UNDERSTANDING MOA & HERBICIDE PROPERTIES TO CHOOSE THE BEST OPTION FOR WEED CONTROL

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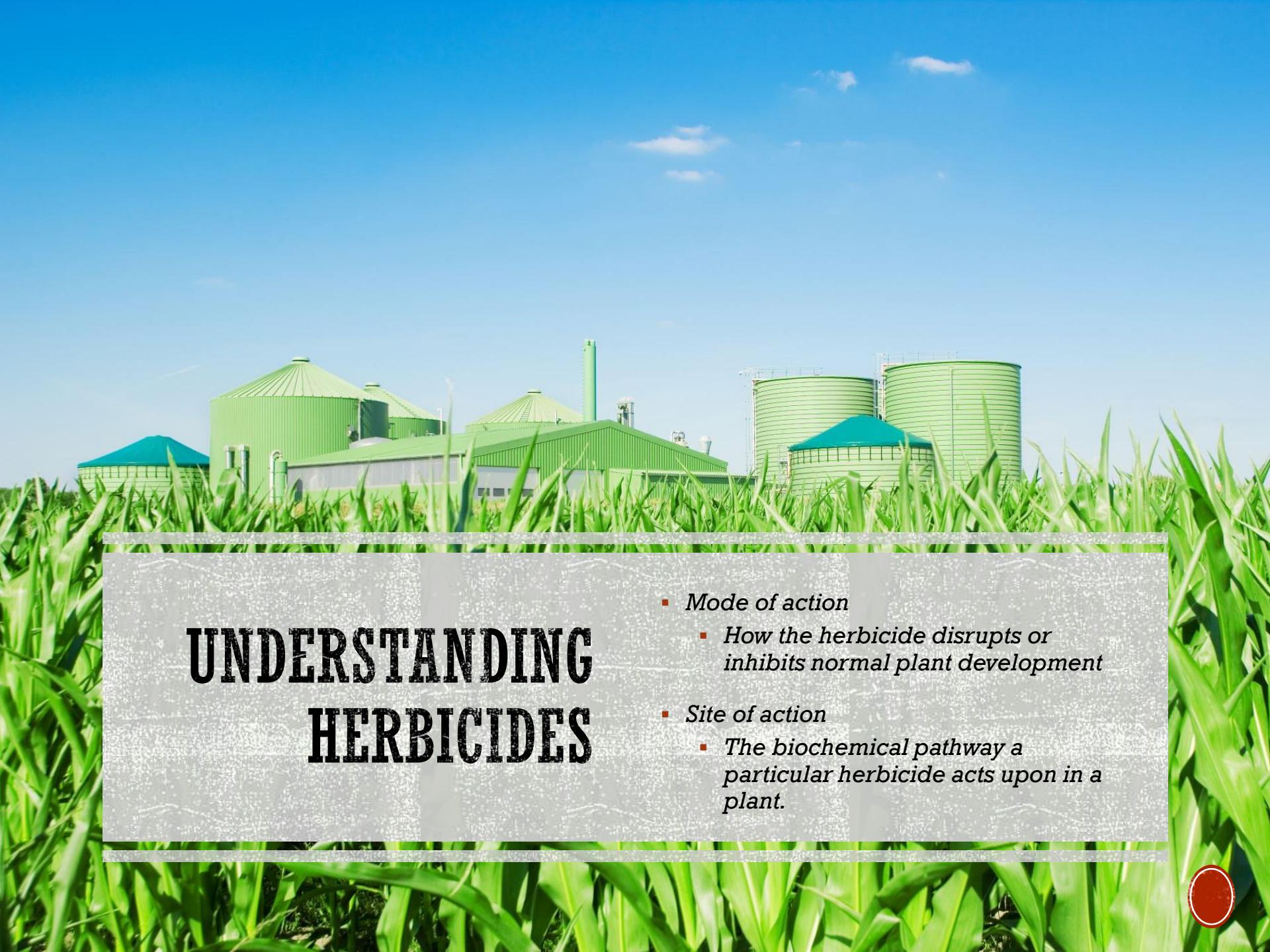


UNDERSTANDING HERBICIDES

- *Mode of action*
  - *How the herbicide disrupts or inhibits normal plant development*
- *Site of action*
  - *The biochemical pathway a particular herbicide acts upon in a plant.*

WHY KNOW HERBICIDE MODES OF ACTION?

- *Better understanding of how herbicides perform*
- *Improve herbicide performance*
- *Diagnose herbicide injury*
- *Prevent and manage herbicide resistance.*
- *Matching herbicides to weeds*

CLASSIFICATION CAN BE BASED ON:

- *Selectivity*
- *Persistence*
- *Mobility within the plant*

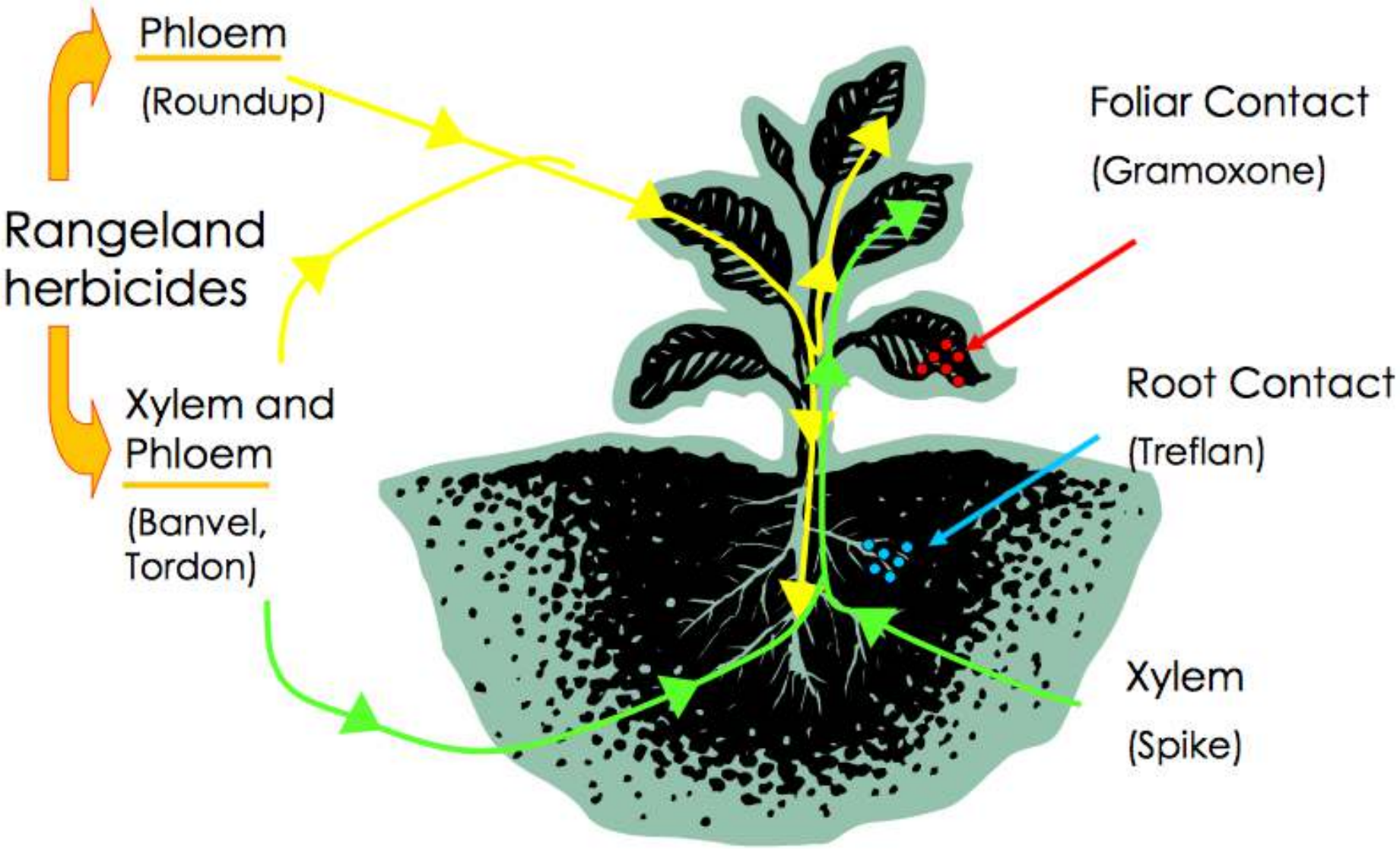
MOA CLASSIFICATION

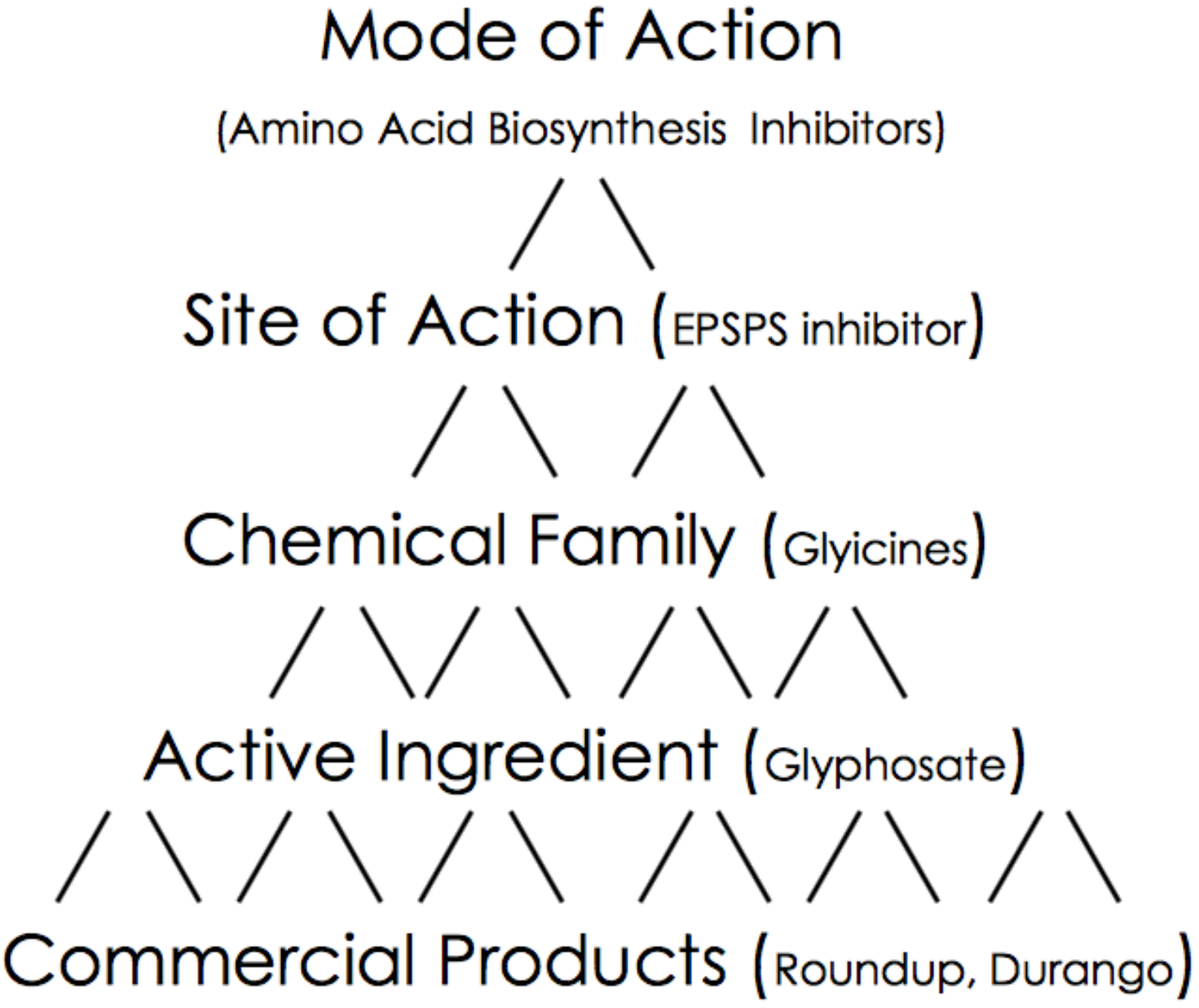
- *Based on HRAC/WSSA group numbers*
- *Each herbicide has one primary MOA*
- *Rotate and stack effective MOAs*

HERBICIDE CLASSIFICATION

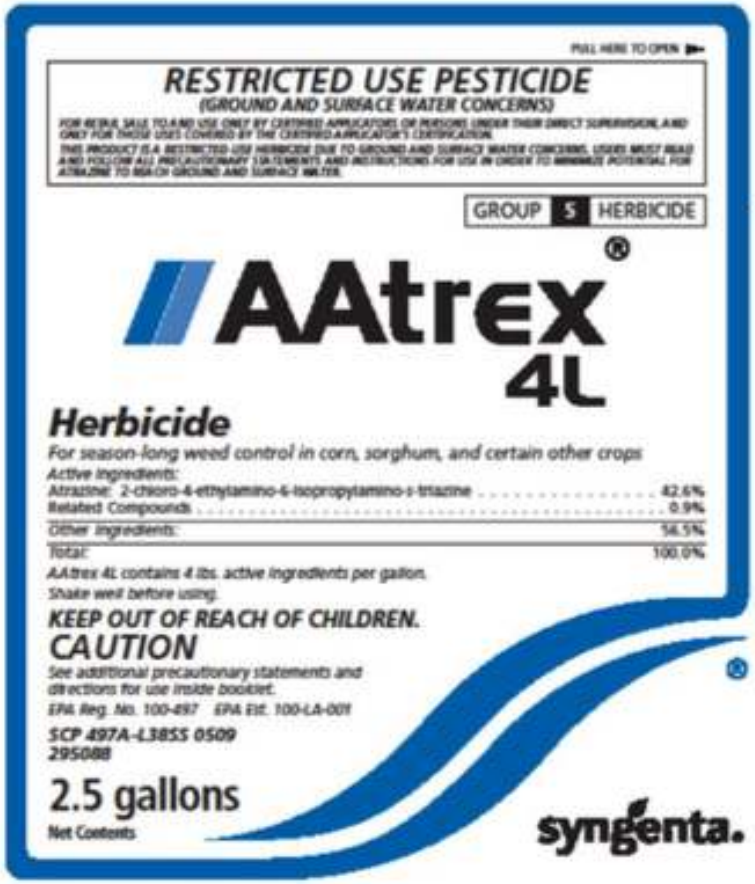
- **Selective**—*Controls or suppresses one species of plant without seriously affecting the growth of another plant species*
  - *Dicamba, 2, 4-D*
- **Nonselective**—*Control plants regardless of species*
  - *Glyphosate (Roundup)*
- **Residual**—*Persist in soil*
  - *Picloram (Tordon)*
- **Non-residual**
  - *Glyohosate (Roundup)*

