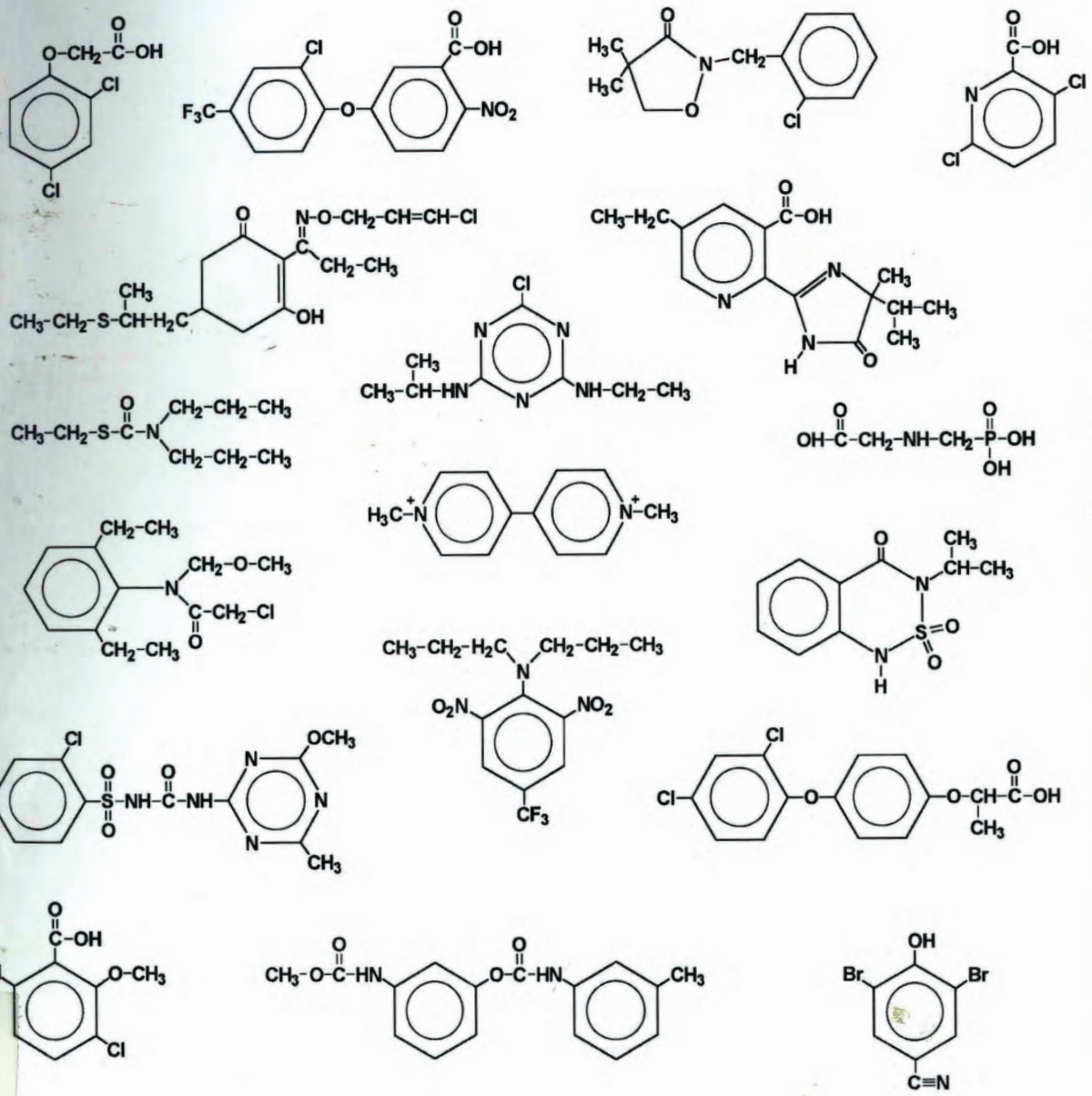
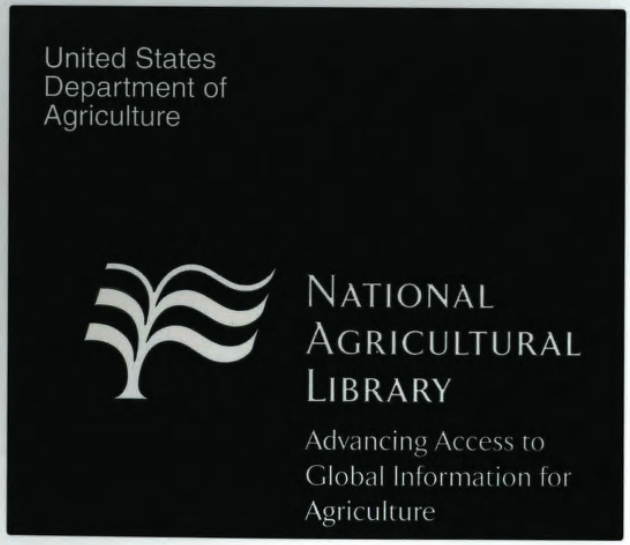
HERBICIDE HANDBOOK

Weed Science Society of America

Eighth Edition – 2002




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HERBICIDE HANDBOOK

Eighth Edition

2002

Editor: William K. Vencill

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[1]See page vii for affiliations.

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The *Herbicide Handbook* of the Weed Science Society of America was first published in 1967. It was, and continues to be, the work of WSSA's Herbicide Handbook Committee. Each edition is dedicated to an individual recognized for outstanding service and accomplishments in herbicide technology. Publication dates and dedication recipients are listed below.

Edition	Year	Dedicated to
First published	1967	Marion W. Parker
Second edition	1970	Kenneth P. Buchholtz
Third edition	1974	Charles J. Willard
Fourth edition	1979	Alden S. Crafts
Fifth edition	1983	Robert H. Beatty
Sixth edition	1989	F. Leonard Timmons
Seventh edition	1994	Fred W. Slife
Eighth edition	2002	Dan Hess & Fred Warren

NOTICE

Chemicals presented in previous editions of the *Herbicide Handbook* that are currently of minimal interest or have not been produced for several years have been omitted from this edition. Such chemicals are listed on page 449. Earlier editions should be retained in order to maintain a record of past and present herbicides.

Cover design by Robert J. Ehr

This book may be purchased from:

Weed Science Society of America
810 East 10th Street
Lawrence, KS 66044-8897

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2,4-D

(2,4-dichlorophenoxy)acetic acid

Nomenclature

Common name: 2,4-D (BSI, ISO, WSSA).

Manufacturers, products, and formulations

Albaugh, Inc.: 2,4-D LV4, 465 g ae/L (3.88 lb ae/gal), io ester, EC; 2,4-D LV6, 660 g ae/L, io ester, EC; 2,4-D AMINE 4, 456 g ae/L, dma salt, SL

Agriliance: 2,4-D LV4, 465 g ae/L (3.88 lb ae/gal), io ester, EC; 2,4-D LV6, 660 g ae/L, io ester, EC; 2,4-D AMINE 4, 456 g ae/L, dma salt, SL; SEE® 2,4-D LV 4, 456 g ae/L, io ester, EC; CLASS® 40A™, 456 g ae/L (3.8 lb ae/gal), dimethylamine (dma) salt, SL; CLASS LV 4™, 456 g ae/L, io ester, EC; CLASS LV 6™, 672 g ae/L (5.6 lb ae/gal), io ester, EC; 2,4-D AMINE 4-POUND, 463 g ae/L (3.86 lb ae/gal), dma salt, SL; LO VOL ESTER 4-POUND, 464 g ae/L (3.87 lb ae/gal), io ester, EC; LO VOL ESTER 6-POUND, 679 g ae/L (5.66 lb ae/gal), io ester, EC; PHENOXY 088, 333 g ai/L dma salt; STRIKE 3 ULTRA®, a mix of 2,4-D + dichlorprop + 2,4-DP at 345 + 18 + 89 g ai/L dma salt, SL.

Aventis: TILLER® EC, mix of fenoxaprop-P ethyl ester + MCPA isooctyl ester (io ester) + 2,4-D io ester at 45 g ai/L + 210 g ae/L + 69.5 g ae/L (0.375 lb ai/gal + 1.75 lb ae/gal + 0.58 lb ae/gal), EC.

BASF: WEEDMASTER®, mix of 2,4-D + dicamba at 348 + 120 g ae/L (2.9 + 1 lb ae/gal), dma salts, SL.

Dow AgroSciences: CROSSBOW™ and TURFLON™ D, mix of 2,4-D + triclopyr at 240 + 120 g ae/L (2 + 1 lb ae/gal), be ester, EC; CURTAIL™, mix of clopyralid + 2,4-D at 45.6 + 240 g ae/L (0.38 + 2 lb ae/gal), monoethanolamine and triisopropanolamine salts, SL; GRAZON P+D and TORDON™ 101 MIXTURE, mix of picloram + 2,4-D at 65 + 240 g ae/L (0.54 + 2 lb ae/gal), triisopropanolamine (tipa) salts, SL; TORDON RTU™ and PATHWAY, mix of picloram + 2,4-D at 32.4 + 120 g ae/L (0.27 + 1 lb ae/gal), tipa salts, SL.

