

Herbicide Resistance = Why We Need New Herbicides

Bill Haller and Lyn Gettys

University of Florida Center for Aquatic and Invasive Plants
Gainesville FL

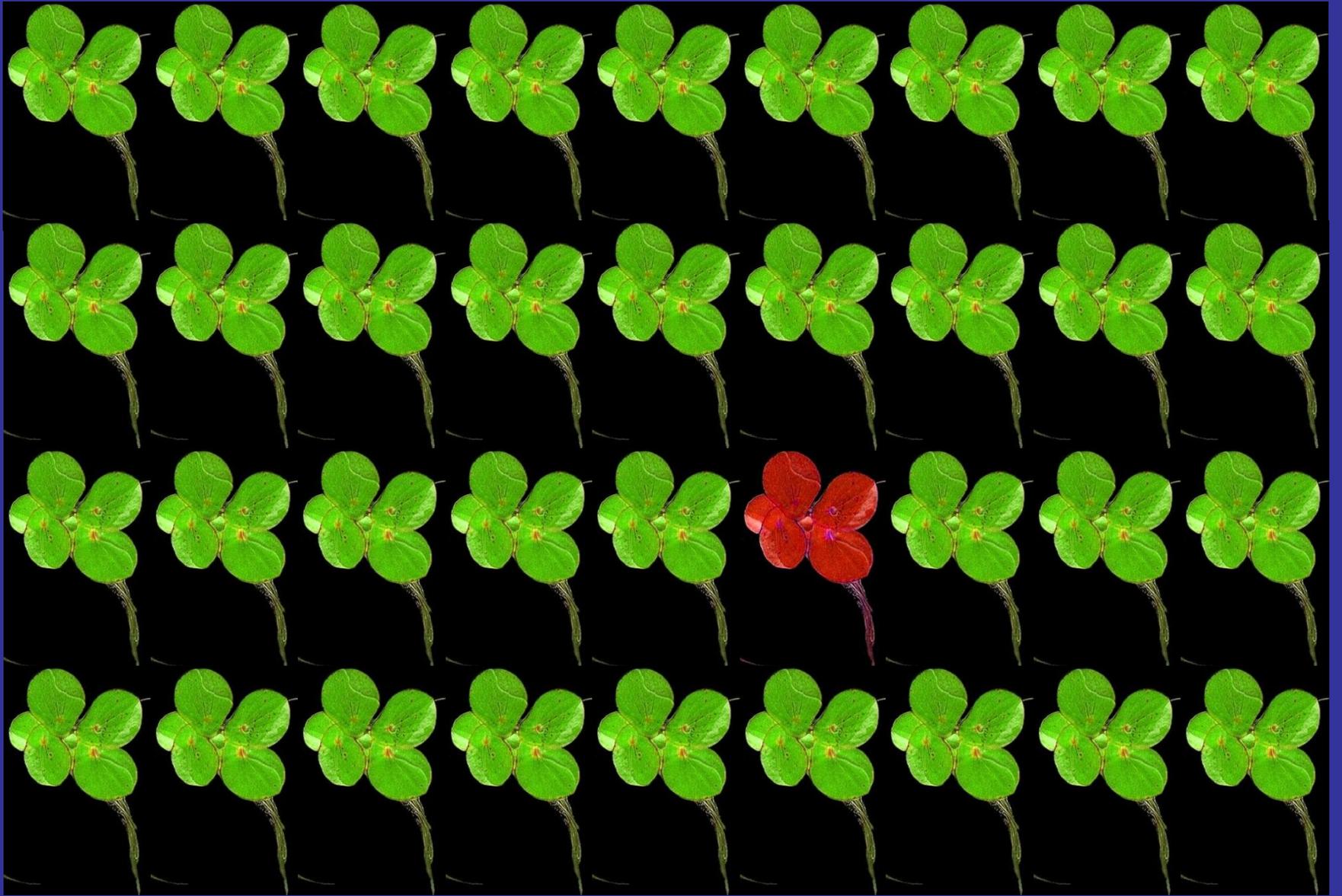
<http://plants.ifas.ufl.edu>

What is herbicide resistance?

