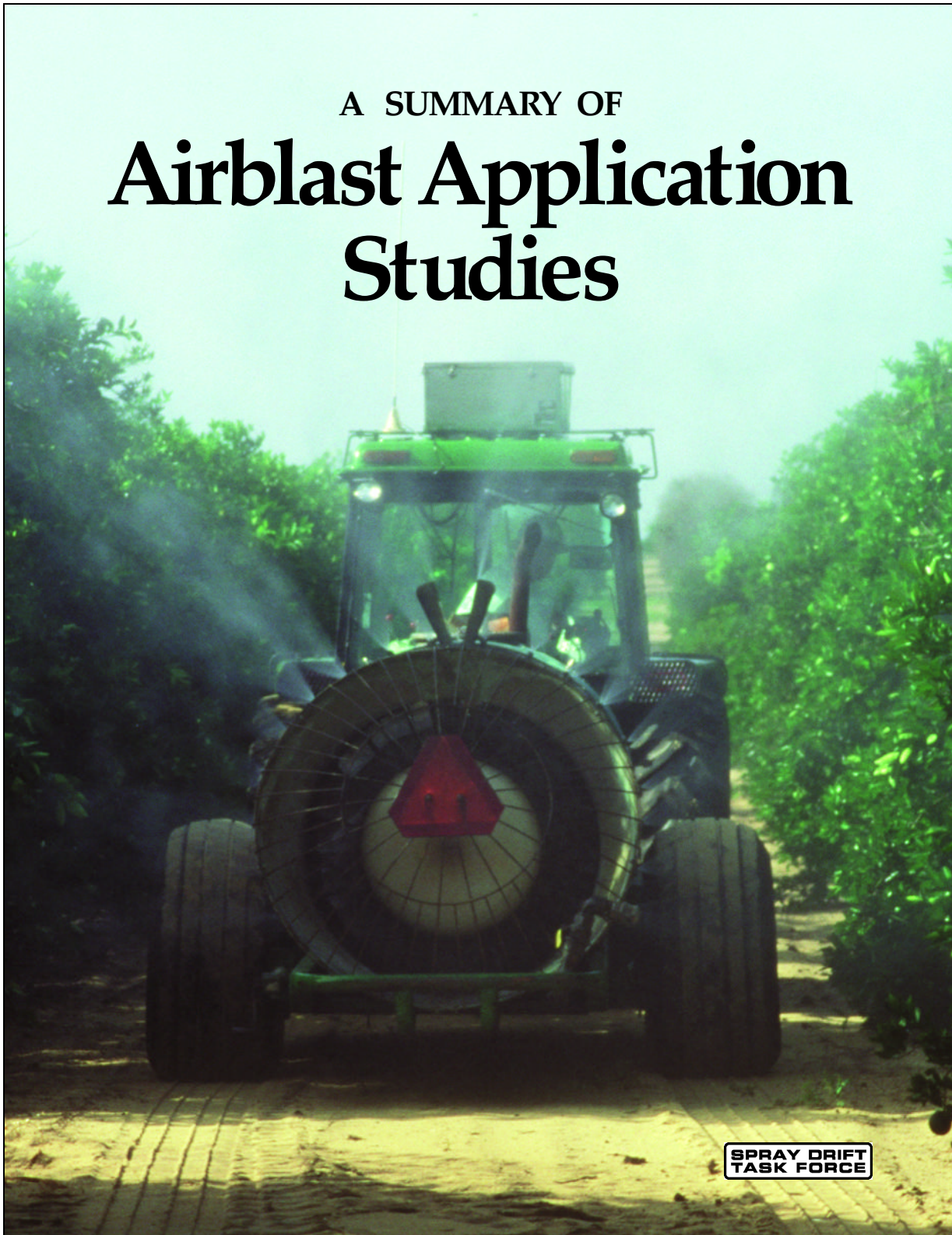


A SUMMARY OF
**Airblast Application
Studies**



**SPRAY DRIFT
TASK FORCE**

Introduction

The incidence and impact of spray drift can be minimized by proper equipment selection and setup, and good application technique. Although the Spray Drift Task Force (SDTF) studies were conducted to support product registration, they provide substantial information that can be used to minimize the incidence and impact of spray drift. The purpose of this report is to describe the SDTF orchard airblast application studies and to raise the level of understanding about the factors that affect spray drift.

The SDTF is a consortium of 38 agricultural chemical companies established in 1990 in response to Environmental Protection Agency (EPA) spray drift data requirements. Data were generated to support the reregistration of approximately 2,000 existing products and the registration of future products from SDTF member companies. The studies were designed and conducted in consultation with scientists at universities, research institutions, and the EPA.