Absorption and Translocation




Mode of Action
(Amino Acid Biosynthesis Inhibitors)
Site of Action (EPSPS inhibitor)
Chemical Family (Glyicines)
Active Ingredient (Glyphosate)
Commercial Products (Roundup, Durango)

Including the Group Number on the label is recommended, but not required, by the EPA



HERBICIDE GROUPS

- *Group by Mode of Action*
  - *Group by Site of Action*
    - *SOA is important because weeds with resistance to one herbicide in the same SOA group, can be resistant to other herbicides in the same SOA group.*

MOA--LIPID SYNTHESIS INHIBITORS

- *Group 1—ACCase Inhibitors (Site of Action)*
  - *Select, Assure, Targa, Poast*
  - *Control only grasses*
- *Corn: limited POST options*
- *Cotton: Clethodim (Select), Sethoxydim (Poast)*
- *Soybeans: Clethodim, Sethoxydim*

GROUP 1 – ACCASE INHIBITORS

- *Key Herbicides:*
  - *Clethodim*
  - *Sethoxydim*
  - *Quizalofop*
- *Controls:*
  - *Annual grasses*
  - *Volunteer corn*
  - *Johnsongrass*

HOW DO ACCase WORK

- *Target enzyme = ACCase*
  - *These herbicides inhibit acetylCoA carboxylase (ACCase), an enzyme needed to start fatty-acid (lipid) synthesis.*
  - *Why fats matter*
    - *Fatty acids are building blocks of cell membranes. Without them, cells can't form or repair membranes.*
  - *Growth shuts down the growing point*
    - *The most actively dividing tissue—the growing point (meristem) is hit first. New leaves stop emerging*
  - *Plant Death*
    - *Existing leaves may stay green briefly, but the plant cannot grow and eventually dies.*

WHAT WEEDS DO ACCase CONTROL?

- *Highly effective on grasses (annual and many perennial)*
- *Little to no activity on broadleaf weeds*
- *Thus primarily used in broadleaf crops and ACCase resistant corn & sorghum*

WHAT YOU'LL SEE AFTER APPLICATION

1-3 days: growth stops (no new leaves)

5-10 days: Yellowing/redding near the whorl

10-21 days: Growing point dies, plant collapses

RESISTANCE CONSIDERATIONS

- *ACCase-resistant grasses*
  - *Ryegrass*
  - *Barnyard grass*
  - *Volunteer corn (Enlist)*
  - *Volunteer sorghum (Double Team)*

MOA—AMINO ACID SYNTHESIS INHIBITORS

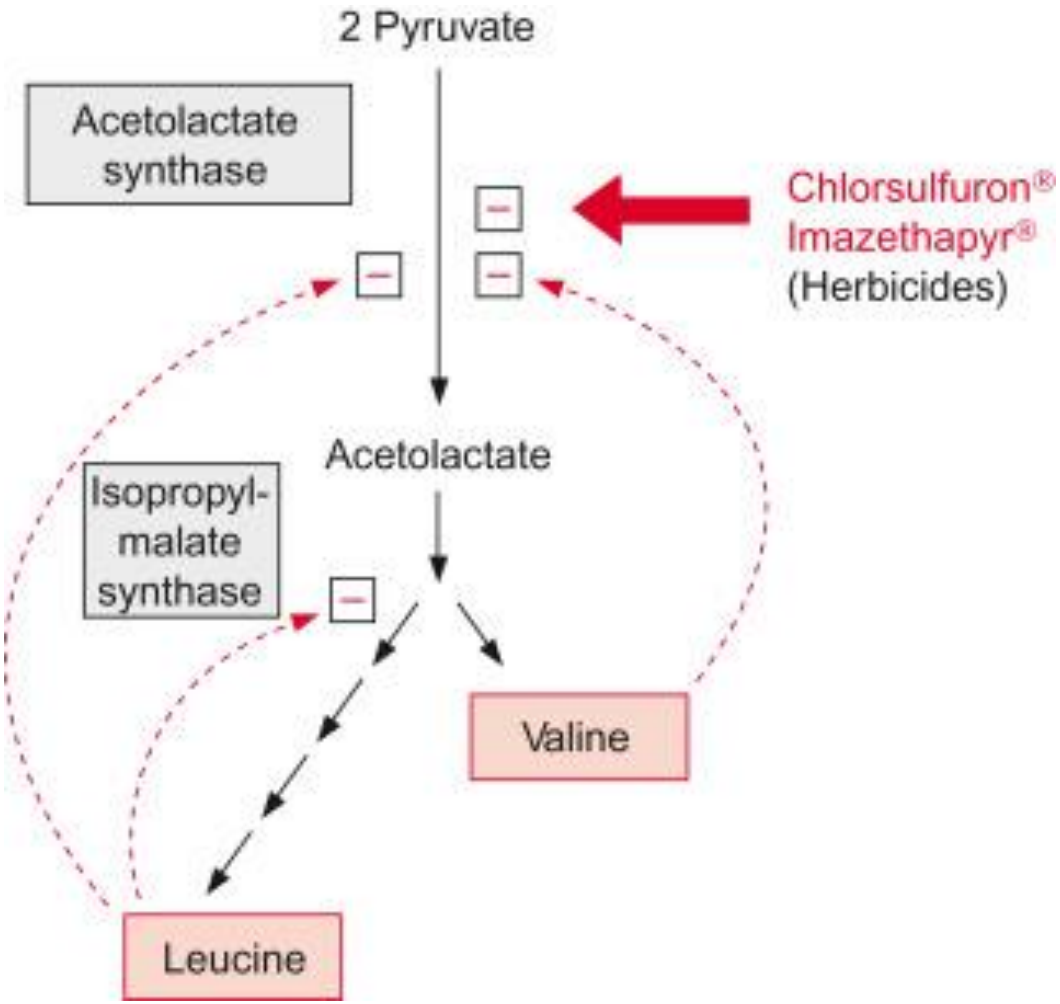
- *Group 2—ALS Inhibitors*
  - *Active as soil and foliar treatments*
  - *Generally more effective on broadleaf weeds*
  - *Corn: Nicosulfuron (Accent), Rimsulfuron (Resolve)*
  - *Cotton: Pyrithiobac (Staple), Trifloxysulfuron (Envoke)*
  - *Soybeans: Imazethapyr (Pursuit), Chlorimuron (Classic)*

GROUP 2 — ALS INHIBITORS

- *Key Herbicides:*
  - *Chlorimuron (Classic)*
  - *Imazethapyr (Pursuit)*
  - *Nicosulfuron (Accent)*
- *Controls:*
  - *Pigweed (susceptible)*
  - *Lambsquarters*
  - *Mustards*
- ⚠ *Widespread resistance*

HOW DO GROUP 2 HERBICIDES WORK

- *Group 2 herbicides inhibit the* **ALS (acetolactate synthase) enzyme**
- *ALS is required to produce* **branched-chain amino acids**
  - *Valine*
  - *Leucine*
  - *Isoleucine*
- *Without these amino acids:*
  - *Protein synthesis stops*
  - *Cell division halts*
  - *Plant growth ceases*
- **Key Takeaway:**
  - *Plants don't die immediately — they stop growing first.*


2 Pyruvate
Acetolactate synthase
Chlorsulfuron®
Imazethapyr®
(Herbicides)
Acetolactate
Isopropyl-malate synthase
Valine
Leucine

HOW GROUP 2 KILL WEEDS

- *Herbicide absorbed through leaves and/or roots*
- *Systemic movement within the plant*
- *ALS enzyme is inhibited*
- *Amino acid production shuts down*
- *Growth stops → slow starvation → death*
- **Important Concept:**
  - *Visual injury lags behind physiological shutdown*

FIELD SYMPTOMS—GROUP 2

- **What You See After Application**
  - *Growth stoppage within days*
  - *New leaves become:*
    - *Chlorotic (yellow)*
    - *Reddish or purple*
  - *Shortened internodes*
  - *Plants appear "stuck" or frozen*
  - *Death occurs* **7–21 days** *after application*
- 💡 *Environmental stress can slow symptom development even further.*

GROUP 2 HERBICIDE FAMILIES

- **Chemical Classes**
  - **Sulfonylureas (SU)**
    - *chlorimuron, nicosulfuron*
  - **Imidazolinones (IMI)**
    - *imazethapyr, imazamox*
  - **Triazolopyrimidines (TP)**
    - *flumetsulam*
  - **Pyrimidinylthiobenzoates (PTB)**
    - *bispyribac*
- → *Different chemistries,* **same enzyme target**

GROUP 2 CHARACTERISTICS

- *Foliar activity*
- *Soil Activity*
  - *Short to very long activity*

RESISTANCE: THE MAJOR CHALLENGE

- **Why Resistance Develops Quickly**
  - *Single-site enzyme target*
  - *One mutation can confer full resistance*
  - *Repeated use strongly selects resistant biotypes*
  - *Cross-resistance common within Group 2*
- 📌 *Group 2s have* **one of the highest resistance risks of any herbicide group**

COMMON RESISTANT WEEDS TO ALS HERBICIDES

- **Widespread Across U.S. Row Crops**
  - *Pigweed species*
  - *Kochia*
  - *Waterhemp*
  - *Palmer amaranth*
  - *Italian ryegrass*
- → *Resistance often unnoticed until control failures are widespread.*

MOA—AMINO ACID SYNTHESIS INHIBITORS

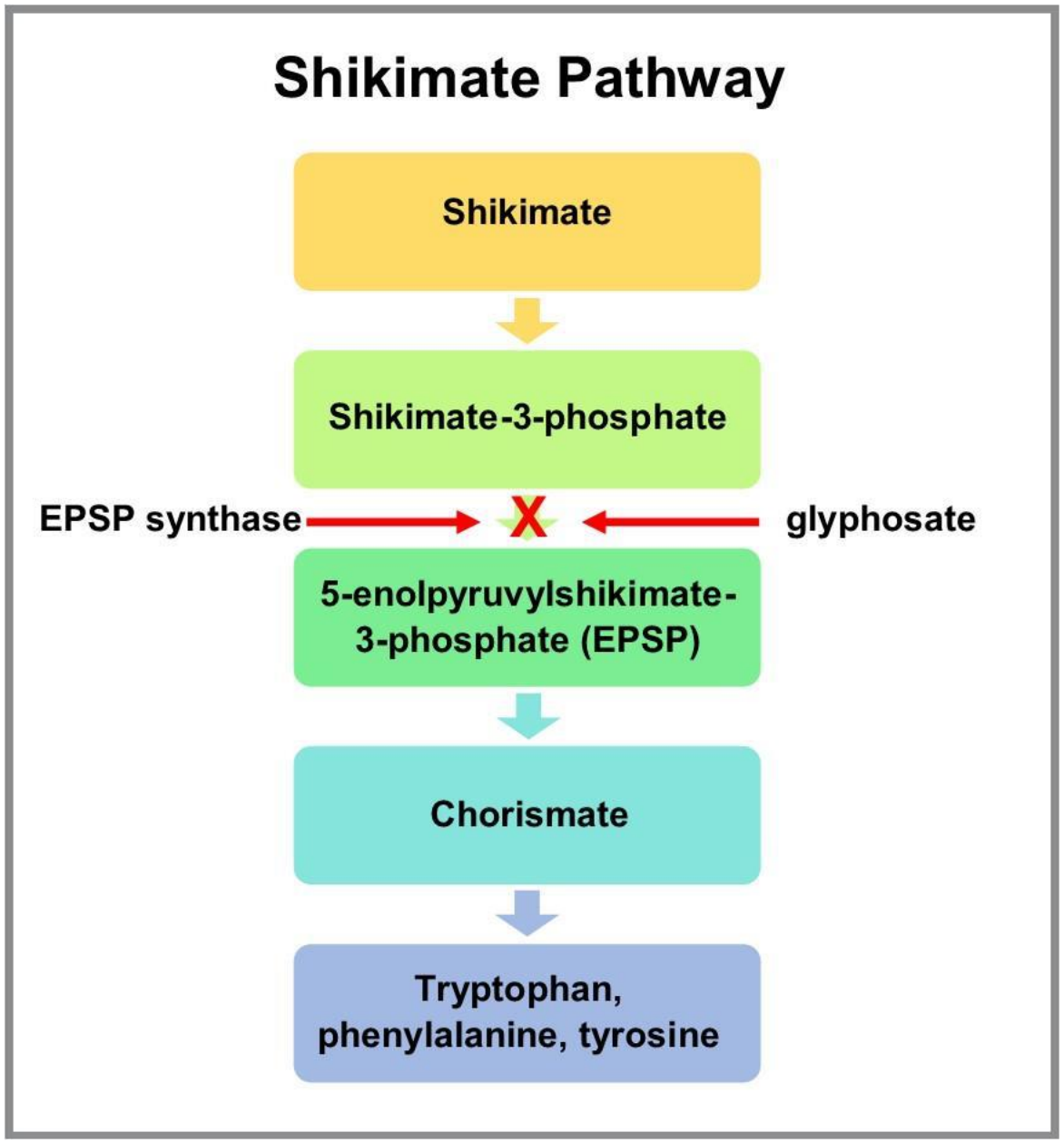
- *Group 9—EPSP Synthase*
  - *Glyphosate (Roundup)*
  - *Non-selective herbicide*
  - *No soil activity*
  - *Corn: Glyphosate (RR corn)*
  - *Cotton: Glyphosate (RR cotton)*
  - *Soybeans: Glyphosate (RR soybeans)*

MOA GROUP 9 HERBICIDES

- *Group 9 herbicides inhibit* **EPSPS** *(5-enolpyruvylshikimate-3-phosphate synthase)*
- *EPSPS is part of the* **shikimate pathway**
- *This pathway produces* **aromatic amino acids***:*
  - *Tryptophan*
  - *Tyrosine*
  - *Phenylalanine*
- **Key Point:**
  → *Without these amino acids, protein synthesis and plant metabolism collapse.*

GROUP 9 – EPSPS INHIBITORS

- *Key Herbicide:*
  - *Glyphosate*
- *Controls:*
  - *Broad-spectrum grasses & broadleaves*
- ⚠ *Extensive resistance*


Shikimate Pathway
Shikimate
Shikimate-3-phosphate
EPSP synthase
glyphosate
5-enolpyruvylshikimate-3-phosphate (EPSP)
Chorismate
Tryptophan, phenylalanine, tyrosine

HOW GROUP 9 HERBICIDES KILL WEEDS

- *Herbicide absorbed through green tissue*
- *Moves systemically within the plant*
- *EPSPS enzyme is inhibited*
- *Aromatic amino acid production stops*
- *Protein synthesis and growth shut down*
- *Gradual whole-plant death*
- 📌 **Important:** *Growth stops before visible injury occurs.*

ABSORPTION & TRANSLOCATION

- **Why Group 9 Is Unique**
- *Absorbed mainly through* **foliar tissue**
- **Highly systemic**
- *Moves through* **phloem and xylem**
- *Translocated to:*
  - *Growing points*
  - *Roots*
  - *Rhizomes and stolons*
- → *This explains strong perennial weed control when applied correctly.*

FIELD SYMPTOMS

- **What You See After Application**
- *Growth stoppage within days*
- *Yellowing (chlorosis) of new growth*
- *Gradual wilting and necrosis*
- *Complete plant death, including roots*
- *Symptoms develop* **5–21 days** *after application*
- ❗ *Stress (drought, cold, dust) can delay or reduce activity.*

STRENGTHS OF GLYPHOSATE

- *Broad-spectrum, non-selective control*
  ✓ Excellent perennial weed activity
  ✓ No soil residual
  ✓ Low mammalian toxicity
  ✓ Enabled reduced tillage and no-till systems
- **Bottom line:**
  Group 9 changed weed control — but simplicity led to overuse.

