How Herbicides Work In Plants-Herbicide Symptomology

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Effective Chemical Weed Management

Herbicide application and placement

Herbicide uptake

Herbicide translocation

-movement within the plant through xylem and phloem tissue

Herbicide toxicity and activity

Herbicide metabolism and degradation

Mode of Action-Definitions

-Sequence of events from herbicide absorption to plant death

-Mechanisms by which a herbicide causes plant death

-The suite of plant process interfered with by a herbicide at the tissue or cellular level

-How a herbicide kills a plant

Site of Action

-Place in the plant where the herbicide acts…

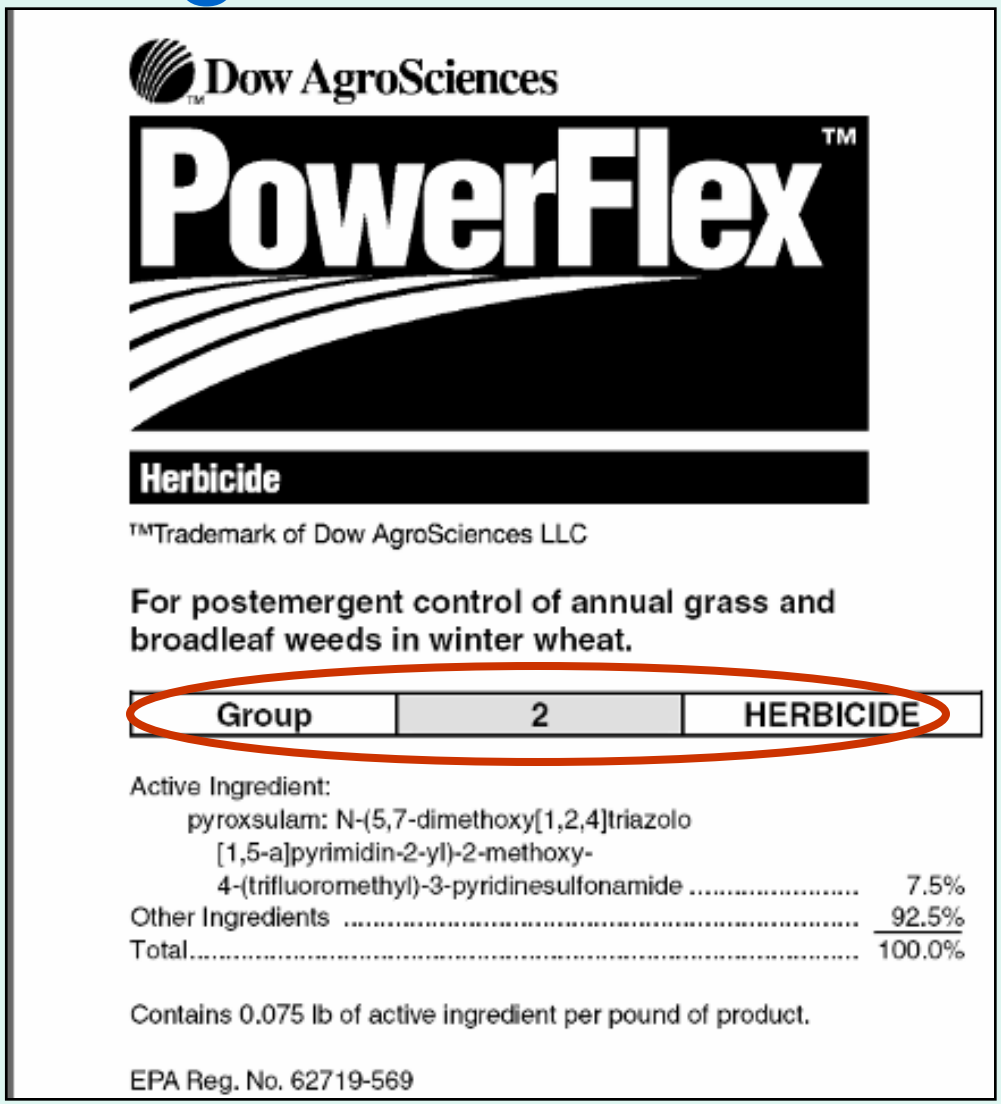
- specific mechanisms of action…

-Organized by “Groups”

-Group number usually printed on the label

Herbicide Classification for Resistance Management

- Herbicides are grouped by site of action
- Users are able to determine related chemistries
- EPA and Agriculture Canada are calling for voluntary labeling that would include group number



Dow AgroSciences

PowerFlex™

Herbicide

™Trademark of Dow AgroSciences LLC

For postemergent control of annual grass and broadleaf weeds in winter wheat.

Group	2	HERBICIDE

Active Ingredient:

pyroxsulam: N-(5,7-dimethoxy[1,2,4]triazolo [1,5-a]pyrimidin-2-yl)-2-methoxy-4-(trifluoromethyl)-3-pyridinesulfonamide 7.5%

Other Ingredients 92.5%

Total..... 100.0%

Contains 0.075 lb of active ingredient per pound of product.

EPA Reg. No. 62719-569

Herbicide-Resistant Weeds and Their Management

When planning a herbicide program to prevent resistance, do not use herbicides from the same group more than once within three years.

This publication contains the

Guide for Herbicide Rotation

reference poster

The authors—Carol Mallory-Smith, Professor of Weed Science, Oregon State University; Andy Hulting, Assistant Professor and Extension Weed Specialist, Oregon State University; Donn Thill, Professor of Weed Science, University of Idaho; Don Morishita, Professor of Weed Science, University of Idaho; Jen Krenz, Faculty Research Assistant, Oregon State University.

Guide for Herbicide Rotation in the Pacific Northwest

To avoid selecting for herbicide-resistant weeds, do not use herbicides from the same color group more than once within three years. Rather, rotate to a different group every year of the production system.