Helena: BARRAGE™, 564 g ae/L (4.7 lb ae/gal), io ester, EC; 2,4-D AMINE #4, 459 g ae/L (3.83 lb ae/gal), dma salt, SL; 2,4-D ESTER 6, 684 g ae/L (5.7 lb ae/gal), 57.8% butyl ester + 17.5% isopropyl ester, EC; 2,4-D LV ESTER, 451 g ae/L, io ester, EC; 2,4-D LV ESTER 6, 677 g ae/L (5.64 lb ae/gal), io ester, EC; WEED RHAP® A-4D, 456 g ae/L (3.8 lb ae/gal), dma salt, SL; WEED-RHAP LV-6D, 672 g ae/L, io ester, EC; 2,4-D AMINE, 451 g ae/L, dma salt, SL.

Monsanto: CAMPAIGN® and LANDMASTER® BW, mix of glyphosate + 2,4-D at 108 + 192 g ae/L (0.9 + 1.6 lb ae/gal), isopropylamine salts, SL.

UAP-Platte: AMINE 4, 449 g ae/L (3.74 lb ae/gal), dma salt, SL; LOW VOL 4, 456 g ae/L, io ester, EC; LOW VOL 6, 672 g ae/L, io ester, EC; SALVO®, 600 g ae/L (5 lb ae/gal), io ester, EC; SAVAGE®, 95% ai (78.9% ae), dma salt, SP; CHASER®, mix of 2,4-D + triclopyr at 240 + 120 g ae/L, be esters, EC; DPD ESTER, mix of 2,4-D + dichlorprop at 226 + 226 g ae/L, io esters, EC; FOUR POWER PLUS®, mix of 2,4-D + dicamba at 480 + 60 g ae/L, dma salts, SL; MEC AMINE-D®, mix of 2,4-D + mecoprop + dicamba at 292 + 156 + 26 g ae/L, dma salts, SL; MEC-AMINE PLUS™, mix of 2,4-D + mecoprop + dicamba at 60 + 180 + 24 g ae/L (0.5 + 1.5 + 0.2 lb ae/gal), dma salts, SL; SHOTGUN® FLOWABLE, a mix of atrazine + 2,4-D at 268 + 120 g ai/L, dma salt, SL..

NuFarm: FORMULA 40, 456 g ae/L, dma and tipa salts, SL; WEEDAR® 64, 456 g ae/L, dma salt, SL; WEEDAR 64-A, 456 g ae/L, diethanolamine salt, SL; WEEDAR EMULSAMINE® E-3, 324 g ae/L (2.7 lb ae/gal), dodecylamine (47.3% ai) and tetradecylamine (11% ai) salts, EC (oil-soluble amine); WEEDONE® LV4, 456 g ae/L, be ester, EC; WEEDONE LV6, 684 g ae/L, be ester, EC; WEEDONE 638, 336 g ae/L (2.8 lb ae/gal), 2,4-D acid (13.8% ai) + be ester (24.5% ai), EC; ACTRIL DS, mix of ioxynil octanoate ester + 2,4-D ester at 100 + 600 g/L (0.83 + 5 lb/gal), EC (Africa, Americas, Asia, Australia); ENVERT® 171, mix of dichlorprop + 2,4-D at 135 + 114 g ae/L (1.125 + 0.95 lb ae/gal), be ester, EC; WEEDONE 170, mix of 2,4-D + dichlorprop at 222 + 222 g ae/L (1.85 + 1.85 lb ae/gal), be ester, EC; WEEDONE CB, mix of 2,4-D + dichlorprop at 80 + 80 g ae/L (0.67 + 0.67 lb ae/gal), be ester, EC. 2,4-D Granular; AM-40 AMINE SALT, 456 g ae/L, dma salt, SL; DRI-CLEAN, 80.5% ; DIS-SOLVE®, mix of 2,4-D + mecoprop + dichlorprop at 39 + 20 + 20% ae, dma salts, SP in water-soluble bags containing 284 or 1135 g product/bag; TRIAMINE®, mix of 2,4-D + mecoprop + dichlorprop at 156 + 156 + 156 g ae/L, dma salts, SL; TRIAMINE JET SPRAYT, mix of 2,4-D + mecoprop + dichlorprop at 2.7 + 2.7 + 2.7 g ae/L, dma salts (0.023 + 0.023 + 0.023 lb ae/gal); TRIPLET™ SF, mix of 2,4-D + mecoprop + dicamba at 292 + 156 + 26 g ae/L, dma salts (2.44 + 1.3 + 0.22 lb ae/gal), dma salts, SL; TRIPLET WSP, mix of 2,4-D + mecoprop + dichlorprop (60.2 + 24.2 + 6.02%); TRIPLET SENSITIVE, mix of 2,4-D + mecoprop + dichlorprop at 98 + 170 + 42 g ae/L, dma salts (0.82 + 1.43 + 0.35 lb ae/gal); MILLENIUM ULTRA, mix of 2,4-D + 2,4-DP + dicamba at 357 + 42 + 42 g ae/L, dma salts (3+0.375+0.375 lb ae/gal); MILLENIUM ULTRA PLUS, mix of 2,4-D + mecoprop + dichlorprop + MSMA at 156 + 156 + 156 g ae/L, dma salts, SL; VETERAN 720, mix of 2,4-D + dicamba at 226 + 119 g ae/L, dma salts (1.9 + 1.0 lb ae/ gal).

PBI/Gordon: SUPER TRIMEC®, mix of 2,4-D iso

For symbol and abbreviation definitions, see page 453.

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ester + mecoprop io ester + dicamba acid at 240 + 240 + 60 g ae/L (2 + 2 + 0.5 lb ae/gal), EC; TRIMEC SOUTHERN, mix of 2,4-D + mecoprop + dicamba at 180 + 332 + 37 g ae/L (1.5 + 2.77 + 0.31 lb ae/gal), dma salts, SL; TRIMEC 899, mix of 2,4-D + mecoprop + dicamba at 292 + 156 + 26 g ae/L (2.44 + 1.3 + 0.22 lb ae/gal), dma salts, SL; TRIMEC 992, mix of 2,4-D + mecoprop + dicamba at 292 + 156 + 26 g ae/L (2.44 + 1.3 + 0.22 lb ae/gal), dma salts, SL; TRIMEC BENTGRASS FORMULA, mix of 2,4-D + mecoprop + dicamba at 54 + 176 + 23 g ae/L (0.45 + 1.46 + 0.19 lb ae/gal), dma salts, SL; TRIMEC CLASSIC , mix of 2,4-D + mecoprop + dicamba at 243 + 130 + 25 g ae/L (2.03 + 1.08 + 0.21 lb ae/gal), dma salts, SL; TRIMEC PLUS, mix of MSMA + 2,4-D + mecoprop + dicamba at 216 + 58 + 58 + 14 g ae/L (1.8 + 0.48 + 0.48 + 0.12 lb ae/gal), dma salts, SL; TRIMEC LAF 637, mix of 2,4-D + mecoprop + dicamba at 398 + 134 + 17 g ae/L (3.35 + 1.13 + 0.14 lb ae/gal), dma salts, SL; TRIMEC CLASSIC DSC, mix of 2,4-D + mecoprop + dicamba at 25.34 + 13.75 + 2.8%; TRIMEC TURFESTER, mix of 2,4-D + mecoprop + dicamba at 125 + 125 + 30 g ae/L (1.05 + 1.05 + 0.25 lb ae/gal), iso salts, SL.

Wilbur-Ellis: AMINE 4, 456 g ae/L, dma salt, SL; L.V. 4, 456 g ae/L, io ester, EC; L.V. 6, 676.5 g ae/L (5.64 lb ae/gal), io ester, EC.

Other names: AGROTECT; AMOXONE; CHLOROXONE; CROPRIDER; DINOXOL; DORMONE; FERNESTA; HEDONAL; LAWN-KEEP; MACONDRAY; MALERBANE CEREALI; MIRACLE; PENNAMINE; PLANOTOX; PLANTGARD; TRIBUTON; WEEDATUL; WEEDTRINE-II; WEEDTROL.

Chemical family: Phenoxy, phenoxyalkanoic acid, or phenoxyacetic acid.

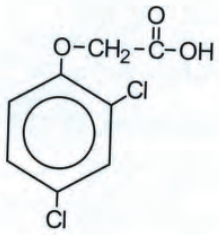
AWLN: *Acid* QV1OR* bG dG; *Be ester* GR* cG dO1VO2O4; *Dma salt* QV1OR* bG dG &1M1; *Io ester* GR* cG dO1VO5Y1&1.

CAS number: *Acid* 94-75-7; *Be ester* 1929-73-3; *Dma salt* 2008-39-1; *Io ester* 1928-43-4.

