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HOW HERBICIDES WORK

UPTAKE, TRANSLOCATION, AND MODE OF ACTION







OREGON STATE UNIVERSITY
EXTENSION SERVICE

Contents

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How Herbicides Work:

Uptake, Translocation, and Mode of Action

Effective weed management with herbicides depends on the coordination of several factors (Figure 1):

- Herbicide application and placement
- Herbicide uptake
- Herbicide translocation (movement within the plant)
- Herbicide metabolism (breakdown within the plant)
- Herbicide toxicity or activity

Herbicide Application and Placement

Herbicides must be applied in a way that maximizes their contact with target weeds. This is particularly important for postemergence *contact* herbicides such as paraquat. These herbicides affect only the part of the plant they contact. Thus, even and thorough plant coverage results in the best weed control.

In contrast, some postemergence herbicides, such as glyphosate, move from the foliar application site to the target site within the plant through the plant's transport system. These products are known as *translocated* herbicides.

Soil-applied herbicides must be applied evenly across the field to maximize contact with germinating weeds. Proper seedbed preparation and soil moisture can eliminate soil clods that protect weed seeds from the herbicide.

Some soil-applied herbicides, such as trifluralin, do not move easily within the soil; they must be incorporated into the soil to maximize contact with weeds. Soil-incorporated herbicides become more

