

SECTION B.

AGRICHEMICALS AND THEIR PROPERTIES

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Section contents

Agrichemicals and Their Properties (Revised March 2020)	B-1
Restricted-use Herbicides in Idaho, Oregon, and Washington (Reviewed March 2019)	B-26
Testing for and Deactivating Herbicide Residues (Revised March 2020) ..	B-27
Managing Herbicide-Resistant Weeds (Revised March 2015)	B-28
Cleaning Spraytanks (Revised March 2020)	B-35

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 LD₅₀ (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 LD₅₀ - 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 LD₅₀ - 1,960 mg/kg

Action in plant Mimics natural plant hormones.

Site of action Group 4: synthetic auxin

Chemical family Phenoxy acetic acid

Koc Average is 440 mL/g (estimated) for the acid, 500 mL/g for the butoxyethyl ester, and 20 mL/g (estimated) for the dimethylamine salt

2,4-DP

See *dichlorprop*

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 LD₅₀ - 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 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.

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 LD₅₀ - 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 LD₅₀ - 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

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 LD₅₀ - 1,750 mg/kg

Action in plant Inhibits photosynthesis.

Site of action Group 5: photosystem II inhibitor

Chemical family Triazine

Koc Average Koc is 300 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 LD₅₀ - >2,000 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 LD₅₀ > 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

Remarks Organic herbicide. Nonselective contact herbicide. A C9 saturated-chain fatty acid.

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

ATRAZINE (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

Remarks A dinitroaniline compound used as preplant, soil-incorporated, selective herbicide. Requires incorporation with or immediately after application to prevent loss of activity. Residual activity at higher rates or in dry regions may be a problem on subsequent crops.

Water solubility 0.1 ppm

Storage conditions Store above 40°F. If frozen, poor weed control may result.

Acute toxicity LD₅₀ - 5,000 mg/kg

Action in plant Inhibits mitosis, both in shoots and in roots.

Site of action Group 3: microtubule assembly inhibitor

Chemical family Dinitroaniline

Koc Average is 10,000 mL/g

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 ACCase inhibitor

Chemical family Organophosphorus

Koc Average is 1,433 to 4,326 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.

Water solubility 500 ppm

Storage conditions Store between 32° and 122°F. Warm to 70°F and agitate until crystals dissolve, or do not use.

Acute toxicity LD₅₀ - 1,860 mg/kg

Action in plant Inhibits photosynthesis.

Site of action Group 6: photosystem II inhibitor

Chemical family Benzothiadiazole

Koc Average is 34 mL/g

BICYCLOPYRONE

Trade name(s) included in a premix of Acuron

Manufacturer(s) Syngenta

Remarks Controls broadleaf weeds in corn.

Acute toxicity LD₅₀ - 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 to 390 mL/g

BISPYRIBAC-SODIUM

Trade name(s) Velocity

Manufacturer(s) Valent

Formulation(s) 80% wettable powder

Remarks For use in turf, such as golf course turfgrass and sod farms. Postemergence herbicide to control annual bluegrass, rough bluegrass, and certain broadleaf weeds in certain grasses.

Water solubility 73,000 ppm

Storage conditions Stable under normal storage conditions.

Acute toxicity LD₅₀ - 2,635 mg/kg

Action in plant Inhibits acetolactate synthase (ALS) enzyme

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

Chemical family Pyrimidinylthiobenzoate

Koc 852 to 1,793 mL/g

BORATES, BORON

Trade name(s) Ureabor, Monobor-Chlorate,

Manufacturer(s) J. R. Simplot Co., Pro-Serve

Formulation(s) Several. Mixed with sodium chlorate and ureas.

Remarks Nonselective broadleaf and grass weed control combinations. Borates are excellent fire retardants. Combinations are excellent for eliminating all vegetation. Some formulations are used before laying asphalt paving.

Water solubility Quite soluble but varies with formulation.

Storage conditions Stable.

Acute toxicity LD₅₀ - 2,000 to 5,560 mg/kg

Action in plant Salt action that disrupts cell membranes.

Site of action Unknown

Chemical family Inorganic

BROMACIL

Trade name(s) Hyvar X, Hyvar X-L

Manufacturer(s) Corteva

Formulation(s) 80% wettable powder, 2 lb/gal water-soluble liquid

Remarks 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.

Water solubility 815 ppm

Storage conditions Stable to 0°F, but water-soluble formulations become less soluble when exposed to air.

Acute toxicity LD₅₀ - 5,200 mg/kg

Action in plant Inhibits photosynthesis.

Site of action Group 5: photosystem II inhibitor

Chemical family Uracil

Koc Average is 32 mL/g

BROMOXNYL

Trade name(s) Buctril, Bromox, Moxy, Broclean, Connect Bromoxnyl

Manufacturer(s) Bayer CropScience and others

Formulation(s) 2 and 4 lb/gal emulsifiable concentrate; 20% water-soluble powder

Remarks 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.

Water solubility 13,000 ppm

Storage conditions Store above 32°F. If frozen, agitate before using.

Acute toxicity LD₅₀ - 160 mg/kg

Action in plant Inhibits photosynthesis.

Site of action Group 6: photosystem II inhibitor

Chemical family Nitrile

Koc Average is 10,000 mL/g (estimated) for the octanoate ester

BUTYLATE

Trade name(s) Sutan, Sutan + (butylate plus safener)

Manufacturer(s) Helm Agro

Formulation(s) 6.7 lb/gal emulsifiable concentrate

Remarks A thiocarbamate compound used as a selective preplant-incorporated herbicide. Because of its volatility, it must be incorporated immediately after application.

Water solubility 45 ppm

Storage conditions Stable at moderate temperatures. If frozen, roll container to mix.

Acute toxicity LD₅₀ - 3,878 mg/kg

Action in plant Inhibits shoot growth.

