Transcript: Best Practices for Aerial Application Webinar

Khue Nguyen:
Hello, everyone. Welcome to today's webinar titled "Best Practices for Aerial Application." This webinar is produced by the U.S. EPA's Office of Pesticide Programs. The views expressed by our presenter are for educational purposes only and do not represent the official views or positions of the EPA.

My name is Khue Nguyen. I'm a chemical review manager in the Office of Pesticide Programs. I am your moderator today. In today's webinar, we will cover different methods of aerial application, best practices for reducing spray drift when using aerial application equipment, nozzle selection, and the use of adjuvants as they relate to aerial application. This webinar effort is part of a larger EPA effort to promote pesticide spray drift management and promote the conservation of native habitat.

This webinar is the second of a three-part series intended to educate stakeholders on ways to reduce pesticide spray drift. The first webinar in the series occurred on March 15, 2018, and was presented by Dr. Greg Kruger from the University of Nebraska-Lincoln. It covered the fundamentals of pesticide spray drift management. If you missed the webinar, the materials are posted online at the link shown.

Today's webinar takes a closer look at aerial application and is presented by Dr. Bradley Fritz of the USDA. Dr. Greg Kruger will join us later for the Q & A session as co-moderator today. The Q & A part will be a more informal discussion-style format. Together, both Dr. Fritz and Dr. Kruger have broad expertise in their subject areas and can address more technical questions from those in the audience that are more familiar with the material that's being discussed today.

We have a third webinar coming up on October 25th, 2018, which will take a closer look at ground application and will be presented by Dr. Greg Kruger. Registration for the October webinar is now open at the link shown. Dr. Bradley Fritz will also join us on October 25th for the Q & A discussion.

Just to give you an idea of who is in the room here, Dr. Greg Kruger is joining us in the Q & A segment. He is a weed science and pesticide application technology specialist from the University of Nebraska-Lincoln. He is the director of the pesticide application technology lab at the university. His research covers areas such as droplet size and efficacy, spray drift deposition and canopy penetration, and the influence of nozzle type and other parameters on droplet size.

At this time, I would like to introduce our presenter, Dr. Bradley Fritz. Dr. Fritz is an agricultural engineer at the United States Department of Agriculture. He is currently the research leader of the Aerial Application Technology Research Unit at the USDA's Agricultural Research Service in College Station Texas. His research spans the broad area of agricultural application technology with a focus on aerial pesticide application.

His recent research interests include examining the role of spray nozzles, spray solutions and operational settings such as pressure and airspeed on the resulting droplet size of the spray. He is also interested in exploring the transfer and fate of applied spray under field conditions. Dr. Fritz has published numerous studies. You can check out his latest research at the link shown on the screen. Please welcome Dr. Fritz.

Bradley Fritz:
Thank you, Khue. I also want to say thank you to all the other folks here at EPA that put a lot of effort into making this webinar happen. There's a lot of work behind the scenes to make something like this come off and happen. So thank you to everybody.

Before we get started, I also do a quick disclaimer. Just -- that's part of the role I'm in. I want to say that the use of trade, firm, or corporation names in this presentation is for the information and convenience of the viewer. Such use does not constitute the official endorsement or approval by the USDA, Department of Agriculture, or the Agricultural Research Service, and any other product or service that may be used and suitable is also acceptable.

Sorry about that. Before I get into the guts of the presentation, I thought it would be worth spending a little bit of time doing a brief overview of what aerial application looks like in the U.S., sort of a background on the industry just so that those of you online that maybe aren't as familiar with the industry have a little bit better appreciation of the size and scope of aerial application in the U.S.

Across the U.S., we're looking at more than 1,300 aerial application services, and that's comprised of more than 4,000 individual aircraft. If you go to crop protection products applied in the U.S. on commercial farms, it's about a quarter of the total application in the U.S.

Talking forest protection products, the majority of those products are done aerially. And all this together accounts for more than 71 million acres treated aerially. So it's a very large industry covering a lot of area.

A component that we won't really touch on today, but this is something to be aware of, is there's some aerial applicators out there that are also working in the public health arena doing control operations for like insect disease vector such as mosquitoes. And there's also a component dealing with wildlife and forest fire suppression.

If we look at aerial application in the crops that are being covered, based on one of the recent industry surveys, the five most predominant crops that are covered by the industry -- and again, this is not an inclusive list of everything being done, but is representative of a gross estimate across the entire industry. It's sort of what you'd expect: Corn, wheat, barley, soybeans, pasturelands, rangelands, and alfalfa. And again, this is going to vary with any region within the U.S. This list may be a little bit different, but you would see this just across the U.S.

If we look at the industry as a whole in looking at what the equipment standards are, it's a very advanced industry. As it stands now, the majority of the industry, almost 90 percent, is made up of fixed-wing aircraft. Two thirds of those are the faster turbine-based aircraft with about a third being piston engine aircraft. And then the remaining part of the industry, about 12 percent, would be the rotary or the helicopter platforms.

If we look at industry standards in terms of equipment, the current standard in terms of just basic, minimal technologies being used, particularly if we talk about newer aircraft, we're going to be aircraft integrated with GPS systems that help them with their navigation, those have tied the flow control to help them maintain application rate through the field, and then typically using aerial specific nozzles which have nozzles and check valves and spray systems that are designed exclusively for aircraft.

And we're seeing, more and more, some newer technologies come onboard. Some may not be familiar with the acronym, AIMMS, but there is a system out there that can go onboard the aircraft to do real-time meteorological measurements. And we're starting to see newer spray systems such as some pulse width modulation systems that offer some unique abilities.

If we talk about the average applicator in the U.S., we're looking at an industry that is very experienced, with the average applicator having more than 20 years of experience. The guys that are out there doing this job are not only commercial pilots, but they have to have their applicator license. And both of those mean that they're having to participate in annual training programs. They're doing annual system testing.

And it's a very progressive industry in that they're very self-regulating and self-supporting with the number of training programs and sessions that the industry sponsors that they put on, that covers everything from regulatory issues, safety and environmental stewardship, looking at the latest advances in aerial application technology, and then, you know, concerns such as homeland security and aircraft -- or airfield safety.

You'll see throughout this webinar that there's a lot of different technical things that go into this that the guys doing this job have to have a fairly broad understanding of topics ranging from physics and chemistry to biology, plant physiology, even mathematics and meteorology. So it's a very broad and diverse set of skills that go into doing this kind of work and doing it correctly.

So before we jump into some more aerial-specific technologies, it's worth spending a few minutes on a little bit of background on spray droplet sizing and just understanding the basics, because a lot of what comes out of the basics will be part of the remainder of the topics that we'll cover.

