SECTION B.

AGRICHEMICALS AND THEIR PROPERTIES

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

The Acute toxicity 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 organic matter (OM) in a soil. Values less than 300 indicate high potential for leaching. This value is often an average of several soil types with varying levels of OM and, therefore, should be used with the understanding that the actual values could be plus or minus twice the listed value for a particular soil.

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

2,4-D

Trade name(s) *Many*

Manufacturer(s) *Corteva, Helena, Nufarm, and others*

Formulation(s) *Numerous acids, salts (amines usually), and esters. Sold as liquids, water-soluble powders, dusts (seldom used due to drift hazard), granules, and pellets.*

Remarks *A selective, foliar-absorbed, translocated phenoxy herbicide used mainly in postemergence applications. 2,4-D is effective against many annual and perennial broadleaf weeds. Ester formulations are the most volatile, the amines least volatile. Plants are most susceptible when they are young and growing rapidly.*

Water solubility *900 ppm*

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

Acute toxicity *LD_{50} - 300 to 1,000 mg/kg*

Action in plant *Mimics natural plant hormones.*

Site of action *Group 4: synthetic auxin*

Chemical family *Phenoxy acetic acid*

Koc *Average is 20 mL/g for the acid and DMA salt, and 100 mL/g (estimated) for esters of the oil-soluble amine*

2,4-DB

Trade name(s) *Butyrac, 2,4-DB 200*

Manufacturer(s) *Albaugh, Drexel, Winfield,*

Formulation(s) *1.75 and 2 lb/gal emulsifiable and soluble concentrates, formulated as amine salts and esters, and 75% water-soluble powders.*

Remarks *A phenoxy compound used as a selective, postemergence, translocated herbicide, particularly for broadleaf weed control in legumes. Material is beta-oxidized to 2,4-D very slowly by most legumes and rapidly by broadleaf weeds. Selectivity decreases with maturity*

of the legumes.

Water solubility *40 ppm*

Storage conditions *Read each product label.*

Acute toxicity *LD_{50} - 1,960 mg/kg*

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, Cadence, Surpass*

Manufacturer(s) *Bayer CropScience, Corteva, Loveland*

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

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

Water solubility *223 ppm*

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

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

Action in plant *Disrupts protein synthesis.*

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

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) *Acifluorfen 2*

Manufacturer(s) *Red Eagle International*

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

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

Water solubility *250,000 ppm*

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

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

Action in plant *Acts as a selective contact that disrupts chlorophyll biosynthesis leading to leaky membranes which dry and disintegrate*

quickly.

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, Acrocide H*

Manufacturer(s) *Baker Petrolite, Multi Chem Group*

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

Action in plant *Inhibits photosynthesis at photosystem II Site A.*

Site of action *Group 5: photosystem II inhibitor*

Chemical family *Triazine*

Koc *Average is 300 mL/g*

AMICARBAZONE

Trade name(s) *Xonerate , Xonerate 2SC*

Manufacturer(s) *UPL, FMC*

Formulation(s) *70% water dispersible granule, 2 lb/gal*

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 *LD_{50} - >2,000 mg/kg (male rat); 1105 mg/kg (female rat)*

Action in plant *Inhibits photosynthesis at photosystem II Site A.*

Site of action *Group 5: photosystem II inhibitor*

Chemical family *Triazolinone*

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

AMINOCYCLOPYRACHLOR

Trade name(s) *Aptexor, Method*

Manufacturer(s) *Bayer, DuPont*

Formulation(s) *10%, 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 *LD_{50} - more than 5,000 mg/kg*

Action in plant *Mimics natural plant hormones.*

Site of action *Group 4: synthetic auxin*

Chemical family *6-Chloropicolinates*

Koc *Average is 10.8 mL/g*

AMMONIUM NONANOATE

Trade name(s) *Axxe, Mirimichi Green, Suerte*

Manufacturer(s) *BioSafe Systems, Mirimichi, Sipcam Agro*

Formulation(s) *3.3 lb ai/gal*

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

ASULAM

Trade name(s) *Addax, Asulox, Asulox XP*

Manufacturer(s) *Atticus, Loveland, UPL, Bayer CropScience*

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 *LD_{50} - 8,000 mg/kg*

Action in plant *Inhibits cell division and expansion probably at the mitosis stage.*

Site of action *Group 18: dihydropteroate (DHP) synthase inhibitor*

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 and others*

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 *LD_{50} - 5,100 mg/kg*

Action in plant *Inhibits photosynthesis at photosystem II Site A.*

Site of action *Group 5: photosystem II inhibitor*

Chemical family *Triazine*

Koc *Average is 100 mL/g*

BENEFIN

Trade name(s) *Anderson's Pro Turf, Balan*

Manufacturer(s) *Andersons, Loveland Products*

Formulation(s) *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) *Gordan's Pro, Prefar*

Manufacturer(s) *Gowan Co., PBI/Gordon*

Formulation(s) *4 lb/gal emulsifiable concentrate, 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 *LD_{50} - 770 mg/kg*

Action in plant *Inhibits roots of seedlings.*

Site of action *Group 0: unknown*

Chemical family *Organophosphorus*

Koc *Average is 1,433 to 4,326 mL/g*

BENTAZON

Trade name(s) *Basagran, BasagranT/O, Broadloom and others*

Manufacturer(s) *BASF, UPL, 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 at photosystem II Site B.*

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 and Talinor*

Manufacturer(s) *Syngenta*

Remarks *Controls broadleaf weeds in corn.*

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

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

Site of action *Group 27: 4-hydroxyphenylpyruvatedioxygenase (4-HPPD) inhibitor*

Chemical family *Triketone*

Koc *14 to 390 mL/g*

BISPYRIBAC-SODIUM

Trade name(s) *Tradewind*

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 *LD_{50} - 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 *LD_{50} - 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) *Bromacil 80, Hyvar X, Hyvar X-IVM and others*

Manufacturer(s) *Alligare, Bayer, Corteva*

Formulation(s) *80% wettable powder, 2 lb/gal water-soluble liquid, 1.5% and 3% water EC, 4% granular*

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 *LD_{50} - 5,200 mg/kg*

Action in plant *Inhibits photosynthesis at photosystem II Site A.*

Site of action *Group 5: photosystem II inhibitor*

Chemical family *Uracil*

Koc *Average is 32 mL/g*

BROMOXYNIL

Trade name(s) *Broclean, Brox, Maestro, Moxy*

Manufacturer(s) *Loveland, Winfield United and others*

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

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 *LD_{50} - 160 mg/kg*

Action in plant *Inhibits photosynthesis at photosystem II Site B. also characterized as a uncoupler.*

Site of action *Group 6: photosystem II inhibitor; Group 24: Uncouplers*

Chemical family *Nitrile*

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

Koc *Average is 400 mL/g*

CARFENTRAZONE

Trade name(s) *Aim, QuickSilver, Shark, Stingray and others*

Manufacturer(s) *FMC Corp., Nufarm*

Formulation(s) *1.9 and 2 lb/gal emulsifiable concentrates*

Remarks *Postemergent, contact herbicide for controlling broadleaf weeds.*

Water solubility *12 ppm*

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

Acute toxicity *LD_{50} - 5,140 mg/kg*

Action in plant *Disrupts cell membranes.*

Site of action *Group 14: protoporphyrinogen oxidase inhibitor*

Chemical family *Triazinone*

Koc *750 mL/g (25 C) for carfentrazone-ethyl*

CHLORIMURON

Trade name(s) *Curio, Chlorimuron*

Manufacturer(s) *Nufarm, Redeagle International, Sharda*

Formulation(s) *25% dispersible granules*

Remarks *Control of buttercup in cranberries*

Water solubility *11 ppm at pH 5; 450 at pH 6.5*

Storage conditions *Store in original container in cool dry place.*

Acute toxicity *LD_{50} – 4102 mg/kg*

Action in plant *Interferes with enzyme acetolactate synthase, resulting in a rapid cessation of cell division and plant growth in roots and shoots.*

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

Chemical family *Sulfonylurea*

Koc *Average is 110 mL/g at pH 7*

CHLORSULFURON

Trade name(s) *Glean XP, Telar DF, Telar XP*

Manufacturer(s) *Corteva, Bayer, FMC*

Formulation(s) *75% dry flowable*

Remarks *A selective preemergence or early postemergence herbicide used at low rates. Carefully consider crop rotation plans before using. Recommended for use in wheat, barley, oats, and in fallow on soils of pH 7.5 or less. Telar formulation is a selective broadleaf herbicide used preemergence to postemergence in noncropland areas.*

Water solubility *587 ppm at pH 5; 31,800 ppm at pH 7*

Storage conditions *Stable when excess moisture or humidity are excluded from container.*

Acute toxicity *LD_{50} - 5,545 mg/kg*

Action in plant *Interferes with enzyme acetolactate synthase, resulting in a rapid cessation of cell division and plant growth in both roots and shoots.*

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

Chemical family *Sulfonylurea*

Koc *Average is 40 mL/g at pH 7*

CLETHODIM

Trade name(s) *Arrow, Envoy Plus, Intensity, Section, Select, SelectMax, Shadow, Volunteer*

Manufacturer(s) *Valent, Tenkoz, Albaugh, Winfield, Loveland, ADAMA*

Formulation(s) *0.97, 2 and 3 lb/gal emulsifiable concentrate*

Remarks *A selective postemergence grass-control herbicide. Controls most annual and perennial grasses except fine fescues. Using a crop oil concentrate enhances activity.*

