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The Science of Ag Aviation

Innovative research by the USDA-ARS Aerial Application Technology Group keeps aerial applicators on the cutting edge

The Industry Loses a Legend: Leland Snow 1930–2011

FACTS TO THE FUTURE

Innovative research by the USDA-ARS Aerial Application Technology Group keeps aerial applicators on the cutting edge

By Scott Bretthauer, Ph.D.
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The Aerial Application Technology Group's Clint Hoffmann and Brad Fritz secure fishing line in an Illinois cornfield for an in-canopy swath analysis they are conducting with Scott Bretthauer, author of this article. The fishing line is used to measure multiple swath deposition patterns in corn.

Over the years as an Operation S.A.F.E. analyst, member of the PAASS Program Development Committee and a researcher involved with aerial application, I have developed a deep appreciation for the USDA-ARS Aerial Application Technology Group (AAT). They conduct a variety of research projects related to aerial application and provide valuable information to the industry. They also provide unbiased information that can be used to defend the aerial application industry against those who seek to regulate it more heavily. As United States agriculture continues to deal with various pest problems, it is critical for growers to have agricultural aviation available as the solution to their pest management problems. No other application method can provide the timely, effective and safe applications that agricultural aviation can.

Based in College Station, Texas, the Aerial Application Technology Group is part of the USDA Agricultural Research Service's Areawide Pest Management Research Unit. It is the largest aerial application research group in the country and has access to resources that no other research group has available. As AAT's lead

scientist, Dr. Clint Hoffmann leads a team of scientists, engineers and support personal committed to finding solutions to challenges facing the aerial application industry and agriculture as a whole.

The information supplied by AAT is used for three important purposes. First, it is used directly by aerial applicators to improve the quality of their applications. Second, it serves as an unbiased source that can be used by government regulatory agencies to assist them in developing reasonable regulations for our industry. Third, the data can be used to show growers who might use aerial application and the general public that aerial applications are both extremely effective and safe.

Since 2001, AAT has played a prominent role in dispelling the notion that agricultural aircraft could be used as a terrorist weapon to dispense biological weapons. While those of us in the industry recognize this is an impossible scenario, having AAT verify to the federal government that agricultural aircraft cannot be used as terrorist weapons has prevented the aerial application industry from being heavily scrutinized and subjected to additional security regulations.

The speed and effectiveness of aerial application means it is the only viable option for treating the outbreak of rapidly spreading destructive pests, particularly those invading from other parts of the world, such as soybean rust. Ensuring agricultural aviation remains a pest control option in the future is vital for United States agriculture. AAT provides the information that ensures it will be. In this article I would like to highlight research from AAT related to two topics important for the future of aerial application: reducing drift and improving the effectiveness of aerial applications.

USDA-ARS Aerial Spray Nozzle Models

One of the biggest and most important projects completed by the AAT group was the creation of the Aerial Spray Nozzle Models, which were completed in 2004. These models, which are available for download at http://apmru.usda.gov/downloads/downloads.htm, serve two very important purposes. First, they assist aerial applicators in selecting and setting up nozzles on their aircraft to achieve a droplet spectrum that will provide sufficient coverage for the product they are applying while also minimizing the risk of drift. Second, it provides irrefutable evidence to pesticide manufacturers, regulators and others as to the high quality of spray possible from aerial applications.

Developing the models was a complicated project. To begin the project, the USDA worked with NAAA to poll aerial applicators across the nation to determine the most commonly used nozzle types for aerial applications. These nozzles were then selected for evaluation. To simulate the high speeds used in aerial applications, a high speed wind tunnel was used to generate suitable airspeeds. An agricultural surfactant was used to mimic the spray solution characteristics of agricultural spray mixes. Each of the nozzles to be tested was then mounted at the outlet of the wind tunnel and operated at various orifice sizes, pressures, deflection angles and airspeeds. A laser diffraction instrument was used to measure the spray droplet size throughout the spray plume created by the nozzle.

The spray droplet models were then created using data from these tests. They allow an aerial applicator to select the nozzle type they are interested in using, the airspeed at which they intend to operate, the orifice size and pressure for their application, and the nozzle deflection angle. The model will then provide droplet size data for that particular setup. If the droplet size generated by the models is undesirable for the application, the applicator can quickly change various parameters until a more suitable droplet size is generated. This is a huge advantage, because the aerial applicator can quickly and conveniently test multiple nozzle types and settings right from the computer.

Information provided by the models includes spray droplet characteristics and the ASABE droplet spectra classifications. An example of the nozzle model output can be seen in table 1.What does all this mean to an aerial applicator? It means you can accurately assess how well you're

A number of pesticide labels approved by the EPA have mandatory buffer zones on all sides of the application site, downwind and upwind, for certain applications. Having AAT provide scientific proof that this is unnecessary is critical when working with the EPA to help them understand that upwind buffer zones provide no additional safety, and thus only serve to restrict agricultural production.

targeting the ideal droplet size for the product and pest (Dv0.5), what your risk of drift is (Dv0.1, % volume <100 microns and <200 microns), whether you are wasting spray in very large droplets (Dv0.9), and how wide your droplet spectrum is (relative span). There is not currently a comparable tool for ground applicators that provides the same level of detail as the aerial spray nozzle models.