WHY RESISTANCE DEVELOPED

- *Single enzyme target*
- *Repeated, exclusive use for decades*
- *Heavy reliance in Roundup Ready systems*
- *Minimal diversification of MOAs*
- 📌 *Resistance does* **not** *mean failure of the chemistry — it means poor programs.*

COMMON GLYPHOSATE-RESISTANT WEEDS

- **Confirmed Across Row Crops**
  - *Palmer amaranth*
  - *Waterhemp*
  - *Horseweed (marestail)*
  - *Italian ryegrass*
  - *Johnsongrass*
  - *Kochia*
- → *Resistance mechanisms vary by species and geography.*

BEST MANAGEMENT PRACTICES

- **Using Group 9 Effectively Today**
  - *Apply to* **small, actively growing weeds**
  - *Use* **multiple effective MOAs**
  - *Add* **residual herbicides**
  - *Avoid repeated glyphosate-only applications*
  - *Control escapes* **before seed production**
- ❗ *Group 9 should support the program — not carry it.*

MOA—GROWTH REGULATORS

- *Group 4—Specific site unknown*
  - *Three SOA Groups*
    - *Phenoxy—2, 4-D*
    - *Benzoic Acid—Dicamba*
    - *Carboxylic Acid—Starane*
  - *Corn: 2,4-D, Dicamba*
  - *Cotton: Dicamba (Xtend), 2,4-D (Enlist)*
  - *Soybeans: Dicamba (Xtend), 2,4-D (Enlist)*

GROUP 4 — SYNTHETIC AUXINS

- *Key Herbicides:*
  - *2,4-D*
  - *Dicamba*
  - *Clopyralid*
- *Controls:*
  - *Kochia*
  - *Palmer amaranth (small)*
  - *Marestail*

HOW DO THEY WORK

- **How Group 4 Herbicides Kill Weeds**
  - *Herbicide absorbed through leaves, stems, or roots*
  - *Translocated throughout the plant*
  - *Auxin receptors overstimulated*
  - *Abnormal cell growth and division*
  - *Vascular tissue becomes disorganized*
  - *Plant collapses and dies*
- 📌 **Unlike contact herbicides, death is systemic and whole-plant.**

ADSORPTION & MOVEMENT

- **Systemic Activity**
  - *Absorbed through* **foliar tissue and roots**
  - *Moves in* **phloem and xylem**
  - *Accumulates in:*
    - *Meristems*
    - *Growing points*
    - *New leaves and stems*
- **→** *Most effective on* **small, actively growing broadleaf weeds**

Classic Group 4 Injury

- *Leaf cupping and crinkling*
- *Twisted stems (epinasty)*
- *Swollen nodes*
- *Brittle stems*
- *Root malformation*

Symptom timing:

- *Often visible within* **hours to days**

GROUP 4 HERBICIDE FAMILIES

- **Chemical Classes**
  - **Phenoxy acids** – *2,4-D, MCPA*
  - **Benzoic acids** – *dicamba*
  - **Pyridine carboxylic acids** – *clopyralid (Stinger), picloram (Tordon), fluroxypyr (Starane)*
  - **Quinoline carboxylic acids** – *quinclorac (Facet)*
- → *Different chemistries,* **same hormonal mode of action**

RESISTANCE & MODERN CHALLENGES

- **What's Changing**
  - *Historically low resistance risk*
  - *Resistant biotypes now confirmed:*
    - *Kochia*
    - *Waterhemp*
    - *Palmer amaranth*
  - *Resistance mechanisms are* **complex**, *not single-gene*
- 📌 *Stewardship is increasingly important.*

STEWARDSHIP & BEST PRACTICES

- **Using Group 4 Responsibly**
  - *Target* **small, actively growing weeds**
  - *Rotate* **modes of action**
  - *Use residual herbicides*
  - *Follow label requirements for:*
    - *Nozzles*
    - *Wind speed*
    - *Temperature inversions*
  - *Manage drift and volatility carefully*
- ❗ *Improper use threatens both* **efficacy and crop safety**.

MOA—PHOTOSYNTHESIS INHIBITORS

- *Group 5—Photosystem II Inhibitors*
  - *Different binding site than Group 6 & 7*
  - *Triazine—Atrazine, Propazine (MiloPro)*
  - *Corn: Atrazine*
  - *Cotton: Limited use*
  - *Soybeans: Metribuzin*

GROUP 5 — PSII INHIBITORS

- *Key Herbicides:*
  - *Atrazine*
  - *Metribuzin*
- *Controls:*
  - *Pigweed (susceptible)*
  - *Lambsquarters*
- ⚠ *Resistance common*

WHAT ARE GROUP 5 HERBICIDES

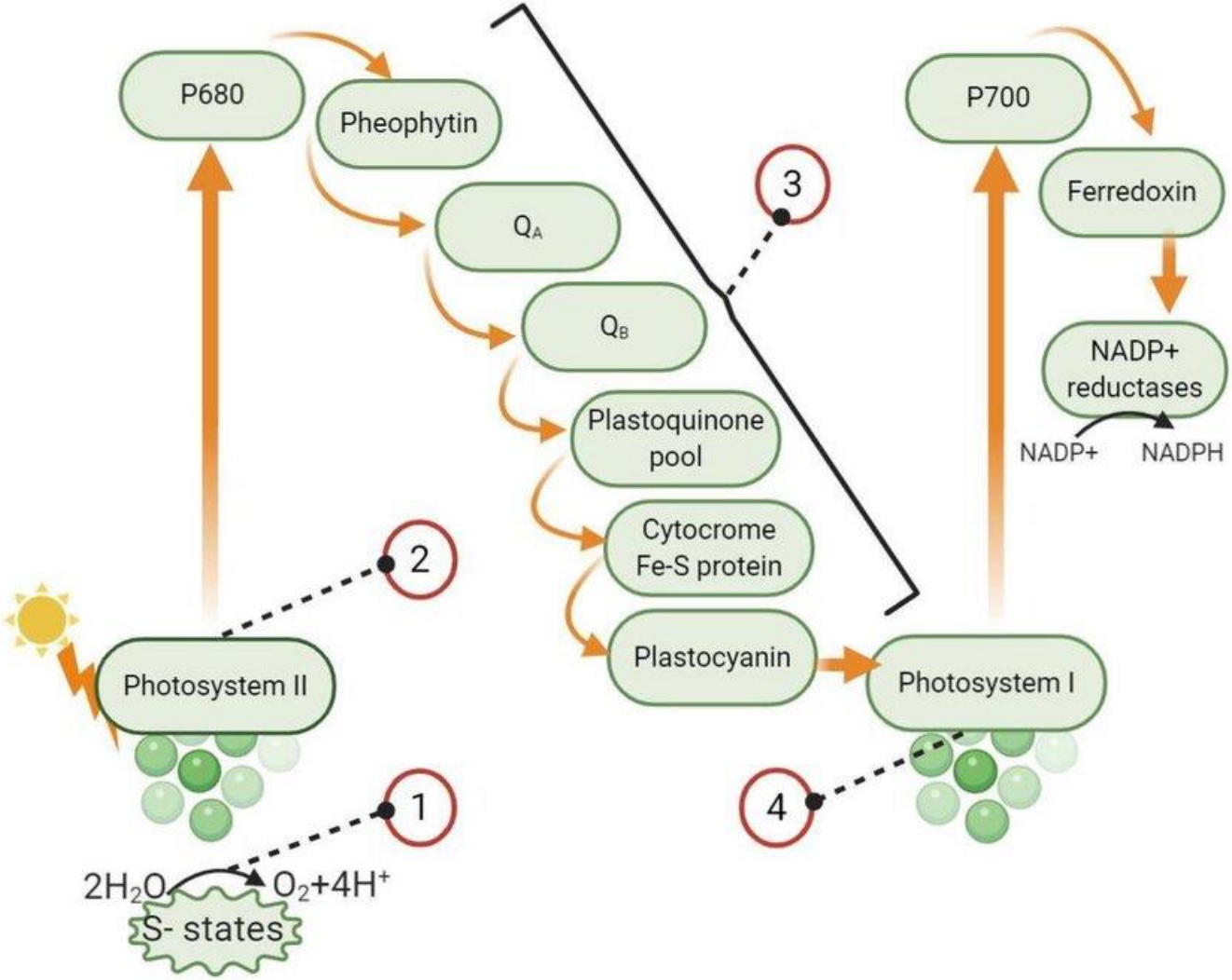
- **Basic Definition**
  - *Group 5 herbicides inhibit* **Photosystem II (PSII)** *in photosynthesis*
  - *They block* **electron transport** *during light reactions*
  - *Energy from sunlight cannot be converted into usable plant energy*
- **Key Point:**
  → *Plants absorb light energy but* **cannot use it**, *leading to oxidative damage.*

GROUP 5 MOA

How Group 5 Herbicides Kill Weeds

- *Herbicide absorbed through roots and/or foliage*
- *Moves to chloroplasts in green tissue*
- *Binds to the* **D1 protein** *in Photosystem II*
- *Electron transport is blocked*
- *Reactive oxygen species form*
- *Cell membranes are destroyed → tissue death*

📌 **This is a light-dependent process.**


P680
Pheophytin
Q_A
Q_B
Plastoquinone pool
Cytocrome Fe-S protein
Plastocyanin
P700
Ferredoxin
NADP+ reductases
NADP+
NADPH
3
2
1
4
Photosystem II
Photosystem I
$2H_2O$
O_2+4H^+
S- states

WHY LIGHT MATTERS

- **A Critical Concept**
  - *Injury only occurs in* **photosynthetically active tissue**
  - *Damage increases with:*
    - *Bright sunlight*
    - *Warm temperatures*
  - *Shaded tissue may show delayed symptoms*
- → *This explains why symptoms often worsen rapidly after sunny conditions.*

GROUP 5 FIELD SYMPTOMS

- **What You See After Application**
  - *Leaf chlorosis (yellowing)*
  - *Interveinal bleaching*
  - *Necrosis starting at leaf margins or tips*
  - *Rapid tissue burn under high light*
  - *Death occurs within* **days** *in susceptible weeds*
- ❗ *Symptoms resemble* **sunburn** *on plant tissue.*

GROUP 5 HERBICIDE FAMILIES

- **Chemical Classes**
  - **Triazines**
    - *atrazine, simazine*
  - **Triazinones**
    - *Metribuzin*
- → *Different chemistries,* **same PSII binding site**

ABSORPTION & USE PATTERNS

- **How They Are Typically Applied**
- *Primarily* **soil-applied (PRE)**
- *Taken up by* **roots**
- *Some have* **foliar activity** *on small weeds*
- *Residual activity varies with:*
  - *Soil type*
  - *Organic matter*
  - *Rainfall*
- 📌 *Crop tolerance is based on* **metabolism or sequestration**.

WHY ARE GROUP 5 HERBICIDES VALUEABLE

- **Strengths**
- ✓ *Effective on many broadleaf weeds*
  ✓ *Residual soil activity*
  ✓ *Cost-effective*
  ✓ *Useful in burndown and preemerge programs*
  ✓ *Long history of performance*

RESISTANCE CHALLENGES

- **A Long-Term Issue**
- *Resistance developed after* **repeated, single-MOA use**
- *Common resistant weeds include:*
  - *Pigweed species*
  - *Lambsquarters*
  - *Kochia*
- **Resistance mechanism:**
- *Alteration of PSII binding site (D1 protein mutation)*
- 📌 *Cross-resistance across Group 5 is common.*

STEWARDSHIP & BEST PRACTICES

- **Using Group 5 Effectively**
  - *Rotate* **modes of action**
  - *Use in* **tank mixes or PRE programs**
  - *Match rate to* **soil texture and OM**
  - *Avoid repeated exclusive use*
  - *Control escapes before seed production*
- ❗ *Group 5 works best as a* **program component**, *not a standalone solution.*

MOA—PHOTOSYNTHESIS INHIBITORS

- *Group 6—Photosystem II Inhibitors*
  - *Different binding site than Group 5 & 7*
  - *Nitrile—Bromoxynil (Buctril)*

GROUP 6 – PSII CONTACT INHIBITORS

- *Key Herbicide:*
  - *Bentazon (Basagran)*
  - *Bromoxynil (Buctril)*
- *Controls:*
  - *Morningglory*
  - *Velvetleaf*
  - *Yellow nutsedge (suppression)*

WHAT ARE GROUP 6 HERBICIDES

- **Basic Definition**
  - *Group 6 herbicides inhibit* **Photosystem II (PSII)** *in photosynthesis*
  - *They block electron transport at a* **different binding site** *than Group 5*
  - *Photosynthesis becomes disrupted, leading to* **rapid cell damage**
- **Key Point:**
  → *Group 6 causes* **fast, contact injury**, *not slow systemic death.*

GROUP 6 MOA

- **How Group 6 Herbicides Kill Weeds**
  - *Herbicide absorbed through* **leaf tissue**
  - *Moves into chloroplasts*
  - *Inhibits Photosystem II electron transport*
  - *Energy absorbed from sunlight cannot be used*
- **Reactive oxygen species (ROS)** *form*
  - *Cell membranes rupture → tissue desiccation*
- 📌 **This damage is light-driven and rapid.**

WHY GROUP 6 WORK SO FAST

- **Contact Activity Explained**
  - *Minimal translocation in the plant*
  - *Injury occurs only where spray contacts green tissue*
  - *Sunlight accelerates damage*
  - *No meaningful root uptake or residual activity*
- → *Coverage is critical for good control.*

GROUP 6 FIELD SYMPTOMS

- **What You See After Application**
  - *Leaf speckling or spotting*
  - *Rapid chlorosis (yellowing)*
  - *Necrosis within* **hours to 2 days**
  - *Burned appearance on treated leaves*
  - *Regrowth possible if growing points are missed*
- ❗ *Symptoms often look like* **chemical burn or scorch**.