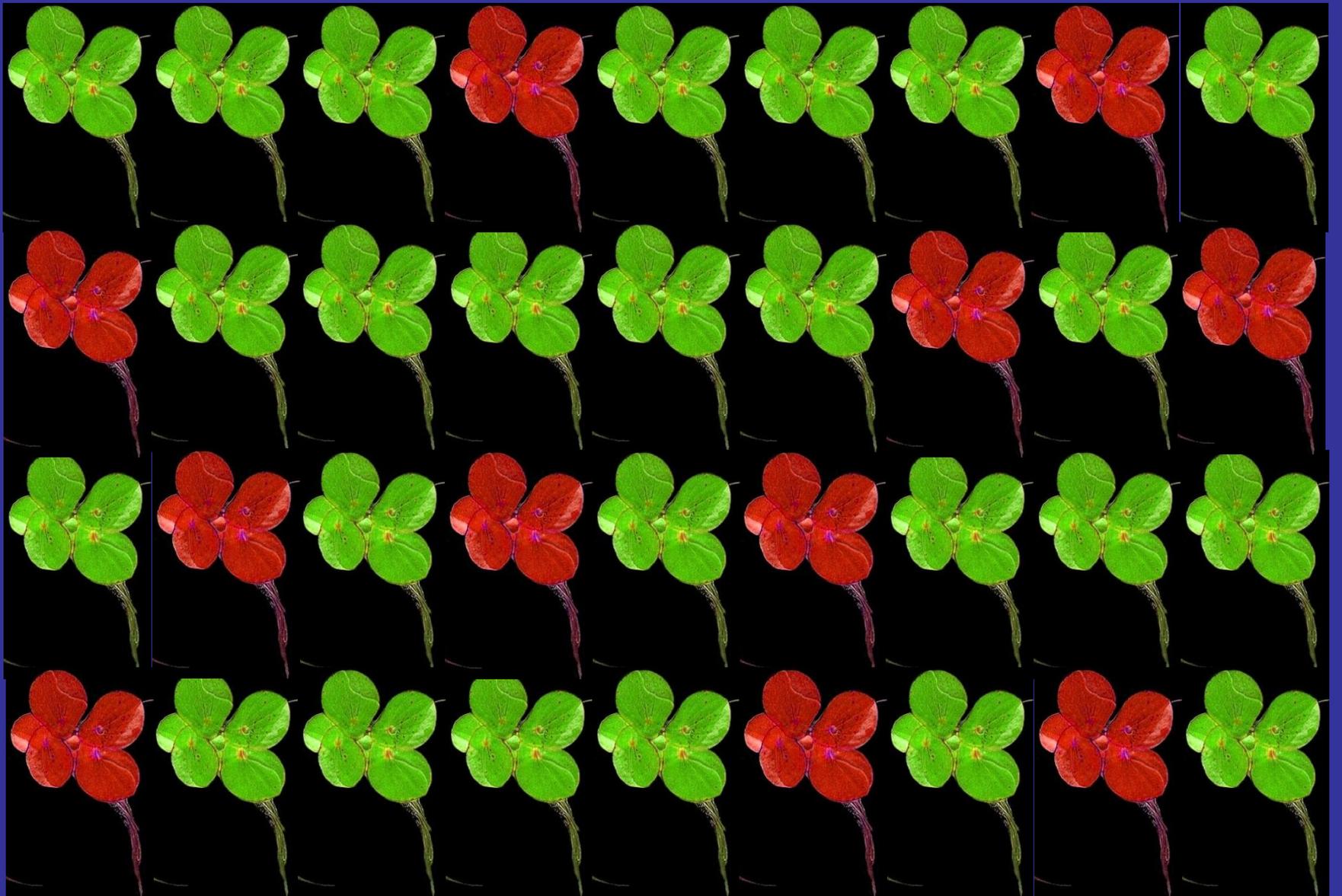
- Not chemical induced genetic change
 - Change in plant populations
- Theory: every plant species has biotypes that are resistant to every herbicide
- Has “that” biotype been sprayed yet?
- Numbers game: depending on the genetic diversity of the species