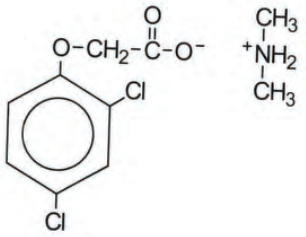
Chemical and Physical Properties

Chemical structure

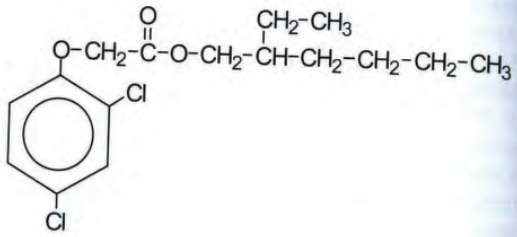
2,4-D acid



2,4-D dimethylamine salt



2,4-D isooctyl ester (2-ethylhexyl ester)



**Note: Throughout this 2,4-D entry, mention of the isooctyl ester (io ester) indicates the 2-ethylhexyl ester.

Molecular formula: *Acid* $C_8H_6Cl_2O_3$; *Butoxyethyl ester (be ester)* $C_{14}H_{18}Cl_2O_4$; *Dimethylamine (dma) salt* $C_{10}H_{13}Cl_2NO_3$; *Isooctyl ester* $C_{16}H_{22}Cl_2O_3$.

Molecular weight: *Acid* 221.04; *Be ester* 321.20; *Dma salt* 266.12; *Isooctyl ester* 333.25.

Description: *Acid and dma salt* white crystals, odorless (pure); *Be ester* viscous, colorless liquid, odorless (pure)

Density: 1.565 g/mL at 30°C

Melting point: *Acid* 135-138°C technical, 140-141°C pure; *Be ester* Liquid at room temperature; *Dma salt* 85-87°C.

Boiling point: *Acid* 160°C at 0.4 mm Hg; *Be ester* 156-162°C at 1-1.5 mm Hg, 185-190°C at 5.5-7 mm Hg.

Vapor pressure: 1.9×10^{-5} Pa(1.4×10^{-7} mm Hg) at 25°C

Stability: *Acid* Stable at MP; *Dma salt* Decomposes at MP.

Solubility

Acid

water 900 mg/L at 25°C

organic solvents g/100 mL at 25°C:

acetone 67.3	kerosene 0.08-0.28
benzene 0.94 (28°C)	isopropanol 24.8 (31°)
carbon tetrachloride 0.16	methylisobutylketone 25
diesel oil 0.08-0.28	ortho-dichlorobenzene 0.52
dioxane 81 (31°C)	toluene 0.058
ethanol 100	xylene 0.5
ethyl ether 19.3	
carbon disulfide 0.63 (29°C)	
petroleum distillate slightly soluble	

Butoxyethyl ester

For symbol and abbreviation definitions, see page 453.

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water 100 mg/L (estimated) at 20°C (ref. 12)
organic solvents at 20°C:
miscible in acetone, acetonitrile, *n*-hexane, and methanol.

Dimethylamine salt
water 796 g/L at 20°C (ref. 12)
g/100 mL at 20°C:

acetonitrile 1.06	octanol 5.41
n-hexane 0.00357	toluene 0.165
methanol >50	

Isooctyl ester
water 0.0324 mg/L

pK_a: 2.8 (ref. 12)

K_{ow}: Not available.

Herbicidal Use

2,4-D is foliar-applied and can be used as follows: POST at 0.56-2.24 kg ae/ha (0.5-2 lb ae/A) in turf; POST at 0.28-0.56 kg ae/ha (0.25-0.5 lb ae/A) in wheat, barley, oats, rye, sorghum, and sweet corn; preplant or POST at 0.28-0.56 kg ae/ha in field corn; preplant at 0.42-1.12 kg ae/ha (0.375-1 lb ae/A) in soybeans; POST at 0.28-0.67 kg ae/ha (0.25-0.6 lb ae/A) in millet; pre-harvest at 0.56-1.7 kg ae/ha (0.5-1.5 lb ae/A) in wheat; POST at 0.28-2.24 kg ae/ha in pastures and Conservation Reserve Program (CRP) land; POST at 0.56-2.24 kg ae/ha in fallow; at 22.4 kg ae/ha (20 lb ae/A) in aquatic situations; POST at 1.12-2.24 kg ae/ha in asparagus; directed-POST at 1.12 kg ae/ha in fruit trees including apples, peaches, and pears; and POST at 1.12 kg ae/ha in dormant strawberries. 2,4-D controls many broadleaf weeds including carpetweed, dandelion, cocklebur, horseweed, morningglory spp., pigweed spp., lambsquarters, ragweed spp., shepherd's-purse, and velvetleaf, with little to no activity against grasses. Aquatic weeds controlled include Eurasian water milfoil, water hyacinth, bulrush, bladderwort, and water lily.

Use Precautions

Fire hazard: Parent acid, salts, and water-based salt formulations are nonflammable. Commercial formulations of the acid may have flash points as low as 88°C (190°F) (COC). Some ester formulations have flash points as low as 190°C (374°F) (nonflammable).

Corrosiveness: Most formulated products are noncorrosive to spray equipment. Some may damage painted surfaces.

Storage stability: Most amine formulations have long storage stability and are insensitive to light and temperature. Shelf life of ester formulations varies; most retain satisfactory emulsifying properties after 3 yr.

Cleaning glassware/spray equipment: Wash with water and detergent solution. Alcohol or ketone type solvents may be used for ester formulations which may be more difficult to remove from spray tanks. Ideally, equipment should not be used for application of other pesticides or fertilizers because small amounts of residues in spray equipment can be redissolved into the next load and may cause injury if applied POST to sensitive broadleaf crops.

Incompatibilities: Ester formulations may be used in relatively hard water. Reduced weed control or precipitation may occur with amine formulations applied in hard water. Most amine formulations contain inhibitors to prevent precipitation in water containing up to 2000 ppm of dissolved salts. Certain amine formulations can be used with soluble fertilizers by pre-mixing with water, but often are incompatible with liquid fertilizer. A compatibility test should be conducted with 2,4-D products before using with other pesticides or fertilizers.

Behavior in Plants

Symptomology: Symptoms are typical of other auxin-type herbicides, and include epinastic bending and twisting of stems and petioles, stem swelling (particularly at nodes) and elongation, and leaf cupping and curling. Leaf shape and venation often appear abnormal. This is followed by chlorosis at the growing points, growth inhibition, wilting, and necrosis. Death of susceptible plants occurs slowly, usually within 3-5 wk. At low concentrations, young leaves may appear puckered and the tips of new leaves may develop into narrow extensions of the midrib.

Absorption: Plant roots absorb polar (salt) forms of 2,4-D more readily than esters, whereas the nonpolar ester forms more rapidly penetrate foliage. A rain-free period of 4 h usually is adequate for uptake and effective weed control. The ester forms tend to resist washing from the leaves and are rapidly converted to the acid once inside the plant. A significant proportion of 2,4-D accumulating in cells is due to passive diffusion of the lipid-soluble protonated form of the weak acid down a concentration gradient (5). Once inside the relatively alkaline cytoplasm, the protonated acid dissociates to the anion and is consequently trapped in the symplasm because of the low solubility of the anion in membrane lipids. An active transport system also may assist in 2,4-D transport across the plasmalemma (6). Active transport of 2,4-D may occur via the same transport system as for endogenous auxin (IAA) (9).

Translocation: Transported primarily via the symplastic pathway (including the phloem) and accumulates principally at the growing points of the shoot and root. Following root uptake, 2,4-D translocates somewhat in the transpiration stream by the apoplastic pathway. Translocation generally is slower in grasses and other tolerant species. The basis for limited translocation may be the formation of immobile complexes, reduced xylem transport, and anatomical differences among species (1).

Mechanism of action: Not completely understood but similar to that of endogenous auxin (IAA) and other auxin-type herbicides. The specific cellular or molecular binding site relevant to the action of IAA and the auxin-type herbicides has not been identified. Nevertheless, the primary action of these compounds appears to involve cell wall plasticity and nucleic acid metabolism. 2,4-D is thought to acidify the cell wall by stimulating the activity of a membrane-bound ATPase-driven proton pump. The reduction in apoplasmic pH induces cell elongation by increasing the activity of cer-

For symbol and abbreviation definitions, see page 453.

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tain enzymes responsible for cell wall loosening. Low concentrations of 2,4-D also stimulate RNA polymerase, resulting in subsequent increases in RNA, DNA, and protein biosynthesis. Abnormal increases in these processes presumably lead to uncontrolled cell division and growth, which results in vascular tissue destruction. In contrast, high concentrations of 2,4-D and other auxin-type herbicides inhibit cell division and growth, usually in meristematic regions that accumulate photosynthate assimilates and herbicide from the phloem. 2,4-D and other auxin-type herbicides stimulate ethylene evolution which may in some cases produce the characteristic epinastic symptoms associated with exposure to these herbicides (10).