ABSORPTION & MOVEMENT

- **How Group 6 Behaves in Plants**
  - *Absorbed through* **foliar tissue only**
  - *Very limited movement inside the plant*
  - *No downward translocation to roots*
  - *Requires* **thorough spray coverage**
- 📌 *Poor coverage = poor control.*

- **Why They're Still Used**
- ✓ *Rapid weed injury*
  ✓ *Useful POST broadleaf option*
  ✓ *No soil persistence*
  ✓ *Low risk of carryover injury*
  ✓ *Valuable rotation tool*

LIMITATIONS & CHALLENGES

- **What to Watch For**
  - *Weak on grasses*
  - *Limited activity on large weeds*
  - *No control of underground growing points*
  - *Can require multiple passes*
  - *Coverage and timing are critical*
- → *Best on* **small, actively growing broadleaf weeds**.

RESISTANCE CONSIDERATIONS

- *Resistance is* **less widespread** *than Groups 5 or 7*
- *Documented resistance exists in some species*
- *Resistance typically involves:*
  - *Reduced binding*
  - *Enhanced metabolism*
- 📌 *Rotation is still essential.*

MOA—PHOTOSYNTHESIS INHIBITORS

- *Group 7—Photosystem II Inhibitors*
  - *Different binding site than Group 5 & 6*
  - *Ureas—linuron (Linex)*
  - *Cotton: Diuron*
  - *Corn/Soybeans: Limited use*

GROUP 7 — PSII RESIDUAL INHIBITORS

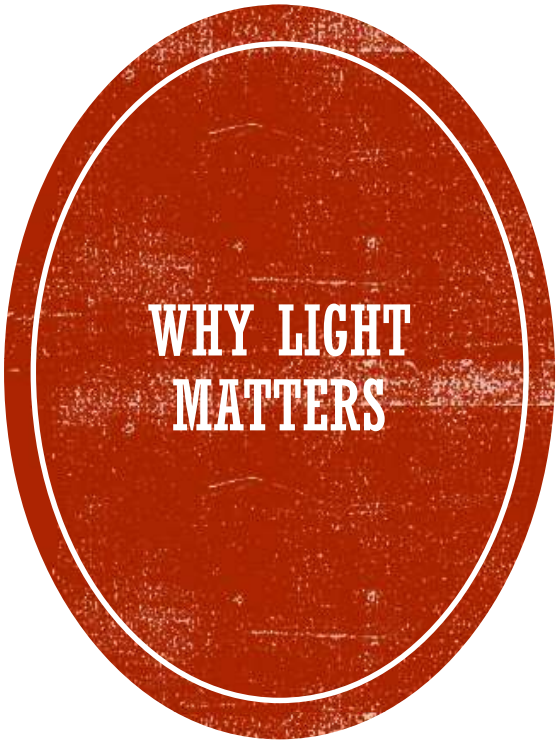
- *Key Herbicides:*
  - *Diuron*
  - *Linuron*
- *Controls:*
  - *Annual grasses*
  - *Small-seeded broadleaves*

HOW GROUP 7 HERBICIDES WORK

- **Basic Definition**
  - *Group 7 herbicides inhibit* **Photosystem II (PSII)** *in photosynthesis*
  - *They block* **electron transport**, *similar to Groups 5 and 6*
- **Key difference:** *Group 7 binds at a* **different site on the D1 protein**
- **Key Point:**
  → *Same photosynthetic system,* **different binding site**, *different resistance profile.*

GROUP 7 MOA—HOW THEY KILL WEEDS

- *Herbicide absorbed primarily through* **roots**, *sometimes foliage*
- *Translocated to green tissue*
- *Binds to PSII at the* **Group 7-specific site**
- *Electron transport is blocked*
- *Light energy cannot be processed*
- **Reactive oxygen species (ROS)** *accumulate*
- *Cell membranes are destroyed → tissue death*
- 📌 **Light is required for injury to occur.**



Light-Activated Injury

- *PSII inhibitors require* **active photosynthesis**
- *Injury is faster under:*
  - *Bright sunlight*
  - *Warm temperatures*
- *Damage often increases rapidly after emergence into sunlight*
- → *Symptoms may appear suddenly after sunny conditions.*

GROUP 7 MAJOR HERBICIDES

- **Common Active Ingredients**
  - **Diuron**
  - **Linuron**
- **Typical Uses**
  - *Soil-applied PRE or early POST*
  - *Residual weed control*
- *Frequently used in* **row crop and perennial systems**

ABSORPTION & USES

- **How Group 7 Is Commonly Used**
- *Primarily* **soil-applied**
- *Uptake mainly through* **roots**
- *Limited foliar activity on small weeds*
- *Provides* **residual control**
- *Crop selectivity often based on* **metabolism or placement**
- 📌 *Residual activity depends on soil type and rainfall.*

WHY ARE GROUP 7 HERBICIDES VALUEABLE

- **Why They're Valuable**
- ✓ *Effective residual control*
  ✓ *Good activity on small emerged weeds*
  ✓ *Useful PRE and early POST option*
  ✓ *Different PSII binding site than Groups 5 and 6*
  ✓ *Important tool in resistance management*

RESISTANCE CONSIDERATIONS

- **What to Know**
- *Resistance exists but is* **less widespread** *than Group 5*
- *Resistance mechanisms:*
  - *Target-site mutations*
  - *Enhanced metabolism*
- *Cross-resistance:*
  - *Possible* **within Group 7**
  - *Not guaranteed across Groups 5, 6, and 7*
- 📌 *Binding site differences matter in MOA rotation.*

MOA—NITROGEN METABOLISM

- *Group 10—Glutamine Synthesis Inhibitor*
  - *Liberty (glufosinate)*
  - *Non-selective herbicide*
  - *No movement within plant*
    - *Spray coverage is critical*
  - *Little or no soil activity*
  - *Corn: Glufosinate (Liberty)*
  - *Cotton: Glufosinate (LibertyLink)*
  - *Soybeans: Glufosinate (LibertyLink)*

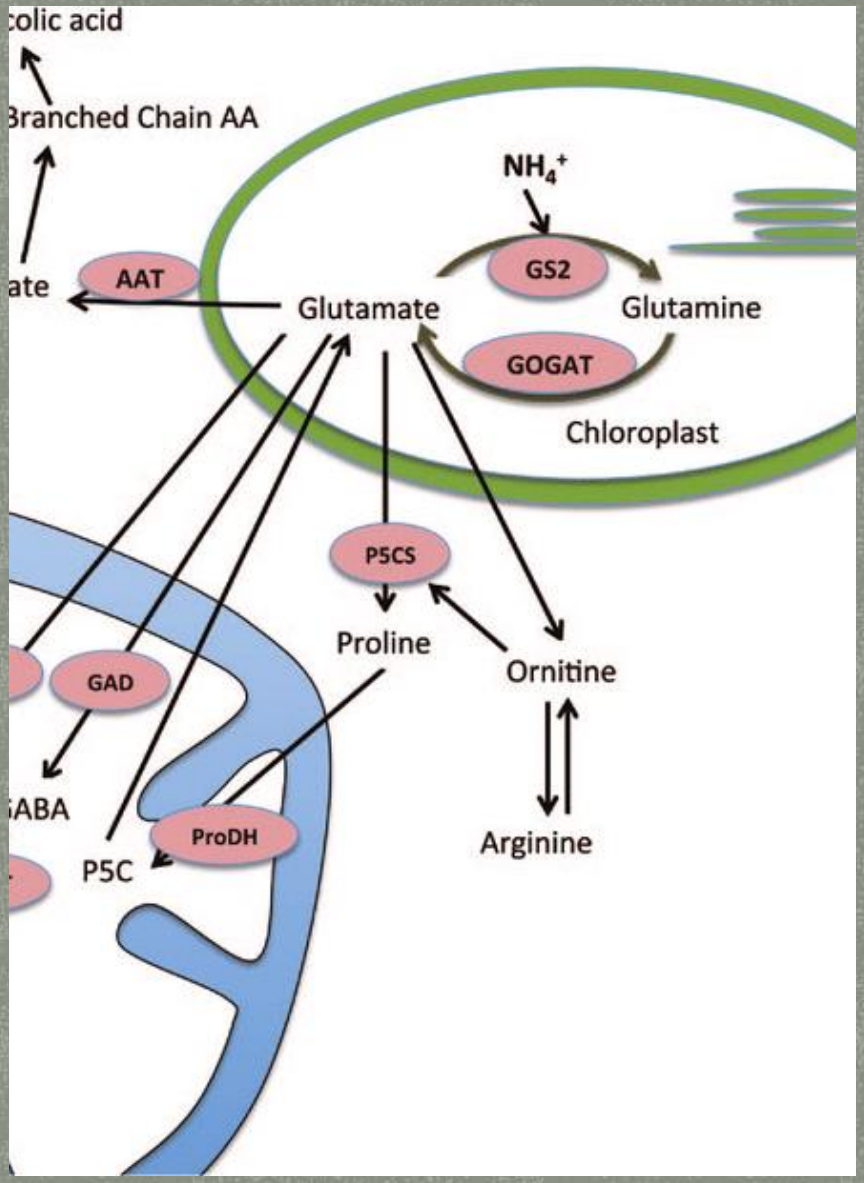
GROUP 10 – GLUTAMINE SYNTHETASE INHIBITORS

- *Key Herbicide:*
  - *Glufosinate*
- *Controls:*
  - *Glyphosate-resistant pigweed*
  - *Annual grasses*
  - *Broadleaves*

WHAT ARE GROUP 10 HERBICIDES

- **Basic Definition**
  - *Group 10 herbicides inhibit the enzyme* **glutamine synthetase (GS)**
  - *GS is essential for:*
    - *Nitrogen metabolism*
    - *Ammonia detoxification*
    - *Amino acid synthesis*
  - *Blocking GS causes* **toxic ammonia buildup** *in plant cells*
- **Key Point:**
  → *Plants poison themselves internally.*

- **How Group 10 Herbicides Kill Weeds**
  - *Herbicide absorbed through green tissue*
  - *Inhibits* **glutamine synthetase**
  - *Ammonia rapidly accumulates in cells*
  - *Photosynthesis shuts down*
  - *Cell membranes are destroyed*
  - *Rapid tissue death occurs*
- 📌 **Light accelerates injury**, *similar to contact herbicides.*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Branched Chain AA
ate
AAT
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NH_4^+
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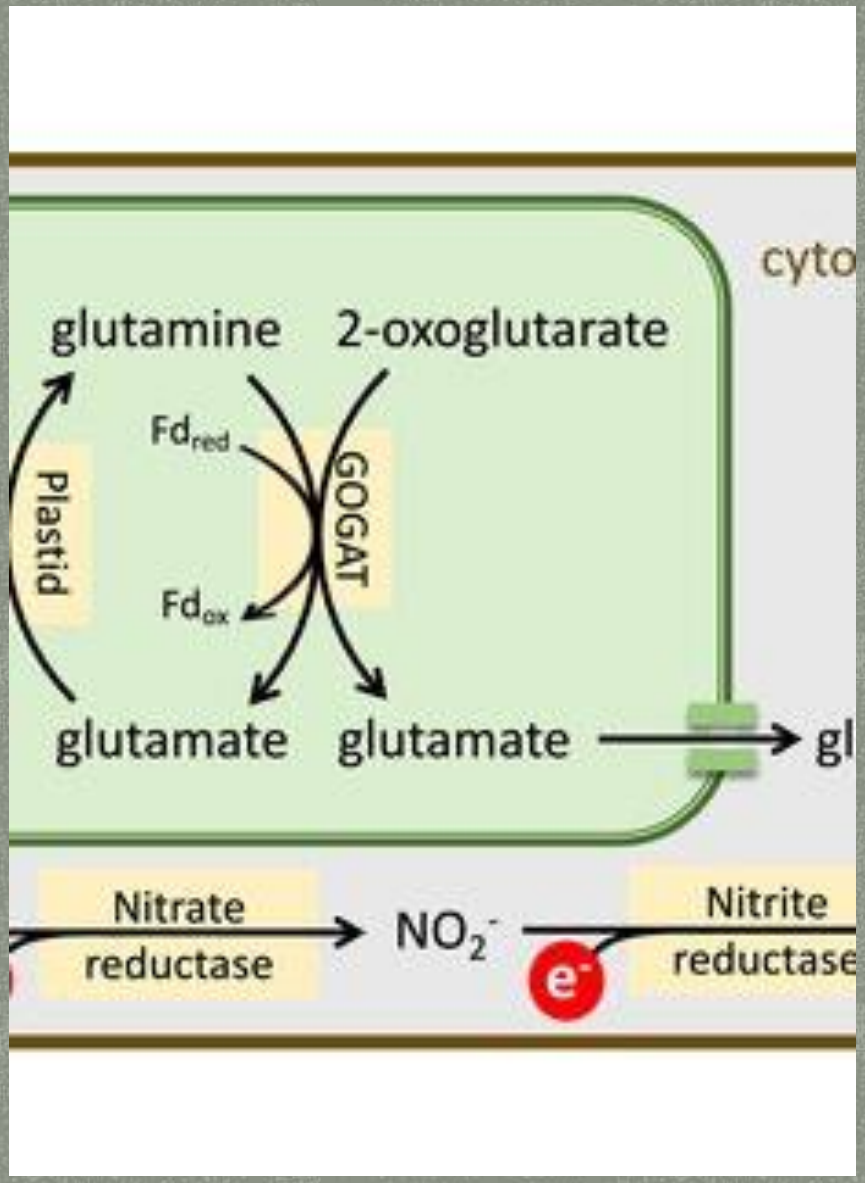
P5CS
Proline
Ornitine
GAD
ABA
ProDH
P5C
Arginine


