Best Practices for Ground Application Webinar—October 25, 2018

Transcript

Khue Nguyen:
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Welcome again. 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 review the similarities and differences between ground and aerial pesticide application. We will discuss some of the technologies available for ground application, and we will wrap up with an intensive discussion of the biology of weed management. This webinar is part of a larger EPA effort to promote pesticide spray drift management and promote the conservation of native habitat.

This is the last of a three-part series intended to educate stakeholders on ways to reduce pesticide spray drift. The first webinar occurred on March 15th, 2018 and was presented by Dr. Greg Kruger. It covered the fundamentals of pesticide spray drift management. If you missed the webinar, the materials are posted online at the link shown on the screen. The second webinar occurred on September 27th, 2018 and took a closer look at aerial application. It was presented by Dr. Bradley Fritz of USDA. Today's webinar will take a closer look at ground application and will be presented by Dr. Greg Kruger. Dr. Bradley Fritz will join us again today for the Q&A discussion.

Just to give you an idea of who's in the room with us here, Dr. Fritz presented the September aerial application webinar, but he is also joining us again today for the Q&A discussion. He 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. You can check out his latest research at the link shown on the screen.

At this time, I would like to present our speaker. Dr. Greg Kruger 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. He is also the Weed Science Society of America's liaison to EPA and provides technical expertise to EPA on matters related to weed management. Please welcome, Dr. Kruger.

Greg Kruger:
All right, good afternoon or good morning to you if you're on the west coast or other places around the world. It's a real privilege to get to do another one of these. And thank you, Khue for

helping put these together. They've been excellent so far, and I'll try to hold up my end of the deal over the next hour.

For many of you, if you've been online for these already and you're probably familiar, I thought before I got too deep into it that we would do just a quick review. Like I do with every single one of my talks. I always like to give credit where credit's due. And today I get the opportunity to present research from a lot of the different students and technicians that have been in my group over the past nine years or so. I know several of you are online and listening today, and you guys are part of the reason that we've had the opportunity to share this type of information.

So, just a quick review of the first two webinars, so that we can kind of lay the foundation for anybody that might have missed one or both of those. Spray drift, I think it's important to have a definition so that we're all talking about the same thing. This definition of spray drift that I'm going to be using throughout this presentation, and the same one that we've used for the last two, is "the movement of spray particles and vapors off target causing less effective control and possible entry to susceptible wildlife vegetation and people." It's not a definition I came up with. It's from the National Coalition on Drift Management, from 1997. And again, like we talked about the first time, there's really two different things that you should note in there.

And that's that there's two different types of drift. The first one being vapor drift. And this is associated with volatilization, or the conversion of that pesticide application to a gas and moving off target in that state. And particle drift, which is the movement of spray particles during or after the spray application. So, when we talk about the drift, drift really encompasses both. Like the first webinar I presented, and much of what Brad presented in the last one, then we're going to have a heavy focus on the particle side. We're really not going to get into vapor drift today.

Now, just a quick review on particle drift. Again, if I've got any aerial guys in here that were on the webinar for Brad, keep in mind that, as Brad pointed out in that webinar, things can be a little bit different from the aerial application side than the ground side on some of these factors that we talked about. Yet some of these principles are going to hold true across both the application platforms, but most of what I talk about today is going to be heavily focused towards ground applications. Again, kind of circling back to where we started.

So the big four factors we talked about were wind speed and coupled with that is wind direction. The second one that we talked about, in terms of being very important for mitigating drift, is understanding boom height and minimizing boom height as much as possible. The closer we get to that application target the more effective we are going to be at depositing those smaller droplets. The third one we talked about in that first webinar was the distance to susceptible vegetation, and we really can summarize that up into one simple word. And that's buffers. So, the greater the buffer distance the less likely we are to see off-target movement into those unattended areas.

And the last one, which we had spent the most time on, is spray particle size. And this is the one that really we started to see some differences between ground and aerial applications with differences in use of pressure nozzle selection orifice size and flow rates. So, particle size becomes a very key player in terms of off-target movement. Obviously, the larger the droplet size in both cases the greater the deposition rate or the less drift we're going to see.

So, just as a kind of a recap and a reminder, we've got these two videos here showing two different nozzles. Both have very, very different droplet sizes and very different drift potentials. The one on the left is an XR nozzle. And you can kind of see that black or gray hazy background. That's all those fines that are hanging in the air, and those are the ones that are going to have the highest potential for drift. On the right-hand side is the extreme opposite for our ground applications, and that's a TTI 11004. Again, you can see how we've managed to get rid of that black hazy background with all those fines, and we've got an ultra coarse spray quality here.

And when we talk about managing particle size, nozzle becomes the first point that we would start in terms of talking about droplet size. So then, based on the past research, we know that about 70 to 75 percent of that change in droplet size for ground applications is going to be attributable to the nozzle selection.

