Spore Wars Transcript

We have a Star Wars motif, but this is not science fiction, we're going to talk about what's happening in fields all over America. We call it "Spore Wars" and I hope to convince you that it is, indeed a war between growers and fungi.

The earth's environment does have a dark side. There are about 20,000 species of plant parasitic fungi that are out there, and that attack crops. They withdraw nutrients, and they have to do that in order to complete their life cycle. What happens is that the crops die, the crops rot, and so we have episode one where we talk about the fear of the fungi.

So this is an apple that is pretty far along with an infection. I think it's black rot and the fungus has gotten in it. You can see it's sucked a lot of nutrients out and crushed the cells, the cells have died. This is just a mass of rotting apple flesh.

Here's one of those 20,000 parasitic species. These are tiny little mushrooms, and you can see that they are ejecting spores when the conditions are right in the spring: the humidity, the temperature, rainfall. Each one of these cups can release 30 millions spores. It only takes one spore to start an infection.

This is a peach that survived the winter and was infected by a fungus that causes brown rot. Then in the spring, the cups grow out of this mummified peach and each one of these cups can release 30 million spores to infect all peaches in a new orchard.

This is my very favorite fungus, this is cedar apple rust. And here on the east coast, where we have cedar trees, if you look up in the cedar trees, you can see these tiny little rust balls. In the spring, they absorb water and they begin to swell up.

And they look like this. And so up in the cedar tree, you have these cedar apple rust galls that's swelled up and it's got these tendrils down. One engorged gall can release 100 billion spores. And they release so many spores because one of those spores has to find an apple tree to complete its life cycle. It goes through a year on the cedar tree and a year on the apple tree.

This is what happens on the apple tree. You can see a bunch of cedar apple rust spore have reached the apple foliage and what's happened is that they have penetrated the apple foliage or that apple itself where cells are being crushed and nutrients are being withdrawn. They will complete their life cycle by going back to the cedar tree.

This is a growing problem in America, phytophthora in cucumbers and other cucurbits. And what happens with these diseases is that you have one spore that landed on that cucumber and started an infection, but then what happens is that the infection on a single cucumber, you can get 840 million spores that can go an infect all the cucumbers in the field.

This is sort of the microscopic level of spores at work, doing what they do. When they land on tissue of an apple, cucumber, whatever, you can see the spore growing a germ tooth. You can see the tube that grows out when the conditions are right. They find an opening in the plant tissue and they are going in because they have to get to the nutrients within the plant in order to complete its life cycle.

This is a cross section of a blueberry. This blueberry has been infected with a fungus that causes mummyberry and you can see the fungus that's developed at the top of the blueberry, where it kind of looks like an alien. It's crushing cells and withdrawing nutrients.

Now a lot of the spores can travel long distances. I've talked about them being in a field, but wheat rust spores don't make it through the winter up in North Dakota or South Dakota. They make it through the winter in Southern Texas, and the winds pick them up in the spring and as you can see them in the skies of North Dakota or Kansas as they move north.

Just to summarize about spores, it's usually in the early spring, where you have countless numbers of spores. I'd love to give you a number, but the number's just gigantic. It's not even a number that we can even comprehend how many number of spores are floating around in the environment. And most spores land on surfaces that they can't even infect. They land on cars, they land on buildings. We inhale a lot of them. It's only those spores that land on susceptible plant tissue that causes a disease, and they germinate and establish infection.

They do find their target. These are estimates from the Department of Agriculture from a series of studies they did on plant disease in the 90s. You can see that USDA estimates that for every year, every acre of strawberry is infected with the grey mold fungus. Every acre of peaches is infected with brown rot. Every acre of cranberry in the east is infected with early rot. Every acre of apples in the east is infected with scab. I want to make the point that these aren't just random things that happen every so often. The USDA estimates that for these common fungal problems, they find their mark on every acre.

So we're going to talk a little bit about history now. Uncontrolled plant disease epidemics, influencing the outcome of wars, causing the death of millions of people, contributing to the downfall of civilization, and as an aside, permanently changing the drinking habits of France. These are all things that we have learned through studying history. This is episode 2, revenge of the fungi.

We'll start with the Roman Empire. The Roman Empire was built on the notion of "free bread and circus". The population got a free loaf of bread and they could go down to the circus at the coliseum. Wheat was their most important crop. They grew wheat really well particularly in the Mediterranean and northern Africa.