Storage conditions *Stable*

Acute toxicity *LD_{50} - 2,920 mg/kg*

Action in plant *Inhibits growing points in grasses.*

Site of action *Group 1: acetyl CoA carboxylase (ACCase) inhibitor*

Chemical **family** *Cyclohexanedione*

CLODINAFOP

Trade name(s) *Discover NG, Next Step*

Manufacturer(s) *Syngenta, UPL*

Formulation(s) *0.5 lb/gal emulsifiable concentrate*

Remarks *Controls annual grasses postemergence.*

Water solubility *4,000 ppm*

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

Acute toxicity *LD_{50} - 1,829 mg/kg*

Action in plant *Inhibits growing points in grasses.*

Site of action *Group 1: acetyl CoA carboxylase (ACCase) inhibitor*

Chemical family *Aryloxyphenoxy propionate*

Koc *Median was 1,588 mL/g.*

CLOMAZONE

Trade name(s) *Caravel, Command, Up-Stage*

Manufacturer(s) *FMC Corp., Sipcam, UPL*

Formulation(s) *3 lb/gal encapsulated herbicide*

Remarks *A selective, preplant-incorporated herbicide; controls several annual weeds. Some foliar activity. Offsite movement can whiten or yellow plant foliage.*

Water solubility *1,100 ppm*

Storage conditions *Store above 40°F. If frozen, warm to 60°F and shake or roll container.*

Acute toxicity *LD_{50} - 1,369 mg/kg*

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

Site of action *Group 13: deoxy-D-xylose phosphate (DOXP) synthase inhibitor*

Chemical family *Isoxazolidinone*

Koc *Average is 300 mL/g*

CLOPYRALID

Trade name(s) *Clean Slate, Stigmata, Stinger, Transline and others*

Manufacturer(s) *Atticus Ag, Corteva, NuFarm and others*

Formulation(s) *3 lb/gal soluble concentrate*

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

Water solubility *1,000 ppm*

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

Acute toxicity *LD_{50} - 4,300 mg/kg*

Action in plant *Mimics natural plant hormones.*

Site of action *Group 4: synthetic auxin*

Chemical family *6-Chloropicolinates*

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

COPPER SULFATE

Trade name(s) *Copper Sulfate, Blue Stone, Zep Root Kill*

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

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

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

Water solubility *Very soluble*

Storage conditions *Stable when kept dry.*

Acute toxicity *LD_{50} - 470 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, Rovic*

Manufacturer(s) *Helm Agro*

Formulation(s) *6 lb/gal emulsifiable concentrate,*

Remarks *A selective, thiocarbamate herbicide applied preplant and soil incorporated. For best results, incorporate immediately into the top*

2 to 3 inches of soil. Cycloate is absorbed by seed and stem tissue of seedlings.

Water solubility *85 ppm*

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

Acute toxicity *LD_{50} - 3,160 mg/kg*

Action in plant *Inhibits shoot growth.*

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

Chemical family *Thiocarbamate*

Koc *Average is 600 mL/g*

D-LIMONENE

Trade name(s) *Avenger AG Optima, Avenger Weed Killer*

Manufacturer(s) *Avenger Products LLC*

Formulation(s) *55 and 70% EC*

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

DAZOMET

Trade name(s) *Basamid*

Manufacturer(s) *AMVAC*

Formulation(s) *99% granule*

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

Water solubility *2,000 ppm*

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

Acute toxicity *LD_{50} - 320 mg/kg*

Action in plant *Attacks and disintegrates cell membranes.*

Site of action *Not well understood*

Chemical family *Dithiocarbamate*

Koc *Average is10 mL/g (estimated)*

DICAMBA

Trade name(s) *Clarity, Vanquish, Dicamba, Rifle and others*

Manufacturer(s) *BASF, Syngenta, Corteva and others*

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

Action in plant *Inhibits meristematic tissue in growing points of roots and shoots affecting cell wall synthesis.*

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 *LD_{50} - 800 mg/kg*

Action in plant *Mimics natural plant hormones.*

Site of action *Group 4: synthetic auxin*

Chemical family *Phenoxy acetic acid*

Koc *Average is 1,000 mL/g (estimated) for the butoxy ethyl ester*

DICLOFOP (RESTRICTED-USE HERBICIDE)

Trade name(s) *Illoxan*

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 *LD_{50} - 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.*

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

Action in plant *Inhibits indole acetic acid (IAA) transport.*

Site of action *Group 19: auxin transport inhibitor*

Chemical family *Semicarbazone*

Koc *Average is 18 to 156 mL/g*

DIMETHENAMID, DIMETHENAMID-P

Trade name(s) *Outlook, Slider, Sortie, Tower*

Manufacturer(s) *BASF, Helena, Loveland*

Formulation(s) *6 lb/gal emulsifiable concentrate*

Remarks *A chloroacetamide compound used as a selective, preemergence 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 *LD_{50} - 2,400 mg/kg*

Action in plant *Inhibits plant cell division and growth.*

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

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, Dessicash, Reward, Reglone, Weedtrine D (aquatic) and others*

Manufacturer(s) *Alligare, Applied Biochemists, Sharda USA, Syngenta and others*

Formulation(s) *0.4 and 2 lb water-soluble cation/gal (0.74 and 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 *LD_{50} - 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, Signature and others*

Manufacturer(s) *Corteva, Lesco, Loveland and others*

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

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 *LD_{50} - 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*

Manufacturer(s) *Adama, Alligare, Corteva, Loveland and others*

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 *LD_{50} - 3,400 mg/kg*

Action in plant *Inhibits photosynthesis at photosystem II Site A.*

Site of action *Group 5: photosystem II inhibitor*

Chemical family *Substituted urea*

Koc *Average is 480 mL/g*

ENDOTHALL (RESTRICTED-USE HERBICIDE)

Trade name(s) *Aquathol, Aquathol K, Cascade, Hydrothol 191*

Manufacturer(s) *UPL*

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 *LD_{50} - 182 mg/kg*

Action in plant *Disrupts cell membranes*

Site of action *Group 31: serine threonine protein phosphatase (STPP) inhibitor*

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 7E, Eptam 20-G,*

Manufacturer(s) *Gowan*

Formulation(s) *7 lb/gal emulsifiable concentrates, 20% 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 *LD_{50} - 1,652 mg/kg*

Action in plant *Inhibits shoot growth.*

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

Chemical family *Thiocarbamate*

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

ETHALFLURALIN

Trade name(s) *Sonalan, Curbit*

Manufacturer(s) *Gowan, Loveland Products*

Formulation(s) *3 lb/gal emulsifiable concentrate*

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

Water solubility *0.3 ppm*

Storage conditions *Store above 40°F.*

Acute toxicity *LD_{50} - 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*

ETHOFUMESATE

Trade name(s) *Nortron, Prograss, Ethotron, PoaConstrictor and others*

Manufacturer(s) *Bayer CropScience, UPL and other*

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 *LD_{50} - 6,400 mg/kg*

Action in plant *Inhibits shoot and root growth.*

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

Chemical family *Benzofuranes*

Koc *Average is 340 mL/g*

FENOXAPROP

Trade name(s) *Acclaim, Puma, Tacoma and others*

Manufacturer(s) *Bayer CropScience, Winfield United and others*

Formulation(s) *0.57 and 1 lb/gal emulsifiable concentrate*

Remarks *Selective postemergence grass control herbicides effective in some grass seeds, turfgrass, rice, and soybeans.*

Water solubility *0.9 ppm*

Storage conditions *Store between 10° and 100°F. Avoid using or storing near heat or flame.*

Acute toxicity *LD_{50} - 2,357 mg/kg*

Action in plant *Inhibits growing point in grasses.*

Site of action *Group 1: acetyl CoA carboxylase (ACCase) inhibitor*

Chemical family *Aryloxyphenoxy propionate*

Koc *Average is 9,490 mL/g for fenoxaprop ethyl ester*

FLAZASULFURON

Trade name(s) *Mission*

Manufacturer(s) *Summit Agro*

Formulation(s) *25% water-dispersible granule*

Remarks *Broadleaf herbicide used in turf for removal of overseeded cool-season grasses as well as control of annual and perennial grasses, sedges, and broadleaf weeds in warm-season turf, vineyards and Christmas trees.*

Water solubility *2100 ppm at pH 7*

Storage conditions *Store in cool, dry conditions.*

Acute toxicity *LD_{50} - 4,690 mg/kg*

Action in plant *Inhibits acetolactate synthase (ALS) enzyme.*

Site of action *Group 2: acetolactate synthase inhibitor*

Chemical family *Sulfonylurea*

Koc *Not available*

FLORASULAM

Trade name(s) *Defendor and ingredient in Orion, GoldSky, FirstStep, and Spitfire*

Manufacturer(s) *Corteva, Syngenta*

Formulation(s) *0.42 lb/gal emulsifiable concentrate and packaged with other herbicides*

Remarks *Broadleaf herbicide used in cereals for broadleaf weed control.*

Water solubility *84 ppm at pH 5, 6360 ppm at pH 7, and 94,200 ppm at pH 9*

Storage conditions *Not available*

Acute toxicity *LD_{50} - greater than 6,000 mg/kg*

Action in plant *Inhibits acetolactate synthase (ALS) enzyme*

Site of action *Group 2: acetolactate synthase inhibitor*

Chemical family *Sulfonanalide*

Koc *Average is 2 to 69 mL/g; average 18 mL/g*

FLORPYRAUXIFEN-BENZYL

Trade name(s) *Hulk, Procellacor*

Manufacturer(s) *Corteva*

Formulation(s) *0.21 lb/gal emulsifiable concentrate*

Remarks *A postemergence herbicide for selective control of susceptible broadleaf weeds in tree crops. Susceptible weeds emerged at the time of application will be controlled without regrowth. Procellacor is the formulation for aquatic sites. Terravue is a mixture of florpyrauxifen-benzyl (6%) with aminopyralid (71%)*

