Herbicide Injury Symptomology

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Herbicide Injury

What are the causes?

Causes of Herbicide Injury

- In some cases, some injury to target crop is expected.
- Injury to target crop may be enhanced by environmental conditions.
- In some cases, there is no good explanation for injury to target crop.
- Injury often caused by applicator error.

Applicator Errors Leading to Herbicide Injury

Target crop	Non-target areas
Improper application rate	Carryover
Improper application method	Drift
Improper application timing	Weather
Pesticide interactions	
Equipment contamination	
Wrong chemical	

Investigating

Herbicide Injury Situations

What to do, what to look for

Investigating Herbicide Injury Situations

1. Gather as much information as possible.

Information

Crop and pesticide use history

Fertility program, how applied

Any history of similar problems

Information

- When treated
- Crop and weed stage at treatment
- Who made application, who mixed, go through whole procedure
- Check out the application equipment
- Environmental conditions at treatment
- When injury observed
- What did injury initially look like
- Who saw the injury

Information

Acres treated, amount used, tank size

Equipment used

- Nozzles, pressure, volume
- Other uses of equipment
- Clean out procedure

Investigating Herbicide Injury Situations

1. Gather as much information as possible.
2. Thoroughly examine plants.

Investigating Herbicide Injury Situations

1. Gather as much information as possible.
2. Thoroughly examine plants.
3. Look for patterns

   sprayer patterns, row patterns, gradients in injury, soil types, topography, etc

Investigating Herbicide Injury Situations

1. Gather as much information as possible.
2. Thoroughly examine plants.
3. Look for patterns.
4. Look at other vegetation.

Investigating Herbicide Injury Situations

1. Gather as much information as possible.
2. Thoroughly examine plants.
3. Look for patterns.
4. Look at other vegetation.
5. Eliminate as many possibilities as you can.
6. Chemical analysis may be helpful.

What is “Mode of Action”?

The biochemical mechanism by which a herbicide causes growth to cease in target plants.

Example: inhibition of ALS (acetolactate synthase), an enzyme involved in synthesis of branched-chain amino acids.

MOA
Inhibition of ACCase
Inhibition of ALS
Inhibition of PS II
Inhibition of PS II
Inhibition of PS II
PS I electron diversion
Inhibition of PPO
Bleaching: inhibition of carotenoid biosynthesis at PDS
Bleaching: inhibition of HPPD
Bleaching: inhibition of carotenoid biosynthesis, unknown target
Inhibition of EPSPS
Inhibition of glutamine synthetase
Microtubule assembly inhibition
Inhibition of long-chain fatty acid synthesis
Inhibition of cell wall synthesis
Inhibition of lipid synthesis; not ACCase inhibition
Synthetic auxins
Inhibition of auxin transport
Unknown

Purpose of MOA Classification Systems

- Rotating MOA's and using mixtures of MOA's is a key component in herbicide resistance management strategies
- A simple classification system helps the layperson

Two Classification Systems For Herbicide MOA

1. HRAC (Herbicide Resistance Action Committee)

   Use a letter system

2. WSSA (Weed Science Society of America)

   Use a number system

HRAC Code	WSSA Code	MOA
A	1	Inhibition of ACCase
B	2	Inhibition of ALS
C1	5	Inhibition of PS II
C2	7	Inhibition of PS II
C3	6	Inhibition of PS II
D	22	PS I electron diversion
E	14	Inhibition of PPO
F1	12	Bleaching: inhibition of carotenoid biosynthesis at PDS
F2	27	Bleaching: inhibition of HPPD
F3	13	Bleaching: inhibition of carotenoid biosynthesis, unknown target
G	9	Inhibition of EPSPS
H	10	Inhibition of glutamine synthetase
K1	3	Microtubule assembly inhibition
K3	15	Inhibition of long-chain fatty acid synthesis
L	20 and 21	Inhibition of cell wall synthesis
N	8	Inhibition of lipid synthesis; not ACCase inhibition
O	4	Synthetic auxins
P	19	Inhibition of auxin transport
Z	17	Unknown

Purpose of MOA Classification Systems

- Rotating MOA's and using mixtures of MOA's is a key component in herbicide resistance management strategies
- A simple classification system helps the layperson
- Classification code required on labels in some countries; still optional in US
- Labels of newer products in US carry WSSA code

Herbicide Mode of Action

1. Growth regulators
2. Amino acid synthesis inhibitors
    a. ALS inhibitors
    b. EPSPS inhibitors
3. Lipid synthesis inhibitors
4. Seedling growth inhibitors
    a. Root inhibitors
    b. Shoot inhibitors
5. Photosynthesis inhibitors
    a. Mobile
    b. Immobile
6. Cell membrane disrupters
7. Pigment inhibitors
8. Ammonia assimilation inhibitors