Herbicide group number and site of action	Herbicide chemical family	Herbicide common name	Herbicide trade names	Resistant weeds in the PNW	Status with resistant weeds
Group 1 Acetyl CoA carboxylase (ACCase) inhibitors	cyclohexanediones	clethodim	Select Max, Envoy, several others	Italian ryegrass	ID
		sethoxydim	Poast, several others	Italian ryegrass	ID
		tralkoxydim	Achieve	Italian ryegrass	ID
	aryloxyphenoxypropanoates	diclofop	Discover NG	Italian ryegrass	ID
				Wild oat	ID
		diclofop	Hoelon	Wild oat	ID, OR, WA
				Italian ryegrass	ID, OR, WA
		fenoxaprop	Puma, Acclaim	Wild oat	ID, OR
		fluazifop	Fusilade DX	Downy brome	OR
		quizalofop	Assure II, Targa	Italian ryegrass	ID
	phenylpyrazolines	pinoxaden	Axial	Italian ryegrass	ID, OR
Group 2 Acetolactate synthase (ALS) inhibitors	imidazolinones	*imazamox	Raptor, Beyond, Clearmax (Beyond + MCPA)	Downy brome	OR
				Spiny sowthistle	WA
		*imazapic	Plateau		
		*imazapyr	Arsenal, Chopper, several others		
		*imazethapyr	Pursuit	Prickly lettuce	ID
				Kochia	ID
				Spiny sowthistle	ID
				Black mustard	ID
				Mayweed chamomile	ID
	sulfonylureas	*chlorsulfuron	Glean, Telar	Prickly lettuce	ID, OR, WA
				Kochia	ID, OR, WA
				Russian thistle	ID, OR, WA
				Italian ryegrass	OR
				Mayweed chamomile	ID, WA
				Smallseed falseflax	OR
		*chlorsulfuron/ metsulfuron	Finesse	Smallseed falseflax	OR
		*ethametsulfuron	Muster		
		*halosulfuron	Sandea		
		mesosulfuron	Osprey	Italian ryegrass	ID
		mesosulfuron/ propoxycarbazone	Olympus Flex		
		*metsulfuron	Ally, Escort, Cimarron	Prickly lettuce	ID, OR
				Kochia	OR
				Russian thistle	OR
				Smallseed falseflax	OR
		*nicosulfuron	Accent		
		*primisulfuron	Beacon	Downy brome	OR
		*prosulfuron	Peak		
		*rimsulfuron	Matrix		
		*sulfometuron	Oust, Spyder		
		*sulfosulfuron	Maverick, Outrider, Certainty	Downy brome	OR
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				Prickly lettuce	ID
				Mayweed chamomile	ID
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		*thifensulfuron/ tribenuron/ metsulfuron	Canvas		
		*triasulfuron	Amber	Prickly lettuce	ID, OR
				Kochia	OR
				Russian thistle	OR
				Italian ryegrass	ID
		tribenuron	Express	Prickly lettuce	ID
				Mayweed chamomile	ID
		*triflusulfuron	UpBeet		
	sulfonylamino-carbonyl-triazolinones	flucarbazone	Everest	Italian ryegrass	ID
		propoxycarbazone	Olympus		
	triazolo-pyrimidines	florasulam	Orion (contains MCPA) - Registration pending		
Group 3 Microtubule assembly inhibitors	dinitroanilines	*benefin	Balan		
		ethalfluralin	Sonalan, Curbit		
		oryzalin	Surflan		
		*pendimethalin	Prowl H2O, Pendulum, several others		
		prodiamine	Barricade, Endurance, several others		
		*trifluralin	Treflan, Trust		
	benzamides	*pronamide	Kerb	Wild oat	OR
Group 4 Synthetic auxins	phenoxyacetic acids	2,4-D	several		
		2,4-DB	several		
		MCP	several		
		mecoprop (MCPP)	several		
	benzoic acids	*dicamba	Banvel, Clarity, several others	Kochia	ID
	pyridines	*aminopyralid	Milestone		
		*clopyralid	Stinger, Transline, ClopyrAg		
		*fluroxypyr	Starane, Vista, Spotlight		

continued next column

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Group 4, continued	pyridines, cont.	*picloram	Tordon K, Tordon 22K	Yellow starthistle	WA
		*triclopyr	Garlon, Remedy, Renovate		
	quinoline carboxylic acids	*quinclorac	Paramount, Drive		
Group 5 Photosystem II inhibitors	triazines	*atrazine	AAtrex	Common lambsquarters	ID, OR, WA
				Pigweed spp.	ID
				Common groundsel	OR, WA
				Annual bluegrass	OR
				Kochia	ID
		*simazine	Princep, Simazine	Common groundsel	WA
	triazinones	*hexazinone	Velpar, Pronone		
		*metribuzin	Sencor, Metri DF		
	uracils	*bromacil	Hyvar X, Hyvar X-L		
		*terbacil	Sinbar	Common groundsel	OR
				Pigweed spp.	OR, WA
				Common lambsquarters	OR
Group 6 Photosystem II inhibitors (same site as groups 5 and 7 but different binding behavior)	benzothiadiazoles	bentazon	Basagran		
	nitriles	bromoxynil	Buctril, Bromox, Bronate (contains MCPA), several others	Common groundsel	OR
Group 7 Photosystem II inhibitors (same site as groups 5 and 6 but different binding behavior)	ureas	*diuron	Karmex, Direx	Common lambsquarters	OR
				Annual bluegrass	OR
		*linuron	Lorox, Linex		
		*tebuthiuron	Spike		
Group 8 Lipid synthesis inhibitors but not ACCase inhibitors	thiocarbamates	butylate	Sutan, Sutan+ (contains safener)		
		cycloate	Ro-Neet		
		EPTC	Eptam		
		EPTC + safener	Eradicane		
		triallate	Far-Go	Wild oat	ID
Group 9 EPSP synthase inhibitors	glycines	glyphosate	Roundup, several others	Italian ryegrass	OR
Group 10 Glutamine synthase inhibitors	phosphinic acids	glufosinate	Rely, Liberty, several others		
Group 14 Inhibitors of protoporphyrinogen oxidase (Protox)	diphenylethers	*acifluorfen	Goal, several others		
		flumiclorac	Resource		
	N-phenylphthalimides	*flumioxazin	Chateau, Valor, SureGuard		
	triazinones	carfentrazone	Aim, several others		
		*sulfentrazone	Spartan, Portfolio		
	phenylpyrazole	pyraflufen	ET, Edict		
Group 15 Inhibitors of very-long-chain fatty acid synthesis	chloroacetamides	acetochlor	Harness, Surpass, several others		
		alachlor	MicroTech, several others		
		dimethenamid-p	Outlook		
		metolachlor	Dual, several others		
		s-metolachlor	Dual Magnum, Dual II Magnum		
	oxyacetamides	flufenacet	Define, Axiom (contains metribuzin)	Italian ryegrass	ID, OR
	acetamides	napropamide	Devrinol		
Group 16 Unknown	benzofuranes	ethofumesate	Nortron, several others	Annual bluegrass	OR
Group 17 Unknown	organoarsenicals	MSMA	several		
Group 20 Inhibitors of cell wall synthesis site A	nitriles	*dichlobenil	Casoron, Barrier		
Group 22 Photosystem I electron diverters	bipyridiliums	diquat	Reglone, Reward		
		paraquat	Gramoxone Inteon, several others		
Group 26 Unknown	pyrazolium	difenzoquat	Avenge	Wild oat	ID
	carboxylic acids	pelargonic acid	Scythe		
Group 28 Inhibitors of 4-HPPD**	isoxazoles	pyrasulfotole	Huskie (contains bromoxynil)		
	triketones	mesotrione	Callisto		
		topramezone	Impact		