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

Chemical family Thiocarbamate

Koc Average is 400 mL/g

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 LD₅₀ - 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 broad-leaf weeds.

Water solubility 12 ppm

Storage conditions Stable under normal storage conditions. Store in tightly closed containers.

Acute toxicity LD₅₀ - 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 LD₅₀ - 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 LD₅₀ - 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 Average is 40 mL/g at pH 7

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 LD₅₀ - 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 LD₅₀ - 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 LD₅₀ - 1,369 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

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 LD₅₀ - 4,300 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)

CLOVE LEAF OIL

Trade name(s) Matran EC

Manufacturer(s) EcoSmart

Formulation(s) 50% emulsifiable concentrate

Remarks Organic herbicide. Nonselective contact herbicide.

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 LD₅₀ - 470 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

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.

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 LD₅₀ - 3,160 mg/kg

Action in plant Inhibits shoot growth.

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

Chemical family Thiocarbamate

Koc Average is 600 mL/g

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

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 LD₅₀ - 320 mg/kg

Action in plant Attacks cell membranes.

Site of action Not well understood

Chemical family Dithiocarbamate

Koc Average is 10 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 LD₅₀ - greater than 3,000 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 LD₅₀ - 3,700 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 SGF, 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 LD₅₀ - 1,028 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

DICHLOBENIL

Trade name(s) Casoron, Barrier

Manufacturer(s) Chemtura, PBI/Gordon

Formulation(s) 50% wettable powder, 4% granules, 15.3% liquid

Remarks A nitrile compound used as a preemergent and early postemergent herbicide in noncrop areas and around established trees and shrubs. Dichlobenil is most effective when applied before weeds emerge, during cool weather, and immediately incorporated through irrigation or rain. It has little, if any, effect on foliage.

Water solubility 25 ppm

Storage conditions Store under cool, dry conditions to avoid volatility.

Acute toxicity LD₅₀ - 5,000 mg/kg

Action in plant Inhibits meristematic tissue in growing points of roots and shoots.

Site of action Group 20: inhibits cell wall synthesis Site A

Chemical family Nitrile

Koc Average is 400 mL/g (estimated)

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 LD₅₀ - 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 1,000 mL/g (estimated) for the butoxyethyl ester

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 LD₅₀ - 580 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 Average is 16,000 mL/g for the methyl ester.

DIFENZOQUAT

Trade name(s) Avenge

Manufacturer(s) Amvac

Formulation(s) 2 lb/gal water miscible concentrate

Remarks A selective herbicide to control wild oat. Rain within 6 hours after application reduces effectiveness.

Water solubility 765,000 ppm

Storage conditions Store above 32°F. Ice will form at 15°F; remix at warmer temperatures before use.

Acute toxicity LD₅₀ - 730 mg/kg

Action in plant Action unknown.

Site of action Group 26: unknown

Chemical family Pyrazolium

Koc Average is 54,500 mL/g

DIFLUFENZOPYR

Trade name(s) Mixed with dicamba and sold as Distinct and Overdrive

Manufacturer(s) BASF

Formulation(s) 70% dry flowable with dicamba

Remarks Postemergence, translocated herbicide to control broadleaf weeds.

Water solubility 270 ppm at pH 5; 5,850 ppm at pH 7

Storage conditions Cool, dry conditions.

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

Action in plant Inhibits auxin transport.

Site of action Group 19: inhibits indole acetic acid transport

Chemical family Semicarbazone

Koc Average is 18 to 156 mL/g

DIMETHENAMID, DIMETHENAMID-P

Trade name(s) Frontier, Outlook

Manufacturer(s) BASF

Formulation(s) 6 and 7.5 lb/gal emulsifiable concentrate

Remarks 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.

Water solubility 1,174 ppm

Storage conditions Stable.

Acute toxicity LD₅₀ - 2,400 mg/kg

Action in plant Inhibits plant cell division and growth.

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

Chemical family Chloroacetamide

Koc Average is 125 mL/g

DIQUAT (A MODERATELY TOXIC HERBICIDE THAT REQUIRES PROTECTIVE GEAR FOR HANDLING AND APPLICATION)

Trade name(s) Diquat Herbicide, Reward, Reglone

Manufacturer(s) Syngenta

Formulation(s) 2 lb water-soluble cation/gal (3.73 lb/gal salt). Cation portion of the molecule is the active ingredient.

Remarks 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.

Water solubility 700,000 ppm

Storage conditions Store above 32°F.

Acute toxicity LD₅₀ - 125 mg/kg for mouse.

Action in plant Acts as contact. Absorbs energy produced by photosynthesis; forms peroxides that disrupt living cells.

Site of action Group 22: photosystem I electron diversion

Chemical family Bipyridilium

Koc Average is 1,000,000 mL/g (estimated)

DITHIOPYR

Trade name(s) Dimension EC, Dimension EW, Dimension Ultra 40 WP, Lifeguard

Manufacturer(s) Corteva

Formulation(s) 1 and 2 lb/gal emulsifiable concentrate and 40% wettable powder

Remarks Selective control of many annual grasses and certain annual broadleaf weeds in established cool- and warm-season turfgrasses in lawns and ornamental turf.

Water solubility 0.7 ppm

Storage conditions Store above 32°F.

Acute toxicity LD₅₀ - more than 5,000 mg/kg

Action in plant Interferes with cell division.

Site of action Group 3: microtubule assembly inhibitor

Chemical family Pyridine

Koc Average is 1,638 mL/g

DIURON

Trade name(s) Karmex, Diuron, Direx, Parrot

Manufacturer(s) Corteva, Griffin Corp., Platte Chemical Co., ADAMA

Formulation(s) 80% wettable powder, 80% dry flowable, 4 lb/gal water dispersible liquid

Remarks 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.

Water solubility 42 ppm

Storage conditions Stable at moderate temperatures.

