

# Preliminary Results Regarding the Effects of Foliar Applied Roundup on Lemon Physiology and Yield<sup>1</sup>

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## Abstract

*The effect of Roundup on lemon trees was evaluated by repeatedly spraying 0.5, 0.75, 1, 1.25, and 1.5 lb a.i./acre on the bottom 20 to 24 inches of the tree canopies. Leaf injury symptoms, flower and fruit counts, and yield data were collected. The Roundup applications caused significant leaf injury in the sprayed area of the canopies and there was significant defoliation of branches at the higher Roundup rates. In 1996, flower and fruitlet counts were not affected by the Roundup applications. However, flower and fruitlet counts in 1997 in the sprayed zone of the canopy were significantly reduced by Roundup and the effect increased with increasing Roundup rate. The 1996 yield data indicated that the Roundup applications did not significantly affect lemon yield, however, the effect of Roundup on the 1997 flower and fruitlet counts suggests that there may be a yield effect in 1997. The preliminary data suggest that accidental drift of Roundup on to lemon trees when spraying weeds on the orchard floor has no short-term effect on grove productivity but this conclusion must be substantiated by further data collection.*

## Introduction

Weeds in Yuma Mesa lemon groves have been managed by frequent disking of the orchards and by the application of preemergence (i.e., soil applied) and postemergence (i.e., foliar applied) herbicides. Disking orchards occasionally damages tree branches and, in the opinion of some growers, may damage shallow tree roots. Disking also incorporates plant debris into the surface soil creating a breeding habitat for eye gnats on the Yuma Mesa. Thus, the use of herbicides has increased in recent years. Preemergence herbicides have not been widely used in Yuma County in the past because flood irrigation of sandy soils, especially on the Yuma Mesa, can leach some herbicides such as bromacil (e.g., Hyvar X and Krovar I), diuron (e.g., Karmex, Krovar I), and simazine (e.g., Princep) into the tree root zone causing injury. However, many preemergence herbicides including Goal, Prowl, Solicam, Surflan, Treflan, and Visor can be used on sandy soils without injuring trees. Postemergence herbicides are used to control weeds that escape the effects of preemergence herbicide applications or to control all weeds in groves that are not treated with preemergence herbicides. One of the most popular postemergence herbicides has been Roundup and occasionally some foliar injury symptoms caused by Roundup can be found on the skirts of trees.

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The use of foliar or postemergence applications of Roundup for weed control in Arizona citrus orchards is a matter of some controversy. Proponents of Roundup use tout its lack of soil residual effects on trees and its effectiveness as a weed killer, particularly on difficult to control perennials such as bermudagrass and purple nutsedge. Proponents of Roundup either consider the incidental treatment of citrus foliage with Roundup as inconsequential or use application methods that minimize Roundup spray contact with citrus foliage. Opponents of Roundup use in citrus orchards feel that even small amounts of Roundup spray drift to citrus foliage can have adverse effects on fruit drop and yield, particularly when multiple applications are made in a growing season. There is little data in the scientific literature available to evaluate the effects of Roundup use in Arizona citrus and conversations with Florida citrus researchers indicates that further work is warranted. Thus the objectives of this study were to evaluate the effect of simulated drift of Roundup spray on to citrus foliage (or inadvertent application of Roundup to citrus foliage) when multiple postemergence applications of Roundup per year are made for weed control.

## Materials and Methods

This experiment was initiated in the spring of 1995 in a flood irrigated lemon grove on the Yuma Mesa (soil series: Superstition Sand) managed by Marlin Farming. The grove that was in full production and contained trees with scions of 'Limoneira 8A' Lisbon lemon on *Citrus volkameriana* rootstock. Weed control in the grove prior to the beginning of the experiment was accomplished using postemergence applications of Roundup. The treatments included an untreated control and five rates of Roundup; 0.5, 0.75, 1.0, 1.25, and 1.5 lb of active ingredient (a.i.) per acre or 0.5, 0.75, 1.0, 1.25, and 1.5 quarts of Roundup per acre. The six treatments were arranged in the orchard using a randomized complete block experimental design with nine blocks. Each plot consisted of a single tree. The experiment began with the first set of Roundup applications on 6/6/95. Subsequent applications were made on 9/1/95, 3/6/96, 7/31/96, 11/22/96, and 5/14/97. The Roundup was applied with a CO<sub>2</sub> pressurized backpack sprayer at about 20 psi using a single TeeJet 8002EVS nozzle with the nozzle orifice pointing at the tree canopy (i.e., oriented 90 degrees from the horizontal). The nozzle was held 10 inches above the ground at about the edge of the canopy and the applicator paced around the perimeter of the tree at a speed of 3 miles per hour. This method of application resulted in about a 20 to 24 inch spray band extending upward from the ground around the perimeter of the canopy at the base of the tree.

