

GROUND SPEED EFFECT ON SPRAY DEPOSITION INSIDE CITRUS TREES

M. Salyani, J.D. Whitney

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ABSTRACT

The effects of sprayer ground speed (1-4 mph) on spray deposition at different locations within citrus tree canopies was characterized using different airblast sprayers, tree types, and sampling methodologies, in two spray tests carried out in Florida citrus. Copper hydroxide with 50% metallic copper was applied as a tracer. Cotton ribbons and citrus leaves were used as sampling targets and deposition was determined by copper colorimetry.

Ground speed did not have a significant effect on mean deposition in the tree canopy; however, variability of deposition increased as speed increased. Sample location had a significant effect on spray deposition and showed significant interactions with speed. **KEYWORDS.** Spray deposition, Airblast sprayer, Speed, Citrus, Colorimeter, Spray targets.

INTRODUCTION

Citrus groves in Florida may receive two to three sprays annually for processed fruit and four to five sprays for fresh market fruit. The cost of spraying (material and application) is significant for citrus production, and may amount to more than one-third of the total production cost for fresh market fruit (Muraro et al., 1988). Analyzing the application cost of airblast spraying in Florida citrus. Whitney (1968) showed that application costs are a function of spray volume, spraying speed, intergrove travel time, and daily service or other non-productive times. It was shown that increasing speed can result in a reduction of spray application cost. Increasing speed decreases labor, fuel, repair and maintenance costs, and may reduce machinery investment cost and provide more timely applications. Practically, it is important to know whether spraying at higher ground speeds can result in the same amount and quality of deposition as spraying at the normally practiced speeds of 1-1.5 mph.

Using a sprayer-model in a wind tunnel, Fox et al. (1985) found that wind velocity and sprayer ground speed had significant effects on the air jet produced by an orchard air sprayer. They concluded that large air deflections (due to high sprayer ground speed and/or crosswind) will reduce the capability of the air delivery system to penetrate all parts of the canopy.

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The authors are M. Salyani, Associate Professor of Agricultural Engineering, and J.D. Whitney, Professor of Agricultural Engineering, University of Florida, IFAS, Citrus Research and Education Center, Lake Alfred, FL 33850.

Randall (1971) investigated the effects of air volume and pressure, wind, and ground speed (2 mph and 4 mph) on the uniformity of spray material on bush apple trees and concluded that the slower a sprayer travels the greater the uniformity of deposit.

Travis et al. (1987) sprayed apple trees at ground speeds of 1.5, 2, 2.5 and 3 mph. They observed greater mean deposits for lower speeds and greatest variability of deposit at the highest speed. Fox et al. (1979) measured air velocity profiles and pesticide deposits at selected distances from sprayer outlet at ground speeds of 2.6, 3.4, and 5 mph. They found that both measured air velocities and deposits decreased as spraying speed and distance from the outlet increased.

Using different airblast sprayers and spray volumes in Florida citrus, Whitney et al. (1989) examined the effect of ground speed (1, 1.75, and 2.5 mph) on upper and lower leaf surface deposition. Speed significantly increased deposition on the upper leaf surface, but not on the lower leaf surface. The total leaf surface deposition increased as ground speed increased. The results were not in agreement with previous works and suggested additional tests under different conditions.

This article reports the results of later tests in Florida citrus using wider speed ranges, different tree types, and different sampling methodologies. The objective of this work is to characterize spray deposition at different locations of citrus tree canopy as a function of sprayer ground speed.

EQUIPMENT AND PROCEDURES

Field tests were conducted in 1988 and 1989. The data were analyzed separately and results are reported separately.

