Herbicide Resistance = Why We Need New Herbicides

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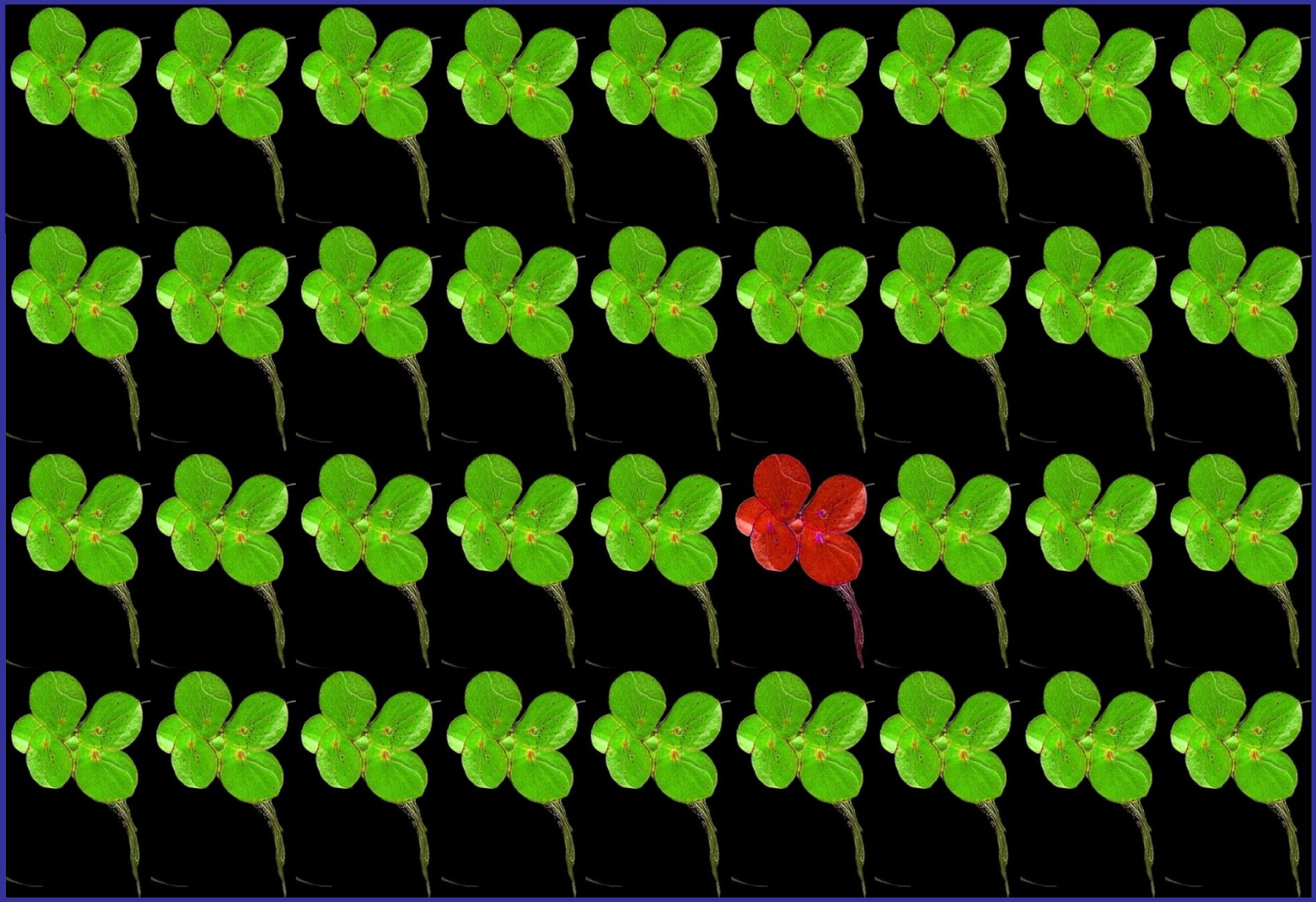
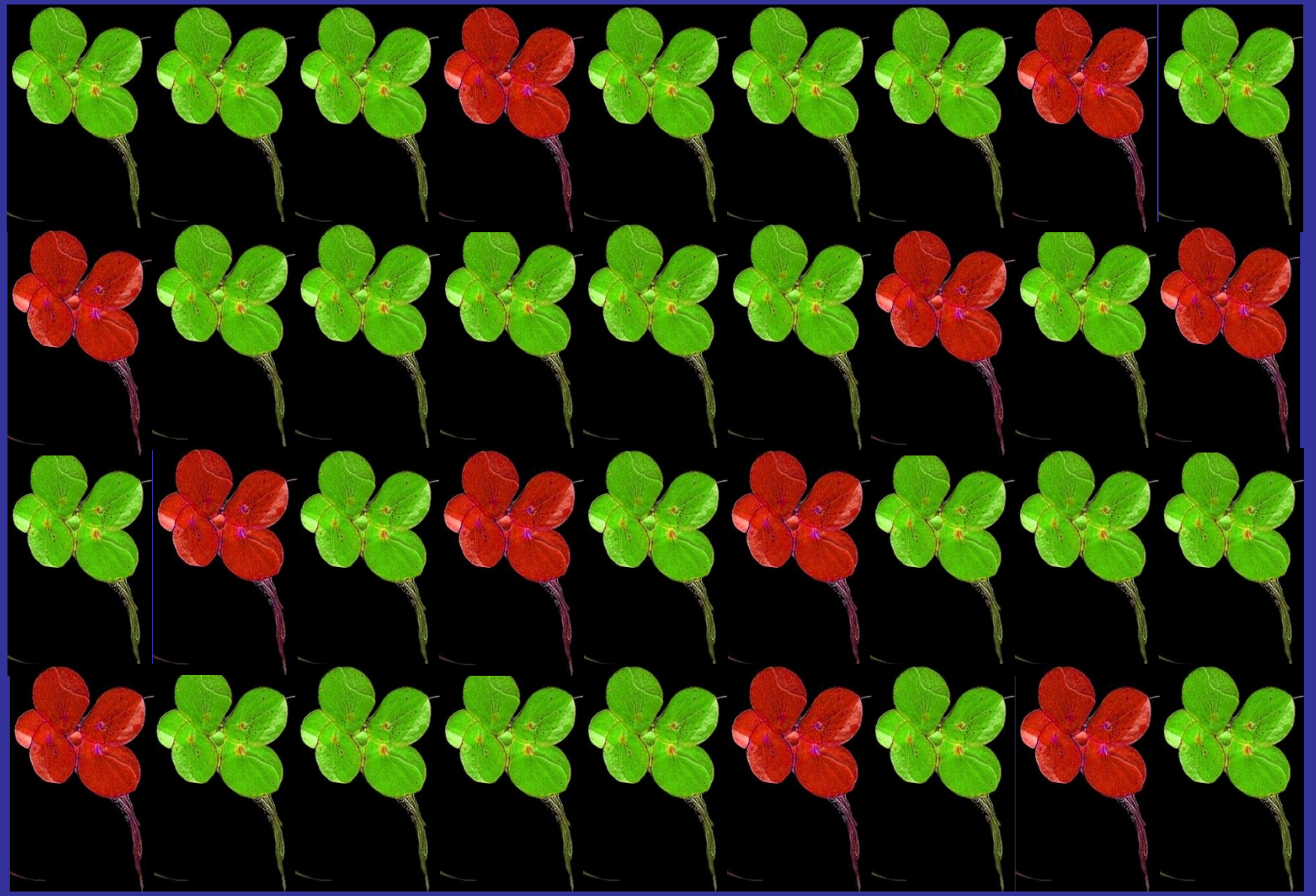
What is herbicide resistance?

