Herbicide-Resistant Weeds: Preventative Management Tactics in Citrus

Sonia Rios
UCCE Subtropical Horticulture Farm Advisor
Riverside/San Diego Co.

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Introduction

• Reasons for vegetation management

  - Reduce safety hazards
    - Line-of-site/visibility
    - Remove fire hazards
    - Remove habitat for undesirable wildlife

  - Prevent the disruption of services
    - Transportation of goods
    - Utilities
Strategies for managing vegetation

• Mechanical
  • i.e. mowing, pruning

• Cultural
  • i.e. controlled burning, fertilizing/liming, mulching

• Chemical
  • i.e. tree growth regulators
  • i.e. herbicides
Herbicides can fail

- Weed Biology
- Life form
  - i.e. Broadleaves vs. grasses
- Morphology
  - i.e. Leaf surface area, angle and texture
- Growth and development
  - i.e. Plant size, plant maturity, plant responses to stress
- Genetics
  - Development of herbicide resistance
Herbicides can fail if...

- Environmental/Meteorological
  - Soil
    - Clay, OM can make herbicides unavailable
    - In less adsorptive soils, leaching can occur
    - Slope can lead to erosion or drainage
  - Wind
    - Spray drift
    - Drought stress
  - Temperature
    - Plant affects
      - Plant growth rate
      - Cuticle development/herbicide absorption
      - Water/herbicide translocation
    - Herbicide affects
      - Volatilization
      - Degradation
Horseweed Biology

- A close relative – horseweed or mare’s tail (*Cnaya canadensis*) has widespread glyphosate resistance
- wind-dispersed seeds that travel up to 3 miles and carry the herbicide resistance in them to new places.
Hairy fleabane Biology

- Resistance to the two most commonly used herbicides – glyphosate (Roundup) and paraquat - is widely reported in California
<table>
<thead>
<tr>
<th>Hairy fleabane growth stage and lb ai/A for good control</th>
<th>Horseweed growth stage and lb ai/A for good control</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-6 leaf = 0.5</td>
<td>5-8 leaf = 1.0</td>
</tr>
<tr>
<td>7-12 leaf = 1.0</td>
<td>11 leaf to 4” bolted = 2.0</td>
</tr>
<tr>
<td>13-19 leaf = 1.5</td>
<td>4” to 12” bolted = 4.0</td>
</tr>
<tr>
<td>20-21 leaf = 2.0</td>
<td></td>
</tr>
<tr>
<td>&gt;25 leaf = erratic</td>
<td></td>
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</tbody>
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Prather, UC KAC 1999 and Shrestha et. al., UC KAC
Palmer Amaranth Biology

- **Summer Annual Dicot**
  - *C₄* plant (Wang et al. 1992)

- **38 species of *Amaranthus* in U.S, 75 Worldwide** (Ward et al. 2013)

- **Rapid growth, up to 1-2 in. a day**
  - (Klingaman and Oliver 1994)

- **Genetic Diversity - Dioecious obligate outcrosser** (Franssen et al. 2001)

- **Traits are passed through pollen**
  - (Sosnoskie et al. 2012)

- **Prolific seed producers** — 200,000-600,000 seeds per female plant
  - (Keeley et al. 1987)
• Glyphosate-resistant (GR) populations of Palmer amaranth have been confirmed throughout the southeast U.S. since 2005 (Culpepper & Sosnoskie)

• Since 2012, growers in California’s San Joaquin Valley (SJV) have observed poor control of Palmer amaranth in glyphosate-tolerant corn (*Zea mays* L.) and cotton (*Gossypium hirsutum* L.).
However, it is not known if these are cases of GR populations OR if these are cases of escapes due to glyphosate applications being made later at more tolerant stages of the weed - Poor application?

Do we have GR Palmer amaranth in CA?
Border and roads become the primary location for weeds.
prevent movement of weed-contaminated amendments, soil and water

avoid overirrigation
minimize soil disturbance
preemergence herbicides
solarization
mulch

cultivation
dense plantings
flaming
mulch
postemergence herbicides

seed dispersal
seed germination
seedling emergence

seed production
seed head

flowers
flower development

maturing weed

last control opportunity before seed production

weed growth

cultivation
hand-hoeing
hand-pulling
maintain mulch
mowing
postemergence herbicides
WEED THRESHOLDS???
Weed density

Grape Yield (Kg)

No effect on time to harvest or grape quality
Caution: This was a flood irrigated vineyard.
No effect on time to harvest
The CWPC in vineyards are the establishment years. Established vineyards in the Valley have a higher threshold for weeds.
The bottom line:

It’s critical to maintain a weed-free environment around young vines for at least 2 years after planting to aid growth and production.

Kurt Hembree, UCCE, Fresno County - May 4, 2011
As of 2012, 396 herbicide-resistant biotypes (worldwide) across 210 species
Horseweed, also called mare's tail

Spread of resistant weeds in the US
Number of glyphosate-resistant species per state

<table>
<thead>
<tr>
<th>Color</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown</td>
<td>7</td>
</tr>
<tr>
<td>Dark Brown</td>
<td>6</td>
</tr>
<tr>
<td>Medium Brown</td>
<td>5</td>
</tr>
<tr>
<td>Orange</td>
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</tr>
<tr>
<td>Light Yellow</td>
<td>2</td>
</tr>
<tr>
<td>White</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Pioneer hi-bred international, spring 2012
What is Herbicide Resistance?

