Effect of Canopy Density on Pesticide Deposition and Distribution in Apple Trees

J. W. TRAVIS, Department of Plant Pathology and Horticultural Science, W. A. SKROCH, Department of Horticultural Science, and T. B. SUTTON, Department of Plant Pathology, North Carolina State University, Raleigh 27695

ABSTRACT

Travis, J. W., Skroch, W. A., and Sutton, T. B. 1987. Effect of canopy density on pesticide deposition and distribution in apple trees. Plant Disease 71:613-615.

Medium and small Golden Delicious apple trees were pruned to high, moderate, and light canopy densities. Four metal chelates (Sequestrene Zinc, Sequestrene Copper, Sequestrene Manganese, and Sequestrene 330 Fe) were applied to each of the trees with an airblast orchard sprayer. The leaf deposits were analyzed by foliar mineral analysis. The highest mean deposition and lowest variation in deposit were observed on the trees with light canopy density. Deposits on trees with high and moderate canopy densities were not different, but deposit variance was greater on trees with high canopy densities.

Commercial apple trees are usually pruned once a year to alter limb structure and reduce foliage density, which improves fruit size and quality and allows maximum pesticide penetration (1,3,4). The importance of limb structure and foliage density to pesticide deposition and distribution in apple trees was recognized by Byass (2), who attempted to construct a geometrical model of apple tree growth to define the tree more adequately as a target and thus improve spray efficiency. Ferree and Hall (3) found that permethrin deposits varied greatly depending on the pruning management system. Travis (7) observed differences in pesticide deposition and distribution on trees of uniform size and shape that had only small differences in foliage density.

All pest management strategies for fruit are based on the assumption that pesticides are uniformly distributed throughout the tree; however, the optimal limb and foliage density for maximum pesticide deposition and uniformity of deposit throughout apple trees has not been determined. The objective of this study was to determine the effect of apple tree foliage density on pesticide deposition and distribution.

Present address of first author: Department of Plant Pathology, Pennsylvania State University, University Park 16802.

Use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service of the products named or criticism of similar ones not mentioned.

Paper 7042 of the Journal Series of the North Carolina Agricultural Research Service, Raleigh 27695-7601. This study was supported by CS Grant 701-15-56.

Accepted for publication 28 January 1987 (submitted for electronic processing).

MATERIALS AND METHODS

Golden Delicious apple trees were pruned during the winter to produce three levels of canopy density: high, moderate, and low, corresponding to densities commonly observed in commercial orchards. The trees previously had been trained to the modified central leader canopy structure. One group of trees (moderate density) was pruned to produce "optimal" canopy density. Another group was pruned lightly (high density) to be more dense than the moderate-density trees, and a third group was pruned heavily (light density) to be less dense than the moderate-density trees. All density levels were within acceptable levels of canopy density for commercial apple trees. Two tree sizes were used: medium (about 3.6 m [depth] × 4.1 m [height] × 4.1 m [width]) and small (about 3.1 m [depth] × 3.1 m [height] × 3.1 m [width]). Each canopy density was replicated three times with each tree size.

In early June, 1 wk before the metal chelate applications, the canopy density was determined for 244-cm^3 (1-ft^3) sample volumes, which were defined within the tree by a Cartesian coordinate frame. Nylon cord was drawn throughout each tree to mark the center point of each 244-cm^3 sample volume in the tree. For each sample volume, the leaf number was estimated on a scale of 1–5 (1 = 0–5, 2 = 6–10, 3 = 11–20, 4 = 21–40, and 5 = 41 or more leaves), and the number of branches was recorded in five branch diameter ranges (B1 = 0–13 mm, B2 = 14–25 mm, B3 = 26–50 mm, B4 = 50–100 mm, and B5 = 101–254 mm). The number of apples in each sample volume was also recorded. This information was compiled and weighted $[(\text{leaf rating} \times 2) + B1/5 + B2/3 + B3 + (B4 \times 3) + (B5 \times 5) + \text{apple number}/4]$ to give a canopy density estimate for each sample volume of the apple tree being tested. The weighting system was based on the assumed importance of each factor (leaf, limb, and apple) as a canopy density component of the tree. Tree limbs and apples are relatively immovable by the airstream and are probably very effective in reducing airstream velocity and droplet penetration in proportion to the total canopy volume occupied. Individually, leaves are less likely to impede airstream penetration, but in total, they are assumed to be the most important factor in reducing airstream velocity.

Chelate foliar micronutrients Sequestrene Copper (13%), Sequestrene 330 Fe (10%), Sequestrene Manganese (12%), and Sequestrene Zinc (14.2%) (Ciba-Geigy, Greensboro, NC) were used to determine deposition and distribution within the trees. These materials can be used as a measure of the deposits achieved with pesticides (9). Samples were collected from every 244 cm^3 (1 ft^3) of each tree. Each sample was labeled with three dimensional coordinates: depth (divisions perpendicular to the sprayer), height (height of the tree), and width (divisions parallel to the sprayer) (Fig. 1). Samples were analyzed, and micrograms of deposit per square centimeter of leaf surface were determined as described by Travis (9). Mean deposits are reported in terms of an initial concentration of 1,920 μg/ml micronutrient in the sprayer tank.