The data collected included evaluation of canopy injury symptoms, counts of blooms and fruitlets (fruit with a diameter less than 1 cm), and lemon yield per tree. Visual estimations of canopy injury symptoms were made on 4/26/96 and 5/14/97 in all treatments and blocks. On each evaluation date, two separate ratings were made; one for the sprayed canopy zone (0 to 2 feet above the ground) and one for the portion of the canopy that was not directly sprayed (greater than 3 feet above the ground). Similarly bloom and fruitlet counts were made in both the sprayed and non-sprayed canopy zones in February to May of both 1996 and 1997. In each tree (i.e., plot), one branch between 15 and 50 inches in length in both the sprayed and non-sprayed zone was selected. Beginning at early bloom (i.e., flowers evident but not yet open), the length of the shoot and number of flowers and fruitlets were counted every two weeks until no more flowers were produced. Flower and fruitlet counts were made on 2/29, 3/12, 3/26, 4/9, 4/23, 5/7, and 5/21 in 1996 and on 2/28, 3/14, 3/28, 4/11, 4/25, and 5/9 in 1997. Flower and fruitlet counts were made for all treatments in blocks one to six. Trees were harvested individually in all treatments and blocks. The fruit from each tree was placed in one or two field boxes. Five full field boxes were each weighed to obtain the average weight of fruit in a full box. For the rest of the field boxes, the portion of a full box was visually estimated and the weight calculated based on the average weight of a full box.

## Results and Discussion

Roundup applications to the bottom 20 to 24 inches of the tree canopies caused visible injury to the bottom of the trees but had no effect on the top or upper portion of the canopy that was not directly sprayed (Table 1). The injury symptoms were primarily narrow "strapped leaves" and branch defoliation but there was also some discoloration or bleaching of sprayed leaves immediately after some applications. The degree of injury at the bottom of the tree canopies increased with increasing rates of Roundup (Table 1). The lack of injury symptoms in the upper portion of the canopy suggests that there was not enough translocation or movement of Roundup from the sprayed zone to other portions of the trees to cause foliar injury

symptoms. The injury observed in the control trees on 4/26/96 was due to Roundup applications prior to the start of our experiment and is decreasing with time.

The effect of Roundup on flower and fruitlet production was variable. In 1996 after three Roundup applications, Roundup had no effect on flower or fruitlet production in either the upper or bottom portions of the tree canopies as judged from the counts collected from single branches in each canopy zone (data not shown). In 1997 after five Roundup applications, Roundup significantly affected flower and fruitlet production in the bottom portion of the canopies but not in the upper portion of the canopy (Table 2). There was substantial flower production only on 2/28/97 and 3/14/97. On both evaluation dates, the higher rates of Roundup significantly reduced the number of blooms produced compared to the untreated control (Table 2). In contrast, Roundup did not have any effect on flower production in the upper portion of the tree canopies (Table 2). The number of fruitlets (fruit with a diameter less than 1 cm) in the sprayed canopy zone was also significantly affected by Roundup in 1997 with fewer fruitlets present on branches sprayed with the higher rates of Roundup (Table 3). As with the injury symptoms and flower counts, Roundup did not affect fruitlet production in the upper portion of the tree canopies.