Acute toxicity LD₅₀ - 3,400 mg/kg

Action in plant Inhibits photosynthesis.

Site of action Group 7: photosystem II inhibitor

Chemical family Substituted urea

Koc Average is 480 mL/g

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 None generally recognized

Koc Average is 20 mL/g (estimated) at pH 7. Ranges from 110-138 mL/g at pH 7.8

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

Action in plant Inhibits shoot growth.

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

Chemical family Thiocarbamate

Koc Average is 200 mL/g, but ranges from 170 to 280 mL/g

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. Ethafluralin has little or no foliar activity.

Water solubility 0.3 ppm

Storage conditions Store above 40°F.

Acute toxicity LD₅₀ - greater than 10,000 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, Progress, 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 LD₅₀ - 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 LD₅₀ - 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 LD₅₀ - greater than 6,000 mg/kg

Action in plant Inhibits acetolactate synthase (ALS) enzyme

Site of action Group 2: acetolactate synthase inhibitor

Chemical family Sulfonamide

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 LD₅₀ - 4,350 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 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 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 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 LD₅₀ - 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 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 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 LD₅₀ - 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 LD₅₀ - 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 submersed 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 LD₅₀ - 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 LD₅₀ - greater than 2,000 mg/kg

Action in plant Mimics 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 LD₅₀ - greater than 5,000 mg/kg

Action in plant Inhibits protoporphyrinogen oxidase (PPO) that disrupts cell membranes

Site of action Group 14: protoporphyrinogen oxidase inhibitor

Chemical family Triazinone

FOMESAFEN

Trade name(s) Reflex

Manufacturer(s) Syngenta

Formulation(s) 2 lb sodium salt/gal

Remarks Selective preemergence herbicide primarily for broadleaf weed control.

Water solubility 50 mg/L for acid; 600,000 mg/L for sodium salt

Storage conditions Store above 32°F to prevent freezing

Acute toxicity LD₅₀ - 1,250 to 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 diphenylether

Koc Average is 60 mL/g for the Na salt

FORAMSULFURON

Trade name(s) Option

Manufacturer(s) Bayer CropScience

Formulation(s) 35% water-dispersible granule

Remarks Selective postemergence herbicide to control grasses and some small-seed broadleaf weeds in corn.

Water solubility 3,290 ppm at 68°F (20°C) and pH 7

Storage conditions Stable storage.

Acute toxicity LD₅₀ - greater than 3,881 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

FOSAMINE

Trade name(s) Krenite S

Manufacturer(s) Corteva

Formulation(s) 4 lb/gal soluble concentrate

Remarks A brush-control herbicide applied during the 2 months before fall coloration.

Water solubility 1,790,000 ppm

Storage conditions Stable as formulated or as spray-tank solution.

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

Action in plant Inhibits bud and new leaf formation in spring.

Site of action Group 26: unknown

Chemical family Organophosphorus

Koc Average is 150 mL/g

GLUFOSINATE

Trade name(s) Finale, Ignite, Ignite 280SL, Rely, Liberty, Derringer

Manufacturer(s) Bayer CropScience

Formulation(s) 1 lb, 1.67, and 2.34 lb/gal aqueous solutions

Remarks 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.

Water solubility 1,370,000 ppm

Storage conditions Stable under normal storage conditions. Do not store near heat or open flame.

Acute toxicity LD₅₀ - 1,620 mg/kg

Action in plant Causes ammonium ions to accumulate, disrupting photosynthesis.

Site of action Group 10: glutamine synthase inhibitor

Chemical family Phosphinic acid

Koc Average is 100 mL/g (estimated)

GLYPHOSATE

Trade name(s) 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

Manufacturer(s) Monsanto Co., Corteva, Syngenta, and others

Formulation(s) 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.

Remarks 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.

Water solubility 12,000 ppm

Storage conditions Store between -20° and 120°F.

Acute toxicity LD₅₀ - 5,400 mg/kg

Action in plant Inhibits three amino acids and protein synthesis.

Site of action Group 9: inhibits EPSP synthase

Chemical family None generally accepted

Koc Average is 24,000 mL/g (estimated)

HALAUXIFEN

Trade name(s) Quelex (Component of Quelex along with Florasulam)

Manufacturer(s) Corteva

Formulation(s) premix ingredient with florasulam (Quelex)e

Remarks A selective herbicide for controlling broadleaf weeds

Storage conditions 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.

Acute toxicity LD₅₀ - > 5,000 mg/kg - rat

Action in plant 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.

Site of action Group 4: synthetic auxin

Chemical family Arylpicolinate

Koc 473 to 2659 ml/g (average = 1418 ml/g)

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 LD₅₀ - 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 93.5 mL/g for a Drummer silty clay loam; **Koc** 113.7 mL/g for Sarpy soil; **Koc** 199.2 mL/g for a Sable soil; **Koc** 31.1 mL/g for a Spinks soil

HEXAZINONE

Trade name(s) Velpar, Velpar DF, Velpar L, 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 LD₅₀ - 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 LD₅₀ - 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 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 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 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 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 LD₅₀ - 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 LD₅₀ - 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

Koc Average is 20 mL/g (estimated) at pH 7, but varies with pH

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 LD₅₀ - 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

INDAZIFLAM

Trade name(s) Alion, Spect(i)cle

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 LD₅₀ (rat) >2000 mg/kg

Action in plant Inhibition of cellulose biosynthesis

Site of action Group 29

Chemical family Alkylazine

Koc 1000 mL/g

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 LD₅₀ - 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

Koc 10-90 mL/g

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 LD₅₀ - 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

Koc 190 to 570 mL/g

LACTOFEN

Trade name(s) Cobra, Phoenix

Manufacturer(s) Valent

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 LD₅₀ - 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

Koc Average is 10,000 mL/g (estimated)

LEMONGRASS OIL

Trade name(s) GreenMatch EX

Manufacturer(s) Marrone Organic

Formulation(s) 50% emulsifiable concentrate

Remarks Organic herbicide. Nonselective contact herbicide.