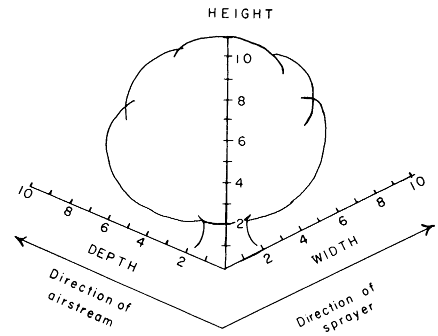

Fig. 1. Diagramatic illustration of the three dimensional coordinates showing direction of sprayer travel and droplet discharge (units in 30.5-cm [1-ft] increments).

The metal chelates were applied to one side of each tree with an FMC John Bean (model E200 TR) speed sprayer. The travel speed of the sprayer was 54 m/min, and the sprayer delivered 617 L/ha. Manifold pressure was 1,378.9 kPa. Two-thirds of the total spray volume was directed to the top one-third of the tree, and the remaining one-third of the spray volume was directed toward the bottom two-thirds of the tree. During the metal chelate applications, the temperature was 22–25 C, the relative humidity was greater than 70%, and the wind speed was less than 1 m/sec.

RESULTS AND DISCUSSION

Tree density. The mean canopy density of each pruning level was different within small and medium trees (Table 1). Canopy density was least near the ground (height 2) on both tree sizes (Fig. 2). Canopy density increased in the mid-canopy region, then decreased in the top of the medium trees (heights 10 to 14) of high and moderate canopy density. On small trees, canopy density increased with increased height on light canopy density trees and fluctuated in moderate and high canopy density trees. Because of the consistent differences in the three canopy densities, differences in deposit were considered a function of canopy density.

Deposition. The greatest deposit occurred on small and medium trees of light canopy density (Table 1). These trees also had the lowest variation in deposit (expressed as $\log_{10}$ of the μg a.i./cm^2 [LV]). This is probably a result of more uniform penetration and distribution of the metal chelates. The mean deposits on high and moderate canopy density trees were not different, although the variation in deposit was greater on high canopy density trees than on moderate canopy density trees of medium size. Sutton and Unrath (6) found that consistent deposit could be maintained on trees of different densities by adjusting the rate of water per hectare to reflect the tree density.

Mean deposition at depths, heights, and widths of trees. The mean deposit at each depth into the trees on both tree sizes was greater on trees of light canopy density than on those of medium and high canopy densities (Fig. 3). Deposits at depth 2 were greater on high canopy density trees than on moderate canopy density trees. However, after depth 6, the mean deposits were greater on moderate canopy density trees than on high canopy density trees. Travis (7) observed that trees of higher canopy density had greater mean deposition in the front of the tree than did trees of lower canopy density. He also observed greater mean deposits in the back of light canopy density trees than in the back of high canopy density trees. Differences in mean deposition as distance into the tree increased were consistent on medium and small trees of the same canopy density.

There was a decrease in mean deposit with increased height on both medium and small trees of high canopy density (Fig. 4). There was no difference in deposit with increased height in small trees of light canopy density or in medium and small trees of moderate canopy density. The decrease in mean deposit on high canopy density trees may have resulted from decreased spray penetration to the upper portions of the tree because of the high canopy densities. Lewis and Hickey (4,5) reported a decrease in pesticide deposit with increased tree height and distance from the sprayer. Brann (1) attributed the reduced deposit in the top of the trees to lower droplet velocities at the greater distances traveled. In general, the effect of height on mean deposition was not

Table 1. Mean deposits on Golden Delicious apple trees of three canopy densities

Tree size	Foliage density	Sample size[x]	Deposit mean[y]	LV[z] ($\mu g/cm^2$)	Canopy density mean[y]
Medium	High	948	9.8 b	0.084	14.2 a
	Moderate	644	10.5 b	0.066	11.0 b
	Light	632	12.1 a	0.057	8.1 c
Small	High	452	13.8 b	0.063	13.0 a
	Moderate	280	13.7 b	0.076	10.3 b
	Light	260	16.1 a	0.032	8.1 c

[x] The number of three-leaf samples collected.
[y] Means followed by the same letter are significantly different ($P = 0.05$) according to Duncan's multiple range test.
[z] Variance of log μg a.i./cm^2 of leaf surface.