THE 1988 TEST

A completely randomized experiment with four speed treatments (1, 1.75, 2.5, 4 mph) and four replications was conducted on 4 plots of tangelo trees. The trees were hedged straight on four sides, did not have large openings in their canopies, had a spacing of 25 x 25 ft., and were about 18 ft. in height and diameter. Nine cotton ribbons 18 ft. long x 1 in. wide were used as spray targets on the center tree of each three tree plot. They were placed inside the tree canopy (fig. 1) at three heights (I = 5 ft., II = 10.5 ft., III = 16 ft.) and three lines (A, B, C; 4 ft. apart).

*Trade and company names mentioned in this article are solely for providing specific information. Their mention does not constitute an endorsement over other products not mentioned.

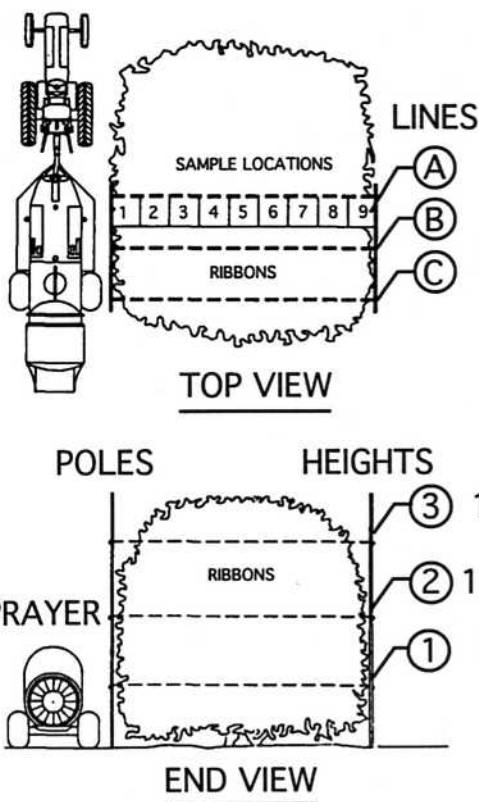


Figure 1-Schematic view of ribbon sample locations in 1988 test.

The spray mixture contained cupric hydroxide (50% metallic copper) with 720 ppm elemental copper as a tracer. An airblast sprayer (FMC Model 1087)* was used in the experiment. Different nozzles were used for each of the four speeds so that the mixture was applied at a constant volume rate of 250 GPA (based on spraying from two sides) to one side of the test trees (Table 1). In all cases, the sprayer was calibrated to deliver approximately two-thirds of nozzle discharge from the top half of the nozzle manifold and one-third from the bottom half, i.e., the normal spraying practice for Florida citrus. The sprayer had an air volume flow rate of 106,000 cfm (measured with a

Pilot tube over air discharge) and was equipped with oscillators. Target samples were sections of the sprayed ribbons (fig. 1). When each ribbon was pulled out of the canopy, it was cut into nine sections (2 ft. long), placed inside coded plastic bags, and brought to the laboratory for copper colorimetry (Salyani and Whitney, 1988). Deposition data were expressed in 1 billionth of a gram (16×10^{-9}) of elemental copper per unit area of ribbon surface (both sides) and variability of deposits among samples (not on individual samples) as coefficient of variation (CV). Analysis of variance on the data was performed as a split-plot design, with speed and sample locations as main plot and subplot effects, respectively.

THE 1989 TEST

A completely randomized block design experiment, with four ground speed treatments (1, 2, 3, 4 mph) and six replications was carried out on three grapefruit and three orange tree plots. Each sprayed plot (replication) consisted of three trees; however, only the center tree of each plot was utilized for mounting spray targets. The grapefruit trees were spaced at 30 x 25 ft., had touching canopies (in the row), about 18 ft. height, and about 24 ft. diameter. Orange trees were single, spaced at 30 x 20 ft., about 15.5 ft. in height and 20 ft. in diameter, and their canopy center had comparatively denser foliage than the grapefruit trees.

