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Hi, I'm Andy Robinson. I'm an extension potato agronomist at North Dakota State University and the University of Minnesota. Today, we're going to talk about recognizing herbicide injury in potatoes.

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Herbicide injury in potatoes has become more common over the last few years. And I don't know if it's because people are recognizing the symptoms of herbicide injury more, or if it is just happening more often, but at the end of the day, it's causing more and more problems and it needs to be understood and hopefully resolved by our understanding of what these herbicides can do to potatoes. So there's a lot of different ways that potato injury is manifested from herbicides. So when you have carry over and seeds, typically you'll have poor emergence, poor stands. When injury happens during the season or the growth of the potatoes, you'll see injury to the leaves and your symptoms may include things such as chlorosis, necrosis, leaf growth can be disrupted or retarded, and also tubers can become misshapen and malformed from this type of exposure. You may also get discoloration symptoms from soil carry over for parasites. So sometimes it's very difficult to determine, but we're going to talk about different modes of action and different ways that potatoes can become exposed to herbicides today.

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So why is herbicide injury a problem? Well, there's a whole list of things that it can do here. You can have reduction of stands. You can slow your canopy closure, leaves become damaged, which all of these things will reduce the amount of sunlight that that plant uptakes, which is going to reduce the amount of energy that is developed within that plant to grow those tubers. Tubers can also become malformed and unmarketable and all this can result in reduced yield and quality. And if herbicide residues are present in tubers at the time of sell, they can be unacceptable and those potatoes tubers can be rejected for food safety reasons.

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So how our potato is exposed to herbicides, you may ask. Well, it's usually either through the soil, which is soil carryover of herbicides, or plants being exposed in some way or form. Once that injury is found, it is often quite difficult to determine the source, but it is possible in some cases, usually when I get called out to a field and there's a herbicide injury case, we can go out and we can look at symptomatology. We can test leaf tissue or tubers for herbicide residues and figure out what herbicide is there in the plant. But again, sometimes you don't know where that came from, and that can be difficult to determine, but you can get that positive result from the lab, but then what do you do and how do you handle that is always the question.

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So I like this figure here from a book, it just kind of shows a different fate of herbicides that they can have. So when a herbicide, any pesticide is sprayed, there's a lot of different things that can occur and when we talk about herbicide injury, we often hear the term herbicide drift. Drift is probably the most commonly used term, probably because it's the most commonly seen injury or injuries seen most commonly with drift of that herbicide, but there's a lot of different other ways that herbicide injury can occur. And one that people may not think about sometimes is actually tank contamination, which this doesn't show. But I think I see a lot of things that are a result of tank contamination. Tanks that are being cleaned out properly, or a little bit of herbicide being left in the bottom of the tank. And people thinking that, Oh, I can just dilute it by adding more water and more product. But point is that herbicides have to go somewhere. Either they, the soil and they are absorbed within the plant, the soil can also adsorb them, microbes can break them down. They can get leached through that soil profile. You can have

volatilization through the air. They can run off. Some compounds are broken down quite rapidly by sunlight. So something has to happen to those services when they are sprayed.

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So here are probably the most common ways potatoes can become exposed to herbicides, soil, carryover, seed contamination, drift, or inversions, which I grouped together, contamination of equipment, volatilization, and misapplication. There are many others, like I said, I've had cases where people have had contaminated water, for example. Uh, but I'm not going to go into those because they are more rare.

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So let's talk about soil carry over. Soil carryover is basically when that herbicide is sprayed in a previous year or crop on that field. And those compounds of the herbicide reside in that soil. They're not completely broken down by time. A crop is planted and the level of those residues in the soil is high enough where it can cause injury to that plant. So typically, most all herbicides that have some type of soil carry over, are going to have label language specific for those crops that it could potentially affect. Some are more vague than others, but an interesting one that we deal with in North Dakota and Minnesota a lot is Raptor. Raptors commonly used in dry beans and the rotation restriction for potatoes. It really varies based on soil pH and the amount of water on that soil. So there's either nine months or there's an 18 month restriction based on again, pH and water. And this is important to know, because if you plan a potato crop on a field that has had a herbicide that could cause injury, you could potentially lose all of that crop in that field. And there is no ability to get any of that back if you willingly knew that you planted into a field that had a herbicide that could cause injury. So if you're renting land, which a lot of growers do, make sure, you know, what previous herbicides have been used and check with the labels or your local extension weed specialist can help you understand what herbicides have carry over potential. We've even seen cases here where a contaminated tank being sprayed on a previous crop, uh, could leave residual herbicides causing problems. If you wanted to look up the NDSU weed guide, there's a list of plant back restrictions for all the different herbicides that are labeled in our state, but you probably have something similar in your state.