Growth Regulators

Family	Examples (common & trade names)
Phenoxy-carboxylic acids	2,4-D, 2,4-DB, MCPA, MCPP (numerous brands of each)
Benzoic acids	dicamba (Banvel, Clarity, Vanquish)
Pyridines	triclopyr (Garlon) clopyralid (Stinger) picloram (Tordon)
Quinoline carboxylic acids	quinclorac (Facet, Paramount)

Growth Regulators

- Exact mode of action unknown
- They have auxin-like properties
- Mode of action involves interference with nucleic acid metabolism and disruption of normal transport systems through induced massive cell proliferation
- Distorted growth

2,4-D Postemergence

Univ. Wisconsin

2,4-D

Epinastic Response to 2,4-D and 2,4-DB

A. York, NCSU

Soybean leaf distortion by 2,4-D

A. York, NCSU

Purdue Univ.

Cotton leaf distortion by 2,4-D

A. York, NCSU


2,4-D INJURY 22 DAYS AFTER SPRAYING
HEALTHY
1st DEGREE
3
5
6
WORST

2,4-D sprayer contamination on tobacco

A. York, NCSU

Malformed wheat heads

2,4-D

Dicamba

Leaf cupping by Dicamba

“Cobra-hood” caused by Dicamba or Picloram

Dicamba drift

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ALS Inhibitors

Family	Examples (common & trade names)
Imidazolinones	imazaquin (Scepter)
	imazethapyr (Pursuit)
Sulfonylureas	chlorimuron (Classic)
	nicosulfuron (Accent)
Triazolopyrimidines	cloransulam (FirstRate)
	flumetsulam (Python)
Pyrimidinyl(thio) benzoates	pyrithiobac (Staple)

ALS Inhibitors

- Inhibit the enzyme acetolactate synthase (ALS)
- ALS is catalyst in first step of biosynthesis of essential amino acids valine, leucine, and isoleucine
- Chlorosis of meristematic tissue, followed by slow general chlorosis and necrosis. Shortened internodes. Sometimes leaf distortion.

ALS Inhibitors postemergence

Nicosulfuron, S. Culpepper, UGA

Imazethapyr + imazapyr, A. York, NCSU

Primisulfuron + prosulfuron, S. Culpepper, UGA

Pyrithiobac, A. York, NCSU

Primisulfuron + prosulfuron, A. York, NCSU

Chlorimuron, S. Culpepper, UGA

ALS Inhibitors

Stunting by trifloxysulfuron applied postemergence

Leaf distortion by chlorimuron

Prosulfuron + Primisulfuron

Chlorsulfuron + metsulfuron carryover

T. Pegram, NCSU

Imazaquin carryover

Corn roots

imazaquin carryover

Nicosulfuron

Postemergence

Leaf crinkling by nicosulfuron

Univ. Wisconsin

Ear pinching by nicosulfuron

Purdue Univ.

ALS Inhibitors Postemergence

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EPSPS Inhibitors

Family	Examples (common & trade names)
Glycines (amino acid derivatives)	glyphosate (numerous trade names)

EPSPS Inhibitors (glyphosate)

- Inhibit shikimic acid pathway by inhibiting 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), thereby limiting synthesis and regulation of aromatic amino acids.
- Also inhibit synthesis of 5-aminolevulinic acid (ALA), thereby blocking porphyrin ring synthesis and, subsequently, all compounds normally containing porphyrin rings, such as chlorophyll, cytochromes, and peroxidases.
- Chlorosis appearing first in growing points and immature leaves.

Glyphosate

Glyphosate applied to non-RR corn

Glyphosate on non-RR corn; sprayer contamination


Glyphosate drift on non-RR corn

Glyphosate on non-RR corn; sprayer contamination

Glyphosate drift

Glyphosate drift

Double rate of glyphosate on RR soybean

Glyphosate sprayer contamination

Glyphosate on RR cotton

Glyphosate on RR cotton

Glyphosate on RR cotton

Glyphosate overtop RR cotton after 4-leaf stage

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Lipid Synthesis Inhibitors (ACCase inhibitors)

Family	Examples (common & trade names)
Aryloxyphenoxy-propionates	diclofop (Hoelon) fluazifop (FusiladeDX) quizalofop (AssureII)
Cyclohexanediones	clethodim (Select) sethoxydim (Poast)

ACCase Inhibitors

- Inhibit biosynthesis of lipids by inhibiting the enzyme acetyl-CoA carboxylase (ACCase)
- Affect only grasses; do not affect broadleaf plants
- Leaf chlorosis, eventually necrosis. Older leaves often turn purple or red before becoming necrotic.
- Leaf sheaths become brown and mushy at and just above their point of attachment to the node.
- Work slowly.