Shoots (with 6-10 leaves) from the same kind of tree were used as spray targets. They were washed in a 0.05 N nitric acid solution and then in deionized water to remove their residual copper residues, air dried, and positioned with spring clips at different locations on the center tree of each plot (fig. 2). Target shoots were placed at two heights (6 and 12 ft.) and three locations (X, Y, Z), for a total of six sample positions per tree. At locations X and Y (nearest to the sprayer and on the trunk line, respectively) the clips were taped to tree limbs (2 - 2 1/2 ft. inside the canopy) and at location Z (center of poles).

The spray mixture contained cupric hydroxide with 240 ppm elemental copper. An FMC airblast sprayer (Model 9100) was nozzled to apply 500 gal/A at 1 mph from two sides of the tree. The sprayer used 10 ceramic disc-core nozzles. Again, two-thirds of the sprayer discharge was from

TABLE 1. Sprayer nozzle arrangement for the 1988 test.

Ground speed mph	Nozzle disc No./No. of whirl plate holes*							Flow rate per side GPM	Volume rate GPA
	Bottom	Nozzle manifolds					Top		
1	3/2	3/2	4/2	4/2	5/2	5/2	5/2	6.3	250
1 3/4	3/2	3/2	3/2	3/2	5/2	7/2	7/2	11.0	250
2 1/2	4/2	4/2	5/2	4/2	6/2	6/2	6/2	15.8	250
4	3/2	4/2	4/2	5/2	6/3	6/3	7/3	25.3	250
	6/2	6/2	5/2	6/2	7/3	7/3	7/3		
	5/2	5/2	6/2	6/2	7/3	7/3	8/3		

* FMC nozzles with ceramic disc and core (whirl plate).

* Nominal flow and volume rates at 200 PSI. The actual rates were within 5% of the nominal values. The volume rate is based on spraying from two sides.

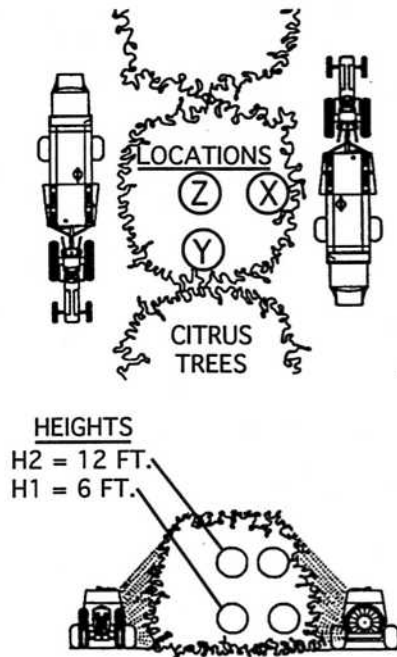


Figure 2- Schematic view of leaf sample locations in 1989 test.

the top five nozzles (No. 6 discs with three-hole whirl plates) and one-third from the bottom five nozzles (No. 6 discs with two-hole whirl plates). Nozzle selections and sprayer output (15.1 gpm/side at 160 psi) were kept the same for all speeds; therefore, volume rate/gpa decreased in proportion to the speed increase. The sprayer had an air volume flow rate of 106,000 cfm and was equipped with oscillators.

The sample from each location comprised 3-5 leaves from the sprayed target shoot. They were clipped randomly, placed in coded plastic bags, and taken to the laboratory for copper colorimetry. After measuring copper deposits on leaves, the surface areas of leaf samples were measured with a Delta-T Type AMB Area Meter.

Since nozzle selections and sprayer discharge were not changed to compensate for the speed increase (as in the 1988 test), raw deposit data corresponding to the speeds of 1, 2, 3 and 4 mph, were multiplied by speed factors 1, 2, 3, and 4, respectively, to obtain comparable data for all speeds. Deposition data were expressed in ng = 1 billionth of a gram per unit area of leaf surface (both sides) and analyzed as a split-plot design with speed as main plot effect and sample locations as subplot effects.

RESULTS AND DISCUSSION

Statistical significances of results, where mentioned, refer to F-values at 5% level.