When the EPA assesses the risk of drift from aerial applications for various pesticides being registered or re-registered, it often uses a fine droplet spectrum for its models. Using the USDA-ARS Aerial Spray Nozzle Models, it can be shown that many nozzle setups on agricultural aircraft produce a medium or coarse droplet spectrum when classified using the Dv0.1 value, which represents the portion of the spray volume at risk for drift. This means the EPA can run more realistic models when determining the risk of drift from aerial applications. Without the nozzle models, it would be difficult to prove to the EPA that using a fine droplet spectrum for their models is not realistic. NAAA is urging the EPA to use these types of third-party, scientifically valid models when it does its risk assessments on aerial drift of pesticide products.

40-DEGREE FLAT FAN NOZZLE (LARGE ORIFICE)
FOR USE ON FIXED-WING AIRCRAFT
AERIAL APPLICATORS SPRAY NOZZLE HANDBOOK
USDA ARS AH-726
I. W. Kirk, Agricultural Engineer, Areawide Pest Management Research Unit,
Southern Plains Agricultural Research Center, Agricultural Research Service, U. S. Department of Agriculture, 2771 F&B Road, College Station, TX 77845-4966, USA.

Directions: Enter 40 DEGREE FLAT FAN nozzle settings, pressure, and airspeed in the cells highlighted below.
(Atomization parameters are valid only with nozzle and operational settings specified in the Acceptable Range.)

	Nozzle Tip Size, (Enter 15 for 4015, etc.)	Nozzle Angle, degrees	Pressure, psi	Airspeed, mph
Acceptable Range:	10 to 30	0 to 90	20 to 60	100 to 160
	15	23	40	140

Atomization parameters are displayed in the box below.

CAUTION: Do not enter or clear data in the cells in this box!

$D_{V0.1}$ =	174 µm	= Droplet size such that 10% of the spray volume is in droplets smaller than $D_{V0.1}$.
$D_{V0.5}$ =	303 µm	= Volume median diameter
$D_{V0.9}$ =	465 µm	= Droplet size such that 90% of the spray volume is in droplets smaller than $D_{V0.9}$.
RS =	0.96	= Relative Span
%V<100µm =	4.21 %	= Percentage of spray volume in droplets smaller than 100 µm diameter.
%V<200µm =	12.33 %	= Percentage of spray volume in droplets smaller than 200 µm diameter.
$DSC_{V0.1}$ =	COARSE	= Droplet Spectra Classification based on $D_{V0.1}$.
$DSC_{V0.5}$ =	MEDIUM	= Droplet Spectra Classification based on $D_{V0.5}$.
$DSC_{V0.9}$ =	FINE	= Droplet Spectra Classification based on $D_{V0.9}$.
DSC =	FINE	= ASAE S572 AUG99 Droplet Spectra Classification

Table 1. An example spray nozzle model from the USDA-ARS Aerial Application Technology Group. This model is for a 40-degree flat fan with a size 15 orifice setup with 23-degree deflection and operated at 40 psi and 140 mph. This setup would provide a good balance between coverage and drift reduction. Note that while the overall droplet spectrum is classified as fine, the classification for the Dv0.1 value (the portion of the droplet spectrum that represents the risk for drift) is coarse. Many nozzle manufacturers use these models on their website to assist aerial applicators when choosing their nozzles.

The AAT group is currently planning on expanding their droplet size database even more. They intend to test pesticide formulations and adjuvants to determine the impact these products have on the droplet size. Recent studies along these lines found that glyphosate and foliar fungicides reduce the droplet size. Understanding how pesticide formulations and adjuvants impact droplet size will help aerial applicators set up their aircraft more accurately and better select and use adjuvants. In addition to testing actual pesticide products, AAT has tested several products in effort to find a "blank" that can be safely used at Operation S.A.F.E. fly-ins to mimic the impact that pesticide formulations have on droplet size and spray patterns. The goal is to use these blanks to improve the accuracy of pattern and droplet size testing at fly-ins.

The Aerial Application Technology Group's new high speed wind tunnel and droplet sizing system is capable of airspeeds over 200 mph.

AAT also recently installed a new high speed wind tunnel capable of generating even higher airspeeds so the models can be expanded to include speeds commonly used with larger, faster turbine aircraft. This new wind tunnel was used to answer a common question from aerial applicators: should I be using air-induction nozzles? AAT provided an answer in Savannah at the NAAA Convention—in a word, no (*see pg. 25*). As the additional research is completed with various pesticides and adjuvants and at higher airspeeds,

aerial applicators can expect updated and easier to use nozzle models.

Other Drift Reduction Projects

Other projects dealing with drift included examinations of drift reduction additives using both laboratory and field trials. The goal of using any drift reduction adjuvant is to reduce the risk of drift by reducing the formation of small, drift-prone droplets. One concern is that the drift reduction additive increases the overall droplet size, which can have a negative impact on coverage and application effectiveness. The AAT group has conducted field trials to measure how well various drift reduction adjuvants reduce the downwind deposition of sprays. Evaluating these products in their high speed wind tunnel then allows them to evaluate how the products change the overall droplet size so that aerial applicators can be sure they chose a drift reduction adjuvant that lowers their risk of drift but does not reduce the effectiveness of their application. Additional work with drift reduction adjuvants will also likely be a part of future research plans.

The Aerial Application Technology Group consists of five scientists and six support personnel, including, from left to right: Phil Jank, Dr. Juan Lopez, Curtis Hubbard, Dr. Dan Martin, AAT pilot Lee Denham, lead scientist Dr. Clint Hoffmann, Charlie Harris, Dr. Yubin Lan, Chris Parker, Dr. Brad Fritz and Dr. Mohamed Latheef.