The purpose of the SDTF studies was to quantify primary spray drift from aerial, ground hydraulic, airblast and chemigation applications. Using a common experimental design, more than 300 applications were made in 10 field studies covering a range of application practices for each type of application.

The data generated in the field studies were used to establish quantitative databases which, when accepted by EPA, will be used to conduct environmental risk assessments. These databases are also being used to validate computer models that the EPA can use in lieu of directly accessing the databases. The models will provide a much faster way to estimate drift, and will cover a wider range of application scenarios than tested in the field studies. The models are being jointly developed by the EPA, SDTF and United States Department of Agriculture (USDA).

Overall, the SDTF studies confirm conventional knowledge on the relative role of the factors that affect spray drift. Droplet size was confirmed to be the most important factor. The studies also confirmed that the active ingredient does not significantly affect spray drift. The physical properties of the spray mixture generally have a small effect relative to the combined effects of equipment parameters, application technique, crop canopy and the weather. This confirmed that spray drift is primarily a generic phenomenon, and justified use of a common set of databases and models for all products. The SDTF developed an extensive database and model quantifying how the liquid physical properties of the spray mixture affect droplet size.

The SDTF measured primary spray drift, the off-site movement of spray droplets before deposition. It did not cover vapor drift, or any other form of secondary drift (after deposition), because secondary drift is predominantly specific to the active ingredient.

Prior to initiating the studies, the SDTF consulted with technical experts from research institutions around the world and compiled a list of 2,500 drift-related studies from the scientific literature. Because of differing techniques, it was difficult to compare results across the studies. However, the information from these references was useful in developing test protocols that were consistently followed throughout the field studies.

The objective of the orchard airblast studies was to quantify drift from a range of orchard types, environmental conditions, and sprayer types. Because the spray plume from airblast sprayers is often very visible, a perception existed that there was a high level of drift from most orchard airblast applications. However, the amount of drift measured from most orchard types was relatively low. Although these results were consistent with other orchard drift studies in the published literature, the SDTF conducted additional studies to better understand how factors such as canopy characteristics and sprayer type affect the amount of drift.

The information being presented is not an in-depth presentation of all data generated by the SDTF. Use of pesticide products is strictly governed by label instructions. Always read and follow the label directions.

Procedures

Test site location and layout

Applications were made to grapes, apples (foliated and dormant), almonds, and oranges located in the southwest corner of the San Joaquin Valley of California. A pecan study was conducted in southwest Georgia and grapefruit (full-sized and young trees) studies were conducted on the central east coast of Florida.

The test application area consisted of the outside six rows (12 rows for grapes) of commercial orchards (figure 1). Within each six row area, applications were made separately to the three inner and outer rows. The inner rows always contributed less drift than the outer rows. Therefore, in this report the drift from the inner and outer rows was combined to give the total for all six rows.

Aerial View of Test Site

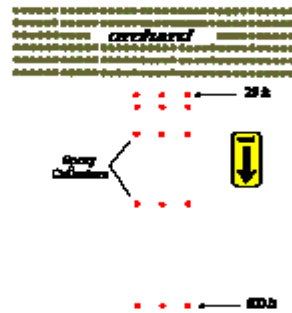


figure 1

Three lines of horizontal alpha-cellulose (absorbent material similar to thick blotting paper) were placed on the ground at selected intervals from 25 feet to 600 feet downwind from the edge of the orchards. These collectors simulated the potential exposure of terrestrial and aquatic habitats to drift.

Ground deposition measurements began 25 feet downwind because this was a typical distance from the edge of the trees to the true edge of the orchard. In the initial studies (California), ground deposition measurements were made to 1800 feet downwind. However, because there were normally no measurable levels of ground deposition beyond 600 feet, sampling stopped at this distance in the later studies.

Findings

Typical drift levels from orchard airblast application

The goal of orchard airblast applicators is to protect crops from diseases and insects, while keeping drift as close to zero as possible. The SDTF studies show that drift can be kept very low by using good application procedures.

Based on data generated by the SDTF, in a typical orchard airblast application to a 1200 feet wide grove of oranges, over 99% of the applied active ingredient stays on the crop and less than 0.5% drifts (figure 2).

Typical Orchard Airblast Application



figure 2

Although airblast applications are commonly made in orchards at least 1,200 feet wide, using an application area of this size was not practical. Instead, six row sections of orchards (12 rows in grapes) were used in the SDTF studies. This design generated data representative of larger orchards because most drift originates from the outer rows.

