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Herbicide Mode-Of-Action Summary

Merrill A. Ross, Professor of Weed Science
Daniel J. Childs, Extension Weed Specialist
Department of Botany and Plant Pathology, Purdue University

Weed Science

The mode-of-action is the overall manner in which a herbicide affects a plant at the tissue or cellular level. Herbicides with the same mode-of-action will have the same translocation (movement) pattern and produce similar injury symptoms. Selectivity on crops and weeds, behavior in the soil and use patterns are less predictable, but are often similar for herbicides with the same mode-of-action.

This publication organizes herbicides into those which are applied to foliage (many of these are applied to soil as well) and those herbicides applied almost strictly to soil. The foliar applied groups are then divided into three categories according to movement through the plant: 1) symplastically translocated (source to sink capable of downward movement), 2) apoplastically translocated (capable of only upward movement), and 3) those which do not move appreciably (kill very quickly). Each translocation group is subdivided into mode-of-action groups which are further categorized by herbicide chemistry group. Strictly soil applied herbicides are divided into mode-of-action and then into herbicide chemistry groups.

Plants are complex organisms with well-defined structures in which multitudes of vital (living) processes take place in well ordered and integrated sequences. Plants are made up of organs (root, stem, leaf, and flower); organs consist of tissues (meristems, conducting, photosynthetic, structural); and tissues are made up of cells. Plant cells contain subunits including walls, membrane systems (golgi, plasma membrane, nuclear membrane, endoplasmic reticulum) and organelles (mitochondria, nucleus, chloroplasts), and undifferentiated cytoplasm.

Some vital metabolic plant processes include photosynthesis (capture of light energy and carbohydrate synthesis), amino acid and protein synthesis, fat (lipid) synthesis, pigment synthesis, nucleic acid synthesis (RNA - DNA essential to information storage and transfer), respiration (oxidation of carbohydrate to provide CO_2 and usable energy), energy transfer (nucleic acids) and maintenance of membrane integrity. Other vital processes include growth and differentiation, mitosis (cell division) in plant meristems, meiosis (division resulting in gamete and seed formation), uptake of ions and molecules, translocation of ions and molecules, and transpiration. One or more of the vital processes must be disrupted in order for a herbicide to kill a weed.

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I. Foliar Applied Herbicides

A. Downwardly Mobile Herbicides [Symplastically Translocated (leaf to growing points)]

These herbicides are capable of moving from leaves (sources of sugar production) with sugars to sites of metabolic activity (sinks of sugar utilization) such as underground meristems (root tips), shoot meristems (shoot tips), storage organs and other live tissues. Since movement to sites is essential for continued plant growth, these herbicides have the potential to kill simple perennial and creeping perennial weeds with only one or two foliar applications.

Symptoms are evident on new growth first. Pigment loss (yellow or white), stoppage of growth, and distorted (malformed) new growth are typical symptoms. Most injury appears only after several days or weeks. Plants die slowly. Herbicides in this group are usually molecular (non-charged) at low pHs found in the cell walls and negatively charged at higher pHs encountered in the cytoplasm of leaf sieve cells of the phloem (the ionization inside the cytoplasm of the phloem accounts for trapping and movement of these herbicides).

1. Auxin Growth Regulators

The effects associated with auxins help set them apart from other downwardly mobile herbicides. Bending and twisting of leaves and stems is evident almost immediately after application. Delayed symptom development includes root formation on dicot stems; misshapened leaves, stems, and flowers; and abnormal roots.

Soil activity varies from almost none to long residual depending on herbicide and dose.

Auxin growth regulator herbicides are used for control of annual, simple perennial, and creeping perennial broadleaves in grass crops (corn, small grains, sorghum, turf, pastures, sodded roadsides and rangeland) and in non-crop situations. All are organic acids which take on a negative charge after ionization of acids and salts. Esters are hydrolyzed to acids or salts in both plants and soils. Injury to off-target vegetation is a major problem associated with these herbicides.

