The Uptake, Mode of Action, and Fate of Herbicides Used in Hayfields

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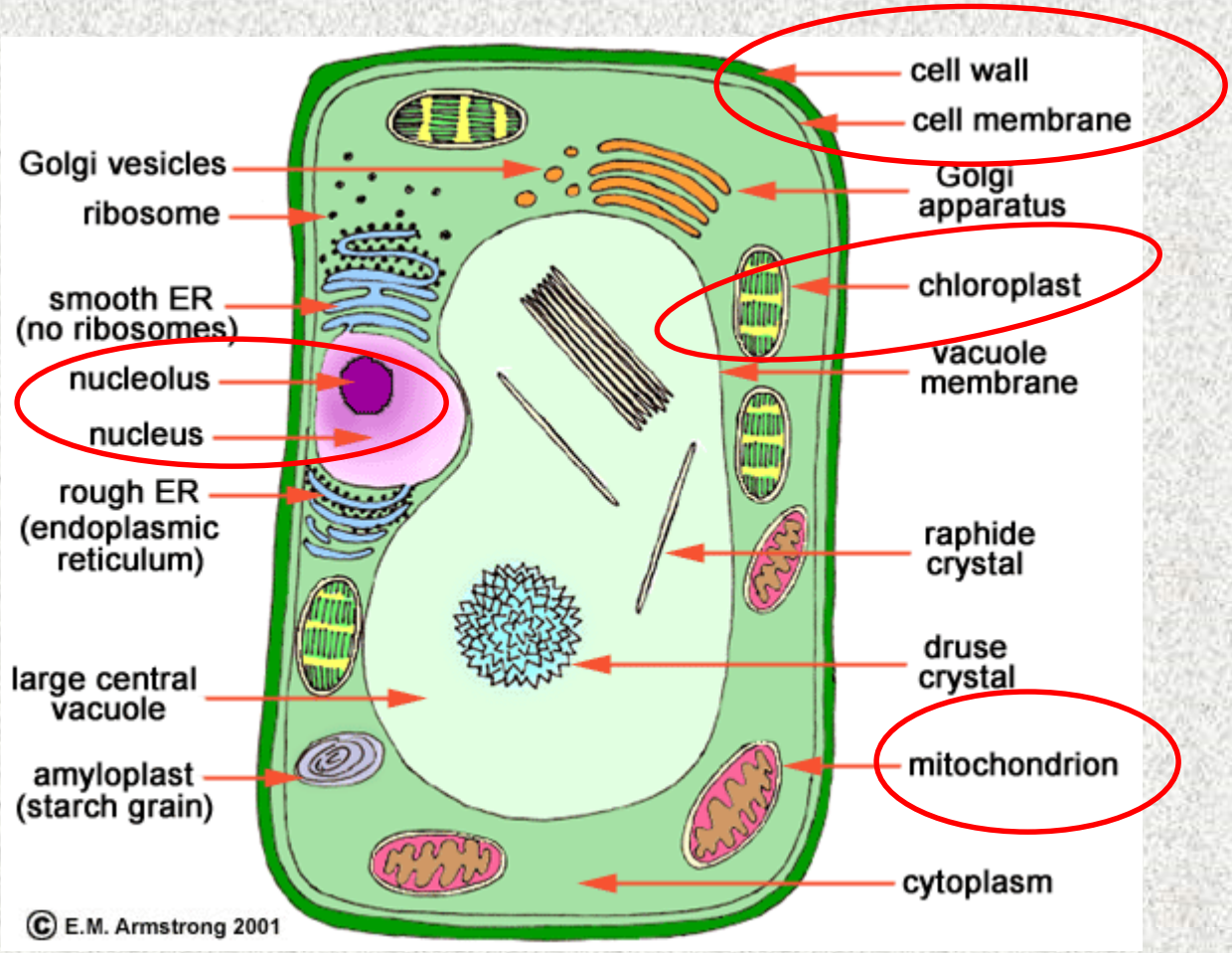
Mode of Action - Terminology

- **Mode of Action:**
  - **How a particular herbicide acts on a plant**
  - **Response of plant to phytotoxic effects of the herbicide**
  - **How the plant responds to the herbicide**

Plant target Sites



Mode of Action

- **Primary Mechanism of Action**: plant processes affected by lowest phytotoxic dose of herbicide.
- **Secondary Mechanism of Action**: other plant processes affected by herbicide.