Water solubility *0.015 ppm*

Storage conditions *(none listed on label)*

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

Action in plant *Systemic herbicide which translocate throughout the plant to growing points where it suppresses regrowth from crown buds. Broadleaf weeds display epinasty growth like that caused by other synthetic auxins.*

Site of action *Group 4: synthetic auxin*

Chemical family *Arylpicolinate*

Koc *Expected to be relatively immobile in soil, Koc > 5,000, (15,305 – 33,500)*

FLUAZIFOP

Trade name(s) *Fusilade DX*

Manufacturer(s) *Syngenta*

Formulation(s) *2 lb/gal emulsifiable concentrate*

Remarks *A selective, postemergence grass herbicide to control most annual and perennial grasses except annual bluegrass and all fine fescues. A nonionic surfactant or crop oil concentrate enhances activity.*

Water solubility *1.1 ppm*

Storage conditions *Store at moderate temperatures.*

Acute toxicity *LD_{50} - 4,350 mg/kg*

Action in plant *Inhibits growing 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, Ozone, Pre-Pare*

Manufacturer(s) *Albaugh, Arysta LifeSciences, UPL*

Formulation(s) *18.7, 19.09, 20.6, 35 and 70% water-dispersible granule (66% acid equivalent)*

Remarks *Low-rate herbicide applied postemergence to control grasses in wheat. Has some activity on broadleaf weeds.*

Water solubility *44,000 ppm*

Storage conditions *Store in cool, dry conditions.*

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

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

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

Chemical family *Sulfonylaminocarbonyltriazolinone*

FLUFENACET

Trade name(s) *Component of Axiom*

Manufacturer(s) *Bayer CropScience*

Formulation(s) *54.4 % dry flowable*

Remarks *Effective on several annual grasses and some small-seed broadleaf weeds. Axiom is flufenacet + metribuzin.*

Water solubility *56 ppm*

Storage conditions *Store in a cool dry place. Storage above 100°F results in loss of active ingredient.*

Acute toxicity *LD_{50} - 371 mg/kg*

Action in plant *Interferes with meristematic activity.*

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

Chemical family *Oxyacetamide*

Koc *Average is 354 mL/g for sandy loam with 2.4% OM, 5% clay and pH 6.4*

FLUMICLORAC

Trade name(s) *Resource*

Manufacturer(s) *Valent USA Corp*

Formulation(s) *0.86 lb/gal emulsifiable concentrate*

Remarks *Contact postemergence herbicide for controlling certain annual broadleaf weeds in field corn and soybeans.*

Water solubility *0.189 ppm*

Storage conditions *Stable under normal storage conditions.*

Acute toxicity *LD_{50} - 3,600 mg/kg*

Action in plant *Acts as a contact-type herbicide disrupting chlorophyl synthesis leading to cell membrane disintegration.*

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) *41% and 51% water-dispersible granule, 0.25% granular*

Remarks *A preemergence and postemergence herbicide for controlling some broadleaf weeds. Has some residual effect when used preemergence. Rapidly burns down broadleaf weeds when used postemergence.*

Water solubility *1.78 ppm*

Storage conditions *Stable under normal storage conditions.*

Acute toxicity *LD_{50} - greater than 5,000 ppm*

Action in plant *Acts as a contact-type herbicide disrupting chlorophyl synthesis leading to cell membrane disintegration.*

Site of action *Group 14: protoporphyrinogen oxidase inhibitor*

Chemical family *N-phenylphthalimide*

FLURIDONE

Trade name(s) *Sonar, Avast! and others*

Manufacturer(s) *Alligare, SePRO and others*

Formulation(s) *4 lb/gal flowable, 2.7%, 3.7%, 5%, 6.3% 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 *LD_{50} - greater than 10,000 mg/kg*

Action in plant *Inhibits carotene formation, resulting in chlorophyll destruction and causes bleaching.*

Site of action *Group 12: phytoene desaturase (PDS) inhibitor*

Chemical family *None generally recognized*

Koc *Average is 1000 mL/g*

FLUROXYPYR

Trade name(s) *Obtain, Vista XRT, Starane, Starane Ultra and others*

Manufacturer(s) *Corteva, Loveland and others*

Formulation(s) *1.5 and 2.8 lb/gal emulsifiable concentrate, 40% WDG*

Remarks *A growth-regulating, foliage-applied herbicide to control broadleaf plants. Effects are similar to those of 2,4-D.*

Water solubility *0.11 ppm*

Storage conditions *Store above 10°F.*

Acute toxicity *LD_{50} - greater than 2,000 mg/kg*

Action in plant *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 *LD_{50} - greater than 5,000 mg/kg*

Action in plant *Acts as a contact-type herbicide disrupting chlorophyl synthesis leading to cell membrane disintegration.*

Site of action *Group 14: protoporphyrinogen oxidase inhibitor*

Chemical family *Triazinone*

FOMESAFEN

Trade name(s) *Agent, Reflex, Top Gun Flex*

Manufacturer(s) *Loveland, Syngenta and Winfield Solutions*

Formulation(s) *1.88 and 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 *LD_{50} – 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) *Revolver*

Manufacturer(s) *Bayer Crop Science*

Formulation(s) *0.19 lb ai / gal*

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 *LD_{50} - 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) *Albaugh*

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

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

Site of action *Group 0: unknown*

Chemical family *Organophosphorus*

Koc *Average is 150 mL/g*

GLUFOSINATE

Trade name(s) *Finale, Rely, Liberty, Lifeline and others*

Manufacturer(s) *BASF, Bayer CropScience, UPL and others*

Formulation(s) *1 lb 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 *LD_{50} - 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, Rattler, Glypro, Gly Star, AquaNeat, Tomahawk, Glyphosate, Durango, and many others*

Manufacturer(s) *Bayer CropScience, 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 *LD_{50} - 5,400 mg/kg*

Action in plant *Inhibits three important amino acids and protein synthesis.*

Site of action *Group 9: enolvpyruvyl shikimate phosphate (EPSP) synthase inhibitor*

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)*

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 *LD_{50} - > 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) *Empero, Sandea, Sedgehammer and others*

Manufacturer(s) *Atticus, Gowan, Nufarm America and others*

Formulation(s) *5% and 75% water-soluble granule*

Remarks *A selective herbicide for controlling broadleaf weeds and yellow nutsedge in several crops*

Water solubility *15 ppm at pH 5; 1,630 ppm at pH 7.*

Storage conditions *Stable when excess moisture or humidity are excluded from container.*

Acute toxicity *LD_{50} - 8,860 mg/kg*

Action in plant *Interferes with acetolactate synthase enzyme, resulting in a rapid cessation of cell division and plant growth in both roots and shoots.*

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

Chemical family *Sulfonylurea*

Koc *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, Pronone*

Manufacturer(s) *Bayer Environmental Science, DuPont, Helena and others*

Formulation(s) *2 lb/gal miscible liquid, 75% granule, 10% granule*

Remarks *A foliar- or soil-applied herbicide with soil activity for broadleaf weed, brush, and grass control in cropland, noncropland, forest lands, and rangeland. Westar is sulfometuron + hexazinone.*

Water solubility *33,000 ppm*

Storage conditions *Store above 32°F.*

Acute toxicity *LD_{50} - 860 mg/kg*

Action in plant *Inhibits photosynthesis at photosystem II Site A.*

Site of action *Group 5: photosystem II inhibitor*

Chemical family *Triazinone*

Koc *Average is 54 mL/g*

IMAZAMOX

Trade name(s) *Raptor, Beyond Xtra, Clearcast*

Manufacturer(s) *BASF*

Formulation(s) *1 lb/gal emulsifiable concentrate*

Remarks *An adjuvant and fertilizer are required for maximum weed control. Activity similar to imazethapyr, with shorter soil residual.*

Water solubility *Miscible*

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

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

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

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

Chemical family *Imidazolinone*

IMAZAPIC

Trade name(s) *Plateau, Impose, Open Range*

Manufacturer(s) *BASF, ADAMA, Wilber Ellis*

Formulation(s) *0.885% and 70% dispersible granule, 2 lb/gal soluble concentrate*

Remarks *Manufacturer has elected to sell Plateau only to government agencies and not to farmers or ranchers. A selective postemergence herbicide effective for controlling broadleaf weeds and some grasses.*

Water solubility *2,200 ppm*

Storage conditions *Store liquid formulation above 20°F.*

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

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

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

Chemical family *Imidazolinone*

IMAZAPYR

Trade name(s) *Arsenal, Chopper, Arsenal Applicators Concentrate, Stalker, Habitat, Polaris*

Manufacturer(s) *Alligare, BASF, NuFarm America*

Formulation(s) *0.5% Granule, Aqueous solutions of 2, and 4 lb/gal without a surfactant*

Remarks *Nonselective, imidazolinone herbicide applied preemergence or postemergence for long-term total vegetation control. Readily absorbed through foliage and roots. Registered for use only on noncropland.*

Water solubility *15,000 ppm*

Storage conditions *Store above 10°F. Once mixed, solution can be stored in spray tank until ready to be applied.*