Because the application area was smaller than for a typical orchard, and because most drift comes from the outer downwind rows, the percentage of active ingredient deposited on the ground downwind of the grove in the SDTF studies was approximately 4% (figure 3), rather than 0.5%. This percentage of drift is artificially high due to the relative size and

SDTF Application to Oranges



figure 3

location of the application areas.

Figure 4 shows how the 4% of drift from the outer six rows of the California orange grove deposited downwind. The amount of material deposited on the ground decreased rapidly with distance and approached zero at 100 feet downwind.

Drift from Application to Oranges

1 = 0.55 oz per acre

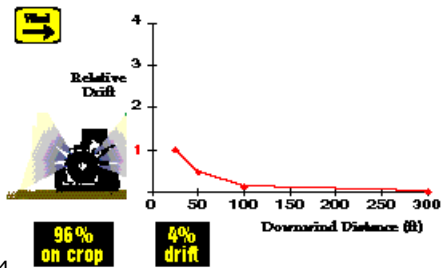


figure 4

Ascale of relative drift is used in this and subsequent graphs to facilitate comparisons among treatments. The deposition from California oranges will be used as a standard of comparison, and was set to 1.0 at 25 feet. For an application of one pound of active ingredient per acre, this represents 0.55 ounces per acre deposited on the ground at 25 feet. A Relative Drift value of 0.5 indicates that one-half as much was deposited. A value of 2 indicates that twice as much was deposited.

In figures 5, 10, 16, 18, 20 and 23 the deposition profile for California oranges was chosen as the standard for comparison because it represented an intermediate drift level relative to the other orchard scenarios that were tested. The deposition profile for oranges is always shown in red. In this report, ground deposition measurements are only shown to 300 feet downwind in order to better illustrate the differences among treatments.

How orchard type affects ground deposition

Figure 5 shows the ground deposition data from the alpha cellulose cards for each orchard type tested. The highest levels of ground deposition occurred from dormant apples where there was no foliage to intercept the spray droplets, and from a young grapefruit grove where there were relatively large gaps between trees. Ground deposition was approximately 22 times greater at 25 feet from dormant compared to foliated apples, and three times greater from young grapefruit trees compared to mature grapefruit trees.

The highest drift from a mature, fully foliated crop came from pecans due to their great height. The next highest drift came from grapefruit and oranges, whose

dense foliage forced spray droplets over the tops of the trees. Almonds, the second tallest crop, was next. Almonds had less dense foliage than citrus which acted as an effective filter. The lowest drift came from apples and grapes, the shortest crops evaluated. The ground deposition from apples was approximately five times less than from the California oranges at 25 feet downwind.

How orchard type affects ground deposition

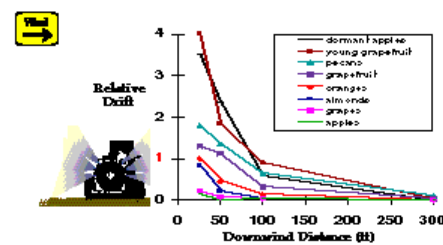


figure 5

Vertical deposition profile

A special series of applications was used to better understand how canopy characteristics influence the movement of spray droplets within, and subsequently outside, different orchard types. In these applications, the sprayer made a single pass between two rows (figure 6). Three vertical string collectors were suspended from 40-foot (12 meters) towers that were placed after the first five downwind rows to measure the vertical deposition profile. The string collectors were cut and analyzed in one-meter increments. Data in this report are presented as the average amount of active ingredient collected on each one-meter section of the three string collectors. On all vertical profile graphs (figures 7, 8, 9, 11, 12, 14, 15, 17, 19, 21, 22) the horizontal axis indicates the percentage of applied active ingredient. Because the scale changes radically among the graphs, the 1% level is always

Single Row Application (Orchard)

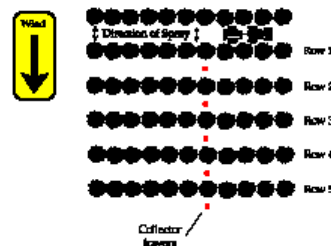


figure 6

highlighted in red in order to facilitate comparisons. Although the interaction of many canopy-related factors effect the amount of drift from orchards, results from the SDTF attempted to separate effects due to 1) height and shape, 2) foliage density, and 3) space between trees.

How canopy height and shape affect drift

Grapes

The grape vines formed continuous rows of foliage approximately 6 feet tall. Since the vines were substantially shorter than the trees, the string collectors only extended to 20 feet (6 meters). The row spacing in grapes was narrower than the tree crops tested, so string collectors were placed every two rows to keep the distance between the collectors relatively constant.