Pest and crop-specific projects that AAT conducts provide two benefits. For aerial applicators, they provide useful information on nozzle selection, aircraft setup and operation for achieving the best pest control. For others, they provide proof that aerial applications, and in particular low volume applications, are very effective for controlling pests.

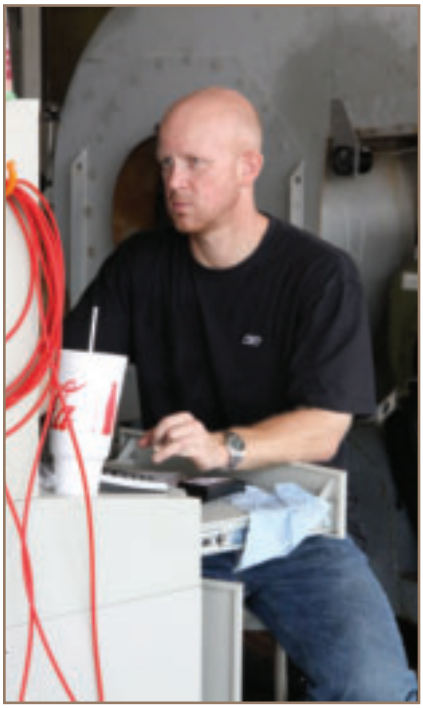
The AAT group also conducts research related to weather conditions and drift. In recent years they have focused on inversions in order to help aerial applicators better understand how drift occurs when applications are made during an inversion. Results from these projects have been used in the PAASS program in order to better educate aerial applicators about how to identify inversions so that applications can be avoided when they occur.

Establishing reasonable buffer zones is another issue affecting the industry. One important paper where the lead author was a member of the AAT group deals with the use of buffer zones during aerial applications. The article reviewed research and models related to drift to examine whether upwind buffers zones are needed for aerial applications. The authors concluded that a review of the research does not support the need for upwind buffers zone for aerial applications carried out in wind speeds greater than 3 miles per hour. In fact, the only time upwind drift is possible is when the upwind vortex from the aircraft exceeds the force of the wind. Even in these situations, the material deposited upwind of the upwind edge of the swath and the upwind distance it is carried is very slight. Since aerial applicators are taught, through the PAASS Program and other pesticide education programs, to avoid applications when wind speeds are less than 3 mph, it can be concluded that upwind buffer zones are not necessary. While this may seem obvious, it is important to remember that a number of pesticide labels approved by the EPA have mandatory buffer zones on all sides of the application site, downwind and upwind, for certain applications. Having AAT provide scientific proof that this is unnecessary is critical when working with the EPA to help them understand that upwind buffer zones provide no additional safety, and thus only serve to restrict agricultural production.

The AAT group is also involved with the EPA's Drift Reduction Technology (DRT) Program. The concept of the DRT program is to provide an incentive to all applicators, not just aerial, to use technology proven to reduce the risk of drift during pesticide applications. The use of DRTs, according to EPA's draft policy,

can result in reduced buffer zone distances for applicators making an application. AAT is working with the EPA to develop testing procedures to evaluate DRTs, which can include nozzle type, setup, drift reduction adjuvants and operation parameters. The testing procedures involve the use of multiple samplers placed downwind of the application, both on the ground and on towers. Deposition on these downwind samplers from the various DRTs is compared with deposition from a reference application setup. This comparison is then used to calculate how much each individual DRT reduced drift. A preliminary study showed that the use of an aerial flat-fan nozzle reduced drift between 70 percent and 84 percent, depending on the airspeed, from that of the reference spray system. *[Editor's Note: See pg. 26 for further information about that study.]*

NAAREF relies heavily on AAT to prepare the drift mitigation module for the PAASS Program. Data from their research projects are often used within the modules, which are presented to approximately 1,700 ag pilots and operators nationwide. AAT's research engineers readily allow themselves to be filmed explaining various points about drift reduction, and they serve on the Program Development Committee offering their expertise for the module's content. The PAASS Program is recognized by both the FAA and EPA as an outstanding safety education program, and since its inception, the number of ag aviation related accidents and drift complaints have gone down. Because of the substance of the PAASS Program and proven results in strengthening the industry's stewardship—thanks to the quality of the curriculum as developed by the AAT group and other ag scientists—insurance companies offer many ag pilots and operators that participate in the program a reduction in insurance costs.



Brad Fritz enters data into the Aerial Application Technology Group's droplet sizing system.

AAT Application Efficacy Research

In addition to drift reduction research projects, the AAT group conducts various projects examining the effectiveness of aerial application scenarios. AAT researchers have undertaken a wide range of projects to determine the optimum nozzle type, setup and spray volume for different pests. These projects have included studies to examine the best method for controlling fusarium head blight, a major disease pest of wheat and barley. AAT has also played a key role in determining the best spray setup for making low volume foliar applications of fungicide on corn. Applying glyphosate at low volumes has also been investigated by AAT. These pest and crop-specific projects provide two benefits to the aerial application industry. For aerial applicators, they provide useful information on nozzle selection, aircraft setup and operation for achieving the best pest control. For others, they provide proof that aerial applications, and in particular low volume applications, are very effective for controlling pests.

Future work will continue to deal with drift reduction and improving application efficacy. In addition, AAT is working to develop new equipment for use at Operation S.A.F.E. pattern testing fly-ins. The group's facilities also serve as a location for calculating spread factors, which are used to calculate droplet size and deposition from water sensitive and Kromekote papers. Without the correct spread factor, the exact droplet size cannot be measured. This allows Operation S.A.F.E. analysts and researchers to evaluate the impact of various spray formulations on the spray pattern and droplet size in the field.