Now, you can see these little reddish rust spots on the wheat. Well, the Romans didn't know what it was, they didn't know that it was a plant disease. They knew that when

they got these spots on their wheat, they got lower harvest. They didn't know that it was wheat rust. They called it rust because it looked like a rusty spot. What did the Romans do? They did what they always do, they set up a rust god. They had a god of rust that they would pray to, "please spare our wheat crop". They thought it was the god that inflicted this on them. Robigus was the rust god; he had his own temple. And on every April 25th, they would march out of Rome, they'd have a little red dog that they would slaughter, and pray to the god. That was their idea of trying to control plant disease. They did this for 1700 years. It's not something that they did for a few years. It didn't work.

In about 100 AD, the weather in the Mediterranean Basin changed quite a bit. It was very cool and wet. And there were very severe outbreaks of wheat rust. Wheat harvest went down which caused food riots and famine. And if you read the history of the fall of the Roman empire, wheat rust, uncontrolled plant disease was contributed to the fall of the Roman empire.

Let's bring you up to date. What do we do in America? In the United States, if growers find a lot of rust spores in their fields up in Kansas, Minnesota, North Dakota, they spray fungicides. And the data show that you can take a field that would get an 80% infection of wheat rust and knock that down to 2% with fungicides. So that's how our growers control this problem at the present time.

Now let's talk about drinking habits in France. Grapes have always been very important. If you look at it historically, in the 1840s, there were tens of millions of grapes in France. They produce a billion gallons of wine a year. They kept out foreign drinks, the demon rum, all those sugary drinks, whiskeys and malts were kept out. The wine grape growers had a monopoly in France.

But then something happened. In 1848, they saw for the first time the powdery mildew fungus. And now they've gotten the microscope so they can actually see the fungus. This was something that the Romans couldn't do. And they certainly could see what it did to their grapes. For the first time, they got powdery mildew.

Here's what happened by 1854. There was a 75% decline in their wine production and they lost 150 million gallons of wine a year due to this fungus. It was uncontrolled. The price wind doubled. They dropped all their tariffs. The French had to have their alcohol. And all the demon rums, the whiskeys, and malts got their monopoly back.

They did solve their problem with powdery mildew. They solved their problem with the first fungicide. The first fungicide being sulfur. They can dig sulfur crystals out of the ground, pulverize them, and turn them into a nice powder. The French discovered in the 1850s that if you spray powdered sulfur onto grapes, that it would kill 100% of the powdery mildew fungus.

So that's what they started doing. This is a chart showing wine production in France. As I mentioned, between 1840 and 1855, they lost 75% of their production. They started

spraying their grapes in 1858 to kill powdery mildew fungus and by 1860s, their production had gone back to normal. The point here is that in the last 150 years, the French have been spraying just about every grapevine in France with either sulfur or another fungicide to kill this fungus. It's a fungicide that works very, very well.

And to bring you up today, what are we doing in the United States to control powdery mildew? Well, this is a picture of a helicopter spraying sulfur in CA. Our growers in CA produce a half a billion gallons of wine every year, 100% are treated with fungicides to control powdery mildew. 40 million pounds of sulfur still being used. In California, this wine grape industry started in the early 1900s, so it's been sprayed about a hundred years. We've never had wine grape production in CA without sulfur or something other fungicide being sprayed to kill powdery mildew.

We're talking about one of the granddaddies of plant diseases: potato late blight fungus, a fungus that's changed the course of history. You can see the fungus itself, these lemon shaped spores. The rotting potato is something to hold and to smell. If you have chance to smell a potato that's been infected with the late blight fungus, it's not very nice. It's just a slimy mess.

Potato late blight started the in United States and in Mexico. In 1844, growers and university people began to see that there were rotting potatoes and they didn't really know what was causing this. But you can see some of the losses. There was no protection against this. This fungus came in 1844 and rotted 50% of NY's potatoes and about 20-25% in the east coast.

In 1845, the fungus had made it across the Atlantic. You can see the little white dot that sits on top of Brussels. That's where the fungus first came into Europe and you can see through 1845, it spread. And so there are rotted potatoes in Belgium, France, and into Spain, and into Italy. And by mid-August, the fungus had reached Ireland. And so there are rotted potatoes all over Europe.

Just a word about Ireland. It's a beautiful country. Perfect conditions, lots of healthy population. 1845: their population went up to 8 million people. The peasant population was totally dependent on the potatoes. That's all that they fed to their animals, their livestock, their farm animals. They were totally dependent on this crop.

Here's what happened in Ireland, this is in the history books. In 1845, the late blight fungus got there in October, 40% of their potatoes were rotted. In 1846, the conditions were perfect for late blight and 100% of their potatoes rotted. All of their potatoes in Ireland rotted that year and this is a population that's totally dependent on potatoes.

So the Irish potato famine changed the course of history in Ireland and in the United States. 1.5 million people died. 1.5 million people moved to America, mostly in the United States. They lost a total of 3 million people out of a population of 8 million.