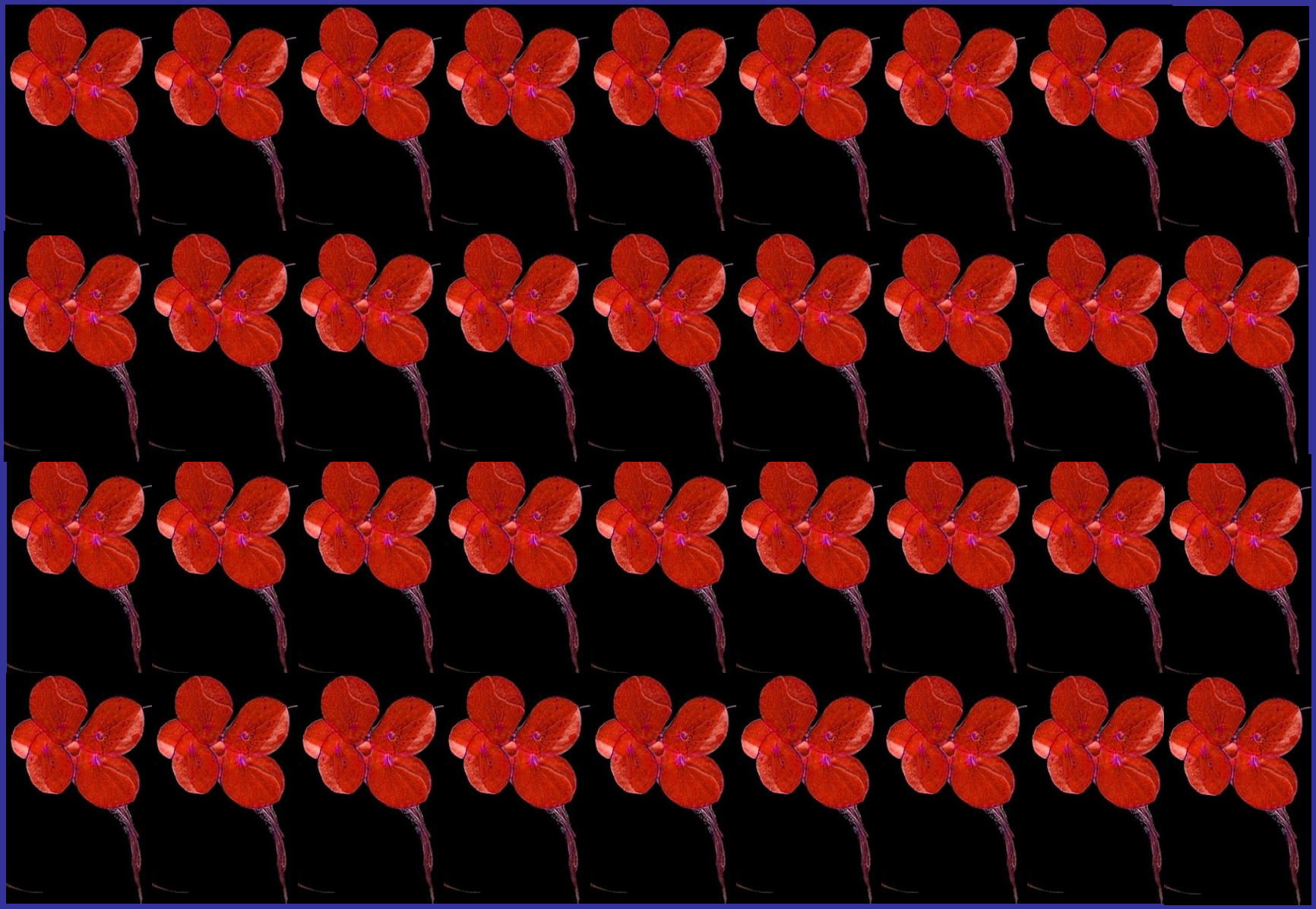
- Not chemical induced genetic change
  - Change in plant populations
- Theory: every plant species has biotypes that are resistant to every herbicide
- Has “that” biotype been sprayed yet?
- Numbers game: depending on the genetic diversity of the species