cyto
glutamine
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Fd_{red}
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Plastid
GOGAT
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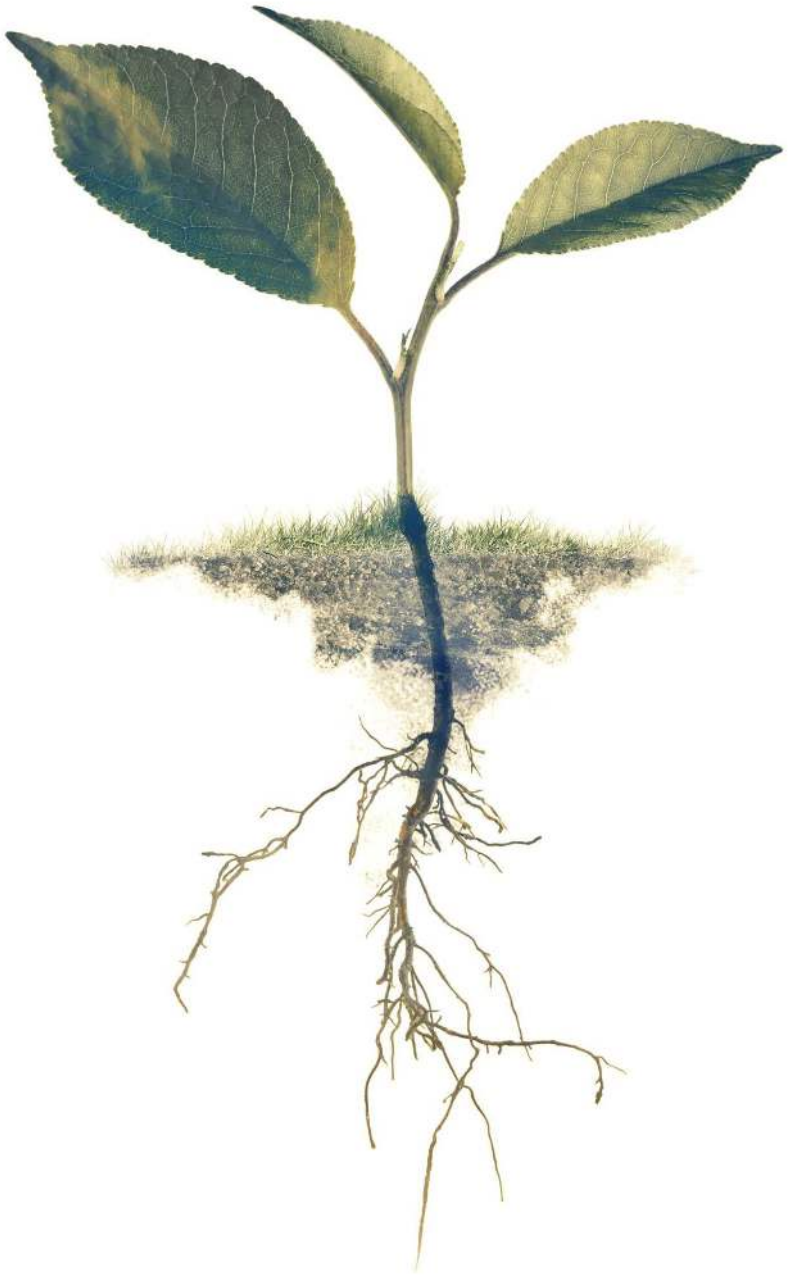
glutamate
gl
Nitrate
reductase
NO_2^-
Nitrite
reductase
e⁻

WHY INJURY HAPPENS SO FAST

Ammonia Toxicity Explained

- *Ammonia damages:*
  - *Chloroplasts*
  - *Cell membranes*
- *Photosynthesis is interrupted almost immediately*
- *Plant cannot detoxify nitrogen*
- *Tissue collapses quickly under sunny conditions*
- → *This is* **metabolic poisoning**, *not growth regulation.*

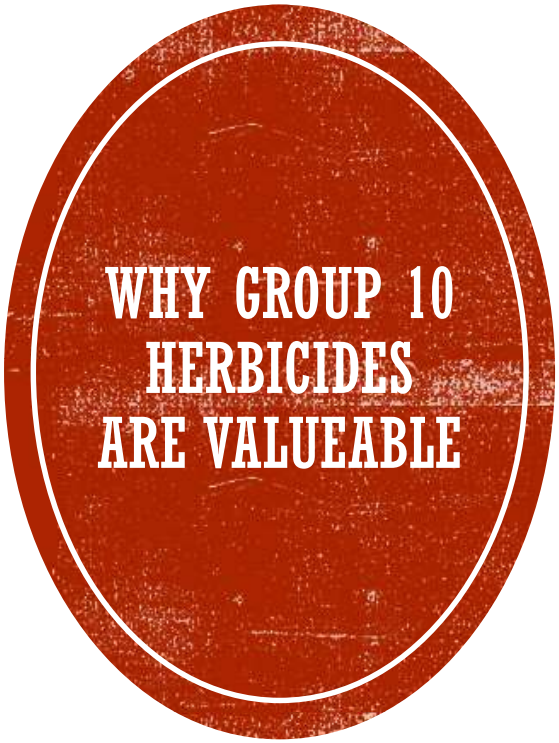


Absorption and Movement

- **Contact Activity**
- *Absorbed through* **foliar tissue only**
- *Very limited movement within the plant*
- *Little to no translocation to roots or growing points*
- *Requires* **excellent spray coverage**
- 📌 *Regrowth can occur if growing points are missed.*

FIELD SYMPTOMS

- **What You See After Application**
- *Rapid chlorosis (yellowing)*
- *Leaf water-soaking*
- *Necrosis within* **1–3 days**
- *Scorched or burned appearance*
- *Incomplete control on large weeds possible*
- ❗ *Symptoms often resemble* **fast chemical burn**.



- **Why They're Valuable**
- ✓ *Fast activity*
  ✓ *Broad-spectrum control*
  ✓ *Effective on many glyphosate-resistant weeds*
  ✓ *Different MOA than Groups 2, 4, 5, and 9*
  ✓ *Important resistance-management too*

LIMITATIONS & CHALLENGES

- **What to Watch For**
  - *Limited translocation*
  - *Coverage is critical*
  - *Less effective on large weeds*
  - *No residual activity*
  - *Performance reduced under cool, cloudy conditions*
- → *Timing and application quality are everything.*

RESISTANCE CONSIDERATIONS

Current Status

- *Resistance exists but is* **far less common** *than Group 9*
- *Documented species include:*
  - *Ryegrass*
  - *Palmer amaranth (isolated cases)*
- *Resistance mechanisms include:*
  - *Reduced uptake*
  - *Enhanced metabolism*
- 📌 *Stewardship now prevents major problems later.*

KEYS TO SUCCESS

- **Using Group 10 Effectively**
  - *Target* **small, actively growing weeds**
  - *Use* **high spray volumes**
  - *Apply under* **warm, sunny conditions**
  - *Rotate and mix with other effective MOAs*
  - *Control escapes before seed production*
- ❗ *Group 10 is best used as a* **precision POST tool**, *not a rescue treatment.*

MOA—PPO INHIBITORS

- *Group 14—PPO Inhibitors*
  - *Diphenylether*
    - *Reflex*
  - *N-phenylphthalimide*
    - *Valor*
  - *Aryl triazinone*
    - *Aim*
  - *Corn: Flumioxazin (Valor – PRE)*
  - *Cotton: Fomesafen (Reflex), Flumioxazin (Valor-Pre & Hood)*
  - *Soybeans: Fomesafen (Reflex), Sulfentrazone (Authority)*

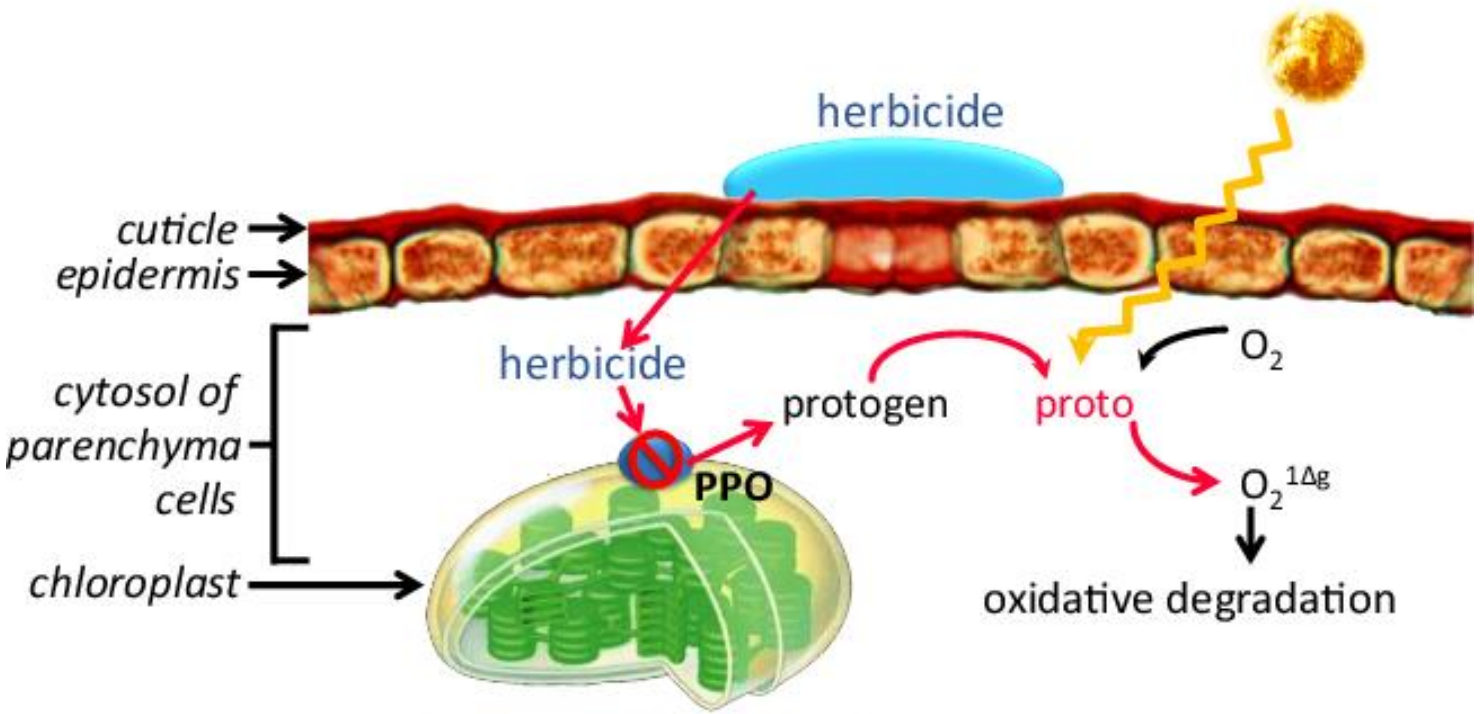
GROUP 14 – PPO INHIBITORS

- *Key Herbicides:*
  - *Fomesafen (Reflex)*
  - *Lactofen (Cobra)*
  - *Flumioxazin (Valor)*
  - *Sulfentrazone (Spartan)*
  - *Saflufenacil (Sharpen)*
  - *Oxyfluorfen (Goal)*
  - *Tiafenacil (Reviton)*
- *Controls:*
  - *Palmer amaranth*
  - *Waterhemp*
  - *Morningglory*
- → *Different chemistries,* **same PPO target enzyme**

WHAT ARE GROUP 14 HERBICIDES

Basic Definition

- *Group 14 herbicides inhibit* **PPO (protoporphyrinogen oxidase)**
- *PPO is a key enzyme in:*
  - **Chlorophyll synthesis**
  - **Heme synthesis**
- *Inhibition causes buildup of* **phototoxic compounds**
- *Some only have contact activity and some have contact and residual*
- **Key Point:**
  → *Plants generate toxic molecules that destroy their own cell membranes.*


herbicide
cuticle
epidermis
herbicide
protogen
proto
O_2
cytosol of parenchyma cells
PPO
$O_2^{1\Delta g}$
chloroplast
oxidative degradation

- **How Group 14 Herbicides Kill Weeds**
  - *Herbicide absorbed through leaves and/or roots*
  - *PPO enzyme is inhibited*
  - *Protoporphyrinogen IX accumulates*
  - *Converts to* **protoporphyrin IX** *in light*
  - *Reactive oxygen species (ROS) form*
  - **Cell membranes are destroyed** → *tissue death*
- 📌 **Light and oxygen are required** *for injury.*

WHY ARE RESULTS SO FAST

- **Light-Activated Cell Destruction**
- *Toxic compounds react with:*
  - *Sunlight*
  - *Oxygen*
- *Lipid peroxidation damages membranes*
- *Cells lose integrity and leak*
- *Visible injury occurs* **within hours**
- → *This is why symptoms appear rapidly under bright conditions.*

ABOSORPTION & MOVEMENT

- **Contact-Dominant Activity**
- *Absorbed through:*
  - **Foliar tissue**
  - **Roots** *(some compounds)*
- *Limited translocation in most species*
- *Injury occurs mainly at contact points*
- *Coverage is critical for POST applications*
- 📌 *Some Group 14s provide* **soil residual activity**.