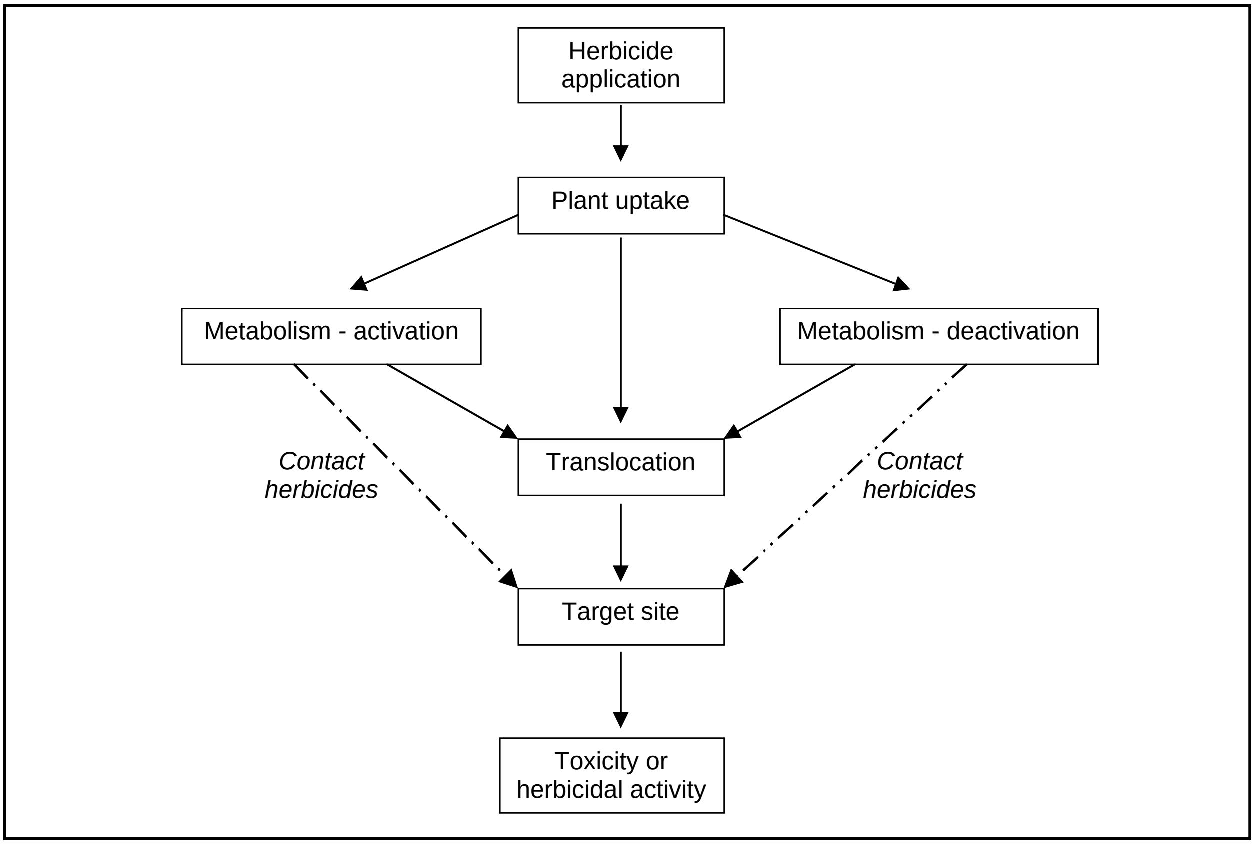


Figure 1.—Routing of herbicides from the sprayer nozzle to the site of activity within a plant.

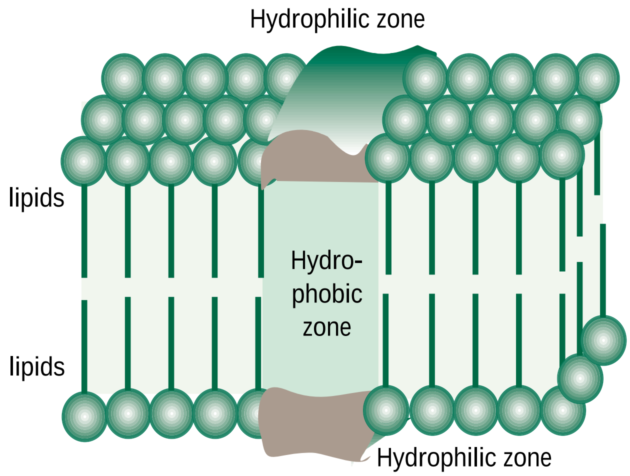


Figure 2.—Cell membranes are made up of a double layer of lipids, with proteins traversing the two layers and protruding from the inner and outer surface. The exposed portions of the protein are hydrophilic; the embedded portion is hydrophobic.

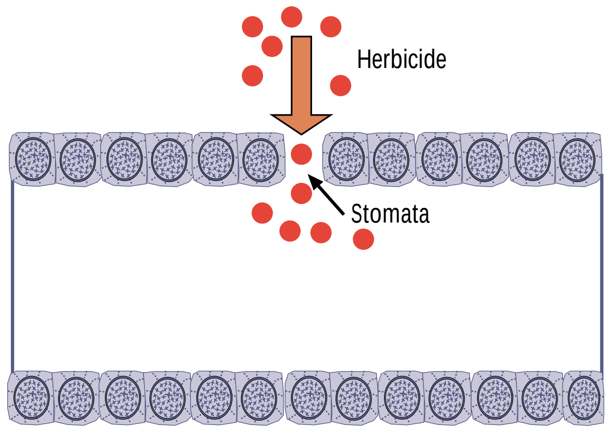


Figure 3.—Openings in the leaf surface called stomata allow herbicides to enter the plant along with carbon dioxide. Water vapor and oxygen exit through the stomata.

diluted when tilled in deeply. Thus, it is important to incorporate them evenly and only to the depth of germinating weeds. Poor herbicide incorporation often results in strips in the field where there is ineffective weed control.

Herbicide Uptake

Postemergence herbicides must overcome several barriers to move from the leaf surface into the plant. Leaf hairs often intercept spray particles, holding them away from the leaf surface. The leaf surface itself is protected from dehydration by a waxy coating called the *cuticle*. Some herbicides will not penetrate the cuticle (particularly hydrophilic, or "water-loving," herbicides), while others become trapped within the cuticle (hydrophobic, or "water-hating," herbicides) (Figure 2). The cuticle becomes thicker during hot, dry weather, making it more difficult for herbicides to pass through. Spray additives can enhance herbicide penetration.

Postemergence herbicides also can enter the leaf through openings called *stomata*, which act like gates, allowing some compounds to enter while excluding others (Figure 3). In hot, dry weather, the stomata close, preventing herbicide penetration.

Soil conditions also play a role in herbicide uptake. Soil-applied herbicides must contact roots and/or shoots of the target plant. Surface-applied herbicides often move with water through the soil to reach plant roots. Thus, when soil moisture is limited, weed control might be compromised by a lack of weed exposure to the herbicide.