The 1988 Test

Spraying speed did not have a significant effect on mean spray deposition (Table 2). The lowest and highest deposits occurred at the lowest and highest speeds, respectively. Overall variability of deposits was similar at all speeds. The high CV values reflect large differences in deposits at different locations of the canopy and closely represent

pesticide distributions normally experienced in applications to citrus groves.

There were significant differences in mean copper deposits at the heights (fig. 3) and was basically due to the large output from the top half of the nozzle manifold. This was not a particularly desirable result, but represented a realistic picture of deposition with the normal practice in sprayer nozzling. The interaction of speed with height was also significant. While for the two lower speeds mean deposits at 10.5 ft. were slightly less than at 16 ft., there were substantially more deposits at 10.5 ft. than at 16 ft. for the two higher speeds. The variability (CV) in deposits was least at the 5 ft. height compared to the other two heights and CVs slightly increased with speed. CVs at 10.5 ft. generally remained the same for all speeds. The 16 ft. height had the highest CVs which decreased slightly as speed increased.

Deposition on different lines was significantly different; but, line x speed interaction was not significant (fig. 4). Line A (running through tree center) and line C (near the edge of canopy) had respectively the lowest and highest deposits at all speeds. However, the highest variability was observed on line B, which was surrounded by maximum amount of foliage. It should be noted that most sections of the line C at the 16 ft. height were located outside the rounded top of the tree canopy and may have contributed toward heavier deposits for that line. However, exclusion of the data for that line did not give a significant change in the results of the analysis.

The depth of sample section inside the canopy, which was a function of distance from the sprayer, had a significant effect on deposition and the amount of deposits decreased as sample depth increased (fig. 5). There was no significant interaction between speed and sample depth and the decreasing trend in deposition was similar at all speeds. However, variability of deposits at each depth was not the same at all speeds. In general, CV increased as speed increased and the increase was more pronounced at deeper sample locations.

THE 1989 TEST

Spraying speed did not have a significant effect on mean copper deposition and deposits were about the same at all speeds (Table 3); however, variability of deposits generally increased as speed increased.

There were significantly more deposits at 12 ft. than at 6 ft. heights. As mentioned earlier, this difference was a function of nozzle arrangement; nevertheless, speed and height showed no significant interaction (fig. 6). Deposition at 6 ft. was substantially less than that at 12 ft., at all speeds;

TABLE 2. Mean copper deposit on ribbons at different ground speeds (1988 test)

Ground speed MPH	Flow rate per side GPM	Volume rate GPA	Mean* deposit ng/cm ²	CV %
1	6.3	250	560	116
1 3/4	11.0	250	620	108
2 1/2	15.8	250	600	108
4	25.3	250	640	113

* The trees were sprayed from one side, with a 720 ppm elemental copper tracer.

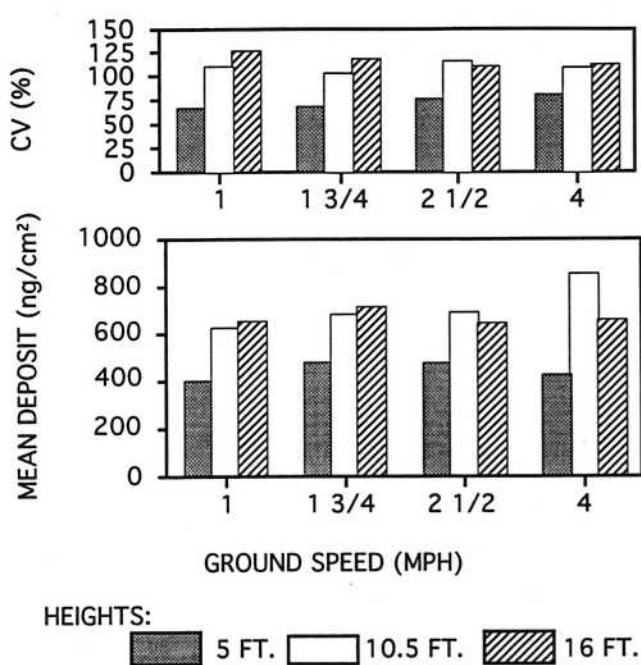


Figure 3-Copper deposition on ribbons at different heights (1988).

however, at 4 mph the difference was decreased. Except at 12 ft. height and 4 mph speed, CVs for both heights increased as speed increased.