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So herbicide movement, when it's from a soil carryover situation was going to happen in these situations, is those plant roots, as they explore the soil and they take up water and nutrients and other materials from that soil, it will also take up those herbicides. And typically those types of herbicides that are taken up from the roots are going to be translocated throughout that plant, or even within the tubers if they reside in the soil enough.

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So this is a nice figure here, from Dr. Mel Allen that shows the different types of absorption and translocation of different herbicides. And just to give you a picture of how some of these work, this is what different herbicide modes of action look like. So you have, what's called a foliar contact, such as Reglone or diaquat while this use, that's only going to kill what it touches. So that's why we use high water volume. You've got those that are root contact, or they're going to affect the early growth and cell development of plants and weeds. So such as Treflan, dual, outlook or like that. Those that are Xylem mobile, they're going to move up within the plant such as metribuzin. And you can use that soil applied or foliar, but those typically are taken out by the roots, up into the plant and moved. Then you have those that are pholem mobile. They're going to go to the growing points. A good example of that is

Roundup or glyphosate. And then you have those other Xylem and phloem mobile, mobile moving both directions through the plant, such as matrix and Dicamba.

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If you suspect soil carry over, what types of things do you look for? Typically in a field with soil carry over herbicides, you're going to see very specific patterns within the field is typically a very large area that will be affected from that soil carry over. If that whole entire field was sprayed with that herbicide, you might see it across the whole field. If part of that field, maybe half or a quarter of that field shows injury and the other half or quarter or three quarters may not show as much injury. Maybe that load of herbicide use was higher on that one end the field, or maybe the soil type might be slightly different where it didn't get broken down as quickly. But typically you'll see large chunks of area where all the plants are going to show some effect from that herbicide. So common symptoms we see with soil carryover, you'll see slow emergence. Some compounds can cause prune or Brown or bottlebrush roots. Stunting of plants is common. Some, some compounds, even though there is soil carry over, you may not see those symptoms. So those plants are six to eight inches tall as those roots explore the soil more. And it takes up more of that compound in the, in the soil. Um, but anyways, this, depending on the herbicide and the toxicity to the plant, sometimes it can grow out of it. And sometimes they don't. Sometimes you have very ugly tubers that are very much malformed and unmarketable if it's really bad.

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So here's this an example of a field of soil carry over. You can see on the main section of this slide, the plants are small stunted. And if you look over to the far right side, you can see how the plants look a little bit healthier and bigger.

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A close look at these plants. This is what you see. Leaves are very small and the leaflets or tips are kind of in a pointed or a skinny formation. Uh, this is actually the result of a compound called imazapyr.

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Here's more pictures of what this does. So this is an ALS inhibiting compound, and it can cause what we often call the bottle brushing of roots. As you can see here very nicely, and this is what it did to these potato plants. And the tubers were also malformed as a result.

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Here's a place in the field where actually a sprayer was cleaned out. It was, uh, a field actually, we were doing research in and, um, you can see here, this is the effect of Raptor at a, at a very high rate, from a clean out in the field. But again, the plants are small. They're stunted the leaves aren't fully grown, even see a little bit of chlorosis from that soil carry over.

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And here's another field of a growers where they'd had applied Clopyralid in a previous year, but this is a low spot in a field. So it seems that a lot of that Clopyralid , uh, moved with the water to this low spot and caused a much higher concentration just in this one spot in the field while the rest of the field looks just fine and normal.

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And this is an up close look of what the Clopyralid did to these plants. This is your typical epinasty symptoms that plant growth regulators will call us on plants.

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So here's something to look at. Do you think this is soil carry over? Or could it be something else? Well, in this case, actually this is not a herbicide injury issue. This is actually a result of a very high concentration of Pratalenchus penetrants, which is root lesion nematodes, and the left side, where the plants are growing. That was actually fumigated with Metham sodium. And on the right side, there was no fumigation used, just showing the difference of what fumigation could do on a nematode.