Now, this is where we're going to kind of change focuses a little bit in today's webinar versus the first two webinars. And we're really going to get into delving in deep in terms of the relationship between drift and efficacy, talk about the efficacy component, what we can do to optimize applications from an efficacy standpoint, and what we might be able to do in certain cases to minimize drift while optimizing those the efficacy of that particular product.

And the reason we want to talk about this is that if we're not effectively managing the pest, we're really not out there using that pesticide for the purpose it was intended. So, our first focus has to be on managing that pest that we're out there trying to control. And then within the framework of that, we want to try to mitigate drift as much as possible.

Keeping in mind I think it's really important to note that we are going to see some off-target movement with every application. I think it's easy to forget that when we don't see it. But we are going to have some off-target movement with every application.

Now, this is another slide that we used in the first round. And this really shows the complexity of that pesticide application. And we talked about the drift component on that right-hand side, and what's coming off from the atomization, the volatilization, and from the atomization and deposition process. Today we're really going to get down and try to get to that biological effect, focus on that, and then talk about how we manage those processes from there.

So, I just want to start with talking about a couple different efficacy trials that we've done over time and how those kinds of different trials show how droplet size is important from an efficacy standpoint. And then we'll try to tie that back into the drift reduction and off-target movement piece in a little bit.

So, this is some work that was done out in western Nebraska. This is looking at triazine resistant kochia. What you see on this slide is the control ratings at nine days after application. Using three different nozzles: an XR, a DG, and a TF or Turbo Flood. And those nozzles were operating at 30 psi. The application was using paraquat atrazine. So, we really got only one effective mode of action on that triazine resistant kochia, and that's the paraquat. We know that paraquat is a contact-based herbicide. And so, really, what you're going to see in this is driven off of that activity of the paraquat in that application.

And what you see -- we've got three sets of bars. They're going across the x-axis. We've got 10 gallons per acre, seven and a half, and five. And we've got three different nozzles at each of those applications giving us three different droplet sizes: a medium, a coarse, and an extremely coarse.

So, if we just kind of focus in on that 10 gallons per acre, those brown bars, to start with. What we've got on the y-axis is control, and we've got our control ratings on a scale of zero to a 100. So, I see that there's many of my colleagues online are very familiar with this. If you haven't done this type of work, basically, what we've got is 100 percent control would be a dead weed or a dead pest, and 0 percent control would be no application or no injury observable from that application.

So, now if we look at the set of brown bars, again you can see the XR nozzle had the highest level of control. We had a slight drop off when we get to that drift guard. And then when we get to that extremely coarse application or that Turbo Flood, you can see a significant drop-off in terms of the efficacy that we get from that. That's the trade-off between droplet size and coverage. So, the larger droplet size gets the less the coverage gets.

Now just like that what we see is that as we reduce the spray volume, we're also going to reduce the coverage. So, if we look at the 10 GPA, versus the seven-and-a-half, versus the five GPA you can see a slight decrease as we reduce the volume within the XR nozzles and the DG nozzles and in the Turbo Flood nozzles as well. And that's because we're giving up coverage by reducing volumes.

So, when we talk about contact-based herbicides like paraquat we've really got to make sure that we're targeting coverage. There are really three ways that we can increase coverage. First, is increased volume. The second is going to be to decrease the droplet size. And the third one is going to be adding some sort of a spreader or surfactant to that application.

Obviously, if we decrease droplet size, we're talking about an increase in drift potential. So, if we want to balance the efficacy and the drift potential, decreasing the droplet size is not going to be the optimum way to do that. We really need to push towards using higher volumes.

Now, this next slide is really some work that was conducted by Paul Fang and his group at Monsanto. And this one is now looking at a systemic based herbicide. They used an XR nozzle to produce a fine spray droplet, a Turbo Tee to produce a medium spray droplet, and then an AI nozzle to produce a coarse spray droplet. And what they did then is looked at the absorption and translocation of glyphosate on Roundup Ready corn.

And what they found is that the smaller the droplet size the less absorption or uptake they got as well as the less translocation they got, or movement of that glyphosate throughout the plant. So, here's one of those opportunities with glyphosate that we can actually push towards those larger droplet sizes without giving up any efficacy. But yet we're also going to be mitigating or reducing the drift potential at the same time.

Now the next couple slides are some work that one of my former students, Dr. Cody Creech, put together from some of his research. And what you see here is the impact of nozzle type on droplet retention. So -- I don't know if it's probably cut off on your slide. I can't see it at the bottom of mine. But what we have are three different nozzles going across the x-axis. The first one is going to have the smallest droplet size, which is observed by the black square and in the green bar. Going to the right you can see the droplet size getting larger, from 250 to approximately 500 microns to a little bit larger than 750 microns, for the three bars.

What those three bars are XR, AI XR, and a TTI nozzle going left to right. So, as we change that nozzle size, we increase the droplet size. The green bars that you're looking at, that you see stair-stepping down, are the relative fluorescent units, or how much product was retained on the plant at the time of application relative to those three nozzles. So, as we increase droplet size you see that inverse relationship or that decreased droplet retention on the plant.

