APPENDIX D

Spray Drift Task Force report Summaries

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

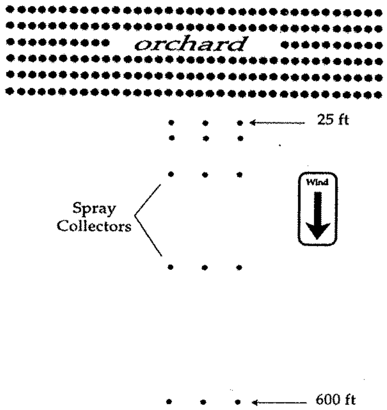


figure 1

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

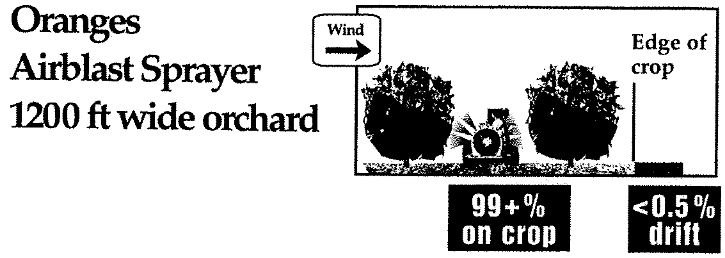


figure 2

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 location of the application areas.

SDTF Application to Oranges

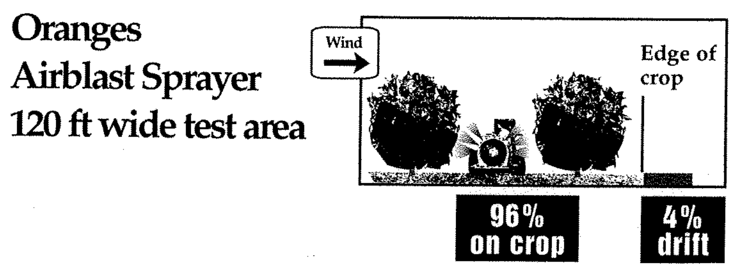


figure 3

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.

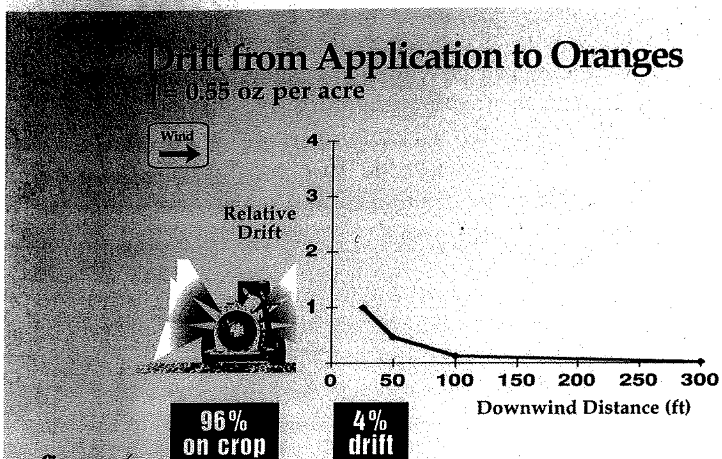


figure 4

A scale 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

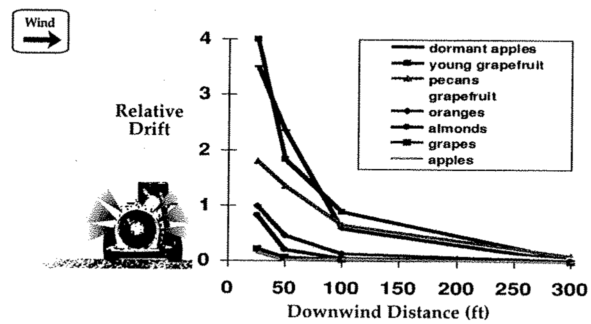


figure 5

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 highlighted in red in order to facilitate comparisons.

Single Row Application (Orchard)

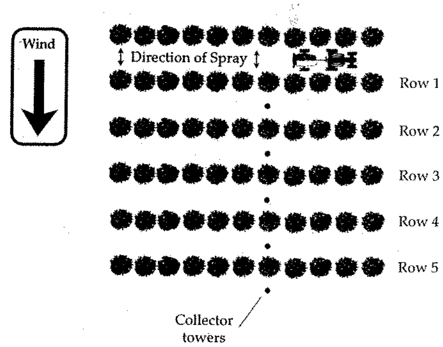


figure 6

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)

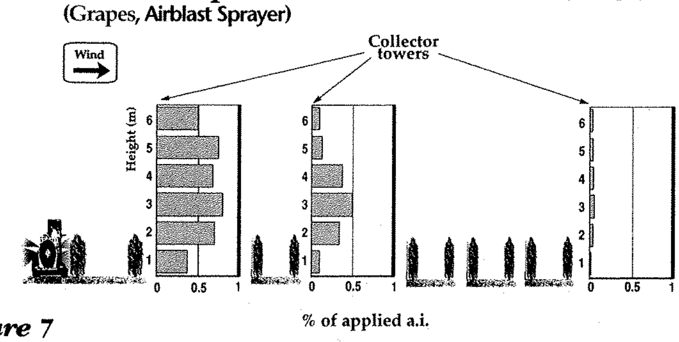


figure 7

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)

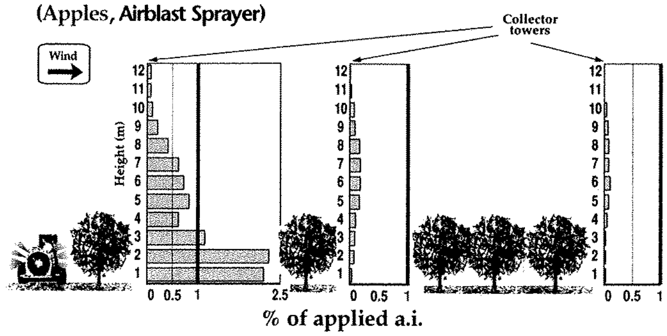


figure 8

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 shape of the canopy.

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

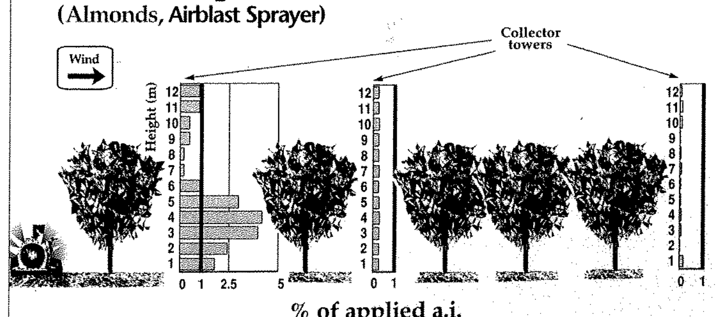


figure 9

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 height (figure 10).

How canopy height and shape affect ground deposition

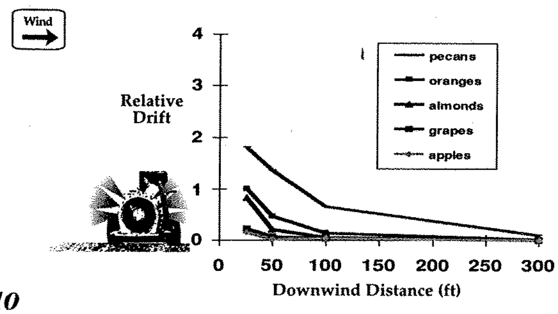


figure 10

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.

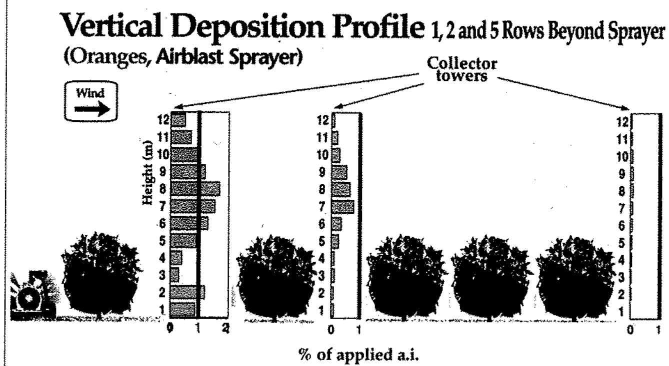


figure 11

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

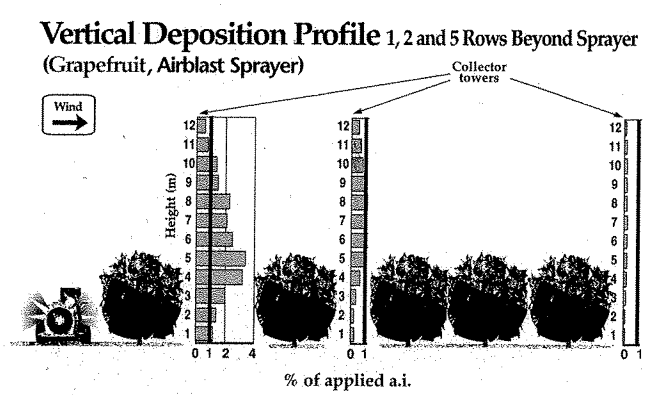
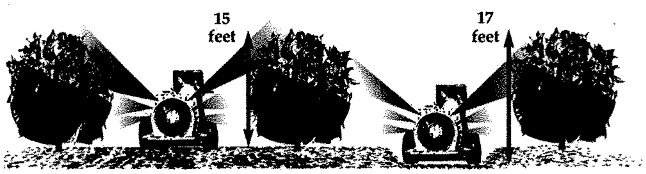


figure 12

Florida Grapefruit Grove
(Typical airblast application)



igure 13

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 than in a 4.4 mph wind.

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

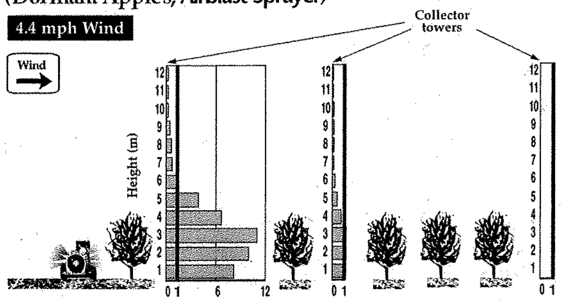


figure 14

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

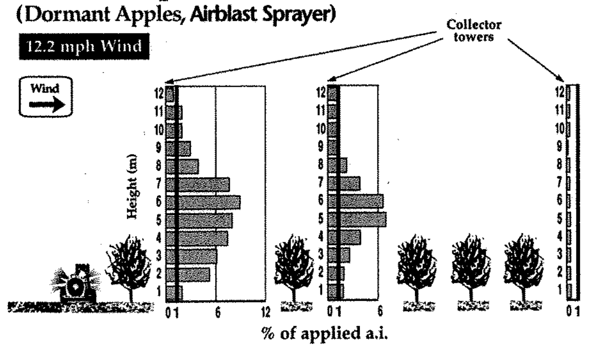


figure 15

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

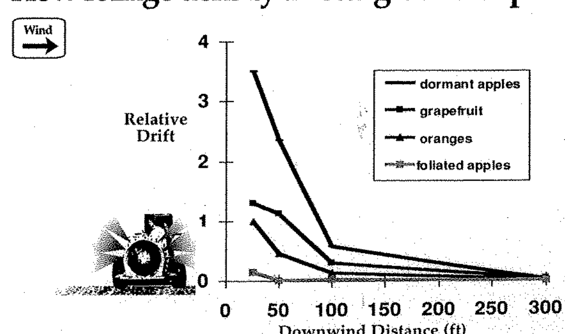


figure 16

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 difference had disappeared by 300 feet downwind.