** 4-hydroxyphenylpyruvate isoxygenase

Search

Search

All PNW Handbooks

Weed Management Handbook

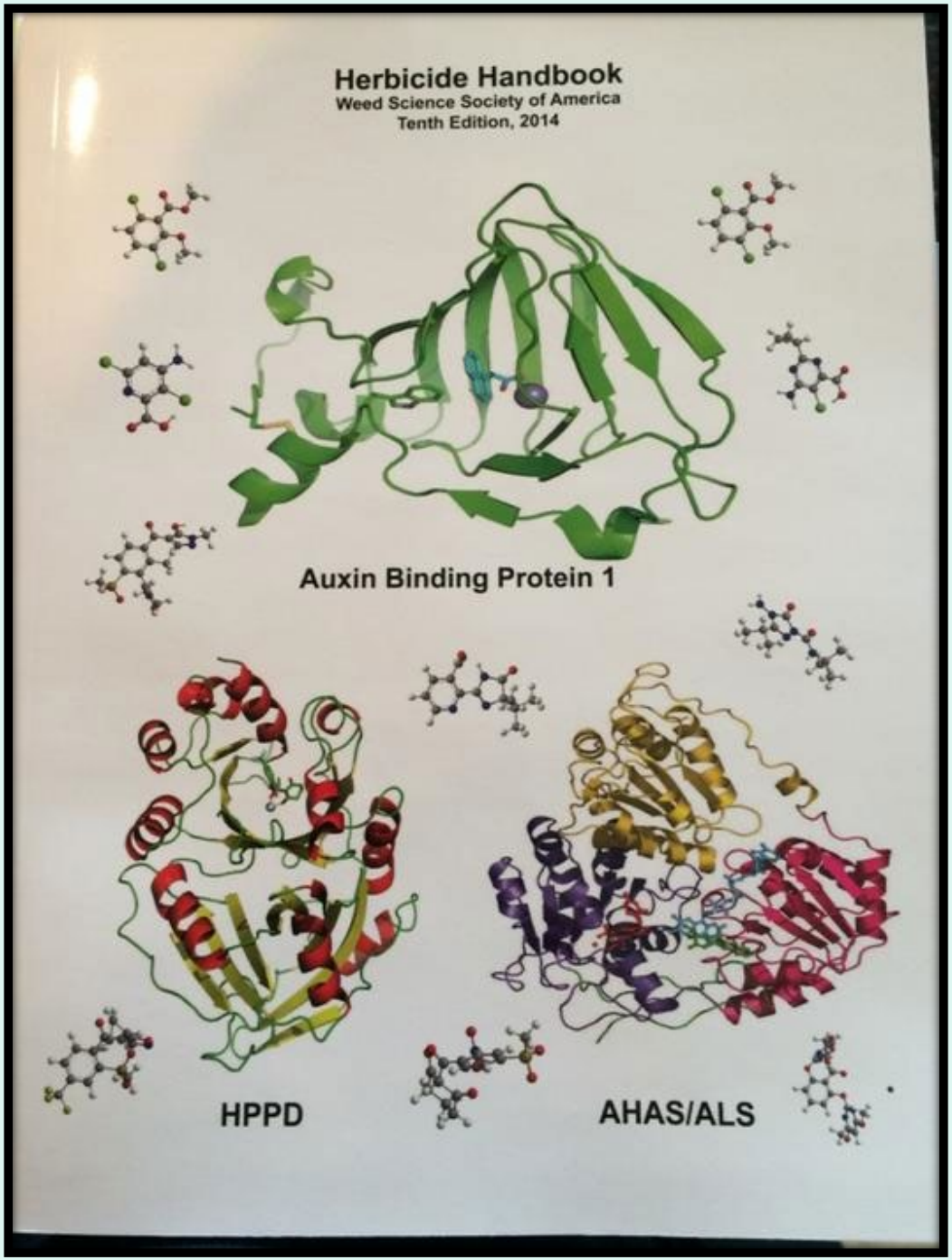
Pacific Northwest Weed Management Handbook

This handbook is designed as a quick and ready reference for weed control practices and herbicides used in various cropping systems or sites in Idaho, Oregon, and Washington.

This handbook will be useful to Extension agents, company field representatives, commercial spray applicators and consultants, herbicide dealers, teachers, and producers.

Recommendations are based on research results from the Agricultural Experiment Stations and Extension Services of Oregon, Idaho, and Washington. A few suggestions are included from research conducted in other states, and from U.S. Department of Agriculture research centers. In all cases, authors make every effort to list only registered herbicides, and to ensure that the information conforms to product labels and company recommendations.

Field bindweed (*Convolvulus arvensis*) thrives in the high moisture and fertility conditions of crops such as blueberries, reducing yield and interfering with harvest.
Photo by Ed Peachey, © Oregon State University


Herbicide Handbook
Weed Science Society of America
Tenth Edition, 2014
Auxin Binding Protein 1
HPPD
AHAS/ALS

Synthetic Auxins-Group 4

Mode of Action

– These herbicides disrupt hormone balance and protein synthesis in plants, leading to a variety of plant growth abnormalities

Chemical Families

– Phenoxy Acetic Acids: 2,4-D, 2,4-DB, MCP

– Benzoic Acids: dicamba (Banvel)

– Pyridines: fluroxypyr (Starane), picloram (Tordon), clopyralid (Stinger), triclopyr (Garlon 4), aminopyralid (Milestone)

Synthetic Auxins-Group 4

Site of Action

– **Site(s) of action is unknown, believed to have multiple sites of action**

Translocation

– **Extensively translocated in xylem and phloem, herbicides accumulate in newest leaves and meristems**

Synthetic Auxins-Group 4

Uses / Notes

– **Primarily "broadleaf killers," used for postemergence broadleaf control in corn, wheat, rye, barley, turf, pasture, roadsides**

– **Often have some soil activity**

Symptoms

Broadleaf weeds / crops:

– **Stem twisting and epinasty (downward twisting)**

– **Leaf malformations (leaf cupping, crinkling, strapping [parallel veins], puckering, bubbling)**

– **Callus tissue formation**

Leaf rolling

Stem twisting

Leaf crinkling

Parallel venation or strapping

Callus tissue formation in corn

Amino Acid Synthesis Inhibitors-Group 2

Mode of Action

– **Inhibits a specific enzyme (single site) which prevents production of essential amino acids**

Chemical Families

– **Imidazolinones: imazethapyr (Pursuit), imazamox (Beyond), imazapyr (Arsenal or Habitat)**