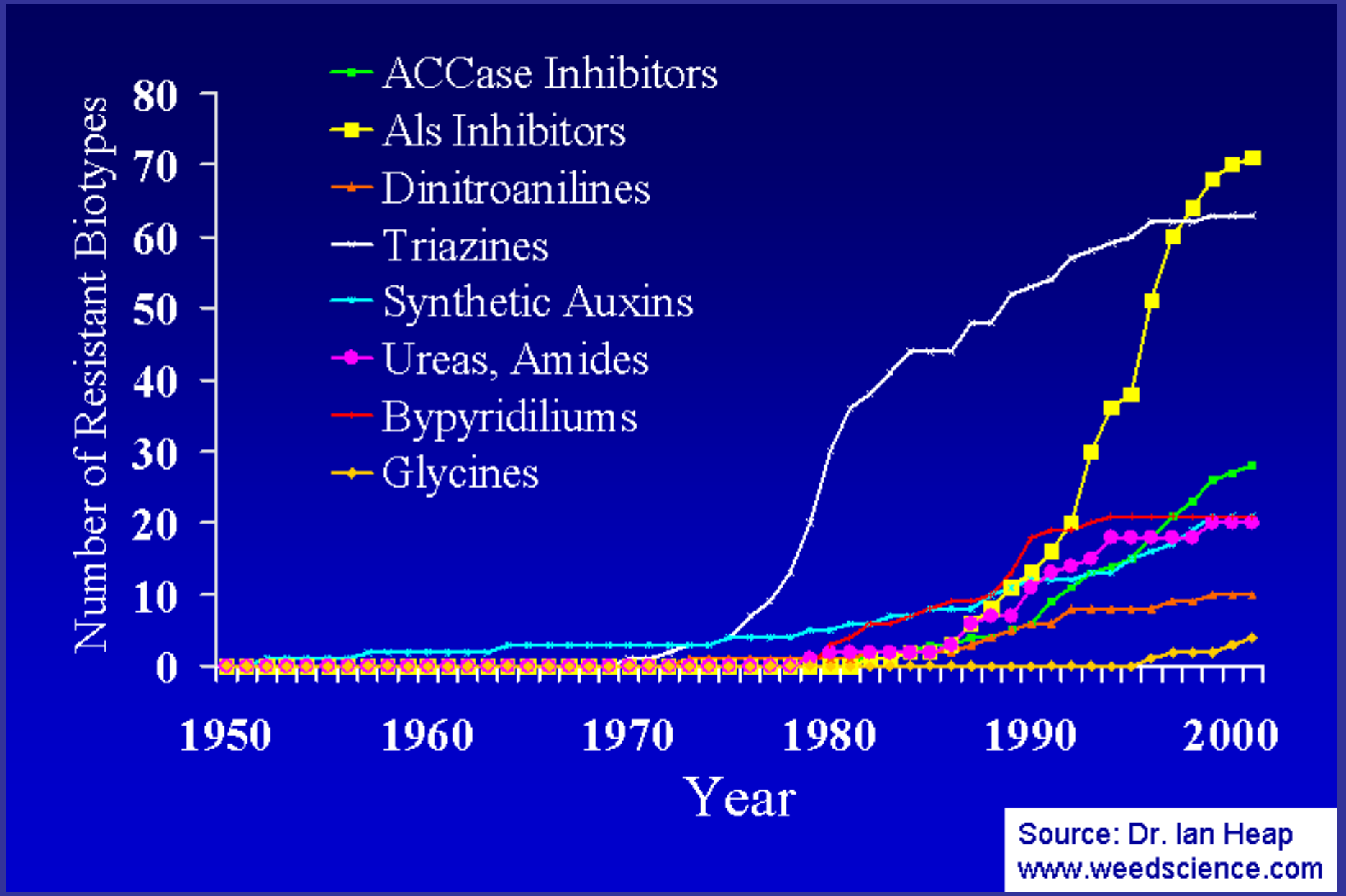
Resistance terminology

- 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








ACCase Inhibitors
Als Inhibitors
Dinitroanilines
Triazines
Synthetic Auxins
Ureas, Amides
Bypyridiliums
Glycines
Number of Resistant Biotypes
0
10
20
30
40
50
60
70