There was a significant difference in deposition at the 3 locations and the interaction of location with speed was significant (fig. 7). Maximum and minimum deposits occurred at X and Y locations, respectively. At location X (nearest to the sprayer) deposit increased as spraying speed increased. This may be attributed to possible run-off effect, thereby resulting in lower deposits at lower speeds. At

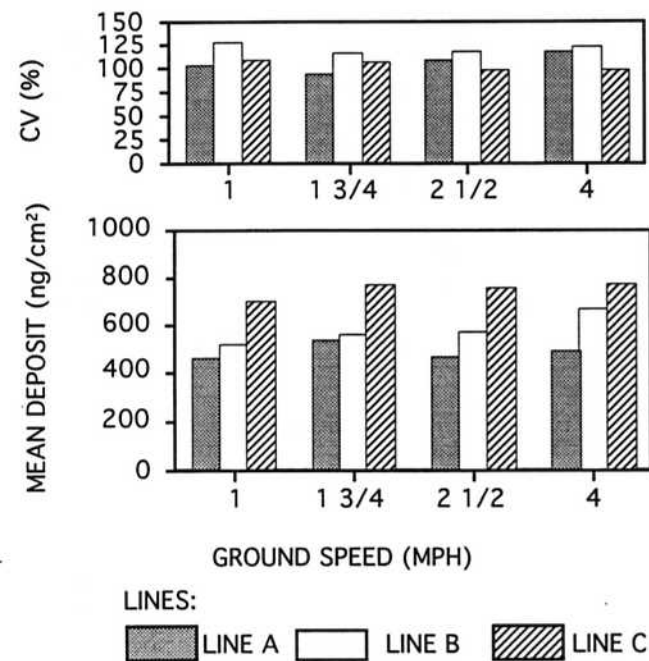


Figure 4-Copper deposition on ribbons on different lines (1988).

location Y (trunk line), where there was a lot of foliage and sample locations were farther from the sprayer, there was a slight decrease in deposition as speed increased. Except for the 1 mph speed, deposition at the center of tree (Z) decreased as speed increased. Variability of deposition was lowest at X, but it did not change consistently with speed.

Overall, grapefruit trees had higher deposits than orange trees; however, the difference was not the same at all locations (fig. 8). At location Y there was slightly more deposit on orange trees than on grapefruit trees. This may have been due to the grapefruit canopy touching in the rows, while orange trees were standing individually, thereby having a better chance of receiving trailing sprays (passing around outside tree canopy). At Z, orange trees had substantially less deposit than grapefruit trees, which may have been due to the denser foliage (difficulty in penetration) at the center of the orange trees. At all locations, variability of deposition was higher for orange trees.

GENERAL DISCUSSION

Despite differences in the two tests (in spray volume, nozzle size, nature of the target, and type of tree canopy), the results showed that spraying speed did not have a significant effect on mean copper deposition. Sample location significantly affected the deposition and canopy locations normally considered difficult to spray received less deposition and had larger coefficients of variation. Although these tests are not directly comparable to that of Whitney et al. (1989), the results are in general agreement. They all indicate that increasing speed does not necessarily reduce deposition and they do not agree with Fox et al. (1979) and Travis et al. (1987) who found greater deposits at lower speeds (with lower air volume rate sprayers). However, all reports indicate that variability of deposition increases at higher speeds and this should be considered when there is a need for very uniform deposition.