Now when he did that he also did some work looking at different adjuvants. So, you can see, going across that x-axis now, we've got methylated seed oil or MSO. We have a non-ionic surfactant or NIS, a silicone surfactant, crop oil concentrate, a drift retardant, and then, in this case, just straight water. Or we looked at a couple different herbicides without any adjuvant system. So, the data is pulled across those herbicide systems.

And if you look at the black dots again, they are those black squares, what you see is that the droplet size is kind of bouncing around between about 485 to 520 microns in size, but, really no correlation in terms of retention. So, this is telling me that though we've got an opportunity to use some adjuvants to increase retention without affecting droplet size. So, this is an opportunity to increase the droplet retention or increase efficacy without compromising that particular application from a drift management standpoint. So, we're getting a little bit better coverage and retention on that leaf surface without giving up or increasing the drift potential.

So, with the remaining of 40 minutes or so that we have I really want to start digging into several different field studies that we've conducted. So, the next few studies are going to be laid out very similarly. What you see in the top right-hand picture is some different weed species and crop plants that we planted in the field. We plant those in a row and then we spray across. You can see that pictures for an untreated check, but some of the other plots we would spray different applications.

So, these studies were conducted at four locations in Nebraska. At each location we had four replications, and you can see the five different species we listed there. Due to time, we're not going to have the ability to look at every single one of those species for every single herbicide that we looked at.

But now what we did is for each herbicide we looked at we used five different nozzles. An XR 11002 giving us a fine spray quality. We used the XR 11003 operated at 43 and a half psi which is that reference curve from the ASABE S572 standard. Which has been referenced in the previous two webinars as the boundary between the fine-medium. And then we used a Turbo Tee 11002 to give us a medium spray quality and AI XR 11002 to give us a coarse spray quality and then an AI 11002 to give us an extremely coarse spray quality. This, again, was part of Dr. Creech 's work as a Ph.D. student, and it really gave us an initial look at what was going on and why certain labels had certain application information in them.

So, what you see here is the is the glyphosate application on amaranth. And I want to point out, before we dig into this data too much, that for this study we did use a half-rate or half of the maximum labeled rate for each of the products. In this case, we were even a little bit less than what most people would consider a half-rate with the glyphosate. And we used 11 ounces per acre. And the reason we do that is if we get 100 percent control it becomes very difficult to tell what's going on from a droplet size perspective, so we're trying to reduce that rate to get partial control.

And then the amaranth that we used here -- I know many of you instantaneously go to Palmer or waterhemp. In this case, we use a grain amaranth, and the reason that we do that is because it's very, very difficult to get a consistent weed population when you seed it in with some of these other crops. So, we get just a little bit more uniformity. It makes the radius a little bit easier to manage.

The downside to doing that, as many of you know, we've got a lot of different herbicide resistances in those two-weed species. The grain amaranth has not been selected for glyphosate resistance or other resistances, so it's still very, very susceptible. And you can see that here where 11 ounces has given us between 95 and 98 or 99 percent control across the treatments.

Now what we have here is we've plotted the droplet size on the x-axis. This is the DV 10 value. So, if you're thinking that the 250-micron droplet is extremely small for an extremely coarse you'd be correct. The reason we plotted it against the DV 10 values in this case is we wanted to show the drift potential of that application. So, for those dots that you see on the figure here, the farther that dot is to the left the greater the drift potential. The farther up that figure the dot is the better the weed control. So, we start to look for the trends to determine what the optimum application scenario would be for each weed species in each crop or each application that we use.

So, in this case, so you can see we've got a very linear type response. There’s not much difference between control for each of those applications. So, we really are looking at trying to mitigate droplet size because the efficacy is about the same regardless of which droplet size we're talking about. So in this case with glyphosate, the recommendation would be to use an extremely coarse droplet, maybe even an ultra-coarse -- even though we didn't push that far in this particular study, and mitigate drift as much as possible since we're not giving up any control.

Now on the next one, this is now dicamba. And, again, if you look across here it might look like the extremely coarse is just a little bit more efficacious even than the fine, the medium, or the coarse. But there's no statistical difference in terms of the control across all five of those treatments. But what we do see, again, it's a very linear response for dicamba. Whether we're talking about Clarity applications, pre-plants, in corn, or the new formulations in soybeans or cotton, we're really going to push towards using as large a droplet size as possible. Because we're not giving up that efficacy, and we want to mitigate drift as much as possible.

Okay, for the next one we have we used fomesafen. Again, this is on that amaranth population. Now you can start to see that we're getting a little bit more difference in the different droplet sizes. The extremely coarse doesn't really follow the trend of the first four, but you can kind of see where that fine-medium looks a little bit better than the fine or the coarse. And we'll come back to why that extremely coarse might be a little bit different a little bit later in the talk. But we're starting to see a 10 to 15 percent difference in some of those treatments. And I left the letters off of there for statistical separation just to keep the slide a little bit cleaner, but we did have some statistical difference between the treatments.

