SECTION B.
AGRICHEMICALS AND THEIR PROPERTIES

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Revised March 2020

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This information provides specifications for users of this handbook. For more information regarding the physiological or biochemical activity and behavior in or on soils, refer to the Herbicide Handbook of the Weed Science Society of America.

The Acute toxicity LD$_{50}$ (lethal dose to 50% of the test animals) has been stated for the formulated product when known. Refer to Managing Herbicide-resistant Weeds in this handbook for further information on site of action and chemical family.

The adsorption coefficient ($Koc$) is included for most herbicides. The $Koc$ represents how strongly an herbicide adsorbs to soil when normalized for the amount of organic matter (OM) in a soil. Values less than 300 indicate high potential for leaching. This value is often an average of several soil types with varying levels of OM and, therefore, should be used with the understanding that the actual values could be plus or minus twice the listed value for a particular soil.

Caution! This handbook is not intended as a complete guide to herbicide use. Before using any chemical, read the container’s label. A chemical must be thoroughly tested before it can be recommended for a specific use. Following the label’s recommendation can prevent many problems from arising due to wrong use of a chemical. Any use of a pesticide contrary to instructions on the printed label is illegal and is not recommended.

2,4-D

| Trade name(s) | Many |
| Manufacturer(s) | Corteva, Helena, Nufarm, and others |
| Formulation(s) | Numerous acids, salts (amines usually), and esters. Sold as liquids, water-soluble powders, dusts (seldom used due to drift hazard), granules, and pellets. |
| Remarks | A selective, foliar-absorbed, translocated phenoxy herbicide used mainly in postemergence applications. 2,4-D is effective against many annual and perennial broadleaf weeds. Ester formulations are the most volatile, the amines least volatile. Plants are most susceptible when they are young and growing rapidly. |
| Water solubility | 900 ppm |
| Storage conditions | Amine formulations are relatively stable, whereas esters depend on emulsifying system. Read each product label carefully. |
| Acute toxicity | LD$_{50}$ - 300 to 1,000 mg/kg |

Action in plant | Mimics natural plant hormones. |
Site of action | Group 4: synthetic auxin |
Chemical family | Phenoxy acetic acid |
$Koc$ | Average is 20 mL/g for the acid and DMA salt, and 100 mL/g (estimated) for esters of the oil-soluble amine |

2,4-DB

| Trade name(s) | Butoxone, Butoxone Ester, Butyrac, 2,4-DB 200 |
| Manufacturer(s) | Albaugh, Winfield, Nufarm, and others |
| Formulation(s) | 1.75 and 2 lb/gal emulsifiable and soluble concentrates, formulated as amine salts and esters, and 75% water-soluble powders. |
| Remarks | A phenoxy compound used as a selective, postemergence, translocated herbicide, particularly for broadleaf weed control in legumes. Material is beta-oxidized to 2,4-D very slowly by most legumes and rapidly by broadleaf weeds. Selectivity decreases with maturity of the legumes. |
| Water solubility | 40 ppm |
| Storage conditions | Read each product label. |
| Acute toxicity | LD$_{50}$ - 1,960 mg/kg |

ACETIC ACID

| Trade name(s) | WeedPharm Weed and Grass Killer and others |
| Manufacturer(s) | Pharm Solutions |
| Formulation(s) | 20% acetic acid |
| Remarks | Organic herbicide. Nonselective contact herbicide, applied undiluted to three- to five-leaf, actively growing weeds. Results are best when applied in full sunshine at temperatures above 50°F. |
### ACETOCHLOR

**Trade name(s)** Breakfree, Harness, Surpass, Cadence, TopNotch, Degree, Confidence

**Manufacturer(s)** Monsanto Co., Corteva, Winfield

**Formulation(s)** 6.4 and 7 lb/gal emulsifiable concentrate; 3.2 lb/gal capsule suspension

**Remarks** A selective, soil-active herbicide applied preplant or preemergence to corn.

**Water solubility** 223 ppm

**Storage conditions** Store in a cool, dry, well-ventilated area away from sources of heat or flame.

**Acute toxicity** $LD_{50} - 2,148$ mg/kg

**Action in plant** Disrupts protein synthesis.

**Site of action** Group 15: inhibits very long chain fatty acid synthesis

**Chemical family** Chloroacetamide

**Koc** Average is 0.4 mL/g for a Lintonia sand with 0.7% OM; 1.1 mL/g for a Ray silt loam with 1.2% OM; 1.6 mL/g for a Spinks sandy loam with 2.4% OM, 2.7 mL/g for a Drenner silty clay loam with 3.4% OM.

### AMETRYN

**Trade name(s)** Evik

**Manufacturer(s)** Syngenta

**Formulation(s)** 80% wettable powder

**Remarks** A selective, contact herbicide with some soil residual activity. Postemergence treatments must be directed on most crops. Absorbed through foliage and roots; penetrates foliage rapidly, minimizing its removal by rain.

**Water solubility** 185 ppm

**Storage conditions** Slight sensitivity to extreme temperatures and natural light.

**Acute toxicity** $LD_{50} - 1,750$ mg/kg

**Action in plant** Inhibits photosynthesis.

**Site of action** Group 5: photosystem II inhibitor

**Chemical family** Triazine

**Koc** Average is 300 mL/g

### ACIFLUORFEN

**Trade name(s)** Blazer, Snapback, Ultra Blazer

**Manufacturer(s)** BASF Corp, United Phosphorous

**Formulation(s)** 2 lb/gal water miscible concentrate

**Remarks** A selective preemergence or postemergence contact herbicide for use in certain large-seed legume crops.

**Water solubility** 250,000 ppm

**Storage conditions** Store above 32°F. Warm and shake, if frozen.

**Acute toxicity** $LD_{50} - 3,330$ mg/kg

**Action in plant** Acts as a selective contact that disrupts cell membrane.

**Site of action** Group 14: protoporphyrinogen oxidase inhibitor

**Chemical family** Diphenylether

**Koc** Average is 113 mL/g (estimated)

### ACROLEIN (RESTRICTED-USE HERBICIDE)

**Trade name(s)** Magnacide H

**Manufacturer(s)** Baker Petrolite

**Formulation(s)** 92% liquid

**Remarks** A highly volatile, contact, aquatic herbicide. Use only under the supervision of licensed pesticide applicators.

**Water solubility** 215,000 ppm

**Storage conditions** Highly reactive or forms insoluble polymers (white precipitate) in presence of oxygen. Therefore, avoid contamination with any foreign materials, especially alkaline or strong acids. Do not store opened product.

**Acute toxicity** $LD_{50} - 46$ mg/kg

**Action in plant** General cell toxicant that destroys enzyme systems.

**Site of action** General cell toxicant

**Chemical family** None generally accepted

**Koc** Average is 0.5 mL/g

### AMICARBAZONE

**Trade name(s)** Xonerate

**Manufacturer(s)** Arysta

**Formulation(s)** 70% water dispersible granule

**Remarks** A selective postemergence herbicide with some soil residual activity for control of annual bluegrass and other grass and broadleaf weeds in turf.

**Water solubility** Not available

**Storage conditions** Store in a cool, dry place

**Acute toxicity** Dermal and oral $LD_{50} > 5,000$ mg/kg (male rat); 1105 mg/kg (female rat)

**Action in plant** Inhibits photosynthesis.

**Site of action** Group 5: photosystem II inhibitor

**Chemical family** Triazolinone

**Koc** 23 to 37 mL/g on silt loam

### AMINOCYCLOPYRACHLOR

**Trade name(s)** Method, Perspective, Streamline, and Viewpoint are premixes that include aminocyclopyrachlor

**Manufacturer(s)** Corteva

**Formulation(s)** 25% and 50% SG

**Remarks** Highly active on most broadleaf weeds and brush. Some conifers are very sensitive to this, including ponderosa pine.

**Water solubility** 3,100 to 3,800 ppm (pH 4 to 9, respectively)

**Storage conditions** Store in a cool, dry place

**Acute toxicity** Dermal and oral $LD_{50} > 5,000$ mg/kg

**Action in plant** Mimics natural plant hormones.

**Site of action** Group 4: synthetic auxin

**Chemical family** pyrimidine carboxylic acid

**Koc** Average is 24 mL/g
AMINOPYRALID

Trade name(s) Milestone
Manufacturer(s) Corteva
Formulation(s) 2 lb (ae) soluble concentrate
Remarks A selective, foliage-applied herbicide used to control broadleaf weeds with some residual activity in the soil. Opensight is aminopyralid + metsulfuron; Capstone is aminopyralid + triclopyr amine.

Water solubility 2,480 ppm
Storage conditions Store above freezing; but if exposed to freezing, warm to at least 40°F and agitate well.
Acute toxicity LD₅₀ - more than 5,000 mg/kg
Action in plant Mimics natural plant hormones.
Site of action Group 4: synthetic auxin
Chemical family Pyridine
Koc Average is 10.8 mL/g

AMMONIUM NONANOATE

Trade name(s) Racer
Manufacturer(s) Falcon Lab
Formulation(s) 3.3 lb ai/gal

ASULAM

Trade name(s) Asulox, Asulox XP
Manufacturer(s) United Phosphorus, Inc.
Formulation(s) 3.12 and 3.34 lb/gal soluble concentrate
Remarks A carbamate to control actively growing grasses and certain broadleaf weeds. Effective on johnsongrass, field horsetail, bracken fern, tansy ragwort, dock, and red sorrel.

Water solubility 20,000 ppm
Storage conditions Store above 20°F. If frozen, warm to 70°F and agitate.
Acute toxicity LD₅₀ - 8,000 mg/kg
Action in plant Inhibits mitosis.
Site of action Group 18: inhibits DHP synthase step
Chemical family Carbamate
Koc Average is 40 mL/g for the acid; ranges from 60 to 120 mL/g across the different soils for the Na salt

ASULAM (MOST PRODUCTS CONTAINING ATRAZINE ARE DESIGNATED RESTRICTED-USE)

Trade name(s) AAtrex, Atrazine
Manufacturer(s) Syngenta, Corteva, and others
Formulation(s) 80% wettable powder, 4 lb/gal liquid, 90% water-dispersible granule
Remarks A selective, root-absorbed herbicide. Some foliar absorption but with little translocation. Most plant tissue contacted by spray is injured. More soluble and less strongly adsorbed on soil than simazine; thus, less moisture is needed to activate it. More active on soils with high pH.

Water solubility 33 ppm
Storage conditions Very stable
Acute toxicity LD₅₀ - 5,100 mg/kg
Action in plant Inhibits photosynthesis.
Site of action Group 5: photosystem II inhibitor
Chemical family Triazine
Koc Average is 100 mL/g

BENEFIN

Trade name(s) Balan
Manufacturer(s) Loveland Products
Formulation(s) 1.5 lb/gal emulsifiable concentrate, 2.5% granule, 60% dry flowable

BENSULIDE

Trade name(s) Betasan, Prefar, Betamec
Manufacturer(s) Gowan Co., PBI/Gordon
Formulation(s) 2.9 and 4 lb/gal emulsifiable concentrate, 3.6% and 12.5% granules
Remarks A selective compound applied preemergence. It must be applied to soil before weeds emerge.

Water solubility 25 ppm
Storage conditions Store above 42°F depending on emulsifiable formulation. Do not store or use near heat or flame. Warm and agitate until crystals dissolve, or do not use.
Acute toxicity LD₅₀ - 770 mg/kg
Action in plant Inhibits roots of seedlings.
Site of action Group 8: lipid synthesis inhibitor but not an ACCCase inhibitor
Chemical family Organophosphorus
Koc Average is 10,000 mL/g

BENTAZON

Trade name(s) Basagran, BasagranT/O
Manufacturer(s) BASF, Arysta, Winfield
Formulation(s) 4 or 5 lb/gal soluble concentrate
Remarks A selective herbicide to control many broadleaf weeds and yellow nutsedge. Rain within 24 hours after application may reduce effectiveness. Bentazon is a postemergence contact spray, so thorough coverage is essential.
<table>
<thead>
<tr>
<th><strong>Trade name(s)</strong></th>
<th>Hyvar X, Hyvar X-L.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturer(s)</strong></td>
<td>Corteva</td>
</tr>
<tr>
<td><strong>Formulation(s)</strong></td>
<td>80% wettable powder, 2 lb/gal water-soluble liquid</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td>A substituted uracil compound used preemergence or as a spot-treatment on brush. A nonselective soil-residual herbicide; controls a wide range of weeds and brush.</td>
</tr>
<tr>
<td><strong>Water solubility</strong></td>
<td>815 ppm</td>
</tr>
<tr>
<td><strong>Storage conditions</strong></td>
<td>Stable at 0°F, but water-soluble formulations become less soluble when exposed to air.</td>
</tr>
<tr>
<td><strong>Acute toxicity</strong></td>
<td>LD₅₀ - 5,200 mg/kg</td>
</tr>
<tr>
<td><strong>Action in plant</strong></td>
<td>Inhibits photosynthesis.</td>
</tr>
<tr>
<td><strong>Site of action</strong></td>
<td>Group 5: photosystem II inhibitor</td>
</tr>
<tr>
<td><strong>Chemical family</strong></td>
<td>Uracil</td>
</tr>
<tr>
<td><strong>Koc</strong></td>
<td>Average is 32 mL/g</td>
</tr>
</tbody>
</table>

### BROMOXYNIL

<table>
<thead>
<tr>
<th><strong>Trade name(s)</strong></th>
<th>Buctril, Bromox, Moxy, Broclean, Connect Bromoxynil</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturer(s)</strong></td>
<td>Bayer CropScience and others</td>
</tr>
<tr>
<td><strong>Formulation(s)</strong></td>
<td>2 and 4 lb/gal emulsifiable concentrate; 20% water-soluble powder</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td>A selective, postemergence, contact herbicide. Controls some weeds resistant to 2,4-D. Can be safely applied to seedling grains and grasses. Has little soil activity.</td>
</tr>
<tr>
<td><strong>Water solubility</strong></td>
<td>13,000 ppm</td>
</tr>
<tr>
<td><strong>Storage conditions</strong></td>
<td>Store above 32°F. If frozen, agitate before using.</td>
</tr>
<tr>
<td><strong>Acute toxicity</strong></td>
<td>LD₅₀ - 160 mg/kg</td>
</tr>
<tr>
<td><strong>Action in plant</strong></td>
<td>Inhibits photosynthesis.</td>
</tr>
<tr>
<td><strong>Site of action</strong></td>
<td>Group 6: photosystem II inhibitor</td>
</tr>
<tr>
<td><strong>Chemical family</strong></td>
<td>Nitrile</td>
</tr>
<tr>
<td><strong>Koc</strong></td>
<td>Average is 10,000 mL/g (estimated) for the octanoate ester</td>
</tr>
</tbody>
</table>

### BUTYLATE

<table>
<thead>
<tr>
<th><strong>Trade name(s)</strong></th>
<th>Sutan, Sutan + (butylate plus safener)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturer(s)</strong></td>
<td>Helm Agro</td>
</tr>
<tr>
<td><strong>Formulation(s)</strong></td>
<td>6.7 lb/gal emulsifiable concentrate</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td>A thiocarbamate compound used as a selective preplant-incorporated herbicide. Because of its volatility, it must be incorporated immediately after application.</td>
</tr>
<tr>
<td><strong>Water solubility</strong></td>
<td>45 ppm</td>
</tr>
<tr>
<td><strong>Storage conditions</strong></td>
<td>Stable at moderate temperatures. If frozen, roll container to mix.</td>
</tr>
<tr>
<td><strong>Acute toxicity</strong></td>
<td>LD₅₀ - 3,878 mg/kg</td>
</tr>
<tr>
<td><strong>Action in plant</strong></td>
<td>Inhibits shoot growth.</td>
</tr>
<tr>
<td><strong>Site of action</strong></td>
<td>Group 8: lipid synthesis inhibitor but not an ACCase inhibitor</td>
</tr>
<tr>
<td><strong>Chemical family</strong></td>
<td>Thiocarbamate</td>
</tr>
<tr>
<td><strong>Koc</strong></td>
<td>Average is 400 mL/g</td>
</tr>
</tbody>
</table>
CACODYLIC ACID

Trade name(s)  Montar
Manufacturer(s) Monterey Chemical
Formulation(s)  2.48 lb/gal soluble solution
Remarks  A postemergence, nonselective contact herbicide. Its phytotoxic properties are quickly inactivated on contact with soil.
Water solubility  667,000 ppm
Storage conditions  Stable
Acute toxicity  LD$_{50}$ - 830 mg/kg
Action in plant  Contact-type herbicide.
Site of action  Not well understood
Chemical family  Organoarsenical
Koc  Average is 1,000 mL/g (estimated)

CARFENTRAZONE

Trade name(s)  Aim, QuickSilver, Shark, Stingray
Manufacturer(s) FMC Corp.
Formulation(s)  1.9 and 2 lb/gal emulsifiable concentrates
Remarks  Postemergent, contact herbicide for controlling broadleaf weeds.
Water solubility  12 ppm
Storage conditions  Stable under normal storage conditions. Store in tightly closed containers.
Acute toxicity  LD$_{50}$ - 5,140 mg/kg
Action in plant  Disrupts cell membranes.
Site of action  Group 14: protoporphyrinogen oxidase inhibitor
Chemical family  Triazinone
Koc  750 mL/g (25 C) for carfentrazone-ethyl

CHLORIMURON

Trade name(s)  Curio
Manufacturer(s) Nufarm
Formulation(s)  25% dispersible granules
Remarks  Control of buttercup in cranberries
Water solubility  11 ppm at pH 5; 450 at pH 6.5
Storage conditions  Store in original container in cool dry place.
Acute toxicity  LD$_{50}$ - 4102 mg/kg
Action in plant  Interferes with enzyme acetolactate synthase, resulting in a rapid cessation of cell division and plant growth in roots and shoots.
Site of action  Group 2: acetolactate synthase (ALS) inhibitor
Chemical family  Sulfonylurea
Koc  Average is 110 mL/g at pH 7

CHLORSULFURON

Trade name(s)  Glean XP, Telar DF
Manufacturer(s) Corteva
Formulation(s)  75% dry flowable
Remarks  A selective preemergence or early postemergence herbicide used at low rates. Carefully consider crop rotation plans before using. Recommended for use in wheat, barley, oats, and in fallow on soils of pH 7.5 or less. Telar formulation is a selective broadleaf herbicide used preemergence to postemergence in noncropland areas.
Water solubility  587 ppm at pH 5; 31,800 ppm at pH 7
Storage conditions  Stable when excess moisture or humidity are excluded from container.
Acute toxicity  LD$_{50}$ - 5,545 mg/kg
Action in plant  Interferes with enzyme acetolactate synthase, resulting in a rapid cessation of cell division and plant growth in both roots and shoots.
Site of action  Group 2: acetolactate synthase (ALS) inhibitor
Chemical family  Sulfonylurea
Koc  Median was 1,588 mL/g.