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These are what the plants look like when the nematode attacks them at such a voracious attention. You see that the sprouts actually end up dying. They get secondary pathogens entering into the sprouts and kills them. So the point of this is that when we're looking for herbicide injury, not everything is a herbicide. And that's part of what my job is, is when I'm helping growers as determined are the symptoms they're seeing from a herbicide, or is it from something else?

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And this is what the plants look like from that root lesion, nematode. And typically, they have shortened stolons and, uh, kind of a higher tuber set.

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So exposure to foliage is another way that potato plants can be injured. And so there's a lot of ways this happens, sprayer, contamination, drift and inversions, volatilization even misapplications. So the important thing here is make sure you follow the tank clean out instructions. You don't want to drift a big thing. I always tell our growers is you need to communicate with your neighbors, especially if you're seed grower, those neighbors need to know you're growing seed potatoes. And that crop is very expensive and valuable to replace. And they do not want to drift on that because it's going to cause them a lot of problems and a lot of problems. And then the other important thing too, is a lot of times when I am speaking to growers to potato growers, they're often not the ones spraying the fields. They often have other people that are doing the spraying. And so it's important to communicate with them, the importance of good spray technique, cleaning out your tank. You're not spraying in poor wind conditions where you're going to have an increase potential for drift or volatilization.

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So typically when we get herbicide contact to the foliage, it's going to either touch the foliage and damage what it hits or it's going to move such as a translocating herbicide. And so the most common groups of herbicides that we see injury in potatoes are the ALS inhibitors, which is a very large group, we have growth regulators. And then what we call the EPS P synthase inhibitor. That's just glyphosate, but those are going to move to the strongest sinks, which means it's going to move down into the tubers or roots and to the growing points. That's where you're going to see your symptoms.

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So again, like I said, that's where you look, you look at the new growth. Look at the newer leaves. The tubers or roots or leaves are typically pretty telling the only time where maybe the leaf symptomology doesn't work, the best would be really late in the season prior to harvest. Sometimes those leaves will not express injury just because they're pushing so much energy down to those tubers.

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So these symptoms will typically show up within a few days to a few weeks after exposure really depends on the compound and the amount of product that they're exposed to the higher, the amount of product. Typically the faster it will show. Um, these symptoms are really based on the type of herbicide. So for plant growth regulators, that would be your 2,4-D, Dicamba, clopyralid, picloram, around those types of herbicides. You're going to see what we often refer to as epinasty, that's the twisting of the leaves, the stems, a cupping wrinkling of the leaf margins, and misshapen tubers, and this typically happens quite rapidly within a few days to a week or 10 days, maybe glyphosate, um, very commonly used in the Midwest for many crops. And so we do see in potatoes, unfortunately, a fair amount. It's going to be a little bit slower acting, but you're going to see yellowing of the youngest leaves and it can cause crack tubers. And then our ALS inhibitors are also going to be very similar to glyphosate. They're going to be very slow. It might take a week or two, maybe even three in some cases to show symptomology, but, um, again, very similar to glyphosate.

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So what do you do if you find herbicide damage? Well, it's important to act immediately when you do see it because symptoms typically will dissipate over time as new growth continues and or you forget where it's at in the field. So, NDSU has a nice extension article about documenting suspected herbicide injury. You can look that up if you'd like, it's important to you to check with your state department of ag to determine steps. If you need to document this for any future needs that you might have to cover yourself. Every state has different rules. So contact your state department of ag and work with them. If you need to have them do an inspect inspection. So as I often tell our growers as extension, I'm here to educate and help people understand what went wrong or what the problem is and what it means, but extension, we educate the state. They regulate, I have no authority to go in and look at spray records or to determine exactly how it came. That's the state's responsibility. That's why it's important to get them involved.

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So if drift happens in a field, typically you'll see a pattern along the edge of a field. And typically that pattern will be strongest the closest to the neighboring field, and it will dissipate as it goes further out into the field.

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So here's a picture of a drift situation. Um, you can't really see it, but on the other side of that fence, there was corn. And on the left side, of course has potatoes. There's Dicamba sprayed on the corn and it drifted over into the potatoes.

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And this is the type of symptoms we see classic plant growth, regulator epinasty or twisting of the leaves and stems.