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

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 LD₅₀ - 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

Trade name(s) Many

Manufacturer(s) Albaugh, Loveland Products

Formulation(s) 2 and 4 lb/gal soluble and emulsifiable concentrates formulated as amine salts, sodium salts, and esters.

Remarks A postemergence, selective, translocated phenoxy herbicide. Material is less phytotoxic to some crops.

Water solubility 825 ppm

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

Acute toxicity LD₅₀ - 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

MCPB

Trade name(s) Thistrol, Can-Trol

Manufacturer(s) Nufarm

Formulation(s) 2 lb/gal soluble concentrate

Remarks A phenoxy compound used as a selective herbicide applied postemergence. Material is beta-oxidized to MCPA by susceptible plants.

Water solubility 44 ppm

Storage conditions Store above 32°F. If frozen, warm for several days and mix.

Acute toxicity LD₅₀ - 700 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 (estimated) at pH 7 for the Na salt

MECOPROP, MCPP

Trade name(s) Mecopar, Mecopex Turf Herbicide, MCPP, Mecomec 4

Manufacturer(s) PBI/Gordon

Formulation(s) 2, 2.5, and 4 lb/gal soluble concentrates, available as amine and potassium salts

Remarks A phenoxy compound used as a selective herbicide applied postemergence. Safer on bentgrass lawns and greens than other phenoxy compounds.

Water solubility 620 ppm

Storage conditions Stable at moderate temperatures and redissolves, if frozen.

Acute toxicity LD₅₀ - 650 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 (estimated) at pH 7

MESOSULFURON

Trade name(s) Osprey

Manufacturer(s) Bayer

Formulation(s) 4.5% water-dispersible granule

Remarks Postemergence herbicide used primarily to control annual grasses and some broadleaf weeds in winter wheat.

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

Storage conditions Protect from extreme heat and cold

Acute toxicity LD₅₀ - 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

Trade name(s) Callisto, Broadworks

Manufacturer(s) Syngenta

Formulation(s) 4 lb/gal suspension concentrate

Remarks Mesotrione is a synthetic relative of natural herbicides produced by the plant *Callistemon citrinus*. Controls broadleaf weeds in corn.

Water solubility 15,000 ppm

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

Acute toxicity LD₅₀ - 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

Trade name(s) Vapam, Sectagon

Manufacturer(s) AMVAC, Tessengerlo Kerley Inc. (NovaSource)

Formulation(s) Soluble concentrate

Remarks Temporary soil fumigant as a preplant treatment. Controls weeds, most weed seeds, certain microorganisms, and

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 LD₅₀ - 285 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 LD₅₀ - 1 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

METOLACHLOR, 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 LD₅₀ - 2,150 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 LD₅₀ - 4,000 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;

Koc 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 LD₅₀ - greater than 5,000 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 LD₅₀ - 3,900 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 LD₅₀ - 1,359 mg/kg

Action in plant Unknown

Site of action Group 17: not well understood

Chemical family Organoarsenical

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 LD₅₀ - 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

NAPTALAM

Trade name(s)

Manufacturer(s) Chemtura

Formulation(s) 2 lb/gal soluble concentrate

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 LD₅₀ - 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 Phthalamate

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 LD₅₀ - 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, Solicam, 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 LD₅₀ - 10,000 mg/kg

Action in plant Inhibits carotene formation, resulting in photo-degradation 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 LD₅₀ - 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 LD₅₀ - 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 LD₅₀ - 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 32°F.

Acute toxicity LD₅₀ - 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 LD₅₀ - 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 LD₅₀ - 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 pH5, 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 1: 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 Sulfonylurea

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 LD₅₀ - 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 LD₅₀ - 2,276 mg/kg
Action in plant Inhibits photosynthesis.
Site of action Group 5: photosystem II inhibitor
Chemical family Triazine
Koc 51 mL/g for a silty clay loam with 2.5% OM and pH 6.6

PROMETRYN

Trade name(s) Caparol, Prometryne, 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 LD₅₀ - 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 LD₅₀ - 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

PROPOXYCARBAZONE

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 LD₅₀ - 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 Sulfonylaminocarbonyltriaolinone

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 LD₅₀ - 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

Water solubility 1.5 ppm
Storage conditions Store in freeze-free, dry area.
Acute toxicity LD₅₀ - 4,600 mg/kg
Action in plant Blocks photosynthesis.
Site of action Group 6: photosystem II inhibitor
Chemical family Phenyl-pyridazine

PYRAFLUFEN

Trade name(s) ET, Venue
Manufacturer(s) Nichino America
Formulation(s) 0.177 and 0.208 lb/gal emulsifiable concentrate
Remarks A fast-acting postemergence contact herbicide.
Water solubility 82 ppb
Storage conditions Store in a cool place.
Acute toxicity LD₅₀ - 3,712 mg/kg
Action in plant Inhibits protoporphyrinogen oxidase (PPO) that disrupts cell membranes.
Site of action Group 14: protoporphyrinogen oxidase inhibitor
Chemical family Phenylpyrazole
Koc 1480 to 2700 mL/g

PYRASULFOTOLE

Trade name(s) Huskie (also contains bromoxynil)
Manufacturer(s) Bayer Crop Science
Formulation(s) 2.08 lb/gal emulsifiable concentrate with bromoxynil.
Remarks Controls broadleaf weeds in wheat, barley, and triticale. This formulation has a built-in safener to enhance crop safety.
Water solubility 69,100 ppm
Acute toxicity LD₅₀ - more than 2,000mg/kg
Action in plant Inhibits the HPPD enzyme, resulting in bleached plants.
Site of action Group 27: inhibits 4-hydroxyphenylpyruvate-dioxygenase (4-HPPD)
Chemical family Isoxazole