Most of the spray moving past the first two rows was above the top of the vines (figure 7). However, at no height did it exceed 0.75 % of the total applied active ingredient. As with all the crops tested, the amount of spray moving through the vineyard decreased rapidly, and never exceeded 0.06% of the applied active ingredient at any height after the tenth row. This was due to a combination of droplet settling, and the filtering effect of the foliage.

Vertical Deposition Profile 2, 4 and 10 Rows Beyond Sprayer (Grapes, Airblast Sprayer)

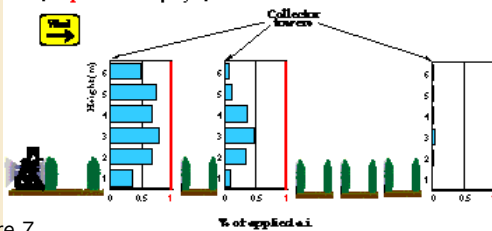


figure 7

Apples

The apple trees used in the SDTF studies were approximately 14 feet (4 meters) tall with open areas at the bottom, no distinct gaps between trees, and a moderately dense canopy. For apples, and the rest of the orchards tested, the string data were collected between each row to a height of 12 meters.

Most of the spray passing the first row moved through

the open space under the trees. The highest amount measured was less than 2.5%, compared to 0.75% in grapes (figure 8). However, because these higher levels were measured relatively close to the ground, the majority of the droplets deposited before passing the second row. Therefore, the vertical profile beyond the second row was very similar to that from grapes. This explains why the downwind ground deposition was very low for both apples and grapes.

Vertical Deposition Profile 1, 2 and 5 Rows Beyond Sprayer (Apples, Airblast Sprayer)

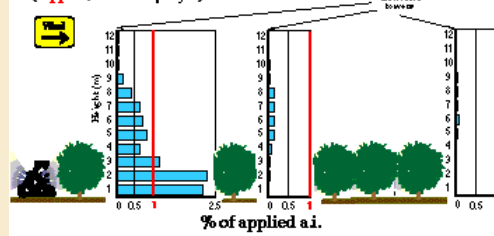


figure 8

Almonds

The almond trees used in the field studies were approximately 26 feet (8 meters) tall, with a relatively diffuse canopy, and large open areas beneath the trees.

As with apples, most of the spray moved past the first row under the trees, and deposited on the ground before passing the second row (figure 9). Due to the greater amount of open area under the canopy, the highest amount measured was close to 4%, as compared to approximately 2.5% in apples. The amount of spray passing over the top of the trees was similar to that measured for apples, but was at a greater height above the ground. This helps explain why the downwind ground deposition was greater than from the apples and grapes. As with the other crops, the vertical profile of the spray reflects the size and

Vertical Deposition Profile 1, 2 and 5 Rows Beyond Sprayer (Almonds, Airblast Sprayer)

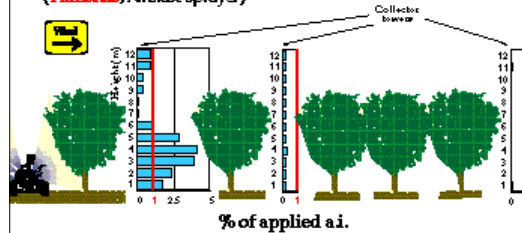


figure 9

Deposition



shape of the canopy.

Pecans

Pecans are the tallest orchard (nut) crop grown in the U.S. The average height of the trees in the SDTF studies was 68 feet (21 meters), which made the use of vertical string collectors impractical. However, the ground deposition levels outside the orchard were substantially higher than for almonds. Logically, this was due to the droplets being propelled to a greater height above the ground.

Summary

Although drift from orchards is due to the interaction of many canopy-related factors, downwind ground deposition tended to increase with increasing tree

How canopy height and shape affect ground deposition

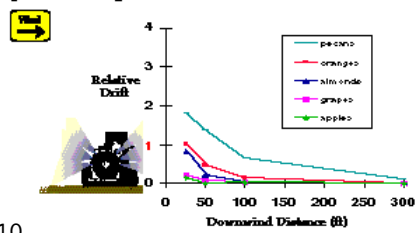


figure 10

height (figure 10).

How foliage density affects drift

Oranges

A dominant factor influencing drift from oranges and grapefruit is foliage density. Orange trees in the SDTF studies averaged 17 feet (5 meters) in height, with a very dense canopy extending close to the ground, and small gaps between the trees.