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Here's another drift situation that was a soybean field right next to this potato field. And then they were spraying glyphosate on the soybeans. I was actually out there inspecting this field one day with the grower and they were putting their second applications with glyphosate, with the wind blowing directly to the potatoes. And yeah, these potatoes, they just lit right up like fluorescent yellow, especially on the edges with that glyphosate. But this is very common glyphosate injury symptomology. You'll see also the pattern here, you've got the very bright yellow leaves at the top of the plant, right near the edge of the

field, where they likely got the highest rate of glyphosate. And as you move across that field or into the field, the symptomology lessens, but I could find injury up to 200 feet off of that edge, just based on my knowledge and experience with this. It was easy for me to, here's another view of what this looked like.

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You can't see it, you know, on the slide very well, past five or 10 feet, but I could find leaflets on the upper canopy out there quite a ways to have injury. So sometimes to the drive by, and I say, Oh, that's not that big of a deal, but it's important to go out there and look and document these types of situations.

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Here's a less symptomatic plant from glyphosate. You can see a little bit of yellowing right here in this leaf. Um, but again, not very strong. This is what it looks like. Sometimes as you get further out in the field and it can be difficult to determine the difference between this or say iron or nitrogen deficiency sometimes, or even very, very rapid plant growth when you don't have as much chlorophyll in some of those cells, you'll get a little bit of yellowing.

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Some of the things that can mimic herbicide injury are drought stress. Oftentimes drought stress can cause what looks like a plant growth regulator injury, where it leaves will cup up and sometimes twist on the, on the petioles. Fertility stress can also cause discoloration and leaves like this picture shows that says potash deficiency and PVY. Because it causes the mosaic can often cause problems. So seed inspectors always hate it when a seed field is sprayed with matrix a few days before they go out and inspect because matrix can make that mosaic look as well. And so that's difficult. And then phosphorous acid. We've seen a lot of burn with that in our area. And sometimes that could be misdiagnosed or be a minute.

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So this is what a phosphorous acid looks like. Sometimes we get some spotted lesions on the leaves as a result of that spray application. This would probably result or be similar to something such as a reglone application where it's just a contact herbicide,

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PVY here you can see this plant. You've got the mosaic a little bit yellowing leaves. Again, this is PVY.

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And then here in this scenario, this is actually two of these are glyphosate injury. This is glyphosate injury in the bottom left and glyphosate injury in the upper, right. This right here in the bottom, right, is iron deficiency. So again, you can have some similar looking things, but it's important to determine what is the cause of that. And one way you can do that too. You can have call your local extension agent or consultant and have them come out and look at it. You can also take tissue samples and send them to a laboratory for analysis.

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So as far as tank and boom contamination, this is a great picture in soybeans Roundup on Liberty link soybeans. They didn't clean out either the tank or the boom and you can see exactly what happened when they didn't clean that out. See the tracks of spray are right there in the middle and as the boom cleaned out, they eventually didn't catch.

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So here's an example of picloram sprayed and it drifted.

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Here it is again, the cupping of the leaves.

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These types of plant growth regulators, a little bit stronger, this class, picloram and tordon and things like that. They're often used for rangeland, weed control, but you'll see pretty severe symptoms such as you can see the severe twisting and wrinkling of the leaves and the petioles in some of these.

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Picloram injury can be pretty ugly and nasty in potatoes as you can see.

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You can also get symptoms in the stolons. As you can see, some of these stolons are actually twisted and bent up as a result of this picloram on the tubers. They become malformed.

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These are russet Burbanks, and that is not how Russet Burbank should look. This pear shape is a result of the herbicide.

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So other herbicides for example, this is Raptor spray during the season on injury and tubers years of massive cracks, the plants. This is from research plots, but as you can see, there's significant cracking on these tubers.

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2,4-D is commonly used in fresh potatoes to enhance reddening color at a very low rate. But, uh, when unintended applications occur, you can get also injury. You'll see a little bit of crinkling of the leaves at a low rate, and even eyes on tubers can be deeper from this herbicide.

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And here's Dicamba on some reds, whites and russets, and you can see what types of injury symptoms is causing and you see severe cracking and malformations in the tubers.

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So some mimic for tuber cracking. There's a lot of things that can cause cracking and tumors. Probably the most important thing is environment stress. Typically you get water stressed that can result in some pretty ugly tuber cracking and tuber cracking can be caused also by some diseases from stress. So there's a lot of things that can cause to for cracking. I think the important thing for herbicides, if you're concerned that it's a herbicide, again, you can take some tuber samples and send them to a laboratory for a test to determine if her type is in there.

