may lead to the loss of investment assets. This particular risk has not been incorporated into the analysis presented in this paper.

Finally, potential investors must recognize the time value of money when considering investment opportunities. It is demonstrated in this paper that real cumulative cash flows may not become positive until between twelve and fourteen years from the time land is purchased. Thus, investors looking for quick returns on their investments may want to consider something other than new citrus groves. Still, for individuals looking for long term investments, citrus groves offer the opportunity for substantial returns on investment.

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DEPOSITION OF DIFFERENT SPRAY VOLUMES ON CITRUS TREES

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Additional index words. citrus, airblast sprayer, copper, colorimetry, uniformity, sample location.

Abstract. **An FMC orchard air sprayer (Model 1087) was used to apply spray solutions at volume rates of 9,400, 4,700, 2,350, 940, and 470 liters/ha. The solutions contained Cupric Hydroxide as deposition tracer which was applied at the rate of 6.714 kg/ha to 6 × 6 tree plots of 'Valencia' orange in a randomized complete block layout with 4 replications. Leaf samples were taken from one quadrant of each of 4 center trees (from each plot), at 2 heights and 2 radii (outside and inside of the tree canopy). Tracer copper deposit per leaf surface area was determined by colorimetry.**

Mean copper deposit and variability of deposition (CV) increased as spray volume decreased. Deposition was greater, higher in the tree and on the outside of the canopy compared to lower level and inside the canopy. Interactions between spray volume and height and spray volume and radii were significant.

Citrus trees are routinely sprayed with insecticides, acaricides, fungicides, nutrients, and growth regulators using different types of sprayers and various combinations of spray volume, liquid pressure, and sprayer speed. Adoption of any spraying parameter combination is influenced by the sprayer characteristics, tree size, chemical formulation, nature of the spray target, spraying time, weather conditions, and overall economics of the application. A proper combination can result in substantial savings in material, labor, fuel, and machinery costs while providing satisfactory pest control with minimal environmental contamination.

While recommended dilute spray volume for Florida citrus ranges from 4,700 to 14,100 liters/ha for trees less than 3 m to more than 5.5 m in height (5), there has been a growing interest in low volume (concentrate) spraying in the past few decades.

Griffiths et al. (4), Stearn et al. (9), and Brooks et al. (2) used concentrated sprays to control citrus mites and scales. Overall, they found that a 6X concentrated spray at 1/8 dilute volume gave as satisfactory results as dilute spray; however, their results varied with different sprayers and spray materials.

Brooks and Whitney (3) compared 6 low volume sprayers with a standard high volume sprayer for spraying citrus. They found the latter superior to others for citrus rust mite control. Brooks (1), using a helicopter and a conventional airblast sprayer (94 vs. 11,750 liters/ha), found virtually no difference in rust mite control. However, the latter gave significantly better control of other pests and fungal diseases.

It is apparent from the literature that some combination of sprayer type, target pest, and pesticide formulation can give satisfactory pest control; however, it is not clear what is responsible for the success or failure of a spray application. To find an answer to this question, we attempted to quantify spray deposition on the tree canopy for different spray volumes and relate it to citrus rust mite control (7). We found that spray volumes ranging from 235 to 4,700 liters/ha did not have a significant effect on mean deposition and citrus rust mite control. In general variability of deposition increased as spray volume decreased.

In view of the above findings, we conducted additional field studies in 1988 to validate previous results. The spe

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cific objective of this study was to characterize spray deposition as a function of spray volume and tree canopy location.

Materials and Methods

An FMC Model 1087 orchard air sprayer was used to apply spray mixtures in 5 volume rates (treatments): 9,400, 4,700, 2,350, 940, and 470 liters/ha (1,000, 500, 250, 100, and 50 gal/acre). The sprayer had an air volute that channeled a part of the fan air upward to discharge a portion of the spray laden air close to the top of the tree. The sprayer was equipped with 17 nozzles per side with the locations of the nozzles as shown in Fig. 1.