The effect of Roundup on tree yield when sprayed on the bottom of the canopy was measured by harvesting individual trees in 1996. Yield data was not collected in 1995 because Roundup had been applied only twice before harvest and it seemed unlikely that there would be a yield effect. Roundup applications to the bottom portion of the tree canopies did not reduce the 1996 total lemon yield per tree at any of the rates applied (Table 4). In addition, Roundup had no effect on the yield of the first pick or the percentage of the total harvest picked on the first harvest date (Table 4). The lack of yield effects contrasts with the obvious foliar symptoms caused by Roundup and the effect of Roundup on 1997 flower and fruitlet production in the bottom portion of the tree canopies. The 1996 yield data suggests that either Roundup does not translocate out of the sprayed portion of the canopy to other parts of the tree, or that the bottom portion of the tree canopy does not contribute significantly to yield, or both. However, the 1996 harvest data may have been collected before the full effects of the Roundup applications could develop and the 1997 flower and fruitlet reductions found in the bottom of the canopies may result in yield reductions in 1997. It is note worthy in regard to the yield data that the defoliation of the lower branches by Roundup applications at the higher rates may limit that amount of Roundup that translocates to the upper portion of the trees. Defoliation would also be expected to reduce flower and fruitlet production because less leaf area is available to feed developing flowers and fruit. We consider the data contained in this paper to be preliminary and plan to continue the study for several more years in order to more accurately determine the effect of foliar Roundup applications on lemon trees.

**Table 1. Visual injury symptoms caused by application of Roundup to the bottom 20 to 24 inches of lemon tree canopies.**

| Portion of Canopy | Roundup Rate<br><i>(lb a.i./acre)</i> | Evaluation Date                      |                                      |
|-------------------|---------------------------------------|--------------------------------------|--------------------------------------|
|                   |                                       | 4/26/96<br><i>(mean ± std. dev.)</i> | 5/14/97<br><i>(mean ± std. dev.)</i> |
| Bottom            | 0                                     | 11.3 ± 10.0                          | 3.2 ± 6.5                            |
|                   | 0.5                                   | 36.4 ± 12.7                          | 10.0 ± 6.1                           |
|                   | 0.75                                  | 46.1 ± 18.0                          | 12.8 ± 10.3                          |
|                   | 1.0                                   | 47.2 ± 20.3                          | 29.4 ± 17.6                          |
|                   | 1.25                                  | 55.6 ± 15.1                          | 46.1 ± 15.8                          |
|                   | 1.5                                   | 59.4 ± 17.2                          | 47.8 ± 18.6                          |
|                   | Top                                   | 0                                    | 0 ± 0                                |
| 0.5               |                                       | 0.1 ± 0.3                            | 0 ± 0                                |
| 0.75              |                                       | 0.1 ± 0.3                            | 0.1 ± 0.3                            |
| 1.0               |                                       | 0 ± 0.0                              | 0.1 ± 0.3                            |
| 1.25              |                                       | 0.1 ± 0.3                            | 1.7 ± 1.5                            |
| 1.5               |                                       | 0.4 ± 0.5                            | 1.3 ± 1.7                            |

Table 2. Effect of Roundup on flower production in 1997. Flower counts were normalized by calculating the number of blooms per 100 inches of branch.

| Portion of Canopy | Roundup Rate<br><i>(lb a.i./acre)</i> | Evaluation Date          |                          |                          |                          |
|-------------------|---------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
|                   |                                       | 2/28/97<br><i>(mean)</i> | 3/14/97<br><i>(mean)</i> | 3/28/97<br><i>(mean)</i> | 4/11/97<br><i>(mean)</i> |
| Bottom            | 0                                     | 156.1                    | 128.5                    | 3.3                      | 0                        |
|                   | 0.5                                   | 90.1                     | 103.1                    | 11.1                     | 1.2                      |
|                   | 0.75                                  | 97.0                     | 90.2                     | 7.5                      | 0                        |
|                   | 1.0                                   | 76.1                     | 67.6                     | 15.3                     | 5.7                      |
|                   | 1.25                                  | 92.3                     | 77.7                     | 1.3                      | 0                        |
|                   | 1.5                                   | 67.6                     | 54.9                     | 14.1                     | 2.1                      |
| Top               | 0                                     | 95.9                     | 90.6                     | 3.5                      | 0                        |
|                   | 0.5                                   | 73.5                     | 65.1                     | 5.0                      | 1.3                      |
|                   | 0.75                                  | 102.7                    | 90.5                     | 6.8                      | 2.7                      |
|                   | 1.0                                   | 86.3                     | 84.7                     | 0                        | 0                        |
|                   | 1.25                                  | 106.2                    | 96.9                     | 5.6                      | 1.9                      |
|                   | 1.5                                   | 156.5                    | 152.4                    | 15.9                     | 5.5                      |