HRAC/WSSA Group Designation: HRAC - O / WSSA -4.

Metabolism in plants: 2,4-D metabolism in plants occurs fairly slowly. In leaves of bladder campion (*Silene vulgaris*) and lentils, at least 63% was unmetabolized after 72 h (11). Differential 2,4-D metabolism rate can account for varying 2,4-D susceptibility among species (4). 2,4-D metabolism reactions are several and can be divided into two phases (2). Phase I reactions include hydroxylation (usually involving an "NIH shift" where the #4 Cl is displaced by a hydroxyl group and moved to the #5 or #3 carbon), decarboxylation, dealkylation, and dechlorination. Phase II reactions include conjugation of amino acids, particularly glutamate and aspartate, to the side chain, and conjugation with glucose at the hydroxylated positions.

Non-herbicidal biological properties: 2,4-D can act as a plant growth regulator, inducing rooting and blossom set when applied at low rates. It controls ripening of bananas and citrus fruits and delays preharvest dropping of some fruits. 2,4-D commonly is used in plant tissue culture as a source of auxin.

Mechanism of resistance in weeds: A biotype of wild mustard from Western Canada is resistant to 2,4-D and other auxin-type herbicides. The mechanism of resistance is not clear, but may be due to an insensitive target site (7).

Behavior in Soil

Sorption

K_{oc}: Average is 20 mL/g for the acid and dma salt, and 100 mL/g (estimated) for esters or the oil-soluble amine (12).

Transformation

Photodegradation: Minor losses in the field.

Other degradation: 2,4-D undergoes microbial breakdown in warm, moist soil. Rate of breakdown increases with increased temperature, moisture, pH, and OM content.

Persistence: Average persistence of phytotoxicity is generally 1-4 wk in warm, moist soil. Average field half-life is 10 d (12).

Mobility: 2,4-D is potentially mobile, but rapid degradation in soil and removal from soil by plant uptake minimizes leaching. Dissipation studies indicate that >95% of applied 2,4-D moves <15 cm (<6 inches). 2,4-D has moved to 30-46 cm (12-18 inches) in sandy soils in California with heavy amounts of applied water.

Volatilization: Minor (typically negligible) losses of the acid and salts in the field. Oil-soluble amines are considered least volatile. Currently registered isooctyl and butoxyethyl ester formulations are considered low-volatile esters. However, even low-volatile esters should be used with caution around or near susceptible crops or desirable plant species.

Formulation effects: See Volatilization above.

Toxicological Properties

Toxicity tests were conducted with technical grade 2,4-D acid unless otherwise indicated.

Acute toxicity

2,4-D acid technical: Oral LD_{50} male rat 764 mg/kg, female rat 639 mg/kg; Dermal LD_{50} rabbit >2000 mg/kg; 4-h Inhal. LC_{50} rat 1.79 mg/L; Skin irrit. rabbit, none; Skin sensitiz. guinea pig, no; Eye irrit. rabbit, severe; Neurotoxicity, negative.

2,4-D dimethylamine salt technical: Oral LD_{50} rat >1000 mg/kg; Dermal LD_{50} male rabbit 1122 mg/kg, female rabbit 909 mg/kg; 4-h Inhal. LC_{50} rat 3.5 mg/L; Skin irrit. rabbit, none; Skin sensitiz. guinea pig, no; Eye irrit. rabbit, severe.

2,4-D isooctyl ester technical: Oral LD_{50} rat 1045 mg/kg; Dermal LD_{50} >5000 mg/kg; 4-h Inhal. LC_{50} rat 5.7 mg/L; Skin irrit. rabbit, none; Skin sensitiz. guinea pig, yes; Eye irrit. rabbit, moderate (clearing in <72 h).

Subchronic toxicity

90-d dietary, mouse: NOEL 15 mg/kg/d.

90-d dietary, rat: NOEL 15 mg/kg/d.

90-d dietary, dog: NOEL 1 mg/kg/d.

Chronic toxicity

24-mo dietary, mouse: NOEL 5 mg/kg/d.

24-mo dietary, rat: NOEL 5 mg/kg/d.

12-mo dietary, dog: NOEL 1 mg/kg/d.

Teratogenicity

Rat: NOEL 75 mg/kg/d; not teratogenic or embryotoxic.

Rabbit: NOEL 30 mg/kg/d; not teratogenic or embrytoxic.

Reproduction

Rat: NOEL 5 mg/kg/d.

Mutagenicity

Gene mutation: Test results negative (three tests each for the acid, isooctyl ester, and dimethylamine salt.)

Structural chromosome aberration: Test results negative.

DNA damage/repair: Test results negative.

For symbol and abbreviation definitions, see page 453.

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Wildlife

2,4-D acid technical: Bobwhite quail, oral LD_{50} 500 mg/kg, 8-d dietary LC_{50} >5620 ppm; Mallard duck, 8-d dietary LC_{50} >5620 ppm; Earthworm in soil, no effect at 2 ppm; Honey bee, topical LD_{50} 1 µg/bee; Daphnia 48-h LC_{50} 25 mg/L; Bluegill sunfish 96-h LC_{50} 263 mg/L; Rainbow trout 96-h LC_{50} 377 mg/L.

2,4-D dimethylamine salt technical: Bobwhite quail, oral LD_{50} 500 mg/kg, 8-day dietary LC_{50} >5620 ppm; Mallard duck, 8-d dietary LC_{50} 5620 ppm; Daphnia 48-h LC_{50} 184 mg/L; Bluegill sunfish 96-h LC_{50} 524 mg/L; Rainbow trout 96-h LC_{50} 250 mg/L.

2,4-D isooctyl ester technical: Bobwhite quail, 8-d dietary LC_{50} >5620 ppm; Mallard duck, oral LD_{50} 663 mg/kg, 8-d dietary LC_{50} >5620 ppm; Daphnia 48-h LC_{50} 5.2 mg/L; Bluegill sunfish 96-h LC_{50} >5 mg/L; Rainbow trout 96-h LC_{50} >5 mg/L.

Use classification: General Use for all formulated products.

Synthesis and Analytical Methods

Synthesis: 2,4-D acid is prepared from 2,4-dichlorophenol and monochloroacetic acid. Salts are made by adding the appropriate amine or inorganic hydroxide to the acid. Esters are synthesized by reacting 2,4-D with the appropriate alcohols.

Purification of technical: The parent acid can be purified by recrystallization from solvents such as benzene, toluene, or xylene. Recrystallize amine salts from acetone or alcohol. 2,4-D esters are purified by vacuum distillation.

Analytical methods: The free acid may be determined in formulated products by IR spectrophotometry (absorption band 792,720 cm^{-1}). For analysis of 2,4-D formulations, see Official Methods of Analysis of the Association of Official Analytical Chemists, 11th Ed., 1970, methods 6.154-6.157, pg. 94-95. Residues in grass (ACR 71.17, Sept. 14, 1971. Dow Chemical Co.), animal tissues (ACR 71.6R. Dec. 28, 1972. Dow Chemical Co) may be determined by GC. Residues also can be determined in milk (3).

Historical: Research on 2,4-D compounds started during World War II, under wartime secrecy. Pokorny (8) described the chemical synthesis of 2,4-D in 1941. Zimmerman and Hitchcock (13) reported the potency of 2,4-D as plant hormones in 1942. Dr. E. J. Krause at the University of Chicago and Drs. P. C. Marth and J. W. Mitchell of USDA were among the earliest workers to envision the herbicidal utility of 2,4-D. English investigators included R. E. Slade, W. G. Templeman, and W. A. Secton as well as T. S. Nutman, H. G. Thornton, and J. H. Quaster, although their work was not published until 1945 due to the war. In 1944, C. L. Hamner and H. B. Tukey published on the action of 2,4-D and 2,4,5-T on bindweed. F. D. Jones described the herbicidal effects of 2,4-D in U.S. patent 2,390,941 assigned to American Chemical Paint Co. Patents on low volatile esters of 2,4-D were described in U.S. patents 2,523,227 and 2,523,228 by by W. R. Mullison assigned to Dow Chemical Co. Low volatility of the butoxyethyl ester was discovered by W. W. Allen and patented under U.S. patent 2,543,397 assigned to Union Carbide.

Information Sources

Primary industry source: Industry Task Force II on 2,4-D Research Data [participants include DowElanco, Rhône-Poulenc, Agri-Gor (Agrolinz and PBI/Gordon), and Nufarm U.S.A. (Farmland, Riverdale, and United Agri Products)].