80
1950
1960
1970
1980
1990
2000
Year
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” x 0.06” = 0.0072 in^2
- 43,560 ft^2 x 144 in^2/ft^2 = 6.3M in^2/acre ÷ 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?

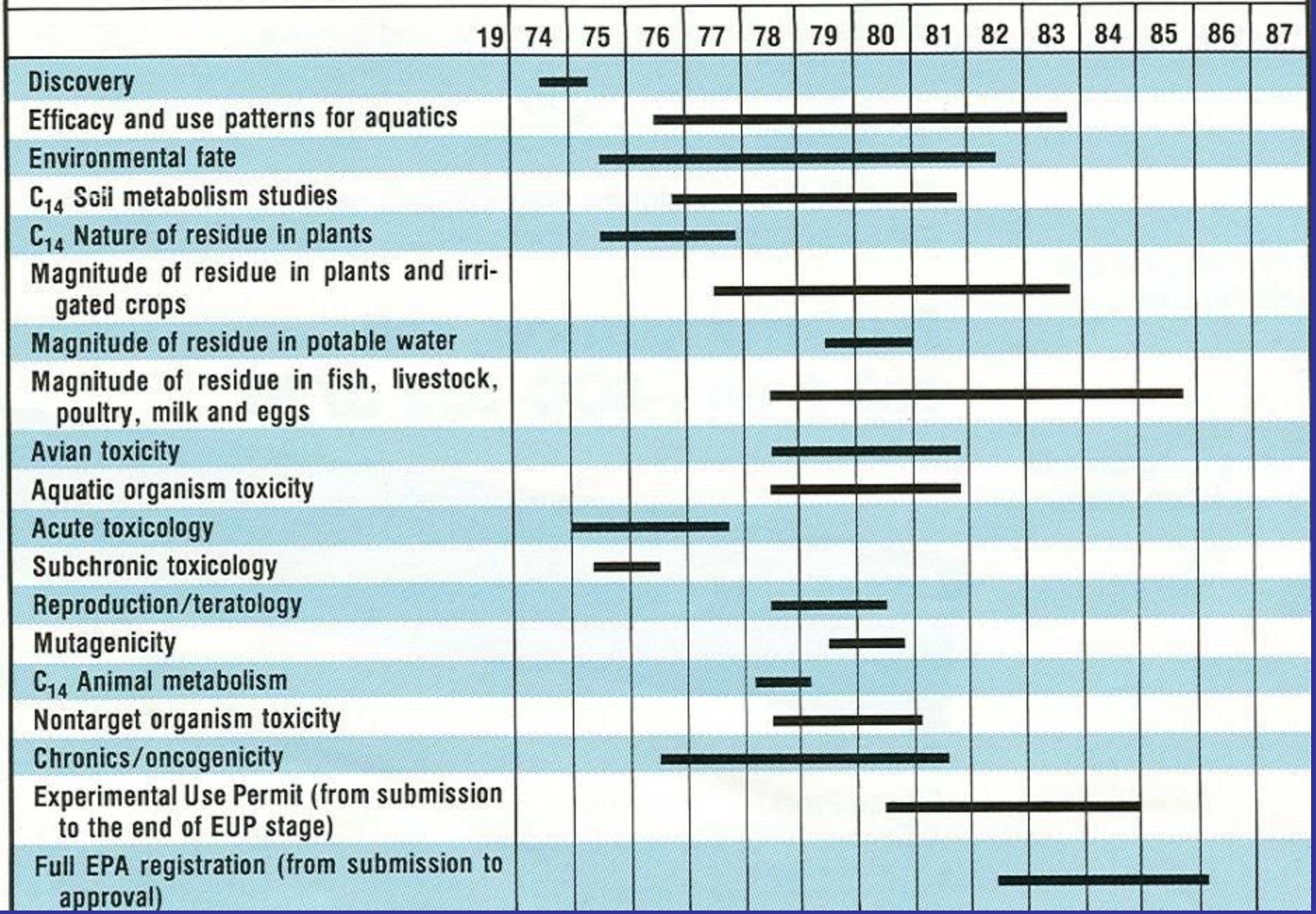
What do aquatic applicators do?