So as we get into this, for those of you that may not have any familiarity at all with spray sizes, spray droplets, the scale of measurement that we're talking about is a micrometer. So to give you a perspective of that, bacteria range from about 1 to 10 micrometers, so very, very, very small. When we start talking human hair, we're talking 20 to 180 microns in diameter. Raindrops are, by definition, up to 500 to 4,000 microns. And our agricultural sprays fall somewhere in between sort of that raindrop size to the human hair size, typically looking at droplets in the general range of 50 to about 2500 microns.

And again, this is not all inclusive of everything. This is just sort of a broad estimate across all the different spray technologies and chemistries that we're looking at.

So droplet diameter is pretty simple. If you were to take that drop, assume it's a sphere. The diameter is simple, the diameter across the width of that droplet. And then one of the things that -- when we're talking about droplet diameter and spray sizing, the volume contained in that droplet becomes important to us because that defines the amount of active material that is being carried by the droplet.

So in this case, the volume of that droplet is calculated as a relation to the cube of the diameter. And why that's important to us is, if we were to take a droplet that's half that diameter, say half diameter D and look at the volume in that droplet, it's 1/8 the volume. And what that means to us is, if we were to take the relationship of the diameter of droplet D and diameter -- diameter of half D and say, how many droplets of half D make up the total volume of the one D diameter, and it takes eight droplets. So breaking one droplet diameter, or diameter D, into half D to get the same volume, it takes eight droplets.

And why that's important is -- let's take one 400-micron drop. And we're going to break that up into 200-micron drops, but make enough droplets to create the same volume. It takes eight 200-micron drops. And if we take that further and break those in half, it takes 64 100-micron drops. So you can see that halving the diameter has a significant impact on the number of droplets.

And again, why that's important to us is it really emphasizes that we want to control that droplet size. Any breakup that we let occur on those droplets starts making significant more numbers of droplets, and in particular, more droplets of smaller sizes over which we have less control. So that's why we're concerned about droplet size in everything that we do in terms of being able to control where that spray goes.

So obviously, sprays aren't made up of a bunch of uniform droplets. Rather, it's a composite of a whole bunch of droplets of different size. And that becomes part of the science of what we do, is understanding that total spray volume and how the different droplets of different sizes make up and characterize that spray.

So when we talk spray droplet sizing, we're concerned about the total volume of the spray and, further, the total volume of droplets of individual diameters with that spray, again, because we're concerned about the amount of active ingredient within each droplet size within that spray.

So one of the things that we do is we have some measurements that we use to characterize spray, and then we have some terminologies that we use. And a lot of you are going to be familiar with these terminologies as you've probably seen them on pesticide labels, likely on extension documents or through research and education seminars or technical talks.

And I'm going to refer to one of the standards that we use as part of our work is from the American Society of Agricultural and Biological Engineers, and it's the standard S327, which is terminologies. And one of the most familiar ones, and probably one of the ones that most people are familiar with, is this $DV_{0.5}$ or the Volume Median Diameter, or VMD. And this is the droplet diameter at which 50 percent of the total spray volume is in droplets of smaller diameter. And we'll illustrate in a second.

But if I were to tell you that you had a spray that had a VMD of 250 microns, then half of that spray volume would be made up of droplets of less than 250 microns in diameter.

We have two other similar terms, a $DV_{0.1}$ and $DV_{0.9}$, and these are very similar in that they're droplet diameters in which 10 percent and 90 percent respectively of the total spray volume is in droplets of a smaller diameter.

And another term we'll introduce here in a second is relative span which relates to these. But our first step is to take a spray, and there's numerous methods out there to evaluate some of these spray systems and understand what that spray looks like, and to characterize it. But using some sort of measurement system and method, we're going to measure what's going on with the spray.

This is just a quick example from one of our setups. This is a 40-degree flat fan at 130-mile an hour with some herbicide mix. And we're using a laser diffraction system in our output like this where we have a cumulative distribution that gives us the different droplet size bins within measurement profile and then the fractional makeup of each of those bins of the total spray volume. And then that gives us basically a droplet size curve from which we can extract the data that we need.

So, I introduced relative span. And why that becomes important is it's an indicator -- I call it width of the distribution. You might want to call it uniformity of the distribution. But it gives you an idea of how much variation you have within a given spray cloud.

And again, why that becomes at least interesting to us is, if we were to take three different spray distributions and all with the same potential VMD of 300 microns, we can have one distribution that had DV_{10} and DV_{90} of 200 and 400, and that gives us a relative span of .67. So, you can see we have a very, very narrowly defined spray characteristics with the majority of our spray in a very, very narrow band of droplet sizes.

Take a different distribution, same VMD, but our DV_{10}, maybe we push it out to 165, or DV_{90}, we push it out to 435, and you see our relative span dumps up to 1.4. And maybe on an extreme case, looking at a distribution, again, a VMD of 300, but a DV_{90} of 90 -- or DV_{10} of 90 and the DV_{90} of 510, we had a relative span of 2.2.

So, you may see some nozzle manufacture catalogs or you may see droplet sizing data come onto some guidance or models that give you this relative span number. And again, it's important to pay attention to it particularly if maybe all you're given is VMD and relative span. Understanding how that relative span relates to the total shape of the spray is pretty important to you setting up your system.

So, the last thing we'll cover fairly quickly here, in terms of the droplet sizing basics, is probably one of the more critical factors, and it's this concept of droplet size class. Through the American Society of Agriculture and Biological Engineers, there's a standard, S572. And for those of you familiar with pesticide product labels, that number, S572, is probably familiar because that will be one of those that tends to be referenced by most of these standards.

The standard defines a set of nozzles and spray pressures, each of which is designed to generate a spray -- spray cloud or a spray with droplet sizes of a certain characteristic. And these range from a spray that would be a very fine spray with, you know, very, very small droplets up to a spray that has very, very large, very large diameter droplets, and then a range of other nozzles in the middle that give you other sprays.

And again, for those of us doing the measurements, these become extremely important to what we do in our day-to-day research and data collection. The intent of the standards is we take these nozzles -- so this will be some sample data from some of the work that I've done over the past several years.

But we would take each of these nozzles that define these curves. We would run that under our measurement system, and then we would be able to plot these lines that define the classes -- or define the boundaries between the classes: very fine, fine, medium, coarse, very coarse, and extra coarse. And so, this essentially is a ruler that defines how these droplet size classes get assigned to any other nozzle, solution, or spray system tested.

So, with these reference curves, you would take any other technology that you did a droplet size measurement on. You would plot it relative to these curves, and then you would be able to determine and assign it a droplet size class. And again, given that we see most labels out there refer to having to meet some sort of a droplet size class, understanding where this comes from is at least helpful in knowing where the data is coming from and how it's used.

So, a quick take-home, you know, understanding that when we half the diameter of a droplet into equal volume, we get eight times the droplets. Quartering gives us 64. So, the take-home is the more we break up a droplet, the more droplets we make of smaller volume and the less control you have over them.