The spray mixtures contained Kelthane MF (dicofol) acaricide, and Cupric Hydroxide (50% metallic copper) as a deposition tracer. The acaricide was applied at 7 liters/ha to control citrus rust mite (see the following paper by McCoy et al. for the results and discussion of the mite control). To obtain a constant tracer rate of 6.716 kg/ha (6 lb./acre) for all spray volumes, the tank concentration of the compound varied from 358 to 7,181 mg a.i./liter. The treatments were applied to 6 × 6 tree plots of 'Valencia' orange (5.5-6.5 m height and 6 × 9 m spacing) in a randomized complete block layout (split-plot design) with 4 replications. The spraying speed was 2.4 km/hr at the 4 lowest spray volumes and 2.1 km/hr at the highest volume. Weather conditions during application were sunny or partly cloudy, winds less than 8 km/hr, and temperature and relative humidity ranging from 24.8°C and 74.5% (morning) to 38.6°C and 29.8% (afternoon).

Shortly after the spray dried on the foliage, 48 leaf samples were collected from 16 locations in each plot (Fig. 2). They were taken at one quadrant of each of 4 center trees, at 2 heights (1.5 and 3.0 m) and 2 radii (outside and ca. 0.6 m inside the tree canopy). Leaf samples were also collected from unsprayed plots to estimate residual copper from previous treatments. Each leaf was placed in a plastic bag and brought to the laboratory for copper analysis (8). The amount of copper deposit was measured with a Hach DR-100 colorimeter and leaf surface area was obtained with a Delta-T area metre. Copper deposit per leaf unit area was calculated using the following equation:

$$CD = (1{,}000 \times CC) / (2 \times LA \times KS)$$

where

CD = copper deposit per unit leaf surface area, μg/cm^2,
CC = copper concentration measured with the colorimeter, mg/liter,
LA = projected area of leaf, cm^2, and
KS = solution volume ratio = (1 liter/50 ml) = 20.

The data were analyzed as a split-plot design where spray volume was considered as the main effect and sample locations on the tree as subplot treatments. Variability of deposition among samples was expressed as the coefficient of variation (CV).