	Common Name	*Trade Name*
Phenoxyaliphatic Acid Herbicides	2,4-D	
	2,4-DB	
	MCPP	(mecoprop)
	MCPA	
	2,4-DP	(dichlorprop)
Benzoic Acids	dicamba	BANVEL/ CLARITY/ VANQUISH/ VETERAN
Picolinic Acids (Pyridines) and Relatives	picloram	TORDON
	clopyralid	STINGER/ LONTREL
	triclopyr	GARLON/ TURFLON
	fluroxypyr	STARANE

	Common Name	*Trade Name*
2. Amino Acid Inhibitors (Aromatic)		
Glyphosate and sulfosate are the compounds with this mode of action. Uses are limited to foliar applications only, since these chemicals are rapidly inactivated in the soil. Symptoms include yellowing of new growth and death of treated plants in days to weeks. These relatively nonselective compounds control annual grasses, annual broadleaves, johnsongrass, quackgrass, yellow nutsedge, cool season pasture and turf grasses, cattail, Canada thistle, hemp dogbane, Jerusalem artichoke, poison ivy, and multiflora rose. Glyphosate tolerant cultivars of soybeans (Roundup Ready) are currently being marketed. Corn and other glyphosate tolerant crops are being tested for future release.	glyphosate	ROUNDUP ULTRA/ RODEO/ACCORD
	sulfosate (glyphosate trimesium)	TOUCHDOWN
3. Amino Acid Inhibitors [Branched-chain (AHAS/ALS)]		
Several groups of different chemistry have this same mode of action. Shoot meristems cease growth; yellow, pink and purple symptoms appear; roots tend to develop poorly; and the secondary roots are shortened and all nearly the same length producing a "bottlebrush" appearance. Complete symptom development is very slow and requires two to three weeks or more. Late postemergence applications of some of these herbicides used on corn may result in malformed (bottle shaped) ears.		
Imidazolinones Weed control in soybeans, alfalfa, wheat, barley, and non-crop situations is the major use of these compounds. Compounds are residual (weeks) to long-residual (several months) depending on herbicide dose. Dry weather and cool temperatures in particular and possibly low pH and high organic matter contribute to persistence in the soil. Imidazolinone tolerant corn cultivars are being marketed for use with imazethapyr.	imazaquin	SCEPTER
	imazethapyr	PURSUIT
	imazapyr	ARSENAL/ CHOPPER
	imazamethabenz	ASSERT
Sulfonylureas Sulfonylurea herbicides are applied preplant incorporated, preemergence, and postemergence at doses of 0.5 to 6 ounces active ingredient per acre. This herbicide group provides selective control of wild garlic and Canada thistle in small grains; broadleaf weeds in soybeans; johnsongrass, shattercane, quackgrass and wirestem muhly in corn; and weeds in conifers, hardwoods and pastures. Several compounds are used for general vegetation control on non-crop sites. High soil pH greatly increases persistence since only biodegradation takes place at higher soil pHs. At soil pHs below 6.8, chemical degradation occurs in addition to biodegradation and speeds inactivation. Sulfonylurea tolerant soybeans are available to farmers.	rimsulfuron	BASIS
	chlorimuron	CLASSIC
	chlorsulfuron	GLEAN/ TELAR
	nicosulfuron	ACCENT
	primisulfuron	BEACON
	thifensulfuron	HARMONY PINNACLE
	tribenuron	EXPRESS
	sulfometuron	OUST
	metsulfuron	ALLY
	halosulfuron	PERMIT/ MANAGE
	prosulfuron	PEAK
Sulfonanilides Selective soil or foliar applied for control of annual broadleaf weeds in corn or soil applied treatments in soybeans.	flumetsulam	BROADSTRIKE

	Common Name	*Trade Name*
4. Chlorophyll/Carotenoid Pigment Inhibitors		
Vivid white new growth, sometimes tinged with pink or purple, characterize the symptoms associated with the pigment inhibitors. New growth initially appears normal except for the conspicuous lack of green and yellow pigments. Uses include, selective weed control in soybeans and cotton, poison ivy control, general vegetation control and aquatic weed control.	clomazone	COMMAND
	amitrole	AMITROL-T
	norflurazon	ZORIAL/ SOLICAM
	fluridone	SONAR
Amitrole is the only compound of this group which moves well in the symplast, however other compounds in the group show initial movement into shoot tips causing new growth to be devoid of green and yellow pigments.		
5. Grass Meristem Destroyers (Lipid Biosynthesis Inhibitors)		
All provide the same symptoms on grass species; namely discoloration and disintegration of meristematic tissue at and above the nodes, including nodes of rhizomes. Leaves yellow, redden and sometimes wilt. Seedling grasses tend to lodge by breaking over at the soil. These herbicides have the potential to be used for selective removal of most grass species from any non-grass crop. There is also some selectivity among grass species (particularly with the aryloxyphenoxypropionates in cool season grasses). The grass meristem destroyers should be used early postemergence on seedling grasses, and postemergence but before the boot stage (the seedhead detectable in the top leaf sheath) on established perennial grasses. Mixing with postemergence broadleaf herbicides frequently results in reduced grass control. When used under less than ideal conditions (no-till, open crop canopies and drought) two applications per season are frequently required.		
These compounds are more active postemergence (foliar) than soil applied. At normally used postemergence doses, soil activity is marginal or lacking.		
Aryloxyphenoxypropionates	fenoxaprop	WHIP/ HORIZON/ OPTION/ ACCLAIM
	fluazifop-P	FUSILADE DX
	quizalofop	ASSURE II
Cyclohexanediones	clethodim	SELECT
	sethoxydim	POAST/ POAST PLUS