The importance of the work conducted by the AAT group cannot be overstated. Besides the information they provide to aerial applicators to help them improve the safety and efficacy of their applications, the ability to dispute false claims from those unfamiliar with agricultural aviation is invaluable. I have personally stopped more than one conversation with those opposed to aerial application by providing data from AAT, in particular the Aerial Spray Nozzle Models. AAT provides the aerial application industry with an unbiased source of information that can be used to improve the accuracy of aerial applications, develop reasonable regulations for our industry and prove to our customers the quality of our work. These facts will help ensure a positive future for aerial application. ■

This Guy Knows Aerial Application

A Q&A with Dr. Clint Hoffmann

The premier agricultural aviation research body in the United States lies deep in the heart of Texas. Down in College Station, the Aerial Application Technology Group (AAT) and its team of scientists, engineers and support personnel are devoted to developing technologies for aerial applicators that mitigate drift and result in more efficacious applications. As this issue's cover story documents, the aerial application industry has benefited from AAT's findings in numerous practical ways. How does AAT determine its research projects? What's on the horizon? How would cuts in federal funding for AAT research impact the industry? *Agricultural Aviation* posed these questions and more to Clint Hoffmann, AAT's lead scientist for aerial application research. In 2009, Hoffmann received NAAA's Outstanding Service Award. He is an outspoken supporter of aerial application and has advocated on the industry's behalf before numerous outside groups and government agencies. In the responses that follow, Dr. Hoffmann takes readers inside the Aerial Application Technology Group and elaborates on the work he and his team of researchers are doing to keep aerial applicators on the cutting edge of technology. *–Jay Calleja, Manager of Communications*

Agricultural Aviation: What kind of impact do you think the USDA-ARS and AAT specifically have had on the aerial application industry?

Clint Hoffmann: The Agricultural Research Service (ARS) serves the needs of American agriculture by providing long-term research programs that address nearly every aspect of agriculture. ARS has two programs (College Station, Texas, and Stoneville, Miss.) that service the aerial application industry. The research missions of these two groups include development and evaluation of new spray equipment and product, spray modeling, precision application, remote sensing of crop conditions and disease stress using multi-spectral cameras mounted on aircraft, product efficacy testing and decision support systems to help aerial applicators make informed decisions quickly and efficiently. Through these research projects, aerial applicators are provided with objective evaluation of numerous products as they come onto the market. Applicators are also provided guidelines and best management practices that lead to more effective spray applications.

AA: How does USDA-ARS decide whether to conduct a particular aerial application research project?

CH: Every ARS research group has a five-year research plan that gets developed through consultation with user groups, ARS National Program leaders, outside experts and the ARS scientists in the project. When putting this plan together, the goal is to lay out a road map that says if this research program completes these three to six objectives, then the program will be successful and serve the needs of their user communities. There are specific accomplishments that are detailed in the plan that the scientists in the project are tasked with completing.

Clint Hoffmann, Agricultural Engineer and Lead Scientist of the USDA Agricultural Research Service's Aerial Application Technology project

Each year around December or January, our group gets together to lay out our research plans for the upcoming year. While keeping an eye on the specific accomplishments that are part of the five-year plan, we also talk about research projects that need to be done related to upcoming issues facing the aerial application industry. Many of these issues are identified in discussions with the NAAA Research and Technology Committee at NAAA Board Meetings and by talking with aerial applicators at the national convention, state conventions or on the phone. These discussions help us to decide if we have the in-house resources to complete a particular project or if we need to collaborate with others outside our group.

AA: What are some major breakthroughs that the Aerial Application Technology Group has achieved that have been beneficial to the industry?

CH: The product that is most commonly used by aerial applicators is the spray atomization models that were first developed by Dr. Buddy Kirk and are currently being updated

and further developed by Dr. Brad Fritz. These models allow aerial applicators the ability to input their application parameters (nozzle type, orifice, airspeed, pressure, orientation) and determine what size of spray droplets they are producing. If a pesticide label requires a certain size of spray droplet, the applicator will know if they are compliant or can change the application parameter to meet the labeled requirements. The newest models are being extended from 160 mph maximum airspeed to 200 mph to meet the needs of applicators who are using some of the newer and faster aerial application aircraft. These models are available on our website at http://apmru.usda.gov/downloads/downloads.htm and some nozzle manufacturer's websites. We are currently in the process of transferring these models into smartphone apps so that aerial applicators can access them more readily.

AA: What can you tell us about equipment/technology that the Aerial Application Technology Group has patented or made available for industry use?

CH: Dr. Jim Carlton patented the aerial electrostatic spray system that is currently being sold by Spectrum Electrostatics Systems. Our group has recently applied for patents on a new volatile organic compound (VOC) sensor and an insect bioassay cage. These last two items are designed to address upcoming issues that may impact the industry. For example, in some areas of California, there has been discussion about "no spray days" to prevent some VOCs associated with pesticide applications that may contribute to the production of ozone and smog. There has been very little field verification of the role of pesticides on VOCs released into the environment. Therefore, to complete field studies associated with VOC detection, we needed more economical sensors for this work. The bioassay cage will lead to more effective evaluations of product used to control mosquitoes.

