



Citrus plots from the herbicide synergy trial at the Southwest Florida Research and Education Center were weed-free approximately 100 days after herbicide treatments.

# Herbicide synergy for citrus weed management

By Ramdas Kanissery, Brent Sellers and Steve Futch

**W**eed control is a major component of Florida citrus grove management. A warm, humid climate and frequent rainfall provide a conducive environment for prolific weed emergence and growth in citrus groves.

Although there are several pre- and post-emergent herbicide products available for managing a diversity of citrus weeds, there is always an inadequacy in the weed control spectrum of any particular herbicide product. Mixing multiple herbicides during a single application is a common practice for improving weed management limitations. Synergism occurs when a combination of two or more herbicides works better, or the effect is more prolonged than the sum of the effects of the individual ingredients alone.

There are several advantages to combining two or more herbicides in a tank mix. These include:

- 1) Facilitating the possibility of cumulatively using less herbicide product
- 2) Reducing herbicide carryover and risk of herbicide injury
- 3) Reducing the number of spraying operations and associated costs

## CHECK HERBICIDE COMPATIBILITY FIRST

To effectively and safely use a particular herbicide mixture, the compatibility of the ingredients in the mix must be tested and thoroughly understood. In many cases, incompatibilities get overlooked and may lead to undesirable consequences. These negative responses in overall weed control to herbicide mixing are referred to as “antagonism.” Undesirable consequences of mixing can lead to antagonism or reduced efficacy from various components of the mixture.

Probably the most notorious incompatibility is expressed when chemical reactions between various products plug spray nozzles to prevent application. Or, the herbicides may appear to be compatible in solution, but weed control will suffer. Such is the case with glyphosate and paraquat, which mix well in solution, but weed control is generally reduced when the products are tank-mixed.

Ideally, it is desirable to use a herbicide combination that has a synergistic effect to improve the spectrum of control, has no antagonistic efficacy effects and has no effect on citrus trees. However, in many cases, the herbicide combinations are selected and commercially used without any prior knowledge of their interactions. So a major question remains about the outcome of the interaction between the herbicides.

The very first place to look for the information on the incompatibilities of herbicide mixing is on the herbicide product label. The label will inform the user if herbicides can be mixed together and the mixing order. Some herbicides can be combined only if mixed in the proper order. If not, incompatibility may occur. The label may provide mixing instructions. A jar test, which is a micro-recreation of what will happen in a spray tank, may be performed to test the mixability of the herbicides.

Information on conducting a jar test and the proper order for mixing herbicides used in citrus production can be found in a previous article (July 2014 issue) in Citrus Industry magazine. Also, for more information

about herbicide application best management practices for citrus, see EDIS publication AE246 (<http://edis.ifas.ufl.edu/ae246>).

There are several causal factors that pose potential interference with a successful tank-mixing of herbicide products. These include formulation incompatibility, adsorption and adjuvant incompatibility.

#### **Formulation incompatibility:**

Herbicide formulations may be physically incompatible, regardless

of mixing order, simply due to the chemical nature of the different formulations. Although additives as emulsifying agents may help, there can be irresolvable issues when two emulsions separate and/or break down in the herbicide mix.

**Adsorption:** Tank-mix incompatibility and spray failure will occur when the active ingredient in a formulation is adsorbed (physical or chemical binding to a surface) onto particles from another product in

the mix. For instance, this happens when a readily adsorbed herbicide like glyphosate is combined with a wettable powder formulation in the spray tank. The product label is a good source of information to avoid this type of herbicide-mix mishap.

#### **Adjuvant incompatibility:**

Adjuvants, like surfactants, are materials used to improve herbicidal efficacy or enhance its applicability. Some adjuvants are present in a formulated product and others are added during the tank-mixing. Reactions can occur between an active ingredient and the adjuvants in the spray tank. For instance, paraquat, which has a strong cationic positive charge, will react with anionic surfactants and result in precipitation. Hence, only non-ionic surfactants must be used with paraquat.

## **HERBICIDE INTERACTIONS IN TARGET WEEDS**

As mentioned previously, not all tank mixes that appear to be physically and chemically compatible in the spray tank will produce a synergistic effect on target weeds. The performance of an herbicide combination on weeds can be affected by various factors that include the rate of penetration into the plants, translocation and biotransformation in the plant tissues and competition for common receptors. The efficacy of an herbicide mix may also depend on the target weed species. Even the application rate will determine the success of an herbicide combination.

Here are some of the general patterns of herbicide-mix interactions within target weeds:

**Herbicide uptake and translocation by weeds:** Herbicide synergism will likely occur if the point of uptake or absorption (leaves, root, stem, etc.) of the herbicides in the mix is different. Conversely, when the interacting herbicide enters the target weed through the same site, one herbicide may reduce the rate of active penetration and uptake of the other herbicide in the mix. Herbicides typically get translocated in plants either through phloem or xylem. If the herbicides in the mixture were translocated simultaneously through the same route, the amount



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reaching the site of herbicidal action (enzyme or a physiological process) might be reduced.