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

Action in plant *Inhibits enzyme used in synthesis of some amino acids.*

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

Chemical family *Imidazolinone*

IMAZAQUIN

Trade name(s) *Scepter*

Manufacturer(s) *AMVAC*

Formulation(s) *70% dispersible granule*

Remarks *A selective preplant-incorporated, preemergence or postemergence herbicide effective in controlling broadleaf weeds and some grasses. A nonionic surfactant or oil adjuvant improves efficacy of postemergence treatments.*

Water solubility *60 ppm*

Storage conditions *Stable in normal storage conditions.*

Acute toxicity *LD_{50} - 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, Praxis, Pemex*

Manufacturer(s) *BASF, Atticus Ag, Sharda*

Formulation(s) *Aqueous solutions of 2 lb/gal*

Remarks *A selective postemergence herbicide effective in controlling broadleaf weeds and some annual grasses.*

Water solubility *Miscible.*

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

Acute toxicity *LD_{50} - 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, Esplanade, Marengo, Specticle, Rejuvra*

Manufacturer(s) *Bayer CropScience*

Formulation(s) *0.62 and 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: cellulose synthesis inhibitor*

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 *LD_{50} - 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, Quali-Pro*

Manufacturer(s) *Corteva, Makhteshim*

Formulation(s) *4.1 lb/gal and 75% dry flowable*

Remarks *A selective preemergence herbicide applied before weed seed germinates. For annual broadleaf weeds in turf and ornamentals.*

Water solubility *1 ppm*

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

Acute toxicity *LD_{50} - 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 29: cellulose synthesis inhibitor*

Chemical family *Benzamide*

Koc *190 to 570 mL/g*

LACTOFEN

Trade name(s) *Boa, Cobra, Mongoose*

Manufacturer(s) *Loveland, Sharda, 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 *LD_{50} - 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)*

LINURON

Trade name(s) *Lorox, Linex*

Manufacturer(s) *Tessenderlo Kerley Inc. (NovaSource)*

Formulation(s) *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 *LD_{50} - 1,500 mg/kg*

Action in plant *Inhibits photosynthesis at photosystem II Site A.*

Site of action *Group 5: 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 *LD_{50} - 800 mg/kg*

Action in plant *Mimics natural plant hormones.*

Site of action *Group 4: synthetic auxin*

Chemical family *Phenoxy acetic acid*

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

MCPB

Trade name(s) *Thistrol,*

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 *LD_{50} - 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) *Mecomec 4 Turf Herbicide, MCPP-p 4 Amine, Trimec 1000*

Manufacturer(s) *NuFarm, 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 *LD_{50} - 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 CropScience*

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

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

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

Chemical family *Sulfonylurea*

MESOTRIONE

Trade name(s) *Callisto, Broadworks, Mesotrione 4SC, Motif and others*

Manufacturer(s) *Albaugh, Syngenta, UPL and others*

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

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

Site of action *Group 27: 4-hydroxyphenylpyruvatedioxygenase (4-HPPD) inhibitor*

Chemical family *Triketone*

Koc *14 - 390 mL/g*

METAM (RESTRICTED-USE HERBICIDE)

Trade name(s) *Metam CLR, Vapam, Sectagon*

Manufacturer(s) *AMVAC, Tessenderlo Kerley Inc. (NovaSource)*

Formulation(s) *4.2 lb and 5.63 lb /gallon 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 *LD_{50} - 285 mg/kg*

Action in plant *Kills living tissue.*

Site of action *Group 0: unknown*

Chemical family *Dithiocarbamate*

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

METHYL BROMIDE (RESTRICTED-USE HERBICIDE)

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

Manufacturer(s) *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 *LD_{50} - 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, Moccasin*

Manufacturer(s) *Syngenta, ADAMA, UPL, Winfield*

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 control. 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 *LD_{50} - 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, UPL, ADAMA, Winfield Solutions and others*

Formulation(s) *3 lb and 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 *LD_{50} - 4,000 mg/kg*

Action in plant *Inhibits photosynthesis at photosystem II Site A.*

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 XP, Ally, Cimarron, Purestand, and others*

Manufacturer(s) *Corteva, Bayer CropScience, FMC, Helena and others*

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 *LD_{50} - 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, MALEIC HYDRAZIDE

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

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

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 *LD_{50} - 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.*

NAPROPAMIDE

Trade name(s) *Devrinol*

Manufacturer(s) *UPL*

Formulation(s) *2 lb/gal emulsifiable concentrate, 10% granular, 50% dry flowable*

Remarks *A preemergence, soil-applied herbicide to control annual grasses and some annual broadleaf weeds. Little, if any, loss from soil surface by volatilization, but if sunlight is intense, loss by photodecomposition is fairly rapid.*

Water solubility *73 ppm*

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

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

Action in plant *Inhibits root growth.*

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

Chemical family *Acetamide*

Koc *Average is 700 mL/g*

NICOSULFURON

Trade name(s) *Accent Q, Accent SC, Primero*

Manufacturer(s) *Corteva, Rotam*

Formulation(s) *4.2 %, 54.5 % and 75% water-dispersible granules*

Remarks *A selective postemergence herbicide used at low rates in corn to control certain grass and broadleaf weeds. Carefully consider crop rotation plans prior to using.*

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

Storage conditions *Stable.*

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

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

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

Chemical family *Sulfonylurea*

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

NORFLURAZON

Trade name(s) *Evital, Solicam,*

Manufacturer(s) *AMVAC, TKI*

Formulation(s) *5% granule, 78.6 % dry flowable*

Remarks *A selective herbicide applied preemergence to control many grasses, sedges, rushes, pigweed, purslane, and ragweed.*

Water solubility *28 ppm*

Storage conditions *Stable.*

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

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

Site of action *Group 12: phytoene desaturase (PDS) inhibitor*

Chemical family *Pyridazinone*

Koc *Average is 700 mL/g*

ORYZALIN

Trade name(s) *Fugitive, Oryzalin Coated Granules, Surflan Flex, Surflan WDG,*

Manufacturer(s) *ADAMA, UPL, Makhteshim, Loveland*

Formulation(s) *1.6 % granules, 85% WDG, 3.2 lb and 4 lb /gal flowable*

Remarks *A selective preemergence herbicide. Oryzalin affects seed germination and inhibits root development. It is strongly adsorbed onto soil and resists movement by water.*

Water solubility *2.5 ppm*

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

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

Action in plant *Inhibits mitosis, primarily in roots.*

Site of action *Group 3: microtubule assembly inhibitor*

Chemical family *Dinitroaniline*

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

OXADIAZON

Trade name(s) *Ronstar G, Ronstar Flo, Ronstar WSG50, Quali-Pro Oxadiazon*

Manufacturer(s) *Bayer CropScience, Makhteshim, Regal Chemical*

Formulation(s) *2% granular, 3.7 lb/gal emulsifiable concentrate, 50% wettable powders*

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

Water solubility *0.7 ppm*

Storage conditions *Stable under moderate conditions.*

Acute toxicity LD_{50} *- 8,000 mg/kg*

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

Site of action *Group 14: protoporphyrinogen oxidase inhibitor*

Chemical family *Oxadiazole*

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

OXYFLUORFEN

Trade name(s) *Goal, Galigan, GoalTender, OxyStar and others*

Manufacturer(s) *Corteva, ADAMA, Albaugh and others*

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

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

Water solubility *0.1 ppm*

Storage conditions *Store above freezing.*

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

Action in plant *Acts as a contact-type herbicide.*

Site of action *Group 14: protoporphyrinogen oxidase inhibitor*

Chemical family *Diphenylether*

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

PARAQUAT (RESTRICTED-USE HERBICIDE)

Trade name(s) *Gramoxone, Firestorm, Parazone, Para-Shot and others*

Manufacturer(s) *Syngenta, Shadra, ADAMA, AMVAC and others*

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 *LD_{50} - 157 mg/kg*

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

Site of action *Group 22: photosystem I electron diversion*

Chemical family *Bipyridilium*

Koc *Estimated at 1,000,000 mL/g*

PELARGONIC ACID

Trade name(s) *Beloukha, Scythe*

Manufacturer(s) *Belchim Crop Protection, Gowan*

Formulation(s) *4.2 lb/gal emulsifiable concentrate*

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

Water solubility *Emulsifiable*

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

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

Site of action *Group 0: unknown*

Chemical family *Carboxylic acid*

PENDIMETHALIN

Trade name(s) *Pendulum Aquacap, Prowl, Prowl H_2O, Stealth, and others*

Manufacturer(s) *BASF, Loveland, UPL and others*

Formulation(s) *3.3, 3.5, 3.8, and 4 lb/gal emulsifiable concentrate; 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 *LD_{50} - 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*

PENOXSULAM

Trade name(s) *Galleon SC, Sapphire*

Manufacturer(s) *Corteva, SePRO*

Formulation(s) *0.31 lb and 2 lb ai/gal soluble concentrate*

Remarks *Postemergence control of certain annual and perennial broadleaf weeds in certain established turfgrasses. Galleon is an aquatic herbicide for use in freshwater sites.*

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 *LD_{50} - 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) *Belchim*

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 *LD_{50} - 2,000 mg/kg*

Action in plant *Inhibits photosynthesis at photosystem II Site A.*

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) *Outpost, Tordon, Trooper*

Manufacturer(s) *Corteva, NuFarm*

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 *LD_{50} - 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, Manuscript*

Manufacturer(s) *Syngenta*

Formulation(s) *0.42 and 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 *LD_{50} - 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 *LD_{50} - 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, Cavalcade, Prodiamine and others*

