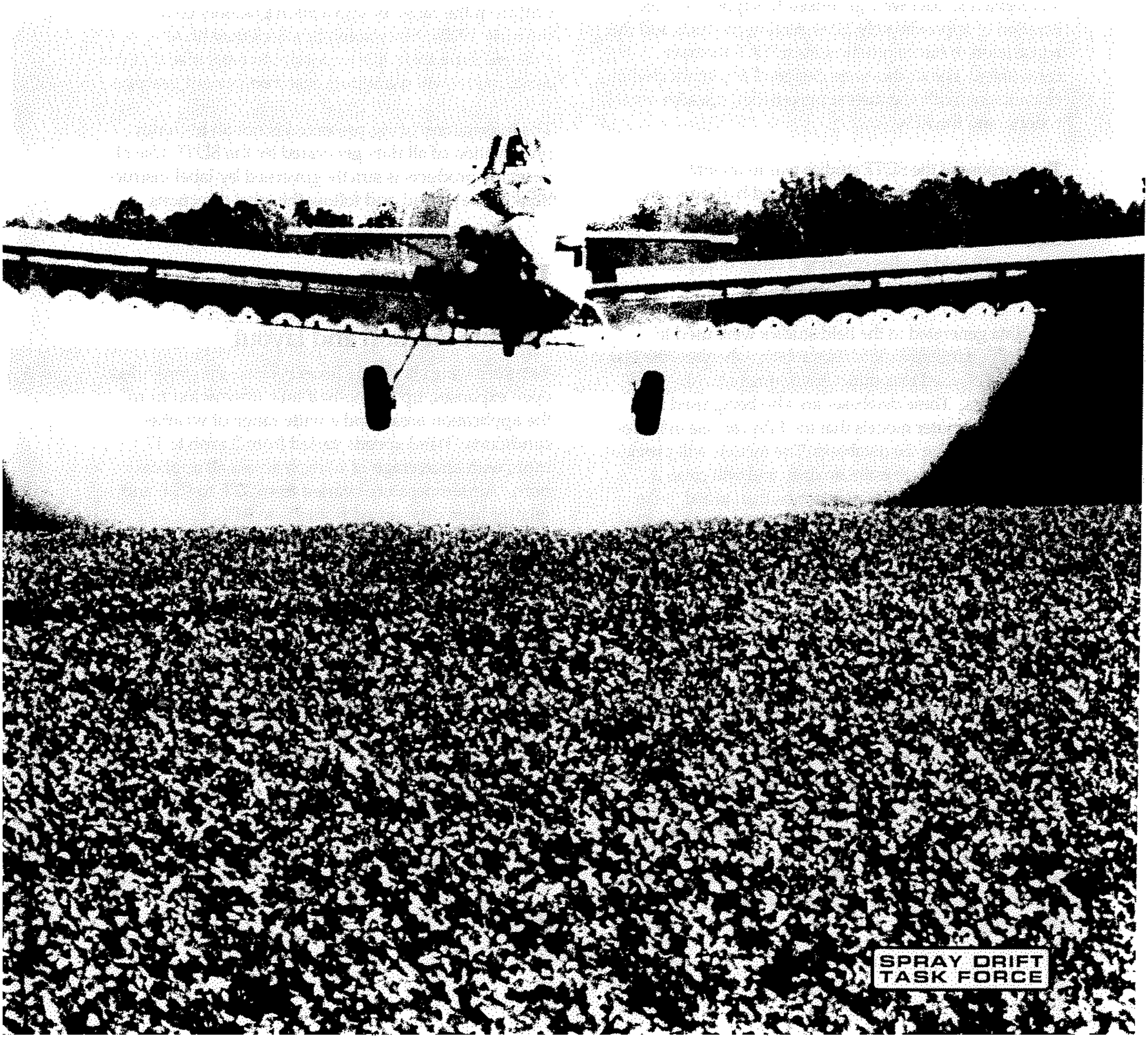
A SUMMARY OF Aerial Application Studies



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

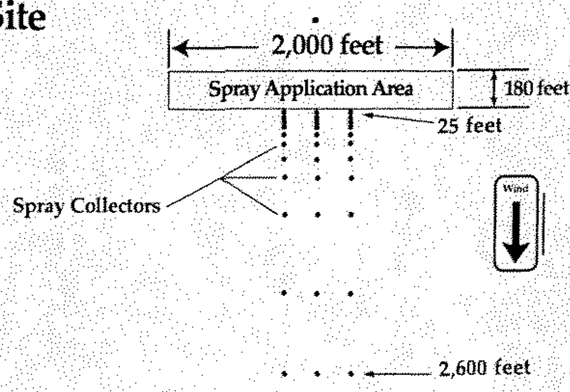


figure 1

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

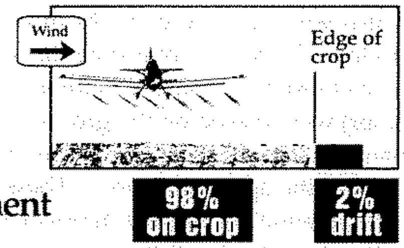


figure 2

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

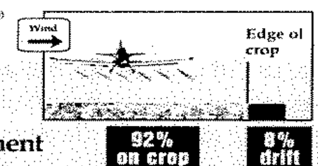


figure 3

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

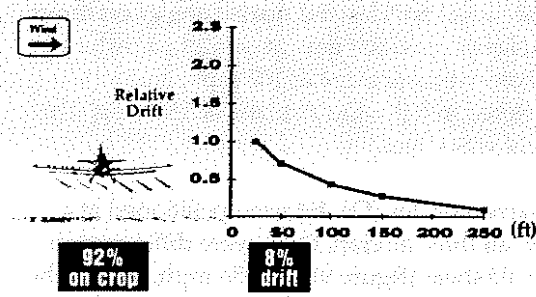


figure 4

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.