#### Mode of action and chemical families of herbicides in the mix:

Herbicides with different modes of action when applied as a tank mix can exhibit reasonable levels of synergy in managing the target weed population. Also, synergism has been found to occur more frequently in mixtures where the companion herbicides belong to related chemical families. The reason for this is that when herbicides have the same chemical structure, they will compete for deactivating the same enzymatic site of action in weeds. However, such competitions could also result in decreased efficacy as opposed to a synergistic effect.

## HERBICIDE SYNERGY RESEARCH

In citrus, trends from previous studies demonstrate good evidence for a successful enhancement of weed control efficacy by combining herbicides in a single application. For example, a two-year study (Futch and Singh, 2000) showed that combinations that involved pre-emergent and post-emergent herbicides provided significantly greater weed control than individual herbicide applications in young citrus groves in Florida.

Although glyphosate is applied for post-emergent weed control in Florida citrus, many weed species commonly found in citrus groves are not effectively managed by glyphosate application alone. Another study (Singh et al., 2011) showed the increase in effectiveness of glyphosate in managing citrus weeds when tank-mixed with compatible herbicide partners.

A trial was conducted at the Southwest Florida Research and Education Center during the fall season of 2017 to evaluate the long-term weed control prospects of mixing pre-emergent and post-emergent herbicide products during a single application (Table 1). When compared to a post-emergent application alone, the herbicide combinations in this study exhibited significantly greater citrus weed control for a longer duration. The

**Table 1:** Citrus weed control using herbicide mixes

(Southwest Florida Research and Education Center, Immokalee, Florida, June 2017–November 2017)

Herbicide products in the test mixture	Active ingredients	Rate (oz. product/acre)	Weed control (%) 150 DAT
Alion Chateau Roundup Power Max	Indaziflam Flumioxazin Glyphosate	3 6 88	82 <sup>b*</sup>
Alion Chateau Roundup Power Max	Indaziflam Flumioxazin Glyphosate	5 8 88	94 <sup>a</sup>
Alion Roundup Power Max	Indaziflam Glyphosate	3 88	58 <sup>c</sup>
Alion Roundup Power Max	Indaziflam Glyphosate	5 88	89 <sup>b</sup>
Chateau Roundup Power Max	Flumioxazin Glyphosate	6 88	18 <sup>d</sup>
Chateau Roundup Power Max	Flumioxazin Glyphosate	8 88	20 <sup>d</sup>
Roundup Power Max	Glyphosate	88	5 <sup>e</sup>

DAT = days after treatment

Indaziflam and flumioxazin are pre-emergent herbicides. Glyphosate is a post-emergent herbicide.

\*Means with the same letter superscripts within a column do not significantly differ.



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spectrum of citrus weeds managed by herbicide synergy in this trial includes broadleaves (goat weed, Spanish needle and pusley), grasses (Johnson grass) and sedges (yellow nutsedge).

## CONCLUSION

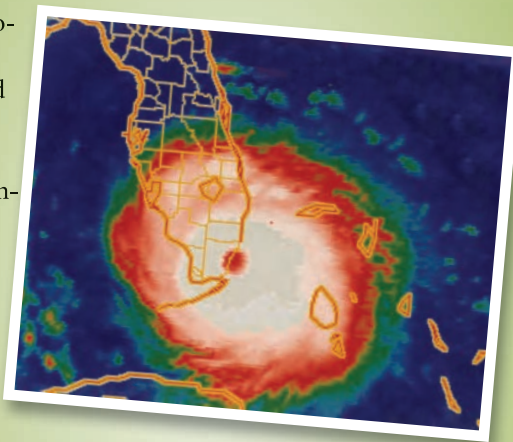
When herbicides are applied in combinations and weed infestation is less than expected compared with when herbicides are applied alone, a synergistic effect is said to exist. There are several factors that should be considered in the selection process of tank-mix partners, route of herbicide uptake, and the mode of action in target weeds that influences the behavior

and efficacy of herbicide mixtures. Recent studies are demonstrating the improvement in citrus weed control when herbicides are applied in combinations. 🍊

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## Post-hurricane weed management considerations

**H**urricanes and associated flooding often impact weed management in affected citrus groves. Weeds may take advantage of the hindered grove operations and herbicide sprays. Also, seeds carried into the field by the storm and flood water may cause new weed problems in groves. One important step in weed management after a hurricane is to monitor new weed development. Create a field map of weed abundance and location and use the information to plan the future weed control program.



Leaching or vertical movement of herbicides will be greater with high levels of rainfall associated with tropical storms and hurricanes. Subsequently, reduced weed control may be observed due to reduced herbicide concentration in surface soil horizons surrounding germinating weed seeds. Damage to citrus trees due to more significant root contact with herbicides as well as groundwater contamination are other possible after-effects of herbicide leaching. Moreover, flooding after hurricanes will impact the degradation or breakdown of herbicides in the soil. Low soil temperatures and persistent wet conditions in the flooded soil alters both microbial and chemical breakdown of herbicides in affected soils.

As storms and floods can facilitate the movement of herbicide residues, a bioassay test could be helpful to determine if the affected soils have herbicide residues well below injury threshold to citrus trees. Herbicide bioassay is a technique that utilizes indicator plants to identify if the herbicide is present in soils at concentrations high enough to inhibit the plant germination and alter plant growth.