University of California
Agriculture and Natural Resources
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Statewide Integrated Pest Management Program

# Preventing and Managing Glyphosate-Resistant Weeds in Orchards and Vineyards

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Weeds are managed in orchards and vineyards for a number of reasons such as reducing competition with the crop for water and nutrients; eliminating hosts of insect, nematode, and disease pests; reducing the incidence of voles, mice, gophers, and other rodents; reducing contamination of harvested fruit with weed seed or plant residues; reducing interference of weeds with pruning, harvest, and other field operations; and increasing air circulation to reduce disease incidence.

Weed management methods used in orchards and vineyards can be categorized into the following:

- Mechanical, e.g., cultivation, flaming, mowing, and mulches (sawdust and synthetic);
- Cultural, e.g., screening irrigation water, cleaning field equipment, controlling weeds on perimeters of fields and fence lines, planting weed-free covers between rows, and planting clean rootstock;
- Chemical, i.e., preemergence and postemergence herbicides; and
- Biological, e.g., releasing living organisms such as insects that specifically inhibit growth or seed production of particular weeds.

Using multiple weed management tactics helps to prevent a buildup of one or two dominant weed species that tolerate the management method employed and also helps prevent the increase of individuals within a species that are resistant to the methods used. Mechanical weed control can be the primary method of weed control in vineyards and orchards or can complement the use of herbicides and other methods. A timely cultivation often eliminates many weed escapes following an herbicide application (Figures 1 and 2). Synthetic weed fabrics can eliminate many weeds and reduce the


Photo by R. Boydston.

**Figure 1. In- and near-row cultivation in a vineyard.**


Photo by R. Boydston.

**Figure 2. In-row cultivators.**

use of herbicides but are expensive to install (Figure 3). Mulches of sawdust, plant residues, paper products, or plastic can prevent the emergence of many weeds but may harbor rodents or other pests and are expensive to maintain. Repeated mowing can be used to reduce weed seed production and generally will favor establishment of grass species.

Glyphosate is often used to manage emerged weeds within the vine or tree row. Once applied, glyphosate is tightly bound to soil and has no residual activity, so weed seeds that germinate after glyphosate is applied can emerge and establish readily. Thus, glyphosate must be used as part of an integrated and comprehensive weed management program to obtain season-long weed control to later flushes of weed emergence. Multiple applications of the same herbicide over time will select for weeds that tolerate that herbicide. These weeds may be naturally tolerant to the herbicide, or the weeds may have evolved resistance to the herbicide. Over time, the frequency of the resistant or tolerant weeds in the population will increase if the same herbicide is used repeatedly without using any other control measures or herbicides with a different mode of action. Due to the low cost of glyphosate and its effectiveness on many weeds, it is tempting for growers to eliminate other weed control practices or use of herbicides with different modes of action.

A number of herbicides with soil residual activity are labeled for use in trees and vines (Tables 1 and 2). These herbicides prevent annual weeds and sometimes perennial weeds from emerging or establishing but most often do not kill weeds that have already emerged. Combining an herbicide that has soil residual activity with glyphosate or with another postemergence herbicide can greatly extend the period of weed control and eliminate or greatly reduce the need for multiple applications of glyphosate. Herbicides kill plants by inhibiting specific physiological processes, often targeting specific enzymes or proteins in plants. The mechanism by which herbicides kill plants is termed *mode of action* or *site of action*. Using an herbicide with a different mode of action (tank mixing or rotating use) helps reduce the chance of glyphosate-resistant weed biotypes increasing in the population.

Some weed species have the ability to develop resistance to glyphosate and other herbicides more quickly than others. Weed characteristics conducive to rapid development of resistance to a particular herbicide include:

- Annual growth habit;
- High seed production;
- Relatively rapid turnover of the seedbank due to a high percentage of seed germination each year (i.e., little seed dormancy);
- Several reproductive generations per growing season (e.g., *Senecio vulgaris*);
- Extreme susceptibility to a particular herbicide; and
- High frequency of resistant gene(s) (e.g., *Lolium rigidum* and *Amaranthus* spp.).