- **Description of MOA**
- **http://www.wssa.net/Weeds/Resistance/WSSA-Mechanism-of-Action.pdf**

Summary of Herbicide Mechanism of Action According to the Weed Science Society of America (WSSA)

1

Acetyl CoA Carboxylase (ACCase) Inhibitors

Aryloxyphenoxypropionate (FOPs) cyclohexanedione (DIMs) and phenylpyrazolin (DENs) herbicides inhibit the enzyme acetyl-CoA carboxylase (ACCase), the enzyme catalyzing the first committed step in *de novo* fatty acid synthesis (Burton 1989; Focke and Lichtenthaler 1987). Inhibition of fatty acid synthesis presumably blocks the production of phospholipids used in building new membranes required for cell growth. Broadleaf species are naturally resistant to cyclohexanedione and aryloxyphenoxy propionate herbicides because of an insensitive ACCase enzyme. Similarly, natural tolerance of some grasses appears to be due to a less sensitive ACCase (Stoltenberg 1989). An alternative mechanism of action has been proposed involving destruction of the electrochemical potential of the cell membrane, but the contribution of this hypothesis remains in question.

2

Acetolactate Synthase (ALS) or Acetohydroxy Acid Synthase (AHAS) Inhibitors

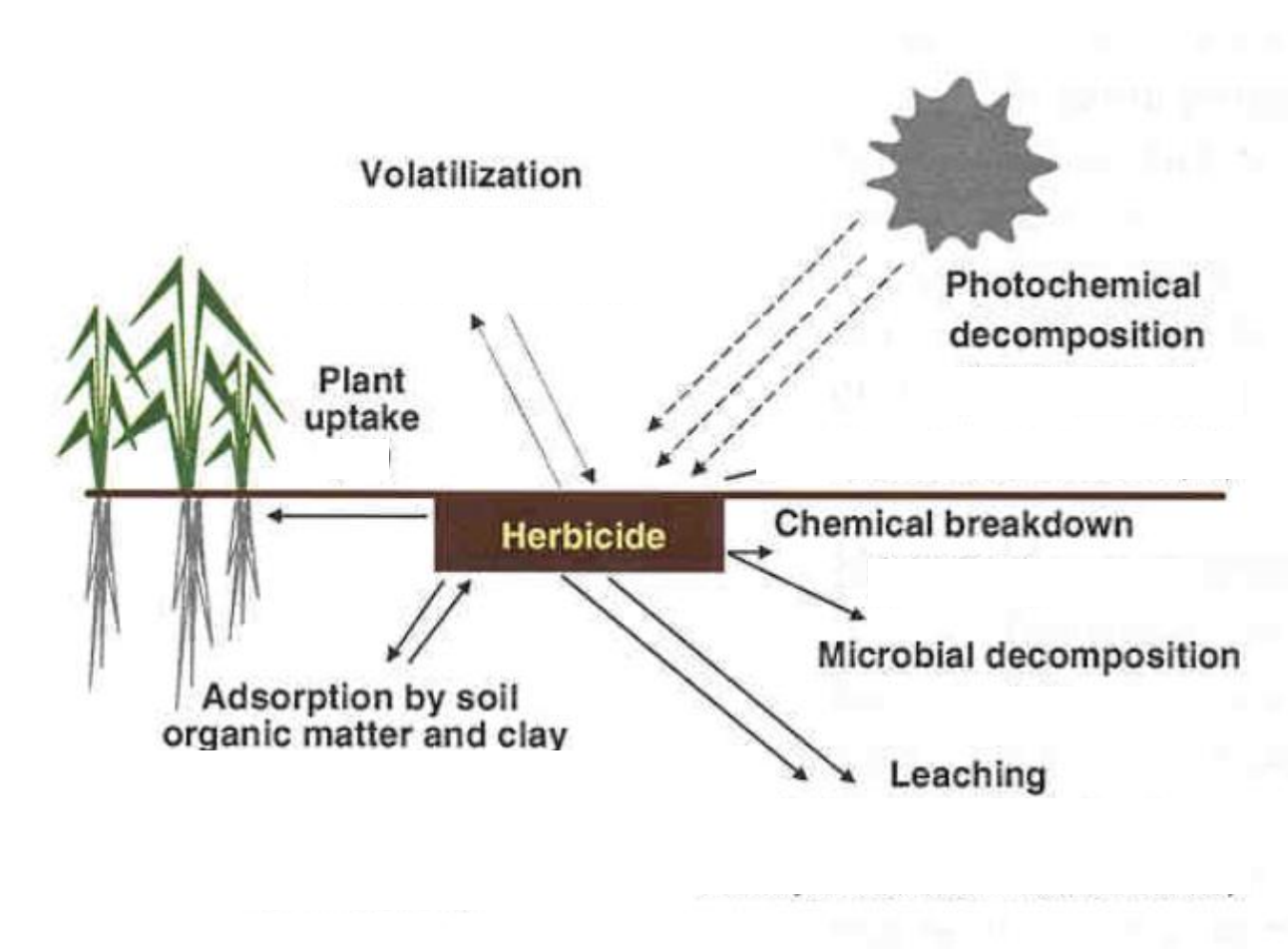
Herbicide Mode of Action - WSSA

- Group herbicides by plant processes affected:
  - Acetyl CoA Carboxylase Inhibitors (1) – sethoxydim
  - Amino acid synthesis inhibitors (2) – SU's, IMI's
  - Microtubule assembly inhibition (3) - pendimethalin
  - Photosynthetic inhibitors (5, 6, 7, 22) – diuron, paraquat, metribuzin
  - EPSP synthesis (9) - glyphosate
  - PPO (14) - flumioxazin

Question

- What happens to herbicides?
- How do these and other herbicides dissipate when applied?
- Limited information in forages
- We know the properties

Environmental fate



1 – ACCase

Acetyl CoA Carboxylase Inhibitors

- Grass herbicides that we use in legumes many times
- Inhibit lipid production
- POST applied
- FOPS & DIMS
- sethoxydim
- Poast
- Resistance issues!!!