Compared to apples and almonds, less spray moved under and through the canopy, but up to three times more moved over the tops of the trees (figure 11). The relatively dense, continuous canopy appears to deflect more of the airflow from the sprayer over the top of the trees. This airflow carries droplets that would not normally have the momentum to rise above the trees. Therefore, the amount of ground deposition outside the orange groves tends to be higher than might be expected from trees of this height.

Vertical Deposition Profile 1, 2 and 5 Rows Beyond Sprayer (Oranges, Airblast Sprayer)

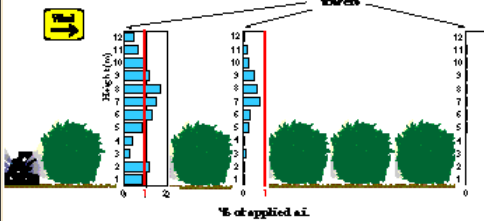


figure 11

Grapefruit

Canopy density in the Florida grapefruit was similar to the California oranges. However, the dense foliage formed a more solid wall because there were virtually no gaps between the trees.

The vertical profile measured in the grapefruit was similar to the oranges, but approximately twice as much spray moved over the tops of the trees (figure 12). This increase may have been due in part to the lack of gaps between trees. However, there is another factor that probably had a much greater influence on the amount of drift from the grapefruit versus the oranges.

The Florida grapefruit trees were grown on raised beds to facilitate irrigation and drainage (figure 13). This resulted in a 2 foot to 3 foot difference in the height of the sprayer as it passed between alternate rows. Since the sprayer was adjusted to reach the top of the trees from the lower position, a portion of the spray was directed above the trees when in the higher

Vertical Deposition Profile 1, 2 and 5 Rows Beyond Sprayer (Grapefruit, Airblast Sprayer)

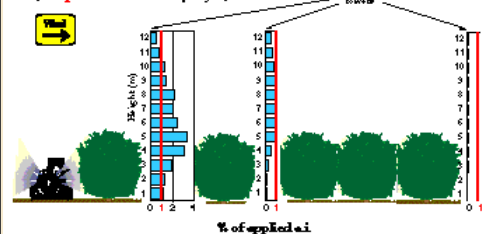
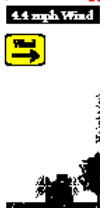


figure 12

Vertical D (Dormant App)



**Florida Grapefruit Grove
(Typical airblast application)**

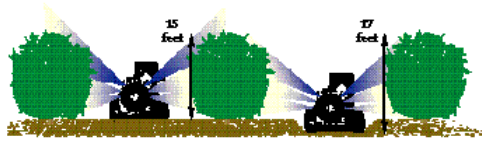


figure 13

position. In comparison, the California orange grove was on flat ground.

Dormant Apples

Compared to citrus, dormant apples are at the opposite extreme of foliage density. The same apple orchard that was tested with full foliage was also tested when dormant (no foliage). Because of the lack of foliage, dormant apples were the only crop tested in which wind speed had a substantial effect on the vertical and ground deposition profiles. This was because it was also the only situation where a change in the wind speed outside the orchard was reflected by a change in wind speed inside the orchard.

In a 4.4 mph wind, approximately five times more spray passed the first row in dormant compared to foliated apples (figures 14 and 15). However, because most of the spray was moving close to the ground, it deposited rapidly before moving very far downwind. At five rows downwind, the amount of spray measured from both dormant and foliated apples was very low. In a 12 mph wind, more of the spray moved above the dormant trees (figure 15) and approximately ten times more spray was measured after the fifth row

**Vertical Deposition Profile 1, 2 and 5 Rows Beyond Sprayer
(Dormant Apples, Airblast Sprayer)**

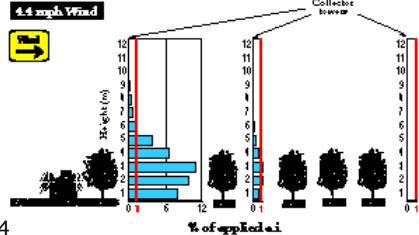


figure 14

than in a 4.4 mph wind.

**Vertical Deposition Profile 1, 2 and 5 Rows Beyond Sprayer
(Dormant Apples, Airblast Sprayer)**

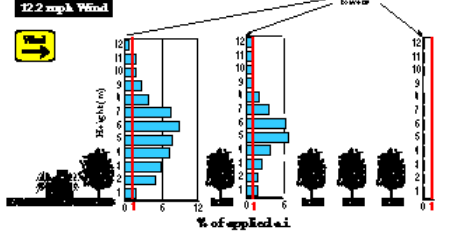


figure 15

Summary

Although the amount of drift from orchards results from the interaction of many canopy-related factors, figure 16 shows the differences in ground deposition that were due primarily to differences in foliage density. The greatest amount of downwind ground deposition was from dormant apples, where only trunks and branches intercepted droplets and modified the effects of the wind. Wind speed in the dormant apple ground deposition studies was intermediate between the 4.4 mph and 12 mph wind speeds measured in the vertical deposition studies. In comparison, ground deposition from the same apple orchard with full foliage was close to the lowest level measured by the SDTF.