The use of cultural practices can decrease the selective pressure for the development of herbicide-resistant weed biotypes. In general, complete reliance on herbicides for weed control enhances the occurrence of herbicide-resistant weeds. Factors that increase the likelihood of developing herbicide-resistant weeds include:

- Little or no cultivation or tillage for weed control or no elimination of weeds that escape herbicide control;
- Continuous or repeated use of a single herbicide or several herbicides that have the same mode of action;
- A high herbicide application rate relative to the amount needed for weed control; and
- Perennial cropping systems (e.g., orchard and vineyard systems and roadsides) with no crop rotation.

Photo by R. Boydston.

**Figure 3. Weed mats in blueberry rows.**

Photo by B. Hanson.

**Figure 4. Glyphosate-resistant marestail in a vineyard undervine strip.**

**Table 1. Herbicides Potentially Labeled for Use in Vineyards and Orchards.**

| Active ingredient | Trade name | MOA[1] group | MOA[1] | Weeds controlled | Soil residual activity | Uses |
|---|---|---|---|---|---|---|
| 2,4-D | many | 4 | synthetic auxin | broadleaves | limited | |
| acetic acid | WeedPharm | n/a | leaf desiccation | broadleaves and grasses | no | organic systems |
| carfentrazone | Aim | 14 | PPO inhibitor | broadleaves | no | |
| clethodim | Select | 1 | ACCase inhibitor | grasses only | no | nonbearing crops |
| clopyralid | Stinger | 4 | synthetic auxin | broadleaves | limited | |
| clove leaf oil | Matran | n/a | leaf desiccation | broadleaves and grasses | no | organic systems |
| dichlobenil | Casoron | 20 | cell wall synthesis inhibitor | broadleaves and grasses | yes | spot treatment perennials |
| diuron | Karmex | 7 | Photosystem II inhibitor | broadleaves and grasses | yes | |
| fluazifop | Fusilade | 1 | ACCase inhibitor | grasses only | no | nonbearing crops |
| flumioxazin | Chateau | 14 | PPO inhibitor | broadleaves and a few grasses | yes | |
| glyphosate | Roundup, others | 9 | EPSP synthase inhibitor | broadleaves and grasses | no | |
| glufosinate | Rely | 10 | glutamine synthase inhibitor | broadleaves and grasses | no | |
| halosulfuron | Sandea | 2 | ALS inhibitor | broadleaves, grasses, and sedges | yes | nutsedge control POST |
| indaziflam | Alion | 29 | cell wall synthesis inhibitor | broadleaves and grasses | yes | |
| isoxaben | Gallery | 21 | cell wall synthesis inhibitor | broadleaves | yes | |
| napropamide | Devrinol | 15 | very long chain fatty acids inhibitor | grasses and some broadleaves | yes | |
| norflurazon | Solicam | 12 | carotenoid biosynthesis inhibitor | broadleaves and grasses | yes | |
| oryzalin | Surflan | 3 | microtubule assembly inhibitor | broadleaves and grasses | yes | |
| oxyfluorfen | Goal | 14 | PPO inhibitor | broadleaves and a few grasses | yes | |
| paraquat | Gramoxone | 22 | Photosystem I inhibitor | broadleaves and grasses | no | |
| pendimethalin | Prowl | 3 | microtubule assembly inhibitor | broadleaves and grasses | yes | |
| pronamide | Kerb | 3 | microtubule assembly inhibitor | broadleaves and grasses | yes | |
| rimsulfuron | Matrix | 2 | ALS inhibitor | broadleaves and grasses | yes | |
| saflufenacil | Treevix | 14 | PPO inhibitor | broadleaves | limited | marestail, sharppoint fluvellin |
| sethoxydim | Poast | 1 | ACCase inhibitor | grasses only | no | |
| simazine | Princep | 5 | Photosystem II inhibitor | broadleaves and grasses | yes | |
| terbacil | Sinbar | 5 | Photosystem II inhibitor | broadleaves and grasses | yes | willowweed (*Epilobium* spp.) |
| trifluralin | Treflan | 3 | microtubule assembly inhibitor | broadleaves and grasses | yes | |