The reason we see in the fine drop off, and the efficacy go up to that fine-medium or medium, is really due to a loss from drift. And when we see the drop off from medium to coarse though that's due to coverage issues. So, if we start to look at some of these products, like the post-emergence PPO inhibitors, we see specific label recommendations on volume in particular as well as droplet size. So, for example, some of the labels will say use a fine, or use a medium, or use a coarse, or maybe use a medium to coarse spray quality. And that's really because they've done -- different companies out there have done a lot of work trying to understand what that optimum range might be, but yet they want to keep you from having any more drift than necessary with those products.

When we look at that -- and here's the first one that we've looked at. A different plant with the same herbicide. This is now fomesafen and on flax. You can see when we go from that medium to coarse we get almost a 30 percent drop off. For those of you online that know or have worked with flax, you know that it's a very upright plant. It's got very small leaflets. It's very difficult to wet, and it's difficult to get the droplets to stick to that leaf surface. So, for contact herbicides that can be quite a problem.

And we see that. As the droplet size got larger and larger, we lost that coverage. And you can see the control now dropped nearly 30 percent, and that's extremely significant. And even our practitioners in the field, if you're walking different fields that would have a plant with that type of weed species or with that type of morphology, you would see that difference in control when you went from a medium to a coarse spray.

Okay, the next one we're looking at here is now clethodim. The clethodim I've used the volunteer corn or the corn population that we planted, the artificial volunteer corn. And the reason we aren't looking at the amaranth or the flax now is because this is an ACCase inhibitor, so it's a product that's only going to have grass/weed control activity. So, here you can see that that medium again pops, but it's kind of all over the board.

And this, again, comes down to the fact that there's very, very specific interactions between the weed species we're targeting and the herbicide we're using. With corn, as many of you know, we've got a very narrow leaf, a long leaf, and that leaf is not perpendicular to the application. So that leaf is going to bow out and droop down, making it easier for larger droplets to hit that leaf surface and runoff. So, even though we've got a systemic, we're seeing that there's a drop-off in efficacy as we get these larger droplet sizes.

With that variability that we saw on a couple of those that really had a scratching our head as to exactly why we're seeing so much variability when we go from one spray quality to another. So, we took a step back and reevaluated what we were looking at. And we revised the study a little bit to look at things from a little bit of a different perspective. And this is where the light bulb really started to go off for us.

Okay. So, for this study what we did is we added carrier volume in as a factor. So, for this one, we looked at four different herbicides, four locations across Nebraska, and we looked at multiple different carrier volumes. Again, plot size and the ratings and stuff like that were identical to what we'd done the year before, but this time we really had interest in looking at contacts versus systemics.

So, the four herbicides we picked the first was Roundup or glyphosate. I've put three GPA. That's just a reminder that the minimum volume for a Roundup PowerMax application is three gallons per acre. The other systemic herbicide that we chose is down the bottom of that list. That's 2,4-D, and that one had a minimum of a 10 GPA application on the label. The two contacts you'll see have higher minimum volumes. The first one being glufosinate or Liberty at 50 gallons per acre. And then lactofen or Cobra at 20 gallons per acre. Those contact-based products, we need that volume to get the coverage.

And then the in terms of application, we looked at five different carrier volumes. And the way we put those carrier volumes out, the five GPA was put out with an XR 11001 nozzle at four miles per hour. The seven and a half gallons per acre application was, again, an XR 11001 at four miles per hour, and the 10 gallons per acre was identical to that.

When we went to the fifteen gallons per acre application what we saw was -- or what we did is we went to an XR 110015, and then for the 20 gallons per acre and XR one 11002 at 4.8 miles per hour. And the reason that we switched nozzles for those last two is that we're using a backpack sprayer to make those applications, so we had to increase the pressure to keep that nozzle and ground speed the same. At a point when you're using a CO_2 tank to increase pressure, you get to that point where you're not comfortable going any higher. And we also would exceed the nozzle manufacturer’s recommended pressures for those applications. So, we put a larger orifice size on so that we get that flow rate. If you're walking an application on, we could have we could have walked slower. But we really didn't want to do that because we felt like it would be more difficult to get a nice uniform application. So, we go to that little bit larger orifice size.

Now I go through all that explanation on those five treatments because it's really important in terms of what we found. Because as we increased pressure -- as we talked about in the first webinar on ground applications -- that droplet size is going to get smaller. So, when we went from five to seven and a half gallon per acre, we got a smaller droplet size. When we go from seven and a half to 10 gallons per acre, we get a smaller droplet size. However, when we increase that orifice size, we were able to drop pressure back down and increase the flow rate giving us a larger droplet size -- and then the same thing from 15 to 20. Meaning the 10 gallons per acre has the smallest droplet size of all of the applications.

Now when we looked at the results for this -- here you can see that efficacy, again, on a scale of zero to 100. We've got five GPAs listed out side-by-side with the shading going from white to black. With the 2,4-D what we see is no statistical difference between the five different GPAs -- and the glyphosate, on the right-hand side, the exact same thing. Those are, again, our two systemics.