Vertical Deposition Profile 1 Row Beyond Sprayer

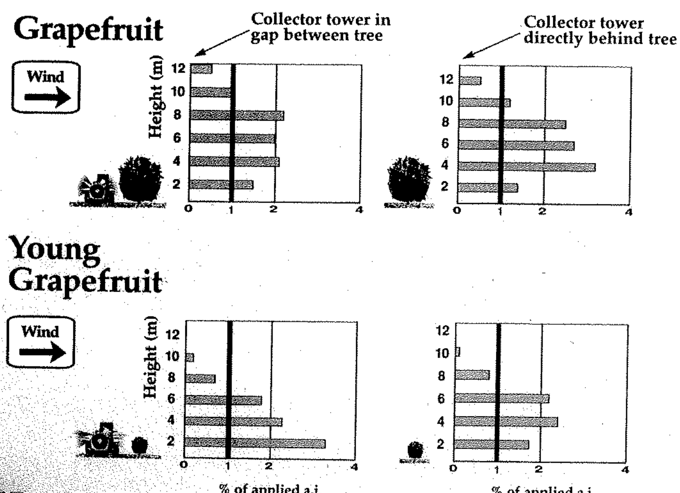


figure 17

How open spaces between trees affect ground deposition

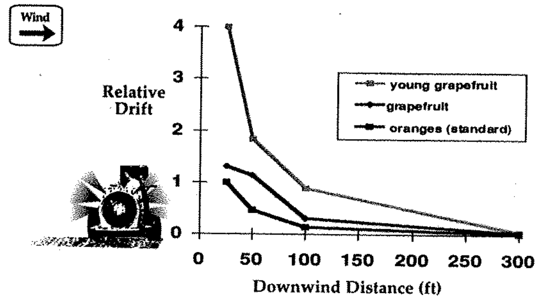


figure 18

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 is clearly an effective alternative to the airblast sprayer.

Vertical Deposition Profile 2 Rows Beyond Sprayer
(Grapes)

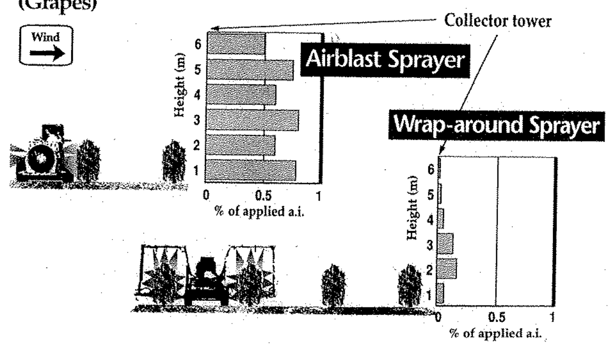


figure 19

How sprayer type affects ground deposition in grapes

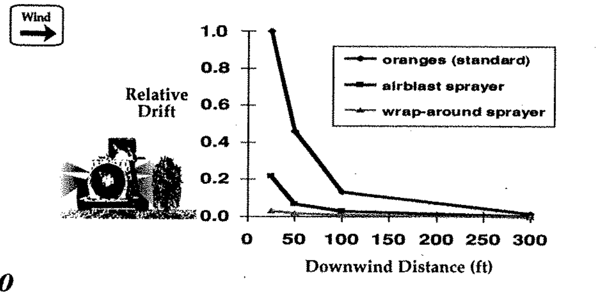


figure 20

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)

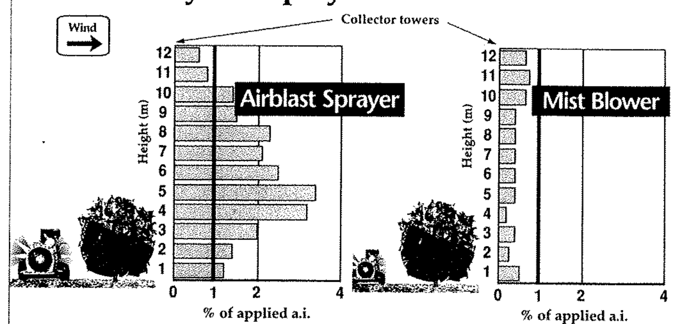


figure 21a

2 Rows Beyond Sprayer

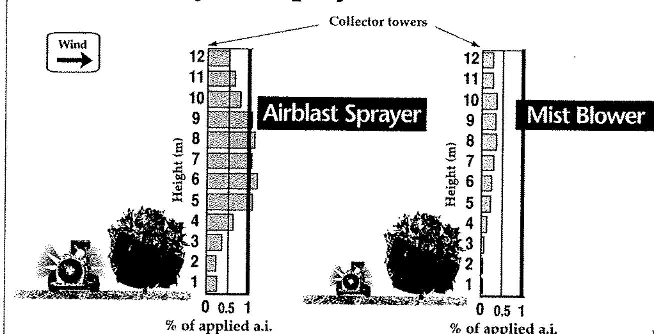


figure 21b

5 Rows Beyond Sprayer

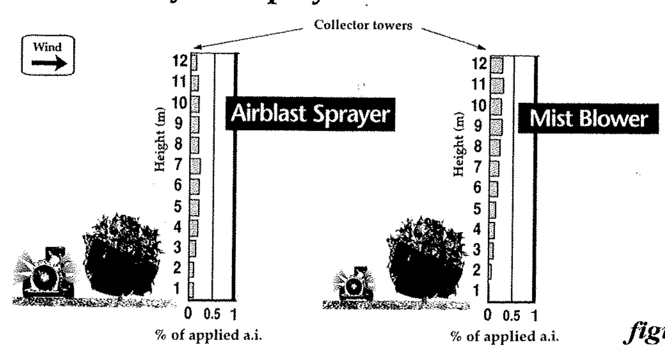


figure 21c

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).

Vertical Deposition Profile (Young Grapefruit)
1 Row Beyond Sprayer

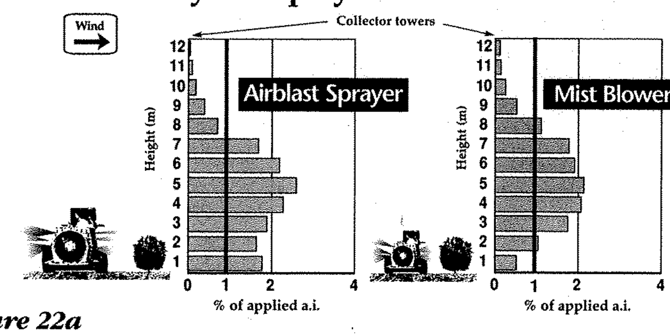


figure 22a

2 Rows Beyond Sprayer

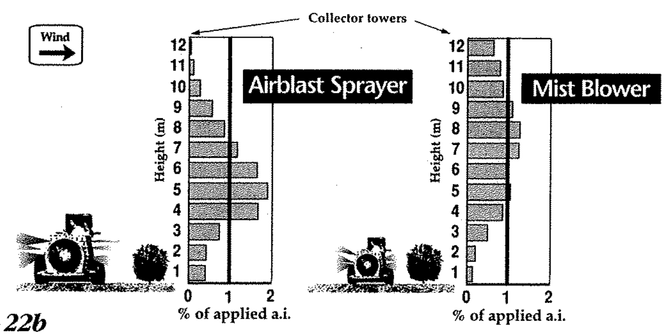


figure 22b

5 Rows Beyond Sprayer

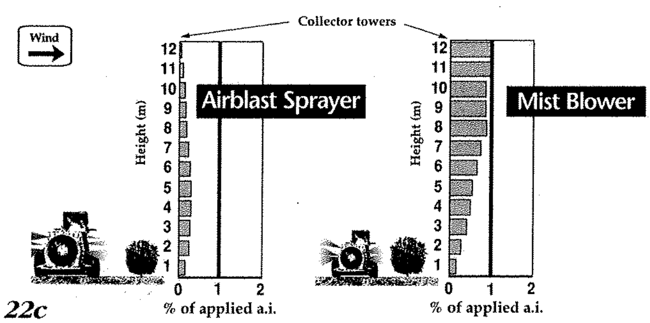


figure 22c

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.

How tree size and sprayer affect ground deposition

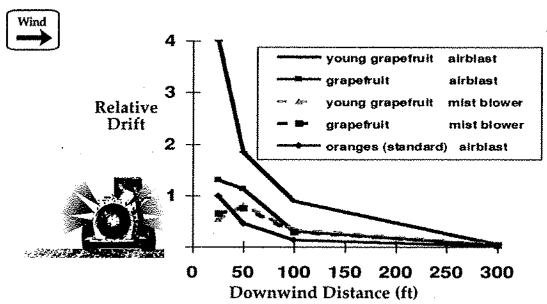


figure 23

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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A SUMMARY OF

Aerial 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 aerial 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, air blast 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, 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 aerial field studies was to quantify drift from the range of application practices common in the early 1990s. Since some practices may have changed since then, it is important to recognize that the aerial model will use inputs based on current practices.

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

Two sites were chosen in Texas because they provided open expanses, up to one-half mile downwind from the application areas, and a wide range of weather conditions. Wind speeds varied from 2 mph to 17 mph, with an average of 10 mph across all applications. Air temperatures varied from 32°F to 95°F and relative humidity varied from 7% to 94%.

Aerial View of Test Site

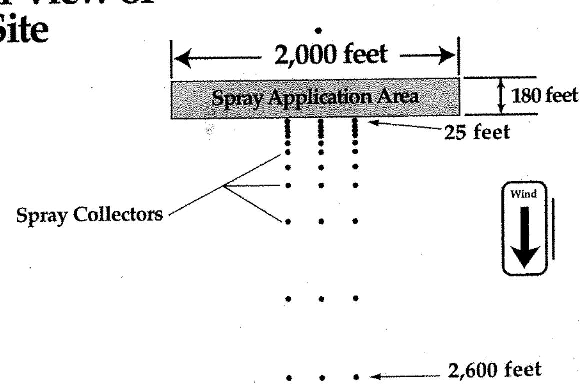

figure 1

The test application area measured 2,000 feet in length and 180 feet in width (figure 1). Four, 45-foot wide parallel swaths were sprayed going from left-to-right and right-to-left. Three lines of horizontal alpha-cellulose cards (absorbent material similar to thick blotting paper) were placed on the ground at 12 selected intervals from 25 feet to 2,600 feet downwind from the edge of the application area. These collectors simulated the potential exposure of terrestrial and aquatic habitats to drift. A collector was also positioned upwind from the application area to verify that drift only occurs in a downwind direction.

