Herbicide Classification and Mode of Action

Kurt Hembree, UCCE, Fresno

Herbicides are classified into different families based according to their modes of action. The families listed below are arranged in alphabetical order, with the individual family designated by **bold-underlined** text. Herbicides currently registered in grape vineyards are written in *italicized* text.

Acetanilides

These herbicides inhibit root and shoot development. Seeds in treated soil germinate, but growth is affected during early development. Seedlings either do not emerge or emerge with a distorted growth habit. The influence on shoot and root growth is due to the affects on cell enlargement. The primary biochemical method of action is still unknown. They are effective at controlling grasses, broadleaves, and nutsedge. Herbicides in this class include metolachlor, alachlor, propachlor, and propanil.

Amides

This class inhibits the roots of germinating seedling weeds by inhibiting cell development. They are more effective at controlling grasses than broadleaf weeds. Herbicides in this class include *napropamide*, *pronamide*, and bensulide.

Devrinol® (napropamide) is registered in tree and vine crops (including grapes), and many vegetable crops. It is absorbed by roots and maintained locally. Cell division is blocked during mitosis. Growth of susceptible seedling roots is halted without malformation. The effect on roots is localized – roots not in direct contact with the herbicide are not affected. No shoot inhibition is observed. Due to photodecomposition and low soil mobility, it is mechanically incorporated, but can be incorporated with rainfall or sprinkler irrigation. Napropamide can remain active in the soil for six months.

Kerb® (pronamide) is registered in several tree and vine crops (including grapes), lettuce, and alfalfa. It is absorbed by seedling roots, but can be absorbed by foliage as well, after which it is translocated throughout the plant. There is little to no translocation when absorbed through leaves, but can kill weed seedlings less than 2" tall if mixed with a surfactant. Its mode of action is of a mitotic inhibitor. It inhibits root and shoot development, not seed germination. Pronamide is readily adsorbed to soil colloids and is not prone to leaching. It persists in the soil about six to eight weeks.

Aryloxyphenoxy Propanoic Acid and Cyclohexanediones

This class inhibits cell division of the shoot and root meristem. They are grass herbicides, selective on broadleaf crops. Herbicides in the class aryloxyphenoxy propanoic acid include *fluazifop-p-butyl*, haloxyfop-methyl, haloxyfop-R-methyl, quizalofop-p, and others and those in the class cyclohexanedione include *clethodim*, *sethoxydim*, and cycloxydim.

Fusilade DX® (fluazifop-p-butyl) is registered in numerous non-bearing tree and vine crops (including grapes). It is absorbed through the cuticle and into leaf cells where it is deesterified. The resulting acids are translocated to the meristem of the shoot and roots, where cell wall formation is inhibited. It controls only grasses and while it is very soluble, it is relatively non-mobile in the soil.

Prism® (clethodim) is registered in many non-bearing tree and vine crops (including grapes), alfalfa, garlic, onions, and tomatoes. It is absorbed through the cuticle and into leaf cells where it is deesterified. The resulting acids are translocated to the meristem of the shoot and roots, where cell

wall formation is inhibited. This herbicide controls only grasses and has a low sorption value, making it prone to leaching.

Poast® (sethoxydim) is registered in many bearing and non-bearing tree and vine crops (including grapes), alfalfa, onions, tomatoes, and others. It is absorbed through the cuticle and deesterified in the leaf. The resulting acids are translocated to the meristem of the shoot and roots, where cell wall formation is inhibited. This herbicide controls only grasses and is not prone to leaching.

Benzamides

This class inhibits root development. Broadleaf weeds are generally more susceptible than grasses. They are used as preemergence treatments. Herbicides in this class include *isoxaben* and dichlobenil.

Gallery T&V® (isoxaben) is registered in many non-bearing tree and vine crops (including grapes). It is absorbed by roots, causing cell elongation and root tip swelling. The mode of action is not known. There is no translocation when absorbed through leaves. It is non-volatile, but prone to leaching in sandy soils, due to its low sorption and relatively high solubility. It can persist up to nine months.

Bipyridinium

This class kills weeds by membrane disruption by interfering with Photosystem I (PI). They only have foliar activity and are non-selective in control. Treated plants are desiccated within several days of treatment. They are contact sprays (no translocation), so weeds must be small to be effectively controlled. Herbicides in this class include *diquat dibromide* and *paraquat*.

Diquat® (diquat dibromide) is registered in many non-bearing tree and vine crops (including grapes), aquatic weed control, alfalfa seed, and in some non-crop areas. The mode of action is the disruption of cell membranes. During PSI, diquat molecules accept electrons to form free radicals. These radicals rapidly produce a super oxide, which undergoes changes to form hydrogen peroxide. The interaction between the hydrogen peroxide and superoxide radicals interact further to form hydroxyl radicals, which quickly degrade cell membranes. It provides non-selective postemergence control of broadleaves and grasses and while it is highly soluble, it adsorbs readily to soil and does not leach.