Manufacturer(s) *Syngenta, Sipcam Agro, and others*

Formulation(s) *4 lb/gal flowable, 65% water-dispersible granules*

Remarks *A dinitroaniline compound that is applied preplant or preemergence depending on site used.*

Water solubility *0.013 ppm*

Storage conditions *Stable*

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

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

Site of action *Group 3: microtubule assembly inhibitor*

Chemical family *Dinitroaniline*

Koc *Average is 13,000 mL/g*

PROMETON

Trade name(s) *Pramitol*

Manufacturer(s) *ADAMA, Loveland, Winfield*

Formulation(s) *25% emulsifiable concentrate (2 lb/gal)*

Remarks *A triazine herbicide applied both preemergence and postemergence as a temporary total vegetation herbicide. Material has considerable foliar action and acts through the roots.*

Water solubility *750 ppm*

Storage conditions *Store above 32°F.*

Acute toxicity *LD_{50} - 2,276 mg/kg*

Action in plant *Inhibits photosynthesis at photosystem II Site A.*

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*

Manufacturer(s) *Syngenta*

Formulation(s) *4 lb/gal flowable*

Remarks *A selective herbicide to control annual grass and broadleaf weeds.*

Water solubility *48 ppm*

Storage conditions *Stable.*

Acute toxicity *LD_{50} - 3,750 mg/kg*

Action in plant *Inhibits photosynthesis at photosystem II Site A.*

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, Willowood Pronamide*

Manufacturer(s) *Corteva, Willowood*

Formulation(s) *Soluble concentrate (SC) 3.3 lb ai/gal, 50% wettable powder*

Remarks *A selective herbicide to control annual and perennial grasses. For postemergence activity, pronamide must move into the root zone. There is little foliar uptake. Apply when temperature is below 55°F to reduce microorganism degradation.*

Water solubility *15 ppm*

Storage conditions *Store between 32° and 122°F under dry conditions. Do not remove package from original container except for immediate use.*

Acute toxicity *LD_{50} - 5,620 mg/kg*

Action in plant *Inhibits mitosis.*

Site of action *Group 3: microtubule assembly inhibitor*

Chemical family *Benzamide*

Koc *Average is 800 mL/g*

PROPOXYCARBAZONE

Trade name(s) *Lambient, Olympus*

Manufacturer(s) *Bayer CropScience, Bayer Environmental Science*

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

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

Water solubility *2,900 ppm at pH 4; 42,000 ppm at pH 7 and pH 9*

Storage conditions *Store in cool, dry place.*

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

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

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

Chemical family *Sulfonylaminocarbonyltriazolinone*

PROSULFURON

Trade name(s) *Peak*

Manufacturer(s) *Gowan, Syngenta*

Formulation(s) *57% water-dispersible granules*

Remarks *A selective postemergence sulfonylurea herbicide used at low rates for annual broadleaf weed control in wheat, barley, oats, rye, triticale, grain sorghum, and proso millet. Carefully consider crop rotation plans before using.*

Water solubility *87 ppm at pH 5; 43,000 ppm at pH 7.7*

Storage conditions *Stable.*

Acute toxicity *LD_{50} - 4,360 mg/kg*

Action in plant *Interferes with plant enzyme acetolactate synthase, resulting in rapid cessation of cell division.*

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

Chemical family *Sulfonylurea*

Koc *18.56 mL/g for a silt loam with 3% OM and pH 6.5*

PYRIDATE

Trade name(s) *Tough*

Manufacturer(s) *Belchim Crop Protection*

Formulation(s) *5 lb/gal emulsifiable concentrate*

Remarks *Postemergent, contact herbicide that controls annual broadleaf weeds in the two- to four-leaf stage.*

Water solubility *1.5 ppm*

Storage conditions *Store in freeze-free, dry area.*

Acute toxicity *LD_{50} - 4,600 mg/kg*

Action in plant *Inhibits photosynthesis at photosystem II Site B.*

Site of action *Group 6: photosystem II inhibitor*

Chemical family *Phenyl-pyridazine*

PYRAFLUFEN

Trade name(s) *Octane, Venue, Vida*

Manufacturer(s) *Gowan, Nichino America, SePRO*

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 *LD_{50} - 3,712 mg/kg*

Action in plant *Acts as a contact-type herbicide disrupting chlorophyl synthesis leading to cell membrane disintegration.*

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 *LD_{50} - more than 2,000mg/kg*

Action in plant *Inhibits the HPPD enzyme, resulting in bleached plants.*

Site of action *Group 27: 4-hydroxyphenylpyruvatedioxygenase (4-HPPD) inhibitor*

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) *BASF Corp*

Formulation(s) *4 lb/ gal soluble concentrate, 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 *LD_{50} - >2,000 mg/kg (rat).*

Action in plant *Inhibits roots and shoots.*

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

Chemical family *Pyrazole*

Koc *57 to 114 ml/g*

PYROXSULAM

Trade name(s) *GR1, GR2, PowerFlex, PowerFlex HL, TeamMate*

Manufacturer(s) *Corteva, FMC*

Formulation(s) *7.5%, 13%, 21.5% water soluble granules*

Remarks *Postemergent 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 *LD_{50} - 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) *Armortech, Q-Ball, Quinstar and others*

Manufacturer(s) *Albaugh, BASF, NuFarm, and others*

Formulation(s) *75% dry flowable, 1.5 and 3.8 lb/gal*

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 *LD_{50} - 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, FirstAct, Highcard, Targa*

Manufacturer(s) *ADAMA, Corteva*

Formulation(s) *0.83 and 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 *LD_{50} - 5,700 mg/kg*

Action in plant *Inhibits an enzyme (ACCase) 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 (ACCase) inhibitor*

Chemical family *Aryloxyphenoxy propionate*

Koc *Average is 510 mL/g for quizalofop ethyl ester*

RIMSULFURON

Trade name(s) *Matrix, Pruvin, Resolve, Solida and others*

Manufacturer(s) *ADAMA, Corteva, DuPont, FMC and others*

Formulation(s) *25% dry flowable*

Remarks *A selective preemergence or postemergence herbicide to control weeds in potatoes. Rimsulfuron + thifensulfuron is marketed under the name Basis for use on field corn.*

Water solubility *7,000 ppm at pH 7*

Storage conditions *Stable. Do not store in moist conditions.*

Acute toxicity *LD_{50} - 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) *Sharpen, Treevix*

Manufacturer(s) *BASF*

Formulation(s) *2.8 lb/gal soluble concentrate, , 70% WDG*

Remarks *Selective herbicide for control of broadleaf weeds, used preplant, preemergence and as a defoliant.*

Water solubility *0.14 ppm at pH 4, 0.25 ppm at pH 5, and 21 ppm at pH 7*

Acute toxicity *LD_{50} - greater than 2,000 mg/kg*

Action in plant *Acts as a contact-type herbicide disrupting chlorophyl synthesis leading to cell membrane disintegration.*

Site of action *Group 14: protoporphyrinogen oxidase inhibitor*

Chemical family *Pyrimidinedione*

Koc *Average is 9 to 56 mL/g*

SETHOXYDIM

Trade name(s) *Poast, Rezult, Segment*

Manufacturer(s) *BASF*

Formulation(s) *1 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 *LD_{50} - 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) *PBI Gordon*

Formulation(s) *50% wettable powder*

Remarks *Selective herbicide; controls annual grass in turf.*

Water solubility *18 ppm*

Storage conditions *Stable under moderate conditions.*

Acute toxicity *LD_{50} - 7,500 mg/kg*

Action in plant *Inhibits photosynthesis at photosystem II Site A. Apparently inhibits root growth.*

Site of action *Group 5: photosystem II inhibitor*

Chemical family *Substituted urea*

Koc *Average is 420 mL/g*

SIMAZINE

Trade name(s) *Princep, Simazine, Sim-Trol*

Manufacturer(s) *Drexel, Loveland, Sipcam Agro, Syngenta, WinField*

Formulation(s) *80% wettable powder, 4 lb/gal flowable liquid, and 90% water-dispersible granules, 90% dry flowable*

Remarks *A triazine herbicide used selectively or as a complete vegetation killer. Requires considerable moisture to activate in soil. Shows long residual action.*

Water solubility *3.5 ppm*

Storage conditions *Stable.*

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

Action in plant *Inhibits photosynthesis at photosystem II Site A.*

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) *Erocide, Purate*

Formulation(s) *40% soluble powder; 4%, 19%, and 28% liquid; 12% and 33% dust; 99% active material in powder form; also formulated with borates, sodium carbonate, calcium/magnesium chloride, 2,4-D, and others.*

Remarks *Inorganic salt. Kills germinating seeds nonselectively; inhibits plant growth. Easily leached from soil.*

Water solubility *790,000 ppm*

Storage conditions *Stable at moderate conditions and when isolated from other pesticides.*

Acute toxicity *LD_{50} - 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) *Antares, Boycott, Portfolio, Spartan, Zeus and others*

Manufacturer(s) *FMC, Helena, UPL Wilber-Ellis and others*

Formulation(s) *75% dispersible granule, 4 and 4.16 lb/gal flowable liquid*

Remarks *Soil-applied, preemergent triazolinone herbicide that can be applied either preplant incorporated or preemergence treatment. Note recropping intervals.*

Water solubility *10 ppm at pH 5 and 300 ppm at pH 7*

Storage conditions *Stable in dry, cool conditions.*

Acute toxicity *LD_{50} - 2,416 mg/kg*

Action in plant *Disrupts cell membranes by inhibiting protoporphyrinogen oxidase (PPO) in the chlorophyll biosynthetic pathway, leading to a buildup of toxic intermediates.*

Site of action *Group 14: protoporphyrinogen oxidase inhibitor*

Chemical family *Triazinone*

Koc *43 mL/g*

SULFOMETURON

Trade name(s) *Oust XP, SFM 75, Spyder*

Manufacturer(s) *Alligare, Nufarm, Bayer*

Formulation(s) *75% dispersible granules*

Remarks *Broad-spectrum herbicide with preemergence and postemergence activity for noncropland and forestry use. Westar is sulfometuron + hexazinone.*

Water solubility *10 ppm at pH 5; 300 ppm at pH 7*

Storage conditions Stable.