CLETHODIM

Trade name(s)  Prism, Select, Envoy, Volunteer, Arrow, Section, Trigger, SelectMax, Shadow, Intensity
Manufacturer(s) Valent, Tenkoz, Albaugh, Arysta, Winfield, Loveland, ADAMA
Formulation(s)  0.94, 0.97 and 2 lb/gal emulsifiable concentrate
Remarks  A selective postemergence grass-control herbicide. Controls most annual and perennial grasses except fine fescues. Using a crop oil concentrate enhances activity.
Storage conditions  Stable
Acute toxicity  LD$_{50}$ - 2,920 mg/kg
Action in plant  Inhibits growing points in grasses.
Site of action  Group 1: acetyl CoA carboxylase (ACCase) inhibitor
Chemical family  Cyclohexanedione

CLODINAFOP

Trade name(s)  Discover, Discover NG
Manufacturer(s) Syngenta
Formulation(s)  0.5 and 2 lb/gal emulsifiable concentrate
Remarks  Controls annual grasses postemergence.
Water solubility  4,000 ppm
Storage conditions  Store in a cool, dry place.
Acute toxicity  LD$_{50}$ - 1,829 mg/kg
Action in plant  Inhibits growing points in grasses.
Site of action  Group 1: acetyl CoA carboxylase (ACCase) inhibitor
Chemical family  Aryloxyphenoxy propionate
Koc  Median was 1,588 mL/g.

CLOMAZONE

Trade name(s)  Command
Manufacturer(s) FMC Corp.
Formulation(s)  3 lb/gal encapsulated herbicide
Remarks  A selective, preplant-incorporated herbicide; controls several annual weeds. Some foliar activity. Offsite movement can whiten or yellow plant foliage.
Water solubility  1,100 ppm
**Storage conditions** Store above 40°F. If frozen, warm to 60°F and shake or roll container.

**Acute toxicity**  \( LD_{50} = 1,369 \text{ mg/kg} \)

**Action in plant** Inhibits synthesis of photosynthetic pigments, both chlorophyll and carotenoids.

**Site of action** Group 13: inhibits DOXP synthase

**Chemical family** Isoxazolidone

**Koc** Average is 300 mL/g

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**CLOPYRALID**

Trade name(s) Stinger, Transline

Manufacturer(s) Corteva

Formulation(s) 3 lb/gal soluble concentrate

Remarks A highly translocated, selective herbicide active primarily through foliage of broadleaf herbaceous weeds (mostly the Asteraceae, Fabaceae, and Polygonaceae families). Curtail is clopyralid + 2,4-D; Redeem R&P and Confront are clopyralid + triclopyr.

**Water solubility** 1,000 ppm

**Storage conditions** Store above 28°F or warm to 40°F and agitate before use.

**Acute toxicity**  \( LD_{50} = 4,300 \text{ mg/kg} \)

**Action in plant** Mimics natural plant hormones.

**Site of action** Group 4: synthetic auxin

**Chemical family** Pyridine

**Koc** Average is 6 mL/g, but ranges to 60 mL/g (increased soil sorption with time)

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**CLOVE LEAF OIL**

Trade name(s) Matran EC

Manufacturer(s) EcoSmart

Formulation(s) 50% emulsifiable concentrate

Remarks Organic herbicide. Nonselective contact herbicide.

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**COPPER SULFATE**

Trade name(s) Copper Sulfate, Blue Stone

Manufacturer(s) Chem One Limited, Griffin, Phelps Dodge, Nufarm

Formulation(s) 25% crystals; also available impregnated in clay and as liquid.

Remarks Used primarily to control algae in impounded waters, lakes, ponds, reservoirs, and irrigation systems.

**Water solubility** Very soluble

**Storage conditions** Stable when kept dry.

**Acute toxicity**  \( LD_{50} = 470 \text{ mg/kg} \)

**Action in plant** Causes imbalance of copper with other enzyme metal cofactors, resulting in enzyme blockage.

**Site of action** Plant cells

**Chemical family** Inorganic

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**CORN OR MAIZE GLUTEN MEAL**

Trade name(s) WOW, A-Maize-N

Manufacturer(s) Gardens Alive!, Wilbur-Ellis

Formulation(s) 100% dry

Remarks Organic herbicide, is a by-product of the wet milling process of making cornstarch or corn syrup.

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**CYCLOATE**

Trade name(s) Ro-Neet

Manufacturer(s) Helm Agro

Formulation(s) 6 lb/gal emulsifiable concentrate, 10% granules

Remarks A selective, thiocarbamate herbicide applied preplant and soil incorporated. For best results, incorporate immediately into the top 2 to 3 inches of soil. Cycloate is absorbed by seed and stem tissue of seedlings.

**Water solubility** 85 ppm

**Storage conditions** Store above 20°F but away from sources of heat and flame. Warm and agitate.

**Acute toxicity**  \( LD_{50} = 3,160 \text{ mg/kg} \)

**Action in plant** Inhibits shoot growth.

**Site of action** Group 8: lipid synthesis inhibitor but not an ACCCase inhibitor

**Chemical family** Thiocarbamate

**Koc** Average is 600 mL/g

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**D-LIMONENE**

Trade name(s) GreenMatch O, Nature’s Avenger

Manufacturer(s) Cutting Edge Formulations and Marrone Organic Innovations

Formulation(s) 17.5 and 70% EC

Remarks OMRI-listed for organic production. D-limonene is a citrus extract. Nonselective contact herbicide

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**DAZOMET**

Trade name(s) Mylone

Manufacturer(s) Hopkins Agricultural Chemical Co.

Formulation(s) 50% dust, 99% granule

Remarks Soil fumigant used in seedbed preparation to control weeds, nematodes, soil fungi, and certain insects. Preplant incorporate using conventional equipment. Adequate soil moisture is important for its biological activity. In soil, dazomet presumably is converted to formaldehyde, hydrogen sulfide, and methyl isothiocyanate.

**Water solubility** 2,000 ppm

**Storage conditions** Store at 32° to 102°F. Keep dry.

**Acute toxicity**  \( LD_{50} = 320 \text{ mg/kg} \)

**Action in plant** Attacks cell membranes.

**Site of action** Not well understood

**Chemical family** Dithiocarbamate

**Koc** Average is10 mL/g (estimated)
### DCPA

**Trade name(s)** Dacthal, Garden Weed Preventer  
**Manufacturer(s)** AMVAC  
**Formulation(s)** 75% wettable powder, 25% and 5% granule, 6 lb flowable  
**Remarks** A soil-active, preemergence, selective herbicide. Must be applied to soil before weed seeds germinate. Moisture needed to activate. Not foliage active.  
**Water solubility** 0.5 ppm  
**Storage conditions** Stable when kept dry.  
**Acute toxicity** \( \text{LD}_{50} \geq 3,000 \text{ mg/kg} \)  
**Action in plant** Inhibits mitosis in roots and shoots.  
**Site of action** Group 3: microtubule assembly inhibitor  
**Chemical family** Phthalic acid  
**Koc** Average is 5,000 mL/g

### DESMEDIPHAM

**Trade name(s)** Component of Betamix and Sugarbeet Mix  
**Manufacturer(s)** Bayer CropScience  
**Formulation(s)** 1.3 lb/gal emulsifiable concentrate  
**Remarks** A foliar-applied, selective herbicide for weeds in sugarbeets. Rain within 6 hours of spraying may reduce weed kill. Do not apply to sugarbeets within 90 days before harvest. Betamix is desmedipham + phenmedipham; Progress is desmedipham + phenmedipham + ethofumesate.  
**Water solubility** 7 ppm  
**Storage conditions** Store above 15°F. If frozen, warm and mix at 50°F. Avoid use or storage near heat or flame.  
**Acute toxicity** \( \text{LD}_{50} = 3,700 \text{ mg/kg} \)  
**Action in plant** Inhibits photosynthesis.  
**Site of action** Group 5: photosystem II inhibitor  
**Chemical family** Phenylcarbamate  
**Koc** Average is 1,500 mL/g

### DICAMBA

**Trade name(s)** Banvel, Banvel II, Banvel SGE, Clarity, Vanquish, Dicamba, Rifle  
**Manufacturer(s)** BASF, Syngenta, Arysta  
**Formulation(s)** 1, 2, and 4 lb/gal water- and oil-soluble concentrates, 10% granules  
**Remarks** A growth-regulating herbicide readily absorbed and translocated from either roots or foliage. Effects similar to those of 2,4-D.  
**Water solubility** 4,500 ppm  
**Storage conditions** Store above 15°F.  
**Acute toxicity** \( \text{LD}_{50} = 1,028 \text{ mg/kg} \)  
**Action in plant** Mimics natural plant hormones.  
**Site of action** Group 4: synthetic auxin  
**Chemical family** Benzoic acid  
**Koc** Average is 2 mL/g

### DICHLORPROP, 2,4-DP

**Trade name(s)** Weedone 2,4-DP  
**Manufacturer(s)** PBI/Gordon, Riverdale, Monterey  
**Formulation(s)** 4 lb/gal emulsifiable concentrate  
**Remarks** A translocated, postemergence herbicide effective against certain broadleaf weeds and brush species.  
**Water solubility** 710 ppm  
**Storage conditions** Read each product label.  
**Acute toxicity** \( \text{LD}_{50} = 800 \text{ mg/kg} \)  
**Action in plant** Mimics natural plant hormones.  
**Site of action** Group 4: synthetic auxin  
**Chemical family** Phenoxy acetic acid  
**Koc** Average is 400 mL/g (estimated)

### DICLOFOP (RESTRICTED-USE HERBICIDE)

**Trade name(s)** Hoelon  
**Manufacturer(s)** Bayer CropScience  
**Formulation(s)** 3 lb/gal emulsifiable concentrate  
**Remarks** A selective herbicide applied postemergence. Controls several grass species; has some residual activity. Antagonistic response if mixed with phenoxy herbicides.  
**Water solubility** 3,000 ppm  
**Storage conditions** Store above 20°F. If frozen, warm and agitate.  
**Acute toxicity** \( \text{LD}_{50} = 580 \text{ mg/kg} \)  
**Action in plant** Mimics natural plant hormones.  
**Site of action** Group 1: acetyl CoA carboxylase (ACCase) inhibitor  
**Chemical family** Aryloxyphenoxy propionate  
**Koc** Average is 1,000 mL/g (estimated) for the butoxyethyl ester
<table>
<thead>
<tr>
<th><strong>DIFENZOQUAT</strong></th>
<th><strong>DIQUAT (A MODERATELY TOXIC HERBICIDE THAT REQUIRES PROTECTIVE GEAR FOR HANDLING AND APPLICATION)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trade name(s)</strong></td>
<td>Avenge</td>
</tr>
<tr>
<td><strong>Manufacturer(s)</strong></td>
<td>Amvac</td>
</tr>
<tr>
<td><strong>Formulation(s)</strong></td>
<td>2 lb/gal water miscible concentrate</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td>A selective herbicide to control wild oat. Rain within 6 hours after application reduces effectiveness.</td>
</tr>
<tr>
<td><strong>Water solubility</strong></td>
<td>765,000 ppm</td>
</tr>
<tr>
<td><strong>Storage conditions</strong></td>
<td>Store above 32°F. Ice will form at 15°F; remix at warmer temperatures before use.</td>
</tr>
<tr>
<td><strong>Acute toxicity</strong></td>
<td>LD₅₀ - 730 mg/kg</td>
</tr>
<tr>
<td><strong>Action in plant</strong></td>
<td>Action unknown.</td>
</tr>
<tr>
<td><strong>Site of action</strong></td>
<td>Group 26: unknown</td>
</tr>
<tr>
<td><strong>Chemical family</strong></td>
<td>Pyrazolium</td>
</tr>
<tr>
<td><strong>Koc</strong></td>
<td>Average is 54,500 mL/g</td>
</tr>
<tr>
<td><strong>Trade name(s)</strong></td>
<td>Diquat Herbicide, Reward, Reglone</td>
</tr>
<tr>
<td><strong>Manufacturer(s)</strong></td>
<td>Syngenta</td>
</tr>
<tr>
<td><strong>Formulation(s)</strong></td>
<td>2 lb water-soluble cation/gal (3.73 lb/gal salt). Cation portion of the molecule is the active ingredient.</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td>A fast-acting, nonselective, foliar-applied, contact herbicide and plant desiccant. Material is slightly translocated. It is completely inactivated on contact with soil. Using a surfactant enhances its activity.</td>
</tr>
<tr>
<td><strong>Water solubility</strong></td>
<td>700,000 ppm</td>
</tr>
<tr>
<td><strong>Storage conditions</strong></td>
<td>Store above 32°F.</td>
</tr>
<tr>
<td><strong>Acute toxicity</strong></td>
<td>LD₅₀ - 125 mg/kg for mouse.</td>
</tr>
<tr>
<td><strong>Action in plant</strong></td>
<td>Acts as contact. Absorbs energy produced by photosynthesis; forms peroxides that disrupt living cells.</td>
</tr>
<tr>
<td><strong>Site of action</strong></td>
<td>Group 22: photosystem I electron diversion</td>
</tr>
<tr>
<td><strong>Chemical family</strong></td>
<td>Bipyridilium</td>
</tr>
<tr>
<td><strong>Koc</strong></td>
<td>Average is 1,000,000 mL/g (estimated)</td>
</tr>
<tr>
<td><strong>Trade name(s)</strong></td>
<td>Dimension EC, Dimension EW, Dimension Ultra 40 WP, Lifeguard</td>
</tr>
<tr>
<td><strong>Manufacturer(s)</strong></td>
<td>Corteva</td>
</tr>
<tr>
<td><strong>Formulation(s)</strong></td>
<td>1 and 2 lb/gal emulsifiable concentrate and 40% wettable powder</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td>Selective control of many annual grasses and certain annual broadleaf weeds in established cool- and warm-season turfgrasses in lawns and ornamental turf.</td>
</tr>
<tr>
<td><strong>Water solubility</strong></td>
<td>0.7 ppm</td>
</tr>
<tr>
<td><strong>Storage conditions</strong></td>
<td>Store above 32°F.</td>
</tr>
<tr>
<td><strong>Acute toxicity</strong></td>
<td>LD₅₀ - more than 5,000 mg/kg</td>
</tr>
<tr>
<td><strong>Action in plant</strong></td>
<td>Interferes with cell division.</td>
</tr>
<tr>
<td><strong>Site of action</strong></td>
<td>Group 3: microtubule assembly inhibitor</td>
</tr>
<tr>
<td><strong>Chemical family</strong></td>
<td>Pyridine</td>
</tr>
<tr>
<td><strong>Koc</strong></td>
<td>Average is 1,638 mL/g</td>
</tr>
<tr>
<td><strong>Trade name(s)</strong></td>
<td>Frontier, Outlook</td>
</tr>
<tr>
<td><strong>Manufacturer(s)</strong></td>
<td>BASF</td>
</tr>
<tr>
<td><strong>Formulation(s)</strong></td>
<td>6 and 7.5 lb/gal emulsifiable concentrate</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td>A chloroacetamide compound used as a selective, pre-emergence herbicide, particularly for grass control in field corn. Also controls several broadleaf weeds. Dimethenamid-P is the more active isomer of dimethenamid and is used at lower rates.</td>
</tr>
<tr>
<td><strong>Water solubility</strong></td>
<td>1,174 ppm</td>
</tr>
<tr>
<td><strong>Storage conditions</strong></td>
<td>Stable.</td>
</tr>
<tr>
<td><strong>Acute toxicity</strong></td>
<td>LD₅₀ - 2,400 mg/kg</td>
</tr>
<tr>
<td><strong>Action in plant</strong></td>
<td>Inhibits plant cell division and growth.</td>
</tr>
<tr>
<td><strong>Site of action</strong></td>
<td>Group 15: inhibits very long chain fatty acid synthesis</td>
</tr>
<tr>
<td><strong>Chemical family</strong></td>
<td>Chloroacetamide</td>
</tr>
<tr>
<td><strong>Koc</strong></td>
<td>Average is 125 mL/g</td>
</tr>
<tr>
<td><strong>Trade name(s)</strong></td>
<td>Karmex, Diuron, Direx, Parrot</td>
</tr>
<tr>
<td><strong>Manufacturer(s)</strong></td>
<td>Corteva, Griffin Corp., Platte Chemical Co., ADAMA</td>
</tr>
<tr>
<td><strong>Formulation(s)</strong></td>
<td>80% wettable powder, 80% dry flowable, 4 lb/gal water dispersible liquid</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td>A substituted urea compound used preemergence to control annual weeds and certain perennials in noncropland and certain agricultural crops. Plant roots absorb and translocate material. It is foliar absorbed when used with a wetting agent. Diuron may persist several months in soil.</td>
</tr>
<tr>
<td><strong>Water solubility</strong></td>
<td>42 ppm</td>
</tr>
<tr>
<td><strong>Storage conditions</strong></td>
<td>Stable at moderate temperatures.</td>
</tr>
<tr>
<td><strong>Acute toxicity</strong></td>
<td>LD₅₀ - 3,400 mg/kg</td>
</tr>
<tr>
<td><strong>Action in plant</strong></td>
<td>Inhibits photosynthesis.</td>
</tr>
</tbody>
</table>
### DSMA

**Trade name(s)**: DSMA Liquid  
**Manufacturer(s)**: Drexel Chemical Co., Monterey  
**Formulation(s)**: 64% soluble powder (100% hexahydrate), 3.6 and 7.2 lb/gal soluble concentrate  
**Remarks**: An organic, arsenical compound used as a selective contact herbicide applied postemergence. DSMA takes up moisture, so store in a dry place. Use a surfactant to ensure activity.