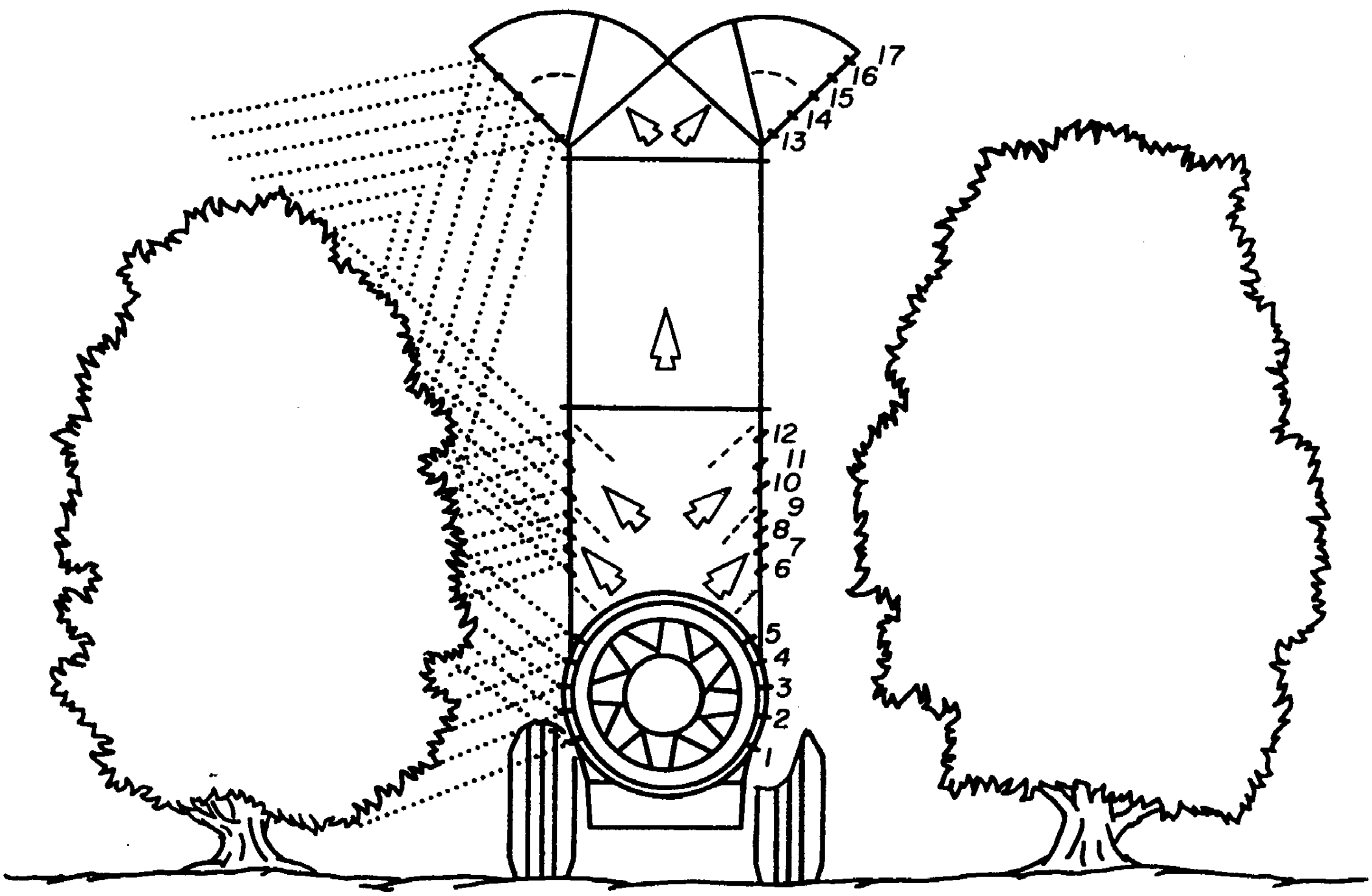

Fig. 1. Schematic view of the sprayer and its nozzle locations.