Our group also works with numerous adjuvant manufacturers to investigate the effects of different adjuvants, often experimental, on spray droplet size. These studies are directed at developing products that can reduce the production of small, drift-prone droplets. Additional studies are conducted on numerous pesticides to determine the impact of application parameters on product efficacy. Studies with new chemistries are initially conducted in a spray table to look at a wide range of droplets sizes and spray rates until the optimal combination is found. Then, field studies are conducted with our aircraft to confirm that careful attention to the application parameters are needed to make the most efficacious application. These recommendations then show up as recommended or required application conditions on product labels.

AA: What kind of information do you provide to the EPA when it is evaluating the drift potential of aerial applications, and what role do you play in discussions with EPA related to reducing drift?

CH: The EPA's Drift Reduction Technology (DRT) program is a good example of our group's approach to long-term research directed toward future needs or developments that will impact the aerial application industry. When the DRT program was first being developed, we realized that some aspects of the program could have a significant impact on the materials and methods applicators use in their daily operations; therefore, we took an active role in the DRT program. Over the last five years, our group worked with other researchers to develop the testing protocols and verification procedures that will be used to objectively evaluate a DRT (nozzles, spray modifications, adjuvants, etc.). By publishing these protocols and procedures in peer-reviewed journals, we are providing the data needed by EPA to make science-based regulations.

AA: NAAA has been a strong advocate for the USDA-ARS Aerial Application Technology Program in the halls of Congress and with federal regulatory agencies, and you and your team have been equally strong advocates for sound science and the aerial application industry. How would you characterize the relationship between NAAA and USDA-ARS?

CH: All of our scientists see the aerial applicator as our main customer group and are committed to serving aerial applicators. Scientists in the AAT commonly consult with NAAA personnel in addition to partners in industry as well the applicators in the field to provide scientific support when addressing these changing and often volatile issues. The AAT group serves as a general clearinghouse of scientific information and data for a multitude of user groups including university, state and federal research groups, industry partners, involved professional organizations—including NAAA, ASABE [American Society of Agricultural and Biological Engineers], ASTM International [American Society for Testing and Materials], CPDA [Chemical Producers and Distributors Association], etc.—private research entities and the applicators themselves. These relationships result in numerous collaborative research relationships often allowing for the completion of larger research projects that could not be completed by any single partner. Additionally, the research conducted by the AAT is

continually transferred to users through professional publications averaging nearly 20 publications a year over the last couple of years.

AA: All federal discretionary spending seems to be constricting. What would happen in the aerial application industry if this funding was markedly decreased or eliminated?

CH: The Aerial Application Technology (AAT) group is the largest aerial application research group in the country with unique capabilities and resources not available to any other research group allowing for dedicated aerial spray technology research. The high and low speed wind tunnels with the capability of assessing aerial spray systems using active ingredient spray formulations are unique resources to this research program in the U.S. The group's dedicated research aircraft with available hanger and airport space allow our group to address and respond to research questions that no one else does. Since the group's aircraft fall under the government aircraft certification, they are uniquely qualified for development and early prototype testing of equipment and aircraft modifications that will help aerial applicators. During this development process, the AAT aircraft can be modified or equipment placed on the aircraft without having to go through the lengthy FAA approval process. Examples of products that have been tested on AAT aircraft include flow control systems, auto guidance systems, wingtip modifications, lowered spray booms, aerial electrostatic equipment and wing mounted spray pods.

If the AAT group were to disappear, initially the agricultural aviation industry would lose its ability to quickly respond to changing regulatory mandates and emerging issues that impact daily business operations. The AAT continues to provide the industry applied research that supports safe, effective and efficacious practices. Without these resources and guidance, the agricultural aviation industry would lose access to state-of-the-art best management practices and would lose a significant part of its ability to evolve toward more improved application practices and systems. This would ultimately lead toward a decrease in applicator effectiveness with an increase in adverse impacts to off-target persons, animals and crops, resulting in punitive legal actions and potential decrease or cessation of their daily business operations. Collectively, all of this would lead to aerial applicators losing the ability to support the American food, feed and fiber industries, ultimately resulting in losses in each as a result of these industries not having adequate resources to respond to crop pest and production issues.

AA: The support for the aerial application industry from the network of scientists not only at USDA-ARS but at other universities and organizations is impressive. Can you talk more about some of the joint ventures you undertake?

CH: Our group has worked with a wide range of researchers and growers over the years. For example, we have conducted studies in cotton in Arizona and Texas, wheat in North Dakota, South Dakota and Minnesota, corn throughout the Midwest, and orchards in California, Texas and Florida. These field studies allow us to work with researchers and applicators in these areas who have the knowledge and experience in the local area. Many of the joint research projects start from discussions at professional meetings and at NAAA conventions. Since field research is a very expensive undertaking, we can leverage both the financial and personnel resources of another researcher to complete these types of research projects.

Another example of how our cooperation with outside organizations benefits the aerial application industry has been our four-year involvement in the Department of Defense Deployed War-Fighter Protection Program (DWFP). Our expertise in droplet sizing and equipment evaluations supports this program's need for objective testing and development of vector control application equipment. The DWFP's financial support of our program, in turn, has allowed us to add to and upgrade our research equipment with the acquisition of two laser diffraction droplet sizing systems and a new high speed wind tunnel, as well as purchasing two unmanned aerial vehicles (UAV) for some of our remote sensing work. All of this supports our study of aerial application, including further support and development of the spray nozzle models. These new laser systems have also allowed our group to provide much needed support to ground and aerial citrus applicators to comply with new pesticide labels allowing for timely treatment of citrus orchards for Asian citrus pysllids.