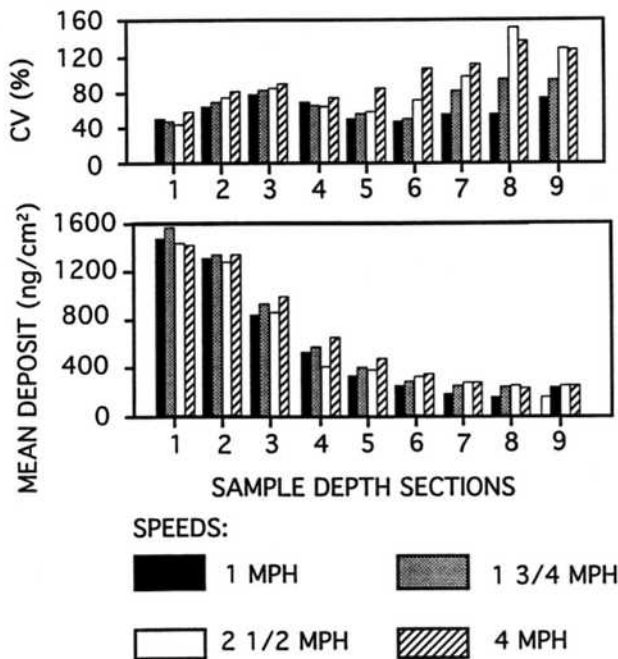


Figure 5-Copper deposition on ribbons for sample depth (1988).

TABLE 3. Mean copper deposit on ribbons at different ground speeds (1989 test)

Ground speed MPH	Flow rate per side GPM	Volume* rate GPA	Speed factor #	Actual ng/cm ²	Calculated ng/cm ²	CV %
1	15	500	1	485	485	58
1 3/4	15	250	2	225	451	73
2 1/2	15	167	3	159	477	84
4	15	125	4	117	468	84

* Volume rate changed with speed (same nozzles were used for all speeds).
 * The trees were sprayed from one side, with a 240 ppm elemental copper tracer. Calculated deposit = actual deposit x speed factor.

It should be noted that the results in this article were obtained with relatively high air volume sprayers (106,000 cfm), which are commonly used in spraying citrus. Results could be difference for sprayers that deliver much less air volume rates; therefore, general inferences should not be applied to all kinds of airblast sprayers. Changing the droplet size spectra with different nozzles and flow rates (1988 test), and change of spray volume rate (1989 test), could mask the effects of ground speed. However, the treatments simulate normal practices in citrus grove spray applications.

CONCLUSIONS

- 1) Ground speeds of 1-4 mph did not have a significant effect on mean spray deposition on citrus trees using high air volume rate airblast sprayers.
- 2) Variability of deposition (CV) increased with increased speed.
- 3) Sample position had a significant effect on deposition and, in general, had significant interactions with speed. Denser foliage and deeper sample positions resulted in lower depositions.