- 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



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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More...
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Earth
200 ft
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Traffic
More...
Map
Satellite
Earth
500 ft
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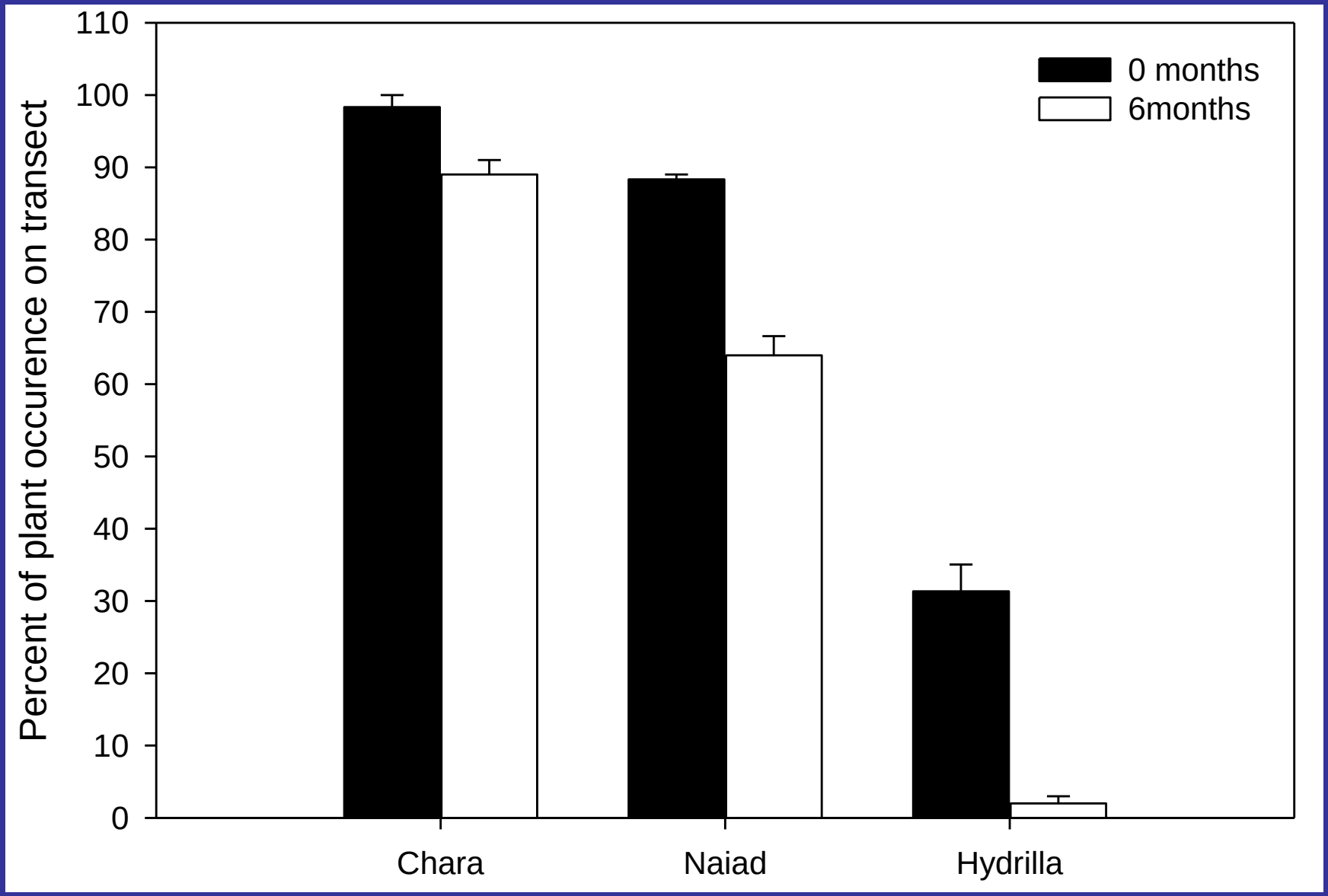
Plant transects: pre and 6 months post