For oranges and grapefruit, the opposite was observed. The high foliage density, which might be expected to reduce drift, actually caused these crops to have a relatively high level of downwind ground deposition because the dense foliage deflected air from the sprayer over the tops of the trees. For grapefruit, the raised bed system also contributed to the higher level of ground deposition.

How foliage density affects ground deposition

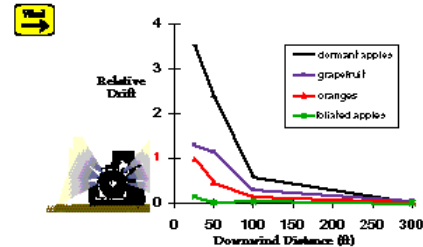


figure 16

How open spaces between trees affect drift

Young Grapefruit

The third canopy characteristic that affected drift was the amount of open spaces between trees. The most extreme example tested by the SDTF was a grove of young grapefruit trees. Average tree height was 7 feet, approximately one half the height of the mature trees. However, unlike the mature grapefruit trees that formed essentially a solid wall of foliage, there was a 5-foot open space (approximate) between each young tree. These are believed to be the smallest citrus trees sprayed with a standard airblast sprayer.

The vertical profile measured in the young grapefruit trees depended on whether the string collectors were located directly behind the trees, or in the gaps. Figure 17 shows that when the strings were directly behind trees, as indicated on the two graphs at the right, the vertical profile was similar to the mature trees.

However, as would be expected, the vertical profile was very different when the string collectors were located between the trees. Most of the spray moving between the young grapefruit trees was relatively close to the ground, where it should have settled out relatively quickly. However, the combined amount of spray moving above and between the young trees resulted in approximately four times more ground deposition at 25 feet, than from the mature trees (figure 18). This

Vertical Deposition Profile 1 Row Beyond Sprayer

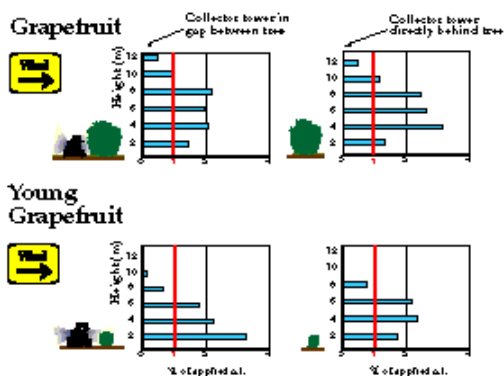


figure 17

How open spaces between trees affect ground deposition

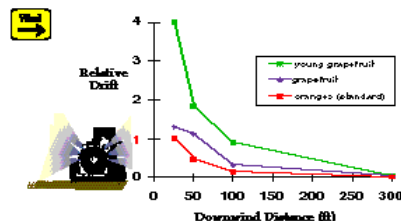


figure 18

difference had disappeared by 300 feet downwind.

How sprayer type affects drift

At the time of the SDTF studies, most orchard and vineyard sprays in the U.S. were applied with radial type airblast sprayers. However, the SDTF also included two other sprayer types, a “wrap-around” hydraulic sprayer used in vineyards, and a low volume “mist blower” used in orchards.

Wrap-Around Sprayer

The wrap-around sprayer has booms positioned horizontally over the tops of the rows and vertically along the sides. It uses hydraulic nozzles, sometimes at very high spray pressures. Unlike the airblast sprayer, there is no fan to increase air flow.

Figure 19 shows the vertical deposition profile two rows downwind from the airblast and wrap-around sprayers in grapes. Although the drift is very low for both sprayers, much less spray was collected from the wrap-around sprayer, particularly above the vines. The low amount of spray intercepted by the string was also reflected in the ground deposition outside the vineyard (figure 20). Ground deposition from the wrap-around sprayer was four times less than from the airblast sprayer at 25 feet downwind. If the major concern is minimizing drift, the wrap-around sprayer

Vertical Deposition Profile 2 Rows Beyond Sprayer (Grapes)

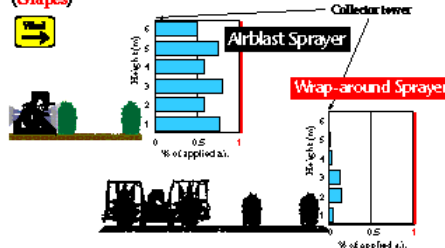


figure 19

How sprayer type affects ground deposition in grapes

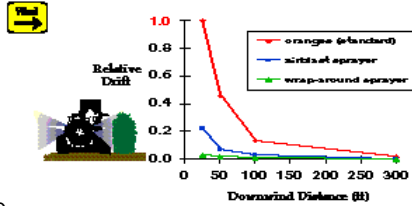


figure 20

is clearly an effective alternative to the airblast sprayer.