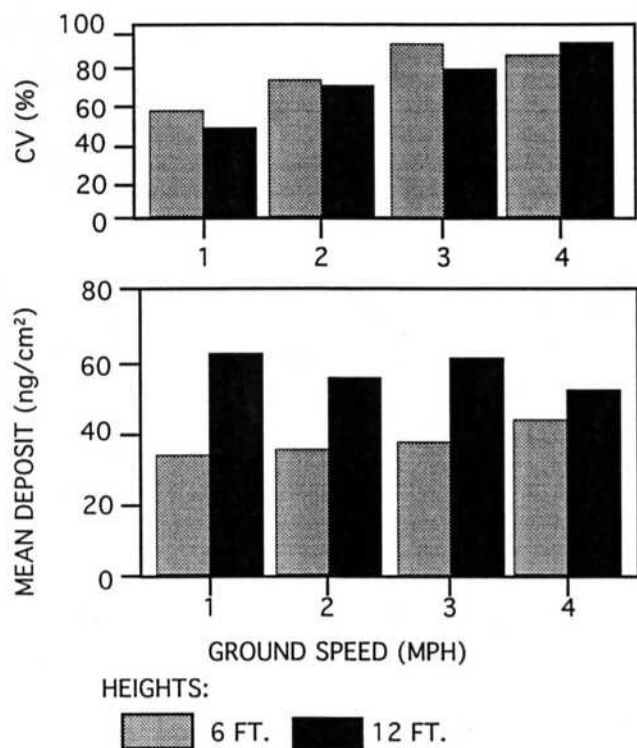


Figure 6-Copper deposition on leaves at different heights (1989).

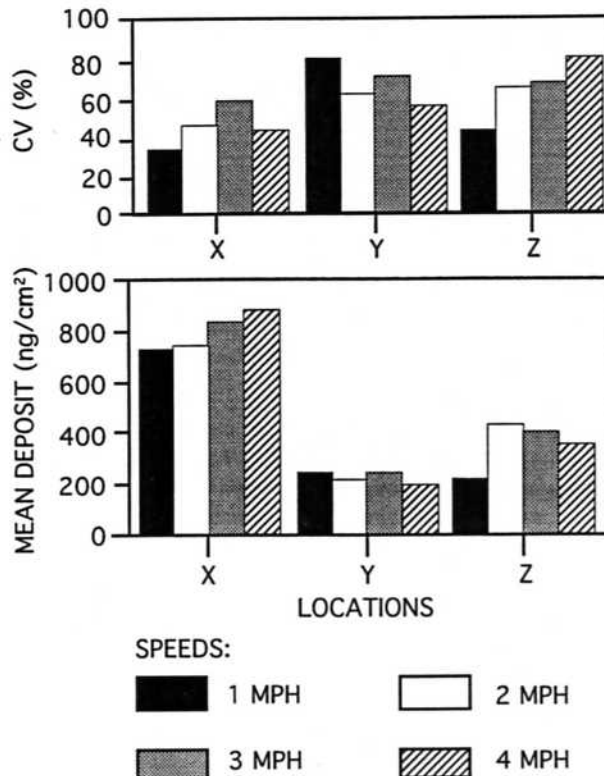


Figure 5-Copper deposition on ribbons for sample depth (1988).

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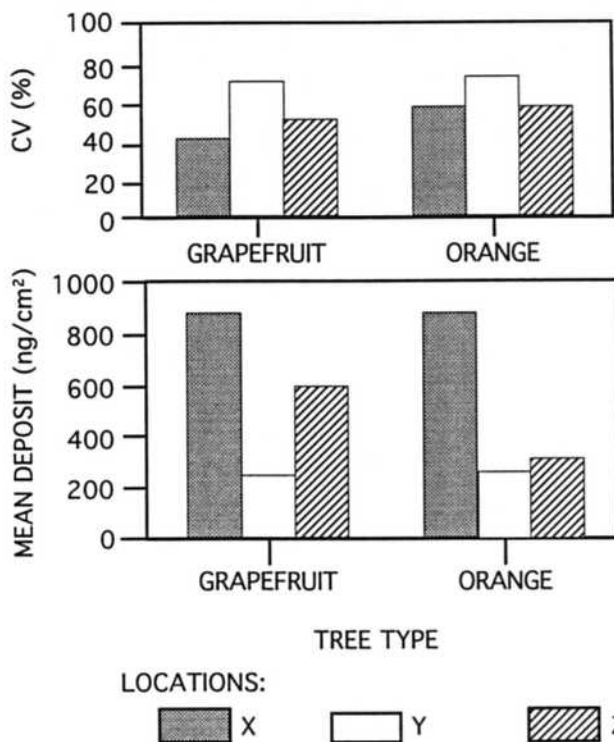


Figure 8-Copper deposition on leaves for different trees (1989).

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