Relating droplet size spectra to drift

All agricultural nozzles produce a range of droplet sizes known as the droplet size spectrum. In order to measure the droplet size spectrum that was applied in each field study treatment (and that represent those produced from commercial applications), the critical application parameters (nozzle type, orifice size, pressure, angle, and air speed) were duplicated in an extensive series of atomization tests conducted in a wind tunnel. The controlled conditions of the wind tunnel allowed the droplet size spectrum to be accurately measured using a laser particle measuring instrument.

The volume median diameter (VMD) is commonly used to characterize droplet size spectra. It is the droplet size at which half the spray volume is composed of larger droplets and half is composed of smaller droplets. Although VMD is useful for characterizing the entire droplet spectrum, it is not the best indicator of drift potential.

A more useful measure for evaluating drift potential is the percentage of spray volume consisting of droplets less than 141 microns in diameter. This value 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.

The cut-off point of 141 microns or 150 microns has been established as a guide to indicate which droplet sizes are most prone to drift. However, it is important to recognize that drift doesn't start and stop at 141 microns. Drift potential continually increases as droplets get smaller than 141 microns, and continually decreases as droplets get bigger.

The wind tunnel atomization tests verified that a broad range of droplet size spectra was applied in the field study treatments. These measurements were critical to understanding the differences in spray drift that were measured for each field study treatment.

Other factors affecting drift

Other variables that were tested include: nozzle heights from 6 feet to 31 feet above the ground; boom lengths of 69% and 84% of the wingspan; oil as a carrier for the ultra low volume (ULV) applications; the effects of liquid physical properties of the pesticide spray mixture; and the effects of crop canopy.

Weather-related factors including wind speed and direction, and air temperature were recorded during the field trials at four separate heights between 1 and 30 feet. Relative humidity, solar radiation, barometric pressure, and atmospheric stability were also recorded.

Experimental design

The varying weather conditions encountered during multiple-application field studies presented a good opportunity to evaluate their effects on drift. However, these variations complicated efforts to measure the effects of equipment-related factors. For example, if a treatment using 8002 nozzles (producing a fine droplet spectrum) was run during low wind speeds, and then a treatment using D8 nozzles (producing a coarse droplet spectrum) was run during high wind speeds, the amount of drift would have been affected both by the change in droplet size and the wind speed.

To factor out the meteorological effects, the SDTF used a covariate experimental design, which is a commonly accepted statistical technique for this type of study. The design entailed a control treatment that was always applied immediately after an experimental treatment. The control treatment was a medium droplet size spectrum produced with D6-46 nozzles at a 45° angle on a fixed-wing airplane traveling at 110 mph. It was always applied in exactly the same manner. The experimental treatment differed from application to application in nozzle type, nozzle orifice size, aircraft speed, etc.

The primary test airplane, a Cessna Ag Husky®, was equipped with a dual application system (tank, pump and boom) that permitted successive applications of the control and experimental treatments without landing. The two booms were never used simultaneously in order to avoid any potential interference between the sprays.

Four swaths of the experimental treatment were applied first, beginning at the downwind side. The control treatment was then immediately applied over the same area. The total elapsed time for both applications was 12 minutes. Continuous weather monitoring showed no appreciable changes in atmospheric conditions during the 12 minute periods. The downwind collectors were analyzed for both diazinon (the tracer used with the control treatment) and malathion (the tracer used with the experimental treatment).

Using this experimental design, differences between replications of the control treatments are due only to atmospheric conditions, since the application procedures were always the same. Differences between experimental treatments are due to changes in the atmospheric conditions and application procedures. Consequently, differences between experimental and control treatments are due to application procedures. This allowed direct comparisons to be made among all the experimental treatments by factoring out the effects of weather (as measured by the control applications).

A total of 90 experimental (45 treatments, 2 replicates each) and a corresponding 90 control applications were made. Besides providing a means of adjusting for atmospheric conditions, the 90 applications of the control treatment also provided an extensive database for evaluating the effects of meteorological parameters on drift.

Aerial drift model

Due to the complexity of evaluating all possible interactions of the numerous application variables, a computer model is the most practical way to conduct spray drift risk assessments. For aerial application, a highly sophisticated simulation model had been developed previously by the USDA Forest Service for forestry applications. The SDTF, EPA and USDA worked together to adapt and validate this model for agricultural applications using the data generated in the SDTF field and atomization studies. After final review and acceptance by the EPA, this model will allow evaluation of a much wider range of applications than those tested in the field studies. Its use will help ensure that SDTF assessments reflect current application practices.

Because so many interacting factors affect aerial spray drift, this report only offers examples of how the major variables affect drift.

Typical Aerial Application

Air Tractor 401®
1200 ft wide field
Medium spray
10 mph crosswind
60 ft swath adjustment
8 ft nozzle height

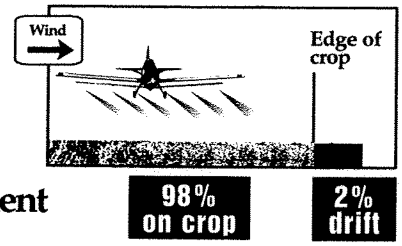

figure 2

Findings

Typical drift levels from aerial application

The goal of aerial applicators is to protect crops from diseases, insects and weeds 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 full field aerial application, 98% of the total applied active ingredient stays on the field and only 2% drifts (figure 2). A typical application was defined as a 1200-foot wide, 20-swath field (suggested by EPA) using an Air Tractor 401® set-up to produce a medium droplet spectrum, in a 10 mph crosswind (typically the maximum allowable wind speed), a 60-foot swath adjustment, and 8-foot nozzle height (application height).

Average SDTF Control Application
(90 replicates)

Cessna Ag Husky®
180 ft wide field
Medium spray
10 mph crosswind
50 ft swath adjustment
8 ft nozzle height

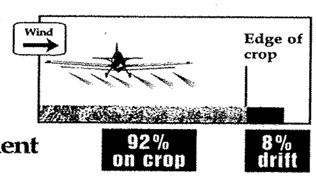

figure 3

Although aerial applications typically consist of twenty or more swaths, using fields of this size was not practical. Instead, a four-swath (180 feet wide) application area was used in the field studies. This design generated data that represented drift from a 20-swath field since most drift originates from the farthest downwind swaths.

Because the application area was smaller than is typical for commercial applications, and because most drift comes from the outer swaths of the field, the percentage of the active ingredient leaving the field in the SDTF studies was 8% rather than 2% (figure 3). This percentage of drift is artificially high due to the relative size of the application areas. The 8% drift is the average of the 90 applications of the control treatment. The SDTF control application differed from the typical application only in the aircraft used, swath width, and the size of the application area.

Figure 4 shows how the 8% of the control treatment that left the field deposited downwind. The amount of material that deposits on the ground decreases rapidly with distance and is already approaching zero at 250 feet downwind. Ground deposition was measured out to one-half mile downwind, but the amount of material was normally too low beyond 250 feet to illustrate any differences between treatments..

Drift from the SDTF Control Application

1.0 = 1.2 oz per acre

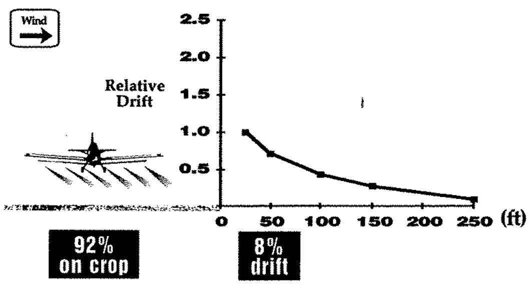

figure 4

Ground deposition measurements began 25 feet downwind, which represents a reasonable distance from the edge of a crop to the effective edge of a field where drift would begin to be of concern.

A scale of Relative Drift is used in this and all subsequent graphs to facilitate comparisons among treatments. Since the control treatment will be used as a standard of comparison, it was set to 1.0 at 25 feet. For an application of one pound of active ingredient per acre, this represents 1.2 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 would indicate twice as much was deposited. In subsequent graphs the deposition profile for the control treatment is shown in red in order to facilitate comparisons.

How swath adjustment reduces drift

When the wind is low, virtually all of the spray is deposited directly under the aircraft allowing the pilot to fly close to the edge of the field (figure 5a). With a crosswind, the spray swath is displaced downwind (figure 5b). Pilots typically compensate for this swath displacement by adjusting the position of the aircraft upwind (figure 5c). The amount of swath adjustment can vary from one half, to more than two swath widths, depending upon wind speeds and proximity to sensitive areas.

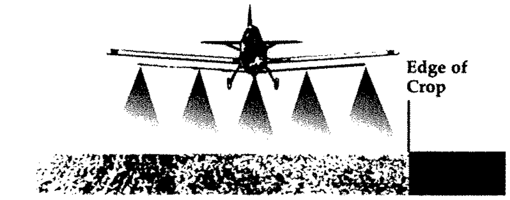

figure 5a

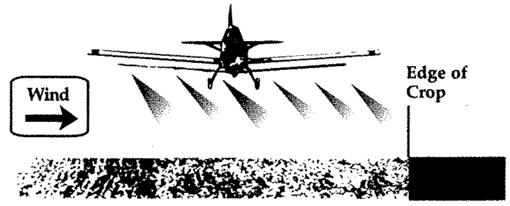

figure 5b

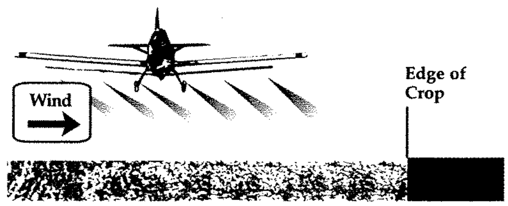

figure 5c

In order to maintain consistency across all applications in the SDTF field studies, the pilot made no swath adjustment. However, in this report a swath adjustment was applied by mathematically shifting the deposition curve upwind by 50 feet. This would be a typical swath adjustment in a 10-mph crosswind, the average wind speed in the field studies.

The effects of swath adjustment are illustrated in figure 6 for no adjustment, a half swath adjustment, and a full swath adjustment as applied for the control treatment. With no swath adjustment, the amount of spray material depositing at 25 feet downwind is approximately three and a half times that from a full swath adjustment. Swath adjustment substantially reduces drift, especially in the first 100 feet. These results are for a medium droplet size spectra from the control

How swath adjustment affects drift

Control Application

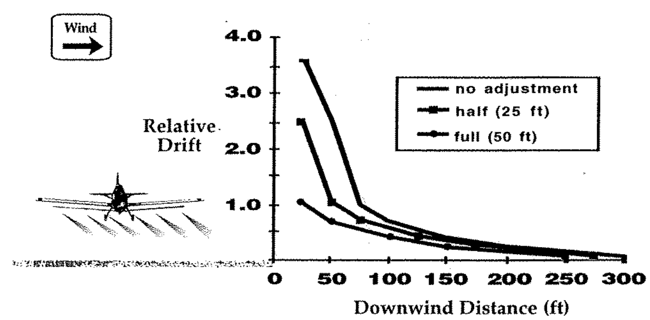

figure 6

treatment. The effects would be even more dramatic with a finer droplet spectrum.

How nozzle and droplet size affect drift

The effect of droplet size on downwind ground deposition is illustrated in figure 7. It shows that drift decreases dramatically as the percent of volume in droplets smaller than 141 microns decreases due to the use of different nozzles, nozzle angles, and/or air speeds.