Herbicide Translocation

A plant's transport system is composed of two "pipes": the xylem and the phloem (Figure 4). The *phloem* is a two-way system composed of living plant cells that moves sugars and amino acids both up and down the plant. The phloem transports sugars to the growing points during spring growth. In perennials, it moves sugars to the roots for storage after the plant flowers. Most perennial weed herbicides are phloem-mobile so that they can be transported to the roots.

The *xylem* is a one-way pipe composed of dead cells that transports water and dissolved nutrients from the roots to the shoots. Water movement is driven by environmental factors such as soil moisture and the air's relative humidity. Water-soluble, soil-applied herbicides typically move in the xylem.

Amino Acid Synthesis Inhibitors

Use

Imidazolinone and **sulfonylurea** herbicides selectively control annual and perennial broadleaf and grass weeds. Some soil-applied products provide residual weed control; the herbicide persists after application and injures or kills germinating weed seedlings.

Amino acid derivative herbicides are nonselective.

Herbicide uptake

Imidazolinone and **sulfonylurea** herbicides are absorbed by foliage and/or roots and moved in the xylem and phloem (Figure 7).

Amino acid derivatives are absorbed by foliage. Soil activity is minimal because the herbicide binds to soil soon after application. Glyphosate moves with carbohydrates in both the xylem and phloem (Figure 8). For effective control of perennial weeds, it must move downward through the phloem. Thus, it is most effective when applied in the fall, when plants are transporting carbohydrates for storage. Glyphosate moves with the carbohydrates to underground storage organs, where it depletes reserves for future growth.

Amino Acid Synthesis Inhibitors

Common name	Trade name(s)	Labeled crops in Oregon*
Imidazolinones		
Imazamox	Raptor	Alfalfa
Imazapyr	Arsenal	Non-cropland
Imazethapyr	Pursuit	Alfalfa, lentils, peas, dry beans
Imazamethabenz	Assert	Wheat, barley, grass seed
Sulfonylureas		
Chlorsulfuron	Glean, Telar	Wheat, barley, oats, chemical fallow, non-cropland
Halosulfuron	Battalion, Permit	Corn, sorghum
Metsulfuron	Ally, Escort	Barley, non-cropland, pasture and rangeland, wheat
Nicosulfuron	Accent	Corn
Primisulfuron	Beacon	Corn, grass seed
Prosulfuron	Peak	Wheat
Rimsulfuron	Matrix	Potatoes
Sulfometuron	Oust	Non-cropland
Sulfosulfuron	Maverick	Wheat
Thifensulfuron	Harmony GT, Pinnacle	Wheat, barley
Triasulfuron	Amber	Barley, pasture and rangeland, wheat
Tribenuron	Express	Barley, wheat, grass seed
Triflusulfuron	UpBeet	Sugar beets
Amino acid derivatives		
Glyphosate	Various names	Non-cropland, chemical fallow, pasture and rangeland, preseeding in several crops
Glufosinate	Liberty, Rely	Grass seed

*Only agronomic (not horticultural) crops are listed. Pesticide labels are subject to change. Always consult the label for current chemical recommendations before using any herbicide.

Glufosinate does not move within the plant and therefore provides little perennial weed control (Figure 9).

Plant systems involved

Proteins are central to all plant functions. Proteins are composed of *amino acids. Enzymes* create various combinations of amino acids to form specific proteins. Some of the enzymes affected by these herbicides are:

- Acetolactate synthase (ALS)—an enzyme found in the *chloroplast* (the part of the cell containing chlorophyll). It regulates the production of three amino acids: valine, leucine, and isoleucine.
- Enolpyruvyl-shikimate-phosphate synthase (EPSPS)—responsible for the production of the amino acids phenylalanine, tyrosine, and tryptophane.
- Glutamine synthase (GS)—responsible for the production of the amino acid glutamine.