This is when plant pathology gets born, and when scientists around the world start looking for ways of killing the fungi very seriously. They dug something else up out of the ground, and that's copper sulfate. Again, a very simple chemical structure used to kill fungi.

What they found was that the best way to use copper sulfate was to boil it with lime. So in villages throughout France and England, they had these town squares that had these vats where they would cook copper sulfate with lime, and there would be a mixture called the Bordeaux Mixture named after a province in France. They began to work with this as a way of killing the fungi.

It worked pretty good. In France, they did experiments. This is really the beginning of plant pathology, and they did these experiments side by side, and they said, "Gee, if I don't spray with Bordeaux mixture, we only get one potato. But if we do spray, we get 5 potatoes." There was a 400% increase in potato yields. United States began to get in the act at this time to with the birth of experiment states in universities. 20 years of tests at the University of VT, where they looked at Bordeaux, all the things that we take for granted: when do you spray, what rate do you spray it, what formulation did you use. They worked on this for 20 years and what they saw was a 64% yield increase in potatoes as a result of spraying the fungicide.

Pictures like this were very common in the early 1900s. One of the things that I stress to audiences is that we've been spraying the potato crop for 100 years with fungicides to kill the late blight fungus. It's not something that started last year or 10 years ago, we've never had a commercial crop in the last 100 years without spraying like this. And so spraying with Bordeaux mixture was very common in Europe and the United States.

And then World War I comes along. Germans shooting at one another in these trenches. The impact that this had on plant pathology was that all the copper that was in Germany was used for the war effort. You needed it for shell casings and electric wire. The Germans didn't have any potato fungicide available in 1915-1916. All the copper was going to the front. Potatoes were really important in the diet of the German people. So what happened?

Well, in 1916, an uncontrollable late blight epidemic in potato fields in Germany. 700,000 German civilians started to death. They were counting on a bountiful potato crop to get them through the winter. Their potatoes rotted because they didn't have a fungicide. This is just what happened, worst case scenario. There's no fungicide, there are no crops, and then 700,000 people died. There was also an important morale weakening factor for the German army. You know, you're in the trenches and you're getting a letter from back home that your mom and sisters have died because they didn't have potatoes, because the copper's in your shell casing.

Let's bring you up to date on the late blight fungus. I'm sure that a lot of people are aware of what's been going on in the last 10 years or so in the United States. There are two mating types for the fungus. There is the asexual type (A1), the lemon shaped spores

clone themselves, this is asexual reproduction. It's fairly simple fungus. But there are really 2 mating types, the A1s and the A2s. When you get those two together, you get a really tough new kind of spore, a spore with a very protective cell wall.

We were fortunate in the United States for many years. Prior to 1992, there were no A1 and A2 mating types in the United States. All the mating types were A1s.

So wouldn't you know that strange things would happen in NY first. That's where they first began to see that in 1993-1994 the matings of A1s and A2s. There were potato losses, there were a lot of potato growers that were coming to EPA and asking for section 18s, new ways of dealing with this problem.

In 1995-1996, A1s and A2s spread throughout the country.

In 1996-1997, at this point, they have displaced all the A1s. All we've got in the United States are the A1s and A2s. We still have our potato crop, we still have a bountiful potato crop and this problem is under control.

And it's under control because growers in the United States have significantly increased they usage of fungicides. This is data from USDA. If you look at fungicide use rates in the early 90s when they just had A1s, 2 lbs/acre in Oregon, North Dakota, and Washington. And now they are spraying 10-12 pounds an acre. So it's a problem that's under control because fungicide use has really gone up in potato production in the last dozen years to take care of this new problem.

So now we're going to shift gears and talk about synthetic chemicals. In the 30s, synthetic chemicals being born and these are new chemicals never previously found on earth. They have entered into our everyday lives as plastics, pharmaceuticals, and detergents and some of these chemicals were found to be lethal to fungi. So now we have Episode 3, the chemicals strike back, synthetic chemicals made in laboratories.

These were the first ones, very simple structures and patented by XXX scientists in the 1930s. They are XXX and XXX, these are fungicides. They didn't catch on right away. They thought they were fungicidal, but they weren't immediately used. It took a cataclysmic event.

The cataclysm was World War Two. The War department asked two questions, again looking back at history, "what amount of fungicides are used by U.S. growers? We don't want to have happen in the U.S. what happened in Germany where they ran out of copper." The War Department said "Tell us how much copper you need, and we'll make sure that you have it. The second question that the War Department asked "Was there a way that we could increase food production by doing a better job of controlling plant disease? We're losing ships. They are being torpedoed." The War Department got very concerned that we might need to increase food production, and to quickly do that, we need to control plant diseases.