The control treatment had 15% of the spray volume in small droplets (less than 141 microns). The smaller D4-45 nozzle at the same angle produced twice the volume of small droplets and twice the amount of drift at 25 feet. The solid stream nozzle (D8) at a 0° angle produced a much lower volume of small droplets and substantially less drift than the control.

How nozzle and droplet size affect drift

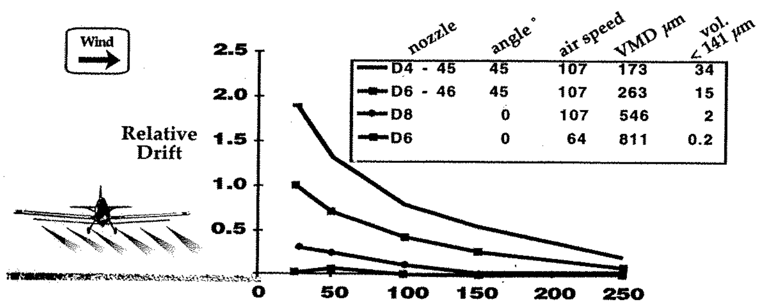

figure 7

Although droplet size was the primary factor affecting drift, the data for the D6 at 64 mph are not directly comparable because they were obtained with a helicopter instead of a fixed wing airplane. The helicopter data are included to illustrate that it is possible to reduce the percentage of small droplets to very low levels with a corresponding decrease in drift. The results show that pilots can minimize drift by managing the factors affecting droplet size.

How air shear affects droplet size and drift

Air shear across the nozzle tip, which is a function of both nozzle angle and aircraft speed, significantly affects droplet size. When nozzles are pointed toward the back of the plane, air shear is less than when the nozzles are pointed downward (figure 8). Air shear across the nozzle tip also increases with faster aircraft speeds, resulting in smaller droplets. The effect of air shear on droplet formation and drift was studied by

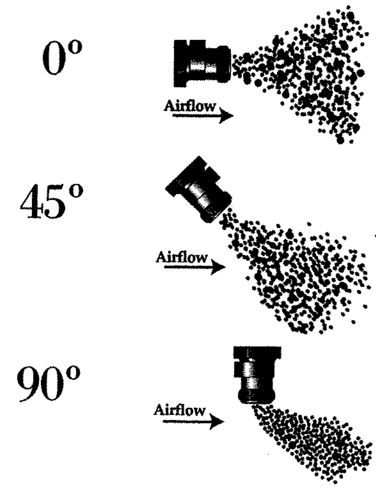

figure 8

setting up identical nozzles and nozzle angles on three aircraft: a helicopter, which flew at 64 mph; a piston-powered, fixed-wing airplane at 107 mph; and a turbine-powered, fixed-wing airplane at 156 mph. The nozzle height was 8 feet.

When the same nozzles (D6-46) were positioned at a 45° angle on all three aircraft, there were differences in drift due to air shear (figure 9). At 156 mph, 39% of the droplet volume was less than 141 microns. As speed and subsequent air shear decreased, the volume percent less than 141 microns decreased to 6% with a corresponding decrease in drift.

It must be emphasized that figure 9 illustrates the effect of air shear on droplet size and drift. It does not indicate that these are typical droplet spectra for each aircraft. Normally the sizes and/or angles of the nozzles are changed to compensate for the air shear at higher speeds.

How air shear affects drift

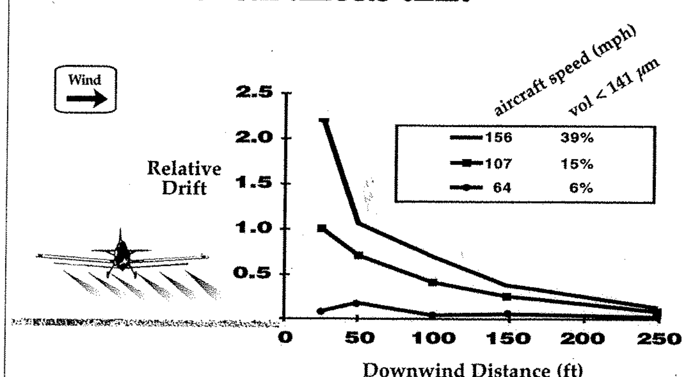

figure 9

How nozzle height affects drift

In aerial applications over agricultural crop areas, spray is typically released when the nozzles are about 8 feet above the ground or crop, compared with forestry and rangeland applications which are sometimes made at 20 feet or higher. Figure 10 compares drift from the control treatment when the nozzle height is changed from 8 feet to 22 feet. It shows that the higher nozzle height results in approximately 2.5 times more drift at 25 feet downwind.

How nozzle height affects drift
Control Application

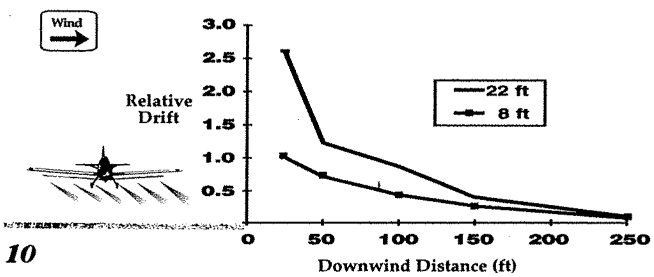

figure 10

With a finer droplet spectrum, this difference would have been greater; with a coarser droplet spectrum, the differences would have been less.

How boom length affects drift

Turbulent air, referred to as vortices, is created by the wings. Wing or rotor tip vortices exist on all aircraft. When the length of the boom is too long, spray droplets are caught in these vortices. The smaller droplets follow the air movement up and over the wing or rotor which effectively increases the application height and increases the potential for drift. When boom lengths are shortened, fewer droplets enter the vortices and drift is reduced.

How boom length affects drift
Model-generated data for Control Application

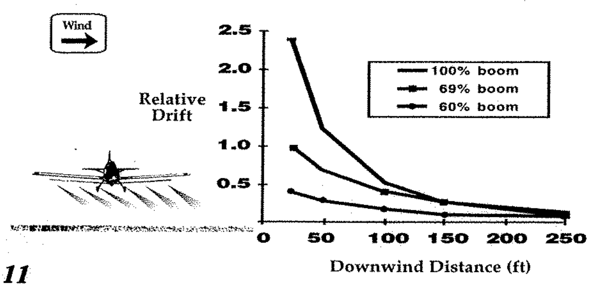

figure 11

Although the SDTF did not extensively test the effects of boom length on drift, the computer drift model affirms that the common practice of maintaining boom length at 70% or less of the wingspan minimizes drift (figure 11). The effect of boom length is more important when spraying a fine versus coarse droplet size spectrum.

How dynamic surface tension affects drift

Physical properties of the tank mixture can influence the formation of droplets by agricultural nozzles, although this effect is most important at higher levels of air shear.

The SDTF examined dynamic surface tension, shear viscosity, and extensional viscosity. Of these three physical properties, dynamic surface tension usually has the greatest influence on droplet size. Figure 12 represents the maximum range of drift attributable to dynamic surface tension for the SDTF control treatment. The 72 dynes/cm represents water, 32 dynes/cm represents the most extreme case, and 45 dynes/cm represents a large percentage of commercial pesticide tank mixtures.

These curves were generated by the computer drift model. Field study data confirmed that for the control treatment, physical properties had a very small effect on drift compared to equipment and application procedures.

How dynamic surface tension affects drift
Model-generated data

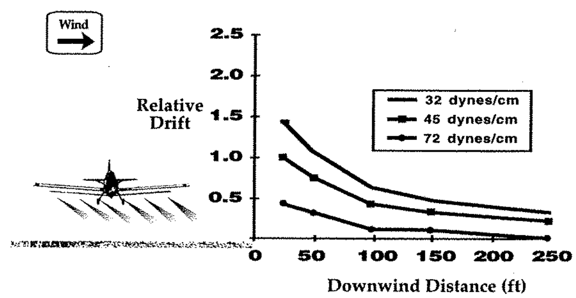

figure 12

How wind speed affects drift

The 90 replicates of the control applications clearly established that wind speed was the most important atmospheric factor affecting drift (figure 13). Although it is commonly accepted that hot, dry conditions accelerate droplet evaporation, which results in smaller droplets, this was not found to be as important as wind speed.

How wind speed affects drift
Control Application

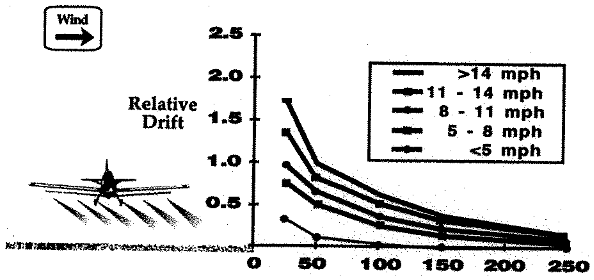

figure 13

How crop canopy affects drift

Ground cover in the application and drift collection areas consisted of short grass. A limited number of treatments were conducted over cotton to determine if there was a significant effect due to the presence of a more developed canopy. These treatments indicated a small decrease in downwind ground deposition over cotton.

Because the effect of canopy was extremely small, and because it was not practical to evaluate the infinite number of canopy shapes, heights, and densities, additional testing was not conducted. However, the treatments on cotton suggest that the SDTF field studies may slightly over-estimate drift for applications that are typically conducted over a well developed canopy.

Conclusions

The results from the SDTF studies confirm present knowledge concerning the role of factors that affect spray drift. In many cases the studies quantified what was already known qualitatively. As expected, droplet size was shown to be the most important factor affecting drift from aerial applications. Logically, the results also confirm that drift only occurs downwind. Waiting until the wind is blowing away from sensitive areas is an effective application practice. Although drift cannot be eliminated totally with current technology, there are many ways to minimize drift to levels approaching zero. The SDTF studies confirm that when good application practices are followed, all but a small percentage of the spray is deposited on target.

Drift levels can be minimized by:

a. Applying the coarsest droplet size spectrum that provides sufficient coverage and pest control.

b. Continuing the standard practice of swath adjustment.

c. Controlling the application height.

d. Using the shortest boom length that is practical.

e. Applying pesticides when wind speeds are low.

Except at high levels of air shear, the physical properties of the spray mixture have only a minimal effect on drift. The SDTF studies show that the pattern and magnitude of drift results from a complex interaction of many factors. The drift model is an effective means of predicting aerial spray drift and permits the evaluation of a much broader range of variables than those tested by the SDTF.

When accepted by the EPA, the SDTF model and databases will be used by the agricultural chemical industry and the EPA for environmental risk assessments. Even though active ingredients do not differ in drift potential, they can differ in the 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 each agricultural product is low enough to avoid harmful environmental effects. When drift cannot be reduced to low enough levels through altering equipment set up and application techniques, buffer zones may be imposed to protect sensitive areas downwind of applications.