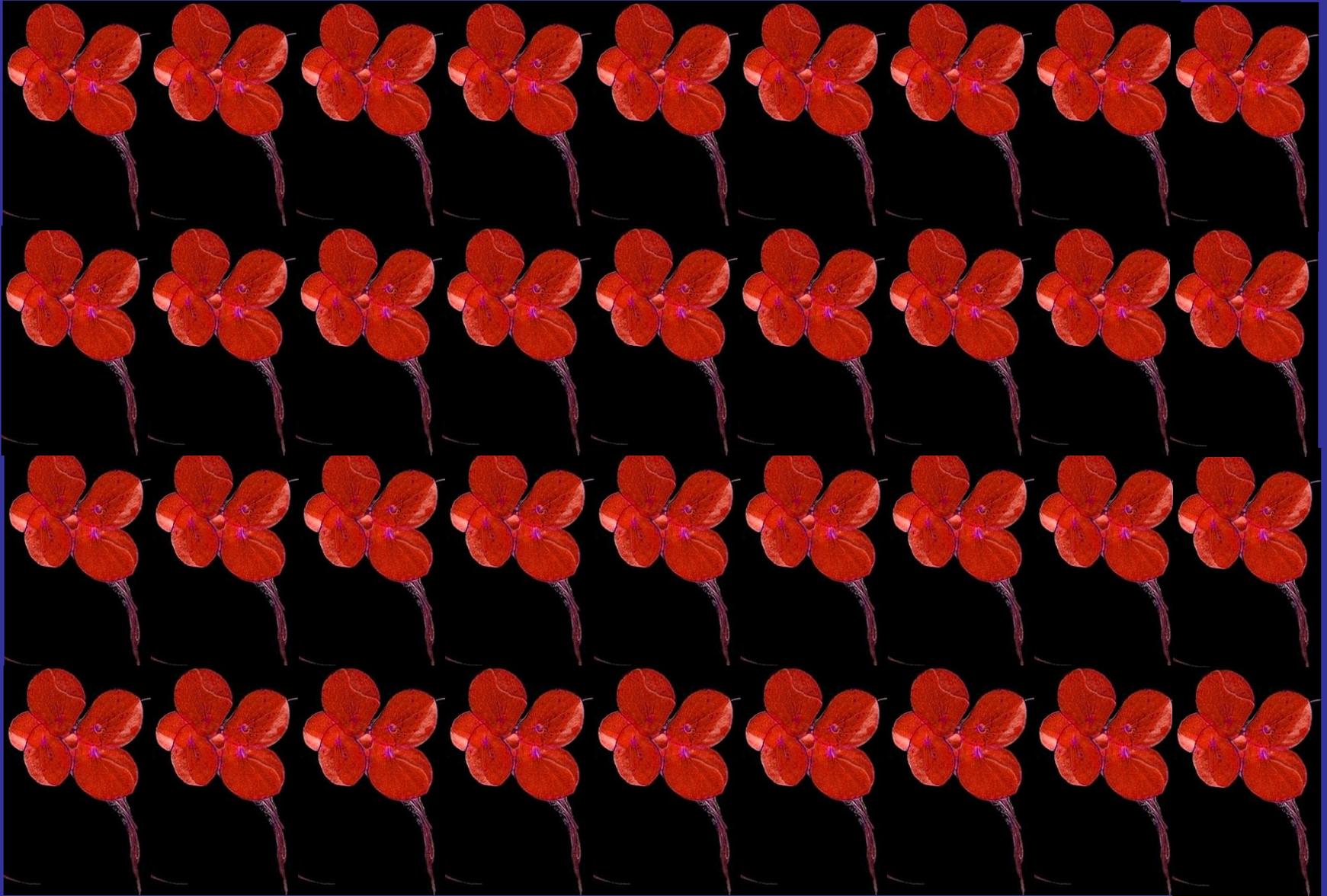
Resistance terminology

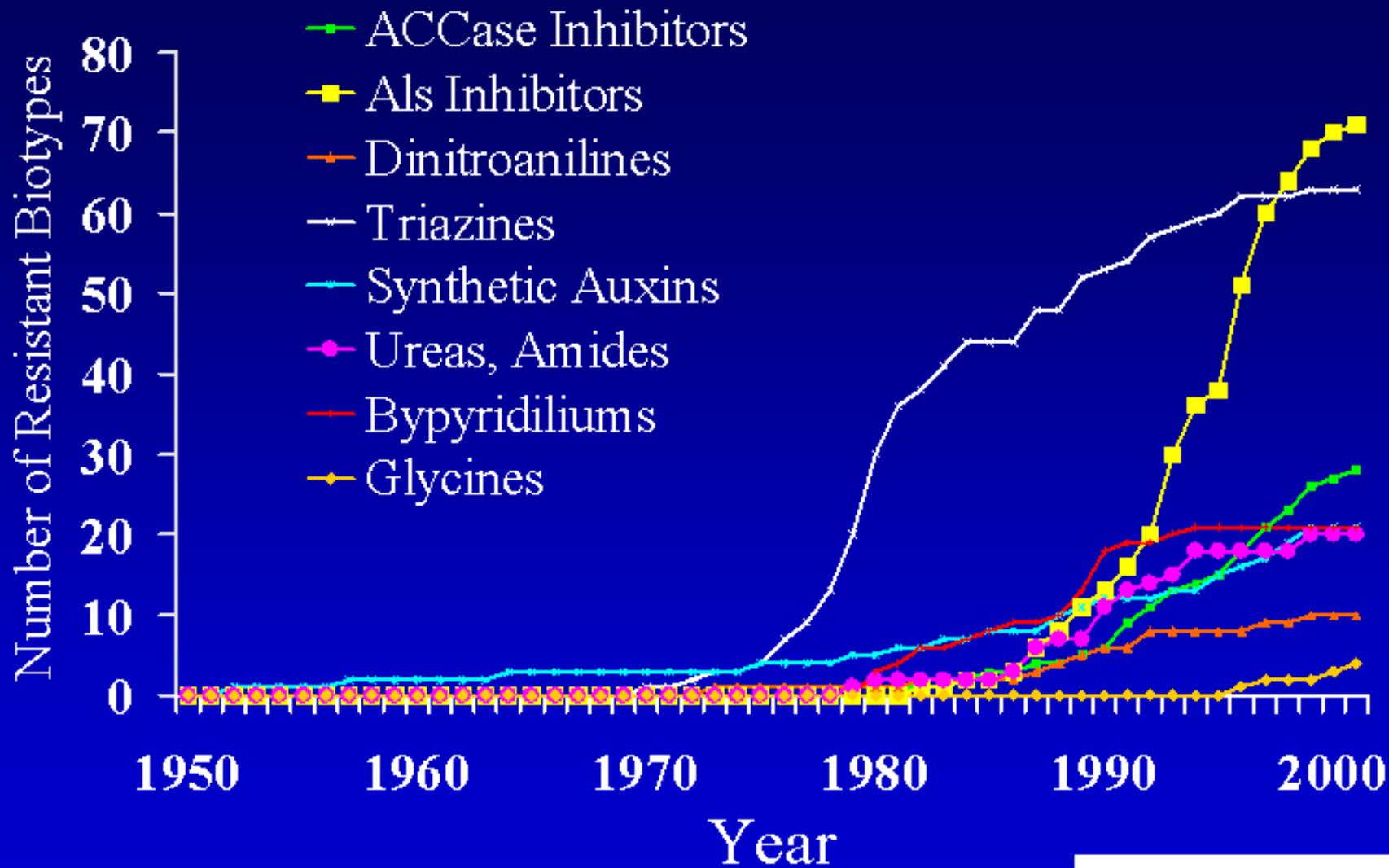
- Susceptible - controlled using normal use-rates
- Tolerant - species never susceptible to herbicide at label use rates
- Resistant - originally susceptible to herbicide; over time control lost through the selection of resistant plants
- Cross resistance - resistant to 2 or more herbicides with similar modes of action
- Multiple resistance - resistant to herbicides with different modes of action