Common Name	*Trade Name*

B. Non Translocated (Contact Herbicides)

Cell Membrane Destroyers

Compounds in this group result in rapid disruption of cell membranes and very rapid kill. The bipyridyliums and the diphenyl ethers penetrate into the cytoplasm, cause the formation of peroxides and free electrons (light is required) which destroy the cell membranes almost immediately. Herbicidal oils dissolve membranes directly. Rapid destruction of cell membranes prevents translocation to other regions of the plant. Severe injury is evident hours after application, first as water-soaked areas which later turn yellow or brown. Maximum kill is attained in a week or less. Partial coverage of a plant with spray results in spotting and/or partial shoot kill. New growth on surviving plants will be normal in appearance. Foliar activity alone can provide only shoot kill.

Bipyridyliums

These foliar applied, strongly cationic, relatively toxic herbicides are used postemergence only. Extremely strong binding to clay prevents activity for weed control or leaching in the soil. Only shoot kill can be expected. Liquids with suspended colloids (muddy water, slurry fertilizers) cause inactivation. These herbicides are used for general shoot kill in numerous situations including burn down in conservation tillage systems and preharvest desiccation. Diquat is used for control of aquatic weeds.

paraquat	GRAMOXONE
diquat	DIQUAT/REWARD

Diphenyl ethers (nitrophenyl ethers)

These herbicides have both foliar and soil activity. They mostly control broadleaves. Acifluorfen is labeled for postemergence applications to soybeans, peanuts, and rice. Fomesafen and lactofen are similar to acifluorfen. Although bronzing or burning of soybean leaf tissue is evident after application, yield is rarely affected. Oxyfluorfen is used preemergence for cole crops and postemergence for mint, onions and conifer nurseries. This herbicide group is relatively unaffected by soil texture and organic matter.

acifluorfen	BLAZER
fomesafen	REFLEX/FLEXSTAR
lactofen	COBRA
oxyfluorfen	GOAL

Other postemergence herbicides

Bentazon is used only postemergence in large seeded legumes and some grass crops for control of annual broadleaf weeds and yellow nutsedge and shoot removal of perennial broadleaf weeds. This compound inhibits photosynthesis in the target plant.

Glufosinate is applied postemergence for control of annuals prior to crop establishment, for noncrop areas and for selective directed placement in specialty crops (apples, grapes, tree nuts). There is no soil activity. The inhibition of the glutamine synthetase enzyme in the effected plant results in the decrease of several amino acids which eventually leads to cell membrane disruption and death of the cell. Symptoms of the plant include chlorosis (yellowing) followed by necrosis (dead tissue) 3 to 5 days after herbicide application. Glufosinate tolerant cultivars of rice, soybeans, and corn are being tested.

Flumiclorac has a similar action to the diphenyl ethers (contact burn) and is labeled for postemergence control of broadleaf weeds in corn and soybeans. It is particularly effective on velvetleaf.

bentazon	BASAGRAN
glufosinate	IGNITE/RELY/ FINALE/LIBERTY
flumiclorac	RESOURCE

C. Upwardly Mobile Only Herbicides (Apoplastically Translocated)

Photosynthetic Inhibitors

These herbicides translocate only apoplastically. Movement is upward with the transpiration stream (water moving through the plant from the soil and evaporating into the atmosphere at the leaf surfaces).

Symptoms develop from bottom to top on plant shoots (older leaves show most injury; newer leaves least injury). Chlorosis first appears between leaf veins and along the margins which is later followed by necrosis of the tissue. Any potential control of established perennials must come from continued soil uptake and not movement downward through the plant from the shoots. Foliar activity alone can provide only shoot kill.

Herbicides in these chemical groups have excellent soil activity. Most have foliar activity as well. These herbicides are used preplant incorporated, preemergence, and to a limited extent early postemergence, for selective control of weeds in annual and established perennial crops. Crops include corn, soybeans, potatoes, celery, parsnips, carrots, cotton, alfalfa, asparagus, mint, and woody species. They are also used for brush in pastures, rangeland, and non-cropland and for general vegetation control. Soil persistence varies from weeks to months depending on compound and dose and soil pH. Soil mobility varies from low to high depending on the compound and soil characteristics.