– **Sulfonylureas: chlorimuron (Classic), nicosulfuron (Accent), primisulfuron (Beacon), thifensulfuron (Harmony GT), halosulfuron (Permit), chlorsulfuron (Glean or Telar), mesosulfuron (Osprey)**

Amino Acid Synthesis Inhibitors-Group 2

Other Chemical Families

- **Triazolopyrimidine:**
  florasulam (Orion)
  pyroxsulam (PowerFlex)

- **Sulfonylaminocarbonyl-triazolinone:**
  flucarbazone (Everest)
  propoxycarbazone (Olympus)

Amino Acid Synthesis Inhibitors-Group 2

Site of Action

– Imidazolinones and Sulfonylureas prevent production of three essential amino acids by inhibiting the same enzyme, acetolactate synthase (ALS)

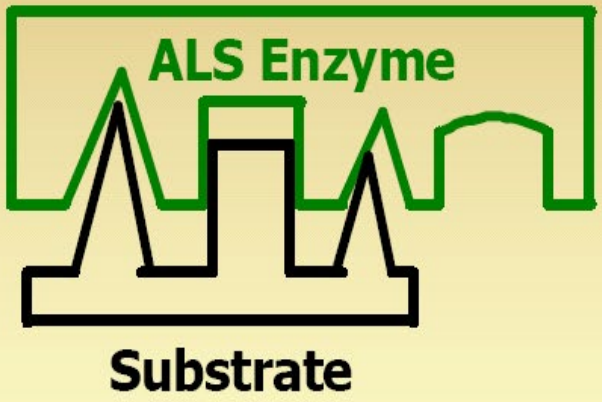
Translocation

– Move through xylem and phloem and accumulate in meristematic region, you will see injury on new leaves

ALS Inhibition

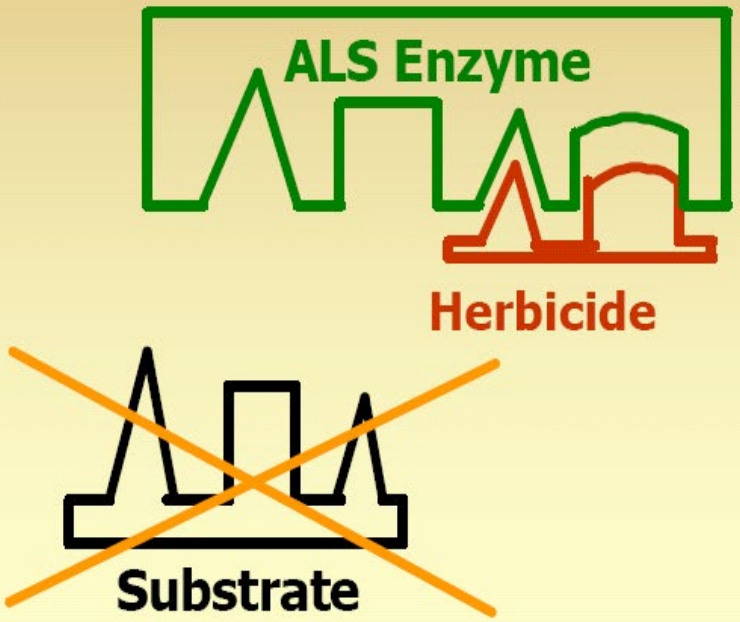
ALS Enzyme Action

- substrate binds to enzyme



Inhibition of ALS Enzyme

- herbicide blocks normal substrate



Amino Acid Synthesis Inhibitors-Group 2

Uses / Notes

- **PRE/POST weed control in various crops**
- **Immediate growth cessation**
- **Slow to develop, gradual chlorosis followed by necrosis of newest growth after several days**
- **Death of growing point**
- **Stunting, slow growth, death of plant may take up to 28 days**
- **IMI's and SU's are difficult to distinguish between**