Source: Dr. Ian Heap
www.weedscience.com

Mechanisms of resistance

- Target site – selects for different enzyme or pathway
- Metabolism or detoxification – broken down in plant
- Compartmentalization/reduced transport – shuttled to vacuole or chelated in cell
- Reduced uptake – thicker cuticle

2000

- No resistant weeds to glyphosate
- Glyphosate resistance conferred to corn, soybeans, cotton...
- 60+ million acres of RoundUp Ready corn
- 2010: at least 5 terrestrial weeds resistant to glyphosate

Chance of selecting...

- One herbicide-resistant plant:
- 0.00000001% or 1 in a billion



Quiz time...

- How many duckweed plants per acre?
- 1 duckweed plant = $0.125'' \times 0.06'' = 0.0072 \text{ in}^2$
- $43,560 \text{ ft}^2 \times 144 \text{ in}^2/\text{ft}^2 = 6.3\text{M} \text{ in}^2/\text{acre} \div 0.0072$
= 900 million duckweed plants/acre
- So treating 1 acre of duckweed = treating 1 billion plants

What do farmers do?

- Switch to different herbicides – atrazine, others
- Rotate crops – corn:soybean:corn:wheat
- Aquatics – rotate milfoil:hydrilla:CLP?

What do aquatic applicators do?

- Can't switch weeds...
- Must alter herbicide mode of action
- Tank mix may help but-
- Be vigilant, aware

Resistance in aquatics

- Documented:
 - Fluridone – hydrilla
 - Diquat – landoltia
 - Endothall – hydrilla
- Suspected:
 - Fluridone – lemna, salvinia
 - Diquat – lemna

KEY EVENTS IN THE DEVELOPMENT OF SONAR

	19	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Discovery		█													
Efficacy and use patterns for aquatics				█	█	█	█	█	█	█	█				
Environmental fate			█	█	█	█	█	█	█	█	█				
C ₁₄ Soil metabolism studies				█	█	█	█	█	█	█					
C ₁₄ Nature of residue in plants			█	█	█	█									
Magnitude of residue in plants and irrigated crops					█	█	█	█	█	█	█				
Magnitude of residue in potable water							█	█							
Magnitude of residue in fish, livestock, poultry, milk and eggs						█	█	█	█	█	█	█	█	█	
Avian toxicity						█	█	█	█	█					
Aquatic organism toxicity						█	█	█	█	█					
Acute toxicology			█	█	█	█									
Subchronic toxicology			█	█											
Reproduction/teratology						█	█	█	█						
Mutagenicity							█	█	█						
C ₁₄ Animal metabolism						█	█								
Nontarget organism toxicity						█	█	█	█	█					
Chronics/oncogenicity				█	█	█	█	█	█	█					
Experimental Use Permit (from submission to the end of EUP stage)								█	█	█	█	█	█		
Full EPA registration (from submission to approval)										█	█	█	█	█	

Goal

- Register at least one product in as many MOA's as possible for resistance management

Aquatic herbicides

- Must have fish and water tolerance (\$)
- Crop tolerances if used for irrigation water (\$)
 - 26 crop groupings x 2 plants
- GLP pond/aerobic and anaerobic soil degradation (\$)
- Terrestrial use and patent life

Developing New Aquatic Registrations

- What weeds controlled
- Selective
- Residues in water
- Market
- Patent life
- Current registration
- Registrant cooperation

Great example: imazapyr

- Habitat, Gullwing, Ecomazapyr, Polaris...
- ALS inhibitor
- Broad-spectrum
 - Grasses, broadleaf
 - Not blackberry, legumes
 - Not hydrilla (Galleon, Clearcast, Tradewind)
- Nature made (making!) resistant plants

15 short years ago (1998)

- Copper: algae
- 2,4-D: water hyacinth
- Endothall: submersed
- Diquat: water lettuce
- Fluridone: hydrilla
- Glyphosate: torpedograss

FYI – in perspective...

- Endothall, copper, diquat, 2,4-D – 1950s
- Glyphosate – 1978
- Fluridone – 1985
- Imazapyr – 1999
- Triclopyr – 2002
- Carfentrazone – 2004
- Penoxsulam – 2007
- Imazamox – 2008
- Flumioxazin – 2010
- Bispyribac – 2011
- 3 EUPs – 2011
- 1 EUP - 2012

Box Score

- Full EPA Aquatic registration: Section 3
- 1979-1998: One
- 1999-2011: Seven





Expand lab/greenhouse studies

1. Need EUP (Experimental Use Permit)
 - Florida DACS, US EPA
2. Draft EUP label
 - No water use
 - Acres/pounds AI monitored
3. Need registrant support
 - Submit EUP with data
 - Is it worth their effort?
 - Patent life, irrigation issues, cost of label, market potential, application rate, selectivity



Traffic

More...

