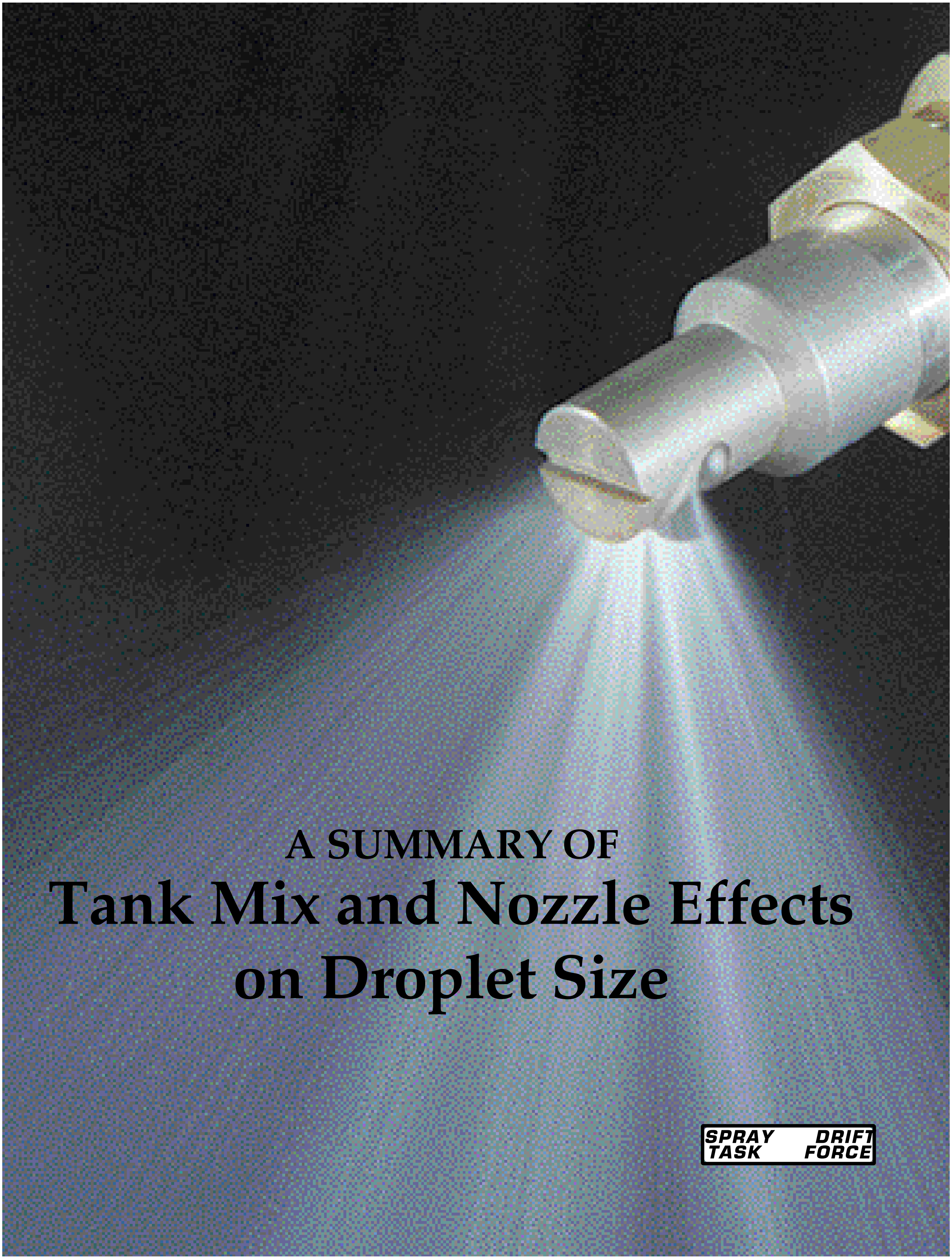


A SUMMARY OF

Tank Mix and Nozzle Effects on Droplet Size

SPRAY DRIFT TASK FORCE

Introduction

The incidence and impact of spray drift can be minimized by proper equipment selection, 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 fact sheet is to describe the SDTF Atomization and Physical Property studies in an effort to raise the level of understanding about the factors that affect spray drift. The National Coalition on Drift Minimization (NCODM) defines spray drift to be the movement of pesticide through the air at the time of pesticide application or soon thereafter from the target site to any non- or off-target site, excluding pesticide movements by erosion, migration, volatility, or windblown soil particles after application.