Finally, funding from ExxonMobil allowed our group to study methods for applying oil dispersants from agricultural and specialized aircraft. This work was complete and published prior to the Gulf oil spill, allowing us to aid the response efforts with the generation of two white papers documenting that aerial applicators and a 747 could meet the application and regulatory guidelines to apply oil dispersants over the Gulf of Mexico.

AA: How do you get the results from your research projects out to the aerial application industry?

CH: One of our main efforts is to present the projects that are the most applicable to aerial applicators at the NAAA/ASABE Technical Session at the NAAA National Convention. We try to tailor the presentations so that applicators can use the results in their daily operations. We also place all of the papers and presentations from the Technical Sessions on our website. Many of our research projects and results support Allied Industry members such as nozzle and adjuvant manufacturers. We meet with these Allied Industry members at other professional meetings throughout the year. Since we are a scientific group, we publish a lot of our research in peer-reviewed journals. We are currently in the process of creating Applied Research Summaries for each of our peer-reviewed manuscripts to make the research results easier to understand. *[Editor's Note: see pg. 25 for an example of these one-page summaries.]*

AA: Can you talk a little bit about the new equipment you are developing for Operation S.A.F.E. fly-ins?

CH: Hopefully, everyone reading this article has been through an Operation S.A.F.E. clinic and/or had their aircraft's pattern evaluated at a fly-in. The swath analysis system developed by WRK Inc. is the most common method for evaluating an aircraft spray pattern using a dye in the spray tank and analyzing the pattern with a cotton string stretched across the flight line. The current WRK system uses an older model fluorometer to read the amount of dye that deposits on the cotton string. This model of flouorometer is no longer manufactured and new ones are quite expensive. Our group has developed an analysis system to replace this fluorometer that can not only evaluate the amount of dye on the line more quickly but will also output the results in real-time. This will speed up fly-in pattern testing. We are currently working with Scott Bretthauer and other supporters of the aerial application program to make this system available to S.A.F.E. Analysts in the upcoming year.

AA: How does the aerial application industry of today compare to the industry when you first joined USDA-ARS in 1989?

CH: The level of professionalism in the industry has been the biggest change that I have seen. Gone are the days of just some crazy guys who just like to fly and aerial application just happens to be their reason to fly. Today's aerial applicator is a businessperson with a passion for flying and feeding the world. Their level of knowledge about all facets of the industry has really grown and they are committed to keep gaining more knowledge. ■

Applied Research Summary

Role of Air-Induction Nozzles in Aerial Application Conditions

Original Citation: Hoffmann, W.C., B.K. Fritz, W.E. Wolf, D.E. Martin, Y. Lan. Role of air induction nozzles in high speed airstreams. ASABE Section Meeting Paper No.AA10-001. St. Joseph, Mich.: ASABE.

Keywords: Air induction nozzles, air induction, droplet size, aerial application, ai nozzles, spray atomization

Research Objective: To measure the spray droplet spectra from air-induction nozzles under aerial application spray scenarios (airspeeds from 120–180 mph).

Research Methods: Air induction nozzles have been used for several years in ground spray applications as a means of generating large droplets and reducing the potential for off-target movement of sprays. Some of the advantages of AI nozzles are larger droplets sizes with less fines at normal operating pressures, better efficacy with some products, and potentially a larger range of operational pressures without significant changes in droplet size. As these advantages have only been tested for ground applications, this project focused on aerial application conditions. It is important to gain a thorough understanding of how these air induction nozzles work in high speed airstreams before placing them on aerial application equipment. Five 110 degree flat fan AI nozzles and one standard (non-AI) 40 degree flat fan nozzle were tested at 3 airspeeds (120, 150, 180 mph). All nozzle evaluations were conducted at a spray pressure of 60 psi using a water nonionic surfactant (NIS) solution (water + NIS at 0.25% by volume) (R-11, Wilbur-Ellis Company, San Antonio, TX). The water plus NIS solution was used because it is a good simulant of most water-based insecticide sprays. A Sympatec Helos laser diffraction droplet sizing system (Sympatec Inc., Clausthal, Germany) was used to measure the droplet size generated by the nozzles. For each airspeed tested, the spray plume from each nozzle was traversed vertically through the laser beam and measurement of the droplet sizes generated were measured.

Research Results: For all 5 AI nozzles and the conventional flat fan nozzle, the volume median diameter decreased by about 50% as the airspeed was increased from 120 to 180 mph. Similarly, the portion of the spray comprised of small droplets, expressed as percent of spray volume contained in droplets less than 100 µm in diameter, significantly increased as the airspeed increased. Comparing the droplet sized created by AI nozzles to the conventional flat fan nozzle, there are no significant differences. This is a result of the high air shear placed on droplets as they exit the nozzle and encounter the high speed air.

Research Application:

- Based on the results of these studies, the AI nozzles did not increase droplet size or decrease fine spray particles as compared to a conventional flat fan nozzle.
- There is little differences between the two nozzle types due to a combination of the high speed air negating the air induction system of these nozzles and the high air shear placed on the spray droplets at airspeeds of 120–180 mph. ■

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Spray Drift Reduction Evaluations
of Spray Nozzles Using a Standardized Testing Protocol

Editor's Note: *Over the last decade the USDA-ARS Aerial Application Technology Group has steadily increased the number of peer-reviewed scientific articles it publishes to the point that it is averaging nearly 20 peer-reviewed publications a year. This paper on drift reduction testing protocols was originally published last year in the* Journal of ASTM International. *What follows is an abridged version.*