Map

Satellite

Earth

200 ft

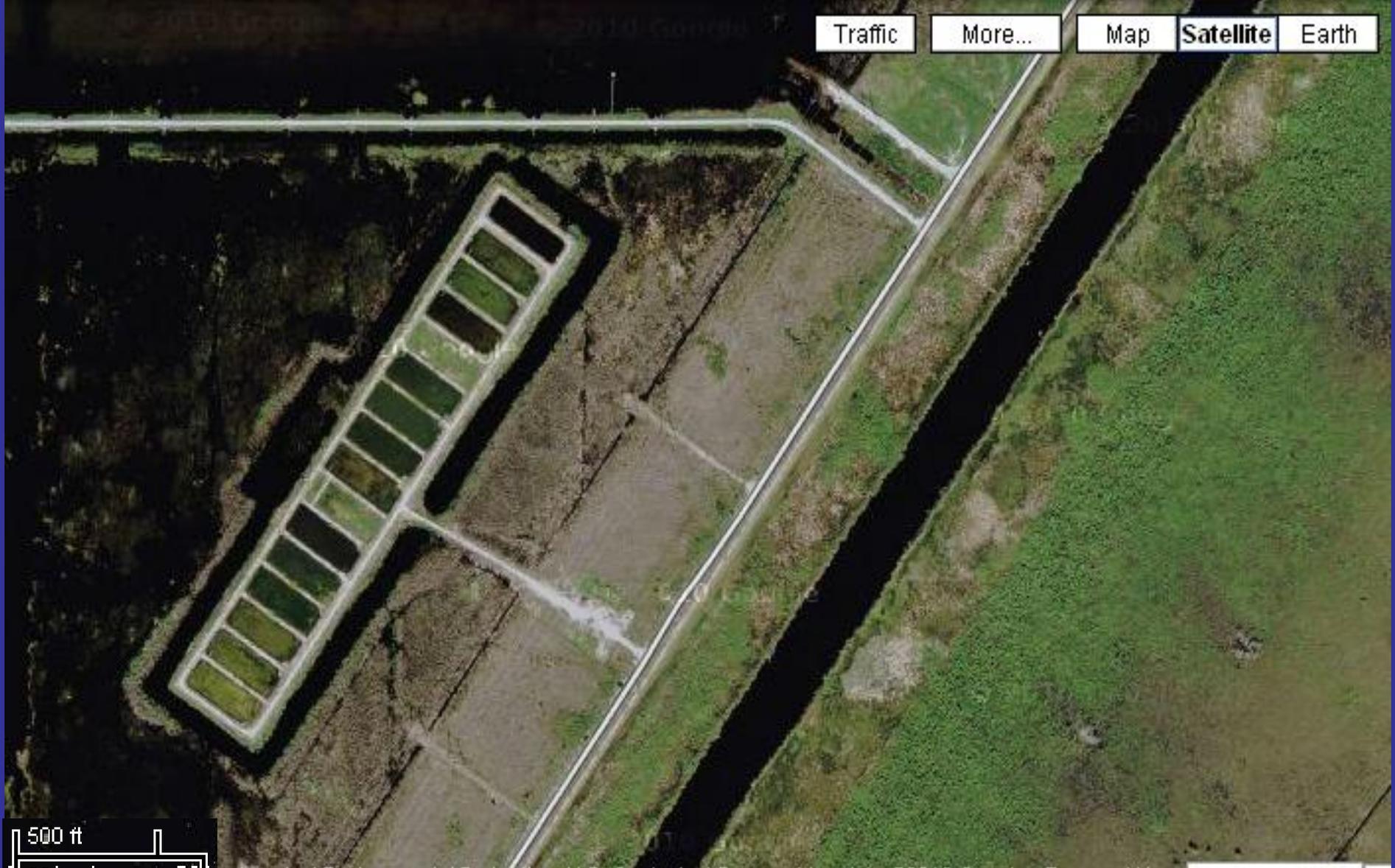
Traffic

More...

