How Herbicides Work

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Herbicides - 101

- **Herbicide** means ‘plant’ and ‘kill’

- Plants have unique systems completely different from animals – like photosynthesis for example

- Herbicides target processes that only occur in plants and since animals and people don’t have these systems, we are generally not affected
How Do Plants Grow?

- It's all about carbon dioxide - CO₂
- Water flow
- Sugar movement
- Nutrient uptake
- Gas exchange - oxygen

Figure 24. Photosynthesis, respiration, leaf water exchange, and translocation of sugar (photosynthate) in a plant.
Terrestrial vs. Aquatic

- Water movement is critical for many herbicides
- Dramatically changed when herbicides are placed in the aquatic environment

Figure 24. Photosynthesis, respiration, leaf water exchange, and translocation of sugar (photosynthate) in a plant.
What Do Herbicides Do?

- Controlled/selective plant poisoning
  - applied to soil (root uptake), water, and/or leaves (foliar uptake)
  - contact or systemic
  - selective vs. non-selective
How Do Herbicides Work?

- Mode and/or mechanism of action
- Specific *plant process* is targeted
  - photosynthesis
  - enzymes
  - growth, hormonal balance
  - unknown?
Mechanisms of Tolerance

Herbicide X not absorbed

Sequestered in vacuole

X does not bind to enzyme Y

X metabolized to Z
**Mechanisms of Resistance**

Herbicide X is not absorbed.

X does not bind to enzyme Y.

X is metabolized to Z.

Sequestered in vacuole.
How Do Herbicides Go Away?

- In the water, herbicides breakdown by sunlight, hydrolysis and microbes
- In soil, herbicides breakdown by above processes but mainly microbes
- In plants, herbicides are degraded several ways
  - Phase I - initial reactions such as oxidation, reduction or hydrolysis
  - Phase II - primary conjugation with endogenous substrates such as sugars, amino acids, or glutathione
  - Phase III - secondary conjugation, formation of insoluble residues or sequestration in the vacuole
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2,4-D, triclopyr, aminopyralid, chlorpyralid, aminocyclopyrachlor

- Absorbed by foliage or underwater tissues
- Moves to areas of new growth
- Causes a disruption in hormone levels
  - Acts like a growth stimulant in some plant tissues and a growth retardant in others
  - Vascular tissue becomes crushed, stops movement of essential nutrients and sugars
- Plant essentially grows itself to death

Growth regulators
Terrestrial Plants

- Readily taken up by foliage, and also by roots
- Soil active and persistent, but generally broken down by soil microbes within 2-6 weeks after application
- Aminopyralid and aminocyclopyrachlor effective at much lower use rates than other growth regulators
Growth Regulator Symptoms

- Twisting
- Discoloration in terminal bud
- Leaves may show strapping or puckering effect
2,4-D & Triclopyr
Diquat

- Absorbed by foliage or underwater tissues
- Does not move within the plant – contact
- Disrupts photosynthesis by stealing electrons
- These electrons are then passed on to oxygen, creating toxic radicals
- Radicals cause the cell membrane to leak
Diquat

- Chemically a very strong cation with a positive (+ charge)
- Rapidly degraded in water, generally within hours after application
  - Absorbed by foliage or underwater tissues
  - Absorbed to particles such as clay, flocculants
- Irreversibly bound to soil particles, no soil activity
Diquat Symptoms

- Browning of leaf tissues
- Rapid, within 1-2 days
Diquat
Endothall

- Absorbed by foliage or underwater tissues
- Does not move within the plant – contact
- Appears to act directly on the cell membrane but how is unknown
- The cell membranes become leaky and cell contents spill out
- Without membranes cells cannot make energy
Endothall

- Rapidly degraded by microbes in water, within days to 1-2 weeks
- Slower breakdown in cooler water temperatures
- Hydrothol formulation a little more persistent than Aquathol
Endothall
Fluridone

- Absorbed only by underwater tissues
- Does not move within the plant, but not contact – takes weeks for control
- Prevents the formation of carotenoids which are chlorophyll protecting pigments
- Unprotected chlorophyll photo-oxidizes (self-destructs), leading to plant starvation
Fluridone

- Persistent in water and soil, especially in hydrosoil
- Depending on rate, symptoms can persist for months
- Slowly degraded by microbes
Fluridone Symptoms

- Bleached, white tissue
- Sometimes pinkish
- Symptoms can persist for weeks
Fluridone
Glyphosate

- Absorbed by foliar tissues only
- Moves to areas of new growth
- Prevents the formation of essential aromatic amino acids in plants
- Without these essential amino acids, the plant cannot make proteins, enzymes, etc.
- Plant cannot continue growing and eventually starves and dies
Glyphosate

- Little to no persistence due to irreversible binding to soil and ions in water
- No activity in soil
- No activity in water
- After binding, slowly degraded by microbes
Glyphosate Injury

- yellowing
- massive budding
Glyphosate
Imazapyr, Imazamox, Imazapic, Penoxulam, Bispyribac, Metsulfuron, Chlorsulfuron

- Absorbed by foliar tissues only
- Moves to areas of new growth
- Prevents the formation of essential branched chain amino acids in plants - ALS
- Without these essential amino acids, the plant cannot make proteins, enzymes, etc.
- Plant cannot continue growing and eventually starves and dies
Imazapyr, Imazamox, Imazapic, Penoxulam, Bispyribac, Metsulfuron, Chlorsulfuron

- Highly variable in persistence
  - Some ALS herbicides last for months in soil
  - Some ALS herbicides are degraded in a few days
- ALS herbicides in aquatics – degraded over a period of weeks
- Degradation occurs through microbes
ALS Injury Symptoms

- Stunted, yellow to purple discoloration
- New growth most affected
ALS herbicides in Water

- Imazapyr, Imazamox, Penoxulam, Bispyribac
Copper

- Absorbed by foliage or underwater tissues
- Does not move within the plant – contact
- Appears to act on cell membranes or photosynthesis but how is unknown
- The cell membranes become leaky, cell contents spill out
- Without membranes the cells cannot make energy
- Synergy with other herbicides – diquat
- Strong cation – bound to soil and particles
Copper
Carfentrazone & Flumioxazin

- Absorbed by foliar tissues only
- Does not move within the plant – contact
- Causes the formation of a light absorbing chlorophyll precursor outside the chloroplast
- This compound absorbs energy from sunlight, but cannot pass through the Z-scheme
- The energy is passed on to oxygen, creating radical oxygen and eventual cell membrane disruption
Carfentrazone & Flumioxazin

- Carfentrazone has very little persistence – broken down rapidly by microbes
- Flumioxazin is broken down through hydrolysis but is pH dependent
  - pH 5 – persistence in days
  - pH 7 – persistence in hours
  - pH 9 – persistence in minutes
Carfentrazone & Flumioxazin Injury Symptoms

- Speckling or bronzing of leaf tissue
- Tolerant plants generally out-grow injury within 2-3 weeks
Carfentrazone & Flumioxazin
Hexazinone, Diuron & Tebuthiuron – Terrestrial ONLY

- Absorbed by foliage or roots
- Contact from foliar, systemic from root uptake
- Blocks photosynthesis
- No electron flow, buildup of excessive energy, creates toxic radicals
- Radicals cause the cell membrane to leak
- Yellowing and browning of leaf tissue
Hexazinone, Diuron & Tebuthiuron – Terrestrial ONLY

- Low water solubility, adsorbed to soil particles
- Can be very persistent in soil – some cases years if high rate is used
- Slowly degraded by soil microbes
Questions?