PYROXASULFONE

Trade name(s) Zidua (also a pre-mix partner with flumioxazin in Fierce; pre-mix partner with carfentrazone in Anthem Flex)
Manufacturer(s) K-I Chemical USA
Formulation(s) 85% water dispersible granule
Remarks A selective preemergence herbicide with soil residual activity for control of Italian ryegrass, and other grass and small-seeded broadleaf weeds.
Water solubility 3.49 ppm
Storage conditions Store in a cool, dry place.
Acute toxicity LD₅₀ - >2,000 mg/kg (rat).
Action in plant Inhibits roots and shoots.
Site of action Group 15: mitosis inhibitor
Chemical family Pyrazole
Koc 57 to 114 ml/g

PYROXSULAM

Trade name(s) PowerFlex HL or TeamMate
Manufacturer(s) Corteva
Formulation(s) 7.5% water soluble granule (0.075 lb ai/lb)
Remarks Postemergence annual grass and broadleaf herbicide for weed control in cereals
Water solubility 16.4 ppm at pH 4; 3,200 ppm at pH 7; 13,700 ppm at pH 9
Storage conditions Dry, well ventilated area
Acute toxicity LD₅₀ - greater than 2,000 mg/kg
Action in plant Interferes with an enzyme, resulting in inhibiting cell division
Site of action Group 2: acetolactate synthase (ALS) inhibitor
Chemical family Triazolopyrimidine sulfonamide

QUINCLORAC

Trade name(s) Paramount, Drive, Drive XLR8, Ryzon
Manufacturer(s) BASF, ADAMA
Formulation(s) 75% dry flowable, 1.5 lb/gal, and 1.5% granules
Remarks Applied postemergence to actively growing weeds. Controls field bindweed and other selected weeds.
Water solubility 62 ppm
Storage conditions Store under dry conditions.
Acute toxicity LD₅₀ - 2,610 mg/kg
Action in plant Not fully understood. In broadleaves, similar to indole acetic acid. In grasses, inhibits cell wall synthesis.
Site of action Group 4: synthetic auxin
Chemical family Quinoline carboxylic acid

QUIZALOFOP

Trade name(s) Assure II, Targa
Manufacturer(s) Corteva
Formulation(s) 0.88 lb/gal emulsifiable concentrate
Remarks 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.
Water solubility 0.3 ppm at 68°F
Storage conditions Do not store below 32°F.
Acute toxicity LD₅₀ - 5,700 mg/kg
Action in plant Inhibits an enzyme (ACCCase) that catalyzes the first step in fatty acid synthesis. This blocks production of new membranes required for cell growth.
Site of action Group 1: acetyl CoA carboxylase (ACCCase) inhibitor
Chemical family Aryloxyphenoxy propionate
Koc Average is 510 mL/g for quizalofop ethyl ester

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 LD₅₀ - 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 LD₅₀ - 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

Storage conditions Store between -4°F and 86°F in sealed containers.

Acute toxicity LD₅₀ - 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 LD₅₀ - 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 LD₅₀ - 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 LD₅₀ - 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 LD₅₀ - 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 LD₅₀ - 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 at pH 7 for Sulfometuron-methyl

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 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

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 LD₅₀ - 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 LD₅₀ - 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 LD₅₀ - 5,000 mg/kg

Action in plant Inhibits photosynthesis.

Site of action Group 5: photosystem II inhibitor

Chemical family Uracil

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 pH4; 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 Sulfonylaminocarbonyltriazolinone

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

Storage conditions Stable.

Acute toxicity LD₅₀ - 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 45 mL/g at pH 7

TOLPYRALTE

Trade name(s) Shieldex

Manufacturer(s) ISK

Formulation(s) 3.33 lb/gal suspension concentrate

Remarks Tolpyralate 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

Storage conditions Store in a cool, dry place. If below freezing, agitate or mix contents of container well before use.

Acute toxicity LD₅₀ - greater than mg/kg

Action in plant Inhibits 4-HPPD enzymes.

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

Chemical family Triketone

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

Storage conditions Store in a cool, dry place. If below freezing, agitate or mix contents of container well before use.

Acute toxicity LD₅₀ - 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 Triketone

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

Storage conditions Store in tightly sealed container.

Acute toxicity LD₅₀ - 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

TRIALATE

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 preemergence and incorporated. May irritate skin and eyes. Buckle is triallate + trifluralin.

Water solubility 4 ppm

Storage conditions Stable.

Acute toxicity LD₅₀ - 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 LD₅₀ - 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 LD₅₀ - 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 LD₅₀ - 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 LD₅₀ - 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 LD₅₀ - 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	imazapyr
2,4-DB	MCPA
benefin	MCPB
bromacil	MCPB
bromoxynil	MCPB
carfentrazone	mesosulfuron
chlorsulfuron	metribuzin
clopyralid	metsulfuron
copper sulfate	MSMA
DCPA	nicosulfuron
dicamba	phenmedipham
dichlobenil	primisulfuron
dichlorpropene	prometon
diflufenzopyr	prosulfuron
diquat	rimsulfuron
diuron	simazine
ethametsulfuron	S-metolachlor
fenoxaprop	sodium chlorate
fluazifop	sodium metaborate
flufenacet	sulfometuron-methyl
fluroxypyr	sulfosulfuron
fluthiacet-methyl	tebuthiuron
glyphosate	thiencarbazone-methyl
halosulfuron	thifensulfuron
hexazinone	triasulfuron
iodosulfuron	tribenuron
imazamox	triclopyr
imazapic	trifluralin
	triflusulfuron

Testing for and Deactivating Herbicide Residues

Ed Peachey

Revised March 2020

Residues of triazine herbicides (such as atrazine and simazine), substituted urea herbicides (such as linuron and diuron), clopyralid, 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—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 by 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 triazine 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-thenamid-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.