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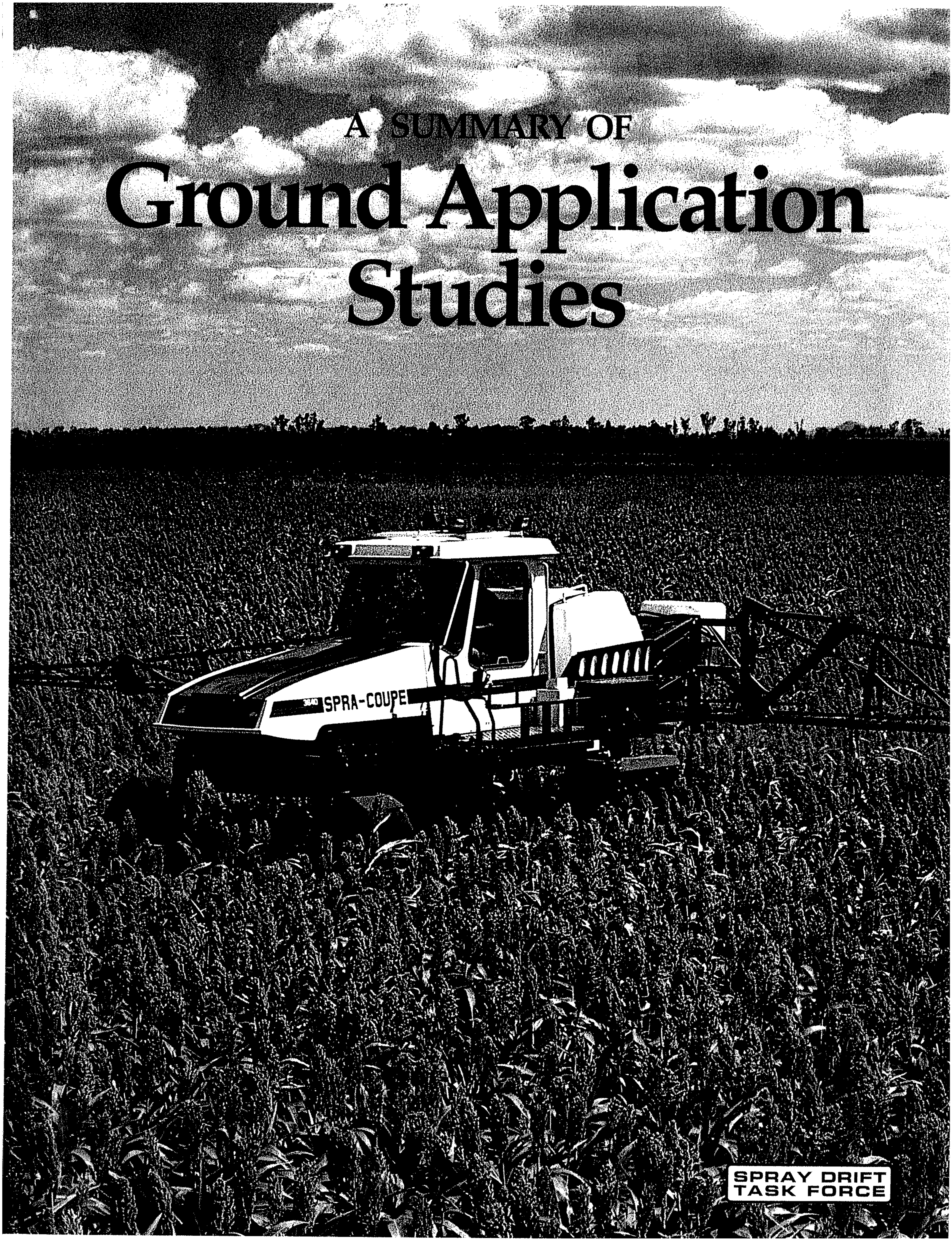
A SUMMARY OF

Ground Application Studies



SPRAY DRIFT TASK FORCE

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The objective of the ground hydraulic studies was to develop a generic database for evaluating the effects on drift from the range of equipment combinations, atmospheric conditions and pesticide spray mixtures used by applicators.

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Procedures

Test site location and layout

The site chosen on the High Plains of Texas near Plainview afforded open expanses, up to one-quarter mile downwind from the application area, and a wide range of weather conditions. Wind speeds varied from 5 to 20 mph, air temperatures varied from 44° F to 91° F, and relative humidity varied from 8% to 82%. A control treatment, applied successively with each variable treatment, helped to define affects due to the weather.

Aerial View of Test Site

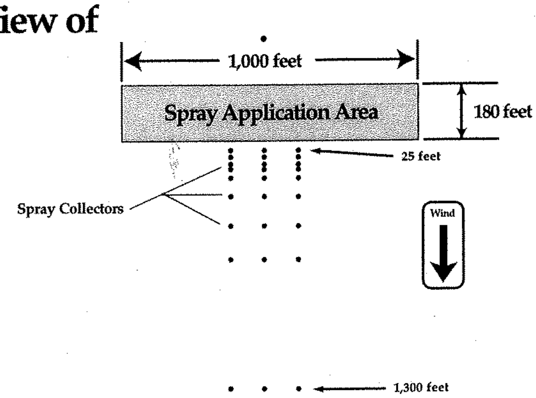


figure 1

The test application area measured 1,000 feet in length and 180 feet in width (figure 1). Four 45-foot wide parallel swaths were sprayed going from left-to-right and right-to-left using a Melroe Spra-Coupe®. Three lines of horizontal alpha-cellulose cards (absorbent material similar to thick blotting paper) were placed on the ground at 9 selected intervals from 25 feet to 1300 feet downwind from the edge of the application area. These collectors simulated the potential exposure of terrestrial and aquatic habitats to drift. A collector was also positioned upwind from the application area to verify that drift only occurs in a downwind direction.

Relating droplet size spectra to drift

All agricultural nozzles produce a range of droplet sizes known as the droplet size spectrum. In order to measure the droplet size spectrum that was applied in each field study treatment (and that represent those produced from commercial applications), the critical application parameters (nozzle type, orifice size, and pressure) were duplicated in an extensive series of atomization tests conducted in a wind tunnel. The controlled conditions of the wind tunnel allowed the droplet size spectrum to be accurately measured using a laser particle measuring instrument.

The volume median diameter (VMD) is commonly used to characterize droplet size spectra. It is the droplet size at which half the spray volume is composed of larger droplets and half is composed of smaller droplets. Although VMD is useful for characterizing the entire droplet spectrum, it is not the best indicator of drift potential.

A more useful measure for evaluating drift potential is the percentage of spray volume consisting of droplets less than 141 microns in diameter. This value 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.

The cut-off point of 141, or 150 microns, has been established as a guide to indicate which droplet sizes are most prone to drift. However, it is important to recognize that drift doesn't start and stop at 141 microns. Drift potential continually increases as droplets get smaller than 141 microns, and continually decreases as droplets get bigger.

The wind tunnel atomization tests verified that a broad range of droplet size spectra was applied in the field study treatments. This information was critical to understanding the differences in spray drift that were measured for each field study treatment.

The SDTF atomization studies also verified that the physical properties of the spray mixture have only a minimal affect on the droplet size spectrum from ground hydraulic nozzles relative to the effects of nozzle parameters. Any small differences in droplet size due to differences in physical properties would not be expected to significantly affect drift.

Test application variables

Nozzle type, orifice size and spray pressure are equipment factors that affect the droplet size spectrum for ground hydraulic sprayers. These factors were varied in the SDTF studies to provide a range of droplet size spectra similar to those used by applicators in the field (table 1).

• *8010LP* flat fan nozzle at 20 pounds per square inch (psi) pressure produced the coarsest droplet spectrum. It represented high-volume custom sprayers such as those used for turf and right-of-way applications.

• *8004LP* flat fan nozzle at 20 psi pressure produced a finer droplet spectrum than the 8010LP nozzles, but a coarser droplet spectrum than the 8004 at 40 psi. The 8004LP is a low pressure equivalent of the 8004, thus any difference in droplet size is due primarily to the lower pressure.

Nozzle	Pressure (psi)	VMD (microns)	Volume < 141 microns (%)
8010LP	20	762	1
8004LP	20	486	2
8004	40	341	7
TX6	55	175	26

table 1

Typical Ground Hydraulic Application

1200 ft wide field
8004 nozzles
40 psi pressure
20 inch nozzle height
10 mph crosswind

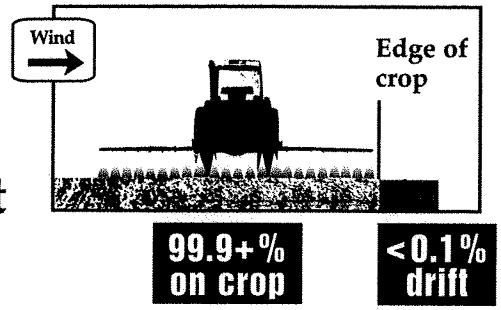


figure 2

• *8004* flat fan nozzle at 40 psi pressure produced a finer droplet spectrum than the 8004LP, but a coarser spectrum than the TX6. It is widely used for agricultural applications.

• *TX6* hollow cone nozzle at 55 psi pressure produced the finest droplet spectrum. These nozzles are commonly used to enhance penetration of insecticides and fungicides into a crop canopy. The TX6 also represents the fine droplet spectra from low volume applications.

Spray boom heights of 20 inches (typical for most agricultural applications) and 50 inches (the greatest height that could be attained with the Melroe Spra-Coupe) were evaluated for every nozzle except the 8004LP. Applications at speeds of 5 mph and 15 mph were evaluated, but are not discussed further since they were found to have no significant effect on drift.

Findings

Typical drift levels from ground hydraulic applications

The goal of ground applicators is to protect crops from diseases, insects, and weeds 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 full field ground hydraulic application, more than 99.9 percent of the applied active ingredient stays on the field and less than one tenth of one percent drifts (figure 2). A typical application was defined as a 1200-foot wide, 20-swath field (suggested by the EPA), using 8004 flat fan nozzles at 40 psi, a 20-inch nozzle height, and a 10 mph crosswind.

Although ground hydraulic applications typically consist of a 1200-foot wide application area, using fields of this size was not practical. Instead, a four-swath (180 feet wide) application area was used in the field studies. This design generated data that represented drift from a 20-swath field, since most drift originates from the farthest downwind swaths.

Because the application area was smaller than is typical for commercial applications, and because most drift comes from the outer swaths of the field, the percentage of the active ingredient leaving the field in the SDTF studies was slightly higher than the typical full field application, but was still only about 0.5% (figure 3). This percentage of drift is artificially high due to the relative size of the application areas. The 0.5% drift is calculated from the average of 24 applications of the control treatment. The SDTF control application differed from the typical application only in the size of the application area.

Average SDTF Control Application
24 replicates

180 ft wide field
8004 nozzles
40 psi pressure
20 inch nozzle height
10 mph crosswind

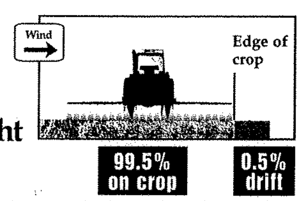


figure 3

Figure 4 shows how the 0.5% of the control treatment that left the field deposited downwind. The amount of material that deposited on the ground decreased rapidly with distance. Ground deposition was measured out to one quarter mile downwind, but data are only presented for the first 300 feet to better illustrate the differences in drift between treatments. At 300 feet, the amount of ground deposition was already extremely low. Ground deposition measurements began 25 feet downwind, which represents a reasonable distance from the edge of a crop to the effective edge of a field where drift would begin to be of concern.