Stunting, purpling, chlorosis

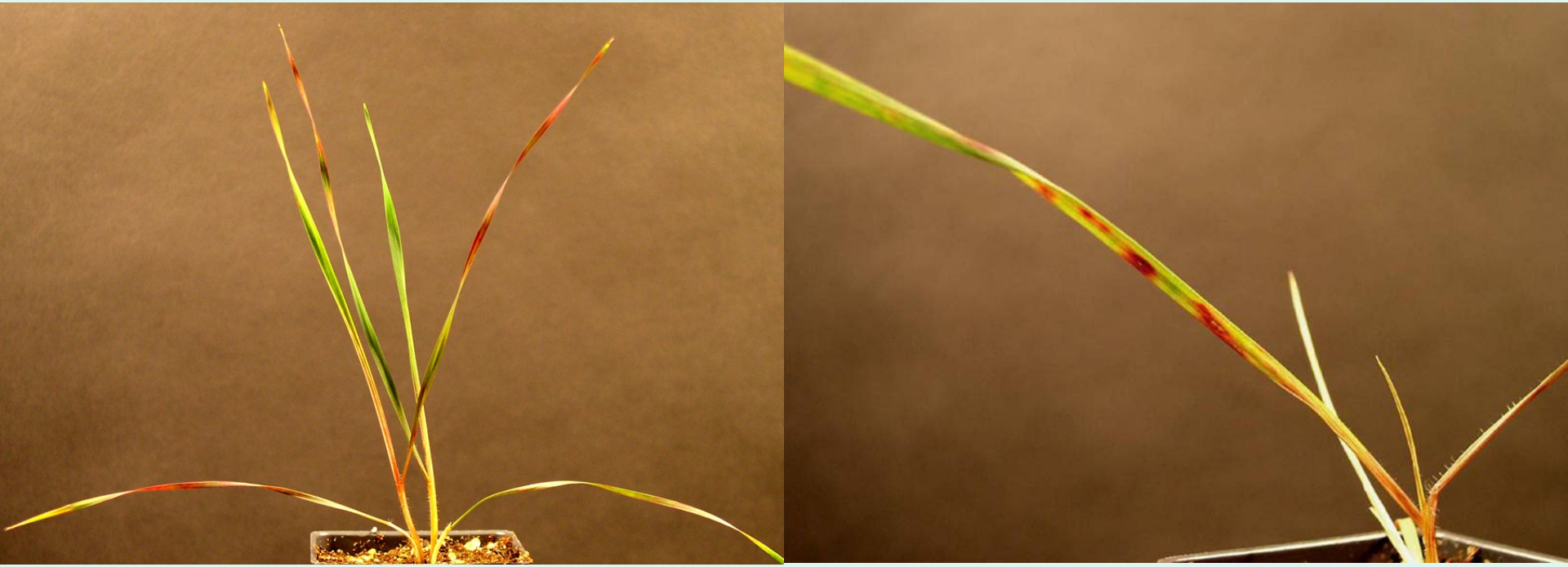
Red or purple leaf veins

Amino Acid Synthesis Inhibitors-Group 2

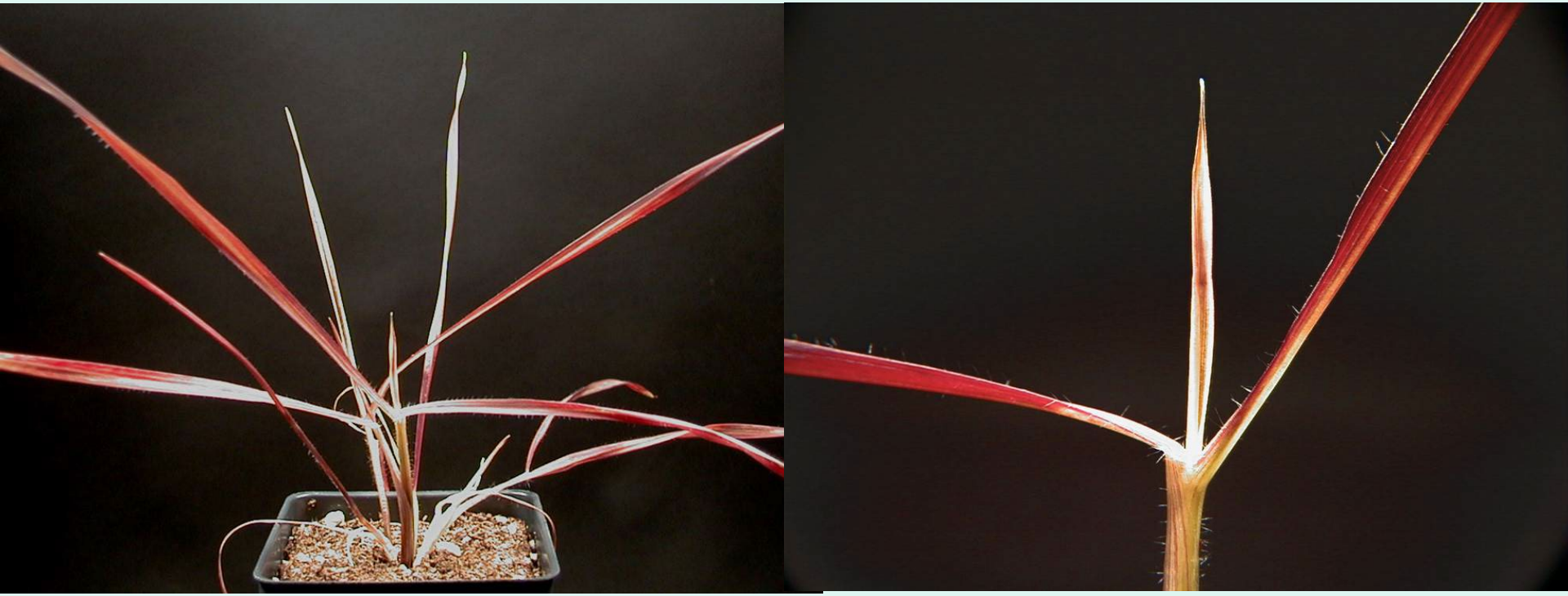
Symptoms

Grass symptoms:

- **General stunting**
- **Purpling of leaves, interveinal chlorosis of newly emerging leaves**
- **Chlorotic bands near base of leaf blade**
- **Lateral root pruning = bottle-brush appearance**
- **Irregular leaf shape (crinkled and wavy leaf margins)**



Chlorosis and purpling in jointed goatgrass



Chlorosis and purpling in jointed goatgrass

Chlorosis and purpling

Translucent leaf tissue

EPSP Synthase Inhibitors-Group 9

Mode of Action

– **Inhibits a specific enzyme (single site) which prevents production of essential amino acids**

Chemical Familiy

– **Glycines : glyphosate**

(RoundUp formulations and others)

EPSP Synthase Inhibitors-Group 9

Site of action

– **Glycines prevent production of three other essential amino acids by inhibiting EPSP Synthase**