A volume distribution is these terminologies that we're dealing with, and these give you the indication of that relative size-- or the classification and the size of the spray relative to the active ingredient being contained within those droplets. And then again, droplet size distribution is that relative rating of the spray.

So, with that in mind, let's take a look at generally what some of the aerial application nozzles look like and some of the droplet size trends that we see. This is by no means an inclusive catalog of pictures of nozzles that are out there and used on aerial systems.

But generally, we break these nozzles up into two classes. I like to term them as hydraulic nozzles, and this tends to be flat fan-type nozzles where you have basically a cut at the end of the nozzle that creates this flat sheet. We have straight stream nozzles that are just basically a cylindrical nozzle that will gives us a cylindrical spray coming out of the back, and then what I call an anvil impaction nozzle. So, we'll have something like a straight stream coming out, deflecting against a surface that then deflects that spray and breaks it and spreads it into a sheet.

And so, you can see the yellow nozzles over here are those representative of flat fans, straight streams, and some of the anvil impaction nozzles.

Another less commonly used type nozzle, but one that is used by the industry, are rotary atomizers. These, rather than the actual force of the spray being ejected through the nozzle creating the breakup, you have liquid basically going into a cage structure that rotates, and then that drives the spray liquid radially through a cage, creating the breakup on top of the air shear coming across it.

And there's two classes of these -- you can have some that have their own veins that the air drives the rotational velocity, or you can actually hook it up to an electrical pump where you have control over it in the cockpit.

So just general trends, if we generally look at across hydraulic nozzles, the most dominant thing about aerial application, probably the defining characteristic of aerial application is that we have this extra factor on top of it compared to what you would see in a ground or a boom sprayer.

It's actually the fact that we're flying this nozzle through the air, and we're seeing this airstream that's basically coming across the nozzle, interacting with the spray, we get this secondary breakup from that airstream. And that is pretty universally the dominant factor that drives what we see in terms of droplet breakup.

So just as an example, this is a 40-degree flat fan. And looking at airspeeds from 50 mile an hour up to 180 mile an hour -- and you can see a very dramatic decrease in the VMD as we run through those airspeeds. And again, we'll see some more indication of how dominant this air shear/airspeed effect is across these nozzles in a little bit.

If we look at spray pressure -- and this is something I'll spend a little bit of time on because this is something that we see that's unique to aerial systems, and it's something that you'll see later in terms of labels that we're challenged with, is that opposite of what we see with the ground or boom sprayer -- and those of you that are familiar with ground boom sprayers, it's fairly well accepted and understood that as you increase spray pressure through a nozzle, you decrease droplet size. And that's true on boom sprayers.

When we take these flat fans and straight stream nozzles and put them on an aerial system, what's driving the atomization process is that secondary breakup. And that secondary breakup is a factor that's related to the differential velocity between that spray liquid exiting a nozzle and the surrounding airstream.

So, one of the unique things with aerial systems is, as we increase the spray pressure out of the nozzle, we're actually increasing the velocity of that liquid out of the nozzle. And we're offsetting basically the difference between liquid velocity and the airstream velocity, so we're effectively decreasing the differential velocity and decreasing atomization.

So here are the same nozzles that we looked at in the previous graph. We're increasing spray pressure from 30 psi to 90 psi, and you can see an increase of 50 microns just by increasing spray pressure. So, this is one of the unique things that is, again, unique to aerial systems, and it's something we've been looking at the past couple years as a way of mitigating this increased breakup we see at higher airspeeds.

Orifice size also has a relationship, and this is one of those that varies by nozzle type. So, if we look at, say, a flat fan nozzle, which is the blue line, we can see that as we increase orifice size, we actually increase droplet size. And I think that's pretty well accepted and pretty common -- for those of you that are familiar with ground boom sprayers, we see that same relationship.

However, if we look at the straight stream nozzles, we actually see an opposite effect. As we increase our orifice size, we actually decrease our droplet size, and it's because we're changing the shape of that. It's actually making for a wider spray volume cross-section, so we're actually increasing breakup out of that nozzle. So, it's just something to consider.

And we'll talk a little bit later about some tools that you can use to see some of these trends for yourself and make decisions during your setup.

One of the other things we see with aerial systems that potentially gives the pilot some more control over changing the breakup, maybe they're operating at a slower airspeed and want to increase breakup a little bit, is the ability to deflect the nozzle into the airstream essentially increasing the air shear across the tip and increasing breakup.

So again, we look at the same 40-degree flat fan nozzle. As we increase that orientation angle from zero degrees, which would be basically horizontal straight back into the airstream, up to 90 degrees, which would be perpendicular downward into the airstream, you can see that has a very significant effect on VMD -- I mean essentially halving the VMD as we go from zero to 90 degrees.

A little bit of background on some of these rotary atomizers. They have a little bit different performance when we start putting them in the airstream, related to the hydraulic nozzles. In this case, I'm looking at the rotary atomizer, and I'm going to keep the blade angle at 55 degrees but increase the airspeed from 120 mile an hour up to 166.

So, one of the things that you would expect that would happen is, as you increase airspeed, your rotational velocity increases. In this case, we're increasing from 80 rpm -- I'm sorry, from 4,000 rpm up to almost 7,000 rpm. And then that has the effect of increasing breakup and decreasing our droplet size. In this case, our VMD goes from about 120 microns down to about 60 microns, so a very significant breakup as we change that rotational velocity.

So, one of the unique things about these rotaries is you can actually adjust those blade angles so that you maintain rotational velocity as you change airspeed.

So, in this case, I went through a setup of trying to maintain a rotational velocity fairly close to 4,000 rpm. And so, blade angles, then, as we go from 120 degrees to 166, 167 degrees, we're increasing blade angle from 55 degrees up to 67 degrees, maintaining that rotational velocity. And then you can see that has the effect of -- we still don't maintain a complete, unchanged droplet size distribution, but we cut in half the breakup that we get across that range just by maintaining the rotational velocity. So again, I'll show you some tools later that you can use when you're setting up these systems.

So, I know this is one of the sections that folks are very interested in. And one of the things I just have to do. This is my own disclaimer, my own preface. I'm going to have to say that I am not a chemist and by no means an expert in adjuvant technologies. What I'm going to present in the following is really going to be some general types and uses and some of the general trends that we've seen over the years as we've worked with and tested these products, particularly as it relates to spray atomization and what that spray performance out of the nozzle looks like.

Having given that disclaimer, and in light of not wanting to leave you out there in the dark with no resources, there are a number of excellent resources out there. But one of the really good ones that I've used over and over is this document put out by Purdue Extension. There is a web link. Again, you can get this from the handouts.

But this Extension document really covers all the different adjuvant types, how they work, where to use them, why to use them, what they do. I mean, it's an excellent document that is just something good to have in your pocket as you're maybe just considering different products to use. This gives you a really good overview and provides a great background.