References

1. Ashton, F. M. and A. S. Crafts. 1981. Mode of Action of Herbicides, 2nd Ed. Wiley-Interscience, New York.
2. Ashton, F. M. and T. J. Monaco. 1991. Weed Science, Principles and Practices, 3rd Ed. Wiley-Interscience, New York.
3. Bjerke, E. L. et al. 1972. J. Agric. Food Chem. 20:963.
4. Davis and Linscott. 1986. Weed Sci. 34:373.
5. Kasai and Bayer. 1991. J. Pestic. Sci. 16:163.
6. Kasai and Bayer. 1991. J. Pestic. Sci. 16:171.
7. Peniuk M. G. et al. 1992. Abstr. Weed Sci. Soc. Am. 32:55.
8. Pokorny. 1941. J. Amer. Chem. Soc. 63:1768.
9. Rubery, P. H. 1977. Planta 135:275.
10. Tittle, F. L. et al. 1990. Plant Physiol. 94:1143.
11. Wall, D. A. et al. 1991. Weed Res. 31:81.
12. Wauchope, R. D. et al. 1992. Rev. Environ. Contam. Toxicol. 123 :1.
13. Zimmerman and Hitchcock. 1942. Contrib. Boyce Thompson Inst. 12:321.

For symbol and abbreviation definitions, see page 453.

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DICHLORPROP

(±)-2-(2,4-dichlorophenoxy)propanoic acid

Nomenclature

Common name: dichlorprop (BSI, ISO, WSSA)

Manufacturers, products, and formulations

***Agriliance*:** STRIKE 3 ULTRA®, a mix of 2,4-D + dichlorprop + 2,4-DP at 345 + 18 + 89 g ai/L dma salt, SL.
Kwizda: OPTICA DP®, 600 g ai/L, EC (Austria).

NuFarm: WEEDONE® 2,4-DP, 443 g ae/L (3.7 lb ae/gal), butoxyethyl ester (be ester), EC; ENVERT® 171, mix of dichlorprop + 2,4-D at 135 + 114 g ae/L (1.125 + 0.95 lb ae/gal), be esters, EC; WEEDONE 170 BRUSH OUT, mix of 2,4-D + dichlorprop at 222 + 222 g ae/L (1.85 + 1.85 lb ae/gal), be ester, EC; WEEDONE CB, mix of 2,4-D + dichlorprop at 80 + 80 g ae/L (0.67 + 0.67 lb ae/gal), be ester, EC.

Platte: DPD ESTER, mix of 2,4-D + dichlorprop at 226 + 226 g ae/L (1.88 + 1.88 lb ae/gal), isooctyl esters (io esters), EC.

Riverdale: BRUSH KILLER 2D+2DP LOW VOL and TURF D + DP, mix of 2,4-D + dichlorprop at 219 + 224 g ae/L (1.83 + 1.87 lb ae/gal), io esters, EC; DISSOLVE®, mix of 2,4-D + mecoprop + dichlorprop at 39 + 20 + 20% ae, dimethylamine (dma) salts, SP in water-soluble bags containing 284 or 1135 g product/bag; TRIAMINE®, mix of 2,4-D + mecoprop + dichlorprop at 156 + 156 + 156 g ae/L (1.3 + 1.3 + 1.3 lb ae/gal), dma salts, SL; TRIAMINE II, mix of MCPA + mecoprop + dichlorprop at 156 + 156 + 156 g ae/L, dma salts, SL; TRI-ESTER™, mix of 2,4-D + mecoprop + dichlorprop at 168 + 168 + 240 g ae/L (1.4 + 1.4 + 2 lb ae/gal), io esters, EC; TRI-ESTER II, mix of MCPA + mecoprop + dichlorprop at 168 + 168 + 168 g ae/L, io esters, EC.

Other names: CARESINE 2; CERTROL PA; CORNOX RK; DESORMONE; 2,4-DP (USSR); HEDONAL; HEMOXONE; HERBITOX; KILDIP; MAYCLENE; POLYCLENE; RD 406; SERITOX 50; TANTIZON COMBI; TETROXONE M; VEGA; WINTERCORN EXTRA; (*RS*)-2-(2,4-dichlorophenoxy)propionic acid (IUPAC); 2-(2,4-dichlorophenoxy)propionic acid; (±)-2-(2,4-dichlorophenoxy)propionic acid.

Chemical family: Phenoxy or phenoxyalkanoic acid.

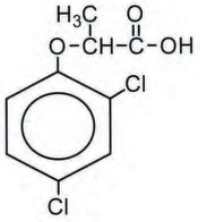
AWLN: *Acid* QVY1&OR* bG dG; *Be ester* GR* cG dOY1&VO2O4; *Dma salt* QVY1&OR* bG dG &1M1; *Io ester* GR* cG dOY1&VO5Y1&1.

CAS number: *Acid* 7547-66-2; *Be ester* 120-36-5 for *R* and *S* isomeric mixture; *Io ester* 28631-35-8.

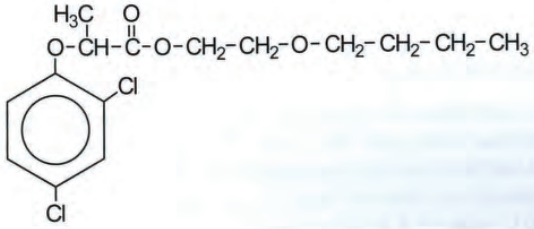
Chemical and Physical Properties

Chemical structure

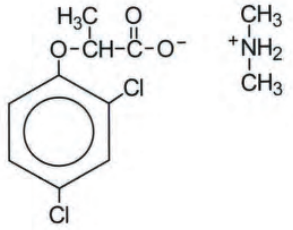
Dichlorprop acid



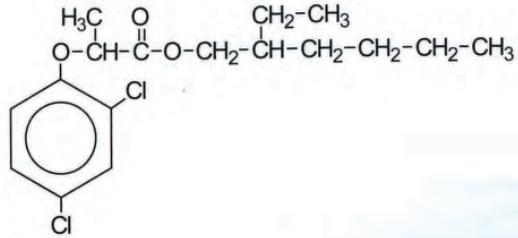
Dichlorprop butoxyethyl ester



Dichlorprop dimethylamine salt



Dichlorprop isooctyl ester



For symbol and abbreviation definitions, see page 453.

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Molecular formula: *Acid* $C_9H_8Cl_2O_3$; *Butoxyethyl ester (Be ester)* $C_{15}H_{20}Cl_2O_4$; *Dimethylamine (Dma) salt* $C_{11}H_{15}Cl_2NO_3$; *Isooctyl ester (Io ester)* $C_{17}H_{24}Cl_2O_3$.

Molecular weight: *Acid* 235.07; *Be ester* 335.23; *Dma salt* 280.15; *Io ester* 347.28.

Description: White to tan crystalline solid, faint phenolic odor.

Density: ~1.42 g/mL

Melting point: 116-117.5°C

Boiling point: Unknown.

Vapor pressure: $<1 \times 10^{-2}$ mPa (3×10^{-6} mm Hg) at 20°C

Stability: Not available.

Solubility

Acid

water 710 mg/L at 28°C

organic solvents g/100 mL at 28°C:

acetone 59.5, isopropanol 51, benzene 8.5,kerosene 0.21

ethanol 153, toluene 6.9, heptane 0.5,xylene 5.1

Butoxyethyl ester

water 50 mg/L (estimated) at 25°C (ref. 2)

pK_a: 2.86 (ref. 2)

K_{ow}: Not available.

Herbicidal Use

Dichlorprop can be applied as follows: in a spray-to-wet application at 443 g ae/100 L water (3.7 lb ae/100 gal water) for general brush control along fencerows, highways, and utility rights-of-way; directed spray-to-wet application at 1.77 kg/100 L water (14.8 lb/100 gal water) in pine plantations; POST at 12.4 kg ae/ha (11.1 lb ae/A) along railroad rights-of-way; POST at 8.3-12.4 kg ae/ha (7.4-11.1 lb ae/A) in utility rights-of-way; POST at 0.52-2.07 kg ae/ha (0.46-1.85 lb ae/A) for control of solid stands of oak or sandsage; POST at 4.14-10.4 kg ae/ha (3.7-9.25 lb ae/A) for general brush control along fencerows, highways, and utility rights-of-ways. Dichlorprop controls many hardwood and coniferous brush species.

Use Precautions

Fire hazard: Not available.

Corrosiveness: Not available.

Storage stability: Not available.

Cleaning glassware and spray equipment: Not available.

Emergency exposure: If ingested, induce vomiting.

Incompatibilities: Not available.

Behavior in Plants

Symptomology: Symptoms are typical of other auxin-type herbicides, and include epinastic bending and twisting of stems and petioles, stem swelling (particularly at nodes) and elongation, and leaf cupping and curling. Leaf shape and venation often appear abnormal. This is followed by chlorosis at the growing points, growth inhibition, wilting, and necrosis. Death of susceptible plants occurs slowly, usually within 3-5 wk. At low concentrations, young leaves may appear puckered and the tips of new leaves may develop into narrow extensions of the midrib.

Absorption/translocation: Not available.