A scale of Relative Drift is used in this and all subsequent graphs to facilitate comparisons among treatments. Since the control treatment will be used as a standard of comparison, it was set to 1.0 at 25 feet. For an application of one pound of active ingredient per acre, this represents only 0.08 ounce 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 2.0 indicates that twice as much was deposited. In subsequent graphs the deposition profile for the control treatment is shown in red in order to facilitate comparisons.

Drift from the SDTF Control Application
1.0 = 0.08 oz per acre

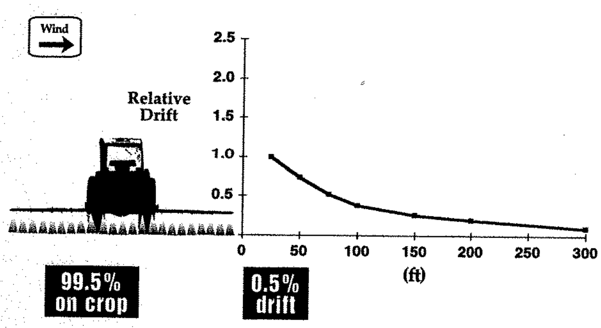


figure 4

How droplet size affects drift

The effect of droplet size on downwind ground deposition is illustrated in figure 5. Ground deposition from all four nozzles at the 20-inch boom height was low. As expected, there was a strong correlation between the volume less than 141 microns, and drift. In 7 mph to 8 mph winds, drift from the TX6 nozzle was greater than from the 8004 nozzle. In 11 mph winds, drift from the 8004LP nozzle was greater than from the 8010LP nozzles. Even though the wind speed was lower, drift was greater from the TX6 and 8004 than from the 8004LP and 8010LP nozzles. The largest difference in drift was between the TX6 and the other nozzles. This corresponded to the difference in the volume of droplets less than 141 microns.

How droplet size affects drift
20 inch nozzle height

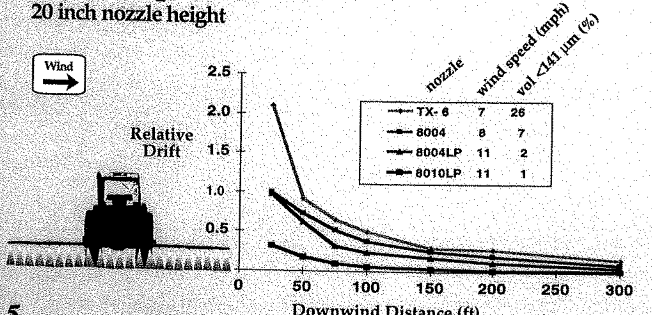


figure 5

How droplet size and wind speed affect drift

Wind speed significantly increased drift only for the TX6 nozzle, which produced the finest droplet spectrum (figure 6). For nozzles producing coarser droplet spectra (illustrated by the 8004LP), there was essentially no difference in drift between 8 mph and 16 mph winds.

How droplet size and wind speed affect drift
20 inch nozzle height

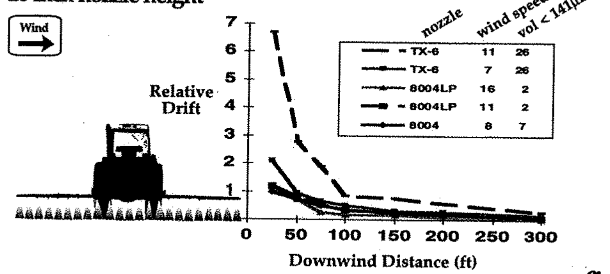


figure 6

In the scientific literature, there are correlations between wind speed and drift for ground hydraulic sprayers. However, except for the TX6 nozzle, the SDTF studies found no correlation between wind speed and drift. This apparent discrepancy is probably due to differences in the distance at which ground deposition measurements began. In the literature, correlations are usually based on drift from 0 feet to 25 feet downwind, where most of the drift occurs. In the SDTF studies, downwind deposition measurements began at 25 feet from the edge of the application area.

How nozzle height affects drift

Regardless of the droplet size spectrum, ground deposition from the 50-inch boom height was always greater than from the 20-inch height. The effect of nozzle height is illustrated for the coarsest (8010LP) and finest (TX6) droplet size spectrum in figures 7 and 8, respectively. Although drift was higher with the 50 inch boom height for both nozzles, the difference was much greater for the TX6, and was evident at greater distances downwind. This was due to the much finer droplet size spectrum compared to the 8010LP nozzle. At 25 feet downwind, the TX6 nozzle at 50 inches resulted in almost three times higher deposition than at 20 inches. This was approximately seven times higher deposition than the control treatment. These results illustrate the need to keep all nozzles, particularly those producing fine droplet spectra, at the lowest possible height that provides uniform coverage.

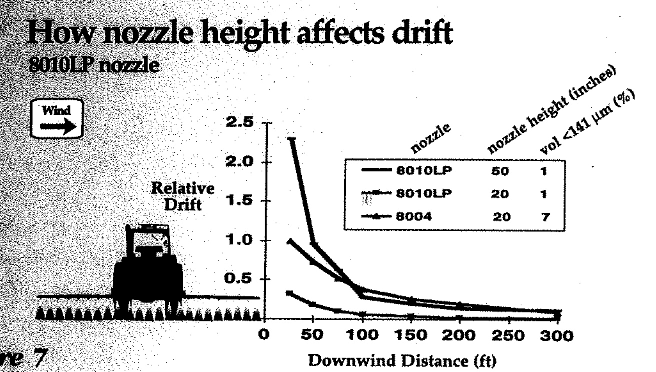


figure 7

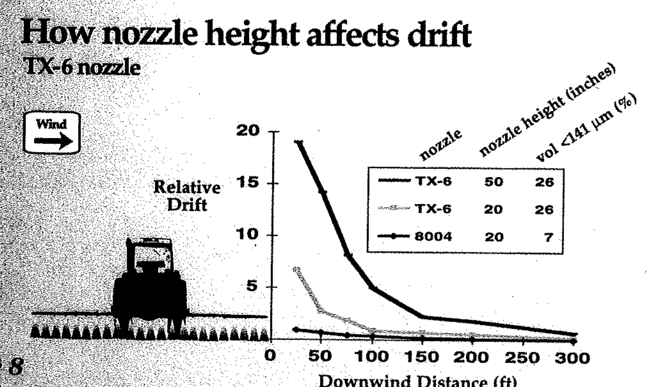


figure 8

Conclusions

The results from the SDTF studies confirm conventional knowledge concerning the role of factors that affect spray drift. In many cases the studies quantified what was already known qualitatively. As expected, droplet size was shown to be the most important factor affecting drift from ground applications. Logically, the results also confirm that drift only occurs downwind. Waiting until the wind is blowing away from sensitive areas is an effective application practice. Although drift cannot be eliminated totally with current technology, there are many ways to minimize drift to levels approaching zero. The SDTF studies confirm that when good application practices are followed, all but a small percentage of the spray is deposited on target.

Drift levels can be minimized by:

a. Applying the coarsest droplet size spectrum that provides sufficient coverage and pest control.

b. Using the lowest nozzle height that provides uniform coverage.

c. Applying pesticides when wind speeds are low and consistent in direction.

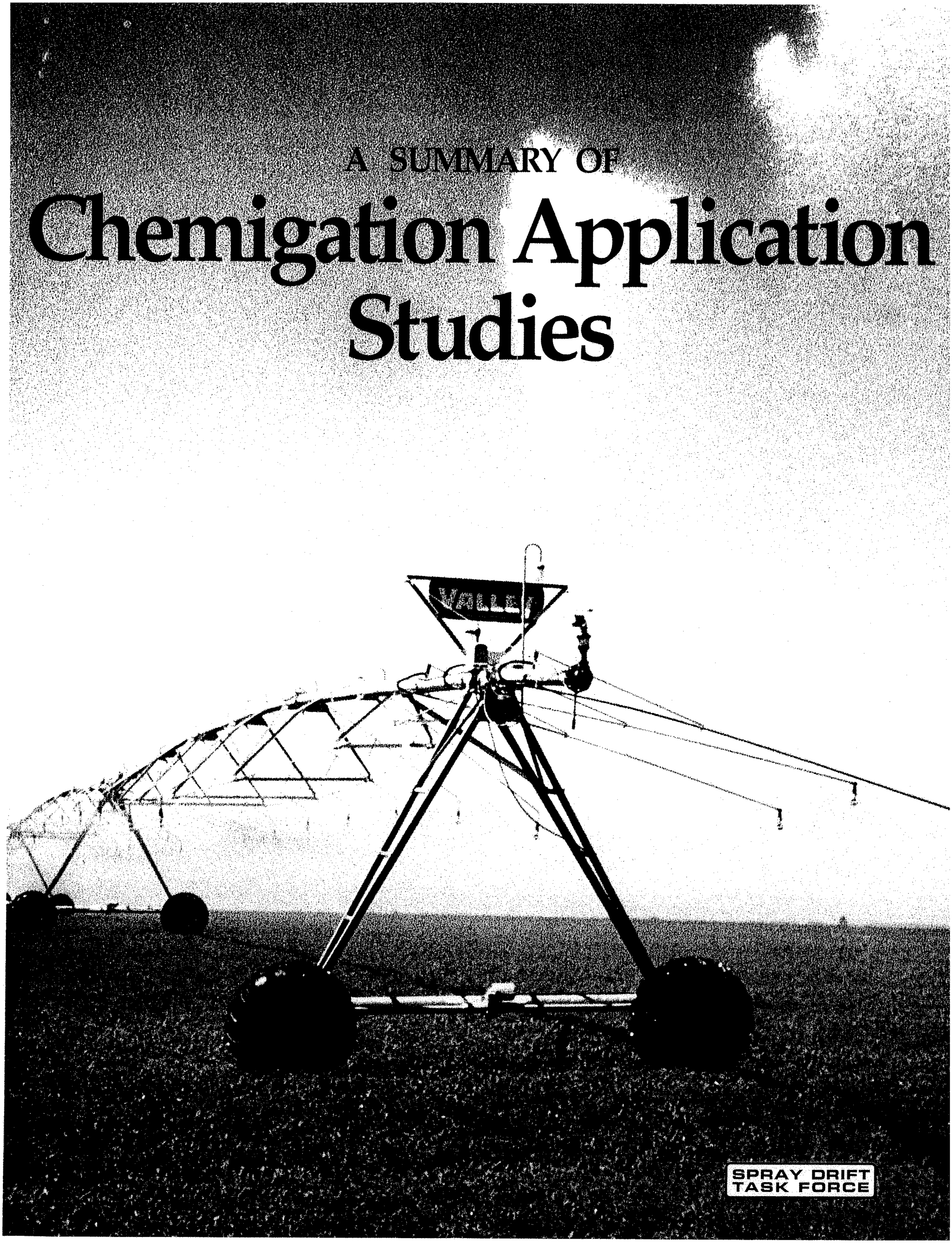
When accepted by the EPA, the SDTF model and databases will be used by the agricultural chemical industry and the EPA in environmental risk assessments. Even though active ingredients do not differ in drift potential, they can differ in the potential to cause adverse environmental effects. Since drift cannot be completely eliminated with current technology, the SDTF databases and models will be used to determine if the drift from each agricultural product is low enough to avoid harmful environmental effects. When drift cannot be reduced to low enough levels through altering equipment set up and application techniques, buffer zones may 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.