So, I guess, again, like we did with droplet size, let's start with a definition. What is an adjuvant? And for this, I'm going to pull the ASTM standard 1519 that relates to tank mix adjuvants. And they defined an adjuvant as "a material added to a tank mix to aid or modify the action of an agrichemical or the physical characteristics of the mixture." So obviously, that's a pretty broad and pretty well catchall description of anything you add to the tank mix.

And basically, the intent of that is to do that. And a lot of times we think about adjuvants, and at least those of us involved in application technology and particularly spray application technology, the default is maybe to assume that we're putting something in there to change the spray performance. And that's really not the case.

More often than not, these adjuvants are added to overcome some other issue, maybe a water quality issue like hardness or pH, or maybe we're working with a particularly difficult plant species or weed species where we need to change the way that spray, once it interacts with the target, how its uptake or how it penetrates the surface, or even spray system limitations. Maybe we have something that we just need to correct within our spray system, and even environmental conditions within the field.

So, we've got a couple of these things, I mean, things like pH, maybe, again, some of this fine droplet formation, reducing that, reducing evaporative losses in particularly dry or low-humidity situations, improving rainfastness, increasing plant uptake, or increasing retention and spread. So, again, this is one of these hard subjects to really catch all because there's literally hundreds and hundreds of different products out there of different types, all of which are designed to do something different.

So having said that, I want to spend just a few minutes on what we've seen in terms of how some of these adjuvants -- and again, I'm only going to be able to cover, you know, a very, very, very thin slice across the adjuvant market, of how they affect the spray atomization when we start looking at aerial systems.

So, these plots, I don't mean to be overly complicated, but it's hard to show the information that we see without plotting out some of the data. So, this was, again, just looking at a standard 40-degree nozzle, changing airspeeds, and we're looking at seven different tank mixes, from a formulated glyphosate product to a formulated glyphosate product with six different adjuvants in it.

And rather than focusing on numbers, I'm going to go back to the class concept where we look at where we start seeing changes in droplet size class relative to these curves.

Again, the first thing to notice, like we talked about earlier, is airspeed is the dominant factor in this. You can see some separations among the solutions at these lower airspeeds. As we get up to 140, 150, 160 and above, we start seeing the differences between these spray solutions disappear. And that's because, again, that airspeed effect is what's driving the breakup. It's overwhelming in the adjuvant and nozzle effect.

But if we want to look at difference in some of these -- and again, I'm going to say that this is not at all representative of all adjuvants within each of these types. There's just no way to do that. But generally, with this data that we've seen, we see a smaller DV_{10}, so a smaller droplet size with the formulated glyphosate product alone, and then these thickening type adjuvants, the silicones and the polymer-type adjuvants. And then we see the crop oils, the microemulsions and the methylated seed oils maybe not changing the droplet size or getting a little bit bigger droplet size, at least on the DV_{10}.

If we go to the DV_{50} or the VMD, again, overlaying class, again, we see there are some differences at the lower airspeeds. But as we start getting particularly this 130, 140 mile an hour, we start seeing these differences disappear across the majority of the spray droplets in that spray volume. However, we do see some of these thickening agents maybe increasing the VMD just a little bit.

And again, if we look at DV_{90} -- so this is going to be an indicator of the larger droplets in the spray. Same sort of trends at these lower airspeeds. We're not seeing that much separation. As we increase, we see less differences. And in this particular set of data, we see these two thickening agents, the polymers increasing DV_{90} with the remaining of the spray solutions being very close to each other.

And so again, this is not indicative of all of these classes of adjuvants and all the different adjuvants that are available in these classes, but it was just some general trends that we've seen as we've tested over the years.

One of the terms we haven't talked about is percent fines. Or in this case, I'm using the percent of spray volume less than 100 microns. When we're talking about spray drift and controlling our spray and controlling our application, this is the part of the spray that we're really most concerned with. This is the part of the spray that we don't have much control over after we let it go from the airplane. When we start getting below 100 microns, we're basically at the whim of the environment. Whatever the wind is doing is where those droplets are going to go.

So again, as we increase airspeed, we see the expected increase in fines in the spray. And again, let's overlay the classes, and we can see, again, this trend that we have seen through this, that the formulated product alone and the thickening agents tend to give us a little more fines, where the COC, the microemulsions will give us a little bit less fines.

To throw another monkey wrench into this is if we change nozzle types. On this case, let's look at some similar spray tank mixtures but with the rotary atomizers. We actually see a reversing of the relationship. So, in this case, we're looking at a rotary atomizer with a few of the same products. And where we saw with the hydraulic nozzles that the formulated glyphosate product and the polymer-type product giving us the smaller droplet sizes, in this case, it gives us larger droplet sizes with the microemulsions and MSOs giving us smaller droplet sizes.

So that's just something to be aware of is, as you change atomization technologies or nozzle technologies, your solution effect is potentially going to be different, all of which makes this a very complicated process.

So again, just some general trends. It's just important to be aware that different combinations of nozzle and adjuvant are going to have a different impact or going to result in a different spray size. It's just something to be aware of as part of this set-up process.

With aerial systems, air shears are a dominant factor. So really, that's the first thing you need to consider when setting up your system. When we go across these broad adjuvant types, the old type products will slightly increase size or have no effect, where the thickening-type agents may tend to increase that relative span, will give us more bigger droplets and more smaller droplets without changing that VMD very much.

And again, one of the things we always say is, regardless of the adjuvant type or the spray formulation that you're using, your nozzle selection is the one that's the most important to consider as you're setting up your spray system. And it's the first thing you need to consider as you're setting up.

So, with that, we'll roll into just some general topics looking at setting up your system. As you go into an application, obviously, you know, you're applying some pesticide product. And the first thing you ought to do is look at that label. That label's going to give you information on the product, and it's going to give you some requirements and restrictions on things like droplet size, weather conditions, what products you can or can't put into the tank, how you should mix that product, spray rate, timing of application, a whole host of things that you need to be aware of just in setting up for that particular application.

When we start talking about setting up the spray system, one of the things that I think most, whether it's aerial or ground boom sprayers, what most people are going to do is tend to set up toward whatever the lowest allowable spray rate is unless there is a reason to go to a higher spray rate just because that's where you tend to be more efficient.

So again, that's going to lead you into setting up your nozzle and then working toward getting that nozzle up on the boom. And then once it's set up on the boom, getting your boom set up so that you have a nice uniform spray deposition pattern under the aircraft and you understand what your effective swath is.

So that process is a little bit of an iterative process when we talk about aerial systems, is that as we're trying to target a given spray rate and droplet size, we're working with several things. We're working with how fast we're flying the airplane through the field, the type of nozzle that we're using, the spray pressure that we're using, the number of nozzles that we're using. And any change to any one of those factors is going to change both the droplet size and the spray rate.

