Planning for herbicide-resistance management in orchards and vineyards of California

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Weed management in cropping systems and non-crop areas today is at a crossroads because the traditional approach to control weeds with herbicides is challenged by environmental, economic, and social concerns. Further, widespread development of herbicide-resistance has also been observed. Herbicide resistance is not a new phenomena, in fact, the first case of a herbicide-resistant weed was reported as early as 1957 when spreading dayflower (*Commelina diffusa*) developed resistance to 2,4-D in Hawaii. Since then, 183 species of weeds and 307 biotypes have developed resistance to different classes of herbicides. Further, some weeds have developed resistance to multiple classes of herbicides. Therefore, it is an established fact that cropping systems that rely solely on chemical control may be faced with the challenge of development of herbicide resistant weeds. As agriculture in California faces stricter environmental regulations, there may be fewer herbicides available. A management plan is, therefore, needed to prevent or delay the onset of herbicide-resistance in weeds. An integrated weed management program supplemented by a good resistance management strategy is necessary for the sustainability of orchards and vineyards in California.

What is herbicide resistance?

Herbicide resistance is the inherited ability of a crop or weed biotype to survive an herbicide application to which the original population was susceptible. In other words, it is the capability of the weeds to survive and grow at herbicide dosages many times greater than usually needed for control of that species. Within a population of the same species, some plants can be resistant whereas, some can be susceptible to a certain herbicide. For example, Figure 1 shows two horseweed or marestail (*Conyza canadensis*) plants growing next to each other. They were sprayed at the same time with the same herbicide, but one plant is dying whereas the other shows no injury symptoms. If the same herbicide continues to be applied year after year to the site where these weeds were found, it is very likely to be dominated by the offspring of any resistant individuals, thereby creating a 'resistant' population.

Figure 1. A pair of horseweed plants showing resistance and susceptibility to an herbicide application.

Herbicide resistance should not be confused with weed species shifts. Some weeds have a natural tolerance to certain herbicides. Application of those particular herbicides will not provide control of these tolerant species and ultimately they will become the dominant weeds at that site. In other words, a species shift has occurred. The population of the species that are controlled with the herbicides has been eliminated or reduced to be replaced or dominated by a population of tolerant species.

Herbicide resistance should not be confused with herbicide failure. Several conditions are necessary for an herbicide to be effective. For example, the sprayer should be correctly calibrated, the pH of the water in the spray tank should not be too low or too high, the application rate should be according to recommendations, the environmental conditions (humidity, temperature, moisture, cloud cover, wind speed etc.) at the time of application should be appropriate, and above all the size and growth stage of the weed should be taken into consideration. Weeds are most susceptible to herbicides at the seedling or early stage of growth. Herbicide applications at later growth stages may not provide adequate control.

How can herbicide-resistance be prevented?

Rotate herbicides. Application of herbicides with the same mode of action year after year should be avoided. The Weed Science Society of America (WSSA) has classified herbicides into different groups according to their mode of action. Fortunately, we have herbicides of several different modes of action registered for use in California orchards and vineyards. However, areas with groundwater regulations may be restricted to certain herbicides. Nevertheless, we have several choices that can help us avoid the continuous use of herbicides with the same mode of action or in the same color group as shown in Table 1 and Table 2. The tables provide a list of herbicides currently registered for use in tree fruits (peaches, plums, and nectarines) and grapes and in California, their mode of action, and their common and trade names. The table also provides a list of weeds that are known to have developed resistance in California and in other states. As it can be seen in the table, weeds that have developed resistance to these herbicides in other states are also common weeds in California orchards and vineyards. Thus, care should be taken in applying those herbicide groups to which the weed species have already developed resistance elsewhere. Tank mixing herbicides with different modes of action can also be a strategy. However, care should be taken in choosing the appropriate mixes and not using the same mixes year after year.

Monitor orchards and vineyards. It is very important to monitor the orchard and vineyard and keep a record of problem spots and problem weeds. If herbicide-resistance is suspected, this should be confirmed immediately and the strategy to control such species should be altered so that the problem does not grow out of hand. It is important not to let these weeds produce seeds. Monitoring also provides an idea of the success of the weed control strategy and helps determine weed escapes.

Avoid introduction of weed seeds. Weed seeds can be introduced into the orchard and vineyard through irrigation water and contaminated field equipment. Keep irrigation systems free of weeds and weed seeds. Clean field equipment after it has been used in weed infested areas or areas suspected with herbicide-resistant weeds. Management of wind disseminated weed seeds of certain species, e.g. sunflower family is a problem in orchards and vineyards (Figure 2). Although it may not be possible to completely prevent the introduction of wind disseminated weed seeds, introduction and spread of these species can be reduced if the field margins and surrounding vicinities are kept free of weeds. For example, horseweed belongs to the sunflower family and each plant can produce about 200,000 seeds that can travel up to a quarter mile with the wind. Further,

this weed has developed resistance to glyphosate in some areas of Central California. Horseweed is often seen growing in field margins, roadsides, and canal banks. Therefore, the seeds of this weed can easily blow into the orchard and vineyard if left uncontrolled in these areas.

Figure 2. Infestation of horseweed in an orchard and a vineyard

Incorporate other control methods. Other cultural, mechanical, and biological weed control methods should be incorporated in a orchard and vineyard weed management plan. Examples include cultivators, plows, flamers, weeder geese etc.

What to do if herbicide-resistance is suspected?