FIELD SYMPTOMS

- **What You See After Application**
- *Speckling or flecking on leaves*
- *Bronzing or reddening*
- *Rapid necrosis*
- *Leaf crinkling or desiccation*
- *Death of small weeds within* **1–3 days**
- ❗ *Often described as "***leaf burn***" or "***scorch***".*

WHERE GROUP 14 HERBICIDES FIT

- *Preemergence (PRE) residual control*
- *Postemergence (POST) contact activity*
- *Broadleaf-focused control*
- *Important tool in* **resistance-management programs**

📌 *Performance influenced by:*

- *Soil texture and OM (PRE)*
- *Coverage and sunlight (POST)*

STRENGTHS OF GROUP 14 HERBICIDES

Why They're Valuable

- ✓ *Fast, visible activity*
  ✓ *Effective on many ALS- and glyphosate-resistant weeds*
  ✓ *PRE + POST flexibility*
  ✓ *Multiple formulations and placements*
  ✓ *Critical for pigweed management*

RESISTANCE CONSIDERATIONS

What to Know

- *PPO resistance now confirmed in:*
  - *Waterhemp*
  - *Palmer amaranth*
- *Resistance mechanisms include:*
  - *Target-site mutations*
  - *Enhanced metabolism*
- *Cross-resistance* **within Group 14** *can occur*
- 📌 *PPOs must be protected through stewardship.*

STEWARDSHIP & BEST PRACTICES

- **Using Group 14 Effectively**
- *Apply to* **small weeds**
- *Ensure excellent coverage for POST use*
- *Use* **labeled PRE rates** *for residual control*
- *Rotate with* **effective non-PPO MOAs**
- *Avoid back-to-back PPO-only programs*
- ❗ *Group 14 works best as a* **program cornerstone**, *not a rescue pass.*

MOA—CELL MEMBRANE DISRUPTERS

- *Group 22—Photosystem 1 Electron Diverter*
  - *Bipyridilium*
    - *Paraquat (Gramoxone)*
- *Corn: Paraquat (burndown)*
- *Cotton: Paraquat (burndown/hooded)*
- *Soybeans: Paraquat (burndown)*

GROUP 22 – PSI ELECTRON DIVERTERS

- *Key Herbicides:*
  - *Paraquat*
  - *Diquat*
- *Controls:*
  - *Small emerged weeds*
  - *Burndown targets*

WHAT ARE GROUP 22 HERBICIDES?

- *Divert electrons from Photosystem I (PSI)*
- *Disrupt normal photosynthesis*
- *Generate reactive oxygen species (ROS)*
- *Cause rapid cell membrane destruction*

- *Absorbed through green tissue*
- *Intercepts PSI electrons*
- *Free radicals form*
- *Lipid peroxidation occurs*
- *Cells rupture rapidly*

WHY INJURY IS SO FAST

- *Free radicals attack membranes*
- *Chloroplast damage*
- *Immediate desiccation*
- *No recovery of damaged tissue*

ABSORPTION & MOVEMENT

- *Foliar absorption only*
- *No translocation*
- *Contact activity*
- *Growing points must be sprayed*

FIELD SYMPTOMS

- *Rapid leaf speckling*
- *Water-soaked tissue*
- *Browning or blackening*
- *Complete burn-down within hours*

STRENGTHS

- *Extremely fast control*
- *Effective on resistant weeds*
- *Useful burndown tool*
- *No soil carryover*
- *Needed as a desiccant harvest aid in cotton*

LIMITATIONS & RISKS

- *No systemic activity*
- *Regrowth possible*
- *Severe crop injury if contacted*
- *Applicator safety concerns*

RESISTANCE CONSIDERATIONS

- *Resistance less common*
- *Documented in ryegrass*
- *Stewardship still required*

BEST MANAGEMENT PRACTICES

- *Target small weeds*
- *Excellent spray coverage*
- *Apply in bright sunlight*
- *Rotate MOAs*
- *Follow safety labels*

GROUP 27 – HPPD INHIBITORS

- *Corn: Mesotrione (Callisto), Tembotrione (Laudis)*
- *Cotton: HPPD Resistant Varieties—to be labeled someday*
- *Soybeans: HPPD Resistant Varieties—to be labeled someday*

GROUP 27 – HPPD INHIBITORS

- *Key Herbicides:*
  - *Mesotrione (Callisto)*
  - *Tembotrione (Laudis)*
  - *Isoxaflutole (Balance, Alite 27)*
  - *Topramezone (Impact, Armezon)*

- *Controls:*
  - *Broadleaf weeds*
  - *Pigweed*
  - *Waterhemp*

WHAT ARE GROUP 27 HERBICIDES?

- *Inhibit HPPD enzyme (4-hydroxyphenylpyruvate dioxygenase)*
- *HPPD needed for carotenoid production*
- *Carotenoids protect chlorophyll from light damage*

- *Key Point: Without carotenoids, plants bleach and die*

MODE OF ACTION

1. *Herbicide absorbed by roots or leaves*
2. *HPPD enzyme inhibited*
3. *Carotenoid synthesis stops*
4. *Chlorophyll becomes unprotected*
5. *Light destroys chlorophyll*
6. *Photosynthesis stops*

- *Carotenoids protect chlorophyll from photooxidation*
- *Loss of carotenoids allows light damage*
- *Leaves turn white, then necrotic*
- *Injury worsens under bright sunlight*

ABSORPTION AND MOVEMENT

- *Root uptake (PRE activity)*
- *Foliar uptake (POST activity)*
- *Systemic movement within plant*
- *Affects growing points and new leaves*

FIELD SYMPTOMS

- *Whitening of new leaves*
- *Pale yellow tissue progressing to white*
- *Necrosis after bleaching*
- *Plant death in days to weeks*

- *PRE and early POST applications*
- *Broadleaf weed control*
- *Widely used in corn systems*
- *Often tank-mixed with atrazine*

STRENGTHS

- *Unique bleaching mode of action*
- *Strong broadleaf control*
- *PRE and POST flexibility*
- *Key resistance management tool*

RESISTANCE CONSIDERATIONS

- *Resistance confirmed in waterhemp and Palmer amaranth*
- *Often metabolism-based resistance*
- *Cross-resistance possible within Group 27*

- *Apply to small, actively growing weeds*
- *Use multiple effective MOAs*
- *Follow label rates and timings*
- *Prevent seed production*

MOA—SEEDLING ROOT GROWTH INHIBITORS

- *Group 3—Microtubule Inhibitors*
  - *Dinitroaniline*
    - *Prowl, Treflan*

GROUP 3 – MICROTUBULE INHIBITORS

- *Key Herbicides:*
  - *Trifluralin (Treflan)*
  - *Pendimethalin (Prowl)*
  - *Prodiamine (Barricade)*
- *Controls:*
  - *Annual grasses*
  - *Some small-seeded broadleaves*

WHAT ARE GROUP 3 HERBICIDES?

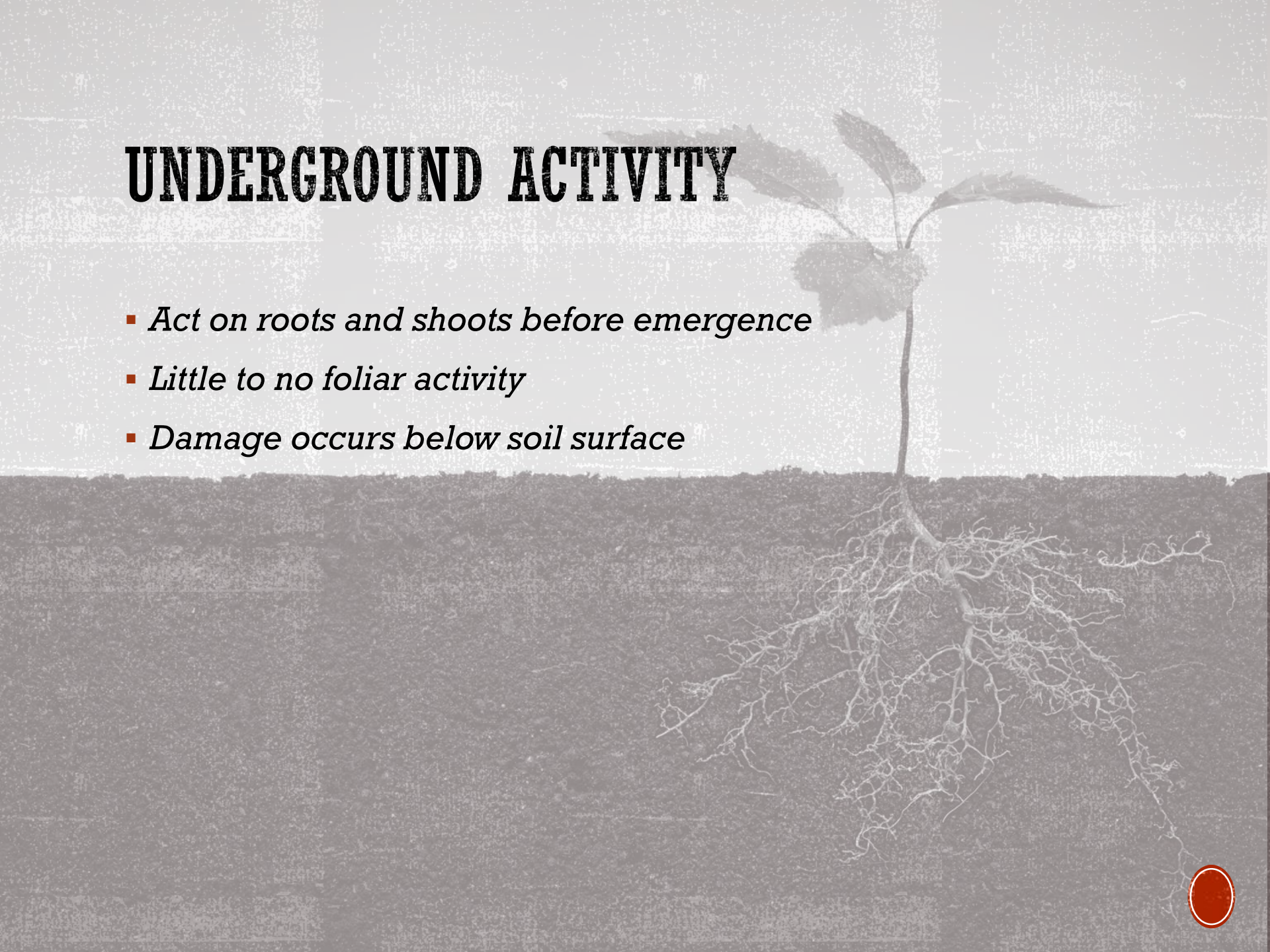
- *Inhibit microtubule formation*
- *Prevent cell division (mitosis)*
- *Roots and shoots cannot develop*

- *Key Point: Weeds die before or just after emergence*

- *Applied PRE or PPI*
- *Absorbed by germinating seedlings*
- *Microtubules cannot form*
- *Cell division stops*
- *Roots and shoots fail*

UNDERGROUND ACTIVITY

- *Act on roots and shoots before emergence*
- *Little to no foliar activity*
- *Damage occurs below soil surface*



ABSORPTION & MOVEMENT

- *Soil-applied herbicides*
- *Absorbed by roots and shoots*
- *Not translocated*
- *No POST activity*

FIELD SYMPTOMS

- *Poor weed emergence*
- *Stunted or missing seedlings*
- *Clubbed or pruned roots*
- *Weeds often absent*

Early-season grass control

PRE or PPI programs

Requires rainfall or incorporation

Strong on annual grasses

STRENGTHS

- *Excellent grass control*
- *Long residual activity*
- *Low POST resistance pressure*
- *Foundation PRE herbicides*

LIMITATIONS

No activity on emerged weeds

Limited broadleaf control

Dry soils reduce performance

Proper placement critical

RESISTANCE CONSIDERATIONS

- *Resistance documented (ryegrass, goosegrass)*
- *Target-site resistance*
- *Rotate with other PRE MOAs*

MOA—SEEDLING SHOOT GROWTH INHIBITORS

- *Group 15—Long-chain Fatty Acid Inhibitor (Lipid inhibitors)*
  - *Chloroacetamide*
    - *Dual II Magnum, Outlook, Warrant*
  - *Corn: S-metolachlor (Dual), Acetochlor (Warrant), Pyroxasulfone (Zidua)*
  - *Cotton: Dual, Warrant, Zidua*
  - *Soybeans: Dual, Warrant, Zidua*

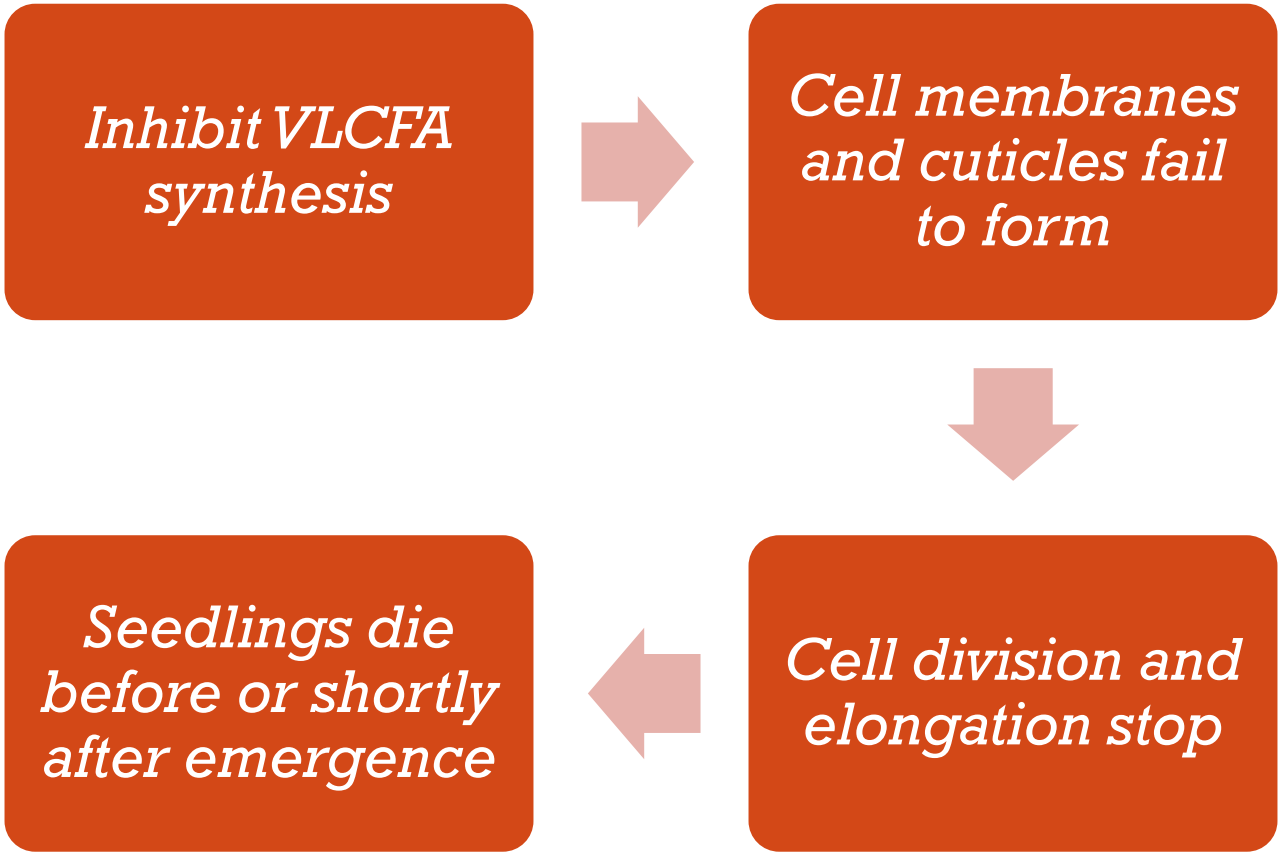
GROUP 15 – VLCFA INHIBITORS

- *Key Herbicides:*
  - *S-metolachlor (Dual)*
  - *Acetochlor (Warrant)*
  - *Dimethenamid (Outlook)*
  - *Pyroxasulfone (Zidua, Anthem)*
  - *Alachlor (Lasso)*
- *Controls:*
  - *Annual grasses*
  - *Some broadleaves*

WHAT ARE GROUP 15 HERBICIDES?