So, this could be sort of a circular process where I'm trying to target a certain rate and size, but I'm going to change maybe my orifice size because I need to increase my spray rate. Well, that's going to change droplet size. And so, I may have to go back and decrease the number of nozzles or increase spray pressure. So again, it becomes a little bit of a project to go through this and really tweak and get your system set up so that it's operating where you want it to operate at.

And then as we make changes to that, it's also going to change the effective swath width potentially. It's going to change the uniformity of what that pattern under the aircraft looks like. And all of those, again, number of nozzles, how high we're flying, the type of aircraft that we're using.

So again, this is not as simple as picking a nozzle, picking an orifice, picking a spray rate, slapping them on the boom, and going out in the field and making an application. It's a fairly complex process that takes a number of steps so that you're to the point where you are doing an application at a, you know, best management practice that you can do.

So again, I mentioned pesticide labels. I think most everybody out there doing any sort of custom application knows that that label is what you're held to in terms of making that application out in the field. And again, this covers a variety of factors. And what I want to do is just look at a few of the things that we see on some of these labels and, again, why maybe some of these labels do frustrate applicators and users alike and why they can be confusing.

One of the things that we'll see on almost all pesticide labels for any type of spray application is droplet size. And we see all sorts of terminology. We see verbage like "medium" or "coarse" coupled with droplet diameter. We may just see "droplet diameter." It may say just "deposit large droplets." We see, again, terminology -- here is one that says, "coarse with 3- to 500 microns," one that just says, "coarse sprays," one that says, "medium sprays with 3- to 400 microns."

So, you can already see, just in this set of labels here, we've got a couple different labels that potentially conflict with each other. So, it's one of those that it's -- there's different interpretations of people out there making these labels and some misunderstanding or just how their data is being measured that can result in different ratings and sizes.

And, anyway, it's just important to be aware that as you're reading through these labels, it's really important to take the intent of -- I mean, you need to follow the label. But most of these are going to be geared toward optimizing your efficacy and minimizing any off-target movement.

So, trying to keep those in mind as you process through the label will help, maybe, with your interpretation.

One of the things that -- again, we talked about this earlier, and this is still pretty prevalent through the industry. One of the things unique, again, to aerial spray systems is that as we increase spray pressure, we don't decrease droplet size. We actually increase droplet size. But there are more than a few product labels out there, when you start looking at the aerial-specific requirements, that will say things like, "Do not exceed recommended spray pressures. Use lower spray pressures. If higher pressures -- or if higher rates are used, go to nozzles that will let you use lower pressures."

Again, here's one that even says, "Use a maximum spray pressure 40 psi. Coarse sprays are less likely to drift. Do not increase volume by increasing pressure." So this becomes a harder one to deal with because it -- you know, I guess, legally, if you're held to the label and it tells you not to exceed 40 psi, but you know that if you went to 60 or 70 psi, you actually increased droplet size, I -- that's one for the lawyers and the litigators.

But in terms of the intent of the label, with this being to really augment your system and your setup so that you increase droplet size and you decrease spray drift, this is one of those ones you just have to interpret that the intent is for you to create a greater spray droplet size. I mean, this is a hard one to deal with because, again, nobody can tell you to go off label because the label is the law.

Just as a quick example of kind of going through a semi real-world example of a setup in terms of a given product and a given system, I pulled just the RoundUp PowerMax label. Nothing special about it other than it was one I think I had saved in my computer. And then if we look at the aerial spray drift management language, we'll see some very generic language like, "The distance of the outer most nozzles to the boom must not exceed three quarters." That's basically a standard practice of the industry anyway. "Nozzles must always point backwards parallel to the airstream." And again, we talked about that earlier. The intent is, keep that nozzle parallel to the airstream so that we maintain droplet size or don't increase our breakup.

This is one that is an interesting one that I read and read and read through the label. And the most you get on droplet size is -- it tells you the importance of droplet size. "The most effective way to reduce drift potential is to apply large droplets. The best drift management strategy is to apply the largest droplets that provide sufficient coverage and control."

So, this label doesn't actually give you a droplet size class or even a droplet size that you have to abide by. It just gives you the intent that -- "apply the largest droplets that provide control but reduce drift." So, it's really, then, open to you as the applicator to interpret that and make your best judgment while setting up your system to meet both of those parameters.

So again, this gives you the freedom of flexibility but at the same time doesn't necessarily give you something to fall back on if you have issues.

A little more of that label -- if you start looking at controlling droplet size again, it tells you volume -- even with this -- all the other with this label, it still tells you, "Nozzles with higher rated flows produce larger droplets."

And again, that's true on some of the flat fan nozzles. If you remember back to the straight stream nozzles, as we increase in orifice size, we actually decrease droplet size. So, this doesn't necessarily hold true. We see this again, this statement, "Operate toward the lower end. Higher pressures reduce droplet size." So again, some issues that I think folks out there in the field that do these labels are aware of this and are working to make some changes to correct some of this stuff.

You're given guidance on minimum number of nozzles that produce uniform coverage. And then here –it’s telling you application height of 10-foot or less. And that one can be a little tricky too, because that potentially gets into safety, flight safety issues, depending on where you're going, how fast you're flying, and what your surrounding environment looks like.

So, to start diving into actual setup of this, I pulled the section for annual weeds, given some guidance on the aerial that says "3 to 5 gallons per acre." And to go through the setup, I just went with sort of a basic setup, a fixed-wing aircraft with typical speeds of 130 to 150, 60 to 70 for swath, again, sort of a generic setup. And my interpretation of the label was a medium to coarse spray.

So, what I'm going to do is do setups for both a medium spray and a coarse spray based on what the label's telling us. So again, this is one of the places you can get the tools or get the models that I'm about to show you. And this goes to some of those graphs that I showed you earlier in this webinar.

From our website, you can actually download the Excel files that will let you run through these models, change the parameters, look at droplet size, and what changes you see relative to nozzle and the different operational parameters. And again, if you go to the website -- I won't go into the use of the models or the background, there's a lot of detailed descriptions and background on the website as well as some of the resources and references that you can refer to as you start working with them.

So, this is just a screenshot of a given setup. What these models walk the user through is, first of all, selecting your nozzle type. In this case, we're going to go with what I've kind of been walking through this whole presentation, is a standard 40-degree flat fan.

And then the next thing you would do was enter your operational settings. So, for this particular setup, I'm looking at a No. 15 orifice, a nozzle angle of zero degrees, a spray pressure of 40 psi, and an airspeed of 140. And then the models, I think, also incorporated -- if you enter in your spray rate and your effective swath width, it will do the nozzle number calculation based on flow rates.

So, for this setup, with this 40-degree flat fan and these operational parameters, the model will give you the DV10, 50, and 90. And more importantly, probably for what you're doing setup-wise, will give you the droplet size class. So again, we can see with this particular setup, we're getting the medium spray, medium at 3-gallon per acre mark using 40 nozzles.

