# FACTORS THAT INFLUENCE SPRAY COVERAGE OF ORCHARD TREES
## 2004 Utah State Horticulture Association Research Project Report

**Shawn Steffan – IPM Project Leader, Utah State University**

### Objectives
Quantify spray coverage in apple and cherry orchards. Variables such as canopy position, sprayer type, water volume, and tractor speed were measured in apple and cherry canopies.

### Justification
Recent pest outbreaks in Utah tree fruit systems have indicated a need for refinements in pest management approaches. Pests such as codling moth, Western cherry fruit fly, spider mites, and fire blight bacteria all require spray treatments to suppress populations below economic injury levels. Older insecticides (Guthion, Imidan, Thiodan, Danitol) are becoming less effective as resistance to insecticides increases. These older materials kill pests via direct contact (without the need for ingestion) which used to provide effective pest suppression without uniform coverage. Newer insecticide chemistries are highly effective and will help manage resistance, but they generally must be ingested by the insect in order to cause death. Improved coverage of fruit and leaves within the canopy in Utah's apple and cherry orchards will likely afford superior insecticide efficacy. This will not only have economic benefits for growers, but the communities near farmland should also benefit from fewer insecticide sprays. This study provides baseline information on the degree of coverage achieved by specific spraying practices in apple and cherry orchards.

### Methods and Materials
Water-sensitive cards were affixed at specific positions within the canopies of apple and tart cherry trees, and water was applied using 3 sprayer-speed combinations: Rears-*slow*, Tower-*slow*, and Tower-*fast* (Figs. 1-3)

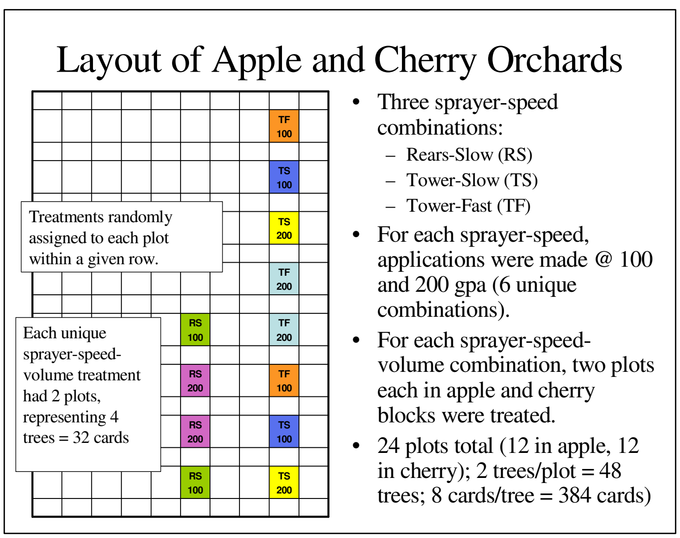


**Figure 1.** The layout of plots within the apple and cherry blocks flagging in the apple block canopy.


**Figure 2.** Tower sprayer in the tart cherry block; in Genola, Utah.

The slow speed was approximately 2.0 mph, and the "fast" speed was approximately 2.5 mph. For each of the three sprayer-speed combinations, two separate volumes of water were applied (100 gallons/acre and 200 gallons/acre), which made six unique sprayer-speed-volume combinations. Each of the six sprayer-speed-volume combinations was tested in four independent plots (two plots per treatment in an apple and cherry orchard), making 24 plots across two orchards.

Within each plot, two trees were used for the coverage measurements. Each tree canopy was divided into four quadrants: upper-exterior, lower-exterior, upper-interior, and lower-interior. In the apple canopy, "upper" represented a height of 9-12 feet, and "lower" represented a height of 4-6 feet. In the tart cherry canopy, the upper height was 12-15 feet, while the lower height was 5-7 feet. Two water-sensitive cards were affixed to branches within each quadrant of a given tree. As much as possible, the cards were affixed to branches that were oriented perpendicular to the rows (and thus, parallel to the general orientation of the spray). This was done to assess the degree of coverage on the sides of fruit and branches, which is likely the most difficult parts of the canopy to cover adequately. Duct tape was used to firmly attach the water-sensitive cards prior to the treatments (Fig. 3). After the water treatments were made, the cards were allowed to dry before being collected.