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

Action in plant *Inhibits with acetolactate synthase enzyme, rapidly stopping cell metabolism.*

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) *Outrider, Certainty, Cryder*

Manufacturer(s) *Valent, Atticus*

Formulation(s) *75% water-soluble granule*

Remarks *Preemergence or postemergence control of several grasses and some broadleaves in wheat and noncrop areas.*

Water solubility *18 ppm, pH 5; 1,627 ppm, pH 7; 482 ppm, pH 9.*

Storage conditions *Store in dry place below 120°F.*

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

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

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

Chemical family *Sulfonylurea*

Koc *5 to 89 mL/g*

TEBUTHIURON

Trade name(s) *Spike, SpraKil S-5, Tebuthiuron*

Manufacturer(s) *Alligare, Corteva, SSI Maxim,*

Formulation(s) *80% dry flowable, 20% pellets, 5% granules*

Remarks *A soil-applied herbicide to control woody plants and vegetation. Its half-life in soil is 12 to 15 months in areas receiving 40 to 60 inches of annual precipitation.*

Water solubility *2,300 ppm*

Storage conditions *Stable.*

Acute toxicity *LD_{50} - 568 mg/kg*

Action in plant *Inhibits photosynthesis at photosystem II Site A.*

Site of action *Group 5: 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 CropScience*

Formulation(s) *3.5 lb/gal flowable liquid*

Remarks *A selective postemergence herbicide for control of broadleaf and grass weeds in corn.*

Water solubility *0.22 ppm, pH 4, 28.3 ppm, pH 7, 29.7, pH 9*

Storage conditions *Store in a cool dry place*

Acute toxicity *LD_{50} - greater than 2,000 mg/kg*

Action in plant *Inhibits HPPD enzymes leading to bleaching symptoms.*

Site of action *Group 27: 4-hydroxyphenyl-pyruvate-dioxygenase (HPPD) inhibitor*

Chemical family *Triketone*

TERBACIL

Trade name(s) *Sinbar*

Manufacturer(s) *Tessenderlo Kerley Inc. (NovaSource)*

Formulation(s) *80% wettable powder*

Remarks *A substituted uracil compound; a preemergence and postemergence selective and nonselective herbicide. Controls a wide range of weeds.*

Water solubility *710 ppm*

Storage conditions *Stable at moderate conditions.*

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

Action in plant *Inhibits photosynthesis at photosystem II Site A.*

Site of action *Group 5: photosystem II inhibitor*

Chemical family *Uracil*

Koc *Average is 55 mL/g*

THIENCARBAZONE

Tradename(s) *Luxxur B, Varro, and in package mixture with tembotrione and sold as Capreno*

Manufacturer(s) *Bayer CropScience*

Formulation(s) *0.083 lb/gal flowable liquid*

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, Treaty, Volta*

Manufacturer(s) *Corteva, FMC, NuFarm, Rotam*

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

Action in plant *Interferes with acetolactate synthase, resulting in a rapid cessation of cell division and plant growth in both shoots and roots.*

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

Chemical family *Sulfonylurea*

Koc *Average is 45 mL/g at pH 7*

TIAFENACIL

Trade name(s) *Reviton, Gamma, Tiafenacil 70WG*

Manufacturer(s) *Helm, ISK Bioscience*

Formulation(s) *2.83 lb ai/gal of SC in Reviton; 70% water dispersible granule in Gamma*

Remarks *A nonselective, postemergence herbicide for burndown applications and use in on non-bearing hazelnuts*

Water solubility *110 ppm at 20 C at pH 7*

Storage conditions *Stable.*

Acute toxicity *LD_{50} - greater than 2,250 mg/kg*

Action in plant *Acts as a contact-type herbicide disrupting chlorophyl synthesis leading to cell membrane disintegration.*

Site of action *Group 14: protoporphyrinogen oxidase (PPO) inhibitor*

Chemical family *Pyrimidinedione*

Koc *Average is 1,965 mL/g*

TOLPYRALATE

Trade name(s) *Shieldex*

Manufacturer(s) *Summit Agro*

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 *LD_{50} - greater than 2,000mg/kg*

Action in plant *Inhibits 4-HPPD enzymes leading to bleaching symptoms.*

Site of action *Group 27: 4-hydroxyphenylpyruvatedioxygenase (4-HPPD) inhibitor*

Chemical family *Triketone*

Koc *11 to 85 mL/g*

TOPRAMEZONE

Trade name(s) *Armezon, Frequency, Impact, Pylex,*

Manufacturer(s) *Amvac Chemical Corp., BASF*

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 *LD_{50} - greater than 2,000 mg/kg*

Action in plant *Inhibits HPPD enzymes leading to bleaching symptoms.*

Site of action *Group 27: 4-hydroxyphenylpyruvatedioxygenase (4-HPPD) inhibitor*

Chemical family *Triketone*

Koc *Average is 22.3 to 172.4 mL/g*

TRIALLATE

Trade name(s) *Avadex, Far-Go*

Manufacturer(s) *Gowan*

Formulation(s) *4 lb/gal emulsifiable concentrate, 10% granules*

Remarks *A selective herbicide for wild oat control, applied preplant or preemergence and incorporated. May irritate skin and eyes. Buckle is triallate + trifluralin.*

Water solubility *4 ppm*

Storage conditions *Stable.*

Acute toxicity *LD_{50} - 2,700 mg/kg*

Action in plant *Inhibits shoots of emerging seedlings.*

Site of action *Group 15: very long chain fatty acid synthesis 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 *LD_{50} - greater than 5,000 mg/kg*

Action in plant *Interferes with the plant enzyme acetolactate synthase, thus rapidly ending cell division.*

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

Chemical family *Sulfonylurea*

Koc *51.6 mL/g for a silt loam 4.5% OM, and pH 7.2*

TRIBENURON

Trade name(s) *Cleat, Express, Luxxur A, Taquet, Victory*

Manufacturer(s) *Corteva, NuFarm, Rotam,*

Formulation(s) *75% dry flowable, 50% granules*

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

Action in plant *Interferes with acetolactate synthase, resulting in a rapid cessation of cell division and plant growth in both shoots and roots.*

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

Chemical family *Sulfonylurea*

Koc *Average is 46 mL/g pH 6.6*

TRICLOPYR

Trade name(s) *Boulder, Garlon 3A, Garlon 4, Remedy, Renovate, Tahoe and others*

Manufacturer(s) *Alligare, Corteva, NuFarm, SePRO and others*

Formulation(s) *3 lb/gal miscible liquid, 2.87, 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 *LD_{50} - 2,140 mg/kg*

Action in plant *Mimics natural plant hormones.*

Site of action *Group 4: synthetic auxin*

Chemical family *Pyridine*

Koc *Average is 20 mL/g (estimated) for the triethylamine salt and 780 mL/g for the butoxy ethyl ester*

TRIFLURALIN

Trade name(s) *Treflan, Trifluralin, Trust,*

Manufacturer(s) *Gowan, Helena, Winfield, Drexel and others*

Formulation(s) *4 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 *LD_{50} - 2,000 mg/kg*

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

Site of action *Group 3: microtubule assembly inhibitor*

Chemical family *Dinitroaniline*

Koc *Average is 7,000 mL/g*

TRIFLUSULFURON

Trade name(s) *UpBeet*

Manufacturer(s) *FMC*

Formulation(s) *50% dry flowable*

Remarks *A selective postemergence herbicide to control weeds in sugar beets.*

Water solubility *3 ppm at pH 5; 110 ppm at pH 7*

Storage conditions *Very stable. Formulated products do not freeze.*

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

Action in plant *Inhibits the plant enzyme acetolactate synthase, resulting in rapid cessation of cell division.*

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

Chemical family *Sulfonylurea*

Koc *35 mL/g in loamy sand with 3.3% OM and 5.9 pH*

Restricted-Use Herbicides in Idaho, Oregon, and Washington

Aaron Becerra-Alvarez

Revised March 2025

Federally Restricted-Use Herbicides

(https://picol.cahnrs.wsu.edu/search?usage=R)

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.