ACCase Inhibitors

Sethoxydim drift


A. York, NCSU
A. York, NCSU

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Root Inhibitors

Family	Examples (common & trade names)
Dinitroanilines	benefin (Balan)
	pendimethalin (Prowl)
	trifluralin (Treflan)
Pyridines	dithiopyr (Dimension)

Dinitroanilines

- Microtubule assembly inhibition
- Interfere with normal mitosis (cell division)
- Swollen root tips

Root pruning with DNA's

Root pruning with DNA's

Stunting by DNA herbicide

Shoot Inhibitors

Family	Examples (common & trade names)
Chloroacetamides	alachlor (Lasso)
	acetochlor (Harness, Surpass)
	metolachlor (Dual)
Thiocarbamates	EPTC (Eptam, Eradicane)
	butylate (Sutan+)

Chloroacetamides

- Inhibit cell division
- Mechanism of action thought to be inhibition of very long-chain fatty acids
- “Drawstring” effect on broadleaves
- Twisted shoots, leaves that do not unfurl normally in grasses

Chloroacetamides

Chloroacetamides

Chloroacetamides
Leafing out underground

Chloroacetamides

Chloroacetamides preemergence

Chloroacetamides

Thiocarbamates

- Exact mechanism of action not understood
- Inhibit lipid synthesis
- Twisted, distorted shoots in grasses
- Leaf seal in broadleaf plants

Thiocarbamates

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Photosynthesis Inhibitors (mobile)

Family	Examples (common & trade names)
Triazines	atrazine (AAtrex)
	simazine (Princep)
Triazinones	metribuzin (Sencor)
Ureas	diuron (Direx, Karmex)
	linuron (Linex, Lorox)

Photosynthesis Inhibitors

- Block electron transport in photosystem II in chloroplast thylakoid membranes.
- Process stops CO_2 fixation and production of ATP and $NADPH_2$
- Death due to formation of triplet state chlorophyll and singlet oxygen, which causes lipid peroxidation.
- Lipids and proteins are oxidized, resulting in loss of chlorophyll and carotenoids and in leaky membranes which allows cells and cell organelles to disintegrate.

Atrazine preemergence on corn


Amaranthus palmeri var. NC SU


Ipomoea purpurea A. York, NC SU

Metribuzin

preemergence

Metribuzin preemergence

Fluometuron carryover

A. York, NCSU

Triazines and Ureas

Triazines and Ureas postemergence

S. Culpepper, UGA

Photosynthesis Inhibitors (non-mobile)

Family	Examples (common & trade names)
Benzothiadiazoles	bentazon (Basagran)
Nitriles	bromoxynil (Buctril)
Phenyl-pyridazines	pyridate (Tough)

Bentazon

S. Culpepper, UGA

Bromoxynil

S. Culpepper, UGA

Bromoxynil

Bromoxynil

A. York, NCSU

Pyridate postemergence, cotton

S. Culpepper, UGA

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Cell Membrane Disruptors (protox inhibitors)

- Protox (protoporphyrinogen oxidase) inhibition.
- Leads ultimately to oxidation of lipids and proteins, resulting in loss of chlorophyll and carotenoids and in leaky membranes which allow cells and cell organelles to disintegrate rapidly.
- Rapid foliar burn

Protox Inhibitors

Family	Examples (common & trade names)
Diphenylethers	acifluorfen (Blazer)
	fomesafen (Reflex)
	lactofen (Cobra)
N-phenylphthalimides	flumiclorac-penty (Resource)
	flumioxazin (Valor)
Triazolinones	carfentrazone (Aim)
	sulfentrazone (Authority, Spartan)

Protox Inhibitors

Acifluorfen, A. York, NCSU

Carfentrazone, A. York, NCSU

Carfentrazone, A. York, NCSU

Protox inhibitors

Fomesafen, A. York, NCSU

Flumiclorac, A. York, NCSU

Lactofen, A. York, NCSU

Acifluorfen, A. York, NCSU

Protox inhibitors

Flumioxazin preemergence

A. York, NCSU

Cell Membrane Disruptors (photosystem I inhibitors)

- Paraquat
- Diverts electrons from photosystem I to form free radicals which rapidly destroy cell membranes.
- Rapid wilting and desiccation of foliage.