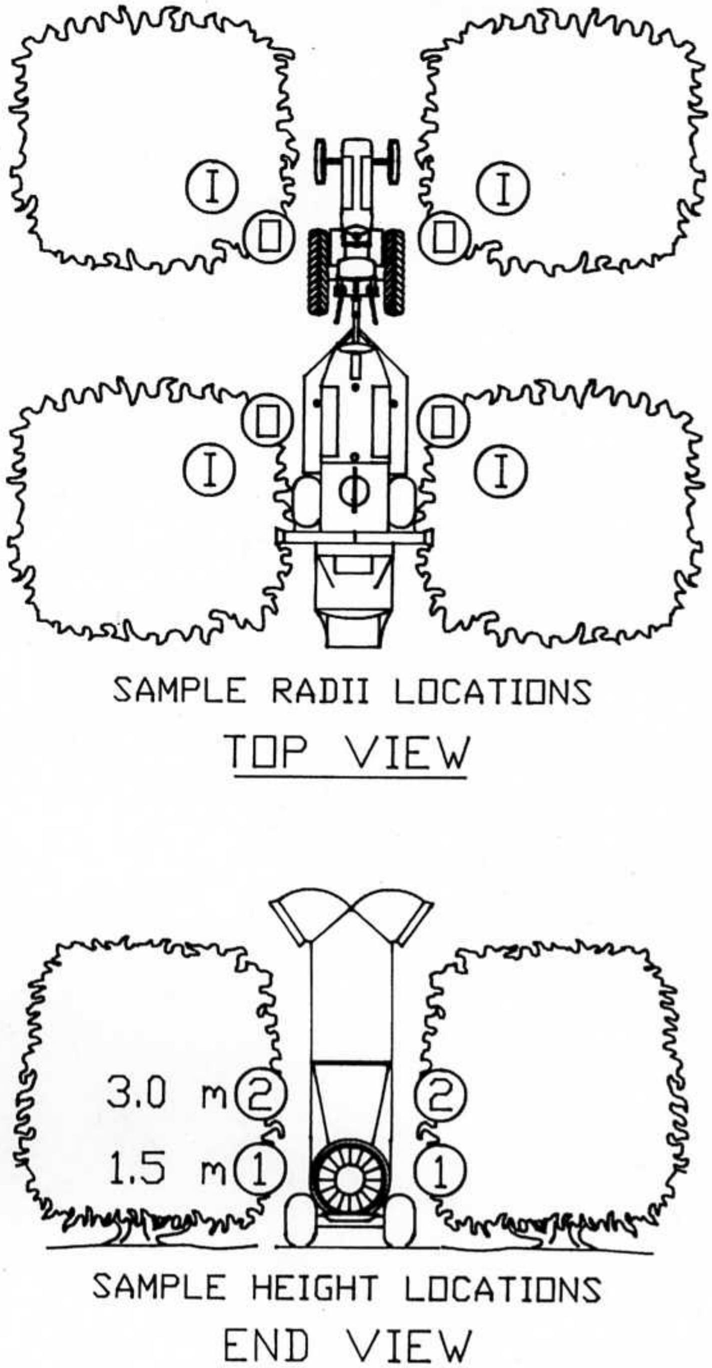

Fig. 2. Sample locations. I = inside; O = outside.

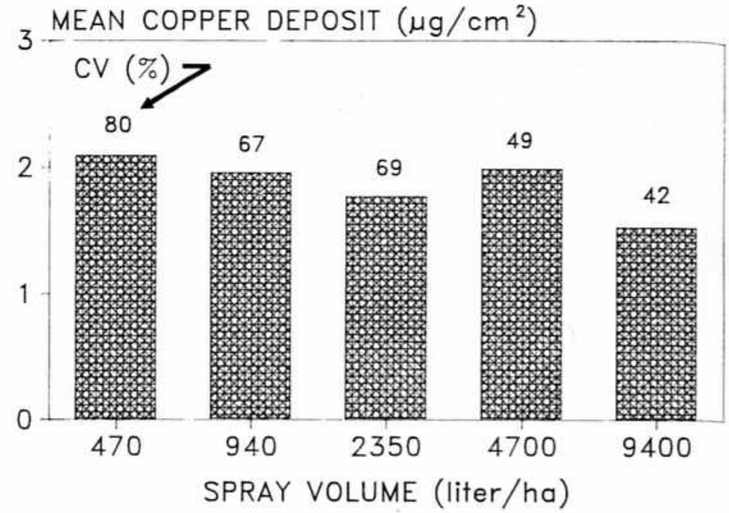

Fig. 3. Mean spray deposition at different spray volumes.

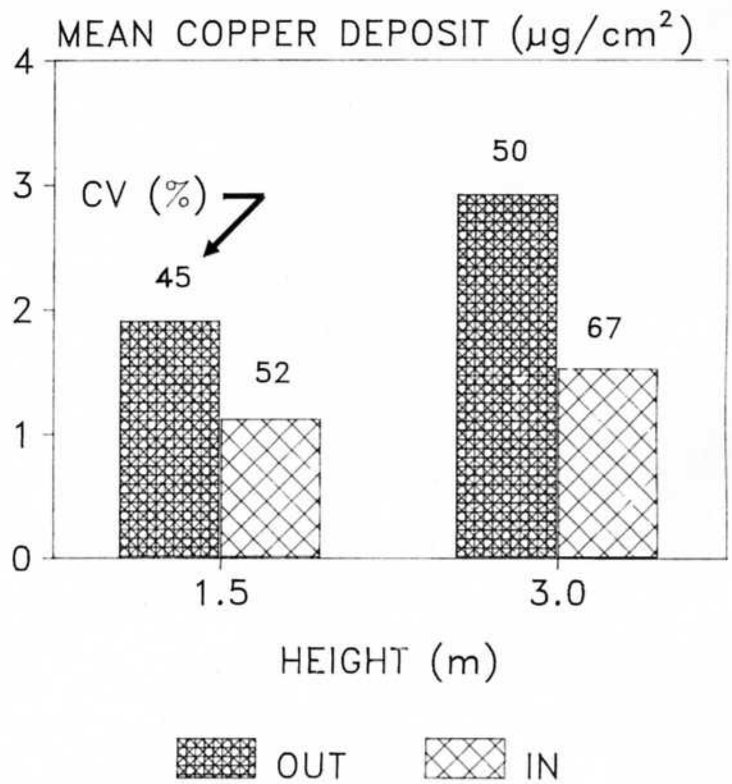

Fig. 4. Mean spray deposition at different sample heights and radii.