- *Acrolein (high acute toxicity)*
- *Atrazine (ground and surface water contamination)*
- *Dazomet (acute inhalation toxicity to humans)*
- *Dichloropropene (due to high acute inhalation toxicity and carcinogenicity)*
- *Metam-sodium (acute inhalation toxicity to humans)*
- *Methyl bromide (acute toxicity, hazards to humans and domestic animals)*
- *Paraquat (acute toxicity)*
- *Phenmedipham (dermal irritation)*
- *Picloram (may injure susceptible, non-target plants)*
- *Pronamide (some formulations; tumors in laboratory animals)*

Additional Restricted-Use Herbicides in WA

(https://picol.cahnrs.wsu.edu/Search/Quick?Express=srup)

Some or all uses of the following herbicide active ingredients are classified as restricted-use *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*
- *All formulations of phenoxy hormone-type herbicides (e.g., 2,4-D, 2,4-DB, 2,4-DP (dichlorprop), MCPA, MCPB, MCPP (mecoprop) and dicamba when distributed in counties located east of the crest of the Cascade Mountains*
- *Bromacil (ground water)*
- *Clopyralid (disposal of grass clippings)*
- *Diuron (ground water)*
- *Hexazinone (ground water)*
- *Metribuzin; (ground water)*
- *Metolachlor (ground water)*
- *Picloram (ground water)*
- *Prometon (ground water)*

- *Simazine (ground water)*
- *Tebuthiuron (ground water)*

Cleaning Spraytanks

Aaron Becerra-Alvarez

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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 (see table), and recirculate for 15 minutes. Spray some of the rinsate though the boom and nozzles, then drain the tank.

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

Remove the nozzles and screens, and clean them separately.

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

Validating Spraytank Cleaning Methods

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

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

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

Herbicide examples	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 XP		1%	✓	
Amber		1/2%	✓	
Armezon				✓
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	
Chateau		1%	✓	
Clarity	✓ R			✓
Classic		1%	✓	
CleanTraxx		1%		

Herbicide examples	Cleaning Agents[1] (consult labels for specific directions)			
	Detergent[2]	Household ammonia (3% active)	Approved cleaning agent	Commercial tank cleaner
Cobra	✓			
Command	✓			
Crossbow	✓			
Curtail, Curtail M		1%		
Dual Magnum	✓			
Eptam/Eradicane	✓			
Escort		1%		
Everest		1%		
Express		1%	✓	
Fallow Master		4%		
Finesse		1%	✓	
Fusilade	✓			
Glean		1%		
Goal/Galigan			✓	
GoldSky		1%		
Harmony Extra		1%	✓	
Harness	✓			
Hornet		✓		✓
Huskie		1%		
Hulk		1%		✓
Impact	✓ R			✓
Karmex/Direx	✓			
Kerb	✓			
Laddok	✓ R			✓
Landmaster BW		4%		
Laudis			4% bleach	
Liberty				✓

Herbicide examples	Cleaning Agents[1] (consult labels for specific directions)			
	Detergent[2]	Household ammonia (3% active)	Approved cleaning agent	Commercial tank cleaner
Lorox, Linex	✓			
Marksman	✓ R			✓
Maverick		✓		
Matrix		1%		
MCPA amine		1%		
MCPA ester	1% kerosene or diesel followed by 1% household ammonia			
Milestone		4%		
Mission		1%		
Nortron	✓			
Olympus (/flex)		✓ R		
Opensight		4%		
Osprey		1%		
Oust (XP/Extra)		1%		✓
Outlook	✓ R			✓
Outrider		1%		
Paramount	✓ R			✓
Peak		2%		
Perfect Match		1%		
Permit		1%		
Perspective		1%		
Pixxaro		1%		
Poast, Poast Plus	✓ R			✓
PowerFlex		1%		
Prowl (EC/H_2O)	✓ R			✓
Pursuit (and Plus)	✓			
Python	✓			
Quelex		1%		

Herbicide examples	Cleaning Agents[1] (consult labels for specific directions)			
	Detergent[2]	Household ammonia (3% active)	Approved cleaning agent	Commercial tank cleaner
Quinstar	✓ R			
Raptor	✓			
Reflex				✓
Rely	✓			
Remedy	✓ R			
Resolve		1%	✓	
Roundup Ultra	✓			
Sandea		1%		
Scepter	✓			
Select	✓			
Sentrallas		1%		
Sharpen	✓			✓
Shieldex		1%		
Sinbar	✓			
Spartan	✓ R	1%		
Spirit		2%		
Starane	✓ R			
Streamline		1%		
Stinger		1%		
SureGuard		1%	✓	
Talinor	✓			✓
Tarzec				✓
Tordon		1%		
Travallas		1%		
Treevix				✓
Treflan	✓ R			
Upbeet		1%		
Valor		✓		

Herbicide examples	Cleaning Agents[1] (consult labels for specific directions)			
	Detergent[2]	Household ammonia (3% active)	Approved cleaning agent	Commercial tank cleaner
WideMatch		1%		
Zeus	✓ R	1%		
Zidua	✓			✓
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.

Testing for and Deactivating Herbicide Residues

Aaron Becerra-Alvarez

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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.*
11. *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 to Remediate Contaminated Soil

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 dimethenamid-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., https://buyactivatedcharcoal.com/) or by contacting commercial agriculture retailers in the PNW. Activated carbon is offered in containers of up to 55 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.

Managing Herbicide-Resistant Weeds[1]

Aaron Becerra-Alvarez and Victor Ribeiro

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[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 https://www.extension.uidaho.edu/publishing/pdf/pnw/pnw0437.pdf

Herbicide resistance is the inherited ability of a plant to survive an 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 exist in a population in extremely small numbers. Repeatedly using one herbicide allows these few plants to survive and reproduce. The frequency of resistant plants then increases in the population because all susceptible individuals are controlled.

Resistant plants likely will persist in infested fields for many years, even in the absence of any additional selection with the herbicide. This is because the competitive ability of the resistant biotypes does not seem to be dramatically compromised. To date, there is no evidence that herbicides cause the genetic mutations that lead to herbicide resistance.

Weed populations may evolve resistance to more than one herbicide. When populations evolve, a pattern of resistance to more than one herbicide within the same mechanism of action (imidazolinones as well as sulfonylureas, for example) is labeled **cross-resistance**. *When populations evolve resistance to more than one herbicide from different mechanisms of action, this pattern is known as* **multiple-resistance**. *Some weed populations that have been exposed to continued selection pressure by herbicides may exhibit both patterns of cross- and multiple-resistance.*

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

The first identified herbicide-resistant weed—wild carrot (Daucus carota), resistant to 2,4-D—was identified in 1957, in Ontario, Canada. Since then, more than 273 populations from distinct weed species evolved resistance to one or more herbicides worldwide. For current information on the status of herbicide-resistant weeds, see: https://weedscience.org.

Herbicide-resistant weeds are common in the Pacific Northwest:

- *Kochia, prickly lettuce, downy brome, and Russian thistle resistant to Group 2 herbicides*
- *Wild oat, downy brome, and Italian ryegrass resistant to several Group 1 herbicides*
- *Redroot pigweed and annual bluegrass resistant to Group 5 herbicides*
- *Prickly lettuce resistant to Group 4 herbicides*
- *Kochia and Italian ryegrass resistant to glyphosate (Group 9)*

A new website created in 2024 aims to provide a tracking of herbicide-resistant weeds in the Pacific Northwest. You can find information at https://pnwhri.org/resources. The map will be updated regularly based on new evidence and confirmation of new herbicide-resistant weeds.

The evolution of herbicide-resistant weeds is strongly linked to repeated use of the same herbicide, or herbicides with the same mechanism of action, in a simplistic cropping system (for example, wheat after wheat) or in non-crop areas (railway or road rights-of-way, for example). Managing herbicides to delay the appearance of herbicide-resistant weed populations requires an understanding of which herbicide chemical families, and which herbicides have the same mechanism of action.

The table below lists herbicides by group number and site of action, chemical family, and common name. It also gives examples of resistant weed populations documented.

To delay selection of herbicide-resistant weed populations, it is recommended to follow good agronomic practices to manage weeds that integrate herbicide use with cultural, physical, and preventive strategies. When using herbicides, proper 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 an herbicide resistance management strategy.

Preventing herbicide-resistant weeds

Herbicide rotation and tank mixtures *Avoid year-after-year use of herbicides that have the same mechanism of action. For example, two chemically different groups of herbicides, the sulfonylureas and imidazolinones, have the same mechanism of action (both are Group 2), and this tankmix should be avoided. Similarly, fluazifop-P-butyl and clethodim (both are Group 1) belong to different chemical families but control susceptible grasses in the same way. Tank mixtures and herbicide rotations from different mechanisms of action are preferred compared to single herbicide treatments. Postemergence herbicides should be used to eliminate all individuals in a population at the recommended rate and application stage. Using lower or higher than recommended rates, as well as treating weeds at growth stages that results in marginal control levels, pose selection pressure that select for the herbicide-resistant individuals within the population.*

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 pressure on weed populations. Tankmixing soil-applied herbicides delays evolution of herbicide resistance, as long as the residual activities and the weed spectrum are similar. If herbicides in the tankmix have different soil residual characteristics, resistant weed biotypes will continue to be selected. For example, if a long-residual or a short-residual herbicide are tankmixed, both herbicides may control emerged and emerging broadleaf weeds. However, the herbicide with short residual activity will dissipate faster, thus the long-residual herbicide will continue, alone, to control weeds throughout the growing season and could continue to select for resistant plants.*

Crop rotation *Because different crops may require different herbicides, rotating crops can naturally reduce reliance on one herbicide or herbicides with similar mechanism of action. 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.*

Mechanical and physical methods *In-row crop cultivation can be an effective tool for eliminating weed escapes that may represent the resistant population. If available and feasible in the cropping system, hand-weeding weed escapes is also an option. Fallow tillage controls herbicide-resistant and herbicide-susceptible weeds equally if seedlings of the two biotypes emerge at the same time. Do not use the same mechanism of action herbicide in fallow as was used to control weeds in the crop.*

Accurate record keeping *To have an effective herbicide rotation or tankmix system to delay 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 efforts, not just management of herbicide-resistant weeds. Integrated weed management uses all the tools available to control weeds, including cultural, mechanical, physical, 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 a considerable number of weed individuals in a population 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. Many weed species exhibit wind pollination, and herbicide resistance traits may be transferred to field populations from adjacent areas. Therefore, controlling weeds growing in field edges, fences, and roadsides is important to avoid gene flow into fields via pollen or seed movement.*

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 controlled.*

Change herbicide program *If weeds become resistant to a particular herbicide, 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 (or same geographical region) with the same herbicide, or an herbicide with the same site of action.*
- *Records show repeated use of one herbicide or of herbicides with the same mechanism of action.*

What to do if you suspect herbicide resistance:

Do not re-spray the field with the same herbicide, or an herbicide with the same mechanism of action.