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Summary

The development and testing of drift reduction technologies has come to the forefront of application research in the past few years in the United States. Drift reduction technologies can be spray nozzles, sprayer modifications, spray delivery assistance, spray property modifiers (adjuvants), and/or landscape modifications. A protocol for testing DRTs in high speed wind tunnels has been previously reported and was expanded to test spray nozzles. This manuscript reports on the initial implementation of the DRT program for conducting DRT evaluations of three spray nozzles under high speed conditions (i.e.,45–65 m/sec (100–140 mph)), which are relevant to the aerial application of crop production and protection materials. The spray nozzles were evaluated in the USDA-ARS High Speed Wind Tunnel facility. Droplet size of each of the nozzles with different airspeeds, spray pressures, and orientation were measured with a Sympatec Helos laser diffraction instrument. The droplet size spectra for each test was input in a spray dispersion model (AGDISP), which calculates the downwind drift expected from a typical aerial application scenario. As compared to the reference nozzle (Flat fan 11003 at 43 psi), the three spray nozzles reduced spray drift by 70–84 percent as compared to the reference nozzle. The nozzles generated spray droplets with volume median diameters 60–80 microns (μm) larger than the reference nozzle. One of the aerial application industry's Best Management Practices (BMP) is to not spray directly on the downwind edge of a field. The spray swath near this edge is moved upwind (i.e. offset) by ½ to 1 swath width. When this BMP was combined with the drift reductions from the spray nozzles, the amount of drift reduction was slightly increased; however, application efficiencies increased to 93–96 percent. These results demonstrate the possibility of combining multiple drift reduction techniques and technologies to greatly reduce spray drift.

Introduction

The first step in implementing the EPA-Drift Reduction Technology (DRT) program is to develop a set of protocols, standard operating procedures and data quality assurance steps so that the results from any trials or research conducted are scientifically valid and repeatable; data quality and protection must also be maintained throughout the study. Best Management Practices (BMP) are common industry practices that are used to apply agrochemicals to optimize swath deposition while minimizing off-target movement. For aerial applications, common BMPs are identification of sensitive areas around a field to be sprayed, modifying spray applications to account for changes in wind speed and direction, proper equipment setup to optimize agrochemical delivery and other professional practices all directed at making the most effective spray application. One common BMP is the use of a swath offset to minimize off-target deposition when an application is made near a downwind field edge.

Sampling spray swath uniformity in cotton fields using cotton string. The balloon in the background in used to lift the string up out of the cotton so that it can be collected on reels for later analyses.

Atomization of the spray from nozzles is influenced by nozzle type, pressure, orientation, airspeed and spray solution. All of these factors are researched by the Aerial Application Technology Group.

This practice involves moving a spray swath some distance upwind of a downwind field edge while spraying in a crosswind.

Objective: To evaluate the DRT testing program for aerial applications under high airspeeds (i.e. >100 km/hr (~60 mph), which is typical for these type of crop production and protection material applications.

Testing Methods

This testing will gather information and data for evaluating the applicability of the pesticide spray DRT protocol for successfully testing commercially ready pesticide spray DRT nozzles. All high speed tests were conducted in the USDA-ARS wind tunnel located in College Station, Texas. Three test nozzles and a reference nozzle were tested using the pesticide spray DRT protocol. The three test nozzles were a Hypro ULD 120-04 nozzle, a Teejet AI-110 VS nozzle and a CP11TT 4008 Flat Fan nozzle. The nozzle used to define the Fine/Medium boundary in the ASABE Standard was selected as the reference nozzle. Specifically,

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Drift Reduction (%)[1]	25 ≤ 50	50 ≤ 75	75 ≤ 90	90 ≤ 95	95 ≤ 99	≥ 99
LERAP Drift Classification	*	**	***	***	***	***
ISO Drift Classification	F	E	D	C	B	A

[1] Drift reduction is the percentage of drift reduction achieved by a technology as compared to a standard reference.

TABLE 1. Drift reduction classification for the LERAP and ISO system based on percentage reduction of candidate system as compared to reference system.

this reference nozzle was a Spraying Systems 110° Flat fan nozzle with an #03 orifice operated at 43 psi.

Modeling Inputs and Setup

Computer models are typically very sensitive to the input variables and AGDISP (Agricultural Dispersion model) is not different. AGDISP Ver. 8.21 was used in the modeling scenarios with the following inputs standard across all scenarios reported in this manuscript:

- **Aircraft:** Air Tractor AT-401 with 66 ft swath width
- **Application Scenario:** 11.5 ft release height with 10 spray applications moving upwind
- **Meteorological Conditions:** Wind Speed: 5 mph @ 90° (crosswind), Temperature: 80°F, Relative Humidity: 70 percent

Based on the droplet size measurements from each of the nozzle evaluations, the corresponding droplet size data were input into the AGDISP model. One of the default settings in the AGDISP model is a swath offset of 0. The effects of changing this offset from 0 to a ½ swath offset were modeled. As noted previously, the practice of using ½ to 1 full swath offset is a common BMP that aerial applicators use during spray applications.

How are DRT's Rated?

The two most commonly used drift reduction classification systems are the Local Environmental Risk Assessment for Pesticide (LERAP) and the International Standards Organization (ISO) systems. The LERAP system uses a system of stars (No stars to ***) to denote the level of drift reduction that a given technology provides as compared to a reference system. The ratings may be used to determine the size of the spray buffer mitigation the applicator can use with a given spray technology. The ISO drift reduction standard defines the six drift reduction classes ranked alphabetically (A-F) with the A class having the greatest percentage reduction and the F class the least (Table 1). The ISO classification is also used as a method to mitigate the size of a no-spray buffer area. Unlike the ISO classification system, the LERAP method groups systems with a 75 percent reduction or greater into a single classification group.