- No to low residual

2 - Amino acid inhibitors

- essential building blocks for plant growth and function
- unlike animals, plants make their own
- amino acids are the primary components of proteins and nucleic acids
- proteins are generally storage proteins or enzymes

2 - Amino Acid Inhibitors

- generally target a specific enzyme
  - Some block vital steps in the formation of amino acids- proteins, enzymes
  - branched chain amino acid inhibitors
    - Leucine, Isoleucine, Valine
- dependent on plant growth for activity
  - better growth - better control, slow death
- systemic herbicides
- Soil activity
  - None (imazamox)
  - Some (Metsulfuron, nicosulfuron)
  - Long activity – (imazapic)

Imazethapyr - imazapic

johnsongrass

Ivyleaf morningglory

ALS Inhibitors

- **Imidazolinones**
  - **Imazapic (Impose)**
  - **Imazamox (Raptor)**
  - **Imzethapyr (Pursuit)**
- **Sulonylureas**
  - **sulfosulfuron**
  - **Nicosulfuron + metsulfuron (Pastora)**
  - **Many others**

Organic matter & clay

- **Positive correlation between sorption & organic matter content**
  - † **OM increase, sorption increase**
- **Alkaline soils with low OM**
  - † **SU degrade slowly**
- **Sulfosulfuron, chlorsulfuron reported**
- **Clay mineral sorption – varies from none to some**

Leaching

- **SU herbicides can be mobile in soil**
  - **Experiments have demonstrated**
- **R_f values from 0.21 to 0.9**
  - **Chlorsulfuron**
  - **Metsulfuron**
  - **Sulfometuron**
- **Primarily dependent on soil type & characteristics – pH, OM, etc.**
- **Never been a major concern low rates**

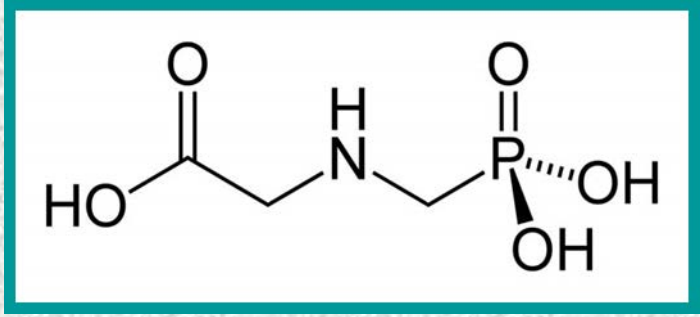
SU facts

- Most all are formulated as WP or DG
- Photolysis minor
- Volatilization minor
- Can move upward even when they were not previously detected
  - via capillary soil water flow

Conclusions

- ↑ soil pH ↑ SU persistence
- ↑ temperature ↑ soil dissipation
- ↑ soil OM content ↓ plant availability
- Low use rates combined with factors above
- Low leaching potential