Mist Blower

An Ag Tech Crop Sprayer was used to represent the “mist blower” class of sprayers. They typically produce a finer droplet size spectrum than airblast sprayers, and are used to apply lower volumes of 25 to 50 gallons per acre versus 60 to more than 800 gallons per acre.

Since different nozzle sizes are typically used around the arc on radial airblast sprayers and mist blowers, the SDTF measured the droplet size spectrum produced by each of the nozzles on both sprayers. The Volume Median Diameter (VMD) ranged from 138 microns to 210 microns for the airblast sprayer, and 73 microns to 110 microns for the mist blower. VMD is the droplet diameter at which half of the spray volume is composed of larger droplets and half is composed of smaller droplets. Therefore, VMD is essentially an average droplet size based on spray volume.

The percentage of the spray volume in droplets less than 141 microns in diameter (% volume <141 microns) ranged from 26% to 52% for the airblast sprayer, and 65% to 90% for the mist blower. The % volume <141 microns was selected because of the characteristics of the particle-measuring instrument, and because it is close to 150 microns, which is commonly considered a point below which droplets are more prone to drift.

Both the VMD and percent volume <141 microns confirm that the mist blower produced a finer droplet size spectrum, and a higher volume of very small drift-prone droplets. This helps explain the difference in vertical and ground deposition profiles observed for the two sprayers.

Summary

In the mature grapefruit grove the vertical deposition profiles were very different for the two sprayers at one row downwind from the sprayer (figure 21a).

Overall, four times more spray was collected from the airblast sprayer. However, for the airblast sprayer, the amount of spray moving past the first row above the tops of the trees decreased with increasing height. For the mist blower, the amount of spray collected increased slightly with height.

At two rows downwind, more spray was still collected from the airblast sprayer, but the vertical profiles showed that a higher proportion of spray from the mist blower was moving at a greater height (figure 21b). At five rows downwind, the total amount collected from the two sprayers was similar, but the mist blower continued to show a higher proportion of the spray at a greater height (figure 21c).

Vertical Deposition Profile 1 Row Beyond Sprayer (Grapefruit)

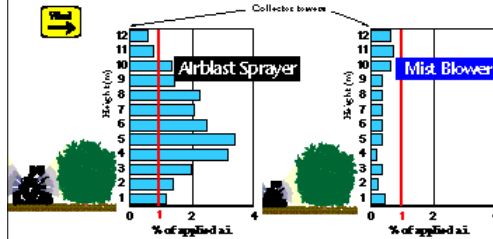


figure 21a

2 Rows Beyond Sprayer

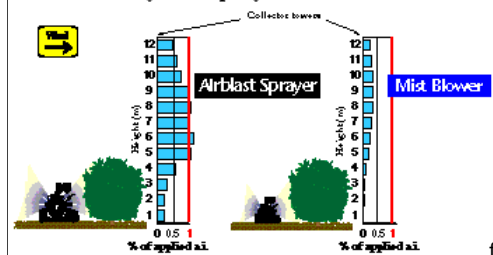


figure 21b

5 Rows Beyond Sprayer

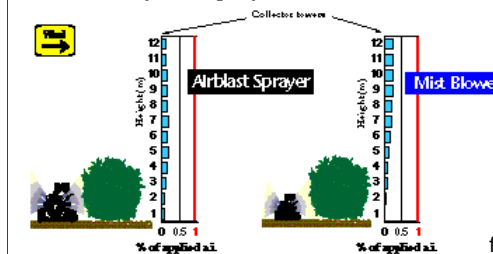


figure 21c

In the young grapefruit, the vertical deposition profile one row downwind was very similar for the two sprayers (figure 22a). However, at two rows downwind, more spray was collected at greater heights from the mist blower (figure 22b). This was the same pattern observed in the mature grapefruit, but the total amount collected was higher. At five rows downwind, considerably more spray was collected from the mist blower, particularly at the greater heights (figure 22c).