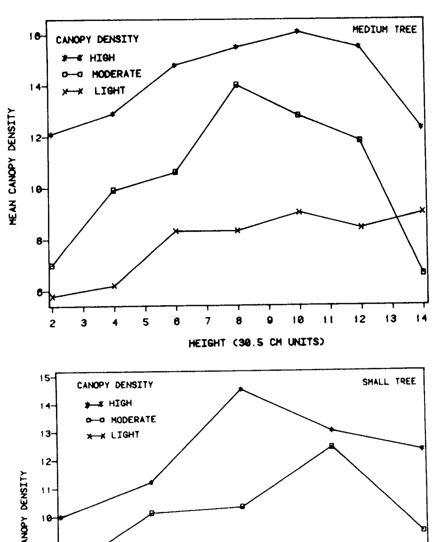

Fig. 2. Canopy densities of medium and small Golden Delicious apple trees at heights in the tree. See text for calculation of density values.

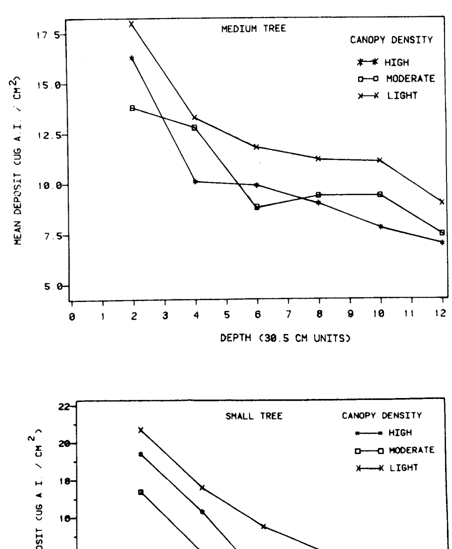

Fig. 3. Mean deposits of depths in medium and small Golden Delicious apple trees of three canopy densities.

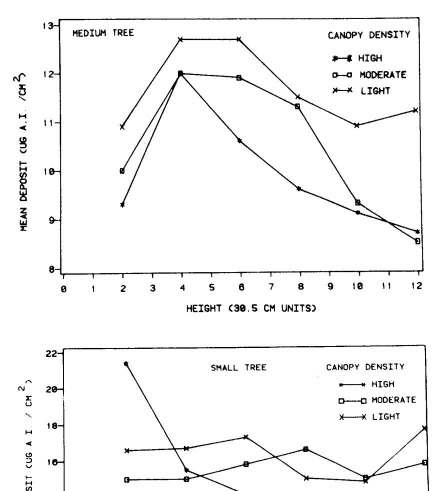

Fig. 4. Mean deposits at heights in medium and small Golden Delicious apple trees of three canopy densities.

great; this is most likely because of the disproportionate spray volume directed to the top one-third of the tree. Travis et al (8) and Brann (1) found that by directing two-thirds of the spray volume to the top one-third of the tree, mean deposits were generally not different with increasing height of the tree.

To achieve effective and efficient management of pests or pathogens, a uniform distribution of the pesticide at a proper level of deposition is required throughout the tree. This study has shown that pesticide deposition in apple trees is affected by the foliage density. Apple trees pruned to a light canopy density had the greatest deposits and the most uniform distribution. This reemphasizes the importance of pruning not only as a practice to improve fruit quality but as an important tactic in disease and insect management programs.

ACKNOWLEDGMENTS

We wish to thank L. R. Pope and A. Nicholas for assistance during this study.

LITERATURE CITED

1. Brann, J. L., Jr. 1965. Factors affecting the thoroughness of spray application. N.Y. State Hortic. Soc. Proc. 110:186-195.
2. Byass, J. B. 1968. Equipment and methods for orchard spray application research. II. The geometry of apple trees. J. Agric. Eng. Res. 13:358-369.
3. Ferree, D. C., and Hall, F. R. 1980. Canopy development, light, and spray penetration in Golden Delicious trees in four management systems. Acta Hortic. 114:91-99.
4. Lewis, F. H., and Hickey, K. D. 1964. Pesticide application from one side on deciduous fruit trees. N.Y. State Hortic. Soc. Proc. 109:209-213.
5. Lewis, F. H., and Hickey, K. D. 1972. Fungicide usage on deciduous fruit trees. Annu. Rev. Phytopathol. 10:399-428.
6. Sutton, T. B., and Unrath, C. R. 1984. Evaluation of the tree-row-volume concept with density adjustments in relation to spray deposits in apple orchards. Plant Dis. 68:480-484.
7. Travis, J. W. 1981. Factors affecting pesticide distribution in apple trees. Ph.D. thesis, North Carolina State University, Raleigh. 72 pp.
8. Travis, J. W., Skroch, W. A., and Sutton, T. B. 1987. Effects of travel speed, application volume, and nozzle arrangement on deposition and distribution of pesticides in apple trees. Plant Dis. 71:606-612.
9. Travis, J. W., Sutton, T. B., and Skroch, W. A. 1985. A technique for determining the deposition of heavy metals in pesticides. Phytopathology 75:783-785.