So, one of the things the models, again, allow you to do is, let's say we wanted to use this same setup but go from a medium spray to a coarse spray. So again, we're going to look at the 40-degree flat fan, the same 15-degree orifice, zero-degree deflection, 40 psi. And in this case, what we're going to do is just bump the airspeed down to 125 miles an hour. And you can see a pretty dramatic effect where we increase all of our droplet size characteristics, and we bump it up to a coarse spray. Again, it's going to reduce the nozzle number a little bit. Because we've slowed down, it's going to take fewer nozzles to meet that spray rate. Again, the models let you walk through these iterations very quickly and at least look at what it takes to make a given setup work.

One of the other things it'll let you do is look at different nozzle types. So, let's say we actually wanted to maintain our airspeed. And if we wanted to keep an airspeed of 150 mile an hour, so instead of the flat fan nozzle, if we switched over to a straight stream nozzle, which we know gives us bigger droplet sizes, we can bump this airspeed to 150 mile an hour and still maintain this coarse spray and our spray rate where we want it.

So, you know, there's quite a few options walking through the different nozzle types and the different operational settings that you can use to meet, you know, the label requirements for a given application. And again, the intent of these models is to really help reduce that iteration process and give you a tool that lets you walk through these different changes very, very quickly and get to a setup that works for your particular setup and one that you know, works with your operational settings.

Just do a quick plug. These models are also available in a mobile platform. If you go to either the Apple or Google stores, you can see the different apps available there. And I'll do a plug for -- since Greg's sitting here by me -- the University of Nebraska has a similar data set and set of data models that you can use for ground boom sprayers and basically the same sort of operational format that you can use as a user.

We talked a little bit earlier about the rotary atomizers. The only set of models out there that I know of is from the Micron Group for the Micronair nozzles. And if you go to their website, you'll see, once you get to the micron page, that there is a link for the models. I think you have to do a -- just kind of a quick user account setup, but then you have access. And it does the same type of thing, it lets you put in operational parameters, airspeeds, formulations, and it'll help you walk through setting up that nozzle to meet the application parameters that you need to meet.

So, once we have our nozzle selected and all of our operational settings ready, the next thing is to actually set those nozzles up on the aircraft and determine how we position those nozzles under the aircraft so that we get a nice uniform swath. And again, why that's important is, the last thing any applicator wants to see post application is to come back to a field and see something like this, where you see, you know, very, very obvious streaking, either from under or over application of a product in the field or just a non-uniform spray pattern under the aircraft to start with.

So, again, a little bit of effort up front to tweak these nozzle setups under the aircraft and really maximize that uniformity is worth its weight in gold when you actually get out into the field.

This is one of those things that, again, by aircraft type, by application height even, by where you're at, how you fly, how you set those nozzles up under the aircraft, and how you'll actually do the [application]-- you know, nozzle-to-nozzle setup is going to vary.

But some general trends to consider, the effect of propwash. You know, one of the most common things we see is this propwash is actually going to push spray from one half -- one side to the other just because you have that rotational effect of the air coming off the prop. And you see this stacking effect. And so that's something that you can account for by maybe taking nozzles off of one side, putting them over on the other so that you fill in that hole.

The other thing is -- and this is something we'll talk about, too, in terms of drift mitigation, are these wingtip vortices, is, getting nozzles too far out on the boom, you're going to start seeing more and more spray getting trained that doesn't actually go down. So, we want to keep those nozzles inward of the far edges of the booms to keep that material from being moved outside of our spray zone and out of our target area.

And then beyond that, there's just things like putting nozzles under the belly, dropping them down a little bit to clear some of the structures under the plane. You know, there's things like your landing gear. You have gate boxes, the pumps, you know, all the stuff that is just noise under the belly of the airplane.

And again, some -- well, this is one of these -- this bottom picture is one that was taken during a fly-in years and years ago. But you can just see that even just these wheel struts have a fairly significant effect on changing the flow-stream patterns of those nozzles that are under the belly and up against where that's at. And all that's going to have an effect on changing the uniformity of your deposited spray end swath.

So, as you change these setups, again, it's important to go through and evaluate what happens and what these patterns look like. And one of the things that the aerial application industry itself has is it has its own program in place that is designed to do this, called Operation S.A.F.E., which is Operation S.A.F.E., and S.A.F.E. stands for Self-regulating Application and Flight Efficiency. And it's designed to help applicators set up and optimize their system and really understand -- you know, get their uniformity, know what uniformity is, know what their effective swath width is so that in the field, they're informed and can make a really optimized application.

And this system uses a set of specialized equipment and measurement systems as well as analysts that were trained and certified to read that data and to help understand what's causing imbalances in your uniformity and how to adjust the system so that you maximize that performance.

So, sort of the last topic is going to be best practices for drift mitigation. And this is one of those that this could be its own four- or five-part webinar. I mean, as critical a factor as it is, there's a number of factors that come into this. But we're going to, at least on a basic level, try to go through some of the basic parameters and at least give a background of understanding so that as you're doing these setups, there's some understanding of what are some of the key factors to consider.

So again, this is not meant to be a completely inclusive list, but there's a number of things that can cause or at least contribute to spray drift. The characteristics of your spray, as we talked about, depending on what your spray formulation looks like, it can change droplet size. Or it can change things like evaporation rate, which will change droplet size as it's moving through the field.

Your aircraft, the type of aircraft that you're flying, how fast you're flying, how high you're flying, how you're positioning your nozzles on that aircraft, all those things can contribute to overall changes in droplet size, how the spray is handed off from the airplane to the wind, and then how that moves that product as it moves through the field.

I think the most important one, the most complicated one -- and I say this because it's the only one of these factors that you, as an applicator, or those of us even doing research, have absolutely no control over -- is the weather. Wind, temperature, and humidity and inversions, I think those are three that everybody involved in any sort of application work are familiar with. I mean, - if you look back at decades of research, the two most dominant things are droplet size and wind and the combination of those.

And you can control droplet size for the most part. Wind, you can't control, other than timing of your application. So, understanding and accounting for and adapting your setup to weather conditions is probably the most critical part of any drift mitigation management practice.

So, with that, I want to just do some quick look at looking at relationships between what we see with different wind speed classes and different droplet size classes. So those of you who are familiar with this, I used a model called AGDISP which lets you model spray movement from aircraft and ground systems.

And in this case, I don't know that this is the default. It might have been one of the default setups, but I'm looking at an Air Tractor 602, 75-foot swath, 65 percent boom width. Environmental conditions: 80-degree Fahrenheit, 50 percent humidity, 20 spray passes. And I'm going to look at four different classes of spray: fine, medium, coarse, and very coarse. And then four wind speeds: 5, 10, 15, and 20 mile an hour. And you'll see how important these factors play against each other and what they do to spray movement.