**Water solubility**: Very soluble

**Storage conditions**: Stable under moderate conditions.

**Acute toxicity**: LD₅₀ - 3,630 mg/kg

**Action in plant**: Unknown

**Site of action**: Group 17: not well understood

**Chemical family**: Organoarsenical

**Koc**: Average is 7000 mL/g (estimated)

### ENDOTHALL (RESTRICTED-USE HERBICIDE)

**Trade name(s)**: Aquathol, Aquathol K, Hydrothol 191, Des-l-Cate, Accelerate  
**Manufacturer(s)**: United Phosphorus, Inc.  
**Formulation(s)**: 0.52, 2, and 3 lb/gal soluble concentrates and 7.2 to 44.7% granules, formulated as dipotassium salt and as a number of amine salts.

**Remarks**: Used in sugar beets and turf, as an aquatic herbicide, and as a preharvest desiccant. Irritates skin and eyes. In water it generally breaks down within 10 days.

**Water solubility**: 100,000 ppm

**Storage conditions**: Store above 32°F. If frozen, warm and agitate.

**Acute toxicity**: LD₅₀ - 182 mg/kg

**Action in plant**: Specific action unknown; disrupts cell membranes.

**Site of action**: Not well understood

**Chemical family**: Organosulphonate

**Koc**: Average is 7000 mL/g (estimated)

### EPTC

**Trade name(s)**: Eptam, Eradicane (EPTC plus safener)  
**Manufacturer(s)**: Gowan  
**Formulation(s)**: 6, 6.7, and 7 lb/gal emulsifiable concentrates,10% granule

**Remarks**: A selective, thiocarbamate herbicide applied preplant and soil incorporated. Must be incorporated immediately after application due to volatility. EPTC is absorbed by the shoots of emerging weed seedlings. Eradicane is used for corn.

**Water solubility**: 370 ppm

**Storage conditions**: Store above -50°F and below moderately warm temperatures. If frozen, roll container to mix.

**Acute toxicity**: LD₅₀ - 1,652 mg/kg

### ETHAFLURALIN

**Trade name(s)**: Sonalan, Curbit  
**Manufacturer(s)**: Loveland Products  
**Formulation(s)**: 3 lb/gal emulsifiable concentrate

**Remarks**: A selective, preemergence herbicide that should be soil incorporated. Do not incorporate when using on cucurbits. Ethalfluralin has little or no foliar activity.

**Water solubility**: 0.3 ppm

**Storage conditions**: Store above 40°F.

**Acute toxicity**: LD₅₀ - greater than 5,000 mg/kg

**Action in plant**: Inhibits mitosis in shoots and roots.

**Site of action**: Group 3: microtubule assembly inhibitor

**Chemical family**: Dinitroaniline

**Koc**: Average is 4,000 mL/g

### ETHAMETSULFURON

**Trade name(s)**: Muster  
**Manufacturer(s)**: Corteva  
**Formulation(s)**: 75% water soluble granule

**Remarks**: Effective in controlling selected broadleaf weeds.

**Water solubility**: 1.7 ppm at pH 5, 50 ppm at pH 7, 410 ppm at pH 9

**Acute toxicity**: LD₅₀ - greater than 5,000 mg/kg

**Action in plant**: Inhibits the plant enzyme acetolactate synthase.

**Site of action**: Group 2: acetolactate synthase (ALS) inhibitor

**Chemical family**: Sulfonylurea

### ETHOFUMESATE

**Trade name(s)**: Nortron, Prograss, Ethotron, Poa Constrictor  
**Manufacturer(s)**: Bayer CropScience, United Phosphorus  
**Formulation(s)**: 1.5 and 4 lb/gal emulsifiable concentrate

**Remarks**: A selective herbicide for weed control in sugar beets and several grass seed crops. Progress is ethofumesate + phenmedipham + desmedipham.

**Water solubility**: 110 ppm

**Storage conditions**: Store above 34°F.

**Acute toxicity**: LD₅₀ - 6,400 mg/kg

**Action in plant**: Unknown

**Site of action**: Group 16: unknown

**Chemical family**: Benzofuran

**Koc**: Average is 340 mL/g
**FENOXAPROP**

- **Trade name(s)**: Acclaim, Puma, Tacoma
- **Manufacturer(s)**: Bayer CropScience
- **Formulation(s)**: 1 lb/gal emulsifiable concentrate
- **Remarks**: Selective postemergence grass control herbicides effective in some grass seeds, turfgrass, rice, and soybeans.
- **Water solubility**: 0.9 ppm
- **Storage conditions**: Store between 10° and 100°F. Avoid using or storing near heat or flame.
- **Acute toxicity**: LD$_{50}$ - 2,357 mg/kg
- **Action in plant**: Inhibits growing point in grasses.
- **Site of action**: Group 1: acetyl CoA carboxylase (ACCase) inhibitor
- **Chemical family**: Aryloxyphenoxy propionate
- **Koc**: Average is 9,490 mL/g for fenoxaprop ethyl ester

**FLAZASULFURON**

- **Trade name(s)**: Mission
- **Manufacturer(s)**: ISK
- **Formulation(s)**: 25% water-dispersible granule
- **Remarks**: Broadleaf herbicide used in turf for removal of overseeded cool-season grasses as well as control of annual and perennial grasses, sedges, and broadleaf weeds in warm-season turf, vineyards and Christmas trees.
- **Water solubility**: 2100 ppm at pH 7
- **Storage conditions**: Store in cool, dry conditions.
- **Acute toxicity**: LD$_{50}$ - 4,690 mg/kg
- **Action in plant**: Inhibits acetolactate synthase (ALS) enzyme.
- **Site of action**: Group 2: acetolactate synthase inhibitor
- **Chemical family**: Sulfonylurea
- **Koc**: Not available

**FLORASULAM**

- **Trade name(s)**: Defendor and ingredient in Orion, GoldSky, FirstStep, and Spitfire
- **Manufacturer(s)**: Corteva, Syngenta
- **Formulation(s)**: 0.42 lb/gal emulsifiable concentrate and packaged with other herbicides
- **Remarks**: Broadleaf herbicide used in cereals for broadleaf weed control.
- **Water solubility**: 84 ppm at pH 5, 6360 ppm at pH 7, and 94,200 ppm at pH 9
- **Storage conditions**: Not available
- **Acute toxicity**: LD$_{50}$ - greater than 6,000 mg/kg
- **Action in plant**: Inhibits acetolactate synthase (ALS) enzyme.
- **Site of action**: Group 2: acetolactate synthase inhibitor
- **Chemical family**: Sulfonanalide
- **Koc**: Average is 2 to 69 mL/g; average 18 mL/g

**FLUAZIFOP**

- **Trade name(s)**: Fusilade DX
- **Manufacturer(s)**: Syngenta
- **Formulation(s)**: 2 lb/gal emulsifiable concentrate
- **Remarks**: A selective, postemergence grass herbicide to control most annual and perennial grasses except annual bluegrass and all fine fescues. A nonionic surfactant or crop oil concentrate enhances activity.
- **Water solubility**: 1.1 ppm
- **Storage conditions**: Store at moderate temperatures.
- **Acute toxicity**: LD$_{50}$ - 4,350 mg/kg
- **Action in plant**: Inhibits growing point in grasses.
- **Site of action**: Group 1: acetyl CoA carboxylase (ACCase) inhibitor
- **Chemical family**: Aryloxyphenoxy propionate
- **Koc**: Average is 5,700 mL/g for the butyl ester

**FLUCARBAZONE**

- **Trade name(s)**: Everest, Pre-Pare
- **Manufacturer(s)**: Arysta
- **Formulation(s)**: 70% water-dispersible granule (66% acid equivalent)
- **Remarks**: Low-rate herbicide applied postemergence to control grasses in wheat. Has some activity on broadleaf weeds.
- **Water solubility**: 44,000 ppm
- **Storage conditions**: Store in cool, dry conditions.
- **Acute toxicity**: LD$_{50}$ - greater than 5,000 mg/kg
- **Action in plant**: Inhibits the plant enzyme acetolactate synthase.
- **Site of action**: Group 2: acetolactate synthase (ALS) inhibitor
- **Chemical family**: Sulfonylaminocarbonyltriazolinone

**FLUFENACET**

- **Trade name(s)**: Component of Axiom
- **Manufacturer(s)**: Bayer CropScience
- **Formulation(s)**: 60% dry flowable, 4 lb/gal soluble concentrate
- **Remarks**: Effective on several annual grasses and some small-seed broadleaf weeds. Axiom is flufenacet + metribuzin.
- **Water solubility**: 56 ppm
- **Storage conditions**: Store in a cool dry place. Storage above 100°F results in loss of active ingredient.
- **Acute toxicity**: LD$_{50}$ - 371 mg/kg
- **Action in plant**: Interferes with meristematic activity.
- **Site of action**: Group 15: inhibits very long chain fatty acid synthesis
- **Chemical family**: Oxyacetamide
- **Koc**: Average is 354 mL/g for sandy loam with 2.4% OM, 5% clay and pH 6.4
**FLUMETSULAM**

**Trade name(s)** Python  
**Manufacturer(s)** Corteva  
**Formulation(s)** 80% water-dispersible granule  
**Remarks** Herbicide applied preplant, preemergence, or early postemergence to control broadleaf weeds in field corn. Flumetsulam is package-mixed with several products and marketed under various trade names.  
**Water solubility** 49 ppm at pH 2.5; 5,600 ppm at pH 7  
**Storage conditions** Stable under normal storage conditions.  
**Acute toxicity** LD$_{50}$ - greater than 5,000 mg/kg  
**Action in plant** Inhibits the plant enzyme acetolactate synthase.  
**Site of action** Group 2: acetolactate synthase (ALS) inhibitor  
**Chemical family** Triazolopyrimidine  
**Koc** 700 mL/g for flumetsulam acid; 12 mL/g for dissociated flumetsulam anion

**FLUMICLORAC**

**Trade name(s)** Resource  
**Manufacturer(s)** Valent USA Corp  
**Formulation(s)** 0.86 lb/gal emulsifiable concentrate  
**Remarks** Contact postemergence herbicide for controlling certain annual broadleaf weeds in field corn and soybeans.  
**Water solubility** 0.189 ppm  
**Storage conditions** Stable under normal storage conditions.  
**Acute toxicity** LD$_{50}$ - 3,600 mg/kg  
**Action in plant** Acts as a contact-type herbicide.  
**Site of action** Group 14: protoporphyrinogen oxidase inhibitor  
**Chemical family** N-phenylphthalimide

**FLUMIOXAZIN**

**Trade name(s)** Valor, Chateau, SureGuard, Payload, BroadStar, Outflank, Warfox  
**Manufacturer(s)** Valent, ADAMA  
**Formulation(s)** 51% water-dispersible granule, 0.25% granular  
**Remarks** A preemergence and postemergence herbicide for controlling some broadleaf weeds. Has some residual effect when used preemergence. Rapidly burns down broadleaf weeds when used postemergence.  
**Water solubility** 1.78 ppm  
**Storage conditions** Stable under normal storage conditions.  
**Acute toxicity** LD$_{50}$ - greater than 5,000 ppm  
**Action in plant** Inhibits protoporphyrinogen oxidase, an enzyme important in the synthesis of chlorophyll; acts as a contact herbicide.  
**Site of action** Group 14: protoporphyrinogen oxidase inhibitor  
**Chemical family** N-phenylphthalimide

**FLURIDONE**

**Trade name(s)** Sonar, SonarOne, Avast!  
**Manufacturer(s)** SePRO  
**Formulation(s)** 4 lb/gal flowable, 5% slow-release pellets  
**Remarks** An aquatic herbicide to control submerged and immersed plants. Not particularly effective in controlling floating aquatic plants.  
**Water solubility** 12 ppm  
**Storage conditions** Store at moderate temperatures, although no adverse effects have been observed after freezing.  
**Acute toxicity** LD$_{50}$ - greater than 10,000 mg/kg  
**Action in plant** Inhibits carotene formation, resulting in chlorophyll destruction.  
**Site of action** Group 12: bleaching; inhibits carotenoid biosynthesis  
**Chemical family** None generally recognized  
**Koc** Average is 1000 mL/g

**FLUROXYPYR**

**Trade name(s)** Vista, Vista XRT, Starane, Starane Ultra, Spotlight  
**Manufacturer(s)** Corteva, Loveland Products  
**Formulation(s)** 1.5 and 2.8 lb/gal emulsifiable concentrate  
**Remarks** A growth-regulating, foliage-applied herbicide to control broadleaf plants. Effects are similar to those of 2,4-D.  
**Water solubility** 0.11 ppm  
**Storage conditions** Store above 10°F.  
**Acute toxicity** LD$_{50}$ - greater than 2,000 mg/kg  
**Action in plant** Mimes natural plant hormones.  
**Site of action** Group 4: synthetic auxin  
**Chemical family** Pyridine  
**Koc** Acid 39 mL/g to 71 mL/g over 4 soils; Ester 20,000 mL/g

**FLUTHIACET**

**Trade name(s)** Cadet  
**Manufacturer(s)** FMC  
**Formulation(s)** 0.91 lb/gal EC  
**Remarks** Cadet is a postemergence herbicide for broadleaf weed control in corn and soybeans in Idaho only.  
**Water solubility** 0.85 ppm  
**Storage conditions** Store in a cool dry place and avoid excess heat. Do not store below 32°F.  
**Acute toxicity** LD$_{50}$ - greater than 5,000 ppm  
**Action in plant** Inhibits protoporphyrinogen oxidase (PPO) that disrupts cell membranes  
**Site of action** Group 14: protoporphyrinogen oxidase inhibitor  
**Chemical family** Triazinone
<table>
<thead>
<tr>
<th><strong>FOMESAFEN</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trade name(s)</strong></td>
<td>Reflex</td>
</tr>
<tr>
<td><strong>Manufacturer(s)</strong></td>
<td>Syngenta</td>
</tr>
<tr>
<td><strong>Formulation(s)</strong></td>
<td>2 lb sodium salt/gal</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td>Selective preemergence herbicide primarily for broadleaf weed control.</td>
</tr>
<tr>
<td><strong>Water solubility</strong></td>
<td>50 mg/L for acid; 600,000 mg/L for sodium salt</td>
</tr>
<tr>
<td><strong>Storage conditions</strong></td>
<td>Store above 32°F to prevent freezing</td>
</tr>
<tr>
<td><strong>Acute toxicity</strong></td>
<td>( \text{LD}_{50} = 1,250 \text{ to } 2,000 \text{ mg/kg} )</td>
</tr>
<tr>
<td><strong>Action in plant</strong></td>
<td>Inhibits protoporphyrinogen oxidase (PPO) that disrupts cell membranes</td>
</tr>
<tr>
<td><strong>Site of action</strong></td>
<td>Group 14: protoporphyrinogen oxidase inhibitor</td>
</tr>
<tr>
<td><strong>Chemical family</strong></td>
<td>diphenylether</td>
</tr>
<tr>
<td><strong>Koc</strong></td>
<td>Average is 60 mL/g for the Na salt</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>FORAMSULFURON</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trade name(s)</strong></td>
<td>Option</td>
</tr>
<tr>
<td><strong>Manufacturer(s)</strong></td>
<td>Bayer CropScience</td>
</tr>
<tr>
<td><strong>Formulation(s)</strong></td>
<td>35% water-dispersible granule</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td>Selective postemergence herbicide to control grasses and some small-seed broadleaf weeds in corn.</td>
</tr>
<tr>
<td><strong>Water solubility</strong></td>
<td>3,290 ppm at 68°F (20°C) and pH 7</td>
</tr>
<tr>
<td><strong>Storage conditions</strong></td>
<td>Stable storage.</td>
</tr>
<tr>
<td><strong>Acute toxicity</strong></td>
<td>( \text{LD}_{50} ) - greater than 3,881 mg/kg</td>
</tr>
<tr>
<td><strong>Action in plant</strong></td>
<td>Interferes with acetolactate synthase enzyme, resulting in a rapid cessation of cell division and plant growth in both roots and shoots.</td>
</tr>
<tr>
<td><strong>Site of action</strong></td>
<td>Group 2: acetolactate synthase (ALS) inhibitor</td>
</tr>
<tr>
<td><strong>Chemical family</strong></td>
<td>Sulfonylurea</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>FOSAMINE</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trade name(s)</strong></td>
<td>Krenite S</td>
</tr>
<tr>
<td><strong>Manufacturer(s)</strong></td>
<td>Corteva</td>
</tr>
<tr>
<td><strong>Formulation(s)</strong></td>
<td>4 lb/gal soluble concentrate</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td>A brush-control herbicide applied during the 2 months before fall coloration.</td>
</tr>
<tr>
<td><strong>Water solubility</strong></td>
<td>1,790,000 ppm</td>
</tr>
<tr>
<td><strong>Storage conditions</strong></td>
<td>Stable as formulated or as spray-tank solution.</td>
</tr>
<tr>
<td><strong>Acute toxicity</strong></td>
<td>( \text{LD}_{50} ) - greater than 5,000 mg/kg</td>
</tr>
<tr>
<td><strong>Action in plant</strong></td>
<td>Inhibits bud and new leaf formation in spring.</td>
</tr>
<tr>
<td><strong>Site of action</strong></td>
<td>Group 26: unknown</td>
</tr>
<tr>
<td><strong>Chemical family</strong></td>
<td>Organophosphorus</td>
</tr>
<tr>
<td><strong>Koc</strong></td>
<td>Average is 150 mL/g</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>GLUFOSINATE</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trade name(s)</strong></td>
<td>Finale, Ignite, Ignite 280SL, Rely, Liberty, Derringer</td>
</tr>
<tr>
<td><strong>Manufacturer(s)</strong></td>
<td>Bayer CropScience</td>
</tr>
<tr>
<td><strong>Formulation(s)</strong></td>
<td>1 lb, 1.67, and 2.34 lb/gal aqueous solutions</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td>A nonselective, postemergent, contact herbicide with some systemic activity. Acts faster than glyphosate but more slowly than paraquat. More active on broadleaf weeds than on grasses.</td>
</tr>
<tr>
<td><strong>Water solubility</strong></td>
<td>1,370,000 ppm</td>
</tr>
<tr>
<td><strong>Storage conditions</strong></td>
<td>Stable under normal storage conditions. Do not store near heat or open flame.</td>
</tr>
<tr>
<td><strong>Acute toxicity</strong></td>
<td>( \text{LD}_{50} ) - 1,620 mg/kg</td>
</tr>
<tr>
<td><strong>Action in plant</strong></td>
<td>Causes ammonium ions to accumulate, disrupting photosynthesis.</td>
</tr>
<tr>
<td><strong>Site of action</strong></td>
<td>Group 10: glutamine synthase inhibitor</td>
</tr>
<tr>
<td><strong>Chemical family</strong></td>
<td>Phosphinic acid</td>
</tr>
<tr>
<td><strong>Koc</strong></td>
<td>Average is 100 mL/g (estimated)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>GLYPHOSATE</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trade name(s)</strong></td>
<td>Roundup, Rodeo, Kleenup, Accord, Honcho, E-Z-Ject, Jury, Mirage, Protocol, Rattler, Ruler, Silhouette, Glypro, Glyphomax, AquaNeat, Touchdown, Glyphosate, Durango, RT Master, and many others</td>
</tr>
<tr>
<td><strong>Manufacturer(s)</strong></td>
<td>Monsanto Co., Corteva, Syngenta, and others</td>
</tr>
<tr>
<td><strong>Formulation(s)</strong></td>
<td>1.23, 2, 3, 3.7, 4, 4.17, 4.75, and 5 lb/gal acid equivalent; 64.9% and 85% acid equivalent soluble powder.</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td>A nonselective translocated herbicide with no apparent soil activity. Rain within 6 hours after application may reduce effectiveness. Glyphosate translocates to roots and rhizomes of perennial weeds. Complete control may require retreatment. Low-volume applications are most effective.</td>
</tr>
<tr>
<td><strong>Water solubility</strong></td>
<td>12,000 ppm</td>
</tr>
<tr>
<td><strong>Storage conditions</strong></td>
<td>Store between -20° and 120°F.</td>
</tr>
<tr>
<td><strong>Acute toxicity</strong></td>
<td>( \text{LD}_{50} ) - 5,400 mg/kg</td>
</tr>
<tr>
<td><strong>Action in plant</strong></td>
<td>Inhibits three amino acids and protein synthesis.</td>
</tr>
<tr>
<td><strong>Site of action</strong></td>
<td>Group 9: inhibits EPSP synthase</td>
</tr>
<tr>
<td><strong>Chemical family</strong></td>
<td>None generally accepted</td>
</tr>
<tr>
<td><strong>Koc</strong></td>
<td>Average is 24,000 mL/g (estimated)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>HALAUXIFEN</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trade name(s)</strong></td>
<td>Quelex (Component of Quelex along with Florasulam)</td>
</tr>
<tr>
<td><strong>Manufacturer(s)</strong></td>
<td>Corteva</td>
</tr>
<tr>
<td><strong>Formulation(s)</strong></td>
<td>premix ingredient with florasulam (Quelex)e</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td>A selective herbicide for controlling broadleaf weeds</td>
</tr>
<tr>
<td><strong>Storage conditions</strong></td>
<td>As Quelex, store in a cool, dry well-ventilated place. Store in original container only. In case of leak or spill, contain material and dispose as waste.</td>
</tr>
<tr>
<td><strong>Acute toxicity</strong></td>
<td>( \text{LD}_{50} ) - &gt; 5,000 mg/kg - rat</td>
</tr>
<tr>
<td><strong>Action in plant</strong></td>
<td>A systemic, phloem and xylem mobile herbicide that is readily absorbed through leaves, shoots, and roots. When foliar applied it will be symplastically translocated throughout the plant and will accumulate in meristematic tissue.</td>
</tr>
<tr>
<td><strong>Site of action</strong></td>
<td>Group 4: synthetic auxin</td>
</tr>
<tr>
<td><strong>Chemical family</strong></td>
<td>Arylpicolinate</td>
</tr>
<tr>
<td><strong>Koc</strong></td>
<td>473 to 2659 ml/g (average = 1418 ml/g)</td>
</tr>
</tbody>
</table>
### HALOSULFURON