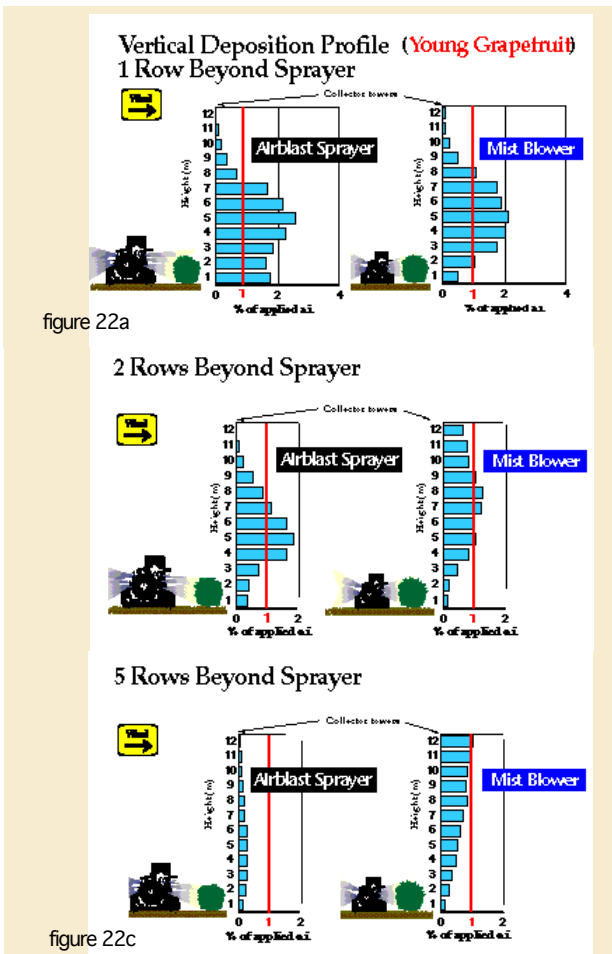


figure 22a

figure 22c

Figure 23 shows the ground deposition data for both sprayer types in young and mature grapefruit. Ground deposition was higher close to the edge of the grove from the airblast sprayer in both mature and young grapefruit. However, at distances beyond 300 feet downwind (data not shown) this relationship reversed and the amount of ground deposition was higher from the mist blower. This was most likely due to the higher volume of small droplets which remained suspended in the air over a longer distance. This conclusion is consistent with the vertical deposition profiles observed in mature and young grapefruit.

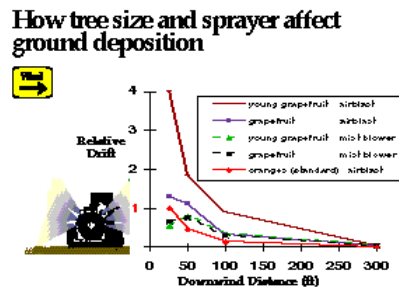


figure 23

Conclusions

Looking broadly at all types of application, droplet size is the most important factor affecting spray drift. However, for orchard airblast, the characteristics of the crop canopy tend to be of at least equal importance since, unlike most other types of application, the spray is always released from within, rather than above the canopy.

The potential for drift is due primarily to the interaction between droplet size and the canopy characteristics: height and shape, foliage density, and the amount of open space between trees. Wind speed tends to increase in importance as the amount of foliage decreases.

The amount of drift from orchard airblast applications was found to be much lower than is often perceived. There are several reasons for this apparent discrepancy.

- a. The relatively high application volumes result in very visible spray plumes, which are comprised primarily of larger droplets that settle out before drifting from the site.
- b. The high spray volumes also result in relatively low concentrations, so that drifting droplets do not contain much active ingredient.
- c. Most of the very small droplets that are capable of drifting long distances are either intercepted by the canopy, or do not have enough momentum to leave the site.
- d. Most of the spray volume leaving a site is comprised of relatively large droplets that do not drift long distances.
- e. The orchard canopies tend to reduce the effects of wind.

When accepted by EPA, the SDTF model and databases will be used by the crop protection industry and EPA in environmental risk assessments. Even though active ingredients do not differ in drift potential, they can differ in their potential to cause adverse environmental effects. Since drift cannot be completely eliminated with current technology, the SDTF database and models will be used to determine if the drift from individual crop protection products is low enough to avoid harmful environmental effects. When drift cannot be reduced to low enough levels by altering spray equipment set-up and application techniques, buffer zones can be imposed to protect sensitive areas downwind of applications.

Mention of a trademark, vendor, technique, or proprietary product does not constitute an endorsement, guarantee, or warranty of the product by the authors, their companies, or the Spray Drift Task Force, and does not imply its approval to the exclusion of other products or techniques that may also be suitable.

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