[1]Mode of Action

There are currently 21 weed species reported to have developed resistance to glyphosate around the world, and 13 of these are found in the United States. Five glyphosate-resistant biotypes have been reported in some grape production areas of California and Oregon—hairy fleabane (*Conyza bonariensis*), marestail or mare's tail (*Conyza canadensis*) (Figure 4), Italian ryegrass (*Lolium multiflorum*), rigid ryegrass (*Lolium rigidum*), and junglerice (*Echinochloa colona*).

**Table 2. Herbicides Labeled for Use in Grape Vineyards and Orchards (Citrus, Nuts, Pome Fruits, and Stone Fruits).[1]**

| Active ingredient | Common product name | Citrus | Grape | Nuts | | | | | | Pome fruits | | Stone fruits | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Almond | Chestnut | Hazelnut | Pecan | Pistachio | Walnut | Apple | Pear | Apricot | Cherry | Nectarine | Peach | Plum | Prune |
| **Time of application to weeds: PRE** | | | | | | | | | | | | | | | | | |
| dichlobenil | Casoron | | | | | | | | | | | | | | | | |
| diuron | Karmex | | | | | | | | | | | | | | | | |
| indaziflam | Alion | | | | | | | | | | | | | | | | |
| isoxaben | Gallery | NB | | NB | | | NB | NB | | | | | | | | | |
| napropamide | Devrinol | | | | | | | | | | | | | | | | |
| norflurazon | Solicam | | | | | | | | | | | | | | | | |
| oryzalin | Surflan | | | | | | | | | | | | | | | | |
| pendimethalin | Prowl | | | | | | | | | | | | | | | | |
| pronamide | Kerb | | | | | | | | | | | | | | | | |
| saflufenacil | Treevix | | | | | | | | | | | | | | | | |
| simazine | Princep | | | | | | | | | | | | | | | | |
| terbacil | Sinbar | | | | | | | | | | NB | NB | NB | | | NB | |
| trifluralin | Treflan | | | | NB | NB | | | | | NB | | NB | | | | |
| **Time of application to weeds: PRE/POST** | | | | | | | | | | | | | | | | | |
| flumioxazin | Chateau | NB | | | | | | | | | | | | | | | |
| halosulfuron | Sandea | | | | | | | | | | | | | | | | |
| oxyfluorfen | Goal | NB | | | | | | | | | | | | | | | |
| **Time of application to weeds: POST** | | | | | | | | | | | | | | | | | |
| 2,4-D | | | | | | | | | | | | | | | | | |
| acetic acid | WeedPharm | | | | | | | | | | | | | | | | |
| carfentrazone | Aim | | | | | | | | | | | | | | | | |
| clethodim | Select | NB | NB | NB | NB | NB | NB | NB | NB | NB | NB | NB | NB | NB | NB | NB | NB |
| clopyralid | Stinger | | | | | | | | | | | | | | | | |
| diquat | Reglone | NB | | NB | | | NB | NB | | | | | | | | | |
| fluazifop | Fusilade | NB | NB | NB | NB | NB | | NB | NB | NB | NB | NB | NB | NB | NB | NB | NB |
| glyphosate | Roundup | | | | | | | | | | | | | | | | |
| glufosinate | Rely | | | | | | | | | | | | | | | | |
| paraquat | Gramoxone | | | | | | | | | | | | | | | | |
| pyraflufen | Venue | | | | | | | | | | | | | | | | |
| rimsulfuron | Matrix | | | | | | | | | | | | | | | | |
| sethoxydim | Poast | | | | | | | | | | | | | | | NB | NB |