Mechanism of action: Not completely understood but similar to that of endogenous auxin (IAA) and other auxin-type herbicides including 2,4-D. The specific cellular or molecular binding site relevant to the action of IAA and the auxin-type herbicides has not been identified. Nevertheless, the primary action of these compounds appears to involve cell wall plasticity and nucleic acid metabolism. Dichlorprop is thought to acidify the cell wall by stimulating the activity of a membrane-bound ATPase proton pump. The reduction in apoplasmic pH induces cell elongation by increasing the activity of enzymes responsible for cell wall loosening. Low concentrations of dichlorprop also stimulate RNA polymerase, resulting in subsequent increases in RNA, DNA, and protein biosynthesis. Abnormal increases in these processes presumably lead to uncontrolled cell division and growth, which results in vascular tissue destruction. In contrast, high concentrations of dichlorprop and other auxin-type herbicides inhibit cell division and growth, usually in meristematic regions that accumulate photosynthate assimilates and herbicide from the phloem. Dichlorprop and other auxin-type herbicides stimulate ethylene evolution which may in some cases produce the characteristic epinastic symptoms associated with exposure to these herbicides (1).

HRAC/ WSSA Group Designation: HRAC -O/ WSSA - 4.

Metabolism in plants: Not available.

Non-herbicidal biological properties: Not available.

Mechanism of resistance in weeds: Not available.

Behavior in Soil

Sorption

K_{oc}: Average is 1000 mL/g (estimated) for the butoxyethyl ester (2).

Transformation: Not available.

Persistence: Average field half-life is 10 d (2).

Mobility: Not available.

Volatilization: Not available.

Toxicological Properties

Toxicity tests were conducted with technical grade dichlorprop acid unless otherwise indicated.

Acute toxicity

Dichlorprop acid technical: Oral LD_{50} rat 800 mg/kg, mouse 400 mg/kg; Dermal LD_{50} mouse 1400 mg/kg; 4-h Inhal. LC_{50} NAv; Skin irrit. rabbit, none; Skin sensitiz., NAv; Eye irrit. rabbit, none.

Subchronic toxicity

98-d dietary, rat: NOEL NAv; not toxic at 12.4 mg/kg/d; slight liver hypertrophy at 50 mg/kg/d.

For symbol and abbreviation definitions, see page 453.

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Chronic toxicity

90-d dietary, rat: NOEL NAv; no effect at 12.4 mg/kg/d.

Teratogenicity: Not available.

Reproduction: Not available.

Mutagenicity: Not available.

Wildlife

Dichlorprop butoxyethyl ester technical: Bluegill sunfish 96-h LC_{50} 1.1 mg/L; Rainbow trout 96-h LC_{50} 100-220 mg/L.

Dichlorprop dimethylamine salt technical: Bluegill sunfish 96-h LC_{50} 165 mg/L.

Dichlorprop isooctyl ester technical: Bluegill sunfish 96-h LC_{50} 16 mg/L.

Use classification: General Use.

Synthesis and Analytical Methods

Synthesis: Produced by coupling 2-chloro-propionic acid with 2,4-dichlorophenol in alkaline solution. A slight molar excess of the phenol and a pH above 9 are needed for good coupling. The acid is obtained by adjusting pH to about 4.9-5.3 and extracting to remove unreacted DCP with toluene. Dichlorprop is then released by adding HCl.

Purification of technical: Recrystallize to improve color.

Analytical methods: Analytical methods are the same as for 2,4-D with the necessary changes in equivalent weights in calculations.

Historical: Introduced as a herbicide commercially in 1961 by the Boots Co. Ltd.

Information Sources

Primary industry source: Aventis Crop Protection.

References

1. Tittle, F. L. et al. 1990. Plant Physiol. 94:1143.
2. Wauchope, R. D. et al. 1992. Rev. Environ. Contam. Toxicol. 123:1.

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MECOPROP

2-(4-chloro-2-methylphenoxy)propanoic acid

Nomenclature

Common name: mecoprop (BSI, ISO, WSSA).

Manufacturers, products, and formulations

PBI/Gordon: MECOMEC 4, 480 g ae/L (4 lb ae/gal), K salt, SL; MECOMEC® 2.5, 300 g ae/L (2.5 lb ae/gal), K salt, SL; SUPER TRIMEC®, mix of 2,4-D isooctyl ester (io ester) + mecoprop io ester + dicamba acid at 240 + 240 + 60 g ae/L (2 + 2 + 0.5 lb ae/gal), EC; ENCORE® DSC, mix of MCPA + mecoprop + dicamba at 32.43 + 14.51 + 3.06% ae, acids, SP in water-soluble bags containing 908 g (2 lb) product/bag; TRIMEC SOUTHERN, mix of 2,4-D + mecoprop + dicamba at 180 + 332 + 37 g ae/L (1.5 + 2.77 + 0.31 lb ae/gal), dma salts, SL; TRIMEC 992, mix of 2,4-D + mecoprop + dicamba at 292 + 156 + 26 g ae/L (2.44 + 1.3 + 0.22 lb ae/gal), dma salts, SL; TRIMEC BENTGRASS FORMULA, mix of 2,4-D + mecoprop + dicamba at 54 + 176 + 23 g ae/L (0.45 + 1.46 + 0.19 lb ae/gal), dma salts, SL; TRIMEC BRUSH KILLER, mix of 2,4-D + mecoprop + dicamba at 226 + 240 + 41 g ae/L (1.88 + 2 + 0.34 lb ae/gal), dma salts, SL; TRIMEC CLASSIC, mix of 2,4-D + mecoprop + dicamba at 243 + 130 + 25 g ae/L (2.03 + 1.08 + 0.21 lb ae/gal), dma salts, SL; TRIMEC ENCORE, mix of MCPA + mecoprop + dicamba at 360 + 154 + 36 g ae/L (3 + 1.28 + 0.3 lb ae/gal), dma salts, SL; TRIMEC LAWN WEED KILLER, mix of 2,4-D + mecoprop + dicamba at 65 + 31 + 7.1 g ae/L (0.543 + 0.26 + 0.059 lb ae/gal), dma salts, SL; TRIMEC PLUS, mix of MSMA + 2,4-D dma + mecoprop dma + dicamba dma at 216 g ai/L + 58 + 58 + 14 g ae/L (1.8 lb ai/gal + 0.48 + 0.48 + 0.12 lb ae/gal), SL.

UAP-Platte: MEC AMINE-D®, mix of 2,4-D + mecoprop + dicamba at 292 + 156 + 26 g ae/L, dma salts, SL; MEC-AMINE PLUS™, mix of 2,4-D + mecoprop + dicamba at 60 + 180 + 24 g ae/L (0.5 + 1.5 + 0.2 lb ae/gal), dma salts, SL.

Aventis: BELGRAN, mix of ioxynil salt + mecoprop salt + isoproturon at 62 + 146 + 300 g/L (0.52 + 1.22 + 2.5 lb/gal), SL (Europe); FOXPRO D+, mix of bifenox + mecoprop p isomer + ioxynil at 300 + 260 + 92 g/L (2.5 + 2.17 + 0.77 lb/gal), salts, SL (Europe); FOXTRIL SUPER, mix of mecoprop p isomer + bifenox + ioxynil at 292 + 250 + 76.6 g/L (2.44 + 2.09 + 0.64 lb/gal), salts, SL (Europe); OXYTRIL M, mix of ioxynil + bromoxynil + mezoprop at 75 + 75 + 375 g ai/L (0.63 + 0.63 + 3.13 lb ai/gal), octanoate esters, EC (Africa).

Riverdale: MCPP-4 AMINE, 476 g ae/L (3.97 lb ae/gal), dma salt, SL; MCPP-80™ AMINE, 78% ae, dma salt, SP; DISSOLVE®, mix of 2,4-D + mecoprop + dichlorprop at 39 + 20 + 20% ae, dma salts, SP in water-soluble bags containing 284 or 1135 g product/bag; TRIAMINE®, mix of 2,4-D + mecoprop + dichlorprop at 156 + 156 + 156 g ae/L, dma salts, SL; TRIAMINE II, mix of MCPA + mecoprop + dichlorprop at 156 + 156 + 156 g ae/L, dma salts, SL; TRI-ESTER™, mix of 2,4-D + mecoprop + dichlorprop at 168 + 168 + 240 g ae/L (1.4 + 1.4 + 2 lb ae/gal), io esters, EC; TRI-ESTER II, mix of MCPA + mecoprop + dichlorprop at 168 + 168 + 168 g ae/L, io esters, EC; TRIPLET™, mix of 2,4-D + mecoprop + dicamba at 292 + 156 + 26 g ae/L (2.44 + 1.3 + 0.22 lb ae/gal), dma salts, SL; TRI-POWER®, mix of MCPA + mecoprop + dicamba at 375 + 150 + 37 g ae/L (3.13 + 1.25 + 0.31 lb ae/gal), dma salts, SL; TRI-POWER DRY, mix of MCPA + mecoprop + dicamba at 50 + 20 + 5% ae, acids, SP in water-soluble bags containing 604 g product/bag.

