td>Selectivity</td>
<td>Broad spectrum</td>
</tr>
<tr>
<td>Degradation</td>
<td>Chemically bound</td>
</tr>
<tr>
<td>Half-Life (days)</td>
<td>3 – 8 (pH dependent)</td>
</tr>
<tr>
<td>Mode of action</td>
<td>Inhibits photosynthesis</td>
</tr>
<tr>
<td>Time to symptomology</td>
<td>Hours to Days</td>
</tr>
<tr>
<td>$K_{OC}$ (mL/g)</td>
<td>Moderate (chel), strong (sulf)</td>
</tr>
<tr>
<td>$K_{OW}$</td>
<td>NA</td>
</tr>
<tr>
<td>pKa</td>
<td>4.23 (Tri form)</td>
</tr>
</tbody>
</table>

*Check labels for herbicide use restrictions.*
Contact Herbicides:

Diquat – 6,7-dihydrodipyrido[1,2-α:2’,1’-c]pyrazinediium ion

- Foliar or submersed application.
  - Do not use in very turbid water
- Some resistance in Landoltia.
  - Reduced uptake likely
- Symptomology – rapid wilting, necrosis, plant death.

<table>
<thead>
<tr>
<th></th>
<th>Diquat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Use Rate (ppm)</td>
<td>0.1 – 0.37</td>
</tr>
<tr>
<td>Selectivity</td>
<td>Broad spectrum</td>
</tr>
<tr>
<td>Degradation</td>
<td>Adsorption, photolysis</td>
</tr>
<tr>
<td>Half-Life (days)</td>
<td>1 – 7</td>
</tr>
<tr>
<td>Mode of action</td>
<td>Inhibits photosynthesis</td>
</tr>
<tr>
<td>Time to symptomology</td>
<td>Hours to Days</td>
</tr>
<tr>
<td>$K_{OC}$ (mL/g)</td>
<td>1,000,000</td>
</tr>
<tr>
<td>$K_{OW}$</td>
<td>0.000055</td>
</tr>
<tr>
<td>pKa</td>
<td>None</td>
</tr>
</tbody>
</table>

* Check labels for herbicide use restrictions.
Contact Herbicides:

**Endothall** – 7-oxabicyclo[2.2.1]heptane-2,3 dicarboxylic acid

- Submersed or foliar application.

- Recently reclassified as a systemic:
  - Short CET

- 2 formulations:
  - Both salts

- Symptomology – defoliation and browning, plant death.

<table>
<thead>
<tr>
<th>Endothall</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Use Rate (ppm)</td>
<td>0.3 – 3.0</td>
</tr>
<tr>
<td>Selectivity</td>
<td>Broad spectrum</td>
</tr>
<tr>
<td>Degradation</td>
<td>Microbial</td>
</tr>
<tr>
<td>Half-Life (days)</td>
<td>3 – 7</td>
</tr>
<tr>
<td>Mode of action</td>
<td>Inhibits photosyn and cell resp.</td>
</tr>
<tr>
<td>Time to symptomology</td>
<td>Days</td>
</tr>
<tr>
<td>$K_{OC}$ (mL/g)</td>
<td>20 (pH 7), 110-138 (pH 7.8)</td>
</tr>
<tr>
<td>$K_{OW}$</td>
<td>NA</td>
</tr>
<tr>
<td>pKa</td>
<td>3.4 &amp; 6.7</td>
</tr>
</tbody>
</table>

* Check labels for herbicide use restrictions.
Contact Herbicides:

Flumioxazin – 2-[7-fluoro-3,4-dihydro-3-oxo-4-(2-propynyl)-2H-1,4-benzoxazin-6-yl]-4,5,6,7-tetrahydro-1H-isoin-dole-1,3(2H)-dione

- Foliar or submersed application.
- Very sensitive to high pH waters.
- Symptomology – rapid wilting, necrosis, plant death.

<table>
<thead>
<tr>
<th></th>
<th>Flumioxazin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Use Rate (ppm)</td>
<td>0.1 – 0.4</td>
</tr>
<tr>
<td>Selectivity</td>
<td>Broad spectrum</td>
</tr>
<tr>
<td>Degradation</td>
<td>Microbial, photolysis, hydrolysis</td>
</tr>
<tr>
<td>Half-Life (days)</td>
<td>3 – 5 (pH 5), 14 – 22 m (pH 9)</td>
</tr>
<tr>
<td>Mode of action</td>
<td>Enzyme inhibitor (PPO)</td>
</tr>
<tr>
<td>Time to symptomology</td>
<td>Hours to Days</td>
</tr>
<tr>
<td>$K_{OC}$ (mL/g)</td>
<td>13,000</td>
</tr>
<tr>
<td>$K_{OW}$</td>
<td>2.55</td>
</tr>
<tr>
<td>pKa</td>
<td>None</td>
</tr>
</tbody>
</table>

* Check labels for herbicide use restrictions.
Dyes:

- Only 2 registered with EPA for control of aquatic vegetation.
- > 2-3 ft depth needed.
- Absorbs and/or reflects sunlight thus inhibits photosynthesis.
- Need to re-apply monthly

<table>
<thead>
<tr>
<th>Dye</th>
<th>Typical Use Rate (ppm)</th>
<th>Selectivity</th>
<th>Degradation</th>
<th>Half-Life (days)</th>
<th>Mode of action</th>
<th>Time to symptomology</th>
<th>$K_{OC}$ (mL/g)</th>
<th>$K_{OW}$</th>
<th>pKa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 - 2</td>
<td>Broad spectrum</td>
<td>NA</td>
<td>Variable</td>
<td>NA (inhibits photosynthesis)</td>
<td>Days</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

* Check labels for herbicide use restrictions.
Adjuvants:

• Non-ionic (NI)/ NI + N/ Organosilicon surfactant

• Crop/vegetable/methylated seed oil concentrates

• Deposition/Spreader/Stickers/Sinking agents

• Activators

• Buffering/conditioning agents

• Anti-foam agents

• Tank cleaners
Final Thoughts:

• Develop a management plan
  • “Measure twice, cut once”

• Define management goals
  • Think twice if management is irreversible or long-term
    • Grass carp, fertilizer

• MONITOR!!
  • Change tactics if techniques don’t work
Web Sites

• **FEDERAL GOVERNMENT**
  • Aquatic Plant Control Research Program
    • www.wes.army.mil/el/aqua/aqua.html
  • USDA Plants
    • www.plants.usda.gov

• **STATE GOVERNMENT**
  • Mississippi Department of Agriculture and Commerce
    • www.mdac.state.ms.us
  • Mississippi Department of Wildlife, Fisheries and Parks
    • www.mdwfp.com

• **UNIVERSITY**
  • Center for Aquatic and Invasive Plants
    • aquat1.ifas.ufl.edu
  • Mississippi State University Extension
    • msucares.com

• **PROFESSIONAL SOCIETY**
  • MidSouth Aquatic Plant Management Society
    • www.msapms.org

• **FOUNDATION**
  • Aquatic Ecosystem Restoration Foundation
    • www.aquatics.org
Questions

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