Gramoxone Extra® (paraquat) is registered in many tree and vine crops (including grapes), non-crop, alfalfa, and on fallow ground. The mode of action is similar to diquat dibromide. During PSI, paraquat molecules accept electrons to form free radicals. These radicals rapidly produce a superoxide, which undergoes changes to form hydrogen peroxide. The interaction between the hydrogen peroxide and superoxide radicals interact further to form hydroxyl radicals, which quickly degrade cell membranes. This herbicide provides non-selective postemergence control of broadleaves and grasses. While paraquat is highly soluble, it adsorbs readily to clay colloids and does not leach.

Carbamate and Thiocarbamates

These classes inhibit cell division: the carbamates in root tips and the thiocarbamates in the shoot. The carbamates are more effective at controlling broadleaf weeds and the the thiocarbamates are effective on grasses and broadleaves. Both groups are used as preemergence herbicides. Some of the carbamate herbicides include propham, chlorpropham, barban, and phenmedipham/desmedipham. The thiocarbamates include *metham sodium*, butylate, cycloate, diallate, EPTC, pebulate, and thiobencarb.

Vapam® (metham sodium) is a preplant soil fumigant in most crops, including grapes. It is converted in moist soil within two hours of application to methylisothiocyanate, a very volatile gas. This gas is

responsible for killing germinating weed seeds. It is unclear as to the exact mode of action. Its active ingredient disappears from the soil within two to three weeks following treatment.

Dinitroaniline

This class of herbicides disrupts mitosis and microtubule formation during cell division in the root meristem. The result is a suppression of roots and enlargement of root tips. They primarily provide preemergence control of seedling grasses, but can control some broadleaf weeds. They are either very volatile or moderately volatile, depending on whether they are classified as methylanilines or sulfonylanilines. Those classified as methylanilines include *trifluralin, pendimethalin*, benefin, ethafluralin, prodiamine, dinitramine, and others. The sulfonylanilines include *oryzalin* and prosulfain.

Treflan® (trifluralin) is registered in numerous crops, including grapes. The mode of action is the prevention of microtubule formation also called the spindle apparatus and subsequent root tip swelling. It can be translocated through the plant once absorbed by the roots or shoots. Trifluralin is highly volatile and is decomposed under both aerobic and anaerobic conditions and must be incorporated.

Prowl® (pendimethalin) is registered in numerous non-bearing tree and vine crops (including grapes), garlic, cotton, and others. The mode of action is the prevention of microtubule formation and root tip swelling. It is translocated through the plant once absorbed by the roots or shoots. It is less volatile than trifluralin, but is decomposes under aerobic or anaerobic conditions and must be incorporated.

Surflan® (oryzalin) is registered in numerous bearing and non-bearing tree and vine crops (including grapes) and home gardens and landscapes. The mode of action is the prevention of microtubule formation and root tip swelling. It is translocated through the plant once absorbed by the roots or shoots. Oryzalin is the least volatile of the dinitroanilines. It can remain on the soil surface for approximately three weeks before it needs to be incorporated with rainfall or sprinkler irrigation.

Diphenyl ether

These herbicides are membrane disrupters. They have both pre- and postemergence activity and are more effective on broadleaf seedlings than grasses. They are strongly adsorbed to soil colloids and undergo little or no leaching. They also have a relatively low toxicity to mammals. Herbicides in this group include *oxyfluorfen*, acifluorfen, lactofen, and others.

Goal® (oxyfluorfen) is registered in most bearing and non-bearing tree and vine crops (including grapes), garlic, onions, and other vegetable crops. The mode of action is the oxidation of lipids and proteins, resulting in the destruction of chlorophyll, carotenoids, ultimately rupturing plant cell membranes. Oxyfluorfen does not leach and can remain on the soil surface for more than three weeks before it must be incorporated with rainfall or sprinkler irrigation. While it does not volatilize, it can undergo codistillation ("lift-off"). If the vapor drifts onto adjacent vegetation, crop injury may occur.

Imidazolinones

This class inhibits cell division within two hours of treatment, leading to a rapid inhibition of shoot and root growth. They are often referred to as ALS inhibitors, since they inhibit the production of acetolactate synthase (ALS), an enzyme essential for the formation of branched chain amino acids. They are used as postemergence herbicides, but also have extremely long soil residual properties, making crop rotation difficult. They are strongest on broadleaves, but have activity on grasses. The herbicides in this group include imazapyr, imazethapyr, imazaquin, imazamox, and imazamethabenz.

Oxadiazole
These herbicides disrupt cell membranes. They have pre- and postemergence activity and are more effective on grasses and broadleaves. They are adsorbed strongly to soil colloids and undergo little or no leaching. They are slightly toxicity to mammals. The only herbicide represented here is oxadiazon.