Map

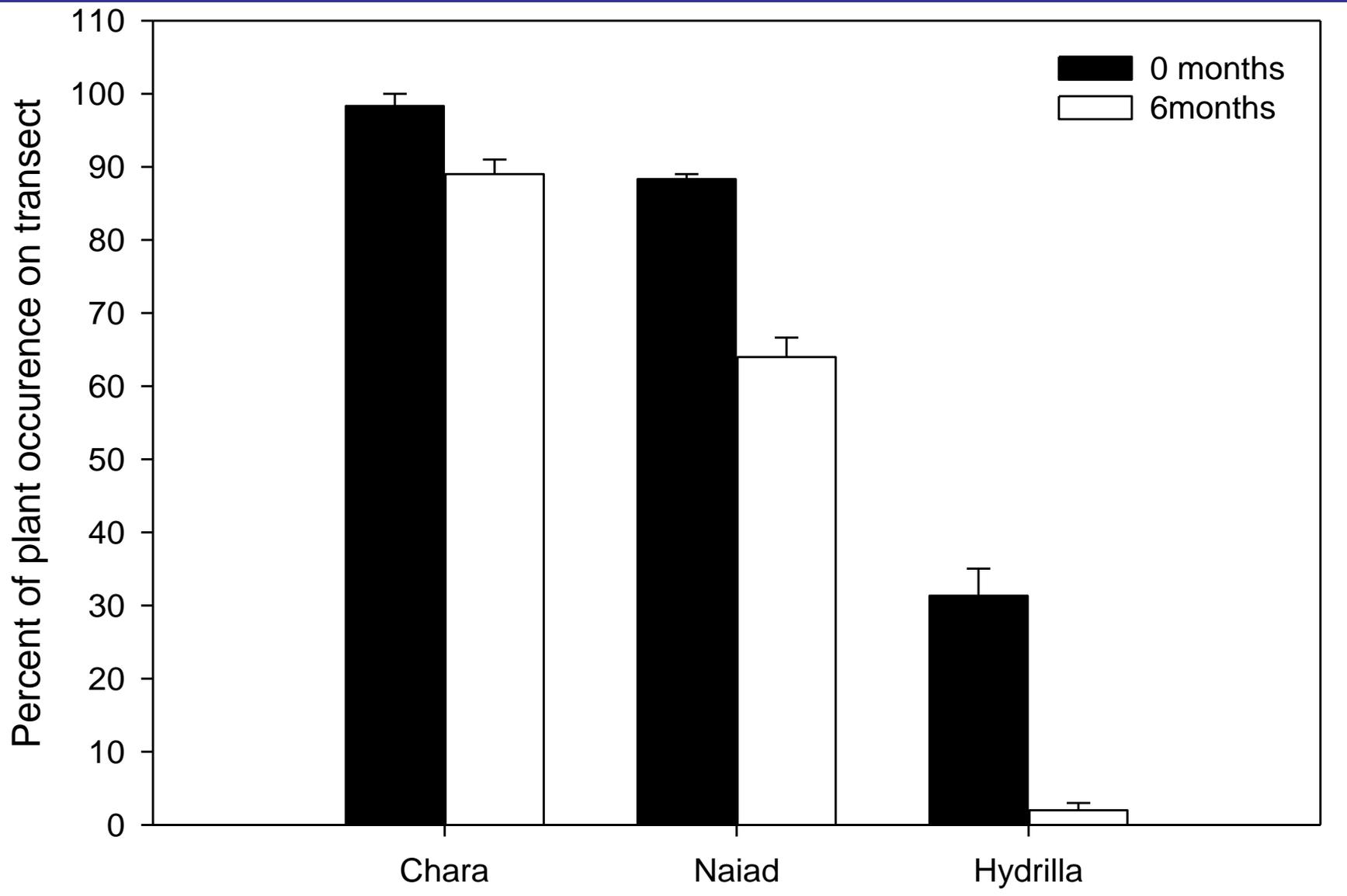
Satellite

Earth





Plant transects: pre and 6 months post



Lessons learned

- Many do not kill hydrilla
- Not unlimited supply
- 15+ years since last MOA
- Being effective is not a guarantee
- BUT tremendous progress!

You can prevent resistance

- Copper UNC
- 2,4-D AUX
- Endothall UNC
- Diquat PSI
- Fluridone CAR
- Glyphosate EPS

Seven registrations 1999-2011

- Section 3

- Imazapyr: 2001 ALS*
- Triclopyr: 2002 AUX
- Carfentrazone: 2004 PPO*
- Penoxsulam: 2007 ALS*
- Imazamox: 2008 ALS*
- Flumioxazin: 2010 PPO*
- Bispyribac: 2011 ALS*

* New MOA

You can prevent resistance

- Hyacinths
 - 2 AUX (2,4-D, triclopyr)
 - 4 ALS (imazamox, imazapyr, penoxsulam, bispyribac)
 - 1 PSI (diquat)
 - 2 PPO (flumioxazin, carfentrazone)
 - 1 EPS (glyphosate)

You can prevent resistance

Duckweed

- 1 PS1 (diquat)
- 1 UNC (copper)
- 1 PPO (flumioxazin)
- 2 ALS (bispyribac, penoxsulam, imazamox?)
- 1 CAR (fluridone)*

* Susceptible duckweed

You can prevent resistance

- Water lettuce
 - 4 ALS (imazamox, imazapyr, penoxsulam, bispyribac)
 - 1 PSI (diquat)
 - 1 PPO (flumioxazin)
 - 1 EPS (glyphosate)

You can prevent resistance

- Hydrilla
 - 3 ALS (imazamox, penoxsulam, bispyribac)
 - 1 PSI (diquat)
 - 1 PPO (flumioxazin)
 - 2 UNC (endothall, copper)
 - 1 CAR (fluridone)*

*Susceptible hydrilla

Trouble?!?