- *Inhibit very-long-chain fatty acid synthesis*
- *Required for cell membranes and cuticles*
- *Seedlings fail to develop normally*

GROUP 15 – MODE OF ACTION



WHY SHOOTS ARE AFFECTED FIRST

- *Highest uptake at coleoptiles and hypocotyls*
- *Shoots fail at soil surface*
- *Roots often malformed*

ABSORPTION & MOVEMENT

- *Soil-applied PRE*
- *Requires moisture for activation*
- *No POST activity on emerged weeds*

GROUP 15 – FIELD SYMPTOMS

- *Failure to emerge*
- *Twisted or malformed shoots*
- *Grass seedlings collapse near soil surface*
- *Often observed as reduced weed density*

MAJOR GROUP 15 HERBICIDES

- *S-metolachlor (Dual)*
- *Acetochlor (Warrant)*
- *Dimethenamid (Outlook)*
- *Pyroxasulfone (Zidua, Anthem)*
- *Alachlor (Lasso)*

USE PATTERNS

- *Foundation PRE residuals*
- *Strong grass control*
- *Used in corn, cotton, soybean, sorghum*

STRENGTHS

- *Long residual*
- *Excellent grass control*
- *Critical resistance tool*

LIMITATIONS

- *No activity on emerged weeds*
- *Requires rainfall*
- *Limited broadleaf control*

RESISTANCE CONSIDERATIONS

Low but increasing resistance

Enhanced metabolism mechanisms

STEWARDSHIP

- *Layer residuals*
- *Rotate MOAs*
- *Manage late escapes*

GROUP 12 – BLEACHING (CAROTENOID INHIBITORS)

- *Cotton: Norflurazon (Solicam, ~~Zorial~~), Fluridone (Brake)*
- *Soybeans/Corn: Limited*

GROUP 12 – PDS INHIBITORS

- *Key Herbicides:*
  - *Norflurazon (Solicam, ~~Zorial~~)*
  - *Diflufenican (Convintro)*

- *Controls:*
  - *Annual grasses*
  - *Small-seeded broadleaves*
  - *Waterhemp*
  - *Palmer amaranth*

WHAT ARE GROUP 12 HERBICIDES?

Inhibit phytoene desaturase (PDS)

PDS needed for carotenoid synthesis

Carotenoids protect chlorophyll from light damage

MODE OF ACTION

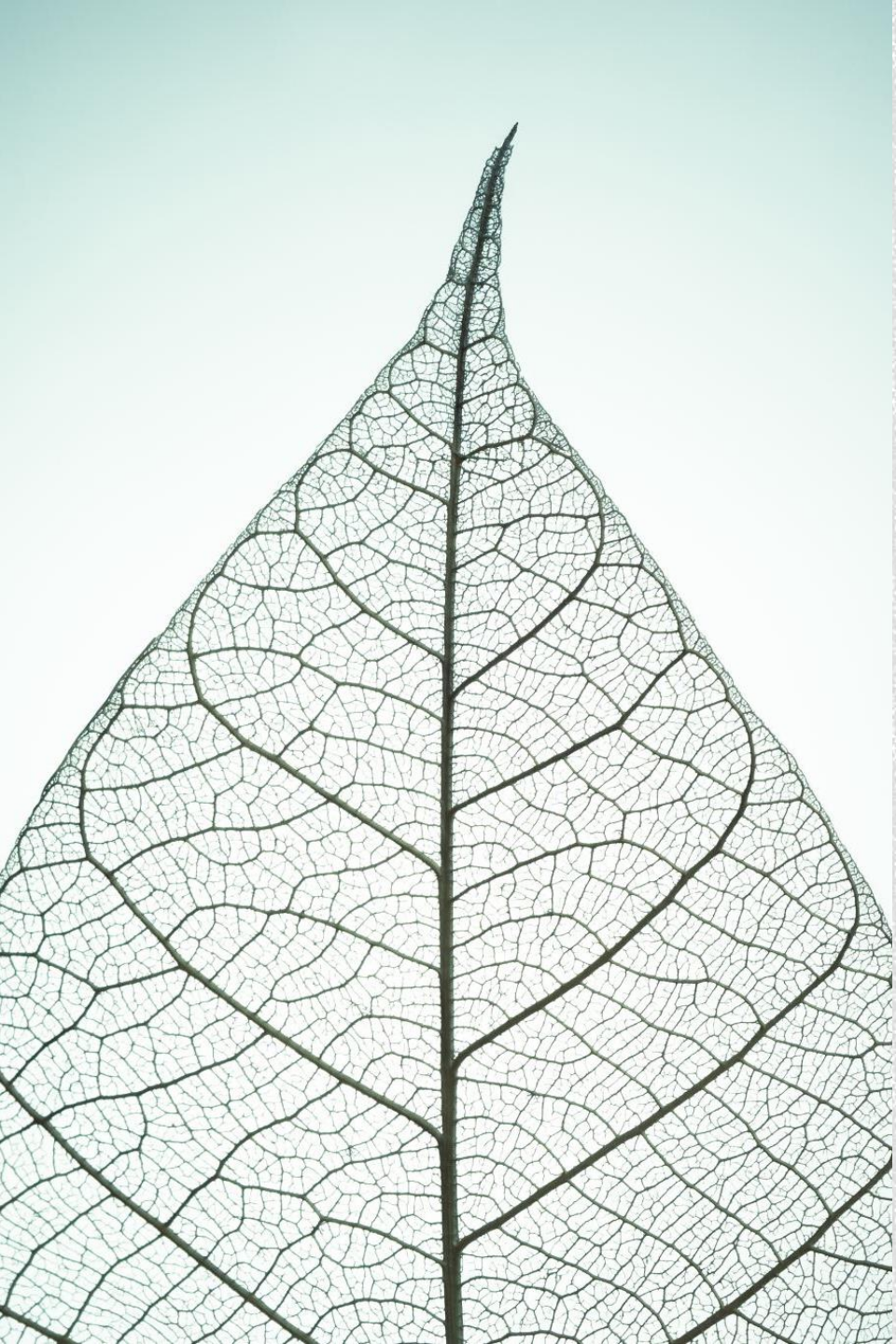
Absorbed primarily through roots

Inhibits PDS enzyme

Carotenoid production stops

Chlorophyll destroyed by light

Photosynthesis shuts down



WHY BLEACHING OCCURS

- *Loss of chlorophyll protection*
- *Reactive oxygen species form*
- *Leaves turn white*
- *Tissue eventually dies*

ABSORPTION & MOVEMENT

- *Primarily soil-applied (PRE)*
- *Absorbed by roots and shoots*
- *Translocated to new growth*
- *Limited POST activity*

FIELD SYMPTOMS

- *White or bleached leaves*
- *Pale yellow seedlings*
- *Stunting*
- *Necrosis after bleaching*

USE PATTERNS

Preemergence residual control

Annual grasses and small broadleaves

Cotton and specialty crops

STRENGTHS

- *Unique bleaching MOA*
- *Residual soil activity*
- *Resistance management value*

LIMITATIONS

Slow visual symptoms

Requires moisture

Limited postemergence control

RESISTANCE CONSIDERATIONS

- *Resistance uncommon*
- *Possible enhanced metabolism*
- *Rotate MOAs*

BEST MANAGEMENT PRACTICES

- *Use labeled rates*
- *Ensure soil moisture*
- *Tank mix with other residuals*

ELEMENTS NEEDED TO BUILD A SUCCESSFUL HERBICIDE PROGRAM

EFFECTIVE HERBICIDES MUST

- *Adequately contact plants*
- *Be absorbed by plants*
- *Move within plants to the site of action, without being deactivated*
- *Reach toxic levels at the site of action*

COTTON HERBICIDE RESISTANCE

- *Due to continuous use of post-emergence herbicide*
  - *Roundup*
- *Roundup become the primary selection mechanism*
  - *Reduced tillage to control weeds*
  - *Reduced use of other post-emergence herbicides*
  - *Reduced use of pre-emergence herbicides*

HOW DO WE PREVENT RESISTANCE?

- *Rotate chemistries as selection mechanism*
- *Rely more on pre-emergence herbicides*
- *Use all the tools in the tool box!!!*
  - *Tillage*
  - *Rotate chemistries of post-emergent herbicides*
  - *Layer residual herbicide*
    - *Pre-emergence herbicides*
    - *Lay-by herbicides*

PRE-EMERGENCE HERBICIDES

PRE-EMERGENCE HERBICIDES

- *Important factors to consider*
  - *Weed spectrum*
  - *Length of residual control*
  - *Cost*
  - *Rotational crop restrictions*
  - *Lay-by options*

PRE-EMERGENCE HERBICIDES

- *Need to combine chemistries for best results*
  - *Causes a syngeristic effect*
  - *Increases weed spectrum*
  - *Prevents weed resistance*

LOOK AT ROTATING CHEMISTRIES DIFFERENTLY

- *Water Solubility?*
  - *Maximum possible concentration of a substance dissolved in water. Water soluble substances easily rinse off with water and disperse readily through the environment on release.*
- *Soil adsorption?*

WATER SOLUBILITY

More water soluble	• *Less water needed to incorporate* • *More mobile in soil* • *More subject to loss with larger amounts of water received* • *Big rains or irrigation*
Less water soluble	• *More water needed to incorporate* • *Less mobile in soil* • *Longer lasting despite rainfall or irrigation*

INCORPORATING PRE-EMERGENCE HERBICIDES

- *Must be incorporated for best results.*
  - *Herbicide needs to be in the soil where weed seeds will absorb the herbicide.*
  - *Incorporation requirements vary with herbicide*
    - *0.25-1.0" water required*
    - *Are we irrigating after planting to get the crop up or to get herbicide incorporated?*
      - *How can we adjust?*
  - *With some materials, too much irrigation/rainfall may cause some crop injury.*
    - *Do not apply over 1 inch of water to incorporate.*

GROUP 5-COTTON HERBICIDES

- *Caparol (Prometryn)*
  - *Adsorption is related to % Clay in Soil rather than % OM*
  - *Atrazine is more mobile than Caparol*
  - *Caparol is least mobile herbicide in this class*
  - *Half life = 60 days*

GROUP 7—COTTON HERBICIDES

- *Direx (diuron)*
  - *Selectivity is often based on placement*
  - *Relatively persistent in soil (half life is typically 6 months)*
  - *Remains in the upper 1 inch of soil (does not leach readily)*
- *Linex (linuron)*
  - *Do not use on sandy soils or soils with less than 1% OM*
  - *Half life = 2-5 months*
    - *1 lb ai lasts about 4 months*
  - *Does not leach*
  - *Activity decreases as OM increases*

GROUP 7-COTTON HERBICIDES

- *Cotoran (Fluometuron)*
  - *Least Persistent of the urea herbicides*
  - *Half life = 30 days*
  - *More mobile in soil than direx & linex*
  - *Do not use on sand, loamy sand or fine sandy loam soils.*

GROUPS 5 & 7 TAKE HOME MESSAGE

- *Commonly referred to as "white herbicides"*
- *Very similar activity*
- *Soil Activity*
  - *Direx>Linex>Cotoran>Caparol*
- *Leachability*
  - *Cotoran>Caparol>Linex>Direx*
- *Post-Activity*
  - *Linex has the most post emergent activity*
  - *Direx is next*
  - *Cotoran & Caparol have very little post activity*

GROUP 3-COTTON HERBICIDES

- *Known as the Yellow Herbicides*
- *Trust (Trifluralin) aka Treflan*
  - *Extremely low water solubility (0.3 ppm)*
    - *Very little leaching*
    - *Strongly adsorbed by soil*
      - *Immobile in sand, sandy loam, silt, loam, and clay loam soils*
  - *Must be applied PPI due to volatility and photodecomposition*
  - *Half life is 2-4 months*
    - *Persists in soil for 6 months*

GROUP 3-COTTON HERBICIDES

- *Prowl 3.3 EC (Pendimethalin)*
  - *Similar water solubility to Trust (0.275 ppm)*
    - *More mobile in soil than Trust*
  - *Strongly adsorbs to OM and clay (tied up)*
  - *Half life = 90 days*
- *Prowl H2O*
  - *Encapsulated formulation*
    - *Better surface stability (ie photodegradation/volatility is lower*
    - *Does not require mechanical incorporation*

GROUP 15-COTTON HERBICIDES

- *Dual Magnum (S-metolachlor)*
  - *Generics available (Charger, Medal, Brawl)*
  - *Water solubility = 480 ppm*
    - *Rainfall/irrigation intesity and timing influence movement in soil*
  - *Average half life is 43 days*
    - *But very dependent on environmental conditions*
    - *Can vary from 15-132 days (43 days)*
  - *Adsorbs moderately to soil*
    - *Increases with OM and Clay content*
    - *Leaching is inhibited in soils with high clay and/or silt*
  - *Can Photodegrade*
    - *50% degradation on sunlit soils in 8 days (WSSA, 1994)*

GROUP 15-COTTON HERBICIDES

- *Outlook (Dimethenamid-P)*
  - *Post-emegence to cotton use only (no pre)*
  - *Half-life = 21 days*
  - *High water solubility (1450 ppm)*
    - *Requires relatively little water to incorporate (0.25")*
    - *Good fit on drip & dryland*
    - *Prone to loss with large rains or irrigations*

GROUP 15-COTTON HERBICIDES

- *Warrant (Acetochlor)*
  - *Used 1970-1990's as Harness and Surpass in Corn*
  - *Warrant is encapsulated form*
  - *Water solubility = 223 ppm*
  - *Not strongly adsorbed by soil*
  - *Half life = 14 days*
  - *Residual is ~30 days due to encapsulated form*
  - *Apply at least 0.75" water to incorporate*
  - *When applying with Roundup, wait 2-3 days before incorporating*

GROUP 15-COTTON HERBICIDES

- *Zidua (Pyroxasulfone)*
  - *Also sold by FMC as Anthem Flexx (Pyroxasulfone + Aim)*
  - *Postemergence-directed application in cotton only*
    - *Lay-by (5th leaf to early bloom)*
    - *Best with hooded sprayer*
  - *Water solubility = 3.5 ppm*
  - *Less tightly bound to clay and organic matter*
  - *Half life = 20-30 days*
  - *Incorporate with at least 0.75" water*

HOW LONG WILL MY RESIDUAL HERBICIDE LAY THERE IN A DRY PERIOD?