Results

As expected, the droplet size decreased for each of the nozzles as the airspeed in the wind tunnel increased from 120 mph to 140 mph. The droplet sizes also increased with N1 and N2 when the spray pressure was increased from 30 to 60 psi. These data were used in all of the subsequent AGDISP modeling work.

Modeling Application Efficiency

After running AGDISP using the droplet size measurements for the different testing scenarios (nozzle, pressure, airspeed), the modeling outputs were recorded. Application efficiency is the amount of spray material, expressed as a percentage of spray released from the simulated aircraft, that deposits in the field or targeted area. For all of the simulations, downwind deposition out to 30 ft was modeled. This is representative of the spray deposition from the edge of the swath to a distance 30 ft downwind. The airborne drift at 10 m represents the portion of the spray volume that remains in the air at this distance. The reference nozzle generated an application efficiency of 86.7 percent with 1.5% of the spray in the air 30 ft from the field boundary in the 120 mph modeling runs. The three nozzles (N1,

Spray nozzles are positioned at the outlet of the high speed wind tunnel, which can generate air-speeds up to 220 mph. The spray droplets are measured about 20 inches downstream with a laser droplet sizing instrument (red and silver instrument in the background).

N2 and N3) tested all had improved application efficiencies (90–92 percent) and large decreases in airborne drift as compared to the reference nozzle. In the 140 mph tests, the Reference nozzle had an application efficiency of 84.6% and 2.45% of the spray was still airborne at 30 ft from the downwind edge of the field. The three nozzles tested all had improved application efficiencies (87–90 percent) and decreases in airborne drift.

Drift Reduction from Nozzles

Drift reduction is defined as the reduction in the airborne portion of the spray as compared to a reference (ISO Standard). The test nozzles reduced airborne spray drift by 70–84 percent in the 120 mph airstreams and from 41–74 percent in the 140 mph airstream tests. At the lower airspeed, the tested nozzles received E and D ratings based on the ISO drift classification scheme and ** and *** based on the LERAP scheme. At 140 mph, the test nozzles received F and E ratings based on the ISO drift classification scheme and * and ** based on the LERAP scheme.

Effects of Swath Offset on Application Efficiency and Drift Reduction

All of the previous scenarios were rerun with a ½ swath offset except the reference nozzle settings. A ½ swath offset was the equivalent of making a spray application 33 ft further upwind from the field edge. For both of the airspeeds, the three nozzles combined with a ½ swath offset resulted in application efficiencies between 93–97 percent and only minor changes in the airborne drift percentages. The offset results in more material depositing in the field, which is why aerial applicators have adopted this practice.

Conclusions

This work examined a drift reduction testing protocol comparing three different nozzles to a reference nozzle. Additionally, an industry Best Management Practice (BMP) of offsetting near field edge spray swaths was examined. The techniques and procedures for determining the nozzle effects on spray droplet size under high-speed air-sheer showed distinct differences between the nozzles tested and the reference nozzle. Using the AGDISP model, these droplet size results were translated to estimates of downwind deposition and airborne drift as a means of comparing the relative efficiencies of each nozzle as compared to the reference nozzle under different airspeeds and pressures. When compared to the reference nozzle, the results showed that:

- The three spray nozzles reduced spray drift potential by 40–84 percent due mainly to the larger $D_{V0.5}$ values, which were 30–80 microns (μm) larger than the $D_{V0.5}$ for the reference nozzle.
- After modeling the aerial application industry's Best Management Practices (BMP) of ½ swath offset, the results showed further increases in drift reduction and large increases application efficiency with application efficiencies ranging from 93–97 percent.
- The combination of multiple drift reduction techniques/technologies can greatly reduce spray drift. ■

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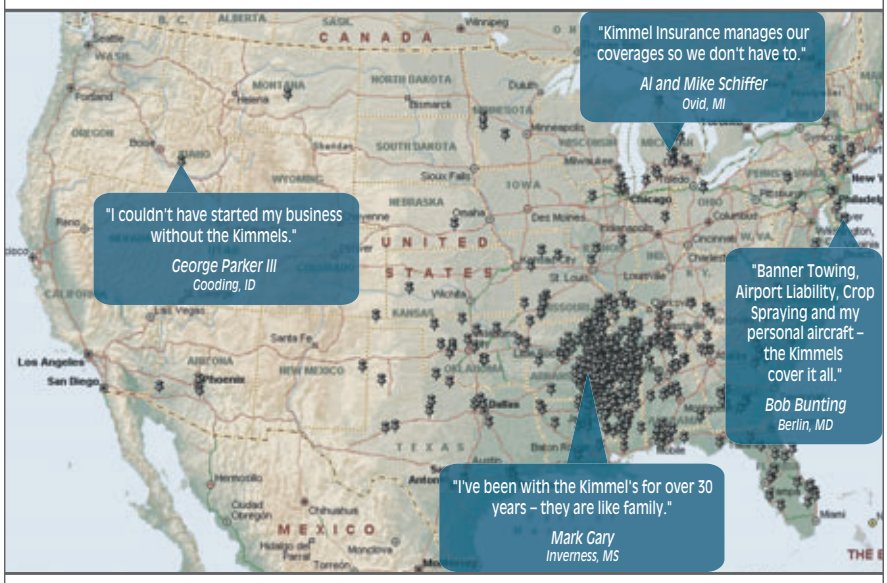

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