**Figure 3.** Water-sensitive cards, affixed with duct tape to the tree canopy.

The degree of coverage on a given card was measured by photographing the card with a digital camera (Nikon Coolpix 4500), using the macro setting, low-light aperture, and polarization lens (to reduce glare). The digital images were adjusted within Photoshop™, often using the Sharpen and Hue functions to help separate the shades of yellow from the range of blues. The processed images were then analyzed using the Image Analysis extension of ArcView GIS™ which allowed for the classification and grouping of pixels based on their color value. Total pixel counts of each color group were then entered into an Excel spreadsheet and the proportion of each image represented by blue pixels was generated for each image. This proportion was the estimate of total coverage for a given card. Statistical analyses of the proportions were conducted using SAS (Mixed Procedure).

Results and Discussion

Overall, the mean coverage measured across all sprayer and crop types was 52.4%. Across both the apple and cherry blocks, the effect of spray volume was significant (*P* = 0.003), which suggests that raising the volume from 100 gpa to 200 gpa increased the degree of canopy coverage (Figs. 4-5). The difference, however, was not as dramatic as anticipated. Mean coverage on cards in apple blocks was 48.2% (Fig. 4), and coverage in the tart cherries was 56.6% (Fig. 5) which represented a significant difference across all sprayers (*P* = 0.019). Given the substantial difference in coverage between the apple and cherry blocks, comparisons of sprayer-speed-volume effects will need to be confined to each crop.

Broad Effects: Apple % Coverage

| Apple Sprayer-Speed | Volume | | Position | | Height | | Overall Effects |
|---|---|---|---|---|---|---|---|
| | 100 | 200 | Int | Ext | Hi | Lo | |
| Rears-S | 41.5 | 49.1 | 31.9 | 58.7 | 42.9 | 47.7 | **45.3** |
| Tower-S | 45.8 | 55.4 | 37.7 | 63.5 | 49.0 | 52.2 | **50.6** |
| Tower-F | 45.1 | 52.5 | 40.6 | 57.1 | 41.4 | 56.2 | **48.8** |
| **Overall** | **44.1** | **52.4** | **36.7** | **59.8** | **44.4** | **52.0** | **48.2** |

**Figure 4.** The mean coverage %s relative to sprayer-speed, volume, position, and height in the apple block.

Sprayer type did not make a significant difference for either the apple or cherry canopy in this trial. In the apple block (Fig. 4), the tower sprayer driven at 2.0 mph registered greater coverage (50.6%) than that of the rears driven at 2.0 mph (45.3%). These findings suggest that the tower sprayer may improve coverage for a dense apple canopy, though the scope of this trial was too narrow to extend broad conclusions to all apple canopy types. In the cherry block (Fig. 5), the tower sprayer driven at 2.0 mph (55.0%) was almost identical to that of the rears (55.7%). While coverage in the cherry canopy was generally better than that of the apple block, the rears performed as well as the tower.

## Broad Effects: Cherry % Coverage

| Cherry Sprayer-Speed | Volume | | Position | | Height | | Overall Effects |
|---|---|---|---|---|---|---|---|
| | 100 | 200 | Int | Ext | Hi | Lo | |
| Rears-S | 49.5 | 61.9 | 55.8 | 55.6 | 48.6 | 62.8 | **55.7** |
| Tower-S | 49.1 | 60.9 | 60.3 | 49.8 | 45.6 | 64.4 | **55.0** |
| Tower-F | 48.6 | 69.7 | 59.4 | 58.9 | 51.4 | 66.9 | **59.1** |
| **Overall** | **49.1** | **64.2** | **58.5** | **54.7** | **48.6** | **64.7** | **56.6** |

**Figure 5.** The mean coverage %s relative to sprayer-speed, volume, position, and height in the tart cherry block.

The effect of speed on the tower sprayer's coverage was determined to be negligible. In the apple blocks, the coverage at the faster speed (2.5 mph) was 48.8%, down from 50.6% at the slow speed. In the cherry block, the faster speed produced 59.1% coverage which was actually higher than the 55.0% registered at the slow speed. What these findings indicate is that the tower sprayer can probably be driven at 2.5 mph without sacrificing much in the way of coverage.