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?)

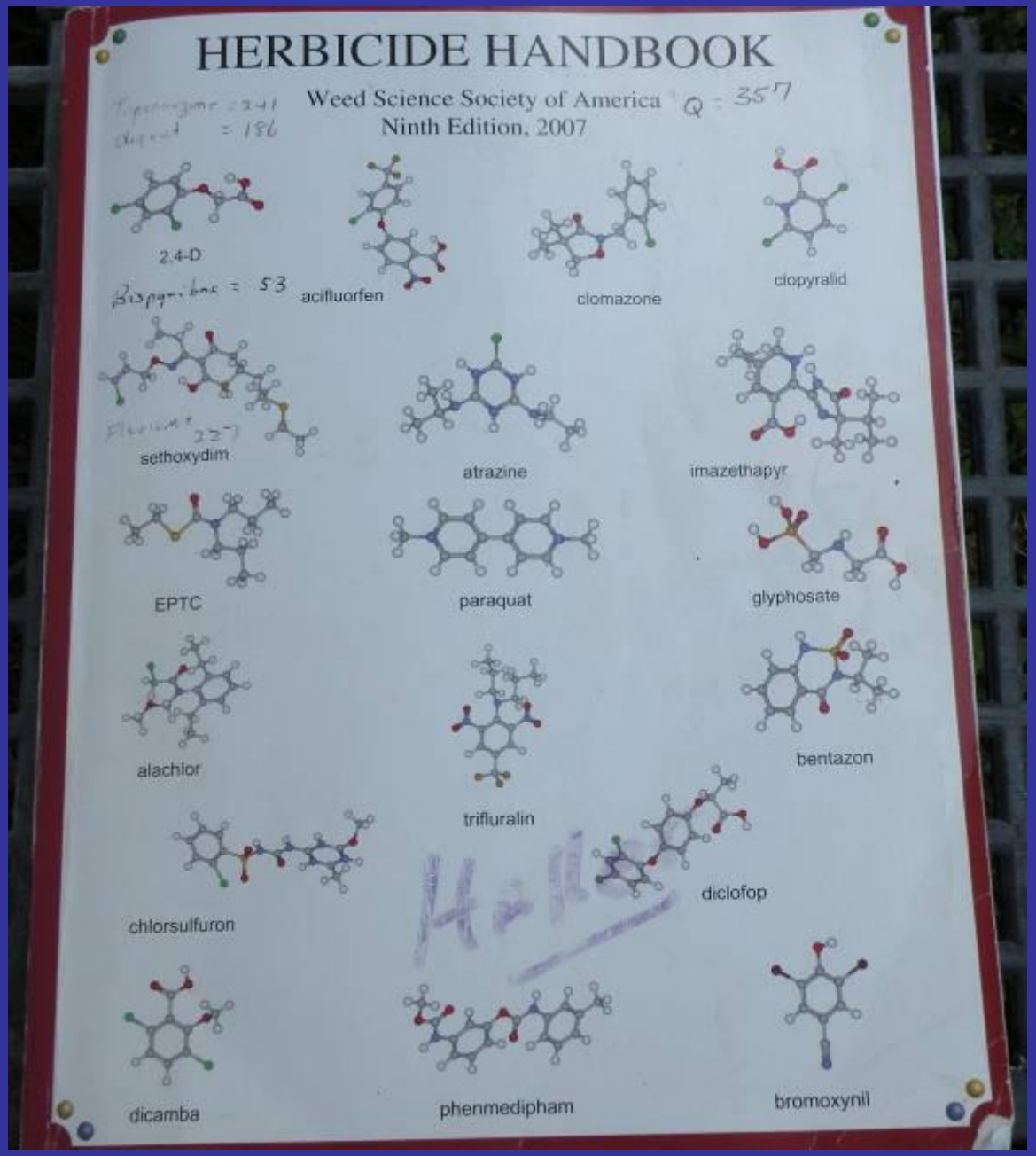
* Thinking ahead

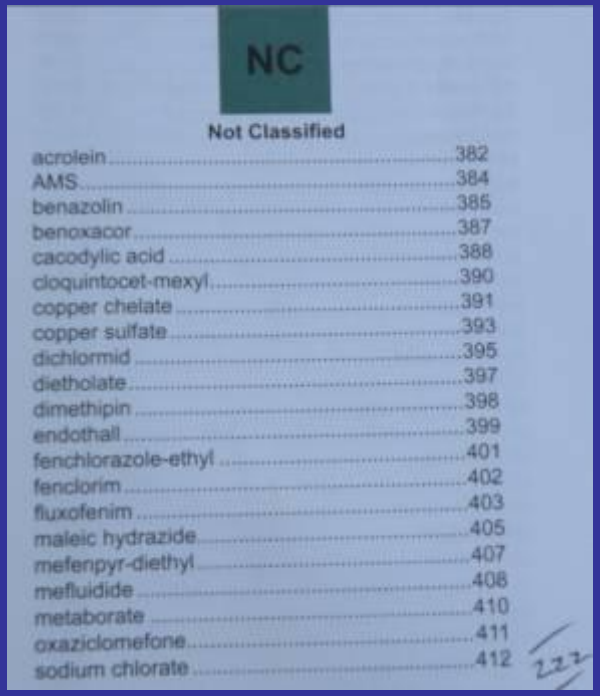
“RESISTANCE IS REAL”

New responsibilities

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