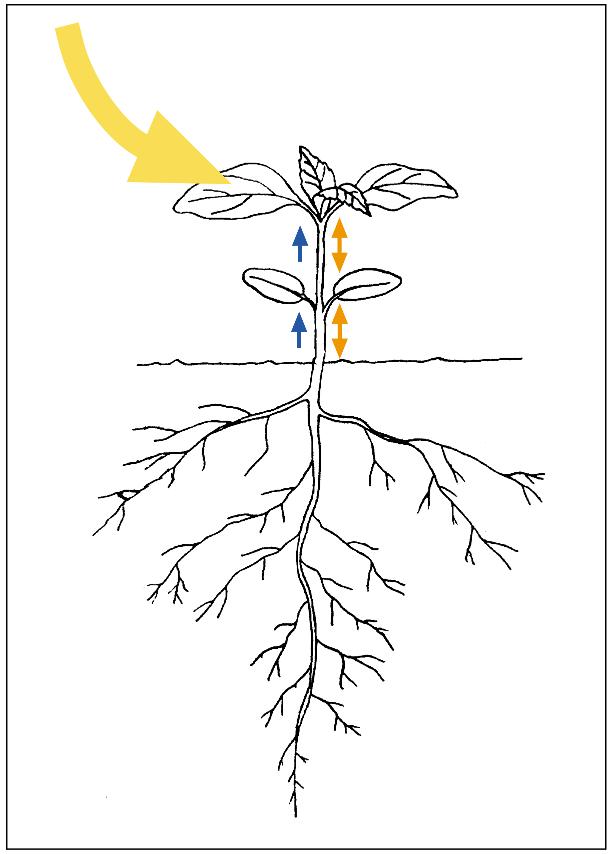


Figure 8.—Glyphosate: Uptake through leaves and transport through both phloem and xylem.

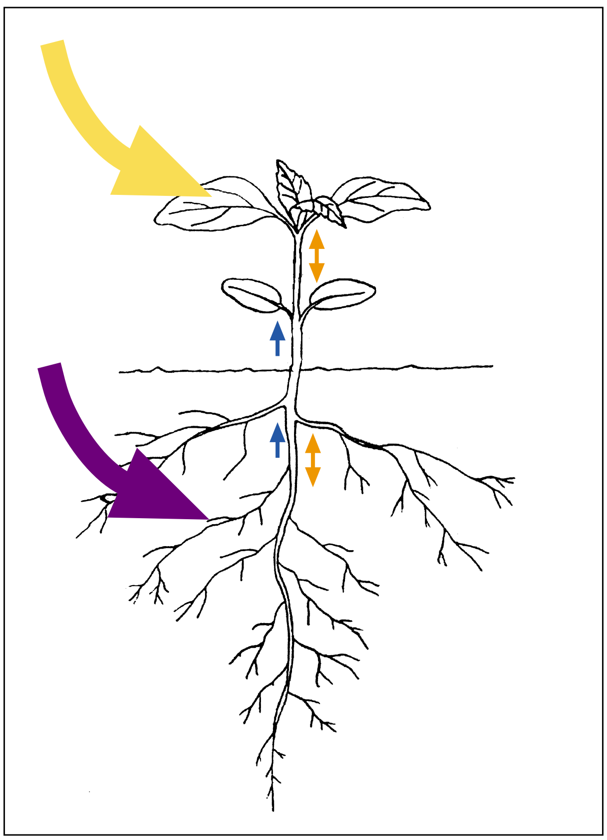


Figure 7.—Imidazolinones and sulfonylureas: Uptake through leaves and roots and transport through both phloem and xylem.

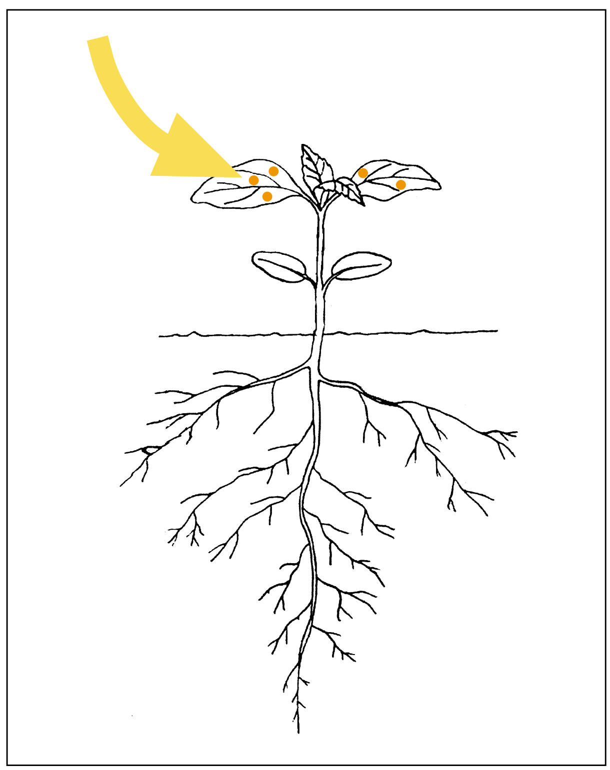


Figure 9.—Glufosinate: Contact only.