When we look at the two contact-based products, you can see that we get an increase in efficacy as we increase the volume going from 5, to 7.5, to 10, to 15, to 20. Again, as we increase that volume, you can see the efficacy continued to increase. On velvetleaf, we've got a plant that's got a very hairy leaf surface. Having that additional volume allows us to get that droplet past those leaf hairs to the cuticle.

When we looked at amaranth though, we saw a very similar story. Slightly different in terms of we didn't get as much statistical separation. And you can see that the efficacy really started to plateau out when we got to about 10 gallons per acre. But, again, two systemics--no statistical difference. Where in the two contacts we see increased efficacy as we get those higher volumes.

Okay, now in this next slide I just really wanted to show you what we were seeing in the field. So, this is the lactofen on the on the left at five gallons per acre. And the lactofen treatment on the right at 10 gallons per acre. And we've now put a little red circle around the amaranth. And you can see on the left a very very different situation than we have on the right. If we were to show you the picture of the lactofen at 20 gallons per acre there wouldn't be any amaranth. We got a complete control at that point.

So, what you see, in terms of that amaranth control, for example, is a difference that would show up in the field. This would be a respray on the left. Where on the right, we probably wouldn't notice the weed escapes there.

Okay, this is the last slide related to this study, but this is really where the rubber meets the road. What you see is the amaranth control coupled with the droplet size for each of those four herbicides across the five carrier volumes. And what we've done, we've plotted out the droplet size in the black boxes, and we've plotted out the control in the black triangles. For the two systemic based products, what we see is, again, that droplet size is the smallest with 10 GPA, and the droplet size gets larger as we go either up or down in GPA. With the exception of the glyphosate at the five gallons per acre down in the right-hand box. And I'll come back to that in a moment.

When we look at the two contact-based products, what we see is that the two -- again the droplet size is the smallest at the 10 GPA, but the two lines are no longer paralleling each other. So, we don't see that control following the droplet size. What we see is the droplets there the control, or those black triangles, as we move right in those two boxes getting higher and higher. Or as we move left those lines are dropping lower. Indicating as we increase droplet size, we're increasing control. Or increasing volume, we're increasing control. Or, where we're moving to the left, we’re decreasing volume. We're losing control with those two contacts.

So, the real take-home on this is that if I'm dealing with the systemic -- most of our systemics are -- we're going to manage or maximize efficacy based on droplet size. With the actually larger droplet sizes in many cases being more efficacious. With our contacts we're going to maximize efficacy by increasing the carrier volume. So, that really starts to take us down a little bit of a different path.

So, the next study I want to talk about is a study that we conducted in North Platte. What we did is we used a Capstan Pinpoint system line. This is some work that another one of my former students, Dr. Tommy Butts, conducted. And what we did is we used that pinpoint system or the pulse width modulation system to deliver specific droplet sizes. So, what we would do is we go into the wind tunnels in the lab at North Platte, determine what treatments would give us a specific droplet size, so which orifice size and pressure gave us a specific droplet size. Then we would take that to the field to deliver a constant volume across a uniform or single tank mix.

So, just to give you a little bit of a feel for what we were looking at. We looked at 150 to 900-micron droplets at both 5 and 20 gallons per acre, using both glufosinate and dicamba. On this slide you can see the combinations of nozzle, orifice size, and pressure as well as the ratio of that pre-orifice to exit orifice in those [unintelligible] nozzles that we use to deliver each of those different droplet sizes. So, going, again, in 150-micron intervals from 150 to 900 microns.

And this next slide shows you the combinations that we use to get the same treatments for a dicamba tank mix. Now I do want to point out that for both the glufosinate and the dicamba we did not use any spray adjuvants, knowing that those spray adjuvants would affect the droplet size for those applications. And when we dug into this what we found is that we see different droplet sizes for both the glyphosate. And there are different optimum droplet sizes for both the glufosinate and the dicamba based on the GPA. In this particular study what we're seeing is that the optimum droplet size for the dicamba application of five gallons per acre was a 150-micron treatment. At 20 gallons per acre, droplet size was 600-microns. Whereas for the glufosinate a five gallons per acre 300-micron treatment seemed to optimize efficacy, and at the 20 gallons per acre the 450-micron droplet seemed to optimize efficacy. And we'll talk about why we think that happened in a moment.

Okay. Oops, sorry, I just skipped past a slide. Sorry about that. When we ran the -- when Doctor Butts ran the models for that data he used a GAM model, which you can see here on the slide, and basically, what we're trying to do is account for the deviance of that regression model. And you can see that change in droplet size in this particular study. We could account for about 57 percent of the variability in efficacy across those different treatments for both a five and 10 gallons per acre. And you can see we've got some funny things happening. And part of that is due to one of the treatments that we had at one of the locations.