**Trade name(s)** Sandea, Permit, Sedgehammer  
**Manufacturer(s)** Nissan Chemical Industries, labeled by Gowan  
**Formulation(s)** 15% and 75% water-soluble granule  
**Remarks** A selective herbicide for controlling broadleaf weeds and yellow nutsedge in several crops  
**Water solubility** 15 ppm at pH 5; 1,630 ppm at pH 7.  
**Storage conditions** Stable when excess moisture or humidity are excluded from container.  
**Acute toxicity** LD$_{50}$ - 8,860 mg/kg  
**Action in plant** Interferes with acetolactate synthase enzyme, resulting in a rapid cessation of cell division and plant growth in both roots and shoots.  
**Site of action** Group 2: acetolactate synthase (ALS) inhibitor  
**Chemical family** Sulfonylurea  
**Koc** Average is 113 mL/g for Sarpy soil; 199 mL/g for a Sable soil; 31 mL/g for a Spinks soil  

### HEXAZINONE

**Trade name(s)** Velpar, Velpar DF, Velpar I, Velpar ULW, Pronone  
**Manufacturer(s)** TKI  
**Formulation(s)** 90% soluble powder, 2 lb/gal miscible liquid, 75% granule, 10% granule  
**Remarks** A foliar- or soil-applied herbicide with soil activity for broadleaf weed, brush, and grass control in cropland, noncropland, forest lands, and rangeland. Westar is sulfometuron + hexazinone.  
**Water solubility** 33,000 ppm  
**Storage conditions** Store above 32°F.  
**Acute toxicity** LD$_{50}$ - 860 mg/kg  
**Action in plant** Inhibits photosynthesis.  
**Site of action** Group 5: photosystem II inhibitor  
**Chemical family** Triazinone  
**Koc** Average is 54 mL/g  

### IMAZAMETHABENZ

**Trade name(s)** Assert  
**Manufacturer(s)** Nufarm  
**Formulation(s)** 2.5 lb/gal liquid concentrate  
**Remarks** A selective, postemergence herbicide for wild oat and some weeds. Readily absorbed through roots and foliage. Assert is a mixture of two positioned isomers.  
**Water solubility** 1,370 ppm m-isomer, 857 ppm p-isomer  
**Storage conditions** Stable at least 33 months at 75°F.  
**Acute toxicity** LD$_{50}$ - 2,679 mg/kg  
**Action in plant** Disrupts protein and DNA synthesis.  
**Site of action** Group 2: acetolactate synthase (ALS) inhibitor  
**Chemical family** Imidazolinone  

### IMAZAMOX

**Trade name(s)** Raptor, Beyond, Clearcast  
**Manufacturer(s)** BASF  
**Formulation(s)** 1 lb/gal emulsifiable concentrate  
**Remarks** An adjuvant and fertilizer are required for maximum weed control. Activity similar to imazethapyr, with shorter soil residual.  
**Water solubility** Miscible  
**Storage conditions** Do not store below 32°F.  
**Acute toxicity** LD$_{50}$ - greater than 5,000 mg/kg  
**Action in plant** Inhibits the plant enzyme acetolactate synthase.  
**Site of action** Group 2: acetolactate synthase (ALS) inhibitor  
**Chemical family** Imidazolinone  

### IMAZAPIC

**Trade name(s)** Plateau, Oasis, Impose  
**Manufacturer(s)** BASF, ADAMA  
**Formulation(s)** 70% dispersible granule and 2 lb/gal soluble concentrate  
**Remarks** Manufacturer has elected to sell Plateau only to government agencies and not to farmers or ranchers. A selective postemergence herbicide effective for controlling broadleaf weeds and some grasses.  
**Water solubility** 2,200 ppm  
**Storage conditions** Store liquid formulation above 20°F.  
**Acute toxicity** LD$_{50}$ - greater than 5,000 mg/kg  
**Action in plant** Inhibits the plant enzyme acetolactate synthase.  
**Site of action** Group 2: acetolactate synthase (ALS) inhibitor  
**Chemical family** Imidazolinone  

### IMAZAPYR

**Trade name(s)** Arsenal, Chopper, Contain, Arsenal Applicator Concentrate, Stalker, Habitat, Imazapyr E-Pro 4, Polaris  
**Manufacturer(s)** BASF  
**Formulation(s)** Aqueous solutions of 2, 1, and 4 lb/gal without a surfactant  
**Remarks** Nonselective, imidazolinone herbicide applied preemergence or postemergence for long-term total vegetation control. Readily absorbed through foliage and roots. Registered for use only on noncropland.  
**Water solubility** 15,000 ppm  
**Storage conditions** Store above 10°F. Once mixed, solution can be stored in spray tank until ready to be applied.  
**Acute toxicity** LD$_{50}$ - 5,000 mg/kg  
**Action in plant** Inhibits enzyme used in synthesis of some amino acids.  
**Site of action** Group 2: acetolactate synthase (ALS) inhibitor  
**Chemical family** Imidazolinone
**IMAZAQUIN**

- **Trade name(s)**: Scepter
- **Manufacturer(s)**: BASF
- **Formulation(s)**: 70% dispersible granule
- **Remarks**: A selective preplant-incorporated, preemergence or postemergence herbicide effective in controlling broadleaf weeds and some grasses. A nonionic surfactant or oil adjuvant improves efficacy of postemergence treatments.

**Water solubility**: 60 ppm

**Storage conditions**: Stable in normal storage conditions.

**Acute toxicity**: LD<sub>50</sub> - greater than 5,000 mg/kg

**Action in plant**: Inhibits plant enzyme acetolactate synthase.

**Site of action**: Group 2: acetolactate synthase (ALS) inhibitor

**Chemical family**: Imidazolinone

**K<sub>oc</sub>**: Average is 20 mL/g (estimated) at pH 7, but varies with pH

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**IMAZETHAPYR**

- **Trade name(s)**: Pursuit
- **Manufacturer(s)**: BASF
- **Formulation(s)**: Aqueous solutions of 2 lb/gal, 70% dispersible granules
- **Remarks**: A selective postemergence herbicide effective in controlling broadleaf weeds and some annual grasses.

**Water solubility**: Miscible.

**Storage conditions**: Do not store below 32°F.

**Acute toxicity**: LD<sub>50</sub> - greater than 5,000 mg/kg

**Action in plant**: Inhibits plant enzyme acetolactate synthase.

**Site of action**: Group 2: acetolactate synthase (ALS) inhibitor

**Chemical family**: Imidazolinone

**K<sub>oc</sub>**: 190 to 570 mL/g

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**INDAZIFLAM**

- **Trade name(s)**: Alion, Spectacle
- **Manufacturer(s)**: Bayer CropScience
- **Formulation(s)**: SC of 1.67 lb/gal or 20% WSP
- **Remarks**: Preemergence broad-spectrum control of annual weeds.

**Water solubility**: 2.8 ppm at pH 9.0

**Storage conditions**: Stable

**Acute toxicity**: Oral and dermal LD<sub>50</sub> (rat) >2000 mg/kg

**Action in plant**: Inhibition of cellulose biosynthesis

**Site of action**: Group 29

**Chemical family**: Imidazolinone

**K<sub>oc</sub>**: Average is 10,000 mL/g (estimated)

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**IODOSULFURON**

- **Trade name(s)**: Autumn
- **Manufacturer(s)**: Bayer CropScience
- **Formulation(s)**: 10% water-dispersible granule
- **Remarks**: Burn down weeds prior to planting corn.

**Water solubility**: 160, 250, and 65,000 ppm at pH 5, 7, and 9 respectively.

**Storage conditions**: Stable.

**Acute toxicity**: LD<sub>50</sub> - 2,678 mg/kg

**Action in plant**: Inhibits the plant enzyme acetolactate synthase.

**Site of action**: Group 2: acetolactate synthase (ALS) inhibitor

**Chemical family**: Sulfonylurea

**K<sub>oc</sub>**: 10-90 mLs/g

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**ISOXABEN**

- **Trade name(s)**: Gallery, Trellis
- **Manufacturer(s)**: Corteva
- **Formulation(s)**: 75% dry flowable
- **Remarks**: A selective preemergence herbicide applied before weed seed germinates. For annual broadleaf weeds in turf and ornamentals.

**Water solubility**: 1 ppm

**Storage conditions**: Stable under moderate conditions. Avoid temperatures above 120°F.

**Acute toxicity**: LD<sub>50</sub> - greater than 5,000 mg/kg

**Action in plant**: Appears to disrupt root and hypocotyl development. Susceptible plants die before emerging.

**Site of action**: Group 21: inhibits cell wall synthesis Site B

**Chemical family**: Benzamide

**K<sub>oc</sub>**: 1000 mL/g

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**LACTOFEN**

- **Trade name(s)**: Cobra, Phoenix
- **Manufacturer(s)**: Valant
- **Formulation(s)**: 2 lb/gal emulsifiable concentrate
- **Remarks**: A selective, contact herbicide with some preemergence activity. Most active on broadleaf plants.

**Water solubility**: 0.1 ppm

**Storage conditions**: Will not freeze down to 0°F. Negligible decomposition in 2-yr stability tests.

**Acute toxicity**: LD<sub>50</sub> - 2,533 mg/kg

**Action in plant**: Thought to result from the generation of toxic oxygen species in the presence of light, resulting in desiccation from peroxidation of membrane lipids.

**Site of action**: Group 14: protoporphyrinogen oxidase inhibitor

**Chemical family**: Diphenylether

**K<sub>oc</sub>**: Average is 10,000 mL/g (estimated)

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**LEMONGRASS OIL**

- **Trade name(s)**: GreenMatch EX
- **Manufacturer(s)**: Marrone Organic
- **Formulation(s)**: 50% emulsifiable concentrate

**Chemical family**: Alkylazine

**K<sub>oc</sub>**: 1000 mL/g

---

**LINURON**

- **Trade name(s)**: Lorox, Linex
- **Manufacturer(s)**: Tessenderlo Kerley Inc. (NovaSource)
- **Formulation(s)**: 50% wettable powder, 50% dry flowable, 4 lb/gal flowable suspension

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Remarks A substituted urea applied pre- and postemergence as a selective herbicide; foliar- and root-absorbed. Soil residual life shorter than other urea herbicides.

**Water solubility** 75 ppm

**Storage conditions** Stable under moderate conditions.

**Acute toxicity** $LD_{50}$ - 1,500 mg/kg

**Action in plant** Inhibits photosynthesis.

**Site of action** Group 7: photosystem II inhibitor

**Chemical family** Substituted urea

**Koc** Average is 400 mL/g

**MCPA**

<table>
<thead>
<tr>
<th>Trade name(s)</th>
<th>Many</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer(s)</td>
<td>Albaugh, Loveland Products</td>
</tr>
<tr>
<td>Formulation(s)</td>
<td>2 and 4 lb/gal soluble and emulsifiable concentrates formulated as amine salts, sodium salts, and esters.</td>
</tr>
<tr>
<td>Remarks</td>
<td>A postemergence, selective, translocated phenoxy herbicide. Material is less phytotoxic to some crops.</td>
</tr>
</tbody>
</table>

**Water solubility** 825 ppm

**Storage conditions** Amines formulations are relatively stable, but esters depend on emulsifying system. Read each product label carefully.

**Acute toxicity** $LD_{50}$ - 800 mg/kg

**Action in plant** Mimics natural plant hormones.

**Site of action** Group 4: synthetic auxin

**Chemical family** Phenoxy acetic acid

**Koc** Average is 110 mL/g for the acid, 1000 mL/g (estimated) for the butoxyethyl and isooctyl esters, and 20 mL/g (estimated) for the dimethylamine salt

**MESOSULFURON**

<table>
<thead>
<tr>
<th>Trade name(s)</th>
<th>Osprey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer(s)</td>
<td>Bayer</td>
</tr>
<tr>
<td>Formulation(s)</td>
<td>4.5% water-dispersible granule</td>
</tr>
<tr>
<td>Remarks</td>
<td>Postemergence herbicide used primarily to control annual grasses and some broadleaf weeds in winter wheat.</td>
</tr>
</tbody>
</table>

**Water solubility** 7 ppm at pH 5; 48 at pH 7

**Storage conditions** Protect from extreme heat and cold

**Acute toxicity** $LD_{50}$ - greater than 5,000 mg/kg

**Action in plant** Inhibits the acetolactate synthase (ALS) enzyme, resulting in rapid cessation of cell division and plant growth in both roots and shoots.

**Site of action** Group 2: acetolactate synthase (ALS) inhibitor

**Chemical family** Sulfonylurea

**MESOTRIONE**

<table>
<thead>
<tr>
<th>Trade name(s)</th>
<th>Callisto, Broadworks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer(s)</td>
<td>Syngenta</td>
</tr>
<tr>
<td>Formulation(s)</td>
<td>4 lb/gal suspension concentrate</td>
</tr>
<tr>
<td>Remarks</td>
<td>Mesotrione is a synthetic relative of natural herbicides produced by the plant Callistemon citrinus. Controls broadleaf weeds in corn.</td>
</tr>
</tbody>
</table>

**Water solubility** 15,000 ppm

**Storage conditions** Can be stored as low as 20°F.

**Acute toxicity** $LD_{50}$ - greater than 5,000 mg/kg

**Action in plant** Inhibits HPPD enzymes essential to photosynthesis.

**Site of action** Group 27: inhibits 4-hydroxyphenylpyruvate-dioxygenase (4-HPPD)

**Chemical family** Triketone

**Koc** 14 - 390 mL/g

**METHAM**

<table>
<thead>
<tr>
<th>Trade name(s)</th>
<th>Vapam, Sectagon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer(s)</td>
<td>AMV AC, Tessenderlo Kerley Inc. (NovaSource)</td>
</tr>
<tr>
<td>Formulation(s)</td>
<td>Soluble concentrate</td>
</tr>
<tr>
<td>Remarks</td>
<td>Temporary soil fumigant as a preplant treatment. Controls weeds, most weed seeds, certain microorganisms, and...</td>
</tr>
</tbody>
</table>
nematodes. Activity depends on decomposition in moist soil to a volatile toxicant.

**Water solubility** 722,000 ppm

**Storage conditions** Store above 0°F to avoid crystallizing.

**Acute toxicity** \( \text{LD}_{50} - 285 \text{ mg/kg} \)

**Action in plant** Kills living tissue.

**Site of action** Group 26: unknown

**Chemical family** Dithiocarbamate

**Koc** Average is 10 mL/g (estimated)

### METHYL BROMIDE (RESTRICTED-USE HERBICIDE)

**Trade name(s)** MBC-33, Meth-O-Gas

**Manufacturer(s)** Corteva, Great Lakes Chemical Co.

**Formulation(s)** Liquid under pressure, methyl bromide 98%, chloropicrin 2% (to give offensive odor).

**Remarks** Temporary soil fumigant as a preplant treatment. Controls weeds, most weed seeds, certain microorganisms, and nematodes. Applied on plant beds under a gas-proof cover. Acts within 48 hours. Use extreme caution in handling this material.