9 – EPSP synthase
Glyphosate



- broadspectrum postemergence weed control
- glyphosate labeled in multitude of areas
- extensively translocated throughout the plant, extremely stable in plant
- blocks synthesis of aromatic amino acids
- Very good for perennial species
- **Weeds:** Nonselective
- Used in renovation and dormant bermudagrass
- Dissipation via adsorption & microbial

Roundup 32 oz, 19 DAT

3, 15, 23
Microtubule growth Inhibition

- plants grow by making new cells
  - process of cell division, mitosis
- plants are particularly susceptible as emerging seedlings
  - both shoot and roots
- newly forming roots can be susceptible at most stages of plant growth

Microtubule growth Inhibition

- most growth inhibition herbicides are soil applied and generally affect seedling weeds
- most interfere w/ mitosis (mitotic poisons)
- others appear to prevent lipid (cell membrane) production
- some prevent cell wall formation
- soil active, little movement once absorbed

Microtubule growth Inhibition

- ***benefin*** **- PPI or PRE with irrigation**
  - **Balan**
- ***pendimethalin*** **– PRE**
  - **Prowl**
- **soil applied - annual grasses and certain broadleaf weeds**
- **vary in volatility and photodegradation**
- **prevent both root and shoot growth, inhibit cell division (mitosis)**
- **Very effective on small seeded weeds**
- **Plants cannot take up water-nutrients - starve**

Microtubule growth Inhibition

4 – PGRs (plant growth regulators)

- ***2,4-D, 2,4-DB, dicamba and more……***
- **BL weed control for a variety of crops (corn, pastures, legumes) and noncropland**
- **Cotton & tomato very sensitive – ppb range**
- **foliar & root uptake- extensive translocation**
- **interferes with nucleic acid (DNA and RNA) and protein synthesis; cells undergo rapid uncontrolled division and elongation**

Synthetic Auxin Injury to Broadleaf Weeds

4- Benzoic Acids

- *dicam* res (broa
- poste s some soil a
- readil g tips
- interf protein synthesis - leading to rapid, uncontrolled growth (similar to phenoxys)

Growth Regulator Herbicides

- Phenoxys
  - 2,4-D
- Benzoics
  - dicamba
- Pyridines
  - clopyralid
  - triclopyr
  - fluroxypyr

14 - PROTOX Inhibitors

- Biological activity
  - Mode of action - PPO or PROTOX inhibitors, contact action
  - require light for activity
  - Selectivity – metabolism

14 - PROTOX Inhibitors

- **PRE & POST applied**
- **Depends on the chemistry**
  - **Flumioxazin (Chateau)**
  - **Carfentrazone (Aim)**

- **Flumioxazin – residual, rate dependent**
- **Carfentrazone no residual activity**