Now when we show you some pictures of this, you'll see very clearly. For the glufosinate application that 300-micron droplet at five gallons per acre I said was the optimum treatment that we applied. You can see we've got a pretty good control. So even at five gallons per acre, we can get pretty good control with Liberty or glufosinate. But keep in mind that's a really small droplet size. It's going to have a really high drift potential. The one way that we can get into a little bit larger droplet size is to increase the volume. And if you think back to a couple slides ago, we said the 450-micron droplet was optimum at the 20 gallons per acre. By increasing that volume, we were able to increase that droplet size a little bit yet maintain or maximize the efficacy for that particular tank solution.

As we go from 300 microns down to 150 microns, you can see a significant drop-off in control. This is a lot of times due to drift or to applying droplets that're so small that they never really reach the target in a liquid form. As we get larger and larger droplets sizes -- you see going from 300 to 450 and then 600, 750, and 900 -- you can see that efficacy drop off. And on the large side, this is because we're losing the coverage.

Now here's the GAM model for the dicamba. Again, even less of the deviance explained with only 28 percent of that deviance now being explained by the change in droplet size for dicamba. And a part of this is due to the versatility of dicamba. What you see when you look at the pictures here; going from about 300 to 750 microns we see very little difference in terms of the efficacy. You can kind of see that pictures. And we even, at 150 microns, have a fairly significant control compared to the control in that left-hand box.

What we did see that was consistent across both the Liberty and the dicamba at five gallons per acre was as we got to that 900-micron droplet there's not much difference in that treatment versus the control. We've just -- even with a systemic based product got too large of a droplet size at too low of a volume to get coverage and control.

Now when we take those GAM models, we can actually predict what the optimum droplet size is across the entire range tested. So, we're basically drawing an interpolation between the data points now. And looking at that five gallons per acre for the dicamba you can see 150-micron droplet, the smallest one we applied, is optimum. Whereas we go up to the 20 gallons per acre we're now at our absolute optimal droplet size was predicted to be 626 microns or an extremely coarse. So, if I want to reduce drift in the case of the dicamba, I’ve got to increase the volume. If I want to reduce drift with the glufosinate -- again you can see the same thing, where five gallons per acres the optimum droplet size was 270 microns. And at 20 gallons per acre, the optimal droplet size is 488 microns. So increase that volume. I can increase the droplet size. That's maximizing efficacy. I can reduce drift.

Okay. So, this next set of studies that I want to talk about is really looking at tank mixtures, and this is some data that was put together by one of my current students, Jesaelen Moraes. And what we see here are four different species that we looked at horseweed kochia, lambsquarters, and grain sorghum. And Jess kindly put a note on here for me to remind you guys that the horseweed population or that conyza population that we were working with was glyphosate resistant.

And the different treatments that we were working with here, or different pesticides and adjuvants we were working with here, were glyphosate and with that glyphosate -- and this is not meant to be an endorsement of any of these products. But the glyphosate product we used was

Roundup PowerMax. And I tell you that because different products are formulated differently. So that brand name or that product name is very important in terms of understanding droplet size or some of those components.

So, for glyphosate we used Roundup PowerMax. For lactofen we used Cobra. For the fomesafen and we used Flexstar, and then with the AMS we used a dry AMS product at 17 pounds per 100 gallons. That was added to all treatments in the study. And the crop oil concentrate was added. It was an 80 percent crop oil concentrate. And it was added to all treatments except for the glyphosate alone.

In this study we looked at a range of different nozzles: XR, AI XR, TTI, from TeeJet. We used Guardian air and a ULD from Hypro, and we used a TD XL nozzle from Greenleaf or Agrotop. And you can see the different features of these nozzles. All of them are air induction nozzles with the exception of that XR extended range nozzle. And those nozzles give us a wide range of different droplet sizes.

Now as we start -- and I'm going to push through this next study a little bit quickly. So, kind of, stick with me. Here are the application parameters. We're using 187 liters per hectare, 9.6 km/h, and 276 kPa on a three-nozzle track sprayer that we have in the lab. Nozzles were spaced 50 centimeters apart, and the application was 50 centimeters above the plant.

What we -- when Jess summarized the data from this -- you can see the ANOVA here -- the only interaction that we saw significant was the herbicide solution by weed species. When we got the three-way combination of solution by nozzle by species it wasn't significant. So, what we did is we pulled the data across -- the data that's presented in this presentation across those different nozzle types.

Then -- the first thing I want to show is the droplet spectrum. So, if we start thinking about drift, understanding of the droplet spectrum is going to be very important. For the glyphosate alone, that's where we saw the smallest droplet size. Any time we had lactofen or fomesafen in the tank we saw an increase in droplet size for the XR nozzle. The same thing is true for the Guardian air, with the exception of the glyphosate plus lactofen plus AMS plus COC. And then, again, that same treatment for the AI XR.