**Water solubility** 530 ppm

**Storage conditions** Store away from heat or flame since contents are pressurized.

**Acute toxicity** \( \text{LD}_{50} - 1 \text{ mg/kg} \) with upper safe limit at 17 ppm in air.

**Action in plant** Kills living tissue.

**Site of action** Unknown

**Chemical family** Halogenated aliphatic

### METROLACHLOR, S-METOLACHLOR

**Trade name(s)** Dual, Dual Magnum, Dual II Magnum, Pennant, Me-Too-Lachlor, Brawl, Parallel, Charge Max

**Manufacturer(s)** Syngenta, ADAMA

**Formulation(s)** 7.62, 7.64, 7.8, and 8 lb/gal emulsifiable concentrate, 5% granule

**Remarks** Acetamide compound; a selective, preemergence herbicide primarily for annual grass and yellow nutsedge. Usually combined with materials that kill annual broadleaf weeds. S-metolachlor is the more active isomer, used at lower rates on the same crops; other characteristics are the same.

**Water solubility** 530 ppm

**Storage conditions** Store above -30°F.

**Acute toxicity** \( \text{LD}_{50} - 2,150 \text{ mg/kg} \) (S-metolachlor)

**Action in plant** Inhibits roots and shoots.

**Site of action** Group 15: inhibits very long chain fatty acid synthesis

**Chemical family** Chloroacetamide

**Koc** Average is 200 mL/g (S-metolachlor)

### METRIBUZIN

**Trade name(s)** Sencor, Metribuzin 4L, TriCor, Glory and others

**Manufacturer(s)** Bayer CropScience, United Phosphorus, Inc., ADAMA

**Formulation(s)** 4 lb/gal flowable liquid; 75% dry flowable

**Remarks** A selective preemergence and postemergence herbicide to control grass and broadleaf weeds. Axiom is metribuzin + flufenacet.

**Water solubility** 1,220 ppm

**Storage conditions** Stable if kept dry and stored under moderate temperatures to 15°F

**Acute toxicity** \( \text{LD}_{50} - 4,000 \text{ mg/kg} \)

**Action in plant** Inhibits photosynthesis.

**Site of action** Group 5: photosystem II inhibitor

**Chemical family** Triazinone

**Koc** 14.5 mL/g for a silt loam with 2.9% OM and pH 5.9; 17 mL/g for a clay loam with 2.2% OM and pH 6.4

### METSULFURON

**Trade name(s)** Escort, Ally, Metsulfuron, and several others

**Manufacturer(s)** Corteva

**Formulation(s)** 60% dry flowable

**Remarks** A selective postemergence herbicide used at low rates to control broadleaf weeds in wheat, barley, and fallow. Escort is used for selective broadleaf weed and brush control in pastures, rangeland, and noncropland.

**Water solubility** 270 ppm at pH 4.6; 9,500 ppm at pH 6.7

**Storage conditions** Stable if kept dry.

**Acute toxicity** \( \text{LD}_{50} - 5,000 \text{ mg/kg} \)

**Action in plant** Interferes with an enzyme, resulting in rapid cessation of cell division in both roots and shoots.

**Site of action** Group 2: acetolactate synthase (ALS) inhibitor

**Chemical family** Sulfonylurea

**Koc** Average is 35 mL/g at pH 7

### MH, MAELIC HYDRAZIDE

**Trade name(s)** MH-30, Sprout Stop, Retard

**Manufacturer(s)** Chemtura, Drexel Chemical

**Formulation(s)** 1.5 lb, 2.25 lb, and 3 lb/gal soluble concentrate; 60% granule

**Remarks** A growth inhibitor and preemergence or postemergence selective herbicide. Inhibits cell division but not cell enlargement. Suppresses growth of grasses and some broadleaf plants. Absorption rate is greater in high humidity.

**Water solubility** 6,000 ppm

**Storage conditions** Stable.

**Acute toxicity** \( \text{LD}_{50} - 3,900 \text{ mg/kg} \)

**Action in plant** Inhibits mitosis.

**Site of action** Not well understood

**Chemical family** None generally accepted

**Koc** Average is 20 mL/g (estimated) for the K salt form and 250 mL/g (estimated) for the acid. Koc was 264 mL/g for clay and 23 mL/g for sand.
**MONOCARBAMIDE DIHYDROGENSULFATE**

Trade name(s)  Enquik
Manufacturer(s) Entek Corp.
Formulation(s)  79% per gal liquid.
Remarks  Corrodes nylon, aluminum, and any copper alloy such as brass. Do not use pumps or fittings containing nylon, mild steel, aluminum, brass, leather, or natural rubber. Non-nylon plastic and 316-L stainless steel are recommended for application equipment.

**Water solubility**  Very soluble

**Storage conditions**  Store between 32° and 176°F.

**Hazards**  Corrosive to eyes and skin. Superquik can attack cotton, nylon, and leather clothing. Do not mix with nitrogen fertilizer; mixtures may explode.

**Action in plant**  Contact and disrupts all membranes.

**Site of action**  Plant cells

**Chemical family**  Inorganic

**MSMA**

Formulation(s)  4 to 8 lb/gal soluble concentrate
Remarks  An organic, arsenic compound used as a selective, contact herbicide applied postemergence. Results are best when air temperature is above 80°F.

**Water solubility**  Very soluble

**Storage conditions**  Stable under moderate conditions.

**Acute toxicity**  $LD_{50}$ - 1,359 mg/kg

**Action in plant**  Unknown

**Site of action**  Group 17: not well understood

**Chemical family**  Organophosphorus

**Koc**  Average is 7000 mL/g (estimated). Sand 250 mL/g; silty loam 2850 mL/g; silty clay 1170 mL/g; sandy loam 2190 mL/g

**NAPROPAMIDE**

Trade name(s)  Devrinol
Manufacturer(s) United Phosphorus
Formulation(s)  2 lb/gal emulsifiable concentrate; 10% granular; 50% wettable powder; 50% dry flowable
Remarks  A preemergence, soil-applied herbicide to control annual grasses and some annual broadleaf weeds. Little, if any, loss from soil surface by volatilization, but if sunlight is intense, loss by photodecomposition is fairly rapid.

**Water solubility**  73 ppm

**Storage conditions**  Store between 20° and 90°F.

**Acute toxicity**  $LD_{50}$ - 5,000 mg/kg

**Action in plant**  Inhibits root growth.

**Site of action**  Group 15: inhibits very long chain fatty acid synthesis

**Chemical family**  acetamide

**Koc**  Average is 700 mL/g

**NAPHTALAM**

Trade name(s)  Surflan, Fugitive
Manufacturer(s) United Phosphorus, ADAMA
Formulation(s)  4 lb/gal flowable
Remarks  A selective, preemergence, phthalic acid herbicide. A nonvolatile chemical activated by moisture, it usually does not last more than 6 to 8 wk in soil.

**Water solubility**  Acid 200 ppm; sodium salt 230,800 ppm

**Storage conditions**  Store below 140°F or it will precipitate. Crystals will form at freezing but will redissolve with agitation at warmer temperatures.

**Acute toxicity**  $LD_{50}$ - 1,770 mg/kg

**Action in plant**  Inhibits transport of auxins; causes negative geotropism.

**Site of action**  Group 19: inhibits indole acetic acid transport

**Chemical family**  Phthalate

**Koc**  Average is 20 mL/g (estimated) at pH 7

**NICOSULFURON**

Trade name(s)  Accent
Manufacturer(s) Corteva
Formulation(s)  75% water-dispersible granules
Remarks  A selective postemergence herbicide used at low rates in corn to control certain grass and broadleaf weeds. Carefully consider crop rotation plans prior to using.

**Water solubility**  360 ppm at pH 5.01; 39,200 ppm at pH 8.8

**Storage conditions**  Stable.

**Acute toxicity**  $LD_{50}$ - greater than 5,000 mg/kg

**Action in plant**  Interferes with plant enzyme acetolactate synthase, quickly stopping cell division.

**Site of action**  Group 2: acetolactate synthase (ALS) inhibitor

**Chemical family**  Sulfonylurea

**Koc**  Average is 30 mL/g at pH 6.5

**NORFLURAZON**

Trade name(s)  Evital, Slicam, Zorial, Predict
Manufacturer(s) TKI
Formulation(s)  80% wettable powder, 5% granule, 80% dry flowable
Remarks  A selective herbicide applied preemergence to control many grasses, sedges, rushes, pigweed, purslane, and ragweed.

**Water solubility**  28 ppm

**Storage conditions**  Stable.

**Acute toxicity**  $LD_{50}$ - 10,000 mg/kg

**Action in plant**  Inhibits carotene formation, resulting in photodegradation of chlorophyll.

**Site of action**  Group 12: bleaching; inhibits carotenoid biosynthesis

**Chemical family**  Pyridazinone

**Koc**  Average is 700 mL/g

**ORYZALIN**

Trade name(s)  Surflan, Fugitive
Manufacturer(s) United Phosphorus, ADAMA
Formulation(s)  4 lb/gal flowable
Remarks A selective preemergence herbicide. Oryzalin affects seed germination and inhibits root development. It is strongly adsorbed onto soil and resists movement by water.

Water solubility 2.5 ppm

Storage conditions Store above 40°F. If frozen, warm and agitate.

Acute toxicity LD$_{50}$ - 10,000 mg/kg

Action in plant Inhibits mitosis, primarily in roots.

Site of action Group 3: microtubule assembly inhibitor

Chemical family Dinitroaniline

Koc Average is 600 mL/g, but ranges from 93-2700 mL/g

**OXADIAZON**

Trade name(s) Chipco Ronstar G, Ronstar, Ornamental Herbicide, Oxadiazon

Manufacturer(s) Bayer CropScience, O.M. Scott

Formulation(s) 2% and 4% granular, 2 lb/gal emulsifiable concentrate, 50% wettable powder

Remarks Selective preemergence control of annual grasses and broadleaf weeds in turf, woody ornamental shrubs, vines, and trees.

Water solubility 0.7 ppm

Storage conditions Stable under moderate conditions.

Acute toxicity LD$_{50}$ - 8,000 mg/kg

Action in plant Controls weed seedlings by contact action during emergence.

Site of action Group 14: protoporphyrinogen oxidase inhibitor

Chemical family Oxadiazole

Koc Average is 3200 mL/g. Strongly absorbed by soil colloids and OM.

**OXYFLUORFEN**

Trade name(s) Goal, Galigan, GoalTender, Oxiflo

Manufacturer(s) Corteva, ADAMA

Formulation(s) 2 and 4 lb/gal emulsifiable concentrate or flowable

Remarks Selective preemergence and postemergence control for grass and broadleaf weeds in several horticultural and agronomic crops. A contact herbicide; requires light for herbicidal activity.

Water solubility 0.1 ppm

Storage conditions Store above freezing.

Acute toxicity LD$_{50}$ - 5,000 mg/kg

Action in plant Acts as a contact-type herbicide.

Site of action Group 14: protoporphyrinogen oxidase inhibitor

Chemical family Diphenylether

Koc Average is 100,000 mL/g (estimated)

**PARAQUAT (RESTRICTED-USE HERBICIDE)**

Trade name(s) Gramoxone Extra, Gramoxone Max, Gramoxone Inteon, Cyclone, Cyclone Concentrate, Firestorm, Parazone

Manufacturer(s) Syngenta, Griffin, Chemtura, ADAMA, AMVAC

Formulation(s) The cation part of the molecule is the active ingredient. 2, 2.5, and 3 lb/gal of the water-soluble cation. The formulation is a distinct green and contains a stenching agent to help prevent accidental swallowing. An emetic is added to induce vomiting in case it is consumed.

Remarks A postemergence, nonselective, somewhat translocated herbicide with fast-acting contact action. Toxic if swallowed, inhaled, or absorbed through the skin. Use protective clothing to avoid inhaling or contact with the skin.

Water solubility Completely soluble.

Storage conditions Store above freezing.

Acute toxicity LD$_{50}$ - 157 mg/kg

Action in plant Acts as contact; absorbs energy produced during photosynthesis and forms peroxides that disrupt living cells.

Site of action Group 22: photosystem I electron diversion

Chemical family Bipyridilium

Koc Estimated at 1,000,000 mL/g

**PEBULATE**

Trade name(s) Tillam

Manufacturer(s) Syngenta, Monterey

Formulation(s) 6 lb/gal emulsifiable concentrate, 10% granular

Remarks A preplant, soil-applied herbicide for weed control in tomatoes and sugar beets.

Water solubility 60 ppm

Storage conditions Stable at moderate temperatures.

Acute toxicity LD$_{50}$ - 921 mg/kg

Action in plant Inhibits mitosis in roots and shoots.

Site of action Group 8: lipid synthesis inhibitor but not an ACCase inhibitor

Chemical family Thiocarbamate

Koc Average is 430 mL/g

**PELARGONIC ACID**

Trade name(s) Scythe

Manufacturer(s) Gowan

Formulation(s) 4.2 lb/gal emulsifiable concentrate

Remarks A contact, nonselective, broad-spectrum, foliar-applied herbicide. Nonsystemic and no soil residual.

Water solubility Emulsifiable

Acute toxicity LD$_{50}$ - greater than 5,000 mg/kg (low toxicity)

Action in plant Control or burndown of a broad spectrum of weeds on contact.

Site of action Group 26: unknown

Chemical family Carboxylic acid
PENDIMETHALIN

Trade name(s) Pendulum Aquacap, Pentagon, Prowl, Stomp, Repose, Hurdle, Prowl H₂O, Stealth, Pendant
Manufacturer(s) BASF, Olympic Horticultural, Corteva
Formulation(s) 3.3, 3.8, and 4 lb/gal emulsifiable concentrate; 60% water-dispersible granules, 2% granular
Remarks Depending on the crop, this is a selective, preplant, preemergence, and early postemergence herbicide that is used to control annual broadleaf and grass weeds.

Water solubility 0.5 ppm
Storage conditions Store above 40°F. If frozen, re-dissolve at warm temperatures. Avoid flame and temperatures above 92°F.
Acute toxicity LD₅₀ - 3,380 mg/kg
Action in plant Inhibits mitosis in roots and shoots.
Site of action Group 3: microtubule assembly inhibitor
Chemical family Dinitroaniline
Koc Average is 17,200 mL/g

PENOSXULAM

Trade name(s) Sapphire
Manufacturer(s) Corteva
Formulation(s) 0.31 lb ai/gal soluble concentrate
Remarks Postemergence control of certain annual and perennial broadleaf weeds in certain established turfgrasses.

Water solubility 5.7 ppm at pH 5, 410 ppm at pH 7 and 1,460 ppm at pH 9
Storage conditions Store in a cool dry area
Acute toxicity LD₅₀ - more than 5,000 mg/kg
Action in plant Inhibits the plant enzyme acetolactate synthase.
Site of action Group 2: acetolactate synthase (ALS) inhibitor
Chemical family Triazolopyrimidine
Koc 104 mL/g

PHENMEDIPHAM (RESTRICTED-USE HERBICIDE)

Trade name(s) Spin-Aid
Manufacturer(s) Bayer CropScience
Formulation(s) 1.3 lb/gal emulsifiable concentrate
Remarks A foliar-applied selective herbicide for weed control in sugar beets, spinach, and table beets. Do not exceed 21 gal/A of spray solution on a broadcast basis. Rain within 6 hours of spraying may reduce weed kill. Betamix is phenmedipham + desmedipham; Progress is phenmedipham + desmedipham + ethofumesate.

Water solubility Less than 1 ppm
Storage conditions Liquid thickens when frozen but returns to normal at warmer temperatures. Avoid use or storage near heat or flame.
Acute toxicity LD₅₀ - 2,000 mg/kg
Action in plant Inhibits photosynthesis.
Site of action Group 5: photosystem II inhibitor
Chemical family Phenylcarbamate
Koc Average is 2,400 mL/g

PICLORAM (RESTRICTED-USE HERBICIDE)

Trade name(s) Tordon 22K, Tordon K
Manufacturer(s) Corteva
Formulation(s) 2 lb/gal water-soluble concentrate
Remarks A highly translocated, selective herbicide active through both foliage and roots on many broadleaf herbaceous weeds and woody plants. Picloram is persistent; diligently follow precautions to avoid injuring desirable plants. Unmetabolized picloram in treated foliage will pass through livestock, and manure and urine can be toxic to plants.

Water solubility 430 ppm
Storage conditions Stable
Acute toxicity LD₅₀ - 8,200 mg/kg
Action in plant Mimics natural plant hormones.
Site of action Group 4: synthetic auxin
Chemical family Pyridine
Koc Average is 16 mL/g for the K salt, but ranges from 17 to 160 mL/g

PINOXADEN

Trade name(s) Axial XL
Manufacturer(s) Syngenta
Formulation(s) 0.83 lb/gal emulsifiable concentrate
Remarks Selective postemergence grass-control herbicide. Controls several annual grasses in several small grains. Packed with an adjuvant that must be used with the herbicide.

Water solubility 20 ppm
Storage conditions Store in a cool, dry place.
Acute toxicity LD₅₀ - 3,129 mg/kg
Action in plant Inhibits fatty acid synthesis.
Site of action Group 2: acetyl CoA carboxylase (ACCase) inhibitor
Chemical family Phenylpyrazolin
Koc 299 to 852 mL/g (5 soils)

PRIMISULFURON

Trade name(s) Beacon
Manufacturer(s) Syngenta
Formulation(s) 75% water-dispersible granules packaged in water-soluble packets.
Remarks A selective postemergence herbicide used at low rates on field corn to control certain grasses and broadleaf weeds. Carefully consider crop rotation plans before using.