So, if we first look at basically droplet size versus wind speed, the graph on the left is the wind speed of 5 mile an hour. The one on the right's 20 mile an hour. And then we have the four classes from fine, medium, coarse, to very coarse.

I guess some of the first things you can observe is, the coarser you get with your spray, the less change you see with changes in wind. And that should make sense because the bigger droplets are going to tend to fall out and not be as impacted by the changing wind speed. And then the finer you get, the more change you get.

But regardless of that, as you go from 5 mile an hour to 20 mile an hour, for each of those spray size classes, you see a very, very dramatic increase in movement, again, at 100, 200, 300 feet downwind. So, this wind speed consideration is one of those that's the most important to consider. And it's one of those that's usually some sort of restriction on the label that, you know, flat out says, "Do not apply above 10 mile an hour, 15 mile an hour." And again, you can see why this is important.

If we look at the different size classes and then the wind speed effects within each size class, again, we can sort of see this trend play out that the coarser we get, the less impact the wind has on that spray. And, again, it makes sense because those droplets are bigger, they're going to tend to fall out quicker, and you're going to have less movement off target with very coarse sprays even with increasing wind speeds. But at our finer droplet sizes, and especially as we increase wind speed, we see these very, very dramatic effects and, you know, fairly significant increased downwind movement from the site of application.

So, understanding that complement of how droplet size and wind speed play together and, you know, adjusting your setup to match that and account for that is probably one of the most important things you can do, at least as an initial step of drift mitigation.

Beyond that, we talked earlier about nozzle positioning on the booms. Again, this is a fairly standard practice in the industry, is not to exceed a nozzle out on the boom that's greater than 75 percent of the wing span. And one of the things that we -- there's been some work the last couple two or three years. Even looking at reduced boom widths further than that of maybe 65 percent, 60 percent, 55 percent. And in a lot of cases, we either don't see a significant change in effective swath width, or maybe a very minor change in swath width, but a fairly significant effect in how much of the spray then gets entrained and carried further downwind. So, I mean, it's just something to consider.

And so again, one of the things that's -- and it should be obvious out of all of this, is, it's those downwind edges where we're seeing the handoff of the spray to the wind. And that's going to be the most significant at the furthest downwind edges of the field.

So you know, you just want to be aware, when you're making those most downwind edge passes, that's where you need to be the most careful and, you know, have the most intent into making a good application. That really does tend to be the case with most of the guys that do this type of work, is they know that that downwind edge is where they need to be the most careful.

Some things that have been done throughout the industry, things like half boom shutoffs where you shut off that half boom on the downwind wing can go a long way toward reducing movement off target.

And again, if we think back to what we can do in terms of changing droplet size, we did some work years ago in just looking even at the models and some modeling. Those last two or three passes through the field, if you reduce your airspeed even 10 or 15 miles an hour, you increase your droplet size enough that you can reduce off-target movement by 10 or 15 percent. So, you know, just something as simple as lowering your airspeed on a few of those passes downwind can pay big dividends in terms of reducing your off-target movement.

So, with that, I'm going to throw up this slide just to show the complexity of -- and again, this is not unique to aerial necessarily. But you know, when you start talking about application technology and all the issues that are playing into setting up your system, understanding what you're doing in the field, I mean, we have everything from understanding what the labels are talking about to understanding the chemistry, the physics of spray atomization and droplet size, weather, spray movement through the field. It's a very, very complex process, and you know, it takes an effort and ongoing education and understanding to stay on top of advances and just understanding what it takes to make things like this happen in the field.

So obviously, we sort of just barely skipped the surface on a lot of these topics throughout this webinar just because they are so involved. But hopefully, we've at least given some resources to move forward, and certainly, there'll be my contact information, Greg's contact information.

You know, that's our job is to be here to help and reach out where we can. So even beyond this webinar, any questions or issues or concerns, you know, please feel free to contact us and, you know, we'll be happy to help and be involved wherever we can.

And with that, I'll throw up, just for more information, our group, or getting contact from us, here's our website. You can find our emails and a lot of the other resources that are available to you.

Khue Nguyen:
And now we will address your questions. So, the first question is, "Could you please address any work that is being done to understand spray droplet distribution and drift potential using drones?" So, who wants to take this question, Greg or Brad?

Bradley Fritz:
I'll start. Some of that work is being done here in the U.S. At least the groups that I know were doing it, most of them are sort of in their infancy of doing the research. I can't, offhand, give you the number of those places that are doing it. If you wanted to follow up, I could certainly connect you with some people that could give you some more resources. I know most of the more in-depth work that I'm familiar with is being done out of country. And, again, there are some links there that we can certainly set you up with.

And again, I hate to make it a generic answer, but that's kind of where things are at. It's hard to do that work right now in the U.S. just because of some of the regulatory issues.

Khue Nguyen:
"When the airspeed decreases, the droplet size increases, but the position of airplane change is probably increasing the vortices. Do you think that reducing the velocity is a good way to reduce drift?"

Bradley Fritz:
That's true. That's also going to play into how those nozzles are positioned along the boom as to

how much to actually get entrained into the vortices. And then there's going to be a tradeoff. I mean, there's going to be a tradeoff in your reducing -- by reducing the airspeed, you are having a fairly significant impact on changing and increasing droplet size along with that potential vortice entrainment.

So it's hard to give a quantitative answer in terms of what that tradeoff looks like. Again, that's one of the powers of a tool like AGDISP, is it does give you the ability to go in and run some scenarios and look at how that would change, because I suspect that varying change in the relationship between the two is going to change by aircraft type as well.

Khue Nguyen:
"You stated that increased boom pressure increases droplet size. Is that only with straight stream or flat fan as well?"

Bradley Fritz:
That's for both. Both straight stream and flat fan, we've seen steady increase in droplet size as we increase spray pressure. And I only show data up to 90 psi-- we've done some work that never -- it was just sort of some preliminary work just out of curiosity up to 120 psi and more and still see increases in droplet size for these hydraulic nozzles.

Khue Nguyen:
Next question: "Could you please better explain how to measure and evaluate aerial spray coverage?"

Bradley Fritz:
Well, so I'm going to take coverage as just deposition or coverage pattern relative -- there's a number of ways. We've used a variety of methods. There are some very simple methods like water sensitive paper that lets you put a quick sample out in the field. You fly over, the spray droplet deposits, it makes a stain, and you can take that, you can process it, and you can understand what the droplet size and the coverage looks like.

There's some more complicated methods where you can use some fluorescent tracer-type dyes using different sampler types, whether it be plant samples, artificial samplers, fall-out plate collectors that you can spray, collect, go back to the field -- or go back to the lab, wash and process and get a measurement of deposition, to some even more complicated measurements that are actually, you know, spraying something like an active product and then taking back and doing the chemical or GC analysis to actually determine how much of that actual product has --

So, there's a whole range from a very, very simplistic to very, very expensive and complicated methods that will let you do that. And again, for anybody that wants more information on that, we can -- there's some publications out there and some other resources that will give you a lot more detail on that type of work.