- Torpedograss
 - 1 EPS (glyphosate)
 - 1 ALS (imazapyr)

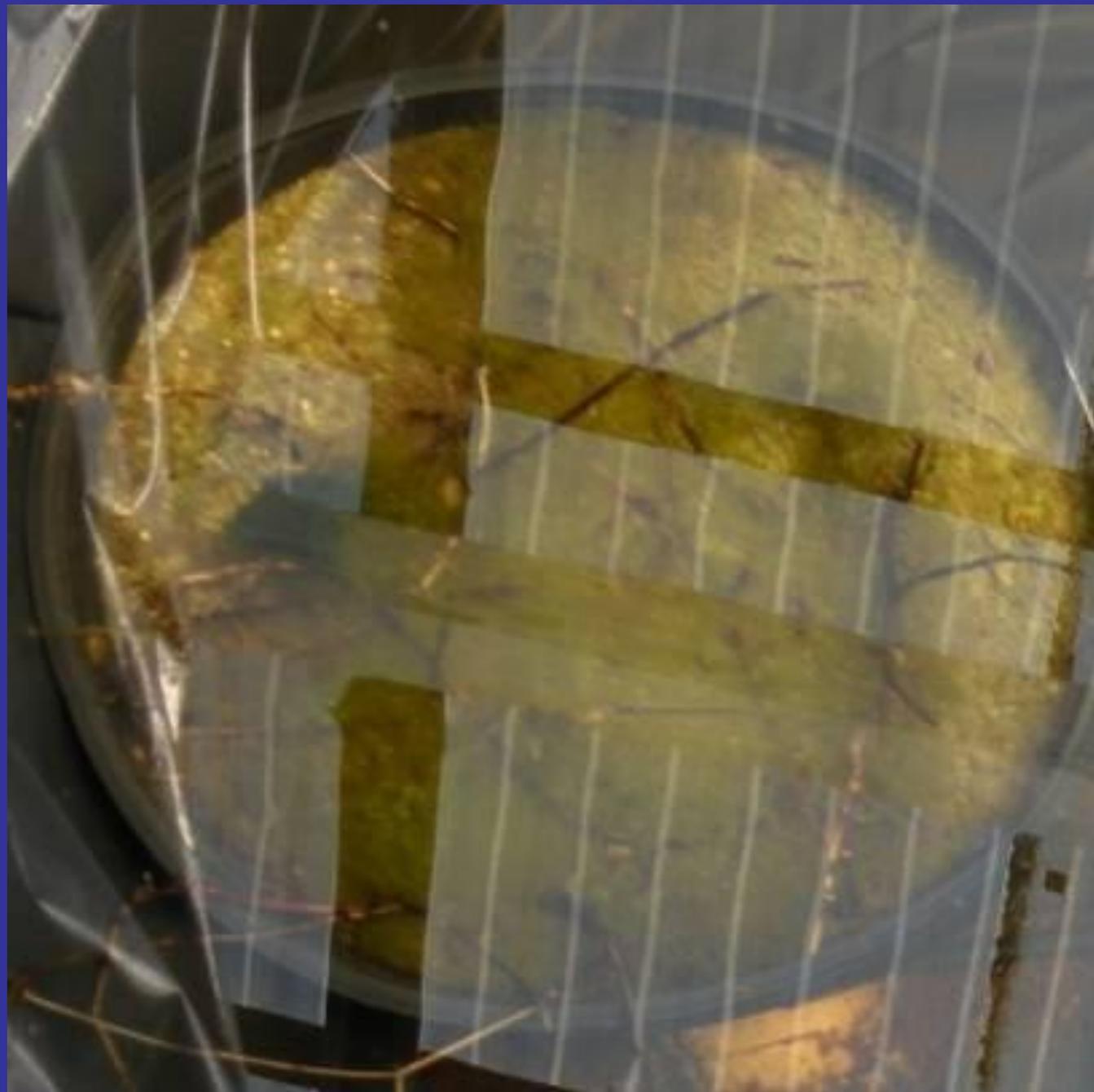


Trouble?!?

- Hygrophila
 - 1 PPO (flumioxazin)
 - 1 UNC (endothall)







Treated July 23, 2010



Clipper: 2 acres @ 8 oz/acre

3 weeks after treatment – August 15, 2010



Trouble?!?

Cabomba

- 1 PPO (flumioxazin)
- 1 UNC (endothall)

Watermeal

- 1 PPO (flumioxazin)
- 1 PS1 (diquat)
- 1CAR (fluridone)
- ALS?

Others

- Floatingheart?
- Rotala?

All applicator responsibilities

- Manage for resistance
- Alternate modes of action*
- Tank mix alternate modes of action (why?)

* Thinking ahead

“RESISTANCE IS REAL”

New responsibilities

- Read labels for fit
- Purchase product
- Try at maximum rates
- Record, monitor performance
- Report successes, failures

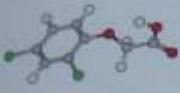
“RESISTANCE STEALS YOUR TOOLS”