Other names: CAMBILENE; CMPP; COMPITOX; CORNOX PLUS; ISO-CORNOX 57; KILPROP; MALERBANE; MCPP (JMAF); mechlorprop (Denmark); MECOPEX; MEPRO; METHOXONE M; PROPONEX-PLUS; RD 4593; SPRINGCLENE 2; U46 KV-FLUID; WINTACORN EXTRA; *dl*-2-(4-chloro-2-methylphenoxy)propionic acid; (*RS*)-2-(4-chloro-*o*-tolyloxy)propionic acid (IUPAC); 2-[(4-chloro-*o*-tolyl)oxy]propionic acid; 2-(2-methyl-4-chlorophenoxy)propionic acid; (±)-2-[(4-chloro-*o*-tolyl)oxy]propionic acid.

Chemical family: Phenoxy or phenoxyalkanoic acid.

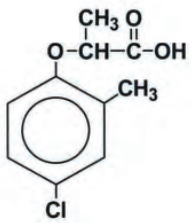
AWLN: *Acid* QVY1&R* dG b1; *Dma salt* QVY1&OR* dG b1 &1M1; *K salt* OVY1&OR* dG b1 .K.

CAS number: *Acid* 7085-19-0; *K salt* 1929-86-8.

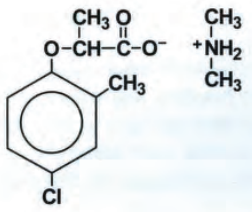
Chemical and Physical Properties

Chemical structure

Mecoprop acid



Mecoprop dimethylamine salt



For symbol and abbreviation definitions, see page 453.

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Molecular formula: *Acid* $C_{10}H_{11}ClO_3$; *Dimethylamine (Dma) salt* $C_{12}H_{18}ClNO_3$; *K salt* $C_{10}H_{10}ClKO_3$.

Molecular weight: *Acid* 214.65; *Dma salt* 259.73; *K salt* 252.74.

Description: Colorless crystalline solid, odorless.

Density: Not available.

Melting point: 94-95°C pure, ≥90°C technical.

Boiling point: Not available.

Vapor pressure: 0.31 mPa at 20 C..

Stability: Not available.

Solubility

Acid

water 620 mg/L at 20°C

Dimethylamine salt

water 660,000 mg/L at 20°C and pH 7

pK_a: 3.11 (ref. 2)

K_{ow}: 1.26 at pH 7

Herbicidal Use

Mecoprop can be applied POST at 2.24-3.36 kg ae/ha (2-3 lb ae/A) in established turf, and POST at 1.5-2.7 kg ae/ha (1.3-2.4 lb ae/A) in cereal crops. It controls several annual and perennial broadleaf weeds including chickweed spp., clover spp., plantain spp., knotweed spp., lambsquarters, pigweed spp., and ground ivy.

Use Precautions

Fire hazard: Mecoprop technical and formulated products are dry or aqueous and nonflammable.

Corrosiveness: Mecoprop acid corrodes metal in the presence of water. Solutions of the K salt do not corrode brass, iron, and mild steel at pH >8.6. Slow corrosion may occur when temperatures approach 80°C (176°F).

Storage stability: Solutions of the K salt of mecoprop are stable for several years under normal storage conditions. At low temperatures, the K salt crystallizes, but the crystals redissolve on warming.

Cleaning glassware/spray equipment: Rinse with water containing a detergent.

Emergency exposure: Symptomatic treatment and removal of poison by gastric lavage. If ingested, induce vomiting.

Incompatibilities: None known.

Behavior in Plants

Symptomology: Symptoms are typical of other auxin-type herbicides, and include epinastic bending and twisting of stems and petioles, stem swelling (particularly at nodes) and elongation, and leaf cupping and curling. Leaf shape and venation often appear abnormal. This is followed by chlorosis at the growing points, growth inhibition, wilting, and necrosis. Death of susceptible plants occurs slowly, usually within 3-5 wk. At low concentrations, young leaves may appear puckered and the tips of new leaves may develop into narrow extensions of the midrib.

Absorption: Mecoprop can be washed off the leaf surface by rain occurring soon after application. Foliar penetration rate is relatively slow. Only 40% of applied mecoprop penetrated the leaf surface of common chickweed by 72 h after application (3). Mecoprop applied as a salt is protonated in the acidic environment outside the plasmalemma, and readily penetrates the plasmalemma as the protonated acid. Once inside the cell, the more-alkaline cytoplasm causes dissociation to produce mecoprop anion which is "trapped" inside the cell due to its reduced ability to traverse the plasmalemma.

Translocation: Mecoprop is transported primarily via the symplastic pathway (including the phloem), accumulating at the growing points. Translocation rate appears to be slow as only 3, 10, and 4% of foliar-absorbed mecoprop was found in apical, basal, and root samples, respectively, of chickweed 72 h after treatment (3). Most of the absorbed mecoprop remained in the treated leaf.

Mechanism of action: Not completely understood but similar to that of endogenous auxin (IAA) and other auxin-type herbicides. The specific cellular or molecular binding site relevant to the action of IAA and the auxin-type herbicides has not been identified. Nevertheless, the primary action of these compounds appears to involve cell wall plasticity and nucleic acid metabolism. Mecoprop is thought to acidify the cell wall by stimulating the activity of a membrane-bound ATPase proton pump. The reduction in apoplasmic pH induces cell elongation by increasing the activity of enzymes responsible for cell wall loosening. Low concentrations of mecoprop also stimulate RNA polymerase, resulting in subsequent increases in RNA, DNA, and protein biosynthesis. Abnormal increases in these processes presumably lead to uncontrolled cell division and growth, which results in vascular tissue destruction. In contrast, high concentrations of mecoprop and other auxin-type herbicides inhibit cell division and growth, usually in meristematic regions that accumulate photosynthate assimilates and herbicide from the phloem. Mecoprop and other auxin-type herbicides stimulate ethylene evolution which may in some cases produce the characteristic epinastic symptoms associated with exposure to these herbicides (8).

HRAC/WSSA Group Designation: HRAC - O/ WSSA - 4.

Metabolism in plants: Mecoprop is metabolized fairly rapidly in chickweed (3). Between 63 and 94% of applied mecoprop was apparently converted to conjugated forms of the herbicide by 72 h after treatment. Over 99% of absorbed mecoprop was metabolized in barley by 3 wk after application, producing conjugates (attached at the carboxyl moiety) with amino acids, proteins, or sugars (1).

Non-herbicidal biological properties: None known.

Mechanism of resistance in weeds: Mecoprop resistance in a biotype of common chickweed has occurred in Britain (7). The mechanism of resistance may involve increased metabolism and formation of nonherbicidal conjugates (3). Resistant chickweed biotypes produce higher ethylene levels than

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in susceptibles (4). Higher ethylene levels could enhance activity of malonyltransferase. Increased malonylation of mecoprop conjugates could stimulate sequestration in the vacuole.

Behavior in Soil

Sorption

K_{oc}: Average is 20 mL/g (estimated) at pH 7 (9).

Transformation: Not available.

Persistence: Average field half-life is 21 d (9). Grasses can be planted 3-4 wk after application of mecoprop at recommended rates; however, only slight reduction in emergence occurs 1-2 wk after application.

Mobility: Not available.

Volatilization: Not available.

Toxicological Properties

Toxicity tests were conducted with technical grade mecoprop acid unless otherwise indicated.

Acute toxicity

Mecoprop acid technical: Oral LD_{50} mouse 650 mg/kg; Dermal LD_{50} rabbit 900 mg/kg; 4-h Inhal. LC_{50} NAv; Skin irrit., NAv; Skin sensitiz., NAv; Eye irrit., NAv.

Mecoprop Na salt technical: Oral LD_{50} mouse 650 mg/kg; Dermal LD_{50} rabbit 900 mg/kg.

Subchronic toxicity: Not available.

Chronic toxicity

7-mo dietary, rat: NOEL NAv; slight enlargement of the kidneys at up to 100 ppm; slight anemia and kidney enlargement at 400 ppm.

Teratogenicity: Not available.

Reproduction: Not available.

Mutagenicity: Not available.

Wildlife: Not available.

Use classification: General Use for all products.

Synthesis and Analytical Methods

Synthesis: Not available.

Purification of technical: Recrystallization.

Analytical methods: Analysis of mecoprop is by GLC of the methyl ester.

Historical: Plant growth regulating activity was described in 1953 (5) and its use as a herbicide in 1956 (6). Introduced by The Boots Co. Ltd; British patents 820,180, 822,973, and 825,875.

Information Sources

Primary industry sources: Aventis and Syngenta.