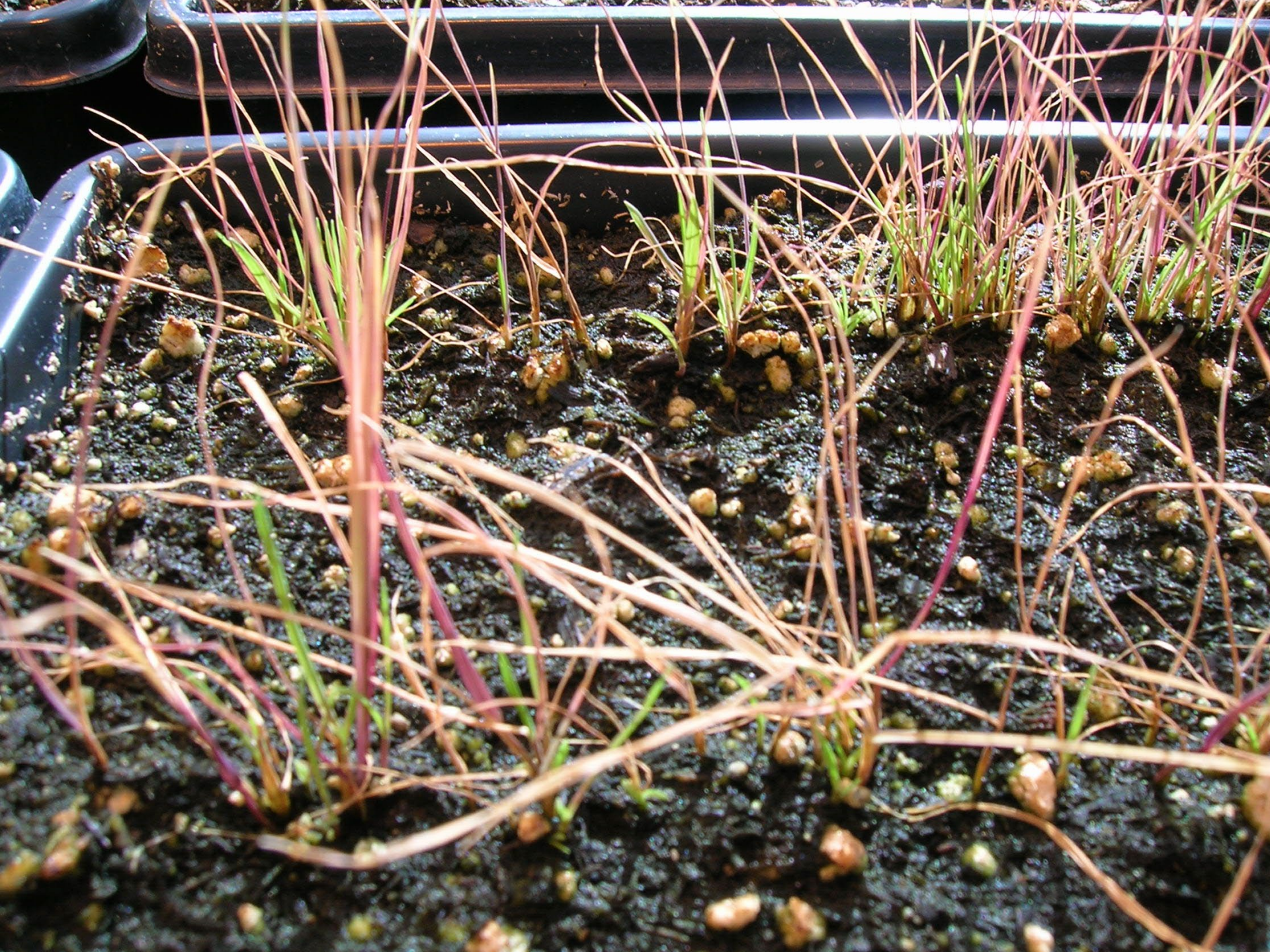
Translocation

– **Move through xylem and phloem and accumulate in meristematic region, will see injury on new leaves**

EPSP Synthase Inhibitors-Group 9

Uses / Notes

- **Burndown applications preplant or chem fallow**
- **POST weed control in various glyphosate-tolerant crops**
- **Nonselective spot spraying applications**
- **Slow to develop, gradual chlorosis followed by necrosis of newest growth after several days**
- **Death of growing point**
- **Stunting, slow growth, death of plant may take up to 28 days**



ACCase Inhibitors-Group 1

Mode of Action

– Prevents the formation of fatty acids, which are essential for the production of lipids. Lipids are vital in the integrity of cell membranes and thus new plant growth

Chemical Families

– Cyclohexanediones: clethodim (Select Max)
– Aryloxyphenoxypropionates: quizalifop (Assure II)
– Phenylpyrazoline: pinoxaden (Axial XL)

ACCase Inhibitors-Group 1

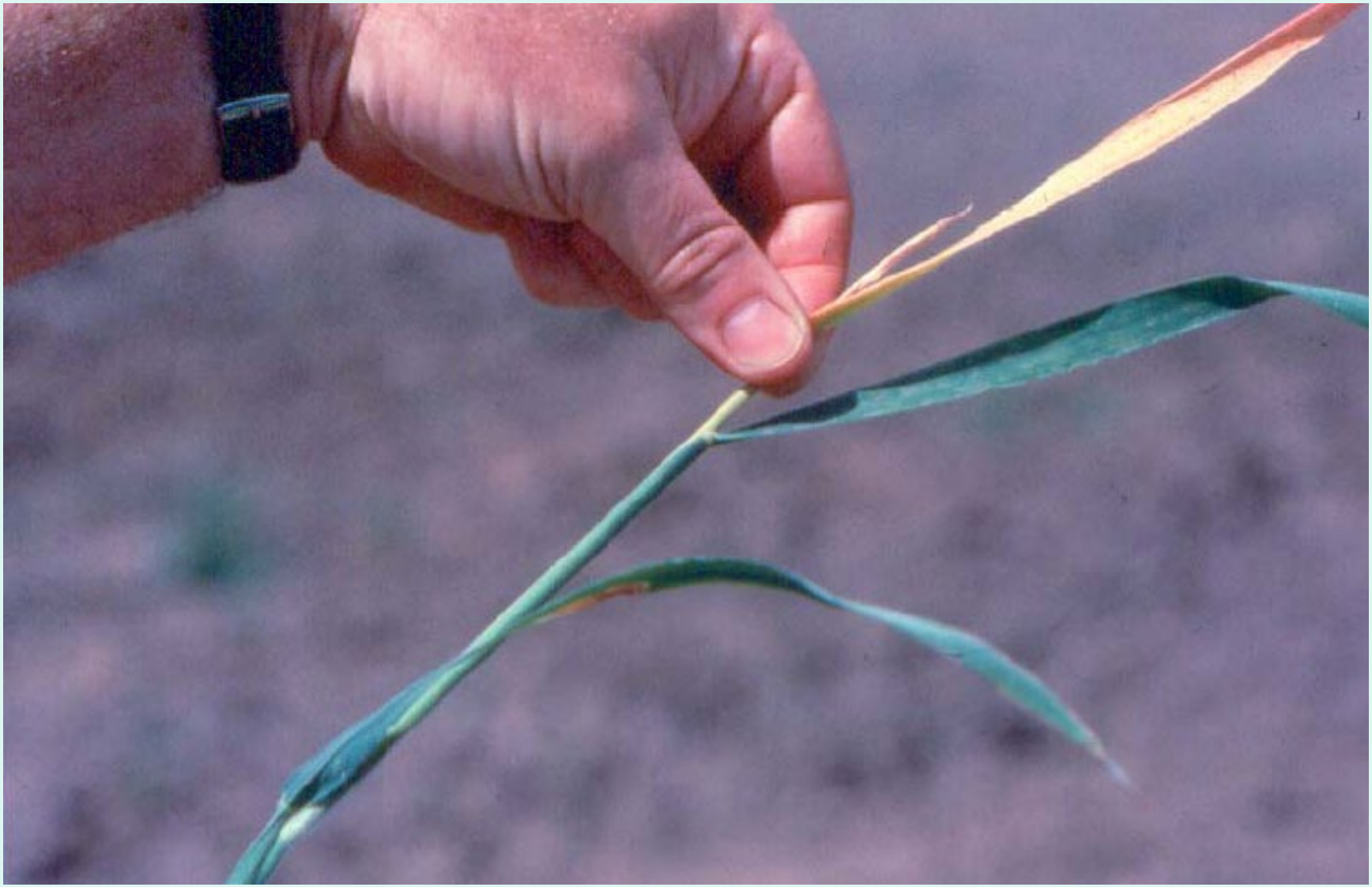
Site of Action
– Inhibits the ACCase enzyme which ceases the synthesis of fatty acids

Translocation
– Symplastic movement - translocate to all areas of new growth via phloem, no soil activity

Uses / Notes
– Postemergence “grass killers” , no BL activity
– Control many annual and perennial grasses