- **Dual Magnum / *s*-metolachlor** – *½ of it is gone in* **~8 days**
- **Outlook** – *½ of it is gone in* **~15 days**
- **Zidua** – *at 3 weeks,* **you still have 90%** *of your Zidua laying there waiting on a rain.*

HERBICIDE PLACEMENT

- *Group 15 herbicides must be in the germination zone of the target weed seedling.*
  - *Crop tolerance is somewhat dependent on placement as well. Example--Cotton*
- *If herbicide is above and seed is below = survival!!*
- *Correct incorporation is key!!!*
  - *Must move the herbicide at least 1 inch deep to prevent pigweed germination.*

HERBICIDE INCORPORATION

- *Are we irrigating to germinate crop or to incorporate herbicide?*
  - *Small seeded, low vigor varieties make us focus on germinating and establishing the crop.*
- *How are we applying the water to incorporate?*
  - *LEPA?*
  - *Spray?*
  - *Efficiency?*

IRRIGATION EFFICIENCY

- *85-95% efficiency*
- *Dependent upon environmental conditions*
  - *Wind*
  - *Humidity*
  - *Temperature*
- *Consistent pressure?*
- *Proper nozzle package*
- *KNOW HOW MUCH YOU ARE APPLYING!!*

- *Apply 1” @ 85% efficiency = 0.85”*
- *Apply 1.17” @ 85% efficiency = 0.99”*
- *Applying to bare soil no cover crop, actual efficiency closer to 70%*
  - *1.17” @ 70% = 0.82”*

GROUP 15-TAKE HOME MESSAGE

Water solubility

- *Zidua<Warrant<Dual<Outlook*
- *More water needed to incorporate Dual (1" or more)*
- *Less water for Outlook (0.5" or less)*

Half Life

- *Warrant<Outlook<Zidua<Dual*
- *Dual lasts longest, Warrant shortest lived (encapsulation helps?)*

Adsorption to clay and/or OM

- *Zidua<Warrant<Outlook<Dual*

POST EMERGENCE HERBICIDES (TO THE WEEDS)

- *Palmer amaranth*
- *Kochia*

Know When Your Weeds Emerge

KOCHIA

MARESTAIL

MARESTAIL

RUSSIAN THISTLE

MORNINGGLORY

FOXTAILS

WATERHEMP & PALMER AMARANTH

CRABGRASS

MUSTARD SPP.

MAR APR MAY JUNE JULY AUG SEPT OCT NOV

Source: BASF Technical Service Observations – TX

BURNDOWN APPLICATIONS

IN 2019--GLYPHOSATE WAS STILL EFFECTIVE WHEN TANK MIXED!!

FAST FORWARD TO TODAY--KOCHIA

4-5 way mixes to kill kochia

- *Roundup + 2, 4-D + Starane + Dicamba + Valor*

And/or 2 trips

- *Liberty + Reviton = KILL SHOT*

PALMER PIGWEED

- *Corn (post)*
  - *4-5 MOA's to get control*
  - *Roundup + Status + Callisto + Zidua*
- *Cotton (post)*
  - *Roundup + Dicamba (when/if labeled)*
  - *Followed by Liberty in 5-7 days*
- *Sorghum (post)*
  - *Bromoxinyl + Dicamba + Staredown*

WEED METABOLIC RESISTANCE

- *The hidden and growing challenge in herbicide performance*

- *What metabolic resistance is*
- *How it differs from target-site resistance*
- *Why it threatens all herbicide programs*

HERBICIDE RESISTANCE OVERVIEW

- *Herbicide resistance is the inherited ability of a weed to survive a lethal dose.*

- *Two major types:*
  - *Target-site resistance*
  - *Non–target-site (metabolic) resistance*

WHAT IS METABOLIC RESISTANCE?

- *Weeds detoxify herbicides before they reach the target site.*
  - *Herbicide is absorbed*
  - *Detoxified inside the plant*
  - *Target site is never affected*

HOW PLANTS DETOXIFY HERBICIDES

- *Phase I – Transformation (oxidation, hydrolysis)*
- *Phase II – Conjugation (binding to sugars or amino acids)*
- *Phase III – Sequestration (storage in vacuoles or cell walls)*

KEY ENZYMES INVOLVED

- *Cytochrome P450 monooxygenases*
- *Glutathione S-transferases (GSTs)*
- *Esterases*
- *Glycosyltransferases*

HOW METABOLIC DIFFERS FROM TARGET-SITE RESISTANCE

- *Often involves multiple genes*
- *Can impact several herbicide groups*
- *Develops gradually*
- *Difficult to diagnose in the field*

WHY METABOLIC RESISTANCE IS DANGEROUS

Can provide cross-resistance to multiple MOAs

Can impact herbicides not yet used

Undermines new chemistry

WEEDS KNOWN FOR METABOLIC RESISTANCE

- *Waterhemp*
- *Palmer amaranth*
- *Kochia*
- *Italian ryegrass*

Group 1 – ACCase inhibitors

Group 2 – ALS inhibitors

Group 5/6/7 – PSII inhibitors

Group 14 – PPO inhibitors

Group 15 – VLCFA inhibitors

Group 27 – HPPD inhibitors

HOW METABOLIC RESISTANCE DEVELOPS

- *Repeated herbicide exposure*
- *Sublethal doses*
- *Poor timing or coverage*
- *Limited diversity in weed control*

FIELD INDICATORS

- *Gradual loss of control*
- *Partial injury instead of full death*
- *Multiple MOAs underperform*
- *Larger weeds escaping*

Rotation alone is not enough

Programs must emphasize diversity

Prevent early-season weed emergence

INTEGRATED RESISTANCE MANAGEMENT

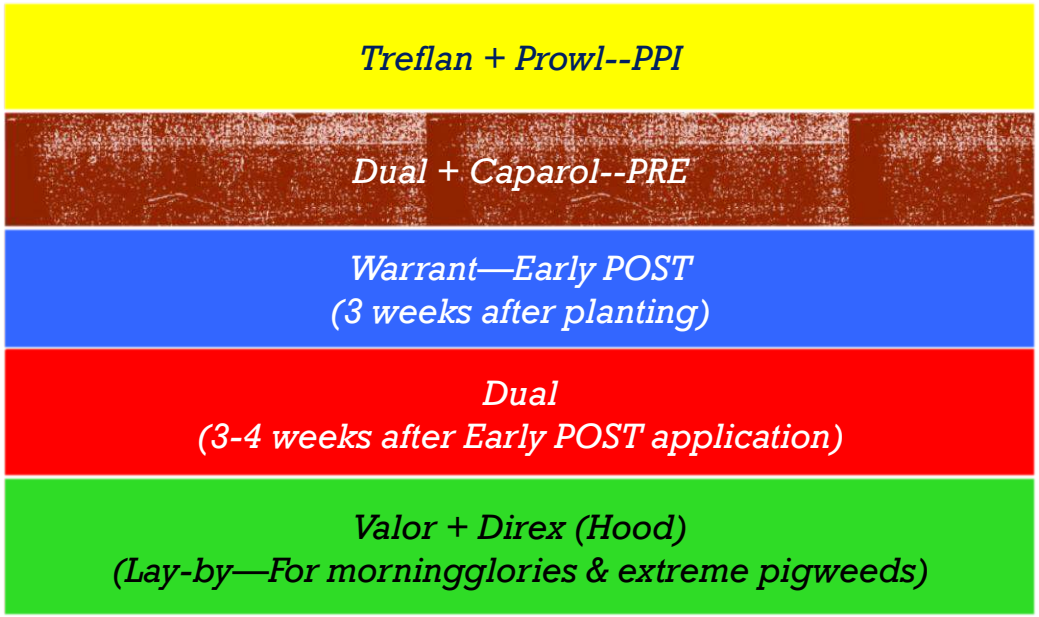
- *Multiple effective MOAs at once*
- *PRE + early POST programs*
- *Crop and cultural rotation*
- *Zero tolerance for escapes*

KEY TAKEAWAYS

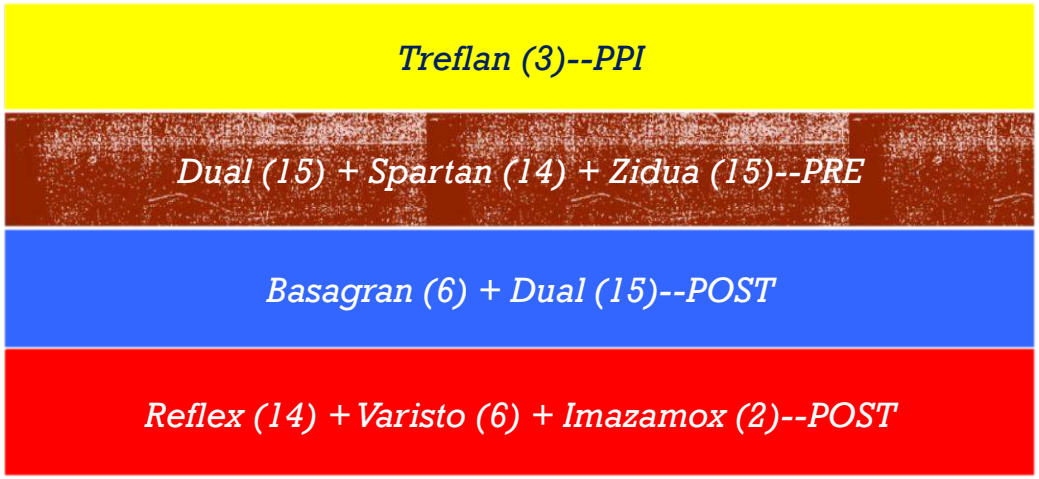
- *Metabolic resistance detoxifies herbicides*
- *Can impact multiple MOAs*
- *Hard to detect and easy to underestimate*
- *Requires proactive, diversified programs*

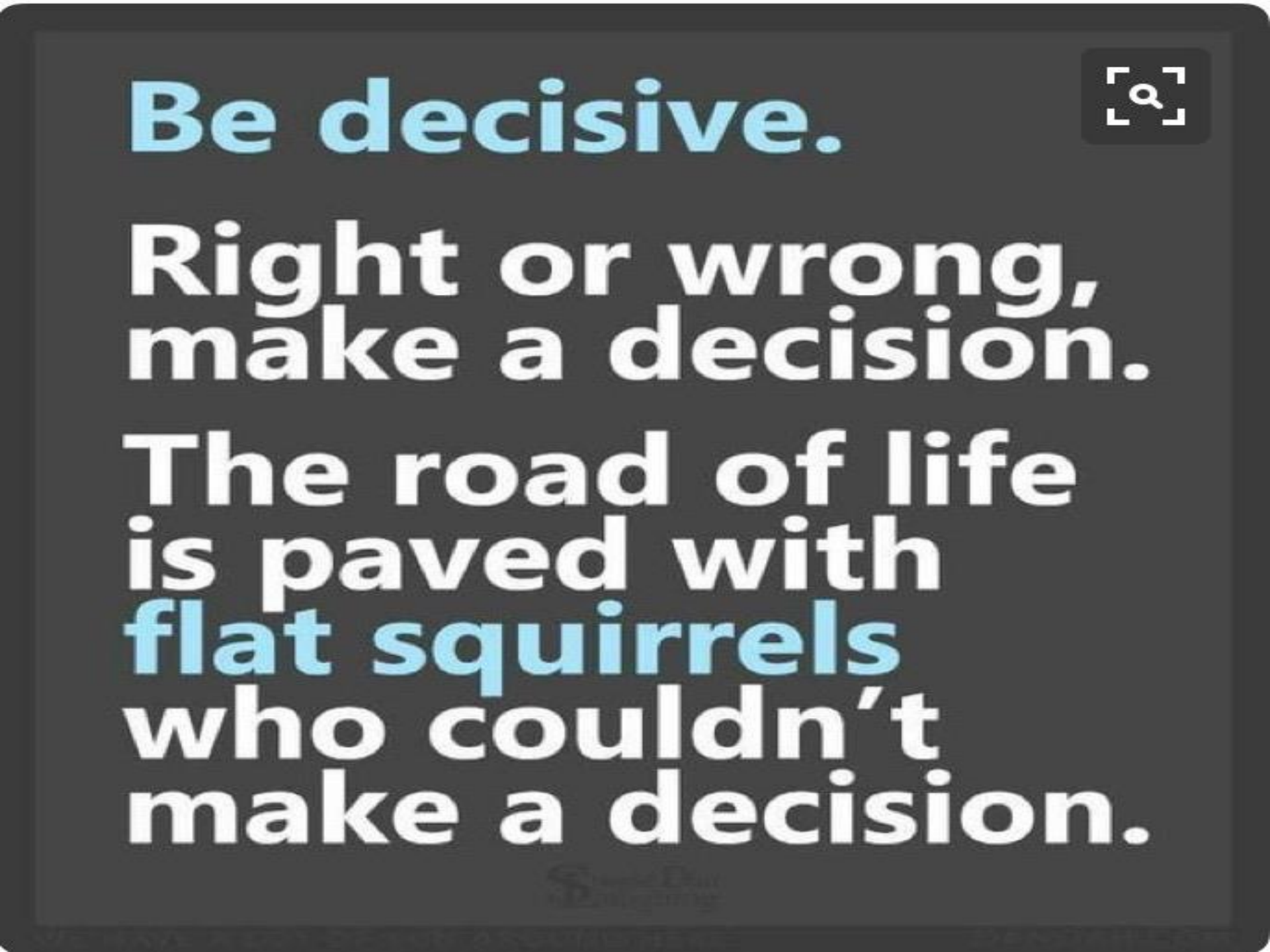

DON'T GET RID
OF THIS
JOHN DEERE
995

LAYER RESIDUALS--COTTON



LAYER RESIDUALS—— CONVENTIONAL SOYBEANS (ND)




Be decisive.
Right or wrong, make a decision.
The road of life is paved with flat squirrels who couldn't make a decision.