Water solubility 1 ppm at pH 5; 600 ppm at pH 8.
Storage conditions Stable
Acute toxicity LD₅₀ - greater than 5,050 mg/kg
Action in plant Interferes with plant enzyme acetolactate synthase, resulting in rapid cessation of cell division.
Site of action Group 2: acetolactate synthase (ALS) inhibitor
Chemical family Sulfonyleurea
Koc Average is 50 mL/g (estimated) for Primisulfuron-methyl
### PRODIAMINE

**Trade name(s)** Barricade, Endurance, Factor, Cavalcade  
**Manufacturer(s)** Syngenta, Regal Chemical Co.  
**Formulation(s)** 65% water-dispersible granules  
**Remarks** A dinitroaniline compound that is applied preplant or preemergence depending on site used.  
**Water solubility** 0.013 ppm  
**Storage conditions** Stable  
**Acute toxicity** LD$_{50}$ - greater than 5,000 mg/kg  
**Action in plant** Inhibits mitosis in both shoots and roots.  
**Site of action** Group 3: microtubule assembly inhibitor  
**Chemical family** Dinitroaniline  
**Koc** Average is 13,000 mL/g

### PROMETON

**Trade name(s)** Pramitol  
**Manufacturer(s)** Syngenta  
**Formulation(s)** 25% emulsifiable concentrate (2 lb/gal), 80% wettable powder  
**Remarks** A triazine herbicide applied both preemergence and postemergence as a temporary total vegetation herbicide. Material has considerable foliar action and acts through the roots.  
**Water solubility** 750 ppm  
**Storage conditions** Store above 32°F.  
**Acute toxicity** LD$_{50}$ - 2,276 mg/kg  
**Action in plant** Inhibits photosynthesis.  
**Site of action** Group 5: photosystem II inhibitor  
**Chemical family** Triazine  
**Koc** Average is 400 mL/g

### PROMETRYN

**Trade name(s)** Caparol, Prometrync, Vegetable Pro  
**Manufacturer(s)** Syngenta, Platte, ADAMA  
**Formulation(s)** 80% wettable powder, 4 lb/gal flowable  
**Remarks** A selective herbicide to control annual grass and broadleaf weeds.  
**Water solubility** 48 ppm  
**Storage conditions** Stable.  
**Acute toxicity** LD$_{50}$ - 3,750 mg/kg  
**Action in plant** Inhibits photosynthesis.  
**Site of action** Group 5: photosystem II inhibitor  
**Chemical family** Triazine  
**Koc** Average is 400 mL/g

### PRONAMIDE (RESTRICTED-USE HERBICIDE)

**Trade name(s)** Kerb  
**Manufacturer(s)** Corteva, United Phosphorus, Inc.  
**Formulation(s)** Soluble concentrate (SC) 3.3 lb ai/gal  
**Remarks** A selective herbicide to control annual and perennial grasses. For postemergence activity, pronamide must move into the root zone. There is little foliar uptake. Apply when temperature is below 55°F to reduce microorganism degradation.  
**Water solubility** 15 ppm  
**Storage conditions** Store between 32° and 122°F under dry conditions. Do not remove package from original container except for immediate use.  
**Acute toxicity** LD$_{50}$ - 5,620 mg/kg  
**Action in plant** Inhibits mitosis.  
**Site of action** Group 3: microtubule assembly inhibitor  
**Chemical family** Benzamide  
**Koc** Average is 800 mL/g

### PROPOXYPYRONE

**Trade name(s)** Olympus  
**Manufacturer(s)** Bayer CropScience  
**Formulation(s)** 70% water-dispersible granule  
**Remarks** Postemergence herbicide used primarily to control annual grasses and some broadleaf weeds in winter wheat.  
**Water solubility** 2,900 ppm at pH 4; 42,000 ppm at pH 7 and pH 9  
**Storage conditions** Store in cool, dry place.  
**Acute toxicity** LD$_{50}$ - greater than 5,000 mg/kg  
**Action in plant** Inhibits the acetolactate synthase (ALS) enzyme, resulting in rapid cessation of cell division and plant growth in both roots and shoots.  
**Site of action** Group 2: acetolactate synthase (ALS) inhibitor  
**Chemical family** Sulfonylaminocarboxyltriazolinone

### PROSULFURON

**Trade name(s)** Peak  
**Manufacturer(s)** Syngenta  
**Formulation(s)** 57% water-dispersible granules  
**Remarks** A selective postemergence sulfonylurea herbicide used at low rates for annual broadleaf weed control in wheat, barley, oats, rye, triticale, grain sorghum, and proso millet. Carefully consider crop rotation plans before using.  
**Water solubility** 87 ppm at pH 5; 43,000 ppm at pH 7.7  
**Storage conditions** Stable.  
**Acute toxicity** LD$_{50}$ - 4,360 mg/kg  
**Action in plant** Interferes with plant enzyme acetolactate synthase, resulting in rapid cessation of cell division.  
**Site of action** Group 2: acetolactate synthase (ALS) inhibitor  
**Chemical family** Sulfonylurea  
**Koc** 18.56 mL/g for a silt loam with 3% OM and pH 6.5

### PYRIDATE

**Trade name(s)** Tough  
**Manufacturer(s)** Syngenta  
**Formulation(s)** 5 lb/gal emulsifiable concentrate  
**Remarks** Postemergent, contact herbicide that controls annual broadleaf weeds in the two- to four-leaf stage. Label has been cancelled by the company; however, existing stock may be used until 12/31/09
<table>
<thead>
<tr>
<th><strong>Product Name</strong></th>
<th><strong>Trade name(s)</strong></th>
<th><strong>Manufacturer(s)</strong></th>
<th><strong>Formulation(s)</strong></th>
<th><strong>Remarks</strong></th>
<th><strong>Water solubility</strong></th>
<th><strong>Acute Toxicity</strong></th>
<th><strong>Action in Plant</strong></th>
<th><strong>Site of Action</strong></th>
<th><strong>Chemical Family</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PYRAFLUFEN</strong></td>
<td>ET, Venue</td>
<td>Nichino America</td>
<td>0.177 and 0.208 lb/gal emulsifiable concentrate</td>
<td>A fast-acting postemergence contact herbicide.</td>
<td>82 ppb</td>
<td>LD₅₀ - 4,600 mg/kg</td>
<td>Blocks photosynthesis.</td>
<td>Group 6: photosystem II inhibitor</td>
<td>Phenyl-pyridazine</td>
</tr>
<tr>
<td><strong>PYRASULFOTOLE</strong></td>
<td>Huskie (also contains bromoxynil)</td>
<td>Bayer Crop Science</td>
<td>2.08 lb/gal emulsifiable concentrate with bromoxynil.</td>
<td>Controls broadleaf weeds in wheat, barley, and triticale. This formulation has a built-in safener to enhance crop safety.</td>
<td>69,100 ppm</td>
<td>LD₅₀ - 3,712 mg/kg</td>
<td>Inhibits protoporphyrinogen oxidase (PPO) that disrupts cell membranes.</td>
<td>Group 14: protoporphyrinogen oxidase inhibitor</td>
<td>Phenylpyrazole</td>
</tr>
<tr>
<td><strong>PYROXASULFONE</strong></td>
<td>Zidua (also a pre-mix partner with flumioxazin in Fierce; pre-mix partner with carfentrazone in Anthem Flex)</td>
<td>K-I Chemical USA</td>
<td>85% water dispersible granule</td>
<td>A selective preemergence herbicide with soil residual activity for control of Italian ryegrass, and other grass and small-seeded broadleaf weeds.</td>
<td>3.49 ppm</td>
<td>LD₅₀ - &gt;2,000 mg/kg (rat).</td>
<td>Inhibits roots and shoots.</td>
<td>Group 15: mitosis inhibitor</td>
<td>Pyrazole</td>
</tr>
<tr>
<td><strong>PYROXSULAM</strong></td>
<td>PowerFlex HL or TeamMate</td>
<td>Corteva</td>
<td>7.5% water soluble granule (0.075 lb ai/lb)</td>
<td>Postemergent annual grass and broadleaf herbicide for weed control in cereals</td>
<td>16.4 ppm at pH 4; 3,200 ppm at pH 7; 13,700 ppm at pH 9</td>
<td>LD₅₀ - greater than 2,000 mg/kg</td>
<td>Interferes with an enzyme, resulting in inhibiting cell division</td>
<td>Group 2: acetolactate synthase (ALS) inhibitor</td>
<td>Triazolopyrimidine sulfonamide</td>
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<tr>
<td><strong>QUINCLORAC</strong></td>
<td>Paramount, Drive, Drive XLR8, Ryzon</td>
<td>BASF, ADAMA</td>
<td>75% dry flowable, 1.5 lb/gal, and 1.5% granules</td>
<td>Applied postemergence to actively growing weeds. Controls field bindweed and other selected weeds.</td>
<td>62 ppm</td>
<td>LD₅₀ - 2,610 mg/kg</td>
<td>Not fully understood. In broadleaves, similar to indole acetic acid. In grasses, inhibits cell wall synthesis.</td>
<td>Group 4: synthetic auxin</td>
<td>Quinoline carboxylic acid</td>
</tr>
<tr>
<td><strong>QUIZALOFOP</strong></td>
<td>Assure II, Targa</td>
<td>Corteva</td>
<td>0.88 lb/gal emulsifiable concentrate</td>
<td>A selective postemergence grass herbicide. Controls most annual and perennial grasses including quackgrass and johnsongrass. A nonionic surfactant or crop oil concentrate is required for maximum effectiveness.</td>
<td>0.3 ppm at 68°F</td>
<td>LD₅₀ - 5,700 mg/kg</td>
<td>Inhibits an enzyme (ACCase) that catalyzes the first step in fatty acid synthesis. This blocks production of new membranes required for cell growth.</td>
<td>Group 1: acetyl CoA carboxylase (ACCase) inhibitor</td>
<td>Aryloxyphenoxy propionate</td>
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<td>Average is 510 mL/g for quizalofop ethyl ester</td>
</tr>
</tbody>
</table>


**RIMSULFURON**  
**Trade name(s)** Matrix, Resolve DF, Pruvin  
**Manufacturer(s)** Corteva, ADAMA  
**Formulation(s)** 25% dry flowable  
**Remarks** A selective preemergence or postemergence herbicide to control weeds in potatoes. Rimsulfuron + thifensulfuron is marketed under the name Basis for use on field corn.  
**Water solubility** 7,000 ppm at pH 7  
**Storage conditions** Stable. Do not store in moist conditions.  
**Acute toxicity** LD<sub>50</sub> - greater than 5,000 mg/kg  
**Action in plant** Interferes with the plant enzyme acetolactate synthase, rapidly stopping cell division.  
**Site of action** Group 2: acetolactate synthase (ALS) inhibitor  
**Chemical family** Sulfonylurea

**SAFLUFENACIL**  
**Trade name(s)** Kixor, Treevix, Sharpen  
**Manufacturer(s)** BASF  
**Formulation(s)** EC  
**Remarks** Selective herbicide for control of broadleaf weeds, used preplant, preemergence and as a defoliant.  
**Water solubility** 0.14 ppm at pH 4, 0.25 ppm at pH 5, and 21 ppm at pH 7  
**Acute toxicity** LD<sub>50</sub> - greater than 2,000 mg/kg  
**Action in plant** Inhibits protoporphyrinogen oxidase (PPO) that disrupts cell membranes.  
**Site of action** Group 14: protoporphyrinogen oxidase inhibitor  
**Chemical family** Pyrimidinedione  
**Koc** Average is 9 to 56 mL/g

**SETHOXYDIM**  
**Trade name(s)** Poast, Poast Plus, Prestige, Vantage  
**Manufacturer(s)** BASF, Nufarm  
**Formulation(s)** 1, 1.3, and 1.5 lb/gal emulsifiable concentrate.  
**Remarks** A selective, postemergence herbicide to control most annual and perennial grasses. A crop oil concentrate enhances activity.  
**Water solubility** 4,700 ppm at pH 7  
**Acute toxicity** LD<sub>50</sub> - 4,900 mg/kg  
**Action in plant** Inhibits growing points of grasses.  
**Site of action** Group 1: acetyl CoA carboxylase (ACCase) inhibitor  
**Chemical family** Cyclohexanedione  
**Koc** Average is 100 mL/g (estimates) at pH 7

**SIDURON**  
**Trade name(s)** Tupersan  
**Manufacturer(s)** Corteva  
**Formulation(s)** 50% wettable powder  
**Remarks** Selective herbicide; controls annual grass in turf.  
**Water solubility** 18 ppm  
**Storage conditions** Stable under moderate conditions.  
**Acute toxicity** LD<sub>50</sub> - 7,500 mg/kg  
**Action in plant** Apparently inhibits root growth.  
**Site of action** Group 7: photosystem II inhibitor  
**Chemical family** Substituted urea  
**Koc** Average is 420 mL/g

**SIMAZINE**  
**Trade name(s)** Princep, Simazine  
**Manufacturer(s)** Syngenta  
**Formulation(s)** 80% wettable powder, 4 lb/gal flowable liquid, and 90% water-dispersible granules  
**Remarks** A triazine herbicide used selectively or as a complete vegetation killer. Requires considerable moisture to activate in soil. Shows long residual action.  
**Water solubility** 3.5 ppm  
**Storage conditions** Stable.  
**Acute toxicity** LD<sub>50</sub> - 5,000 mg/kg  
**Action in plant** Inhibits photosynthesis.  
**Site of action** Group 5: photosystem II inhibitor  
**Chemical family** Triazine  
**Koc** Average is 130 mL/g

**S-METOLACHLOR**  
*See Metolachlor*

**SODIUM CHLORATE**  
**Trade name(s)** Several  
**Manufacturer(s)** American Potash and Chemical Corp., Elf Atochem, Hooker Chemical, J. R. Simplot  
**Formulation(s)** 40% soluble powder; 4%, 19%, and 28% liquid; 12% and 33% dust; 99% active material in powder form; also formulated with borates, sodium carbonate, calcium/magnesium chloride, 2,4-D, and others.  
**Remarks** Inorganic salt. Kills germinating seeds nonselectively; inhibits plant growth. Easily leached from soil.  
**Water solubility** 790,000 ppm  
**Storage conditions** Stable at moderate conditions and when isolated from other pesticides.  
**Acute toxicity** LD<sub>50</sub> - 5,000 mg/kg  
**Action in plant** Unknown.  
**Site of action** None generally accepted  
**Chemical family** Inorganic  
**Koc** 10 mL/g (estimated)
**SULFENTRAZONE**

- **Trade name(s)**: Spartan, Zeus
- **Manufacturer(s)**: FMC Corp.
- **Formulation(s)**: 75% dispersible granule, 4 lb/gal flowable liquid
- **Remarks**: Soil-applied, preemergent triazolinone herbicide that can be applied either preplant incorporated or preemergence treatment. Note recropping intervals.
- **Water solubility**: 10 ppm at pH 5 and 300 ppm at pH 7
- **Storage conditions**: Stable in dry, cool conditions.
- **Acute toxicity**: LD$_{50}$ - 2,416 mg/kg
- **Action in plant**: Disrupts cell membranes by inhibiting protoporphyrinogen oxidase (PPO) in the chlorophyll biosynthetic pathway, leading to a buildup of toxic intermediates.
- **Site of action**: Group 14: protoporphyrinogen oxidase inhibitor
- **Chemical family**: Triazinone
- **Koc**: 43 mL/g

**SULFOMETURON**

- **Trade name(s)**: Oust, Spyder
- **Manufacturer(s)**: Corteva, Nufarm
- **Formulation(s)**: 75% dispersible granules
- **Remarks**: Broad-spectrum herbicide with preemergence and postemergence activity for noncropland and forestry use. Westar is sulfometuron + hexazinone.
- **Water solubility**: 10 ppm at pH 5; 300 ppm at pH 7
- **Storage conditions**: Stable.
- **Acute toxicity**: LD$_{50}$ - 5,000 mg/kg
- **Action in plant**: Interferes with an enzyme, rapidly stopping cell division.
- **Site of action**: Group 2: acetolactate synthase (ALS) inhibitor
- **Chemical family**: Sulfonylurea
- **Koc**: Average is 78 mL/g, but ranges from 22-91 mL/g

**SULFOSULFURON**

- **Trade name(s)**: Maverick, Outrider, Certainty
- **Manufacturer(s)**: Valent
- **Formulation(s)**: 75% water-soluble granule
- **Remarks**: Preemergence or postemergence control of several grasses and some broadleaves in wheat and noncrop areas.
- **Water solubility**: 18 ppm, pH 5; 1,627 ppm, pH 7; 482 ppm, pH 9.
- **Storage conditions**: Store in dry place below 120°F.
- **Acute toxicity**: LD$_{50}$ - greater than 5,000 mg/kg
- **Action in plant**: Inhibits the plant enzyme acetolactate synthase.
- **Site of action**: Group 2: acetolactate synthase (ALS) inhibitor
- **Chemical family**: Sulfonylurea
- **Koc**: 5 to 89 mL/g

**TEBUTHIURON**

- **Trade name(s)**: Spike
- **Manufacturer(s)**: Corteva
- **Formulation(s)**: 80% dry flowable, 20% pellets
- **Remarks**: A soil-applied herbicide to control woody plants and vegetation. Its half-life in soil is 12 to 15 months in areas receiving 40 to 60 inches of annual precipitation.
- **Water solubility**: 2,300 ppm
- **Storage conditions**: Stable.
- **Acute toxicity**: LD$_{50}$ - 568 mg/kg
- **Action in plant**: Symptoms suggest photosynthesis inhibition.
- **Site of action**: Group 7: photosystem II inhibitor
- **Chemical family**: Substituted urea
- **Koc**: Average is 80 mL/g, but ranges from 22-91 mL/g

**TEMBOTRIONE**

- **Trade name(s)**: Laudis
- **Manufacturer(s)**: Bayer
- **Formulation(s)**: 3.5 lb/gal
- **Remarks**: A selective postemergence herbicide for control of broadleaf and grass weeds in corn.
- **Water solubility**: 0.22 ppm, pH 4, 28.3 ppm, pH 7, 29.7, pH 9
- **Storage conditions**: Store in a cool dry place
- **Acute toxicity**: LD$_{50}$ - greater than 2,000 mg/kg
- **Action in plant**: Inhibits HPPD enzymes.
- **Site of action**: Group 27: inhibits 4-hydroxyphenyl-pyruvate-dioxygenase (HPPD)
- **Chemical family**: Triketone

**TERBACIL**

- **Trade name(s)**: Sinbar
- **Manufacturer(s)**: Tessenderlo Kerley Inc. (NovaSource)
- **Formulation(s)**: 80% wettable powder
- **Remarks**: A substituted uracil compound; a preemergence and postemergence selective and nonselective herbicide. Controls a wide range of weeds.
- **Water solubility**: 710 ppm
- **Storage conditions**: Stable at moderate conditions.
- **Acute toxicity**: LD$_{50}$ - 5,000 mg/kg
- **Action in plant**: Inhibits photosynthesis.
- **Site of action**: Group 5: photosystem II inhibitor
- **Chemical family**: Uracl
- **Koc**: Average is 55 mL/g
## Thiencarbazone