The effects of increased spray volume were highly variable relative to sprayer-speed and crop. Specifically, the increase in volume appears to have contributed more to the coverage in the cherry block than in the apple block. In the cherry block, the mean coverage (across all sprayer types) for 100 gpa was 49.1%, and for 200 gpa, 64.1% (an increase of approximately 15%). In the apple block, 100 gpa produced 44.1% compared with 52.4% for 200 gpa, which is a difference of approximately 8%. The differential effect of increasing the spray volume may be explained by a certain aspect of the apple canopy. The apple canopy in this trial generally had larger scaffold branches than the cherry canopy, even though the cherry trees were taller and wider. The larger scaffold branches of the apple canopy were likely obstructing much of the spray, causing a "spray shadow" that could not be overcome even with the higher spray volume.

The role of canopy position (interior vs. exterior), not surprisingly, was an important factor influencing coverage. The spray shadow in the apple canopy was apparent when the coverage values at the interior were compared with those at the exterior (Fig. 4). Across both spray volumes in the apple block, the mean interior coverage was 36.7% while the exterior was 59.8%. The cherry canopy, on the other hand, had greater coverage at the interior (58.5%) than at the exterior (54.7%) (Fig. 5).

Height also played an important role in the coverage values recorded. In the apple canopy, the lower height had an average of 52.0% coverage while the upper height averaged 44.4%. The cherry canopy averaged 64.7% at the lower height and 48.6% at the upper height. In both canopy types, and with each sprayer type, the lower height received superior coverage.

It is interesting to note, however, that there were some significant interactions between height, position, volume, and sprayer type for both apple and cherry canopies. The rears sprayer at 100 gpa, for example, appeared to experience a "spray shadow" (19.1%) in the lower interior quadrant of the apples (Fig. 6), yet in the cherry canopy, this sprayer produced 58.8% coverage at the lower interior (Fig. 7).

In addition, the rears sprayer had trouble reaching the upper-interior of the cherry canopy at 100 gpa, averaging just 33.1% in this quadrant. It appears that with the rears sprayer, 100 gpa allowed a spray shadow to occur at the *upper*-interior. In contrast, the apple canopy experienced a spray shadow at the *lower*-interior with the rears sprayer.

**Apple**: Canopy Position and Height Effects

| 100 R-S | Int | Ext | |
|---|---|---|---|
| High | 31.5 | 50.9 | **41.2** |
| Low | 19.1 | 64.3 | **41.7** |
| | **25.3** | **57.6** | **41.5** |

| 200 R-S | Int | Ext | |
|---|---|---|---|
| High | 34.3 | 54.8 | **44.6** |
| Low | 42.6 | 64.7 | **53.7** |
| | **38.4** | **59.8** | **49.1** |

| 200 T-S | Int | Ext | |
|---|---|---|---|
| High | 52.3 | 66.4 | **59.4** |
| Low | 36.8 | 66.0 | **51.4** |
| | **44.6** | **66.2** | **55.4** |

| 100 T-S | Int | Ext | |
|---|---|---|---|
| High | 31.6 | 45.7 | **38.6** |
| Low | 30.0 | 76.0 | **53.0** |
| | **30.8** | **60.8** | **45.8** |

| 100 T-F | Int | Ext | |
|---|---|---|---|
| High | 31.1 | 49.9 | **40.5** |
| Low | 37.1 | 62.3 | **49.7** |
| | **34.1** | **56.1** | **45.1** |

| 200 T-F | Int | Ext | |
|---|---|---|---|
| High | 46.9 | 37.8 | **42.3** |
| Low | 47.1 | 78.3 | **62.7** |
| | **47.0** | **58.1** | **52.5** |

**Figure 6.** Mean coverage percentages are presented for each of the six sprayer-speed-volume combinations in the apple block. "100" and "200" represent 100 and 200 gpa, respectively; "R-S", "T-S", and "T-F" designate Rear-Slow, Tower-Slow, and Tower-Fast, respectively.

