

Preventing and Managing Glyphosate-Resistant Weeds in Orchards and Vineyards

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 groups:

- mechanical (e.g., cultivation, flaming, mowing, and mulches of sawdust and synthetic material)
- 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 (e.g., preemergence and postemergence herbicides)

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Figure 1. In- and near-row cultivation in a vineyard.
Photo: R. Boydston.



Figure 2. In-row cultivators. Photo: R. Boydston.



Figure 3. Weed mats in blueberry rows. Photo: R. Boydston.

- 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. It 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 it can complement the use of herbicides and other methods. A timely cultivation often eliminates many weed escapes following an herbicide application (figs. 1 and 2). Synthetic weed fabrics can eliminate many weeds and reduce the use of herbicides, but they are expensive to install (fig. 3). Mulches of sawdust, plant residues, paper products, or plastic can prevent the emergence of many weeds, but they may harbor rodents or other pests and are expensive to maintain. Repeated mowing can be used to reduce weed seed production, and generally it will favor the establishment of grass species.

Glyphosate is often used to manage emerged weeds within the tree or vine 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 of

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 of 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. The mechanism by which herbicides kill plants is termed *mode of action* or *site 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 they 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. Using an herbicide with a different mode of action (tank mixing or rotating use) helps reduce

Table 1. Modes of action, weed control spectrum, and soil residual activity of herbicides labeled for use in vineyards and orchards

Active ingredient	Trade name	MOA* group	MOA*	Weeds controlled	Soil residual activity	Uses
2,4-D	multiple names	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	ACCCase 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	
fluzifop	Fusilade	1	ACCCase 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	marestalk, sharpshoot fluvellin
sethoxydim	Poast	1	ACCCase 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 (<i>Epilobium</i> spp.)
trifluralin	Treflan	3	microtubule assembly inhibitor	broadleaves and grasses	yes	

Notes: Check herbicide labels carefully to determine whether the herbicide is labeled for use in your area, for your crop, and for weeds that will be controlled.

*Mode of action: see the Weed Science Society of America (WSSA) website, <http://wssa.net/wp-content/uploads/WSSA-Mechanism-of-Action.pdf>, for a brief description of above-listed modes of action.

Table 2. Herbicides labeled for use in citrus, nut, pome fruit, and stone fruit orchards and vineyards

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																
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
glyphosate	Roundup																
glufosinate	Rely																
paraquat	Gramoxone																
pyraflufen	Venue																
rimsulfuron	Matrix																
safinylfenacil	Treevix																
sethoxydim	Poast																NB NB

KEY
 Shaded grey= labeled
 White = not labeled
 NB = nonbearing only

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 weed seed in the soil 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
- 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 promotes 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
- perennial cropping systems (e.g., orchard and vineyard systems and roadsides) with no crop rotation
- There are currently 24 weed species reported to have developed resistance to glyphosate around the world, and 14 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*), mare's tail or mare's tail (*Conyza canadensis*) (fig. 4), Italian ryegrass (*Lolium multiflorum*), rigid ryegrass (*Lolium rigidum*), and junglerice (*Echinochloa colona*).
- 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

Figure 4. Glyphosate-resistant mare's tail in a vineyard under vine strip.

Photo: B. Hanson.



Figure 5. Vineyard spray strips, Capay Valley, California. Photo: B. Hanson.

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 seed from surviving weeds and have a university extension specialist or crop consultant test for 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 the development of glyphosate resistance, several important steps need to be considered, including
 1. If glyphosate resistance is not present, use preemergence treatments followed by a tank mix of postemergence products. Also consider using other nonselective herbicides such as glufosinate or paraquat tank mixed with PPO inhibitor herbicides. These herbicides (also known as burndown herbicides) kill plants on contact within a few hours or days.
 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 genetic changes in the plant, 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 or combination of herbicides that do not include glyphosate.
 4. The level of glyphosate resistance is usually lower when weeds are very small. If continuing to use glyphosate in orchards or vineyards 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 the section “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 weed control 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 (see Lanini et. al. 2011 for a description of cultivation equipment). Like in the case of 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 trunks. Shields around tires and implements help minimize aboveground damage to trunks.
- Permanent sod strips are often used in orchards and vineyards to improve trafficability and reduce dust. They also prevent establishment of some weedy species, but they must be well managed with mowing to prevent excessive water use. Flame weeding with propane burners 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 the late afternoon or when sunlight is bright and air temperatures are high. Alternatives to open flame propane weeders are infrared heaters and steam weeders that use propane to generate heat.

REFERENCES

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