“RESISTANCE STEALS YOUR TOOLS”

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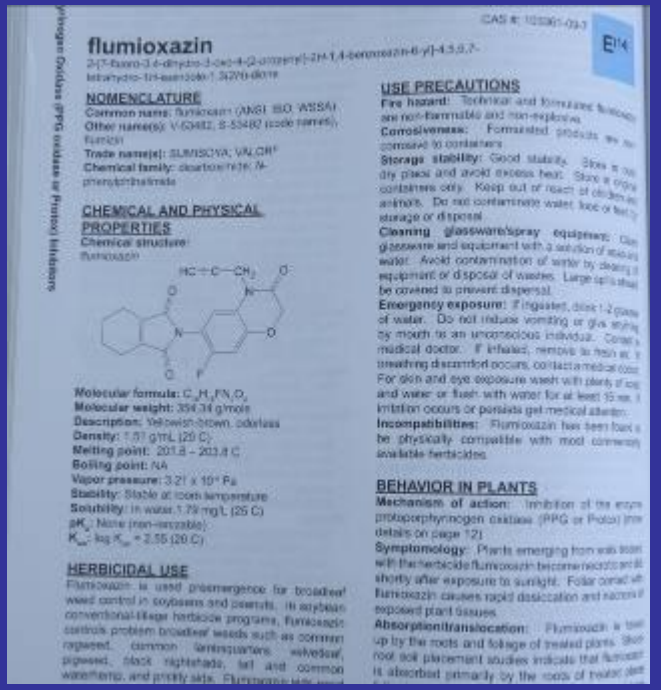
flumioxazin

E14

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Questions?