[1]Shaded, labeled; white, not labeled; NB, nonbearing only

## STRATEGIES TO PREVENT AND SLOW DEVELOPMENT OF HERBICIDE RESISTANCE

Growers should monitor fields for weed escapes and determine if escapes are multiple species or a single species. If there is a mixture of species, the problem is more likely related to environment or poor application. If escapes are primarily a single species, if herbicides previously controlled the species, and if a single herbicide has been used repeatedly, the weed is more likely to be resistant. Do not respray suspected resistant weeds with the same herbicide. Collect samples of the weed and have a university extension specialist or crop consultant confirm resistance.

Elimination of weed seed production is the key to successful weed management and should be practiced even if resistant weeds are not present. In the event that herbicide resistance is suspected, efforts to stop weed seed production become even more important. If an herbicide-resistant species is identified and confirmed, keep the weed from producing seed and clean field equipment to prevent spreading the weed from one field to another. Begin using cultivation, mowing, or herbicides with a different mode of action to prevent the resistant species from flowering and producing seed.

Prevention is the most effective and economical method to reduce the threat of glyphosate-resistant weeds. To prevent development of glyphosate resistance, several important steps need to be considered including:

Photo by B. Hanson.

**Figure 5. Capay Valley, California, vineyard spray strips.**

1. If glyphosate resistance is not present, use preemergence treatments followed by tank mix of post products. Also consider use of other nonselective herbicides such as glufosinate or paraquat with PPO inhibitors for burndown control.

2. To delay resistance from developing, use higher glyphosate rates and do not cut the rate. The resistance is likely to be polygenic (i.e., caused by several factors, not just one genetic mutation), and that requires higher rates. This is contrary to other situations when growers are often asked to cut the rate and reduce selection pressure.

3. If glyphosate resistance is present, growers may continue to use glyphosate but should mix it with other herbicides that are effective on the resistant weeds. Another alternative is to use a different herbicide program.

4. The level of glyphosate resistance is usually lower when weeds are very small. If continuing to use glyphosate in orchards or vineyard with resistant weeds, then tank mix glyphosate with other herbicides and make the application when the weeds are small.

5. Use other means to manage weeds such as cultivation and mowing in orchards. (See Cultivation, Mowing, and Other Nonchemical Control Methods below.)

6. And, of course, do not let weeds go to seed.

## CULTIVATION, MOWING, AND OTHER NONCHEMICAL CONTROL METHODS

Cultivation can be extremely helpful in preventing a shift to species that are tolerant of herbicides or other practices. Small seedlings of many weeds are easily controlled with cultivation. Cultivation equipment used in orchards and vineyards includes narrow under-vine rototillers, small disk harrows, and a wide assortment of tools designed to cut weeds off just under the soil surface. Like other weed management practices, overuse of cultivation may increase cultivation-resistant species, including perennial weeds. Cultivation equipment must be properly set to make sure it does not damage roots or tree trunks. Shields around tires and implements help minimize aboveground damage to tree trunks.

Permanent sod strips are often used in vineyards and orchards to improve trafficability and reduce dust (Figure 5). They also prevent establishment of some weedy species but must be well-managed with mowing to prevent excessive water use. Flame weeding is occasionally used to suppress weeds in orchards and vineyards. As with all weed management techniques, overuse will result in a species shift and, in the case of flame weeding, proliferation of grasses and perennial weeds. Flame weeding is most effective in late afternoon or when sunlight is bright and air temperatures are high. Alternatives to open flame weeders are infrared heaters and steam weeders that use propane to generate heat.

This publication is available online at www.ipm.ucdavis.edu/PDF/PUBS/peachey-managingglyphosateresistance.pdf. Published October 2011. For more information about pests and pest management, visit the University of California Statewide IPM Program Web site at www.ipm.ucdavis.edu.