Results and Discussion

Statistical differences of the results refer to F-values at a 5% level.

Residual copper deposit on unsprayed leaves was low (averaged 8.7% of the treatment deposits) but was not uniform throughout the canopy. Comparatively, there was more residual copper on leaves at lower and inner locations of the canopy than at higher locations and outside the canopy. The east side of the tree had more residue than the west side. Therefore, treatment deposits were adjusted for background residue at different locations.

Spray volume and sample location had a significant effect on deposition. Overall, mean copper deposit and variability of deposition increased as spray volume decreased (Fig. 3). The lowest volume (470 liters/ha) deposited 1.37 times more copper than the highest volume (9,400 liters/ha). The relatively high deposit at 4,700 liters/ha could not be explained and may have resulted from colorimetry errors.

Deposits were higher at the 3.0 m height and outside the canopy compared to 1.5 m height and inside of the canopy (Fig. 4). Variability of deposition increased in the same manner. There was a significant interaction between sample height and spray volume (Fig. 5). While at 3.0 m height mean deposit decreased as spray volume increased, there was no such trend at 1.5 m height. However, variabil-

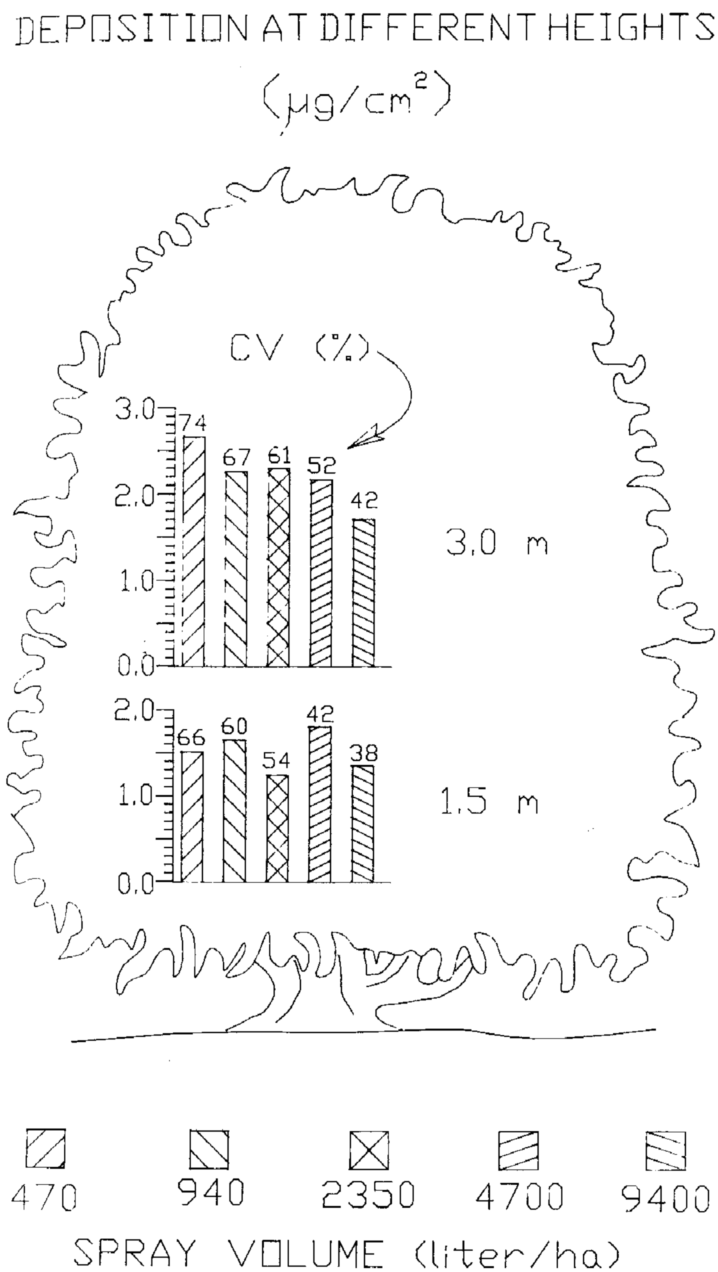

Fig. 6. Deposition of copper outside and inside the canopy for different spray volumes.