The SDTF is a consortium of 38 agricultural chemical companies established in 1990 to generate data to fulfill 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 of SDTF member companies. The studies were designed and conducted in consultation with scientists at universities, research institutions, and the EPA.

The data generated in the field, as well as physical property and atomization studies, were used to establish databases. Using a common experimental design, more than 300 applications were made in ten field studies covering a range of application practices for each type of application. The SDTF measured primary spray drift, and did not study vapor drift, or any other form of secondary drift occurring after initial droplet deposition.

The data generated in the field, physical property and atomization studies were used to establish quantitative databases which will be used by EPA 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 should greatly facilitate the risk assessment process, 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). The AgDRIFT® model predicts spray drift based on droplet size spectrum (spray quality), application height, and weather conditions. The DropKick® model predicts the droplet size spectrum based on nozzle type, orifice size, fan angle, discharge angle relative to airstream, spray pressure and physical properties of the spray mixture.

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 differing experimental techniques were used, it was difficult to compare results across the studies. However, the information from these studies was useful in developing test protocols that were followed by the SDTF.

The results of the SDTF studies support conventional knowledge that spray drift is a predictable phenomenon based on the droplet size spectrum, application height, and weather conditions. As expected, droplet size was confirmed to be a dominant factor affecting spray drift. Among the most dominant factors (droplet size, application height, and wind speed), droplet size and application height can be most readily modified by the applicator.

The information provided in this fact sheet is not an in-depth presentation of all data generated by the SDTF, and as such is not intended to modify or replace specific label or product information. Actual use of pesticide products is strictly governed by label instructions. Always read and follow the label directions. Additional information based on SDTF studies can be found in other fact sheets in this series: "A Summary of Aerial Application Studies", "A Summary of Ground Application Studies", "A Summary of Orchard Airblast Application Studies" and "A Summary of Chemigation Application Studies" (Spray Drift Task Force, 1998).

Purpose and Scope of the SDTF Atomization and Physical Property Studies

The SDTF Atomization and Physical Property Studies:

- measured the droplet size spectra applied in the SDTF field studies
- identified the key physical properties of the spray mixtures that affect atomization using experimental statistical design studies
- provided an atomization database covering spray mixtures with a near-maximum range of physical properties and a wide range of nozzles
- were used to develop the DropKick® model to predict the droplet size spectra which would occur from the use of a wide variety of agricultural nozzles based on the key physical properties of the spray mixture.

The range of nozzles used in these studies represented the types and sizes that are commonly used for the application of agricultural chemicals by air, ground, airblast, and chemigation. Each nozzle was tested at various operating conditions (spray pressure, nozzle angle, and airstream velocity) to span the range of typical application scenarios. The spray mixtures tested in the studies covered the range of physical properties for virtually all crop protection chemicals applied in the United States.

Droplet Size Classification

All agricultural nozzles produce a range of droplet sizes called the droplet size spectrum.

The volume median diameter (VMD or $D_{v0.5}$) is commonly used to characterize droplet size spectra. VMD is the droplet size (in microns) at which half of the spray volume is composed of larger droplets and half the spray of smaller droplets (Figure 1). Although VMD is useful for a general comparison of droplet spectra, it is not the best indicator of drift potential because it only indicates an "average" droplet size. A more useful measurement for indicating drift potential is the percentage of spray volume in small drift prone droplets (typically less than 150 microns diameter).

Larger droplets are heavier and therefore less affected by wind and evaporation. Coarser sprays have a greater percentage of large droplets and are therefore less prone to drift. However, these coarser sprays can sometimes reduce coverage and control. Since minimizing drift potential and maximizing spray coverage are important, an applicator needs a practical means to evaluate the entire droplet spectrum. Currently, the use of droplet size categories (sometimes referred to as spray quality categories) appears to be the most practical approach.

The American Society of Agricultural Engineers (ASAE) used the British Crop Protection Council (BCPC) droplet size classification system as a base for a spray classification system adapted to U.S. agriculture. ASAE standard S-572, "Spray Nozzle Classification by Droplet Spectra" has six categories: Very Fine (VF), Fine (F), Medium (M), Coarse (C), Very Coarse (VC) and Extra Coarse (XC). The boundaries of the categories are defined by the droplet size spectrum from a particular nozzle, flow rate and pressure that is called a reference spray. Reference nozzle sprays, rather than defined droplet spectra, are used to divide the categories due to differences in the instruments used to measure the droplet size spectra.