When we look at the TD XL, again, the same thing we see with the fomesafen and lactofen. A decrease in the droplet size when we add that glyphosate to the tank. With the ULD and TTI, we see a decrease with fomesafen, and we see an increase with the glyphosate plus fomesafen in terms of droplet size. So, a little bit different reaction in terms of droplet size going back to what we talked about in the first webinar. Where we have these interactions between nozzle type and tank solution.

This is just a line graph showing the same thing. This is looking at the percent fines now. You can see the XR nozzle, that yellow line is the highest, and we're seeing the most driftable fines with that nozzle regardless of tank solution. And for most of these, you see a little bit of a bump here where we have glyphosate alone, and that's due to those surfactants through those different nozzles. Again, you can see things like that purple line or that AI XR where we're getting a little bit slightly different interaction there. So, keep in mind, as we think about applications, there are interactions between nozzle types and tank solutions.

Okay. So now we want to take this data. And we've talked about how different individual contacted systemic products work optimizing efficacy. This time we're going to use the Colby equation to try to explain what we're seeing from what a tank mix response. So, the Colby equation accounts or is the response of different herbicides applied singly, and then used to calculate expected responses. And then they're compared to the products when they're applied in combination. And that comes from a paper back in 1967.

So, basically the way we calculate that -- you can see the expected here -- is product one times product two divided by 100. So, basically what we're looking at is we take that first product, and we subtract out. We then take 100 minus that, giving us that observed response for the first herbicide. For the second product, we have 100 minus that second product, where Y is the observed response for that second herbicide. The expected then is 100 minus E. So the expected response is that response of the herbicides A plus B.

So, just an example of what that looks like, here we have observed response for an herbicide A at 30 percent, B at 50 percent and A plus B at 80 percent. We go through the equation, so we go 70 or 100 minus 30 giving us X1. Fifty or 100 minus 50 giving us 50 for Y1. And then divide that by 100 gives us 35. E then is 100 minus 35, or 65. So we plug that 65 into the expected, and what we see here is a synergistic relationship because the observed at 80 is significantly higher than the expected at 65.

If we have something where we have a product A is 30. Product B is 50 now. They're identical to the previous one, but now the combination of the two is 65. So, 65 and 65 are the same thing. We've kind of worked through that equation in the same way. We now have an additive interaction.

And, lastly, we have now this, again, product A 30 percent, product B 50 percent, but when we combine the two, we get 42 percent control -- expected 65. We work through our equations the same way we did for the first two. We now have an antagonistic interaction, where that expected control should have been higher than what we were actually observing in the field or in the lab.

So, we took those different treatments that we had. You can see in the observed values here for glyphosate alone on horseweed and kochia, the lactofen alone, the fomesafen alone, and then you see the tank mixture of glyphosate plus lactofen and glyphosate plus fomesafen. We've got our observed responses.

You can see a decrease in the overall efficacy of those PPO inhibitors for horseweed, and a decrease in the efficacy of the fomesafen and for the kochia. So, we kind of get a little bit of an idea of what we're expecting here. I plug in the numbers of the products by themselves through the Colby equation, calculate our expected values, and what we see is for the horseweed with the lactofen plus glyphosate. We're expecting 65 percent control. We observe 42 percent control. We see an antagonistic interaction there, and the same thing with the fomesafen plus glyphosate.

When we looked at the kochia, you can see the expected is very similar to the observed for the glyphosate plus lactofen. We've got an additive interaction there. However, when we look at the fomesafen plus glyphosate you can see we expected 88 percent. We got 77giving us an antagonistic interaction there.

And what we have here is just pictures at 14 days after application. And you can see the different nozzle types now on those kochia plants. So, you can see the untreated with the glyphosate, glyphosate plus fomesafen tank mixture with the XR and TTI nozzle, and the same thing with the fomesafen applied alone. So, you can see the fomesafen alone has a much better control than when we added the tank mix. So that glyphosate is antagonizing that activity of the fomesafen.

When we look at common lambsquarters and grain sorghum, again, you can see our observed control, 92 and 98 percent for glyphosate alone. When we look at the lactofen and fomesafen we have less control, but when we look at the tank of the two, we've got better control than either of the PPO inhibitors alone. The same thing for the grain sorghum. However, when we look at the expected values -- because of the activity that we're getting out of the glyphosate, again, we've got antagonistic interactions on lambsquarters and the antagonistic interactions on the grain sorghum. Even though we're getting 96 to 97 percent.

Now I know I've got some people out there that are technically savvy in this area, and when we get that high of control, we do want to be a little bit careful. When we get that high of control of any one product alone, or in the 90 percent range here with glyphosate, we want to be a little bit careful how we interpret that. And we probably don't -- or we may not have a true antagonism here because of that.

Okay. Again, what we find -- here’s some different citations in the literature looking at the glyphosate and PPO inhibitors, and kind of confirming what we observed in the greenhouse. We see a reduction of glyphosate absorption and translocation due to the use of those products.

All right, so now that we've kind of worked through that. I apologize it's a lot for one hour. We've now exhausted the hour. I've got a few take-home messages here. They're very similar -- they're the same ones that we had on the first webinar. I want to tell you that these are really important takeaways related to drift and drift management, and it's been an exciting series to go through this.