For more information contact David Johnson at Stewart Agricultural Research Services, Inc., P.O. Box 509, Macon, Missouri 63552. (660) 762-4240 or fax (660) 762-4295.

A SUMMARY OF

Chemigation 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 chemigation 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 re-registration 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. 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, 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 chemigation studies was to develop a database for evaluating the effects on drift from low and high pressure irrigation systems, with and without end guns, over a range of atmospheric conditions.

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

The chemigation studies were conducted in central Washington state near Moses Lake. A center-pivot sprinkler irrigation system with a 623-foot radius covering 28 acres was used in all the field studies (figure 1).

Aerial View of Test Site

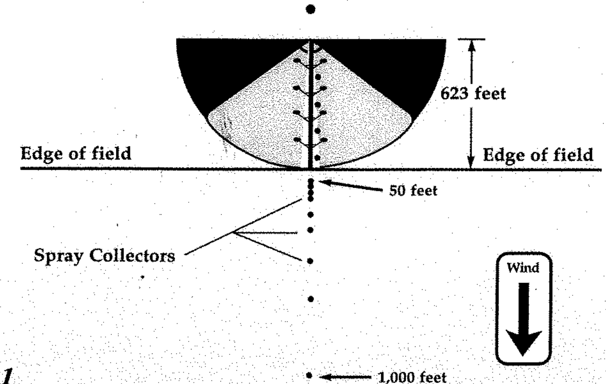


figure 1

For each treatment, the downwind quarter of the circle was irrigated during a 90-minute span, at an application rate of 0.1 acre inches of water. The quarter-circle application area was representative of the whole circle, since drift from the remainder of the circle would be negligible due to the distance from the downwind collectors.

When an end gun was operated as part of the system, the radius of the irrigated area increased to 655 feet (36 acres). The system was configured so that applications typical of high and low pressure systems could be made, with or without an end gun. A critical difference between the systems was that the spray release height for the high pressure system and the end guns was 12 feet, compared to only 5 feet in the low pressure system.

Horizontal alpha-cellulose cards (absorbent material similar to thick blotting paper) were placed on the ground at nine selected intervals from 50 feet to 1,000 feet downwind from the edge of the application area (figure 1). These collectors simulated the potential exposure of terrestrial and aquatic habitats to drift. One collector was also positioned directly upwind from the center pivot to verify that drift only occurs in a downwind direction.

Relating droplet size spectra to drift

All irrigation nozzles produce a range of droplet sizes known as the droplet size spectrum. In order to measure the droplet size spectrum applied in the field study treatments, the impact sprinkler heads and rotary spinners used in the field studies were tested in a large, specially designed facility. The controlled conditions of the facility allowed the droplet size spectra to be accurately measured using a laser particle measuring instrument. It was not possible to measure the droplet size spectrum from the end gun, but it appeared to be coarser than that measured from the impact sprinklers of the high pressure system.

The volume median diameter (VMD) is commonly used to characterize droplet size spectra. It is the droplet size at which half the spray volume is composed of larger droplets and half is composed of smaller droplets. Although VMD is useful for characterizing the entire droplet spectrum, it is not the best indicator of drift potential.

A more useful measure for evaluating drift potential is the percentage of spray volume consisting of droplets less than 141 microns in diameter. This value 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.

The cut-off point of 141, or 150 microns, has been established as a guide to indicate which droplet sizes are most prone to drift. However, it is important to recognize that drift doesn't start and stop at 141 microns. Drift potential continually increases as droplets get smaller than 141 microns, and continually decreases as droplets get bigger.

Test application variables

The field studies consisted of four treatments: a high pressure system and a low pressure system, both with and without an end gun (table 1). The high pressure system was operated at 70 pounds per square inch (psi) with impact sprinklers located on top of the irrigation pipe, approximately 12 feet above the ground. The low pressure system was operated at 20 psi, with rotary spinners located approximately 5 feet above the ground.

Test Application Variables

	System Type*	
	High Pressure	**Low Pressure**
Pressure:	70 psi	20 psi
Sprinkler height:	12 feet	5 feet
Sprinkler type:	impact	rotary spinner
Volume < 141 microns:	0.33%	1.3%
Volume Median Diameter: (VMD)	3,008 μm	1,690 μm

*With and without an end gun

table 1

Findings

Typical drift levels from chemigation

Based on data generated by the SDTF, in a typical chemigation application (160 acre field, high pressure system with end gun, 5 mph wind), more than 99% of the applied active ingredient stays on the field, and less than one percent drifts (figure 2).

Typical Chemigation Application

High pressure system
(with an end gun)
160 acre field
5 mph wind

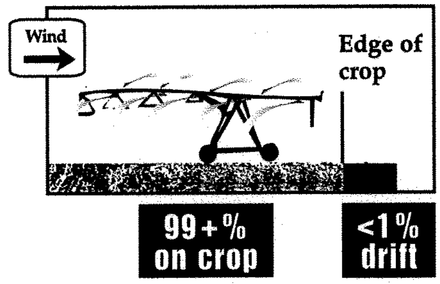


figure 2

In the SDTF studies it was not practical to apply to an entire 160 acre field due to the potential for changes in wind speed and direction during the time required for the irrigation system to travel a full circle. It was also not necessary because virtually all of the drift comes from the outside edge of the downwind portion of the circle. Therefore, applications were made only to the downwind quarter of the circle covering a 40 acre field.

Because the application area was smaller than a typical field, and because most of the drift comes from the outside edge of the downwind quarter of the irrigated circle, the percent of the active ingredient leaving the field is artificially high. Therefore, for the control treatment, the percent of the total active ingredient applied that drifted was approximately 2% rather than less than 1% for a typical application (figure 3). The only difference between the typical and control applications was the size of the application area (160 acres versus 40 acres). The high pressure system with end gun, 40 acre field, and 5 mph wind was chosen as the control because it represented an intermediate level of drift relative to the other SDTF treatments. It is used as a standard for comparison throughout this report.

SDTF Control Application

High pressure system
(with an end gun)
40 acre field
5 mph wind

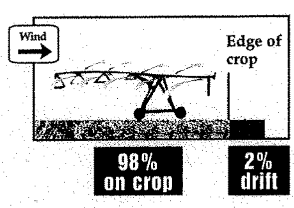


figure 3

Figure 4 shows how the 2% of the applied active ingredient that left the field in the SDTF control application deposited downwind. The amount of ground deposition decreased rapidly with distance and was already approaching zero at 150 feet downwind. Drift was measured up to 1000 feet downwind, but data are only presented for the first 300 feet to better illustrate the differences in drift between treatments. At 300 feet, the amount of ground deposition was already extremely low.

Drift from the SDTF Control Application

1.0 = 0.2 oz per acre

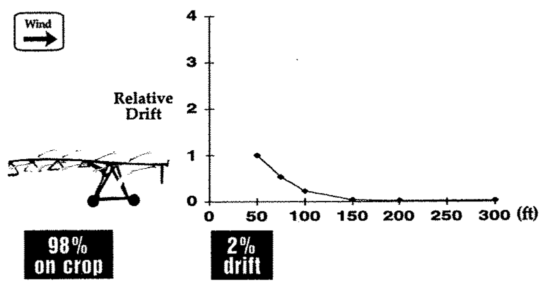


figure 4

Ground deposition measurements began 50 feet downwind from the end of the irrigation system. This distance was necessary to allow for normal variation in the size of the wetted circle inherent to impact sprinkler systems (without the effects of wind). The 50-foot distance ensured that only drift was being measured.

A scale of Relative Drift is used in this and all subsequent graphs to facilitate comparisons among treatments. Since the SDTF control treatment will be used as a standard of comparison, it was set to 1.0 at 50 feet. For an application of one pound of active ingredient per acre, this represents 0.2 ounce per acre deposited on the ground at 50 feet. A Relative Drift value of 0.5 indicates that one-half as much was deposited. A value of 2.0 indicates twice as much was deposited. In subsequent graphs, the deposition profile for the control treatment is shown in red in order to facilitate comparisons.

How droplet size affects drift

The VMD was 1690 microns for the rotary spinner nozzles on the low pressure system, and was 3008 microns for the impact sprinklers on the high pressure system (table 1). The volume of droplets less than 141 microns was 1.3% for the low pressure spinners, and 0.33% for the high pressure sprinklers. Although there was a significant difference between these droplet spectra, the volume of small, drift prone droplets was too low for either system to have a measurable affect on drift.

How sprinkler height affected drift

In 9 mph to 11 mph winds, with no end gun, drift levels were higher from the high pressure sprinklers at 12 feet than from the low pressure spinners at 5 feet (figure 5). When wind speeds were 2 mph to 3 mph, drift levels from both systems were very low, and were not significantly different.

With end guns, drift levels from the high-pressure system (sprinklers at 12 feet) were only slightly higher than from the low pressure system (rotary spinners at 5 feet) in 9 mph winds (figure 6). In 5 mph to 6 mph winds, there was virtually no difference in drift between the two systems. This is because most of the drift came from the end gun which was located at 12 feet on both systems. Higher droplet trajectories and spray velocities leaving the impact sprinklers and end guns may also have contributed to the greater drift levels.

How end guns affect drift

In the high pressure system, which produced the most drift, the addition of an end gun increased drift only slightly (figure 7). Since droplets were already released at 12 feet, the addition of the end gun had only a relatively small additive affect. The addition of an end gun had a much greater effect for the low pressure system because it increased the release height to 12 feet at the outside of the circle from where the majority of drifting droplets originated.

How sprinkler height affects drift
No end gun

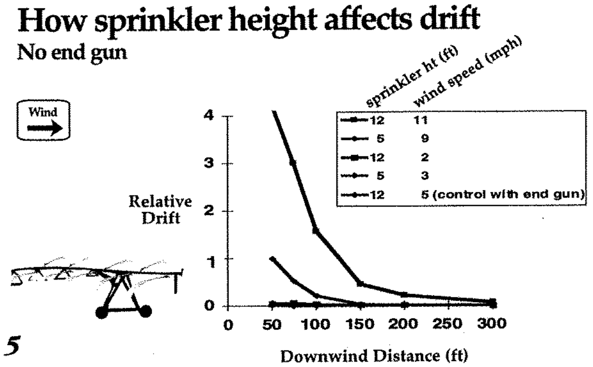


figure 5

How sprinkler height affects drift
With end gun

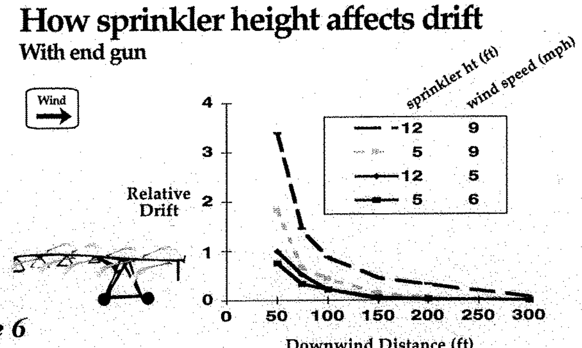


figure 6

How end guns affect drift

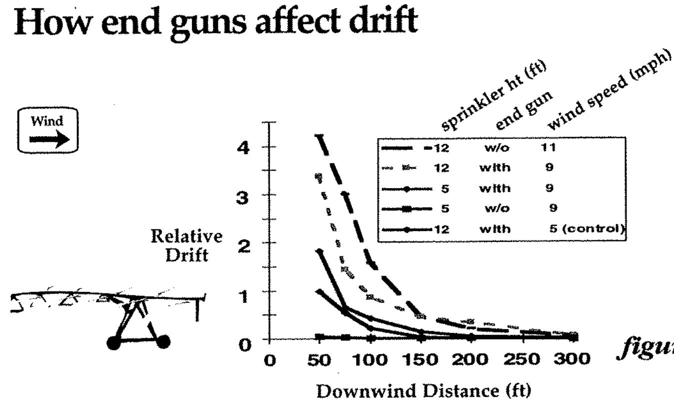


figure 7

How wind speed affects drift

In the high pressure system, with or without an end gun, there was a direct correlation between wind speed and drift. Ground deposition decreased as wind speeds dropped from 11 mph to 2 mph (figure 8).