Anyone wishing to characterize the droplet size spectrum for a particular test nozzle must first "calibrate" their measurement system according to ASAE standard S-572. This procedure defines the boundaries for the six categories. The most common way to visualize the droplet size spectrum is to plot the cumulative spray volume fraction versus the droplet size diameter (e.g., Figure 2). The droplet spectrum of the test nozzle is then compared to the standard curves from the reference sprays. If the cumulative droplet spectrum curve for the test spray falls 1) between two reference sprays, or 2) outside the finest or coarsest reference spray, it is then placed in the appropriate category. If any part of the test nozzle curve (between $D_{v0.1}$ and $D_{v0.9}$, the respective diameters at which 10% and 90% of the droplets are smaller by volume, seen at the bottom and top ends of the curve) crosses any reference spray curve, then the nozzle is placed in the finer of the two categories. ASAE standard S-572 describes this process in detail. Any researcher working with spray equipment or nozzles should refer to this standard. The reader should note that the droplet size spectrum classification is defined by the finest portion of the spray and therefore is usually considered a conservative indication of potential for drift.

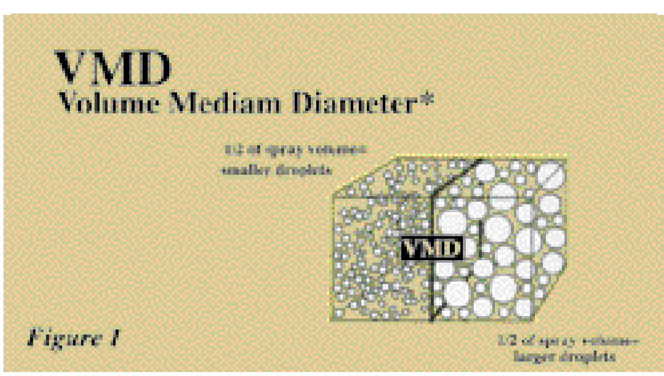
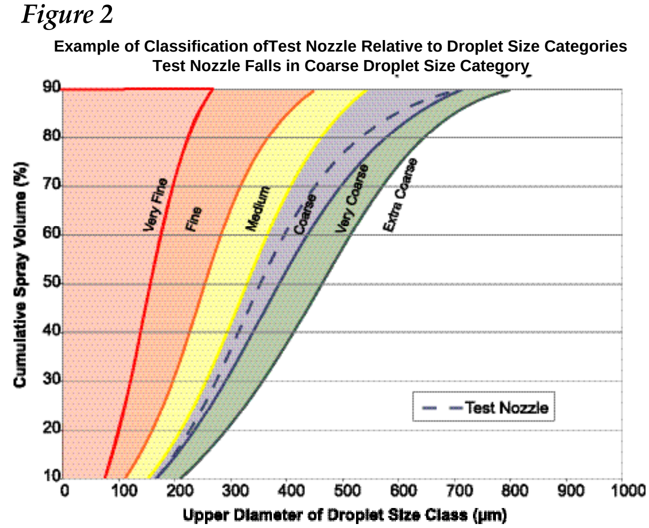


Figure 1

Figure 2



An example of classification for a nozzle is given in Figure 2. The test nozzle (dashed line) falls between the Medium/ Coarse and Coarse/ Very Coarse boundary curves (solid lines), showing that this is a Medium droplet size spectrum.

Factors Affecting Droplet Size

The SDTF confirmed that nozzle type, orifice size, spray angle, spray pressure and the physical properties of the spray mixture are the primary factors affecting droplet size spectra from agricultural nozzles. For aerial application, sprays are usually finer at greater flight speeds, and greater fan angle/discharge angle relative to airstream (Figure 3). For the majority of nozzle types, the flow rate and atomization are a function of the orifice size and the pressure of the liquid being sprayed. However, for rotary atomizers and certain other nozzles, additional factors are involved.