Some of the take-home messages that we just don't want to forget. Particle drift can be influenced by formulation. We saw that over the series looking at both ground and aerial applications. We've seen that nozzle selection has the greatest influence on particle size. Again, true across the ground and aerial applications. Although remember, as Brad talked about in the last series, that application airspeed really becomes another layer of complexity for those aerial applications, as does that deflection angle of that nozzle on the airstream. Adjuvants can be used to reduce drift potential, but you want to be cautious of which nozzles and application scenarios you're pairing those up with.

Please remember there's no substitution for common sense. If the winds blowing droplets are going to move. We see off-target movement with every application, so we want to talk about how can we minimize that off-target movement in every case. We need to be paying attention to what's around us, and drift, like we said, is going to happen. Mitigating drift in every way possible is absolutely essential as long as we're not giving up efficacy.

With that, we're going to open this up to questions. So, I'm going to turn this back over to Khue for a couple notes on logistics

Khue Nguyen:
And now we will go through your questions. In balancing drift versus efficacy, when does droplet size get too big? For example, droplets too large to be retained on the target.

Greg Kruger:
Yeah, thank you, Khue. And thank you for the question. This is going to be one of those where it's really important to recognize that that question is incredibly difficult to answer. It's going to be a product or tank mix specific, and it's also going to be target specific. So, kind of like what we showed today, different species are going to respond differently to different droplet sizes, as are different species response to different herbicides. In some cases, like dicamba or glyphosate, as we showed, we can move to a large, extremely coarse, or even ultra-coarse spray qualities without giving up efficacy. In other cases, with some of these contacts, we've got to be really careful that we don't get those droplet sizes too large because we will see that control drop off. So, it's a difficult question to answer simply because there's so many interactions going on there.

Khue Nguyen:
Next question, what do you suggest as an approach we can take to optimize the balance between drift and efficacy? Particularly where there may be a lack of information like that presented.

Greg Kruger:
So -- another good question. Thank you whoever submitted that one. As we start to dig into this more, we're seeing that there's so many interactions that that's difficult to say as well. What I would say is, as we think about the different types of products we're using, we do know that we can increase volume in all cases, and everything we've seen to this point though we don't dilute out that effect. It's possible that we can get incredibly high volumes and we wash out the activity of that pesticide. But in that normal range for a broadcast row-crop ground application going from five to 20 gallons per acre, we didn't see any loss in efficacy there. So pushing those higher volumes is one of the best ways to start to do that.

Khue Nguyen:
Okay, next question, for plant protection products applied directly to cultivated crops, do these same principles apply? For example, increasing the volume to increasing droplet size in order to maintain biological efficacy.

Greg Kruger:
So, I am not sure I completely follow the question, but I'm going to try to answer based on my understanding of the question. So, when we talk about different crops that we're applying to it's

really about what weeds or what pests we're trying to control in those crops. So, again, those weeds -- whether I'm spraying them in a corn-soybean field or I'm spraying them in pasture or some sort of a specialty crop, we're going to see that the efficacy is going to be same. We're going to have that same efficacy relationship across different crops. When we see -- the principles are going to hold true in terms of volume. Where we tend to see this difference is that if I go to, for example, a turfgrass application what I consider a low volume is going to be very different from a ground application. So, there it's going to get us into a whole lot of different scenarios. We probably don't have time to cover everyone, but in general, we do see the same thing going from one place to another.

Khue Nguyen:
Next question, if you get optimum control from either 300 microns and five gallons per acre or 450 microns and 20 gallons per acre, would you as a farmer really choose the larger particle size and larger volume? You're putting down four times the product.

Greg Kruger:
I'm not putting down four times the product. I'm putting down four times the water. We would keep that product rate the same. Yes, it's an inconvenience to put down more volume, but if I can do it in a safer a more efficacious way -- or safer or more efficacious way I'm going to look to do that. And I say that -- it's a little difficult to say because I grew up on a farm. I know how precious time is, and the more volume we've got the less acres we're going to cover with a single tank load. So, the temptation is going to be really strong to go to that 300-micron five gallons per acre application, but, again, from a stewardship, responsibility, and from a sustainability standpoint, I'm going to look to move that applications to 450-micron, 20 gallons per acre application.

Khue Nguyen:
Next question, is there a clearinghouse or resource where we can find the type of information presented here to help in making application management decisions?

Greg Kruger:
Another good question. The only place I know to go was really some of the stuff that we presented today or the pesticide label. I really didn't emphasize that second one well enough today, but if you dig into the pesticide labels there's a lot of really good information. We talked about that in the first webinar. If you look in that pesticide label, there's information on how to apply products. So, it tells me to use specific spray qualities or minimum GPAs. Whenever I have a question about how to optimize that pesticide application the pesticide label is going to be the best place to start.

Khue Nguyen:
Thank you for joining us. Have a nice day.

[end of transcript]