It is most important to confirm if a weed has developed resistance or if it is merely an escape. Collect seeds from the suspected plant and contact your Farm Advisor or PCA so that they can test and confirm whether the plant has developed herbicide-resistance. Do not continue spraying the field with a higher rate of the herbicide. Use an herbicide with a different mode of action or a different method of control.

References:

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Table 1. Examples of herbicides registered in peaches, plums, and nectarines in California, their classification, and known resistant weeds

Group No.[1]	Mode of Action	Crop	Common Name	Trade Names[2]	Known resistant weeds in CA	Known resistant weeds in other states[3]
1	ACCase inhibitor	Peach, Plum, Nectarine	Fluazifop-P-Butyl Clethodim Sethoxydim	Fusilade Prism Poast	Little seed canarygrass, barnyardgrass, late watergrass,	Wild oat, Smooth crabgrass, Large crabgrass, Italian ryegrass, Perennial ryegrass, Itchgrass, Johnsongrass
3	Microtubule assembly inhibitor	Peach, Plum, Nectarine	Oryzalin Pendimethalin Prodiamine Pronamide Thiazopyr Trifluralin	Surflan Prowl Barricade Kerb Visor Treflan	-	Palmer amaranth, Wild oat, Goosegrass, Annual bluegrass, Green foxtail, Johnsongrass
4	Synthetic auxin	Peach, Nectarine	2,4-D	2,4-D, Envy, Saber	-	Field bindweed, Spreading dayflower, Wild carrot,
5	Photosystem II inhibitor	Peach, Plum, Nectarine	Simazine	Princep	-	Common groundsel, Yellow foxtail, Ladysthumb, Annual bluegrass, Barnyardgrass, Horseweed, Common lambsquarters, Common ragweed, Smooth pigweed,
7	Photosystem II inhibitor (different binding behavior than group 5)	Peach	Diuron	Direx, Karmex	-	Redroot pigweed, Powell amaranth, Horseweed,
9	EPSP synthase inhibitor	Peach, Plum, Nectarine	Glyphosate	Roundup, Touchdown	Rigid ryegrass, horseweed	Palmer amaranth, common ragweed, Italian ryegrass
12	PDS inhibitor	Peach, Plum, Nectarine	Norflurazon	Solicam	-	-
14	Protox inhibitor	Peach, Plum, Nectarine	Oxyfluorfen Flumioxazin	Goal Chateau	-	Common ragweed
15	Long-chain fatty acid synthesis inhibitor	Peach, Plum, Nectarine	Napropamide	Devrinol	-	-
17	Unknown	Peach, Plum	MSMA	Target		
20	Cell wall synthesis inhibitor at site A	Peach, Plum, Nectarine	Dichlobenil	Casoron	-	-
21	Cell wall synthesis inhibitor at site B	Peach, Plum, Nectarine	Isoxaben	Gallery	-	-
22	Photosystem I electron diverter	Peach, Plum, Nectarine	Paraquat	Gramoxone	-	Goosegrass, horseweed, American black nightshade
26	Unknown	Peach	Pelargonic acid	Scythe	-	-

[1]Herbicide groups as described by the Weed Science Society of America; Avoid using herbicides from the same group year after year to prevent resistance
[2]Examples of some trade names; not a complete list
[3]Examples of some resistant weeds; not a complete list

Table 2. Examples of herbicides registered in grapes in California, their classification, and known resistant weeds

Group No.[1]	Mode of Action	Common Name	Trade Names[2]	Known resistant weeds in CA	Known resistant weeds in other states[3]
1	ACCase inhibitor	Fluazifop-P-Butyl Clethodim Sethoxydim	Fusilade DX Prism Poast	Little seed canarygrass, barnyardgrass, late watergrass,	Wild oat, Smooth crabgrass, Large crabgrass, Italian ryegrass, Perennial ryegrass, Itchgrass, Johnsongrass
3	Microtubule assembly inhibitor	Oryzalin Pendimethalin Trifluralin	Surflan Prowl Treflan	-	Palmer amaranth, Wild oat, Goosegrass, Annual bluegrass, Green foxtail, Johnsongrass
4	Synthetic auxin	2,4-D	2,4-D	-	Field bindweed, Spreading dayflower, Wild carrot,
5	Photosystem II inhibitor	Simazine	Princep	-	Common groundsel, Yellow foxtail, Ladysthumb, Annual bluegrass, Barnyardgrass, Horseweed, Common lambsquarters, Common ragweed, Smooth pigweed,
7	Photosystem II inhibitor (different binding behavior than group 5)	Diuron	Karmex	-	Redroot pigweed, Powell amaranth, Horseweed,
9	EPSP synthase inhibitor	Glyphosate	Roundup, Touchdown	Rigid ryegrass, horseweed	Palmer amaranth, common ragweed, Italian ryegrass
10	Glutamine synthase inhibhitor	Glufosinate	Rely	-	-
14	Protox inhibitor	Oxyfluorfen Flumioxazin	Goal Chateau	-	Common ragweed
15	Long-chain fatty acid synthesis inhibitor	Napropamide	Devrinol	-	-
20	Cell wall synthesis inhibitor at site A	Dichlobenil	Casoron	-	-
21	Cell wall synthesis inhibitor at site B	Isoxaben	Gallery	-	-
22	Photosystem I electron diverter	Paraquat	Gramoxone	-	Goosegrass, horseweed, American black nightshade

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