Mode of action

Amino acids are the building blocks of proteins. By interfering with amino acid production, these herbicides reduce protein production, which in turn can cause a buildup of toxic by-products (Figure 10).

Imidazolinone and **sulfonylurea** herbicides bind to the acetolactate synthase (ALS) enzyme, which regulates the production of three amino acids. These amino acids are necessary for normal plant growth and function.

The **amino acid derivative** glyphosate binds to the EPSPS enzyme, which regulates the production of three amino acids. Seventy percent of the carbon captured by plants flows through this system.

Glufosinate inhibits the production of glutamine, which is essential for nitrogen metabolism and electron flow in photosynthesis. The resulting buildup of unstable chlorophyll eventually breaks down cell membranes. Therefore, symptoms often resemble those caused by cell membrane disruptors.

Selectivity

Selectivity of **imidazolinone** and **sulfonylurea** herbicides is based on the tolerant plant's ability to break down the herbicide before it becomes toxic.

Amino acid derivative herbicides exhibit little selectivity or metabolism. When glyphosate is ineffective, the cause often is a thick layer of plant cuticular waxes that limits herbicide penetration.

Symptoms

Imidazolinone and **sulfonylurea** herbicides cause grass plants to be stunted and show yellowing between leaf veins (Plate 3). Some grass