How wind speed affects drift
12 ft sprinkler height

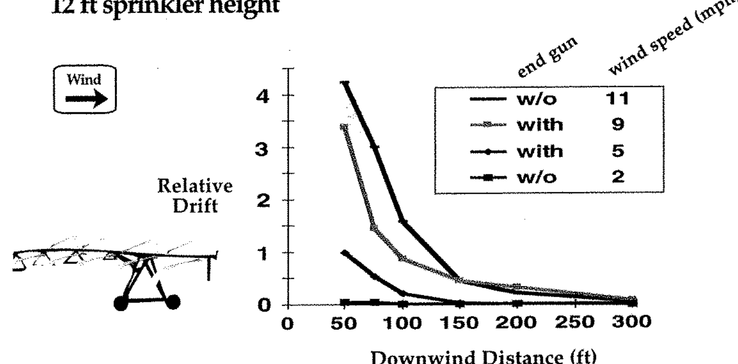
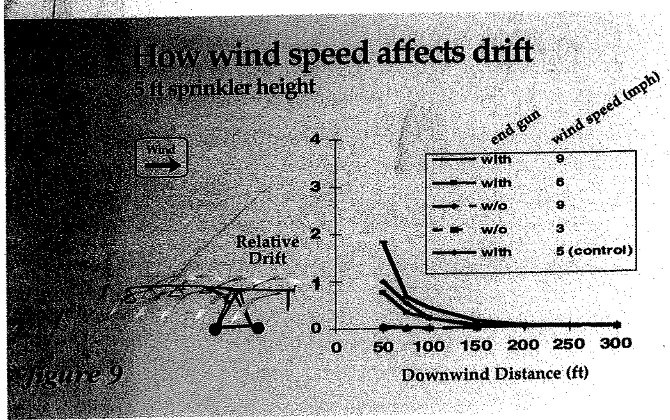


figure 8



In the low pressure system, wind speed only affected drift when there was an end gun (12-foot release height). With no end gun, all droplets were released at the 5-foot height and drift levels were very low, with no significant differences in downwind deposition between 3 mph and 9 mph winds (figure 9).

Conclusions

The level of drift from chemigation is very low because center pivot irrigation systems produce a very low level of small, drift-prone droplets (<141 microns). Drift from the high pressure system was greater than from the low pressure system primarily because of the higher release height of the droplets. The addition of an end gun to the high pressure system did not have a large additive affect on drift because droplets were already being released at 12 feet. However, addition of an end gun to the low pressure system substantially increased drift, bringing it to levels approaching the high pressure system. Wind speeds between 2 mph and 12 mph only had a significant affect on drift when droplets were released at 12 feet from the sprinklers of the high pressure system, or from an end gun. Under the range of wind speeds experienced in this study, the lowest levels of drift were measured from the low pressure system without end guns.

When accepted by the EPA, the SDTF model and databases will be used by the agricultural chemical industry and the EPA in environmental risk assessments. Even though active ingredients do not differ in drift potential, they can differ in the 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 each agricultural product is low enough to avoid harmful environmental effects. When drift cannot be reduced to low enough levels through altering equipment set up and application techniques, buffer zones may be imposed to protect sensitive areas downwind of applications.

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Appendix B

EPA Fact Sheet

EPA United States Environmental Protection Agency

EPA 430-F-03-001

SMART GROWTH NETWORK

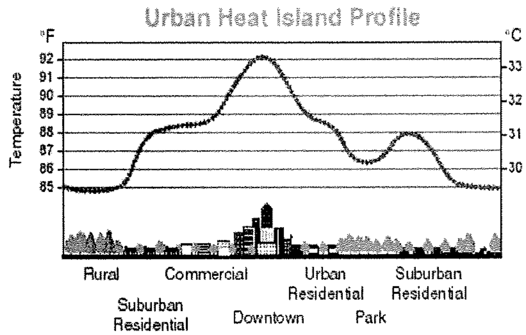
Smart Growth and Urban Heat Islands

Development patterns of the last 50 years have had both positive and negative impacts on communities across the country. One concern has been steadily increasing urban temperatures due to the effects of "urban heat islands." A heat island is an umbrella of air, often over a city or built-up area, that is warmer than the air surrounding it.

The urban heat island profile shown here demonstrates that heat islands are typically most intense over dense urban areas. The profile also shows how parks and other vegetated sections within a downtown area may help to reduce heat islands.

In general, summertime heat islands raise air conditioning demand, air pollution levels (particularly smog), and greenhouse gas emissions. They also increase the incidence of heat-related illness and mortality. In fact, in an average year, approximately 1,100 Americans die from extreme heat -- the leading weather-related killer in the United States. [2]

Heat islands augment this public health threat by directly increasing temperature and indirectly raising ground-level ozone concentrations. Those at significant risk from extreme heat and ozone exposure include the elderly, children, and individuals with pre-existing respiratory disease. Residents who live in homes with dark-colored roofs and no air conditioning may also be more vulnerable than the general population.



Source: EPA 1992 [1]

Because urban design plays a large role in heat island formation, smart growth development strategies provide an opportunity to reduce heat islands.

Smart growth is development that enhances both a community's economy and environment through strategies to help citizens make informed decisions about how and where they want to grow.

In addition to mitigating the heat island effect, smart growth provides a framework for increasing regional environmental protection, enhancing community character, and strengthening local economies. Here are four smart growth solutions that can achieve these goals:

- **Reducing off-street parking and using porous paving materials:** Surface parking lots replace natural vegetation with pavements that transfer heat to the surroundings. Providing on-street parking and planning compact, pedestrian-oriented development promotes transportation choices and can minimize the size and number of parking lots.
- **Planting, preserving, and maintaining trees and vegetation:** Trees and vegetation contribute to the beauty, distinctiveness, and material value of communities by incorporating the natural environment into the built environment. In addition, they cool surrounding areas by increasing evapotranspiration – a natural process that draws heat from the air to convert water in the leaf structure to water vapor. Planted adjacent to homes and buildings, trees provide shade, cool the interior, and reduce air conditioning energy demand. Trees and vegetation planted along medians and sidewalks can decrease evaporative emissions from cars and filter pollution from the air. Rooftop gardens, or green

Everyone wins. Residents get better homes, lower energy bills, and cooler neighborhoods with plenty of green space. Narrower streets and a shorter pipeline means lower installation costs, so the developer gets a subdivision that's cheaper to build. And the City ends up with less streets to maintain and a standard for future development that maintain the community's existing high quality of life.

J.D. Hightower, City Planner for Escalon, CA

Currents – An Energy Newsletter for Local Governments January/February 1999 roofs, can also mitigate urban heat islands while increasing the energy efficiency and attractiveness of commercial and residential buildings.

- **Promoting infill and higher-density development:** Development within existing communities can preserve open space and help offset heat islands and their consequences. A 2001 report found that for every acre of brownfield redevelopment, 4.5 acres of open space is preserved. Additional research found that compact development contributes less heat energy to the surrounding air than low-density dispersed growth patterns.[3]

- **Increasing public education and outreach:** Heat island mitigation strategies should reflect local variation in the built environment, as well as local preferences and attitudes. Policies should be tailored to meet these needs, based on stakeholder input, and effectively communicated to the public. Committees formed to address urban heat mitigation should include representatives from citizen groups, local government, non-governmental organizations, universities, and others concerned about how the community grows. A lead organization should be appointed to disseminate information to the community, solicit feedback, and incorporate issues and concerns into action plans. Working together, communities can address urban heat islands while enhancing the quality and character of their neighborhoods.

Case Study

Chicago is a leader in urban forestry and heat island mitigation. The city has adopted an ***open space impact fee ordinance*** that requires new residential development to contribute a proportionate amount of open space or recreational facilities, or to pay fees that ensure community residents of continued access to greenspace. Chicago also replaced a 10,080 ft^2 conventionally paved alley with a ***light-colored permeable gravel pave system***, which has eliminated chronic flooding without requiring the installation of a sewer system. In addition, between 1991 to 1998 Chicago planted ***over 500,000 trees*** and achieved a citywide tree count of 4.1 million. Chicago's Bureau of Forestry now plants a minimum of 5,000 new trees per year and plans to install -- in addition to 120 miles of existing median planters -- ***280 miles of new median planters by 2005***. In June 2001, Chicago amended its ***energy code*** to include ***requirements for reflective or green roofs***. See: http://www.cityofchicago.org/Environment/

Resources

For more information on heat islands, see www.epa.gov/heatisland, www.hotcities.org, and http://eetd.lbl.gov/HeatIsland.

For more information on smart growth, see www.smartgrowth.org and www.epa.gov/smartgrowth. Additional information on the relationship between the environment and the built environment can be found in "Our Built and Natural Environments: A Technical Review of the Interactions between Land Use, Transportation, and Environmental Quality." EPA 231-R-01-002.

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1 *"Cooling Our Communities – A Guidebook On Tree Planting and Light-Colored Surfacing"* U.S. Environmental Protection Agency 22P-2001, January 1992.
2 Kalkstein, LS, 1993. Health and Climate Change: Direct Impacts in Cities. *The Lancet* 342:1397-99.
3 Stone, B., and M.O. Rodgers. 2001. "Urban Form and Thermal Efficiency: How the Design of Cities Influences the Urban Heat Island Effect." *Journal of the American Planning Association* 67 (2) 186-198.

To learn more about Smart Growth and the Smart Growth Network, please go to http://www.smartgrowth.org.

Office of Air and Radiation (MC 6205J)
Office of the Administrator (MC 1808)
EPA 430-F-03-001

"EPA's mission is to protect public health and the environment. EPA works with state and local decision makers to evaluate, promote, and implement integrated, common-sense strategies that capitalize on public health and air quality improvements, while encouraging economic growth. Studies have demonstrated that mitigating heat islands provide clear environmental and financial benefits including improved local and global air quality, reduced heat-related illness and death, and increased energy savings."