Table 3. Effect of Roundup on fruitlet production in 1997. Fruitlet (fruit with a diameter less than 1 cm) counts were normalized by calculating the number of fruitlets per 100 inches of branch.

| Portion of Canopy | Roundup Rate<br>(lb a.i./acre) | Evaluation Date   |                   |                   |                   |                  |
|-------------------|--------------------------------|-------------------|-------------------|-------------------|-------------------|------------------|
|                   |                                | 3/14/97<br>(mean) | 3/28/97<br>(mean) | 4/11/97<br>(mean) | 4/25/97<br>(mean) | 5/9/97<br>(mean) |
| Bottom            | 0                              | 9.8               | 48.8              | 27.6              | 13.8              | 9.8              |
|                   | 0.5                            | 1.9               | 38.3              | 26.5              | 14.2              | 10.5             |
|                   | 0.75                           | 3.8               | 37.6              | 16.5              | 12.0              | 9.8              |
|                   | 1.0                            | 8.0               | 19.9              | 9.1               | 2.8               | 6.8              |
|                   | 1.25                           | 5.7               | 23.6              | 4.5               | 1.3               | 3.2              |
|                   | 1.5                            | 8.4               | 13.4              | 9.2               | 2.8               | 2.1              |
| Top               | 0                              | 2.4               | 32.4              | 17.6              | 9.4               | 9.4              |
|                   | 0.5                            | 2.1               | 31.5              | 21.8              | 11.3              | 6.3              |
|                   | 0.75                           | 4.7               | 35.8              | 23.0              | 20.9              | 12.2             |
|                   | 1.0                            | 1.6               | 32.7              | 16.5              | 10.9              | 6.9              |
|                   | 1.25                           | 4.3               | 37.0              | 21.0              | 17.9              | 13.6             |
|                   | 1.5                            | 9.7               | 55.2              | 37.2              | 25.5              | 14.5             |

Table 4. Effect of Roundup on the yield of lemon trees when Roundup was sprayed on the bottom 20 to 24 inches of the tree canopies. Data are means  $\pm$  standard deviations.

| Roundup Rate<br>(lb a.i./acre) | Lemon Tree Yield     |                      |                          |                               |
|--------------------------------|----------------------|----------------------|--------------------------|-------------------------------|
|                                | 11/4/96<br>(lb/tree) | 12/2/96<br>(lb/tree) | Total Yield<br>(lb/tree) | First Harvest<br>(% of total) |
| 0                              | 85.6 $\pm$ 23.1      | 50.8 $\pm$ 17.4      | 136.4 $\pm$ 26.8         | 62.6 $\pm$ 10.6               |
| 0.5                            | 81.9 $\pm$ 22.9      | 43.5 $\pm$ 16.9      | 125.4 $\pm$ 30.7         | 65.3 $\pm$ 9.2                |
| 0.75                           | 82.7 $\pm$ 19.0      | 42.9 $\pm$ 16.1      | 125.7 $\pm$ 20.0         | 65.8 $\pm$ 11.9               |
| 1.0                            | 79.9 $\pm$ 21.5      | 57.1 $\pm$ 20.6      | 137.0 $\pm$ 20.4         | 58.5 $\pm$ 12.9               |
| 1.25                           | 81.0 $\pm$ 31.7      | 47.7 $\pm$ 18.0      | 128.5 $\pm$ 45.0         | 62.4 $\pm$ 8.7                |
| 1.5                            | 81.6 $\pm$ 27.9      | 42.4 $\pm$ 13.7      | 124.0 $\pm$ 36.1         | 64.8 $\pm$ 9.7                |