Paraquat

Drift

Direct hit

Paraquat

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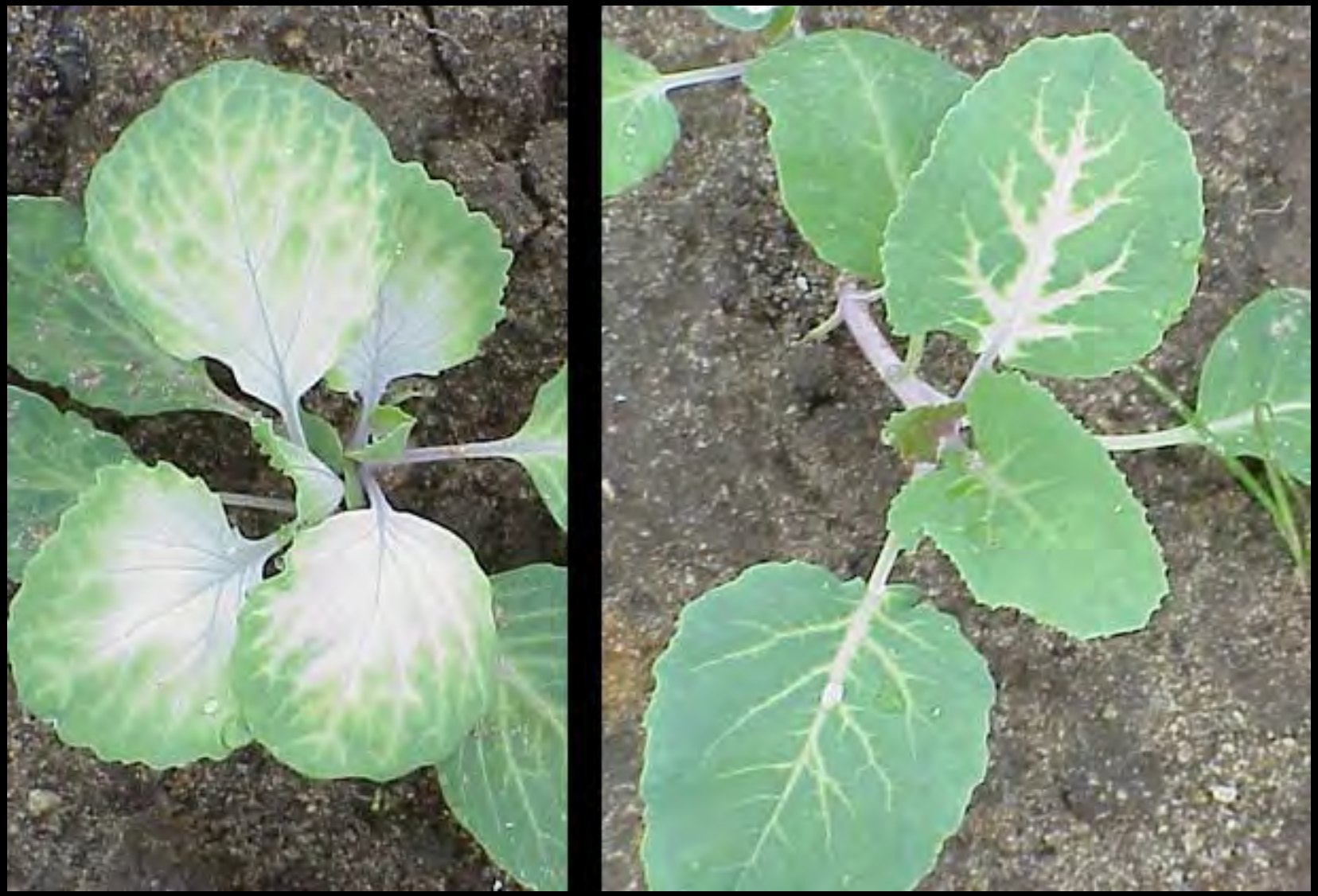
Pigment Inhibitors (bleachers)

Family	Examples (common & trade names)
Isoxazole	isoxaflutole (Balance Pro)
Isoxazolidinone	clomazone (Command)
Pyridazinone	norflurazon (Solicam, Zorial)
Triketone	mesotrione (Callisto)

Pigment Inhibitors

- Disrupt carotenoid (yellow pigments) synthesis
- w/o carotenoid pigments, chlorophyll pigments photodegrade
- Result is bleached plants

Norflurazon carryover on cabbage



Norflurazon

York, NCSU

Clomazone

A. York, NCSU

Clomazone

A. York, NCSU

Clomazone drift

Mesotrione

A. York, NCSU

Mesotrione

A. York, NCSU

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Ammonia Assimilation Inhibitors

Family	Examples (common & trade names)
Phosphinic acids	glufosinate (Liberty, Finale, Ignite)

Ammonia Assimilation Inhibitors

- Inhibit glutamine synthetase, the enzyme that converts glutamate plus ammonia to glutamine
- Causes buildup of ammonia in plants, and destroys cells.
- Necrosis in 3 to 4 days.

Glufosinate

Glufosinate