**Trade name(s)** in package mixture with tembotrione and sold as Capreno  
**Manufacturer(s)** Bayer CropScience  
**Remarks** Herbicide applied postemergence to control broadleaf and grass weeds in corn. Thiencarbazone is package-mixed with tembotrione.  
**Water solubility** 172 ppm at pH 4; 436 ppm at pH 7; 417 ppm at pH 9  
**Acute toxicity** >2,000 mg/lb (technical)  
**Action in plant** Inhibits the plant enzyme acetolactate synthase.  
**Site of action** Group 2: acetolactate synthase (ALS) inhibitor  
**Chemical family** Sulfonilaminocarbonyltriazolinone

## Thifensulfuron

**Trade name(s)** Harmony, Harmony GT  
**Manufacturer(s)** Corteva  
**Formulation(s)** 75% dry flowable  
**Remarks** A selective, postemergence herbicide with short soil persistence used at low rates to control certain broadleaf weeds in wheat and barley. Harmony Extra is thifensulfuron + tribenuron.  
**Water solubility** 24 ppm at pH 4; 2,400 ppm at pH 6  
**Acute toxicity** LD_{50} - greater than 5,000 mg/kg  
**Action in plant** Inhibits the acetolactate synthase, resulting in a rapid cessation of cell division and plant growth in both shoots and roots.  
**Site of action** Group 2: acetolactate synthase (ALS) inhibitor  
**Chemical family** Sulfonilurea  
**Koc** Average is 45 mL/g at pH 7

## Tolpyralte

**Trade name(s)** Shieldex  
**Manufacturer(s)** ISK  
**Formulation(s)** 3.33 lb/gal suspension concentrate  
**Remarks** Tolpyralte is a 4-HPPD inhibitor herbicide for postemergence weed control in corn. It is effective against most major broadleaf weeds and has good activity on a number of grass weed species common to corn, including wild proso millet, while displaying excellent crop safety for all types of corn.  
**Water solubility** ppm at pH 7  
**Acute toxicity** LD_{50} - greater than mg/kg  
**Action in plant** Inhibits growing points in grasses.  
**Site of action** Group 27: inhibits 4-hydroxyphenylpyruvate-dioxygenase (4-HPPD)  
**Chemical family** Trikетone  
**Koc** 11 to 85 mL/g

## Topramezone

**Trade name(s)** Impact  
**Manufacturer(s)** Amvac Chemical Corp.  
**Formulation(s)** 2.8 lb/gal suspension concentrate  
**Remarks** Topramezone is a novel 4-HPPD inhibitor herbicide for postemergence weed control in corn. It is effective against most major broadleaf weeds and has good activity on a number of grass weed species common to corn, including wild proso millet, while displaying excellent tolerance to all types of corn.  
**Water solubility** 15,000 ppm at pH 7  
**Acute toxicity** LD_{50} - greater than 2,000 mg/kg  
**Action in plant** Inhibits HPPD enzymes.  
**Site of action** Group 27: inhibits 4-hydroxyphenylpyruvate-dioxygenase (4-HPPD)  
**Chemical family** Trikетone  
**Koc** Average is 22.3 to 172.4 mL/g

## Tralkoxydim

**Trade name(s)** Achieve  
**Manufacturer(s)** Syngenta  
**Formulation(s)** 40% dispersible granule, 3.33 lb/gal soluble concentrate  
**Remarks** Used to control grasses in wheat and barley.  
**Water solubility** 7 ppm  
**Acute toxicity** LD_{50} - 934 mg/kg  
**Action in plant** Inhibits growing points in grasses.  
**Site of action** Group 1: acetyl CoA carboxylase (ACCase) inhibitor  
**Chemical family** Cyclohexanedione  
**Koc** 30 to 300 mL/g; stronger adsorption in low pH soils

## Triallate

**Trade name(s)** Far-Go  
**Manufacturer(s)** Monsanto Co., Gowan  
**Formulation(s)** 4 lb/gal emulsifiable concentrate, 10% granules  
**Remarks** A selective herbicide for wild oat control, applied pre-plant or pre-emergence and incorporated. May irritate skin and eyes. Buckle is triallate + trifluralin.  
**Water solubility** 4 ppm  
**Acute toxicity** LD_{50} - 2,700 mg/kg  
**Action in plant** Inhibits shoots of emerging seedlings.  
**Site of action** Group 8: lipid synthesis inhibitor but not an ACCase inhibitor  
**Chemical family** Thiocarbamate  
**Koc** Average is 2,400 mL/g
### TRIASULFURON

**Trade name(s)** Amber  
**Manufacturer(s)** Syngenta  
**Formulation(s)** 75% water-dispersible granules packaged in water-soluble packets  
**Remarks** Selective, postemergence herbicide used in small grains to control certain broadleaf weeds. Carefully consider crop rotation plans before using.  
**Water solubility** 40 ppm at pH 5; 1,500 ppm at pH 7  
**Storage conditions** Stable. Do not expose to light or moisture.  
**Acute toxicity** \( \text{LD}_{50} \) - greater than 5,000 mg/kg  
**Action in plant** Interferes with the plant enzyme acetolactate synthase, thus rapidly ending cell division.  
**Site of action** Group 2: acetolactate synthase (ALS) inhibitor  
**Chemical family** Sulfonylurea  
**Koc** 51.6 mL/g for a silt loam 4.5% OM, and pH 7.2

### TRIBENURON

**Trade name(s)** Express  
**Manufacturer(s)** Corteva  
**Formulation(s)** 75% dry flowable  
**Remarks** A selective, postemergence herbicide with short soil persistence used at low rates to control certain broadleaf weeds in wheat and barley. Harmony Extra is tribenuron + thifensulfuron.  
**Water solubility** 28 ppm at pH 4; 280 ppm at pH 6.  
**Acute toxicity** \( \text{LD}_{50} \) - greater than 5,000 mg/kg  
**Action in plant** Interferes with acetolactate synthase, resulting in a rapid cessation of cell division and plant growth in both shoots and roots.  
**Site of action** Group 2: acetolactate synthase (ALS) inhibitor  
**Chemical family** Sulfonylurea  
**Koc** Average is 46 mL/g pH 6.6

### TRICLOPYR

**Trade name(s)** Garlon 3A, Garlon 4 Herbicide, Forestry Garlon 4, Forestry Garlon XRT, Remedy, Renovate 3A, Renovate OTF  
**Manufacturer(s)** Corteva, SePro  
**Formulation(s)** 3 lb/gal miscible liquid, 4 and 6.3 lb/gal emulsifiable concentrate, and a 10% granular flake  
**Remarks** A growth-regulating herbicide to control woody and broadleaf perennial weeds in noncropland, forestland, range, permanent grass pasture, turf, and rights-of-way. Crossbow is triclopyr + 2,4-D; Redeem R&P and Confront are triclopyr + clopyralid.  
**Water solubility** 430 ppm  
**Storage conditions** Store above 35°F. Agitate before use if stored near freezing.  
**Acute toxicity** \( \text{LD}_{50} \) - 2,140 mg/kg  
**Action in plant** Mimics natural plant hormones.  
**Site of action** Group 4: synthetic auxin  
**Chemical family** Pyridine  
**Koc** Average is 20 mL/g (estimated) for the triethylamine salt and 780 mL/g for the butoxyethyl ester

### TRIFLURALIN

**Trade name(s)** Treflan, Trifluralin, Tri-4, Trust  
**Manufacturer(s)** Gowan, Helena, Monterey, Loveland  
**Formulation(s)** 4 and 5 lb/gal emulsifiable concentrate, 5% and 10% granules  
**Remarks** A dinitroaniline compound used as a selective, preemergence herbicide. Requires incorporation after application to prevent loss of activity. Residual activity from higher rates may be a problem with certain sensitive crops. Buckle is trifluralin + triallate.  
**Water solubility** 0.3 ppm  
**Storage conditions** Store the emulsifiable concentrate above 40°F.  
**Acute toxicity** \( \text{LD}_{50} \) - 2,000 mg/kg  
**Action in plant** Inhibits mitosis in shoots and roots.  
**Site of action** Group 3: microtubule assembly inhibitor  
**Chemical family** Dinitroaniline  
**Koc** Average is 7,000 mL/g

### TRIFLUSULFURON

**Trade name(s)** UpBeet  
**Manufacturer(s)** FMC  
**Formulation(s)** 50% dry flowable  
**Remarks** A selective postemergence herbicide to control weeds in sugar beets.  
**Water solubility** 3 ppm at pH 5; 110 ppm at pH 7  
**Storage conditions** Very stable. Formulated products do not freeze.  
**Acute toxicity** \( \text{LD}_{50} \) - greater than 5,000 mg/kg  
**Action in plant** Inhibits the plant enzyme acetolactate synthase, resulting in rapid cessation of cell division.  
**Site of action** Group 2: acetolactate synthase (ALS) inhibitor  
**Chemical family** Sulfonylurea  
**Koc** 35 mL/g in loamy sand with 3.3% OM and 5.9 pH
Restricted-Use Herbicides in Idaho, Oregon, and Washington

Andrew Hulting
Reviewed March 2019

The active ingredients listed below are designated as restricted-use by the U.S. Environmental Protection Agency (EPA); buying them requires a certified pesticide applicator’s license. Herbicides are listed by the active ingredient. Some or all uses of these active ingredients are considered restricted-use. Before purchasing any pesticide, consult the label for usage category.

- acetochlor
- acrolein
- alachlor
- atrazine
- metam-sodium
- paraquat
- picloram
- pronamide

**Additional Restricted-Use Herbicides in PNW States**

Some or all uses of the following herbicide active ingredients are classified as restricted-use in one or more of the three PNW states *in addition to the federal restricted-use pesticides listed above*. Before purchasing any pesticide, consult the label for usage category and site.

All aquatic uses of herbicides in Washington
All sulfonylurea herbicides in Washington

- 2,4-D
- 2,4-DB
- benefin
- bromacil
- bromoxynil
- carfentrazone
- chlorosulfuron
- clopyralid
- copper sulfate
- DCPA
- dicamba
- dichlobenil
- dichlorpropene
- diflufenzopyr
- diquat
- diuron
- ethametsulfuron
- fenoxaprop
- fluazifop
- flufenacet
- fluroxypyr
- fluthiacet-methyl
- glyphosate
- halosulfuron
- hexazinone
- iodosulfuron
- imazamox
- imazapic
- imazapyr
- MCPA
- MCPB
- MCPP
- mesosulfuron
- metribuzin
- metsulfuron
- MSMA
- nicosulfuron
- phenmedipham
- primisulfuron
- prometon
- prosulfuron
- rimsulfuron
- simazine
- S-metolachlor
- sodium chlorate
- sodium metaborate
- sulfometuron-methyl
- sulfosulfuron
- tebuthiuron
- thiencarbazone-methyl
- thifensulfuron
- triasulfuron
- tribenuron
- trifluralin
- triflusulfuron
Residues of triazine herbicides (such as atrazine and simazine), substituted urea herbicides (such as linuron and diuron), clompyralid, or fomesafen may persist in the soil for months. Herbicide labels include rotation, or plant-back, intervals for many crops, but it is often prudent to determine whether harmful residues are present in the soil before planting, particularly when planting very sensitive crops, or when renting land, even when label guidelines are followed. Testing for herbicide residues also can be helpful when attempting to determine the cause of unknown crop injury or failure.

**Testing for Herbicide Residues:**

**Labs and Bioassays**

There are two main options for testing for herbicide residues in soil. The first option is to send a soil sample to a lab for analysis. Chemical screens are performed by many labs for a wide array of herbicides. However, lab analysis may be costly, time consuming, and misleading. Additionally, predicting potential crop damage that may result from herbicide residues detected by laboratory soil analysis is challenging.

Another option is to conduct a bioassay by planting crops of interest in soil collected a few weeks before the scheduled planting date. The following example is specifically designed to test for atrazine residues in soil, and therefore uses oat as the indicator species, because oats are very sensitive to atrazine. A similar tactic can be used to test for residues of other herbicides.

**Example: Testing for atrazine residues in soil.**

1. Secure a representative soil sample from the field you suspect contains atrazine residue. Sample from several locations, as when collecting soil samples, to determine fertilizer requirements. Atrazine residue may be found in patches of a field. Sample enough areas to avoid missing areas that might contain a high residue. Take separate samples from areas where residues may be excessive. Always sample to the full depth of the plow slice, whether or not the field is plowed. Remember that the assay is only as reliable or representative as the samples. Each sample to be assayed requires about 10 lb of soil.

2. Assay samples within a week or two after they are collected from the field. If the samples cannot be assayed immediately, store the soil in a cold place—either in the refrigerator or in a freezer if possible. When samples are stored indoors under warm conditions, the atrazine residue may be lost.

3. If the soil is wet, spread it out and allow it to dry so it can be worked readily. If the soil is cloddy, crush clods to the size of peas or wheat seed, but do not pulverize the soil.

4. Adding about 50% by volume of coarse sand will improve the physical condition of silt and clay soils. If sand is added, mix it well with the soil.

5. Add about 0.5 g of activated carbon to 5 lb of the soil, or of the soil–sand mixture. Mix carbon and soil thoroughly. Carbon deactivates atrazine or other herbicide residue. For purposes of comparison, soil treated this way provides the equivalent of soil without residue.

6. Partially fill two containers with soil that does not contain carbon, and two containers with the soil–carbon mixture. The four containers should hold about a pint to a quart each. Punch holes in the bottom of the containers to allow drainage. Tin cans, paper milk cartons, or ice cream cartons are satisfactory for this purpose.

7. Plant five to eight oat seeds (or seeds of vegetable species of interest) in each container; cover seeds with about 0.5 inch of soil. Wet the soil with water but do not saturate. After emergence, thin to three plants to ensure maximum uptake or absorption of possible residue.

8. Place containers where they will be warm (about 70°F to 75°F), and receive as much sunlight as possible. A strong light source will help development of atrazine injury symptoms.

9. Injury symptoms on seedlings should appear about 3 weeks after planting. If temperatures are below 70°F, more time is required. Water plants sparingly. Do not allow soil to dry out.

10. Severe triazine injury is characterized by drooping leaves and leaf-kill that extends from the leaf tip toward the base. Leaf-kill indicates a significant amount of residue in the soil. Marginal residue content will stunt the oats’ growth without killing the leaves. Stunting can be determined by comparing the growth of oats in soil with carbon. Oats grown in soil with carbon should be normal, and should show no atrazine injury or stunting, unless extremely high residues of atrazine are in the soil sample.

If the oats show any evidence of leaf-kill or stunting, plant an atrazine-tolerant crop in the field from which the samples were obtained.

**Using Activated Charcoal**

Activated charcoal (or carbon) can reduce herbicide contamination in specific areas (gardens, greenhouses, lawns, etc.) and can also be used as a root dip to partially protect transplants (tomatoes, peppers, strawberries, ornamentals, etc.) from atrazine or substituted urea herbicides. Activated carbon can also be used to mitigate pesticide spills.

Other herbicides that carbon can deactivate include trifluralin (Treflan), bromacil (Hyvar X), benefin (Balan), bensulide (Prefar), DCPA (Dacthal), dichlobenil (Casoron), EPTC (Eptam), 2,4-D, terbacil (Sinbar), sulfentrazone (Zeus or Spartan) and chloroacetamide herbicides such as S-metolachlor (Dual Magnum) or dime-thanamid-P (Outlook) and others.

Activated carbon, used in a wide range of applications in diverse industries, is made by heating or chemically treating organic matter to create a porous structure. This gives a large surface area within a relatively small volume. Most activated carbon products are purified by acid and water washes to remove impurities and are available in both granular and powdered form. Charcoal for outdoor grills cannot be ground up to achieve the same pore structure characteristics of activated charcoal on a pound-for-pound basis.

The usefulness of activated carbon is based primarily on its ability to hold molecules within its vast pore structure. The phenomenon of adsorption can take place either in gaseous or liquid phase systems. Adsorption is often selective when applied to systems.
containing more than one component, for example when using activated carbon in gas masks to remove poisonous vapors, and as an antidote for ingested poisons.

Where to Obtain Activated Charcoal

Some garden supply centers carry packaged activated carbon that is designed for the uses outlined here. Activated carbon is used extensively in dry cleaning and water-purification. Usually, sources of activated charcoal can be quickly found by searching online (e.g., GROW-SAFE at http://www.buyactivatedcharcoal.com/activated_charcoal_products/soil_detox), or by contacting a dry cleaning establishment. Some dry-cleaning carbons may contain additives that will make them unsuitable. Activated carbon is offered in containers of 1 to 50 lb. Small quantities of purified activated carbon are available at pharmacies and at chemical supply houses.

Charcoal Application

(Modified for PNW conditions)

Use of activated charcoal should be considered as an emergency treatment for herbicide residues from previous crops, spills, or changes in crop rotations. Before using activated charcoal, however, consider that the herbicide label directions for rotational restrictions must take precedence over efforts to deactivate the herbicide.

Herbicide resistance is not the natural tolerance that some species have to a herbicide. For example, wheat is tolerant to Discover because it can rapidly deactivate it. Wild oat can only slowly deactivate Discover, so the herbicide can be used selectively to remove wild oat from wheat.

The first identified herbicide-resistant weed—spreading dayflower (Commelina diffusa), resistant to 2,4-D—was identified in 1957, in a sugarcane field in Hawaii. Since then, more than 238 weed species resistant to one or more herbicides have been identified worldwide. For current information on the status of herbicide-resistant weeds, see: http://WeedScience.org/.

Herbicide-resistant weeds are common in the Pacific Northwest:

- Kochia, prickly lettuce, and Russian thistle resistant to sulfonylurea herbicides (Glean, Amber, Ally, and other Group 2 inhibitors)
- Wild oat and Italian ryegrass resistant to Group 1 ACCase inhibitors
- Powell amaranth resistant to triazines and other Group 5 Photosynthetic inhibitors
- Yellow starthistle resistant to Tordon and other Group 4 Auxin
- Prickly lettuce resistant to 2,4-D Group 4 Auxin
- Kochia and Italian ryegrass resistant to Group 9 glyphosate

The appearance of herbicide-resistant weeds is strongly linked to repeated use of the same herbicide, or herbicides with the same site of action, in a monoculture cropping system (for example, wheat after wheat) or in non-crop areas (railway or road rights-of-way, for example). Managing herbicides to delay and prevent the appearance of herbicide-resistant weeds requires understanding which chemical family a herbicide belongs, and which herbicides have the same site of action.