Khue Nguyen:
Next question: "Has there been any work done on what effect thermals -- for example, a sunny day or large amounts of dark ground cover -- have on drift potential?"

Bradley Fritz:
That's -- I'm going to have to I don't know specific to thermals other than, when you start talking about any spray or particle movement in the environment, as you change time of day or ground cover, you're changing what's going on in the environment.

So, as you have a different type of ground cover that heats or cools differently, you're going to change the way you have mixing in the environment. And, you know, more mixing means greater amounts of dispersion of the product in the environment, higher wind speeds. So there's some work relative to just the basics and the theory of dust and particulate dispersion that covers some of this.

But specific to aerial sprays, there's only one or two studies out there that I can think of that sort of deal with the specifics of environmental stability. And again, if you want more specific resources, we can help find those.

Khue Nguyen:
Next question: "How do you think formulators can best help mitigate spray drift? What types of chemistries should we explore more intensely to develop better adjuvants?"

Greg Kruger:
So, I can probably try and address that one a little bit. I see Brad pointing at me already. And that's a good question. It's a tough one to answer because, to be honest with you, the best chemistry is probably the one that we don't know yet. As Brad pointed out in this seminar, the faster we go, the more difficult that it gets to use any kind of spray adjuvant to influence spray particle size.

Certainly, the ones that we've seen the best luck with at this point are those emulsion-type category products. So methylated seed oils, crop oils, things along that line. So, at this point, that would be the benchmark. But actually knowing, no. If there's something out there better, that's a good question in terms of development.

Khue Nguyen:
Next question: "Is there any research on drift created by different types of aircraft, for example, monoplanes and biplanes, ultralight aircraft, et cetera?"

Bradley Fritz:
Yes, there is. I can't give you off the top of my head what those differences are or how they compare to each other. Some of the ultralight stuff's a little more complicated because that's more specialized application-type stuff.

But in terms of the other aircraft, yes, there are. And in fact, if you can look at a model like AGDISP, built into that model are a large variety of different type of aircraft that you can actually go in and model what the spray movement and handoff looks like from from the different airplanes.

Khue Nguyen:
Next question: "Are there any resources for how best to set up nozzles for a specific type of aircraft? Also, is there any benefit to adding extra nozzles near the end of each boom within the 75 percent to widen the swath width?"

Bradley Fritz:
In terms of resources on setup, yes. If you navigate to the National Agriculture Aviation Society, they've got some resources and links that you can use. Some of the companies out there -- I'm trying to think specifically. Transland, if you navigate to their products page, I think they have some guidance as well. I think WRK, actually, if you go to their website, WRK of Arkansas, somewhere at the bottom of their page there, there's a worksheet that actually goes through different aircraft type and at least some guidance on generic best setups. AGDISP itself is a resource that will let you look at different nozzles and different setups.

The second part of that, the benefit of adding extra nozzles to the end of each boom to widen the swath width, it doesn't -- if you look at the work that's being done, once you start moving past that 75 percent, almost everything that's out past that 75 percent gets lost in wingtip vortices. So, you can go out to 100 percent, and you don't widen the swath width. Or if you do, you widen it very, very marginally and dramatically increase the amount of product that gets entrained and moved off target. So really, that 75 percent is there as a maximum recommended effective boom width for a reason.

Khue Nguyen:
Next question: "Do you think the core messages and models shared today extend well into forestry applications and mountainous terrain, or would these mainly be an extrapolation for more flat agricultural studies?"

Bradley Fritz:
I would say that these are more suitable to flat agricultural studies. When you start looking at forestry and mountainous terrain in particular, it's a whole different setup. I mean, you're talking about a canopy that's 40, 50, 60, 70 feet, and you're talking about terrain that may change that much or more. So, the application methodology is totally different. You're flying at application heights that are maybe significantly greater than what we do in flat agricultural studies.

The droplet sizes being applied are likely going to be different because it takes a different droplet size spectrum to actually make the droplet penetrate and filter through the canopy without depositing all on top. And usually that means usually a little bit smaller droplet size than maybe what we would typically use in an ag field just because it takes some time and energy for that droplet to filter through that forest canopy.

So, forestry is a different animal than the flat agricultural fields that we are talking about today.

Khue Nguyen:
Next question: "I am interested in the suitability of air induction nozzles for aerial applications. In recent contracts, we have been offered AI nozzles. Are air induction nozzles comparable in terms of drift reduction?"

Bradley Fritz:
So, with the work we've done on air induction nozzles, if you go back to what we talked about, and we talk about aerial systems, aerial systems are unique in that we have air going past the nozzle. That's going to be what drives the most significant part of the atomization process, and with the thought that we can reduce that air shear by increasing the velocity coming out of the nozzle.

What AI nozzles do is they do just the opposite of that. You actually have a pre-orifice to the nozzle that reduces the velocity of the liquid coming out of the nozzle in order to increase droplet size.

So, what we've seen in the work that we've done in our wind tunnels, looking at AI nozzles at aerial application airspeeds, is we see a nozzle that has liquid coming out at a lower velocity with bigger droplets that just get blown apart into much smaller droplets. So, air induction nozzles were never designed or intended or meant to be used on an aerial platform. They're meant for ground boom sprayers.

Khue Nguyen:
Next question: "How far are we from introducing pulse-width modulation systems for aerial application?"

Bradley Fritz:
We're there. There is a company called Capstan that has -- or is right at the brink of having a commercially available system that actually offers some very unique potential opportunities and abilities on the aircraft. So again, that's there and has -- I think there's a number of -- two or three applicators out there anyway that have some of these systems that they've been using them as part of testing the new system.

Khue Nguyen:
Next question. I think this is a -- another mention, reference, for drone applications, "Are there studies on drone applications?"

Bradley Fritz:
Yes, but they're scattered. There's not a whole lot published yet in terms of the number of studies published in the U.S. But there are a few being done. I know there's work being done that, over the next six months to a year, will be published. And more significantly, if you start looking at work being done out of country, there is quite a bit done.

Khue Nguyen:
Okay. So sometimes we get frequent questions from stakeholders referencing the Drift Reduction Technology program at EPA, so one example of such a question is something like, "Our company has tested our adjuvants with various herbicides for droplet size, characterization, and spray performance with Dr. Kruger. Is there an application process or portal for data submissions to EPA for review?"

And our answer to this question is that the DRT program is being revamped at the Agency. EPA is currently working with stakeholders to identify next steps. If DRT data were submitted to the Agency as part of a registration action, the data are being reviewed. Otherwise, the data will be held until next steps are identified. So please contact me directly and I can point you to the right person in OPP who can address your questions about EPA's Drift Reduction Technology program.

I think that's the last question for today. Thanks for joining us. We hope you will join us again for the October 25th webinar. Have a nice day.

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