ity of deposition at both heights increased as spray volume decreased. There was also a significant interaction between radial location of the leaf samples and spray volume (Fig. 6). While mean deposit and variability of deposition outside the canopy increased with decreasing volume, no such trend occurred within the canopy.

The increase in deposition at lower volumes may have been due to a decrease in the amount of spray runoff from the leaf surface, and this is related to the size of spray droplets (6). Smaller size orifices, used in nozzles for lower volumes, tend to generate more small droplets than larger size orifices used for higher volumes. Observing leaves immediately after spraying revealed that as soon as impinged droplets touched each other, they coalesced and eventually ran off the leaf surface. This process, coupled with low wettability of citrus leaves, created a "washing effect" at higher volumes where only a small amount of deposit remained on the leaf surface and at the tip of leaves. By reducing spray volume and increasing the concentration of the spray, smaller and more concentrated droplets did not touch each other readily and, therefore, remained distributed on the leaf surface resulting in increased deposition. This was more evident outside the tree canopy (Fig. 6) where the leaves received sufficient number of droplets to show that effect.

Variability of deposition, in general, is due to natural differences in location and orientation of the leaf samples in the tree canopy. However, the effect of spray volume on the variability of deposition may be attributed to the droplet size and tank mix tracer concentration. Predominantly small drift-prone droplets, generated at lower spray volumes, are mostly transported by the entrained air and deposit inconsistently throughout the canopy. Large size droplets, on the other hand, deposit by direct inertial impaction and thereby result in more uniform and predictable deposition at higher volumes. Increasing tank mix concentration amplifies the variability in deposition so that the presence or absence of few concentrated droplets can make a big difference in measured deposits.