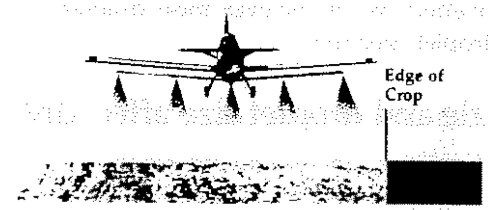


figure 5a

figure 5b

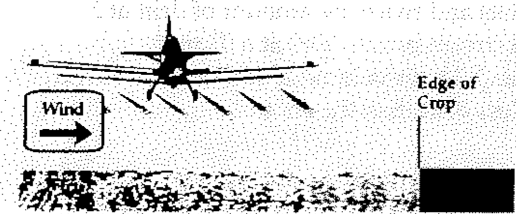


figure 5c

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

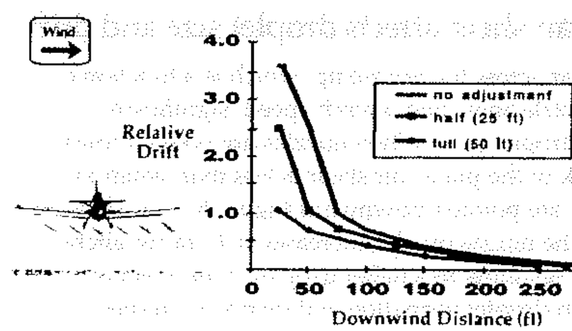


figure 6

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

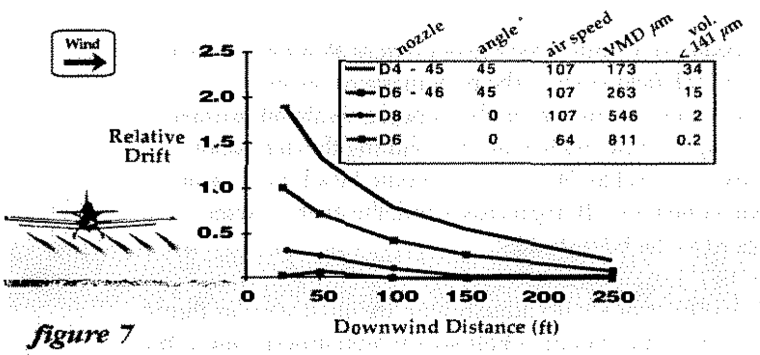


figure 7

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

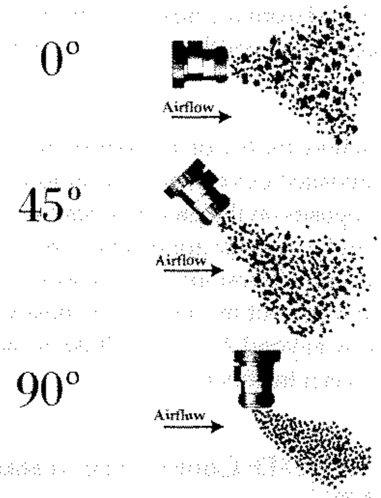


figure 8

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

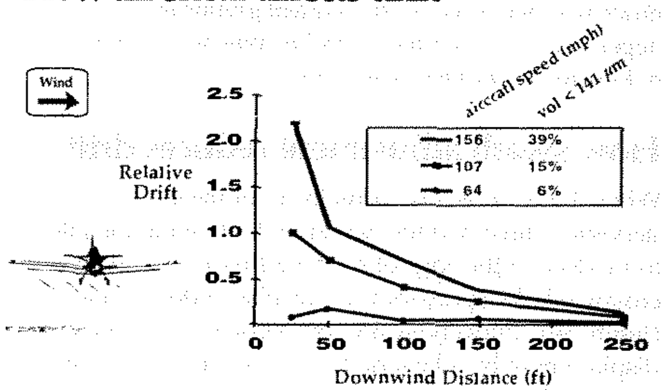


figure 9