fomesafen

Tomato

Ivyleaf morningglory

5, 6, 7, 22 Photosynthesis inhibitors

Metribuzin

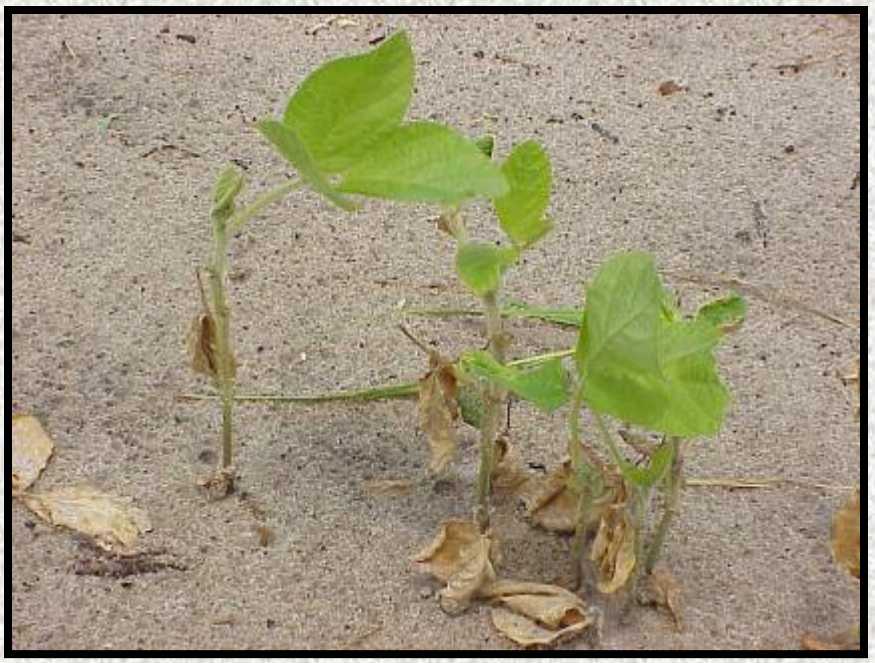
Photosynthesis inhibitors

- **Biological activity**
  - **Photosynthesis (PS I & II) inhibitors**
  - **readily absorbed by plant roots and translocated to leaves via transpiration stream**
  - **Selectivity based on metabolism**
- **Dissipation**
  - **Microbial**
  - **Hydrolysis**
  - **Soil & OM absorption**
- **pH affects availability, increase pH, increase activity**
  - **Metribuzin, WSSA Group 5**

22- paraquat

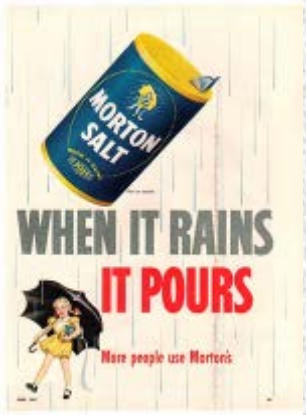
Corn

Soybean



Herbicide chemistry

- **Water solubility is important**
  - **Table salt 360 g/L = 3 lb/gal water**



- **Glyphosate (K+ formulation)**
  - **10.5 g/L = 0.1 lb/gal water**

- **Paraquat**
  - **620 g/L = 5.2 lb/gal water**

Herbicide chemistry
pH and temperature effects

- Water solubility is important
  - Table salt 360 g/L = 3 lb/gal water
- Metsulfuron – Patriot, multiple formulations
  - pH 5.0 - 0.55 g/L = 0.0046 lb/gal water
  - pH 7.0 – 2.8 g/L = 0.023 lb/gal water
  - pH 9.0 - 213 g/L = 1.78 lb/gal water 350x
- Carfentrazone
  - 68 F – 12 g/L = 0.1 lb/gal water
  - 86 F – 23 g/L = 0.2 lb/gal water 2x

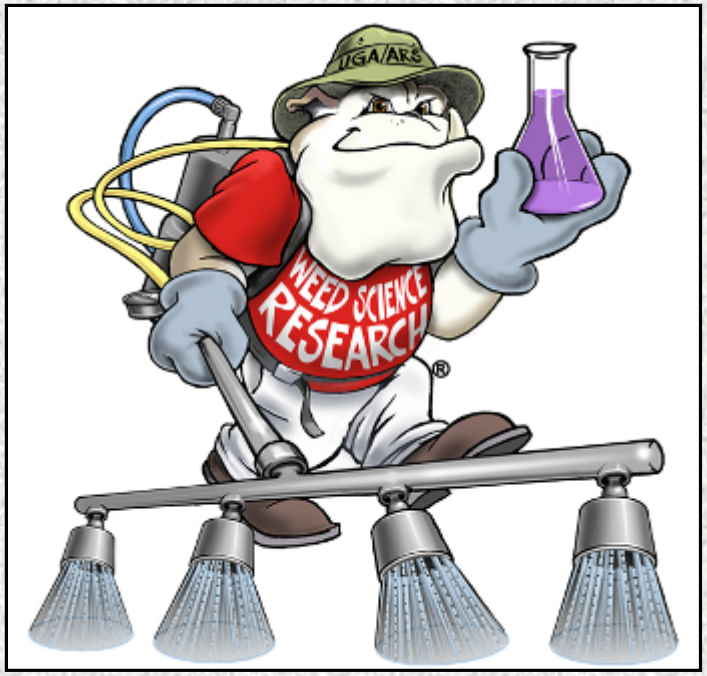
Herbicide chemistry

- **Water solubility is important**
  - **Table salt 360 g/L = 3 lb/gal water**
- **Flumioxazin –**
  - **0.00179 g/L = 0.000015 lb/gal**
    - **Low water solubility can lead to issues…..**
    - **Tank cleanout!!!**

Main points

- **Pesticides have to go somewhere!**
- **Break down can be rapid in the environment**
  - **Depends on pesticide molecule chemistry:**
    - **Volatility**
    - **Solubility**
    - **Stability (resistance to photolysis, hydrolysis, etc.)**
  - **Depends on the environment (moisture, heat)**
  - **Depends on application method (granule, spray)**
- **Leaching**
  - **Need to move into treated soil**
  - **Do not want to move into ground water**

Thank you



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Question????