The efficiency of deactivation depends on the soil's organic matter content and physical condition, the herbicide's activity, and the crop's sensitivity. This treatment will work for some herbicides better than others.

If an area is contaminated with undesirable herbicide residues and a susceptible crop is to be planted, apply activated carbon at 200 lb/a (approximately 5 lb/1,000 sq ft) for each 1 lb ai/a of actual residue detected in the soil. A rule of thumb is that in a soil sample from 0 to 6 inches, a 1 ppm test result would be equivalent to 2 lb active ingredient (ai) of the herbicide/acre or 0.046 lb ai/1,000 sq ft.

The carbon can be mixed at the rate of 1 lb carbon to 10 lb sand and applied with fertilizer-spreading equipment, or sprayed using large-capacity nozzles (0.5 gal/minute or larger). Carbon wets and suspends poorly. Local commercial applicators are available in some areas such as the Willamette Valley of Oregon. Otherwise, a grower can add the carbon to a partially filled spray tank and use the remaining water to help mix the floating carbon while the agitator is operating. Incorporate activated charcoal to 6 inches deep in the soil, then irrigate and let set for several days before planting. A bioassay is recommended to confirm effectiveness.

Reference: H. J. Hopen, *Horticulture Facts*, VC-15-81, Cooperative Extension Service, University of Illinois, Urbana-Champaign, IL 61801.

Managing Herbicide-Resistant Weeds¹

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*.

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.

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>

The table below lists herbicides by group number and site of action, chemical family, common name, and trade name. It also gives examples of resistant weeds. Herbicide families that have the same site of action have the same group number.

A herbicide program to prevent resistance does not use herbicides from the same group more than once in 3 years.

Tank mixing herbicides is not always an effective resistance management strategy. If herbicides in the tank-mixture control different weed species and have different soil residual characteristics, resistant weed biotypes will continue to be selected. For example, if a long-residual (Glean) or a short-residual (2,4-D) herbicide are tank mixed, both herbicides may control emerged broadleaf weeds. However, Glean will continue to control weeds throughout the growing season and could continue to select for resistant plants. Tank mix only when a herbicide combination is required to control the weed spectrum or will reduce herbicide use rates. Tank mixing for other reasons is not economically or ecologically sound.

Management can prevent or delay the appearance of herbicide-resistant weeds. The following practices can be used with the information on herbicide families provided in the table to form a herbicide resistance management strategy.

Preventing herbicide-resistant weeds

Herbicide rotation Avoid year-after-year use of herbicides that have the same site of action. At one time this meant not using herbicides from the same chemical family, but this is no longer the case. For example, two chemically different groups of herbicides, the sulfonylureas and imidazolinones, have the same site of action. For another example, Discover and Poast belong to different chemical families but kill susceptible grasses in the same way.

Short-residual herbicides Using herbicides that do not persist in soil for long periods and are not applied repeatedly within a growing season reduces the selection of herbicide-resistant weeds. However, repeated applications within a growing season of a herbicide with no soil activity (e.g., Gramoxone) has resulted in weeds resistant to the herbicide.

Crop rotation Because different crops may require different herbicides, rotating crops can increase herbicide rotation. But with the large number of sulfonylurea and imidazolinone herbicides available for use in many different crops, crop rotation alone may not be enough to avoid weed resistance to herbicides. This also is true for other herbicides with the same site of action.

Cultivation In row crops, cultivation can be an effective tool for eliminating weed escapes that may represent the resistant population. Fallow tillage controls herbicide-resistant and herbicide-susceptible weeds equally as long as seedlings of the two biotypes emerge at the same time. Do not use the same site-of-action herbicide in fallow as was used to control weeds in the crop.

Accurate record keeping To have an effective herbicide rotation or tank-mix system to prevent resistance, you must know which herbicides have been used in the past, at what rate, and how often.

Clean seed Plant certified seed to prevent introducing herbicide-resistant weed seeds.

Integrated weed management This concept is important for all weed control, not just management of herbicide-resistant weeds. Integrated weed management uses all the tools available to control weeds, including cultural, mechanical, and chemical methods. An integrated approach to weed management, whether it is in crop or non-crop land, is an important environmental and economic consideration.

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 in the same field with the same herbicide, or a herbicide with the same site of action.
- Records show repeated use of one herbicide or of herbicides with the same site of action.

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.

Group Number and Site of Action ¹	Chemical Family	Common Name	Trade Name(s)	Resistant Weeds in the PNW	States with Resistant Weeds
Group 1					
Acetyl CoA carboxylase (ACCase) inhibitors	cyclohexanediones	clethodim	Select Max, Envoy, several others	Italian ryegrass	ID, OR
		sethoxydim	Poast, several others	Italian ryegrass	ID, OR
		tralkoxydim	Achieve	Italian ryegrass	ID
	aryloxyphenoxy propionates	clodinafop	Discover NG	Italian ryegrass	ID, OR
				wild oat	ID
		diclofop	Hoelon	wild oat	ID, OR, WA
				Italian ryegrass	ID, OR, WA
		fenoxaprop	Puma, Acclaim	wild oat	ID, OR
		fluazifop	Fusilade DX	downy brome	OR
	quizalofop	Assure II, Targa	Italian ryegrass	ID	
phenylpyrazoline	pinoxaden	Axial	Italian ryegrass	OR	
Group 2					
Acetolactate synthase (ALS) inhibitors	imidazolinones	*imazamox	Raptor, Beyond, Clearmax (Beyond + MCPA), Clearcast	downy brome	OR
				spiny sowthistle	WA
		*imazapic	Plateau, Oasis		
		*imazapyr	Arsenal, Chopper, several others		
		*imazethapyr	Pursuit	prickly lettuce	ID
				kochia	ID
				spiny sowthistle	ID
				black mustard	ID
		mayweed chamomile	ID		

¹ Herbicide classification according to primary site of action.