	Common Name	*Trade Name*
Triazines Major herbicides for weeds in corn, they are also used in sorghum, numerous woody species, and for total vegetation control. Use for aquatics has been discontinued. Detection in and public concern regarding surface and ground water may result in severe restrictions on use of the triazine herbicides.	atrazine	AATREX/Atrazines
	simazine	PRINCEP
	cyanazine	BLADEX
	prometon	PRAMITOL
	metribuzin	SENCOR/LEXONE
	hexazinone	VELPAR
Uracils	terbacil	SINBAR
	bromacil	HYVAR
Phenylureas	linuron	LOROX/LINEX
	diuron	KARMEX
	tebuthiuron	SPIKE
Others (not typical)	bentazon	BASAGRAN
	bromoxynil	BUCTRIL
	pyridate	TOUGH/ LENTAGRAN

Common Name	*Trade Name*

II. Soil Applied Herbicides

A. Cell Division Inhibitors

1. Root Inhibitors

These herbicide groups have little or no foliar activity and are applied mostly preplant incorporated and preemergence for control of seedling grasses and some annual broadleaves in soybeans, peanuts, dry beans, cole crops, cotton, alfalfa, clovers, lettuce, tobacco, herbaceous ornamentals, established turf, and in woody species (nurseries, orchards, grapes, Christmas trees, etc.).

Dinitroanilines (Dinitrobenzenamines)

These herbicides inhibit the steps in plant cell division responsible for chromosome separation and cell wall formation. Roots are relatively few in number and club shaped. Except for oryzalin, these compounds have water solubility less than one part per million. They bind to soil colloids and are unlikely to leach. Losses occur through volatilization and photodegradation on soil surfaces. Incorporation into the soil by mechanical mixing or by overhead irrigation soon after application is routinely suggested. These root inhibitors do not translocate.

trifluralin	TREFLAN
benefin	BALAN
prodiamine	BARRICADE/ ENDURANCE
oryzalin	SURFLAN
pendimethalin	PROWL/PENTAGON/ STOMP/PENDULUM
ethalfluralin	SONALAN

Miscellaneous Herbicides

DCPA is labeled soil applied for seedling grass control in large seeded legumes, cotton, cole crops, onions, garlic, potatoes, other vegetables, established turf, herbaceous ornamentals, woody ornamentals, and small fruits.

Siduron is labeled soil applied for seedling grass control in newly seeded or newly sprigged turf and established turf. It removes annual grass competition from spring established turf.

DCPA	DACTHAL
siduron	TUPERSAN

2. Shoot Inhibitors

The shoot inhibitors are soil applied for control of seedling grasses, some broadleaves and suppression of some perennials from tubers and rhizomes. Injury appears as malformed (twisted), dark green shoots and leaves on injured young plants. Grass crops with some tolerance to these compounds can be protected from injury with other chemicals [safeners (protectants)]. Crops include corn, large seeded legumes, small seeded legumes, beets, spinach, tomatoes, potatoes, and ornamentals.

Thiocarbamates (Carbamothioates)

This group of very volatile herbicides is used preplant incorporated. They persist in the soil for two to six weeks and are particularly effective for control of seedling grasses including johnsongrass and shattercane.

EPTC	EPTAM/ERADICANE
butylate	SUTAN+
pebulate	TILLAM
cycloate	RO-NEET

	Common Name	*Trade Name*
Substituted Amides (Chloroacetamides) These are the major preemergence herbicides for seedling grass control in corn and soybeans in the Eastern Corn-belt. Several provide decent control of seedling grasses in higher organic matter soils. Most are labeled for preplant incorporated application. Most of these herbicides control yellow nutsedge and black nightshade. Typical persistence in the soil is 10 to 15 weeks.	acetochlor	HARNESS/SURPASS/ TOPNOTCH
	alachlor	LASSO/MICRO-TECH/PARTNER
	metolachlor	DUAL /DUAL II
	propachlor	RAMROD
	dimethenamid	FRONTIER
3. Shoot and Root Inhibitors Preplant incorporated, preemergence and sometimes early postemergence for control of annual grasses, and some annual broadleaves in small seeded legumes, lettuce, established woody species, established turf, strawberries, established herbaceous perennials, tomatoes, cole crops, cotton, cucurbits, peppers, and tobacco.	bensulide	BETASAN/ BENSULIDE/PREFAR
	napropamide	DEVRINOL
	pronamide	KERB
	dichlobenil	CASORON
	dithiopyr	DIMENSION

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WS-16 Weed Control Guidelines for Indiana

WS-22 Herbicide List

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