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

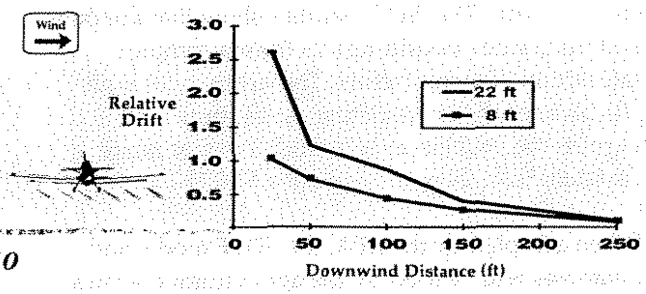


figure 10

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

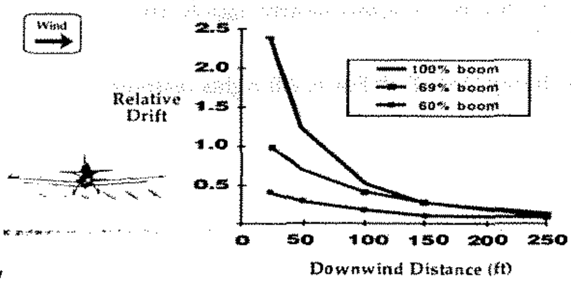


figure 11

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

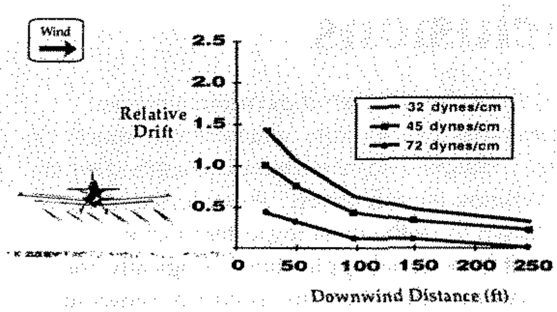


figure 12

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

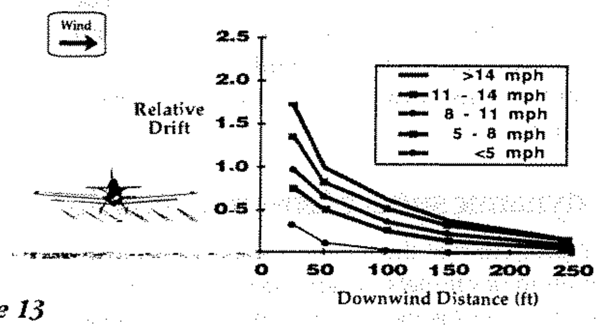


figure 13

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.

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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