Phenoxy – Benzoic
These foliar herbicides are grouped together because of the similar symptoms they share. Though each may produce a different symptom characteristic on any individual plant, they have different rate responses and the symptoms generally cannot be differentiated. Epinasty is usually the end result of massive cell proliferation in various meristems. The herbicide families include:

Phenoxyacetic
2,4-D
MCPA

Phenoxy Propionic
2,4,5-TP
dichlorprop
Mecomec® (mecoprop)

Phenoxy Butyric
MCPB (various trade names)
2,4-DB (various trade names)

Benzoic Acid
Banvel® (dicamba)

Picolinic Acid
Garlon® (triclopyr)
Transline®, Stinger® (clopyralid)

Pyridazinone
These herbicides inhibit chlorophyll synthesis. They have preemergence activity on grasses, broadleaves, and select perennials. The herbicide represented by this class is *Norflurazon*.

Solicam® (norflurazon) is registered in several tree and vine crops (including grapes). It is a photosynthetic inhibitor. It is adsorbed through the roots and translocated upwards, where it inhibits carotenoids and chlorophyll formation. Injured plants show "bleaching" of the foliage. It is adsorbed to the soil colloids and does not leach appreciably. It dissipates from soils through volatilization, photodecomposition, and microbiological degradation. Rates are adjusted to match the soil texture.

Pyridine
These herbicides disrupt cell division. Root symptoms are expressed similarly to that of plants killed by the dinitroanilines. They have preemergence activity only and can remain on the soil surface without loss for at least three weeks. Herbicides in this group include *thiazopyr* and dithiopyr.

Visor® (thiazopyr) is registered in citrus and other non-bearing tree and vine crops (including grapes). It disrupts cell division during the metaphase of mitosis. As a result, microtubules are not formed in the root tip. Root tips soon become enlarged. It provides excellent preemergence control of grasses, several broadleaves, and provides nutsedge suppression. It is stable on the soil surface and not prone to leaching. It needs to be incorporated with rainfall within three weeks of application.

Substituted Urea

This class disrupts photosynthesis in the leaves of susceptible broadleaves and grasses. Most have good soil adsorption and resist leaching. Herbicides in this class include *diuron*, fenuron, monuron, chlorbromuron, neburon, norea, siduron, trimeturon, and several others.

Karmex® (diuron) is registered in tree and vine crops (including grapes), alfalfa, cotton, and non-crop. It acts by interfering with the Hill Reaction during PSII. The herbicide is absorbed by the roots and shoots and carried to the leaves in the transpiration stream. It is most effective on annual broadleaf weeds, but can control some grasses. It is readily adsorbed to soil colloids and resists leaching. It is stable on the soil surface and should be incorporated with rainfall within three weeks of treatment.

Sulfonylureas

These herbicides are active at very low rates and inhibit amino acid biosynthesis. Cell division is halted within two hours of treatment, leading to shoot and root growth inhibition. They are absorbed through either the shoots or roots. These herbicides are often referred to as ALS inhibitors, since they inhibit the production of acetolactate synthase (ALS), an enzyme essential for the formation of branched chain amino acids. They are used as postemergence herbicides, but can have long soil residual properties, making crop rotation difficult in some instances. They are strongest on broadleaves, but may have good activity on grasses. Some of the herbicides in this group include halosulfuron, rimsulfuron, sulfometuron, thifensulfuron, bensulfuron, chlorsulfuron, and sulfometuron.

Triazine

These herbicides inhibit photosynthesis. They are readily absorbed through the roots and somewhat through the leaves. The addition of a surfactant greatly enhances foliar absorption They are generally most effective on annual broadleaf weeds, but can control some grasses. These herbicides are very stable and among the least toxic to man and animals. Herbicides in this group include *simazine*, atrazine, cyanazine, hexazinone, terbutryn, metribuzin, cyprazine, and several others.

Princep® (simazine) is registered in many established tree and vine crops (including grapes) and non-crop areas. The mode of action is the interference of CO_2 fixation and the Hill Reaction during photosynthesis. It is readily carried upward to the leaves of plants in transpiration stream following root absorption and is not transported from the leaves. It accumulates in the leaves, whether applied to the soil or foliage. It is most effective on broadleaf weeds, but can control some grasses. It is readily adsorbed to soil colloids, resists leaching, and is stable on the soil surface for at least three weeks.

Glyphosate

There is only one herbicide in the family. It inhibits biosynthesis of aromatic amino acids required for plant growth. It has postemergence activity only and no soil activity. It is non-volatile, tightly adsorbed, and does not leach. The only herbicide in this class is *glyphosate*.

Roundup Ultra® (glyphosate) is registered in all tree and vine crops (including grapes). Its mode of action is in the prevention of the formation of the amino acids phenylalanine and tyrosine. The herbicide is absorbed through plant foliage and either moved to the roots or maintained in the above ground foliage. Either way, it is active at preventing protein synthesis. It provides nonselective control of annual, biennial, and perennial weeds.