HERBICIDE HANDBOOK

Weed Science Society of America
Ninth Edition, 2007

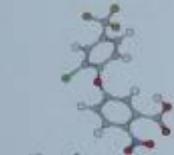
Q = 357

Topical = 241
Dose = 186

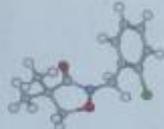


2,4-D

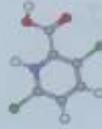
Bispheno = 53



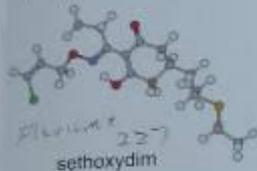
acifluorfen



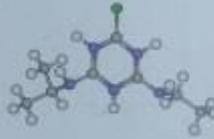
clomazone



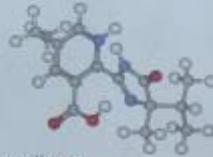
clopyralid



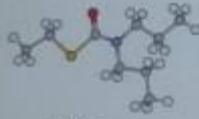
sethoxydim



atrazine



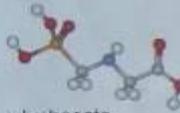
imazethapyr



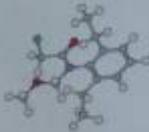
EPTC



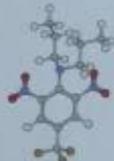
paraquat



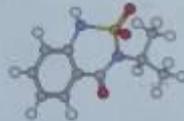
glyphosate



alachlor



trifluralin

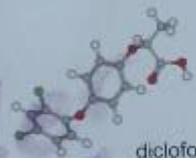


bentazon

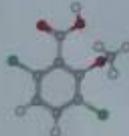


chlorsulfuron

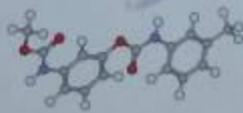
Handwritten note: *Handwritten text, possibly 'Halle' or similar, with a diagonal line through it.*



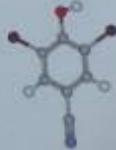
diclofop



dicamba



phenmedipham



bromoxynil

NC

Not Classified

acrolein.....	382
AMS.....	384
benazolin.....	385
benoxacor.....	387
cacodylic acid.....	388
cloquintocet-mexyl.....	390
copper chelate.....	391
copper sulfate.....	393
dichlorimid.....	395
dietholate.....	397
dimethipin.....	398
endothall.....	399
fenchlorazole-ethyl.....	401
fenclorim.....	402
fluxofenim.....	403
maleic hydrazide.....	405
mefenpyr-diethyl.....	407
mefluidide.....	408
metaborate.....	410
oxazicloromefene.....	411
sodium chlorate.....	412

222

flumioxazin

2-[7-Ethoxy-3,4-dihydro-2-oxo-4-(2-oxoethyl)-2H-1,4-benzoxazin-6-yl]-4,5,6,7-tetrahydro-1H-benzothiazol-1,3,5-triazole

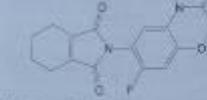
NOMENCLATURE

Common name: flumioxazin (ANSI, ISO, WSSA)
Other names: V-03482, S-33482 (code names), flumoxi

Trade name(s): SLMISOLA, VALOH[®]
Chemical family: carbonylurea, 7H-pyrimidinol

CHEMICAL AND PHYSICAL PROPERTIES

Chemical structure: flumioxazin



Molecular formula: C₂₁H₂₄N₄O₅
Molecular weight: 394.44 g/mol
Description: Yellow-brown, odorless
Density: 1.51 g/mL (20°C)
Melting point: 203.2 - 203.8°C
Boiling point: NA
Vapor pressure: 3.21 x 10⁻⁴ Pa
Stability: Stable at room temperature
Solubility: In water: 1.79 mg/L (25°C)
pK_a: None (non-ionizable)
K_{ow}: log K_{ow} = 2.55 (20°C)

HERBICIDAL USE

Flumioxazin is used preemergence for broadleaf weed control in soybeans and peanuts. In soybean production programs, flumioxazin controls problem broadleaf weeds such as common ragweed, common lambsquarters, wild radish, pigweed, black nightshade, set and common waterhemp, and prickly sida. Flumioxazin is

CAS #: 102361-09-3

EM

USE PRECAUTIONS

Fire hazard: Toxic and flammable substances are non-flammable and non-explosive.

Compatibility: Formulated products are not compatible with containers.

Storage stability: Good stability. Store in cool, dry place and avoid excess heat. Store in original containers only. Keep out of reach of children and animals. Do not contaminate water, food or feed by storage or disposal.

Cleaning glassware/spray equipment: Clean glassware and equipment with a solution of soap and water. Avoid contamination of water by cleaning equipment or disposal of wastes. Large spills should be covered to prevent dispersal.

Emergency exposure: If ingested, drink 1-2 glasses of water. Do not induce vomiting or give anything by mouth to an unconscious individual. Contact a medical doctor. If inhaled, remove to fresh air. If breathing discomfort occurs, contact medical doctor. For skin and eye exposure wash with plenty of soap and water or flush with water for at least 15 min. A irritation occurs or persists get medical attention.

Incompatibilities: Flumioxazin has been found to be physically compatible with most commonly available herbicides.

BEHAVIOR IN PLANTS

Mechanism of action: Inhibition of the enzyme protoporphyrinogen oxidase (PPO or PPOx) (see details on page 17).

Symptomatology: Plants emerging from soil treated with the herbicide flumioxazin become necrotic and die shortly after exposure to sunlight. Foliar contact with flumioxazin causes rapid desiccation and necrosis of exposed plant tissues.

Absorption/translocation: Flumioxazin is taken up by the roots and foliage of treated plants. Root and soil placement studies indicate that flumioxazin is absorbed primarily by the roots of treated plants.

Questions?



Thank you!