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Misapplication is another thing that can happen. This is an interesting field where they sprayed, uh, Liberty around the whole field. And then they realized, Oh, this isn't a Liberty link field. And anyways caused damage to a lot of plants.

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Seed contamination, it's really important to know where your seed comes from and make sure it is free from herbicides diseases and other issues. If you're concerned, do a laboratory tests on your seeds and check them or do a, grow up, have some, pay someone to do a grow, or you do a grow out. But seed here's probably the most important thing that can affect your crop than anything else at the beginning of the year. That's why it's very important to start with good seed and have a good, healthy crop to start with. Cause you can never make a bad crop, a good crop. If the seed is bad, it just doesn't happen. It's very difficult to do. So start with good seed.

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If you have herbicide symptoms in that seed, what are you going to see? These are common symptoms of glyphosate. You see a slow and erratic emergence patterns. You see some plants that are highly affected. Some that are moderately affected. Some that aren't affected at all. It's a really weird scattering effect throughout the whole field. Sometimes you get multiple stems, malformed leaves, uh, there's a lot of different things that can happen from glyphosate.

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Here's an example from a field, as you can see here, you've got plants of all different sizes and you have a lot that don't even have emerged plants within those.

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This is what the seed pieces look like. This is glyphosate symptomology and large stems, multiple stems coming out of eyes.

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Again, some more pictures of what this looks like on a different variety.

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Here's a case where there's two different seed lots planted on the same day. And the one on the left obviously has some issues in the one on the right looks much more normal.

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The one on the Dicamba is also a herbicide that can carry over and seed. When it grows out the next year, you often see a slow emergence, twisted bent stems. The leaves are often crinkled or cupped and just different amounts of this injury will occur between each seed pieces because every seed piece takes up a different amount of herbicide as, as they are pulling energy down from that mother plant.

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And so even with seed and Dicamba, you see a random scattering typically in the field where some look really effected. Some don't look affected all in a lot of in-between. So here's an example of an ugly plant on the left, and that's about looking at plant next to it. Then it really affects the plant in the middle and you get different stages of injury.

Here's some more pictures of the twisting from Dicamba

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And here's two different varieties and you can see even a little bit of a varietal response, but again, you got pretty significant twisting coming of those early leaves. And what's interesting too, on some of these you'll know some of those first leaves, they look fine, but as that plant continued to grow the injury express itself more.

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And even we've seen on some of these stems that they'll get coiled as a result of the herbicide.

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How do you sample for herbicide injury? If you suspect it in your potatoes? The first thing it's important to do is to use clean gloves in the bag because you don't want to have a false positive testing for herbicide residues goes down to parts per billion and even parts per trillion. And just a little bit of residue on your fingers or old pair of gloves can be picked up. And so I like to use those disposable latex gloves, which are very common nowadays. I'll take a pair of those out that are brand new and clean and a clean brown paper bag. And that's what I used to sample. I did multiple samples, six to 10 plants typically that are the most effected plants, the most ugly plants, because you want to find a positive to figure out what it is if you're trying to figure out what's causing that injury. If it's from the seed, if you suspect seed borne, I dig up tubers that haven't emerged that aren't rotted, but troopers that are under the ground, because that also eliminates a potential false positive from something that may have drifted over top. Once I have the tubers, I wash away the soil and dry them. And I like to take pictures of the symptoms, both in the field and of what I picked and label them. I put those bags on ice, ship them overnight to a respectable laboratory and have them run the test for it.

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So what do we do once we know this? So what can we do to help us prevent herbicide injury in our potatoes? Well, number one, know your field history, make sure you're not going to have carry over issues. Two start with good high quality seed. Three use good spray techniques. A lot of our seed growers actually have a separate sprayer. They use just for potatoes and then another spray for their other crops just to eliminate any potential issues that they could have from carryover in the tank, retain contamination. And then if something looks suspicious document, you can call me or send a picture. If you have question or find your local extension agent or agronomist to help you with that.

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Thanks for your attention today. If you have questions, feel free to reach out to me. My email and phone number is here on the slide and I'd be happy to answer any questions that you have. I hope you have a great day. Thank you.

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