* Can persist in soil most of the growing season or from one growing season to the next.

Group Number and Site of Action ¹	Chemical Family	Common Name	Trade Name(s)	Resistant Weeds in the PNW	States with Resistant Weeds
Group 2 (continued)					
Acetolactate synthase (ALS) inhibitors (continued)	sulfonyleureas	*chlorsulfuron	Glean, Telar	prickly lettuce	ID, OR, WA
				kochia	ID, OR, WA
				Russian thistle	ID, OR, WA
				Italian ryegrass	OR
				mayweed chamomile	ID, WA
				smallseed falseflax	OR
		*chlorsulfuron + metsulfuron	Finesse	smallseed falseflax	OR
		*halosulfuron	Sandea		
		mesosulfuron	Osprey	Italian ryegrass	ID
		mesosulfuron + propoxycarbazone	Olympus Flex		
		*metsulfuron	Ally, Escort, Cimarron	prickly lettuce	ID, OR
				kochia	OR
				Russian thistle	OR
				smallseed falseflax	OR
		*nicosulfuron	Accent		
		*primisulfuron	Beacon	downy brome	OR
		*prosulfuron	Peak		
		*rimsulfuron	Matrix		
		*sulfometuron	Oust, Spyder	Italian ryegrass	OR
		*sulfosulfuron	Maverick, Outrider, Certainty	downy brome	OR
		thifensulfuron	Harmony	spiny sowthistle	WA
				prickly lettuce	ID
				mayweed chamomile	ID
		thifensulfuron + tribenuron	Harmony Extra, Affinity		
		*thifensulfuron + tribenuron + metsulfuron	Canvas		
		*triasulfuron	Amber	prickly lettuce	ID, OR
				kochia	OR
Russian thistle	OR				
Italian ryegrass	ID				
tribenuron	Express	prickly lettuce	ID		
		mayweed chamomile	ID		
*triflusulfuron	UpBeet				
sulfonylaminocarbonyl-triazolinones	flucarbazone	Everest	Italian ryegrass	ID, WA	
		propoxycarbazone	Olympus		
triazolopyrimidines	florasulam	Orion (contains MCPA); Goldsky			

¹ Herbicide classification according to primary site of action.

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Group Number and Site of Action ¹	Chemical Family	Common Name	Trade Name(s)	Resistant Weeds in the PNW	States with Resistant Weeds
Group 3					
Microtubule assembly inhibitors	dinitroanilines	benefin	Balan		
		*ethalfluralin	Sonalan, Curbit		
		*oryzalin	Surflan		
		*pendimethalin	Prowl H2O, Pendulum, several others		
		*prodiamine	Barricade, Endurance, several others		
		*trifluralin	Treflan, Trust		
	benzamides	*pronamide	Kerb	wild oat	OR
Group 4					
Synthetic auxins	phenoxy acetic acids	2,4-D	several	prickly lettuce	WA
		2,4-DB	several		
		MCP	several	prickly lettuce	WA
		mecoprop (MCP)	several		
	benzoic acids	*dicamba	Banvel, Clarity, several others	kochia	ID, WA
	pyridines	*aminopyralid	Milestone		
		*clopyralid	Stinger, Transline, Clopyr Ag		
		*fluroxypyr	Starane, Vista, Spotlight		
		*picloram	Tordon K, Tordon 22K	yellow starthistle	WA
		*triclopyr	Garlon, Remedy, Renovate, several others		
	quinoline carboxylic acids	*quinclorac	Paramount, Drive		
Group 5					
Photosystem II inhibitors	triazines	*atrazine	AAtrex, Atrazine	common lambsquarters	ID, OR, WA
				pigweed spp.	ID
				common groundsel	OR, WA
				annual bluegrass	OR
				kochia	ID
				Italian ryegrass	OR
	*simazine	Princep, Simazine	common groundsel	WA	
	as-triazines	*hexazinone	Velpar, others	shepherd's purse Italian ryegrass	OR
		*metribuzin	Sencor, Metri DF	Italian ryegrass	OR
	uracils	*bromacil	Hyvar X, Hyvar X-L		
	*terbacil	Sinbar	common groundsel	OR	
			pigweed spp.	OR, WA	
			common lambsquarters	OR, WA	
Group 6					

¹ Herbicide classification according to primary site of action.

* Can persist in soil most of the growing season or from one growing season to the next.

Group Number and Site of Action ¹	Chemical Family	Common Name	Trade Name(s)	Resistant Weeds in the PNW	States with Resistant Weeds
Photosystem II inhibitors (same site as groups 5 and 7 but different binding behavior)	benzothiadiazoles	bentazon	Basagran		
	nitriles	bromoxynil	Buctril, Bromox, Bronate (contains MCPA), several others	common groundsel	OR
Group 7					
Photosystem II inhibitors (same site as groups 5 and 6 but different binding behavior)	ureas	*diuron	Karmex, Direx	annual bluegrass	OR
		*linuron	Lorox, Linex	common lambsquarters	OR
		*tebuthiuron	Spike		
Group 8					
Lipid synthesis inhibitors but not ACCase inhibitors	thiocarbamates	butylate	Sutan, Sutan + (contains safener)		
		cycloate	Ro-Neet		
		EPTC	Eptam		
		EPTC + safener	Eradicane		
		triallate	Far-Go	wild oat	ID
Group 9					
EPSP synthase inhibitors	glycines	glyphosate	Roundup, several others	Italian ryegrass	OR
				kochia	ID, OR
Group 10					
Glutamine synthase inhibitors	phosphinic acids	glufosinate	Rely, Liberty, Ignite, several others	Italian ryegrass	OR, WA
Group 14					
Inhibitors of protoporphyrinogen oxidase (Protox)	diphenylethers	*oxyfluorfen	Goal, several others		
	N-phenylphthalimides	flumiclorac	Resource		
		*flumioxazin	Chateau, Valor, SureGuard		
	triazinones	carfentrazone	Aim, several others		
		*sulfentrazone	Spartan, Portfolio		
phenylpyrazole	pyraflufen	ET, Edict			
Group 15					
Inhibitors of very long chain fatty acid synthesis	chloroacetamides	acetochlor	Harness, Surpass, several others		
		alachlor	MicroTech, others		
		dimethenamid-P	Outlook		
		metolachlor	Stalwart, others		
		S-metolachlor	Dual Magnum, Dual II Magnum		
	oxyacetamides	flufenacet	Define, Axiom (contains metribuzin)	Italian ryegrass	ID, OR, WA
	acetamides	napropamide	Devrinol		
Group 16					