ACCase Inhibitors-Group 1

Symptoms
Only on Grasses:
– Injury first appears on new emerging whorl leaves
– Immediate growth stoppage
– Very gradual discoloration of tissue
– Slow acting, symptoms take 7 to 14 days to show up
– Chlorosis to reddening followed by necrosis of grass whorl
– Can pull out dead whorl, an early indicator (growing point separates from rest of the plant)



Growing point separation

ALS inhibitors vs. ACCase inhibitors

Inhibited growing points

Necrosis of growing points

Chlorosis and necrosis in wild oat

Necrosis of growing point / translucent leaf

PPO Inhibitors-Group 14

Mode of Action

– These herbicides disrupt cell membranes

Chemical Families

– Bipyridyliums: paraquat (Gramoxone)
– Diphenylethers: oxyfluorfen (Goal)
– N-phenylphthalimides: Flumioxazin (Chateau)
– Aryltriazolinones: carfentrazone-ethyl (Aim)
  sulfentrazone (Spartan)

PPO Inhibitors-Group 14

Site of Action

– Light causes the formation of free radicals. These radicals rupture plant cell membranes resulting in a rapid browning of tissue

Translocation
– None or very limited, necrotic spots

Uses / Notes
– Mostly foliar-applied - uptake into leaves
– Some soil-applied - root and shoot uptake

PPO Inhibitors-Group 14

Symptoms

– Symptoms vary somewhat with herbicide and spray additive

– Rapid necrosis of plant tissue (1 to 2 hours)

– Leaves may have a water-soaked appearance or burned appearance followed by wilting an rapid desiccation

– Burnt, crispy brown tissue, leaf speckling

– Only kills the tissue it comes into contact with

– Plant parts not covered may survive

– Activity increases with sunlight, temperature, and humidity

Water soaked spots

Necrosis of leaf tissue

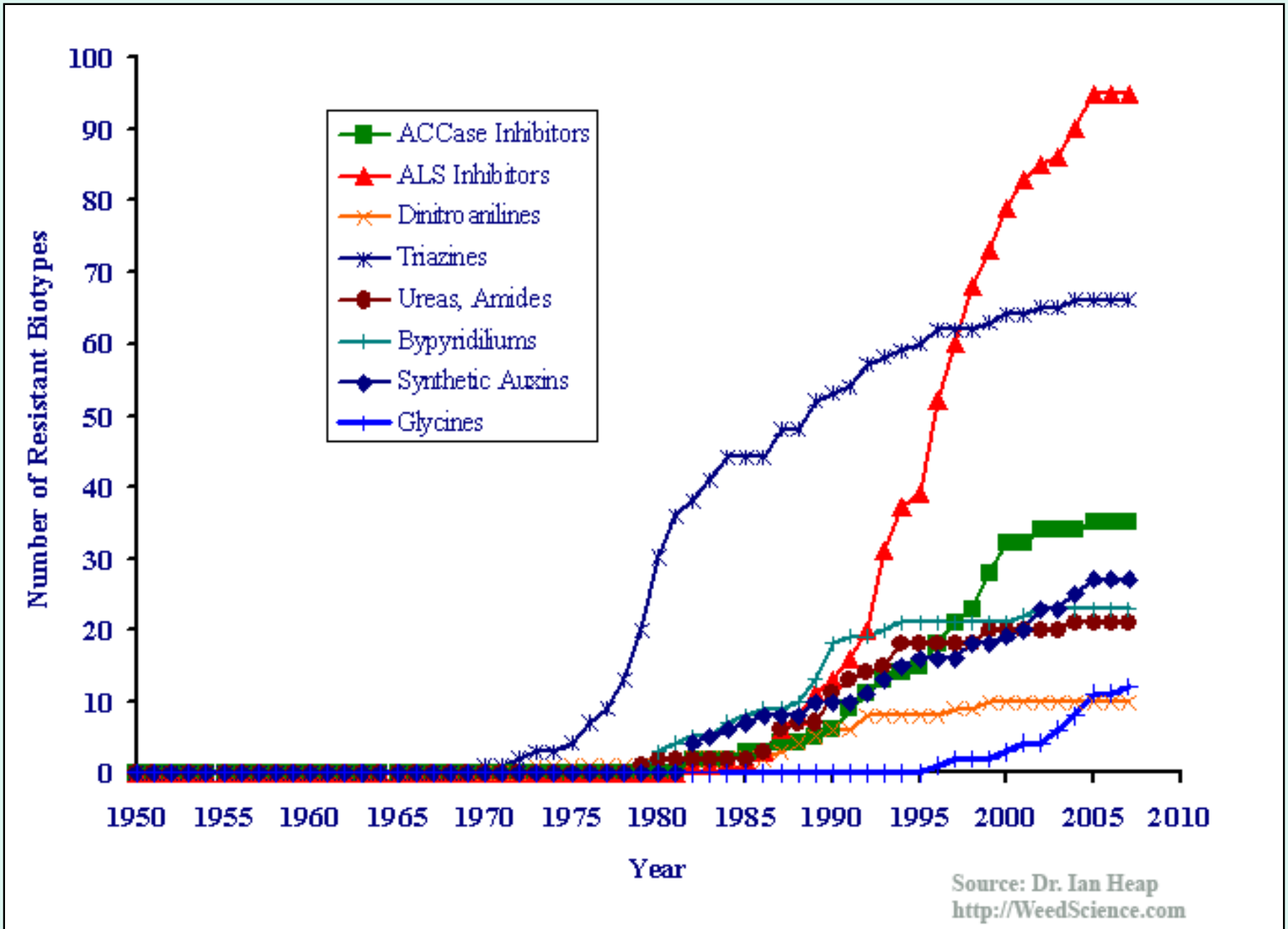
Necrosis of leaf tissue

Spotting of leaf tissue in corn

Inhibitor of 4-HPPD-Group 27

- **Inhibitor of 4-HPPD-Group 27**
  - **translocated to plant growing points**
  - **inhibits plant pigment biosynthesis**
  - **chlorophyll is destroyed, “bleaching” effect**
- **Chemical Families: Isoxazole and Triketones**
  - **pyrasulfotole + bromoxynil (Huskie)**
  - **mesotrione (Callisto)**
- **Potential to manage ALS resistant broadleaf weeds**


Bleaching of
new growth


ACCase Inhibitors
ALS Inhibitors
Dinitro anilines
Triazines
Ureas, Amides
Bypyridiliums
Synthetic Auxins
Glycines
Number of Resistant Biotypes
0
10
20
30
40
50
60
70
80
90
100
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
Source: Dr. Ian Heap
http://WeedScience.com

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		MCP	several		
		mecoprop (MCPP)	several		
	benzoic acids	*dicamba	Banvel, Clarity, several others	Kochia	ID
	pyridines	*aminopyralid	Milestone		
		*clopyralid	Stinger, Transline, ClopyrAg		
		*fluroxypyr	Starane, Vista, Spotlight		