**Cherry**: Position and Height Effects

| 100 R-S | Int | Ext | |
|---|---|---|---|
| High | 33.1 | 44.4 | **38.7** |
| Low | 58.8 | 61.7 | **60.3** |
| | **45.9** | **53.1** | **49.5** |

| 200 R-S | Int | Ext | |
|---|---|---|---|
| High | 68.0 | 49.1 | **58.6** |
| Low | 63.3 | 67.2 | **65.2** |
| | **65.6** | **58.2** | **61.9** |

| 200 T-S | Int | Ext | |
|---|---|---|---|
| High | 65.7 | 40.2 | **53.0** |
| Low | 71.0 | 66.8 | **68.9** |
| | **68.4** | **53.5** | **60.9** |

| 100 T-S | Int | Ext | |
|---|---|---|---|
| High | 37.1 | 39.5 | **38.3** |
| Low | 67.2 | 52.5 | **59.9** |
| | **52.2** | **46.0** | **49.1** |

| 100 T-F | Int | Ext | |
|---|---|---|---|
| High | 38.0 | 53.6 | **45.8** |
| Low | 53.8 | 48.8 | **51.3** |
| | **45.9** | **51.2** | **48.6** |

| 200 T-F | Int | Ext | |
|---|---|---|---|
| High | 61.3 | 52.7 | **57.0** |
| Low | 84.6 | 80.3 | **82.4** |
| | **73.0** | **66.5** | **69.7** |

**Figure 7.** Mean coverage percentages are presented for each of the six sprayer-speed-volume combinations in the cherry block. "100" and "200" represent 100 and 200 gpa, respectively; "R-S", "T-S", and "T-F" designate Rear-Slow, Tower-Slow, and Tower-Fast, respectively.

Increasing the spray volume to 200 gpa provided relatively small improvements in the apple canopy. Coverage levels were only slightly higher in all the quadrants except for the lower-interior which increased significantly (although ultimately, the lower-interior was a modest 42.6%) (Fig. 6). The switch to 200 gpa appears to have penetrated the canopy more, but there is obviously still an issue with the scaffold branches creating spray shadows at the interior position.

In the cherry canopy, the 200 gpa spray greatly increased coverage at the interior position for all sprayer types, particularly at the upper-interior position (Fig. 7). Significant improvement in coverage was observed at the lower-exterior, yet the upper-exterior was relatively low for each sprayer type. It appears that switching to 200 gpa helped to penetrate the interior of the canopy but left the upper-exterior less covered. In fact, 200 gpa produced coverage values at the upper-exterior that were almost identical to those produced with 100 gpa. This phenomenon may be the result of the upper-exterior being almost directly over the tractor and thus avoiding the bulk of the sprays.

As with the rears sprayer, the tower sprayer (driven either fast or slow) produced only modest improvements in apple canopy coverage when 200 gpa were applied. In the cherry canopy, 200 gpa greatly improved canopy coverage for the tower, but as with the rears sprayer, there was a spray shadow at the upper-exterior of the canopy. Despite the spray shadow, the cherries benefited from the increased spray volume, particularly at the interior position (Fig. 7). It seemed that the cherries benefited much more from the increased spray volume than the apples did.

The coverage levels measured during this trial (Fig. 8) suggest that coverage could be improved for both the apples and cherries. While the trees and card placement reflect a "worst-case" scenario, there are likely many orchards in Utah with dense canopies that obstruct access to all surface areas. Perfect coverage may never be possible, particularly with older orchards, but steps should be taken to deal with spray shadows. The spray shadows are likely providing codling moth and Western cherry fruit fly with unprotected fruit, and in years with heavy pressure from either pest, the problems caused by even small spray shadows may become substantial. The obvious solutions will involve improvements in pruning and greater spray volume.

## Distribution and Coverage

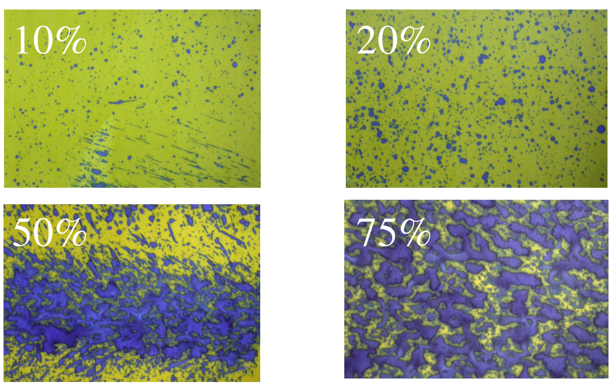


**Figure 8.** Representative images of various degrees of coverage.

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