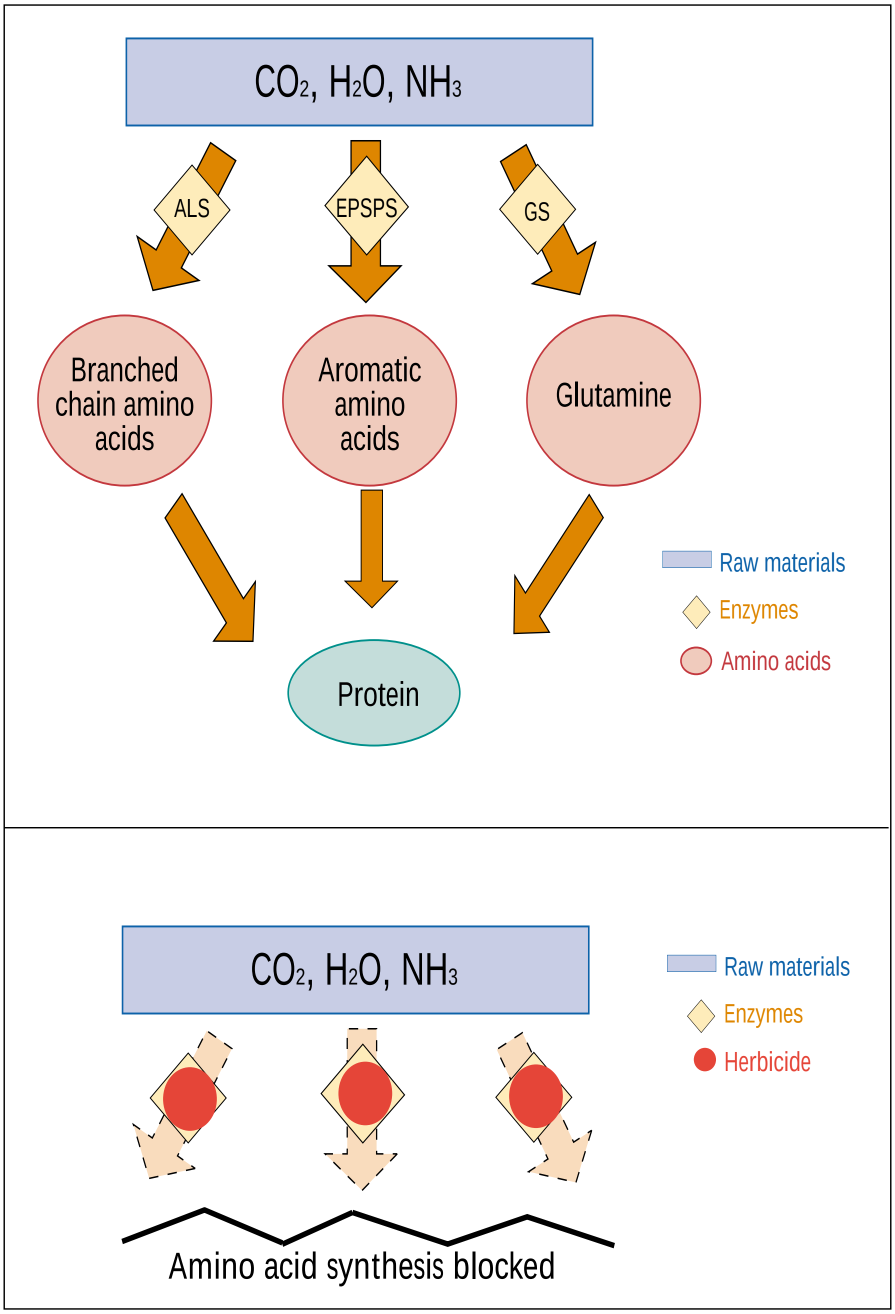


Figure 10.—Top: Enzymes convert raw materials into amino acids, the building blocks of protein. Bottom: Amino acid synthesis inhibitors bind to enzymes, thus reducing the production of amino acids.

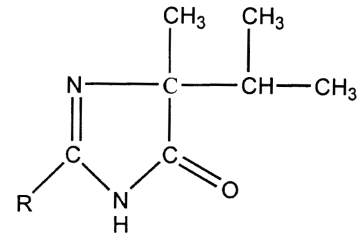
species, such as corn, often have pruned roots or few lateral roots. Broadleaf species might be stunted, with yellow between leaf veins. Leaf veins on beans and other broadleaves often are purple (Plate 4).

With **amino acid derivative** herbicides, injury symptoms might appear slowly as amino acids are depleted and plant membranes weakened. Plant foliage first turns yellow and then brown, usually within 10 to 14 days after application. These herbicides are nonselective, so most species show symptoms.

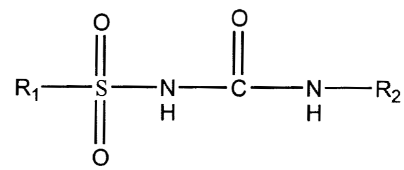
Weed resistance in the Pacific Northwest

Imidazolinone and sulfonylurea herbicides

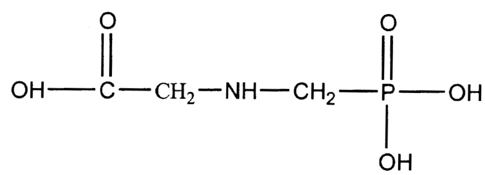
- Kochia (*Kochia scoparia*): chlorsulfuron (OR, WA, ID), metsulfuron-methyl (OR), triasulfuron (OR)
- Prickly lettuce (*Latuca serriola*): chlorsulfuron (OR, WA, ID), metsulfuron-methyl (OR, ID), triasulfuron (OR)
- Russian thistle (*Salsola iberica*): chlorsulfuron (OR, WA, ID), metsulfuron-methyl (OR), triasulfuron (OR)
- Downy brome (*Bromus tectorum*): primisulfuron (OR), sulfosulfuron (OR)
- Mayweed chamomile (*Anthemis cotula*): chlorsulfuron (ID)
- Small-seeded false flax (*Camelina microcarpa*): chlorsulfuron (OR)



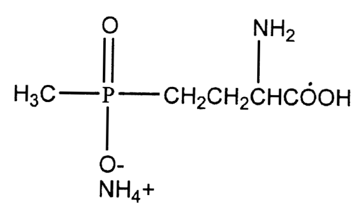
imidazolinones



sulfonylureas



amino acid derivative (glyphosate)



amino acid derivative (glufosinate)

Figure 11.—Chemical structure of amino acid synthesis inhibitors.

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