Report your suspicion to university researchers or Extension personnel, or to the Extension educator in your county.

Collect plants or seed that can be used to confirm resistance has evolved.

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 (Group 2), and Roundup Ready canola, which was genetically engineered to be resistant to glyphosate (Group 9). 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 can also become 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, an herbicide with a different mechanism 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 seed dormancy, which could result in multiple years of an herbicide-resistant volunteer crop problem, even without new seed inputs.

Gene flow from herbicide-resistant crops to weedy relatives can be a concern. Rarely, the trait that confers herbicide resistance in the crop can move into weedy relatives through cross-pollination, resulting in an herbicide-resistant weed population. 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.

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

- *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).*
- *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 Resistance in the Pacific Northwest

To avoid selecting for herbicide-resistant weeds, rotate and tankmix herbicides from different sites of action. Here is a list of recorded resistant weeds to their respective herbicide group and site of action in the Pacific Northwest.
Visit https://pnwhri.org/resources to view the Herbicide Resistance Tracking Map.

Group Number and Site of Action[1]	Chemical Family	Common Name	Resistant Weeds in the PNW	States with Resistant Weeds
Group 1				
Acetyl CoA carboxylase	cyclohexanediones	clethodim	downy brome	OR

Group Number and Site of Action[1]	Chemical Family	Common Name	Resistant Weeds in the PNW	States with Resistant Weeds
(ACCase) inhibitors			Italian ryegrass*	ID
		sethoxydim	downy brome	OR
			Italian ryegrass	ID
			wild oats	WA
	aryloxyphenoxy propionates	clodinafop-propargyl	Italian ryegrass*	ID
			wild oats	ID
		diclofop-methyl	Italian ryegrass*	ID, OR
			wild oats	ID, OR, WA
		fenoxaprop-P-ethyl	wild oats	ID, OR, WA
		fluazifop-P-butyl	downy brome	OR
		quizalofop-P-ethyl	downy brome	OR
			Italian ryegrass*	ID
			wild oats	WA
	phenylpyrazolines	pinoxaden	wild oats	WA
Group 2				
Acetolactate synthase (ALS) inhibitors	imidazolinones	imazamox	downy brome	OR
			spiny sowthistle	WA
		Imazethapyr	mayweed chamomile	ID, WA
			prickly lettuce	ID
	sulfonylureas	chlorsulfuron	kochia	ID, OR, WA
			mayweed chamomile	ID
			prickly lettuce	ID, OR, WA
			Russian thistle	ID, OR, WA
			small seed false flax	OR
		metsulfuron-methyl	kochia	OR
			prickly lettuce	ID, OR
			Russian thistle	OR
			smallseed false flax	OR

Group Number and Site of Action[1]	Chemical Family	Common Name	Resistant Weeds in the PNW	States with Resistant Weeds
		primisulfuron-methyl	downy brome	OR
		sulfosulfuron	downy brome	OR
		triasulfuron	kochia	OR
			Italian ryegrass*	ID
			prickly lettuce	ID, OR
			Russian thistle	OR
		thifensulfuron-methyl	mayweed chamomile	ID, WA
			prickly lettuce	ID
		tribenuron-methyl	mayweed chamomile	ID, WA
			prickly lettuce	ID
			spiny sowthistle	WA
	triazolopyrimidines	cloransulam-methyl	mayweed chamomile	WA
Group 4				
Synthetic auxins	benzoates	dicamba	kochia	ID
			prickly lettuce	WA
	phenoxy-carboxylates	2,4-D	prickly lettuce	WA
		MCPA	prickly lettuce	WA
	pyridine-carboxylates	picloram	yellow starthistle	WA
Group 5				
Photosystem II inhibitors	nitriles	bromoxynil	common groundsel	OR
	triazines	atrazine	annual bluegrass	OR
		simazine	common groundsel	WA
	uracils	terbacil	common lambsquarters	WA
			Powell amaranth	WA

Group Number and Site of Action[1]	Chemical Family	Common Name	Resistant Weeds in the PNW	States with Resistant Weeds
			redroot pigweed	OR, WA
	ureas	diuron	annual bluegrass	OR
	triazinones	metribuzin	annual bluegrass*	OR
			common lambsquarters	WA
			redroot pigweed	ID, WA
			shepherd's purse	OR
		hexazinone	shepherd's purse	OR
Group 8				
Lipid synthesis inhibitors but not ACCase inhibitors	thiocarbamates	triallate	wild oats*	ID
Group 9				
EPSP synthase inhibitors	glycines	glyphosate	Italian ryegrass*	OR
			kochia	ID, OR
			Russian thistle	OR, WA
Group 10				
Glutamine synthase inhibitors	phosphinic acids	glufosinate-ammonium	Italian ryegrass*	OR
Group 15				
Inhibitors of very long chain fatty acid synthesis	α-oxyacetamides	flufenacet	Italian ryegrass*	ID, OR, WA
Group 16				
Unknown	benzofurans	ethofumesate	annual bluegrass	OR
Group 26				
Unknown	pyrazoliums	difenzoquat	wild oat	ID
Unknown	pyrazoles	difenzoquat	wild oats	ID

*Multiple resistant populations have been reported. See weedscience.org for more details.

Cleaning Spraytanks

Aaron Becerra-Alvarez

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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 (see table), and recirculate for 15 minutes. Spray some of the rinsate though the boom and nozzles, then drain the tank.

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

Remove the nozzles and screens, and clean them separately.

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

Validating Spraytank Cleaning Methods

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

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

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

Herbicide examples	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 XP		1%	✓	
Amber		1/2%	✓	
Armezon				✓
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	
Chateau		1%	✓	
Clarity	✓ R			✓
Classic		1%	✓	
CleanTraxx		1%		

Herbicide examples	Cleaning Agents[1] (consult labels for specific directions)			
	Detergent[2]	Household ammonia (3% active)	Approved cleaning agent	Commercial tank cleaner
Cobra	✓			
Command	✓			
Crossbow	✓			
Curtail, Curtail M		1%		
Dual Magnum	✓			
Eptam/Eradicane	✓			
Escort		1%		
Everest		1%		
Express		1%	✓	
Fallow Master		4%		
Finesse		1%	✓	
Fusilade	✓			
Glean		1%		
Goal/Galigan			✓	
GoldSky		1%		
Harmony Extra		1%	✓	
Harness	✓			
Hornet		✓		✓
Huskie		1%		
Hulk		1%		✓
Impact	✓ R			✓
Karmex/Direx	✓			
Kerb	✓			
Laddok	✓ R			✓
Landmaster BW		4%		
Laudis			4% bleach	
Liberty				✓

Herbicide examples	Cleaning Agents[1] (consult labels for specific directions)			
	Detergent[2]	Household ammonia (3% active)	Approved cleaning agent	Commercial tank cleaner
Lorox, Linex	✓			
Marksman	✓ R			✓
Maverick		✓		
Matrix		1%		
MCPA amine		1%		
MCPA ester	1% kerosene or diesel followed by 1% household ammonia			
Milestone		4%		
Mission		1%		
Nortron	✓			
Olympus (/flex)		✓ R		
Opensight		4%		
Osprey		1%		
Oust (XP/Extra)		1%		✓
Outlook	✓ R			✓
Outrider		1%		
Paramount	✓ R			✓
Peak		2%		
Perfect Match		1%		
Permit		1%		
Perspective		1%		
Pixxaro		1%		
Poast, Poast Plus	✓ R			✓
PowerFlex		1%		
Prowl (EC/H_2O)	✓ R			✓
Pursuit (and Plus)	✓			
Python	✓			
Quelex		1%		

Herbicide examples	Cleaning Agents[1] (consult labels for specific directions)			
	Detergent[2]	Household ammonia (3% active)	Approved cleaning agent	Commercial tank cleaner
Quinstar	✓ R			
Raptor	✓			
Reflex				✓
Rely	✓			
Remedy	✓ R			
Resolve		1%	✓	
Roundup Ultra	✓			
Sandea		1%		
Scepter	✓			
Select	✓			
Sentrallas		1%		
Sharpen	✓			✓
Shieldex		1%		
Sinbar	✓			
Spartan	✓ R	1%		
Spirit		2%		
Starane	✓ R			
Streamline		1%		
Stinger		1%		
SureGuard		1%	✓	
Talinor	✓			✓
Tarzec				✓
Tordon		1%		
Travallas		1%		
Treevix				✓
Treflan	✓ R			
Upbeet		1%		
Valor		✓		

Herbicide examples	Cleaning Agents[1] (consult labels for specific directions)			
	Detergent[2]	Household ammonia (3% active)	Approved cleaning agent	Commercial tank cleaner
WideMatch		1%		
Zeus	✓ R	1%		
Zidua	✓			✓
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.