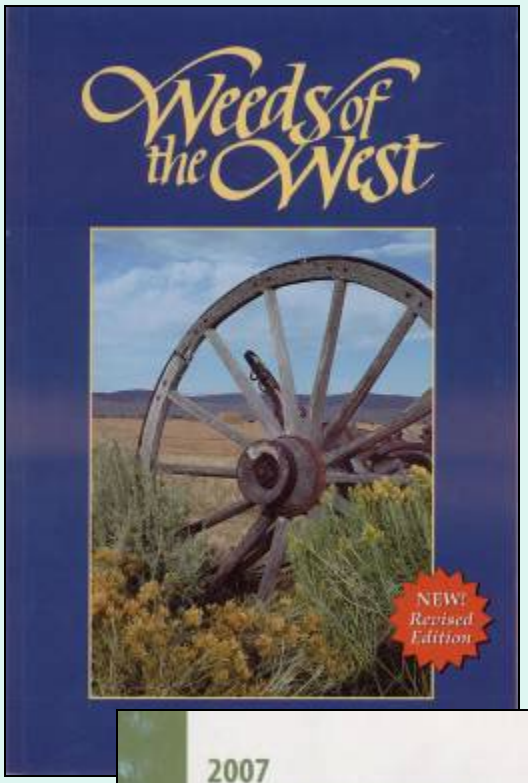
continued next column

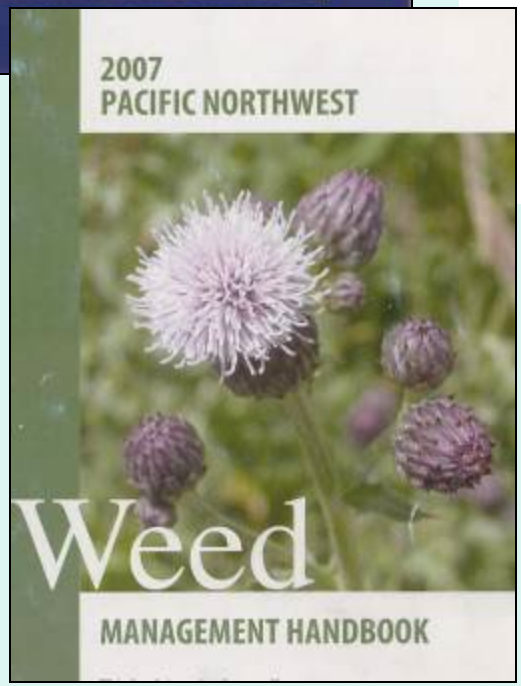
Herbicide group number and site of action	Herbicide chemical family	Herbicide common name	Herbicide trade names	Resistant weeds in the PNW	Status with resistant weeds
Group 4, continued	pyridines, cont.	*picloram	Tordon K, Tordon 22K	Yellow starthistle	WA
		*triclopyr	Garlon, Remedy, Renovate		
	quinoline carboxylic acids	*quinclorac	Paramount, Drive		
Group 5 Photosystem II inhibitors	triazines	*atrazine	AAtrex	Common lambsquarters	ID, OR, WA
				Pigweed spp.	ID
				Common groundsel	OR, WA
				Annual bluegrass	OR
				Kochia	ID
		*simazine	Princep, Simazine	Common groundsel	WA
	triazinones	*hexazinone	Velpar, Pronone		
		*metribuzin	Sencor, Metri DF		
	uracils	*bromacil	Hyvar X, Hyvar X-L		
		*terbacil	Sinbar	Common groundsel	OR
				Pigweed spp.	OR, WA
				Common lambsquarters	OR
Group 6 Photosystem II inhibitors (same site as groups 5 and 7 but different binding behavior)	benzothiadiazoles	bentazon	Basagran		
	nitriles	bromoxynil	Buctril, Bromox, Bronate (contains MCPA), several others	Common groundsel	OR
Group 7 Photosystem II inhibitors (same site as groups 5 and 6 but different binding behavior)	ureas	*diuron	Karmex, Direx	Common lambsquarters	OR
				Annual bluegrass	OR
		*linuron	Lorox, Linex		
		*tebuthiuron	Spike		
Group 8 Lipid synthesis inhibitors but not ACCase inhibitors	thiocarbamates	butylate	Sutan, Sutan+ (contains safener)		
		cycloate	Ro-Neet		
		EPTC	Eptam		
		EPTC + safener	Eradicane		
		triallate	Far-Go	Wild oat	ID
Group 9 EPSP synthase inhibitors	glycines	glyphosate	Roundup, several others	Italian ryegrass	OR
Group 10 Glutamine synthase inhibitors	phosphinic acids	glufosinate	Rely, Liberty, several others		
Group 14 Inhibitors of protoporphyrinogen oxidase (Protox)	diphenylethers	*acifluorfen	Goal, several others		
		flumiclorac	Resource		
	N-phenylphthalimides	*flumioxazin	Chateau, Valor, SureGuard		
	triazinones	carfentrazone	Aim, several others		
		*sulfentrazone	Spartan, Portfolio		
	phenylpyrazole	pyraflufen	ET, Edict		
Group 15 Inhibitors of very-long-chain fatty acid synthesis	chloroacetamides	acetochlor	Harness, Surpass, several others		
		alachlor	MicroTech, several others		
		dimethenamid-p	Outlook		
		metolachlor	Dual, several others		
		s-metolachlor	Dual Magnum, Dual II Magnum		
	oxyacetamides	flufenacet	Define, Axiom (contains metribuzin)	Italian ryegrass	ID, OR
	acetamides	napropamide	Devrinol		
Group 16 Unknown	benzofuranes	ethofumesate	Nortron, several others	Annual bluegrass	OR
Group 17 Unknown	organoarsenicals	MSMA	several		
Group 20 Inhibitors of cell wall synthesis site A	nitriles	*dichlobenil	Casoron, Barrier		
Group 22 Photosystem I electron diverters	bipyridiliums	diquat	Reglone, Reward		
		paraquat	Gramoxone Inteon, several others		
Group 26 Unknown	pyrazolium	difenzoquat	Avenge	Wild oat	ID
	carboxylic acids	pelargonic acid	Scythe		
Group 28 Inhibitors of 4-HPPD**	isoxazoles	pyrasulfotole	Huskie (contains bromoxynil)		
	triketones	mesotrione	Callisto		
		topramezone	Impact		

** 4-hydroxyphenylpyruvate isoxygenase

Resource Recommendations

http://extension.oregonstate.edu





Online Weed ID:
http://www.wssa.net/

PNW Handbook
http://pnwhandbooks.org/weed/