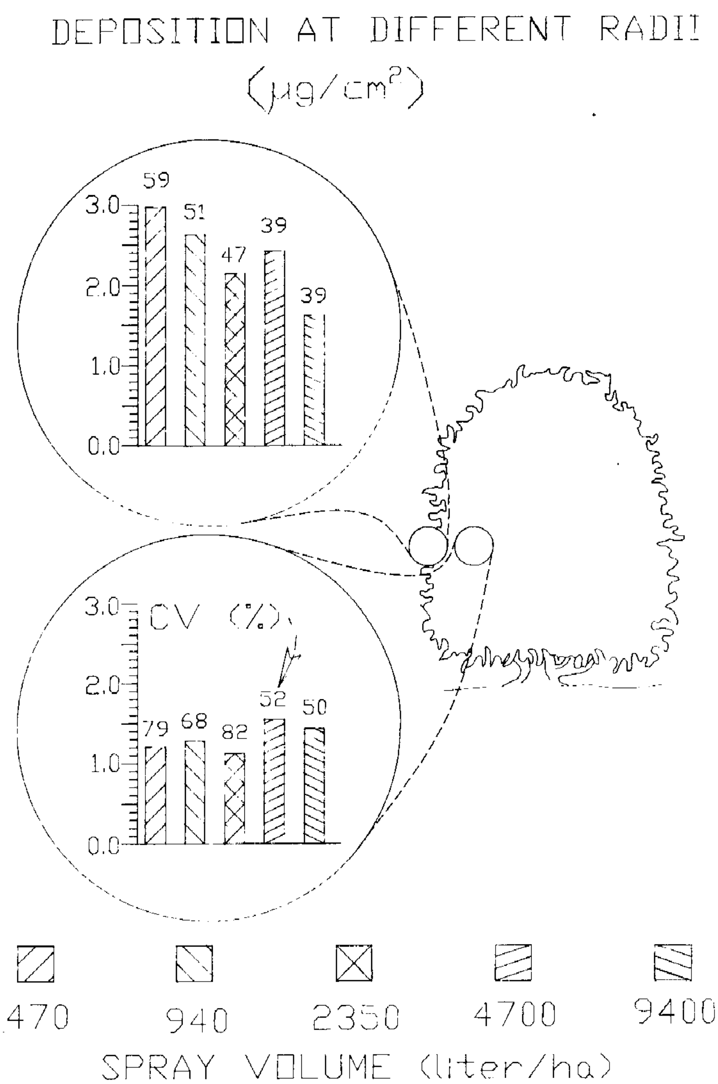

Fig. 6. Deposition of copper outside and inside the canopy for different spray volumes.

Results of this experiment are in general agreement with the results of our previous experiment (7) that were obtained under the same grove conditions with different sample locations. However, different grove and spraying conditions may yield different results.

On the basis of these results, it was concluded that as spray volume decreases, mean deposit and variability of deposition increases. However, the trend is not consistent throughout the canopy and could be affected by sample location.

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SPRAY VOLUME AND ACARICIDE RATE EFFECTS ON THE CONTROL OF THE CITRUS RUST MITE

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Abstract. **In two independent field experiments on mature 15 to 18 ft high 'Valencia' orange trees, residual control of citrus rust mite, *Phyllocoptruta oleivora* (Ashmead) was evaluated at a constant and variable rate of selected acaricides at different spray volumes ranging from 25 to 1000 gal/acre using an airblast sprayer. The preceding paper presents data on foliar spray coverage using copper tracer methodology.**

In all experiments, no significant differences in initial mortality or residual control of citrus rust mite on fruit was found between spray volumes regardless of rate of application or acaricide. Residual control was affected by the kind and rate of acaricide used in the test. No significant interaction between spray volume and acaricide rate was detected indicating that acaricide rate affected the control of citrus rust mite regardless of the change in spray volume.

Residual control of the citrus rust mite on leaves at different canopy locations at different spray volumes was difficult to assess because of high variability in mite population density between samples. Residual mite control was significantly better on leaves in the upper compared to the lower tree canopy. Interestingly, mean cumulative mite days on leaves treated with copper (tracer) were significantly lower than on untreated leaves.

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The citrus rust mite, *Phyllocoptruta oleivora* (Ashmead) is ubiquitous on citrus in most humid citrus-growing regions of the world where it infests twigs, leaves, and fruit of all citrus varieties (15, 25). In Florida, the citrus rust mite (CRM) is primarily a pest of fruit destined for the fresh market though occasionally under ideal physical and cultural conditions favoring the mite (15, 17), its injury from cellular feeding can affect fruit growth (2), fruit drop (1), internal fruit quality (16) and external fruit quality (14, 15).

Since the CRM inhabits the new fruit and foliage each year in March and April (12) and reaches injurious population densities anytime from early June to November (3, 15, 17), it is common for growers to apply 3 to 4 acaricidal sprays during the year. This need to spray frequently for CRM is influenced by its biological attributes; that is, its inherent ability to increase to injurious densities on fruit quickly (14) and its small size which makes it extremely difficult to monitor in the field in order to time acaricide treatment accurately.

Since the CRM prefers to inhabit the fruit and foliage of the outer canopy of the tree (12), both common sense and the published data suggest that thorough spray coverage of the total tree canopy is not crucial, and it should be amenable to control via concentrate (low volume) spraying.

From the pioneer works at the Citrus Experiment Stations at Lake Alfred, FL and Riverside, CA, studies with multi-head sprayers, air-blast sprayers, aircraft and low volume sprayers have demonstrated successful control of citrus rust mite (4, 5, 6, 7, 9, 21) and citrus red mite (10). Recent studies suggest that low volume application also has potential for pests such as greasy spot disease that inhabit the underside of the leaf (24). Recently, Salyani and McCoy (19) found that small spray droplets gave uniform coverage on fruit, less coalescence of droplets for runoff, and a higher mortality of citrus rust mite.

Of the various components that operate in spray technology, spray volume reduction is one key factor that