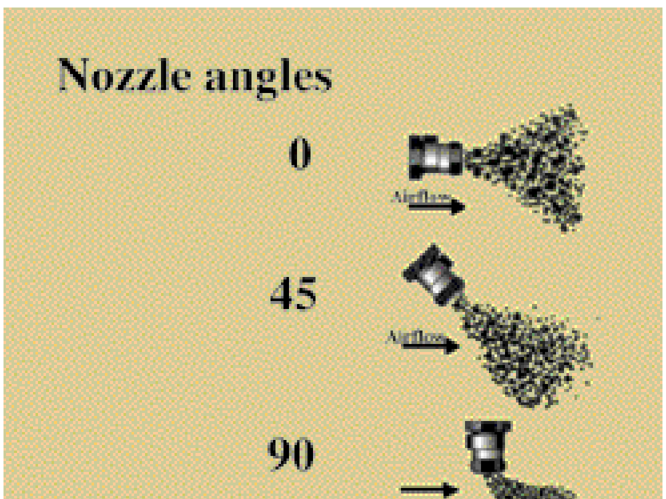


Figure 3

Factors Affecting Droplet Size – Nozzle Type, Orifice Size and Spray Angle

Nozzle type is a major factor affecting droplet size. For example, flood type nozzles tend to produce coarser sprays, while hollow cone nozzles tend to produce finer sprays. For hydraulic nozzles, orifice size is an important factor affecting droplet size. Typically, smaller orifices produce finer sprays. For conventional flat fan nozzles, wider spray angles typically produce finer sprays.

Factors Affecting Droplet Size – Spray Pressure

For most ground hydraulic, chemigation, and airblast applications, increasing the spray pressure results in a finer spray. For aerial application with solid stream nozzles pointed backward, increasing spray pressure can actually result in a coarser spray because it can result in an exit velocity from the nozzle closer to the speed of the aircraft. This can reduce the air shear affect and result in a coarser spray. The combined effects of spray pressure and nozzle orientation can produce a wide range of droplet spectra.

For hydraulic nozzles, spray pressure and orifice size are the primary factors that regulate flow rate. However, it is important to understand that the spray pressure must be increased by 4 times to double the flow rate. Since increasing the spray pressure will result in a finer spray, it is usually better to increase flow rate by increasing the orifice size. Spray pressure should be used only as a means of making small adjustments to the flow rate. Many nozzles are recommended for use in specific pressure ranges. Manufacturer recommendations should be carefully considered in nozzle selection, use and droplet size label compliance. Going outside these recommendations can produce undesirable results.

Factors Affecting Droplet Size – Physical Properties of the Spray Mixture

The SDTF confirmed that the physical properties of the spray mixture affect the droplet size spectrum. However, it is important to emphasize that it is the properties of the spray mixture, not the physical properties of an individual formulation or the active ingredient, that affects the droplet size spectrum. The physical properties of the spray mixture are dependent on the physical properties and the relative proportion of each component in the mixture (including water). These physical properties must be measured for each spray mixture, and cannot be calculated from the physical properties of the active ingredient and/ or its formulation. The SDTF studies identified the three key physical properties of the spray mixture that have a significant effect on droplet size in aerial applications. These physical properties are dynamic surface tension, extensional viscosity and shear viscosity.

Because the atomization and physical property studies evaluated a wide variety of spray mixtures, the SDTF was able to identify the combination of spray mixture physical properties that would result in the finest and coarsest sprays for a given nozzle/ pressure combination. This is an important finding because often it will be impractical to measure the physical properties of the wide variety of spray mixtures allowable under a product label. In these situations, the physical properties resulting in the highest and lowest drift potential can be used to calculate the range of droplet size categories that would be expected from a particular nozzle.

The SDTF tested a few representative adjuvants with a limited number of spray mixtures covering a wide range of formulation types. Tank mix adjuvants such as surfactants, crop oils and drift control agents can significantly affect the physical properties of the spray mixture. Adjuvants and formulations containing alcohols or certain water miscible solvents tend to reduce the dynamic surface tension resulting in finer sprays. However, the effects of adjuvants vary depending on the other components of the spray mixture. Some drift control agents have been reported to lose their effectiveness when circulated through a sprayer pump. Applicators should follow label recommendations concerning addition of adjuvants.

Factors Affecting Droplet Size – Evaporation

The droplet size spectrum can change prior to deposition due to evaporation. The SDTF conducted extensive evaporation studies on a wide range of spray mixtures. These studies indicated that the key physical properties affecting atomization (dynamic surface tension, shear and extensional viscosity) did not affect droplet evaporation rates. The factors that did affect evaporation rates were initial droplet size, air temperature and relative humidity. The evaporation rate and the percent of non-volatile materials in the droplets can affect spray drift potential.