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ABBREVIATIONS AND SYMBOLS

A ..... acre(s)
ae ..... acid equivalent
ai ..... active ingredient
ALS ..... acetolactate synthase
ANSI[1] ..... American National Standards Institute. Prior to 1969 known as American Standards Association (ASA).
ATP ..... adenosine triphosphate
AWLN ..... Advanced Wiswesser Line Notation
BSI[1] ..... British Standards Institute
°C ..... degree(s) Celsius (centigrade)
CAS ..... Chemical Abstracts Service
CHO ..... Chinese hamster ovary
cm ..... centimeter(s)
COC ..... Cleveland open cup (a method of measuring flammability)
CS ..... Capsule suspension (formulation): A stable suspension of capsules in a fluid (normally intended for dilution with water before use).
d ..... day(s)
DAT ..... days after treatment
Dea, dea ..... diethanolamine
Dma, dma ..... dimethylamine (dimethylammonium)
EC ..... Emulsifiable concentrate: A liquid, homogeneous formulation to be applied as an emulsion after dilution in water.
EC_{50} ..... Effective concentration: the concentration causing a 50% response in the test system.
ECD ..... electron capture detection
EO ..... Emulsion, water in oil: A fluid, heterogeneous formulation consisting of a dispersion of fine globules of pesticide in water in a continuous organic liquid phase.
EPA ..... Environmental Protection Agency (U.S.A.)
EW ..... Emulsion, oil in water: A fluid, heterogeneous formulation consisting of a dispersion of fine globules of pesticide in an organic liquid in a continuous water phase.
°F ..... degree(s) Fahrenheit
FID ..... flame ionization detection
FPD ..... flame photometric detection
g ..... gram(s)
gal ..... gallon(s)
GC ..... gas chromatography
GLC ..... gas liquid chromatography
GR ..... Granule (formulation): A free-flowing solid product of a defined granule size range ready for use.
GUS index ... Defined as log(half-life) x (4 - log(K_{oc})). The GUS index correlates with pesticide leaching potential. Values of >2.8 indicate high leaching/runoff potential and values of <1.8 indicate low leaching/runoff potential.
h ..... hour(s)
ha ..... hectare(s)
HGPRT ..... hypoxanthine guanine phosphoribosyl transferase
HPLC ..... High pressure liquid chromatography or high performance liquid chromatography.
IAA ..... indoleacetic acid ("auxin")
ISO[2] ..... International Organization for Standardization, Organisation Internationale de Normalisation
i.d. ..... inside diameter
inhal. ..... inhalation
IR ..... infrared
irrit. ..... irritation
IUPAC ..... International Union of Pure and Applied Chemistry
JAOAC ..... Journal of the Association of Official Analytical Chemists.
JMAF ..... Japanese Ministry for Agriculture, Forestry and Fisheries.
K_d ..... Soil sorption coefficient: the ratio of sorbed pesticide to dissolved pesticide at equilibrium in a water/soil slurry.
K_f ..... Adsorption data for herbicides in soil can be expressed by the Freundlich isotherm, $x/m = K_f C^{1/n}$, where x/m is the amount (grams or moles) of herbicide (x) sorbed per weight of dry soil (m), C is the concentration of the herbicide in soil solution at equilibrium, and K_f and 1/n are empirical constants. K_f indicates the amount or extent of herbicide sorption and 1/n is the slope of the $\log_{10}$ of the equation (sorption isotherm) indicating the concentration dependence of K_f and shedding light on the adsorption mechanism. $K_d = K_f$ when $1/n = 1$.
kg ..... kilogram(s)
K_{oc} ..... Soil organic carbon sorption coefficient: calculated as K_d divided by the weight fraction of organic carbon present in the soil.
K_{ow} ..... Distribution coefficient between octanol (octan-1-ol) and water.
kPa ..... kilopascal(s)
L ..... liter(s)
lb ..... pound(s)
LC ..... liquid chromatography
LC_{50} ..... Median lethal concentration: the concentration that kills 50% of the test population.
LD_{50} ..... Median lethal dose: the dose that kills 50% of the test population.
LOD ..... limit of detection
LOEL ..... Lowest effect level: the lowest dose at which any effect was observed.
M ..... molar (moles/L)
m ..... meter(s)
MAC ..... minimum adverse concentration
MATC ..... maximum acceptable toxicant concentration
min ..... minute(s)
mg ..... milligram(s)
mL ..... milliliter(s)
mm ..... millimeter(s)
mo ..... month(s)
MPa ..... megapascal(s)
MS ..... mass spectroscopy
MTD ..... maximum tolerated dose
1/n ..... see K_f
NAv ..... not available
NEWSS ..... Northeastern Weed Science Society
nm ..... nanometer(s)
NMR ..... nuclear magnetic resonance (spectroscopy)
NOEC ..... no-effect concentration
NOEL ..... no observable effect level
NOAEL ..... no adverse effect level
OM ..... organic matter
oz ..... ounce(s)
p ..... ρ (para)
Pa ..... pascal
pH ..... $-\log_{10}$ of hydrogen ion concentration.
pK_1 ..... $-\log_{10}$ of the equilibrium constant for the reaction ML $\rightarrow$ M + L, where ML is a metal-ligand complex.
pK_a ..... $-\log_{10}$ of the acid dissociation constant.
pK_b ..... $-\log_{10}$ of the base association constant.
POST ..... postemergence
ppb ..... parts per billion by weight

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PPI ..... preplant incorporated
ppm ..... parts per million by weight
PRE ..... preemergence
psi ..... pounds per square inch (lb/inch^2)
® ..... registered trademark
s ..... second(s)
SC ..... Suspension concentrate (formulation): A stable suspension of active ingredients in a fluid intended for dilution with water before use.
SCE ..... sister chromatid exchange
sensitiz. ..... sensitization
SG ..... Soluble granule: A formulation consisting of granules to be applied as a true solution of the active ingredient after dissolving in water but which may contain insoluble inert ingredients.
SL ..... Soluble concentrate: A liquid, homogeneous formulation to be applied as a true solution of the active ingredient after dilution in water.
SP ..... Soluble powder: A powder formulation to be applied as a true solution of the active ingredient after solution in water but which may contain insoluble inert ingredients.
SWSS ..... Southern Weed Science Society
TB ..... Tablet: Solid formulation in the form of small, flat plates.
TCC ..... Tag closed cup (a method for measuring flammability).
Tea, tea ..... triethanolamine
Tipa, tipa ..... triisopropylamine
TLC ..... thin layer chromatography
™ ..... trademark
TOC ..... Tag open cup
UDS ..... unscheduled DNA synthesis
U.S. ..... United States
UV ..... ultraviolet
v/v ..... volume/volume
WG ..... Water dispersible granule: A formulation consisting of granules to be applied after disintegration and dispersion in water.
WHO ..... World Health Organization
WLN ..... Wiswesser Line Notation
WP ..... Wettable powder: A powder formulation to be applied as a suspension after dispersion in water.
WSSA ..... Weed Science Society of America
wt ..... weight
w/v ..... weight/volume
yr ..... year(s)
α ..... alpha
β ..... beta
μ ..... micro (10^{-6}), micron
> ..... greater than, more than
< ..... less than, fewer than
/ ..... per
% ..... percent

[1] American National Standards Institute, 1430 Broadway, New York, NY 10018.
[2] ISO-TC81 Secretariat, British Standards Institute, 2 Park Street, London W1A 2BS, England.

ADJUVANTS

Adjuvant Terminology Guidelines

The Adjuvant Terminology Subcommittee of the Weed Science Society of America (WSSA) has worked for several years to assign common names to adjuvants to avoid confusion and eliminate the need of mentioning trade names in *Weed Science* and other WSSA publications. Lack of standardized terminology inhibits effective communication in science and delays acceptance of results of scientific research. The goal of the subcommittee is to develop a system of standardizing adjuvant chemistry into common name terminology. The use of this terminology can be universally applied across scientific disciplines for more effective communication.

To date, only surfactants have been assigned common names. Other adjuvants such as the nonphytotoxic oils and oil-surfactant blends have not been assigned common names because of the complexity of oil specifications and because most of these products are proprietary and their exact composition is unknown. Also, no attempt has been made to assign names to proprietary mixtures of surfactant, alcohol, and water sold by agricultural cooperatives, local dealers, and industry. The exact composition of many of these is unknown and often changes.

The subcommittee first published its report in March 1975 (*Weed Science* 23:162-163). Common names were assigned to groups of surfactants within a chemistry class but not to individual surfactants. This system can be used to classify approximately 90% of the surfactants that are expected to be reported in WSSA publications.

Surfactant chemistry is complicated because many surfactants are mixtures of related materials. For example, in the manufacture of surfactants such as nonoxynol or octoxynol (see attached list for chemistries), the appropriate phenolic compound is reacted with ethylene oxide (EO) to produce a product containing a desired number of moles of EO per mole of phenol; but the typical reaction may yield homologous phenol compounds with EO chains of varying length. Further purification is either unnecessary or uneconomical, so a commercial phenolic adjuvant with 9 moles of EO per mole of phenol may actually be a blend of compounds having an average of 9 moles of EO per mole of phenol. Similarly, in the synthesis of ethoxylated alcohols, it is possible that the resulting product may be a blend of materials varying not only in degree of ethoxylation but also in alcohol chain length. Even though such surfactants may be mixtures of related materials, the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), and other organizations use single chemical names to describe these materials. The chemical names used by EPA, FDA, and others are often complex.

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