¹ Herbicide classification according to primary site of action.

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Group Number and Site of Action ¹	Chemical Family	Common Name	Trade Name(s)	Resistant Weeds in the PNW	States with Resistant Weeds
Unknown	benzofurans	ethofumesate	Nortron, several others	annual bluegrass	OR
Group 17					
Unknown	organoarsenicals	MSMA	several		
Group 20					
Inhibitors of cell wall synthesis Site A	nitriles	*dichlobenil	Casoron, Barrier		
Group 22					
Photosystem I electron diverters	bipyridiliums	diquat	Reglone, Reward		
		paraquat	Gramoxone Inteon, Firestorm, several others		
Group 26					
Unknown	pyrazoliums	difenzoquat	Avenge	wild oat	ID
	carboxylic acids	pelargonic acid	Scythe		
Group 27					
Inhibitors of 4-hydroxy-phenyl-pyruvated-dioxygenase (4-HPPD)	isoxazoles	pyrasulfotole	Huskie (contains bromoxynil)		
	triketones	mesotrione	Callisto		
		topramezone	Impact		

¹ Herbicide classification according to primary site of action.

* Can persist in soil most of the growing season or from one growing season to the next.

Cleaning Spraytanks

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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 through 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 through 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.

Herbicide	Cleaning Agents ¹ (consult labels for specific directions)			
	Detergent ²	Household ammonia (3% active)	Approved cleaning agent	Commercial tank cleaner
Aim, Aim EC		3%		
Accent		1%	✓	
Accent Gold		1%	✓	
Alion				✓
Ally		1%	✓	
Amber		1/2%	✓	
Assure II		1%	✓	
Atrazine	✓ ^R			
Axiom	✓ ^R			
Banvel		4%		
Basagran	✓ ^R			
Basis Gold		1%		
Beacon		2%		
Beyond	✓			
Blazer	✓ ^R			
Broadstrike	✓ ^R			
Bronate	✓ ^R			
Buctril	✓			
Cadet		✓		✓
Callisto		4%		
Canopy, Canopy XL		1%	✓	
Capreno			4-8% bleach	

Herbicide	Cleaning Agents ¹ (consult labels for specific directions)			
	Detergent ²	Household ammonia (3% active)	Approved cleaning agent	Commercial tank cleaner
Chateau		1%	✓	
Clarity	✓ ^R			✓
Classic		1%	✓	
CleanTraxx		1%		
Cobra	✓			
Command	✓			
Crossbow	✓			
Curtail, Curtail M		1%		
Dual (Magnum,II)	✓			
Eptam/Eradicane	✓			
Escort		1%		
Everest		1%		
Express		1%	✓	
Fallow Master		4%		
Finesse		1%	✓	
Fusilade	✓			
Fusion				✓
Glean		1%		
Goal/Galigan			✓	
Harmony Extra		1%	✓	
Harness	✓			
Hoelon	✓			
Hornet		✓		✓
Impact	✓ ^R			✓
Karmex/Direx	✓			
Kerb	✓			
Laddok	✓ ^R			✓
Landmaster BW		4%		
Laudis			4% bleach	
Liberty				✓
Marksman	✓ ^R			✓
Maverick		✓		
Matrix		1%		
MCPA amine		1%		
MCPA ester	1% kerosene or diesel followed by 1% household ammonia			
MicroTech	✓			
Milestone		4%		
Mission		1%		
Nortron	✓			
Olympus (/flex)		✓ ^R		
Opensight		4%		
Option II		1%		

Herbicide	Cleaning Agents ¹ (consult labels for specific directions)			
	Detergent ²	Household ammonia (3% active)	Approved cleaning agent	Commercial tank cleaner
Osprey		1%		
Oust (XP/Extra)		1%		✓
Outlook	✓ ^R			✓
Paramount	✓ ^R			✓
Peak		2%		
Permit		1%		
Perspective		1%		
Poast, Poast Plus	✓ ^R			✓
PowerFlex		1%		
Prowl (EC/H ₂ O)	✓ ^R			✓
Pursuit(and Plus)	✓			
Pyramin	✓ ^R			✓
Python	✓			
Quinstar	✓ ^R			
Raptor	✓			
Reflex				✓
Rely	✓			
Remedy	✓ ^R			
Resolve		1%	✓	
Roundup Ultra	✓			
Sandea		1%		
Scepter	✓			
Select	✓			
Shieldex		1%		
Sinbar	✓			
Spartan	✓ ^R	1%		
Spirit		2%		
Starane	✓ ^R			
Streamline		1%		
Stinger		1%		
SureGuard		1%	✓	
Tordon		1%		
Touchdown				✓
Treflan	✓ ^R			
Upbeet		1%		
Valor		✓		
Zeus	✓ ^R	1%		
2,4-D amine		1%		
2,4-D ester	1% kerosene or diesel followed by 1% household ammonia			

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.