Figure 4
Droplet Size Table for Hypothetical Nozzle, Predicted Using the Drop Kick® Atomization Model

Pressure	Speed	Flow Rate	Angle in degrees				
psig.	mi/hr.	gpm	0	15	30	45	60
20	40	0.66					
20	50	0.66					
20	60	0.66					
20	80	0.66					
20	100	0.66					
20	120	0.66					
20	140	0.66					
30	40	0.81					
30	50	0.81					
30	60	0.81					
30	80	0.81					
30	100	0.81					
30	120	0.81					
30	140	0.81					

Very Coarse	Coarse	Medium	Fine	Very Fine

The SDTF DropKick® Atomization Model

The SDTF used the information from the atomization studies to create the DropKick® atomization model, which predicts the droplet size spectra from a wide range of nozzles, pressures, air speeds, and spray mixtures. Possible applications of this model include its use by: 1) applicators to estimate droplet size when setting up their sprayer, and 2) EPA, state regulators and others to evaluate the range of droplet size spectra that could result from application scenarios permitted by a product label. An example of a DropKick® analysis for a hypothetical nozzle is shown on Figure 4.

USDA Atomization Models

The United States Dept. of Agriculture - Agricultural Research Service (USDA-ARS) has developed several models for aerial application scenarios that facilitate the prediction of droplet size for specific nozzle types. These models currently cover CP® deflector and solid stream nozzles, Lund®, TVB®, and other solid stream nozzles. Additional models are being developed by USDA-ARS to expand the range of nozzle types that can be modeled.

The SDTF/ EPA/ USDA AgDRIFT® Model

The SDTF, EPA, USDA-ARS and USDA Forest Service have developed a Windows™-based model, AgDRIFT® that can estimate drift from spray applications. This model uses the application and weather conditions to estimate possible off-target spray movement. Reports giving the technical description and validation of the model are in press in the Journal of Environmental Science and Toxicology. A key component of the model is the droplet size spectrum of a given application. AgDRIFT® includes DropKick® and the USDA models, along with other droplet size sources. AgDRIFT® was not developed for making application decisions, but provides a useful tool for studying the relative influence of different factors on drift potential. For example, the effects of droplet size and boom height on drift potential can be studied. In AgDRIFT® Aerial mode, additional factors such as wind speed, boom length, and aircraft nozzle placement can be evaluated.

Conclusions

The SDTF studies support conventional knowledge that spray drift is a predictable phenomenon based on droplet size spectrum, application height, and meteorological conditions.

Grouping similar droplet spectra into droplet size categories provides a practical means to predict how a particular nozzle setup (type, size, pressure, etc.) will affect spray drift potential and coverage. In addition to confirming conventional knowledge that nozzle type, orifice size, and spray pressure are primary factors affecting droplet size, the SDTF determined that three physical properties of the spray mixture typically affect droplet size spectra: 1) dynamic surface tension, 2) extensional viscosity, and 3) shear viscosity.

Since droplet size spectrum, application height, and weather conditions affect spray drift potential, the SDTF focused on these parameters in developing databases and models to predict spray drift potential for all active ingredients. The SDTF developed the atomization databases and DropKick® model to predict the droplet size spectra for broad ranges of spray mixtures, nozzles and use conditions. The SDTF confirmed that the physical properties of the final spray mixture – not the active ingredients or formulated products in that mixture – affect droplet size. Some products may affect the physical properties of a spray mixture. However, it would be necessary to measure the physical properties of all the different spray mixtures allowable under a product label to predict the range of droplet size spectra that could be produced. Therefore, when calculating drift potential it will be more practical to use a default set of reasonable worse case physical properties that favor finer droplet size spectra across a broad range of nozzles. This set of physical properties has already been determined by the SDTF and included in the models. A spray mixture with similar reasonable worse-case physical properties was also used in developing the USDA-ARS atomization models.

Applicators should make every effort to minimize spray drift at the application site. The droplet size spectrum is only one of many variables that must be carefully considered in this effort. Additional information on drift minimization is available from various sources such as USDA applicator guides, state extension service booklets, nozzle catalogs and other publications, and web site information. Since these sources may not be referenced on agricultural chemical product labels, it is important that applicators familiarize themselves with the best and latest available information on the avoidance of spray drift.

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

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