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Herbicide Resistance WSSA Definitions

"Herbicide resistance is the inherited ability of a plant to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type. In a plant, resistance may be naturally occurring or induced by such techniques as genetic engineering or selection of variants produced by tissue culture or mutagenesis."

"Herbicide tolerance is the inherent ability of a species to survive and reproduce after herbicide treatment. This implies that there was no selection or genetic manipulation to make the plant tolerant; it is naturally tolerant."
Herbicide Resistance Defined

Herbicide resistance can be defined as the acquired ability of a weed population to survive a herbicide application that previously was known to control the population. The number of herbicide-resistant individuals in the population changes over time.

Year 1 → Year 2 → Later years

Herbicide tolerance is the inherent ability of a species to survive and reproduce after herbicide treatment. There has been no selection acting on the tolerant weed species, and there has been no change in the weed species lack of response to the herbicide over time.

The number of herbicide-tolerant individuals is not affected directly by the herbicide.

Year 1 → Year 2 → Later years
Herbicide Resistance: Basic Principles

Herbicide resistance is the result of naturally occurring processes.

Herbicide-resistant individuals or biotypes* are present naturally within the weed population at very low frequencies. These individuals have a herbicide resistance mechanism that allows them to survive the application of a herbicide.

Weed control failures do not automatically mean that the weeds are herbicide-resistant.

* Biotypes are plants within a species that have biological characteristics that are not common to the population as a whole.

Resistance is heritable. It can be passed from one generation to the next.
Selection by Herbicides Changes the Population Over Time

**Example**

Year 2

1 in a million resistant to a herbicide

Year 2 begins with more resistant weeds
Selection by Herbicides Changes the Population Over Time

**Example**

Year 2

And in later years even more herbicide-resistant weeds are present
Factors Affecting Speed of Selection

The length of time for selection of resistance varies by:

- Cultural practices
- Frequency of herbicide use
- Herbicide mechanism of action
- Biology of weed species
- Frequency of resistant biotypes among weed species

Another factor affecting the speed of selection is the mechanism of herbicide resistance. There are two general types of mechanisms: (1) exclusionary resistance (for example, differential uptake and translocation, compartmentalization and metabolic detoxification) and (2) target site resistance (alteration of the targeted enzyme and overproduction of a specific enzyme). Exclusionary resistance generally takes longer to evolve in the field.
Level of Herbicide Resistance

The level of herbicide resistance in weeds varies by weed biology and resistance mechanism. In some cases, resistance occurs when the species survives application of a labeled rate, while in other cases, the species can survive up to 1000 times the labeled rate. (1X equals the labeled rate.)

This is important in terms of being able to identify herbicide resistance in the field.
Herbicide Resistance Characteristics

**Low-Level Resistance**

- A continuum of plant responses from slightly injured to nearly dead
- The majority of plants display an intermediate response
- Susceptible plants will be present in the population, especially when herbicide resistance is determined early

**Examples**

| Roundup, etc. | GROUP 9 | HERBICIDE |
| Reflex, Valor, etc. | GROUP 14 | HERBICIDE |
| Clarity, 2,4 D, etc. | GROUP 4 | HERBICIDE |
| Gramoxone, etc. | GROUP 22 | HERBICIDE |

**High-Level Resistance**

- Plants are slightly injured to uninjured
- Few plants have an intermediate responses
- Susceptible plants can be present in the population

**Examples**

| atrazine, Sencor, etc. | CLASS 5 | HERBICIDE |
| Classic, Permit, FirstRate, etc. | GROUP 2 | HERBICIDE |
| Select, Assure, etc. | GROUP 1 | HERBICIDE |
Herbicide Resistance Types

Single Herbicide Resistance
• Resistant to only **one** herbicide

Cross Herbicide Resistance
• Resistant to **two or more** herbicide families with **same mechanism of action**
• Single resistance mechanism

Multiple Herbicide Resistance
• Resistant to **two or more** herbicides with **different mechanisms of action**
• May be the result of two or more different resistance mechanisms
Conclusions

Repeated use of a herbicide selects for herbicide-resistant biotypes. Over time, the number of resistant individuals in the weed population increases until the majority of the population is herbicide-resistant.

Several factors in the field can affect the selection of herbicide-resistant weeds.

Once a weed is resistant to a single herbicide, it is possible for it to be resistant to another herbicide, with either the same or a different mechanism of action.
Credits:

This lesson was developed by a WSSA sub-committee and reviewed by the WSSA Board of Directors and other WSSA members before being released. The sub-committee was composed of the following individuals.

- Wes Everman, PhD (North Carolina State University)
- Les Glasgow, PhD (Syngenta Crop Protection)
- Lynn Ingegneri, PhD (Consultant)
- Jill Schroeder, PhD (New Mexico State University)
- David Shaw, PhD (Mississippi State University)
- John Soteres, PhD (Monsanto Company) (Sub-committee chairman)
- Jeff Stachler, PhD (North Dakota State University and University of Minnesota)
- François Tardif, PhD (University of Guelph)

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Sonia Rios
UCCE Subtropical Horticulture Farm Advisor
Riverside/San Diego Co.

sirios@ucanr.edu
(951) 683-6491 EXT 224

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