Managing Herbicide-Resistant Weeds

Carol Mallory-Smith
Revised March 2015

Herbicide resistance is the inherited ability of a plant to survive a herbicide application to which the wild-type was susceptible. Resistant plants occur naturally within a population and differ slightly in genetic makeup, but remain reproductively compatible with the wild type.

Herbicide-resistant plants are in a population in extremely small numbers. Repeatedly using one herbicide allows these few plants to survive and reproduce. The number of resistant plants then increases in the population until the herbicide no longer effectively controls the weed.

Resistant plants likely will persist in infested fields for many years, even in the absence of any additional selection with the herbicide. There is no evidence that herbicides cause the genetic mutations that lead to herbicide resistance.

Resistant plants may be resistant to other herbicides (imidazolones as well as sulfonylureas, for example) that kill plants in the same way (same site of action or same group). This is called cross-resistance.

Weeds also can be resistant to herbicides with different sites of action (aryloxyphenoxy propanoates as well as sulfonylureas, for example). In Oregon, a biotype of Italian ryegrass is resistant to at least four different herbicide groups. This is called multiple-resistance.

1 Adapted from Herbicide-Resistant Weeds and Their Management, PNW 437, a Pacific Northwest Extension publication (University of Idaho, revised 2011). Authors are Joan Campbell, University of Idaho; Carol Mallory-Smith and Andy Hulting, Oregon State University; Donn Thill, University of Idaho. Online at http://www.cals.uidaho.edu/edComm/pdf/pnw/pnw0437.pdf
Dealing with herbicide-resistant weeds

Monitor fields for weed escapes. Weed escapes are not necessarily resistant, but they may be. A resistance problem may not be visible until 30% or more of the weeds are no longer controlled. Determine whether escapes are only one species or a mixture. If they are a mixture, the problem is more likely related to environment or application. If they are only one species, the problem is more apt to be resistance, especially if the herbicide controlled the species in the past, and if the same herbicide has been used repeatedly in the field.

Keep weeds from spreading. Prevent known resistant weeds from flowering and producing seed. After using machinery in fields or areas with known or suspected infestations of herbicide-resistant weeds, thoroughly clean the equipment to reduce the spread of resistant weeds from one field or area to another. Always plant clean seed.

Change crops and tillage systems. Crop rotation and altered tillage practices can affect the weed populations. Alternating spring and winter crops means that the field will be tilled at different times each year. During one of the field preparation operations, resistant as well as susceptible weeds will be killed.

Change herbicide program. If weed resistance occurs, herbicides with other sites of action and other weed management practices must be used.

Recognizing herbicide-resistant weeds

Irregular patches of a single weed species in the field are an indicator of herbicide resistance, especially when:

- No other application problems are apparent.
- Other weed species are controlled adequately.
- There are no, or minimal, herbicide symptoms on the single weed species not controlled.
- There has been a previous failure to control the same species.
- Herbicide-resistant crops and weeds that spread to adjacent fields or areas.
- Herbicide-resistant crops can be valuable tools to manage difficult weed species not controlled.

What to do if you suspect herbicide resistance:

1. Do not re-spray the field with the same herbicide, or a herbicide with the same site of action.
2. Report your suspicion to university research or Extension personnel, or to the Extension educator in your county.
3. Collect plants or seed that can be used to confirm resistance has developed.

Managing herbicide-resistant crops

Crops resistant to specific herbicides have been developed through genetic engineering and through traditional selective breeding techniques. Examples include Clearfield wheat, which was selected for resistance to imazamox, and Roundup Ready canola, which was genetically engineered to be resistant to glyphosate. Used properly, herbicide-resistant crops can be valuable tools to manage difficult weeds, but they also have two inherent risks that need to be considered before planting: the emergence in subsequent growing seasons of herbicide-resistant volunteers, and the potential for herbicide-resistant crops to cross with weedy relatives.

Volunteer herbicide-resistant crops as weeds. Consider whether the herbicide-resistant crop typically is a volunteer crop in years after its cultivation and, if so, whether herbicide options are available in the crop rotation to remove herbicide-resistant volunteers.
For example, glyphosate is commonly used to control volunteer crops before planting a rotational crop. Glyphosate will not control Roundup Ready crops; therefore a herbicide with a different site of action or a non-chemical control measure is required to control glyphosate-resistant volunteers. Evaluate the impact of using these other herbicides or non-chemical control measures for your operation. Impacts could be increased cost, or increased soil erosion or moisture loss due to increased tillage.

Volunteer crops are considered a problem largely within 1 year of harvest. However, certain species have extended dormancy, which could result in multiple years of a herbicide-resistant volunteer crop problem, even without new seed inputs.

Gene flow from herbicide-resistant crops to weedy relatives Rarely, the trait that confers herbicide resistance in the crop can move into weedy relatives through cross-pollination, resulting in a herbicide-resistant weed. Consider nearby weedy and native relatives of the herbicide-resistant crop as well as their propensity to cross-pollinate. Self-pollinating crops, such as soybean, are considered low-risk for gene flow to weeds or other crops. But a crop such as Roundup Ready, Clearfield, or Liberty Link canola could pollinate nearby herbicide-susceptible canola as well as weedy relatives of canola, resulting in volunteer canola plants or weeds that may be resistant to several herbicide families.

Crops that may pose problems Herbicide-resistant crops at risk for gene flow or volunteer-management problems would include some or all of the following traits:

- The crop cross-pollinates with nearby relatives that are problem weeds, or with other crops.
- Crop seed shatters or vegetative propagules are left in the ground after harvest, resulting in volunteer crops in subsequent years (for example, canola or potato).
- Herbicides for managing volunteer crops are limited to ones in the same family to which the crop is resistant.
- Crop seed is viable in soil for several cropping seasons.
- Using the herbicide-resistant crop increases your reliance on herbicide families that would be applied multiple times per season or several times during a cropping system.

### Herbicide Rotation

To avoid selecting for herbicide-resistant weeds, do not use herbicides from the same group more than once in 3 years. Rather, rotate to a different group every year of the production system.

<table>
<thead>
<tr>
<th>Group Number and Site of Action¹</th>
<th>Chemical Family</th>
<th>Common Name</th>
<th>Trade Name(s)</th>
<th>Resistant Weeds in the PNW</th>
<th>States with Resistant Weeds</th>
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<tbody>
<tr>
<td>Group 1</td>
<td>Acetyl CoA carboxylase (ACCase) inhibitors</td>
<td>cyclohexanediones</td>
<td>clethodim</td>
<td>Select Max, Envoy, several others</td>
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<td>sethoxydim</td>
<td>Poast, several others</td>
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<td>tralkoxydim</td>
<td>Achieve</td>
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<td>Acetolactate synthase (ALS) inhibitors</td>
<td>aryloxyphenoxy propionates</td>
<td>clodinafop</td>
<td>Discover NG</td>
<td>Italian ryegrass</td>
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<td>Hoelon</td>
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<td>fenoxaprop</td>
<td>Puma, Acclaim</td>
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<td>Assure II, Targa</td>
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<td>Phenylpyrazolines</td>
<td>pinoxadene</td>
<td>Axial</td>
<td>Italian ryegrass</td>
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<td>Group 2</td>
<td>Imidazolinones</td>
<td>*imazamox</td>
<td>Raptor, Beyond, Clearmax (Beyond + MCPA), Clearcast</td>
<td>downy brome</td>
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<td>Plateau, Oasis</td>
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<td>Arsenal, Chopper, several others</td>
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<td>Pursuit</td>
<td>kochia</td>
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</table>

¹Herbicide classification according to primary site of action.

* Can persist in soil most of the growing season or from one growing season to the next.
<table>
<thead>
<tr>
<th>Group Number and Site of Action</th>
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<th>Resistant Weeds in the PNW</th>
<th>States with Resistant Weeds</th>
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<td>Group 2 (continued)</td>
<td><strong>Acetolactate synthase (ALS) inhibitors (continued)</strong></td>
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<td>mesosulfuron + propoxycarbazone</td>
<td>Olympus Flex</td>
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<td>*prosulfuron</td>
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<td><strong>sulfonylaminocarbonyl-triazolinones</strong></td>
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<td>Herbicide classification according to primary site of action.</td>
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<td>benefin</td>
<td>Balan</td>
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<td>*oryzalin</td>
<td>Surflan</td>
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<td>*pendimethalin</td>
<td>Prowl H2O, Pendulum, several others</td>
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<td>*prodiamine</td>
<td>Barricade, Endurance, several others</td>
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<td></td>
<td>*trifluralin</td>
<td>Treflan, Trust</td>
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<tr>
<td></td>
<td>benzamides</td>
<td>*pronamide</td>
<td>Kerb</td>
<td>wild oat</td>
<td>OR</td>
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<td><strong>Group 4</strong></td>
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<td>phenoxy acetic acids</td>
<td>2,4-DB</td>
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<td>benzamides</td>
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<td>quinoline carboxylic acids</td>
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<td>pyridines</td>
<td>*clopyralid</td>
<td>Stinger, Transline, Clopyr Ag</td>
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<td>Starane, Vista, Spotlight</td>
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<td>pyridines</td>
<td>*picloram</td>
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<td>yellow starthistle</td>
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<td>pyridines</td>
<td>*triclopyr</td>
<td>Garlon, Remedy, Renovate, several others</td>
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<td><strong>Group 5</strong></td>
<td>triazines</td>
<td>*atrazine</td>
<td>AAtrex, Atrazine</td>
<td>common groundsel</td>
<td>ID, OR, WA</td>
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<tr>
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<td>triazines</td>
<td>*simazine</td>
<td>Princep, Simazine</td>
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<td>WA</td>
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<td>as-triazines</td>
<td>*hexazinone</td>
<td>Velpar, others</td>
<td>shepherd’s purse</td>
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<td>as-triazines</td>
<td>*metribuzin</td>
<td>Sencor, Metri DF</td>
<td>Italian ryegrass</td>
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<td>uracils</td>
<td>*bromacil</td>
<td>Hyvar X, Hyvar X-L</td>
<td>common groundsel</td>
<td>OR</td>
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<tr>
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<td>uracils</td>
<td>*terbacil</td>
<td>Sinbar</td>
<td>pigweed spp.</td>
<td>OR, WA</td>
</tr>
</tbody>
</table>

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</thead>
<tbody>
<tr>
<td>Photosystem II inhibitors (same site as groups 5 and 7 but different binding behavior)</td>
<td>benzothiadiazoles</td>
<td>bentazon</td>
<td>Basagran</td>
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<td>nitriles</td>
<td>bromoxynil</td>
<td>Buctril, Bromox, Bronate (contains MCPA), several others</td>
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<td>common groundsel OR</td>
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<td>Group 7</td>
<td>Photosystem II inhibitors (same site as groups 5 and 6 but different binding behavior)</td>
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<td>*diuron</td>
<td>Karmex, Direx</td>
<td>annual bluegrass OR</td>
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<td></td>
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<td>common lambsquarters OR</td>
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<td>*linuron</td>
<td>Lorox, Linex</td>
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<td>*tebuthiuron</td>
<td>Spike</td>
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<td>Lipid synthesis inhibitors but not ACCase inhibitors</td>
<td>thiocarbamates</td>
<td>butylate</td>
<td>Sutan, Sutan + (contains safener)</td>
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<td>Ro-Neet</td>
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<td>EPTC + safener</td>
<td>Eradicane</td>
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<td>triallate</td>
<td>Far-Go</td>
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<td>Group 9</td>
<td>EPSP synthase inhibitors</td>
<td>glycines</td>
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<td>kochia OR</td>
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<td>Group 10</td>
<td>Glutamine synthase inhibitors</td>
<td>phosphinic acids</td>
<td>glufosinate</td>
<td>Rely, Liberty, Ignite, several others</td>
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<td>Group 14</td>
<td>Inhibitors of protoporphyrinogen oxidase (Protox)</td>
<td>diphenylethers</td>
<td>*oxyfluorfen</td>
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<td>flumiclorac</td>
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<td>*flumioxazin</td>
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<td>triazinones</td>
<td>carfentrazone</td>
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<td>*sulfentrazone</td>
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<td>acetochlor</td>
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<td>alachlor</td>
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<td>dimethenamid-P</td>
<td>Outlook</td>
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<td>metolachlor</td>
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<td>S-metolachlor</td>
<td>Dual Magnum, Dual II Magnum</td>
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<td>oxyacetamides</td>
<td>flufenacet</td>
<td>Define, Axiom (contains metribuzin)</td>
<td>Italian ryegrass ID, OR, WA</td>
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<td>acetamides</td>
<td>napropamide</td>
<td>Devrinol</td>
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</thead>
<tbody>
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<td>Unknown</td>
<td>benzofurans</td>
<td>ethofumesate</td>
<td>Nortron, several others</td>
<td>annual bluegrass</td>
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<td><strong>Group 17</strong></td>
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<td>MSMA</td>
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<td><strong>Group 20</strong></td>
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<td>Inhibitors of cell wall synthesis Site A</td>
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<td>*dichlobenil</td>
<td>Casoron, Barrier</td>
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<td><strong>Group 22</strong></td>
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<td>Photosystem I electron diverters</td>
<td>bipyridiliums</td>
<td>diquat</td>
<td>Reglone, Reward</td>
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<td>parquat</td>
<td>Gramoxone Inteon, Firestorm, several others</td>
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<td>carboxylic acids</td>
<td>pelargonic acid</td>
<td>Scythe</td>
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<td><strong>Group 27</strong></td>
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<td>Inhibitors of 4-hydroxy-phenylpyruvated-dioxygenase (4-HPPD)</td>
<td>isoxazoles</td>
<td>pyrasulfotole</td>
<td>Huskie (contains bromoxynil)</td>
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<td>triketones</td>
<td>mesotrione</td>
<td>Callisto</td>
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<td></td>
<td>topramezone</td>
<td>Impact</td>
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Cleaning Spraytanks

Ed Peachey

Revised March 2020

The proper procedure for cleaning a spraytank depends on several factors including the composition of the spraytank, pesticides used, and sensitivity of the crop to which pesticides will be applied following the cleaning. In some cases, triple rinsing with water will be sufficient, depending on the herbicide used. Typically, a detergent should be added to the water. Removal of many herbicides from spray equipment requires the use of ammonia or approved tank cleaners. Specific directions are included on herbicide labels; they should be consulted and used.

Some pesticides are more difficult to remove from spraytanks than others. These pesticides often have very low use rates (e.g., Aim and Sandea), or may stick to residues of other chemicals that remain in the sprayer. In some cases, additives such as crop oils or nitrogen solutions may allow the release of previously used herbicides, or enhance the efficacy of herbicides that remain in the tank.

There are numerous recommendations about cleaners for specific herbicides. Cleaners usually fit into the categories of detergents, ammonia, chlorine bleach, or commercial tank cleaners.

Ammonia increases the pH of the solution, which increases the solubility of many herbicides and the potential to remove them from the spraytank. Ammonia is commonly used to clean tanks.

Commercial tank cleaners generally raise the pH of the solution and act as detergents.

Chlorine bleach lowers the pH of the solution, which speeds degradation of some herbicides, but does not improve the solubility of many herbicides. Chlorine bleach is not usually recommended as a cleaning agent.

Never mix ammonia with chlorine bleach; this mixture creates dangerous vapors.

A Standard Triple-Rinse Procedure for Cleaning Spraytanks

1st rinse: Drain remaining pesticide from the spraytank and hose down the interior surfaces of the tank. Then flush tank, hoses, boom, and nozzles with clean water for 10 minutes.

2nd rinse: Fill the tank with water, add detergent or other recommended cleaner, and recirculate for 15 minutes. Spray some of the rinsate though the boom and nozzles, then drain the tank.

Pesticide labels for very-low-use-rate herbicides (such as Aim) or growth regulators (such as Landmaster and 2,4-D) often recommend that the cleaning solution be allowed to stand for a few hours in the sprayer, sometimes as long as overnight.

Remove the nozzles and screens, and clean them separately.

3rd rinse: Drain the cleaning solution from the tank, rinse with clean water, then spray rinsate though the boom. Repeat steps 2 and 3 for difficult to remove herbicides.

Validating Spraytank Cleaning Methods

Sometimes, a bioassay can be used to test whether a spraytank has been thoroughly cleaned. The simplest method is to collect rinsate from the final rinse, then, using a sprayer or spray bottle, apply it to plants known to be extremely sensitive to the herbicide in question, then compare the effects on untreated versus treated plants. For instance, rinsate from a tank holding 2,4-D could be applied to tomato plants. A second option would be to fill the cleaned tank with water, then spray the water on a small area of the crop that will be treated.

The disadvantage of these bioassays is that symptoms will often take a few days to develop; in the case of sulfonylurea herbicides, it may take 2 to 3 weeks. Another drawback is that water and cleaners may not remove remaining residues in the spraytank in the same manner as herbicides and other adjuvants that might be used.

Some herbicides are difficult to completely remove from spraytanks and can cause serious injury to susceptible crops if even minute amounts of herbicide remain in the spraytank. Phenoxy herbicides fit this category because of the damage that herbicides such as 2,4-D can cause to tomato and other plants of the family Solanaceae. It is often prudent to simply use dedicated spraytanks to avoid the risk of injury from residues that may remain from other uses.

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Detergent1, Household ammonia (3% active)</th>
<th>Approved cleaning agent</th>
<th>Commercial tank cleaner</th>
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<td>Aim, Aim EC</td>
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<td>Accent</td>
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</tr>
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<td></td>
</tr>
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<tr>
<td>Bronate</td>
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<td>Capreno</td>
<td>4-8% bleach</td>
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PNW Weed Management Handbook
B35
<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Cleaning Agents¹ (consult labels for specific directions)</th>
<th>Herbicide</th>
<th>Cleaning Agents¹ (consult labels for specific directions)</th>
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<tbody>
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<td>Household ammonia (3% active)</td>
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</table>

¹ Recommended cleaning agents on herbicide labels.
² A ✓ followed by the letter R indicates that the label recommends a strong detergent for cleaning the tank. Some labels only recommend rinsing with water. Adding a detergent such as a dry formulated household laundry detergent is often a good idea.