So as an answer to the first question, there was a report that was put out by the War Department in the mid-1940s, where they said that the amounts of fungicides that are being used by American growers in the 1940s was 300 million pounds. That's copper and sulfur. Potatoes, that's coming in at 56 million pounds of copper. For apples, that's 92 million pounds of copper and sulfur. The War Department agreed to the 300 million pounds that you will need to manage disease.

The second thing that they did in the 1940s was that the War Department got together with the Department of Agriculture and said "We want you, the Department of Agriculture, to take all these synthetic chemicals that are being manufactured by XXX, by Dow, by Dupont, and test them to see if they would kill plant diseases. So you can see that one of the most prominent stations was in CT, and in CT, 6,000 chemicals were tested to see if they were fungicidal.

One of the diseases they looked at was potatoes, the late blight disease. They are working with Zineb at this point. Zineb is doing a much better job than the Bordeaux mixture in controlling the late blight disease. It's more efficacious at killing the spores. There was a yield increase of 25-35% when using Zineb over Bordeaux mixture.

Growers started using the new chemicals, from using the Bordeaux mixture to using the new chemicals. You can see exactly when they switched. 1949-1953, that's when they switched over. And you can literally see in this slide that we've got Maine potato, it happened in NY, you have it in Michigan. They were growing 20,000 pounds of potatoes, and that's pretty good. But with the new chemistry, that popped up to 25,000 pounds. The new synthetic chemicals, they were much more efficacious than the old fungicides.

How about apples? This was a fairly common spraying of apples with lime sulfur in the 1920s. There were not EPA requirements for protective gear. These guys would come in during the evening. This stuff was just horrible to work with, but lime sulfur did a wonderful job killing the fungi. Unfortunately, it also damaged the trees: the leaves, the roots.

So in the 1940s, again, CT scientists worked with Ferbam. Ferbam is still out there, it's still being used, but it was the very first fruit fungicide. What they found in their controlled experiments in the 1940s is that they had a 41% yield increase when they used Ferbam instead of sulfur, because Ferbam was kindler and gentler. The synthetic chemical was kindler and gentler to the apple tree. It didn't damage the leaves, roots, or bark. The tree was just healthier and happier and produced more apples.

And again, the growers in the United States switched to synthetic chemicals and you can see the impact on apple yields. In this chart, we tracked pounds of apples per bearing tree. U.S. apple trees were producing about 50 pounds per tree for a long time, and then we switched to a softer chemistry to the Ferbam and Thiram, the yields went up. That's because the new chemicals were kindler and gentler to the tree, they were healthier and they produced more apples.

So this kind of summarized fruit disease control in the United States, it's kind of a benchmark for us. In the 1850s, for peach brown rot, there wasn't anything that they could do. They just took their losses. Down in Georgia, they would just figure that they'd lose 75% of their crop every year to rot. They would go through the orchard, and they would look at 4 peaches and throw away 3 of them because they were diseased and they could take 1 peach to market. So without any control for peaches at all, they lost 75% of their peaches. By the 1920s, they had gotten those treatments and got those losses to 13%. And now with sulfur and synthetic chemicals, maybe there's a 1-2% loss that they would expect. This is the progression made in the United States, moving from no control to synthetic chemicals.

90-99% of the acreage of most fruit and vegetable crops are sprayed every year, and some of our crops are sprayed 10-15 times every year. We're borrowing from Kill Bill here and Star Wars, and this is episode 4: kill the fungi. We're not making any bones about it, the chemicals are being used to kill the fungi.

Fungicide spraying, this is in a potato field. This is production agriculture at its finest. There's a huge sprayer that's going to go over this field 10-15 times to kill the late blight fungus. We estimated in our study that U.S. growers spray about 131 million pounds of fungicides annually. The first number to try to remember, back in the 1940s, growers were spraying 300 million pounds and now they're spraying 131 million. So the older chemicals (the sulfur and copper) had to be used in really high rates, at about 10-15 pounds an acre. The new synthetic chemicals, maybe 0.1 pound per acre? There's been a big reduction in fungicide use in the U.S. with new chemistry.

Alright, spore wars. This is a scan from an electron microscope of a XXX crystal. This is a substance that's never been found in nature before, invented by scientists at Diamond XXX. It's formulated in such a way that it has fungicidal properties.

Here's spore wars at its most basic. We have apple tissue here, and you can see the apple scab spore. The arrow is pointing to a crystal of XXX that's close to that spore. What happens is that the spore beings to grow its germ tooth and it absorbs some of the fungicide, the fungicide goes in and kills the spore.

That's pretty straightforward. We have spores that are alive on the left and then spores that are dead on the right. What's happened is that the fungicide has been absorbed by the spore and the fungicide goes in and shuts down some sort of cell life process and kills the spore.

Theses are potato leaves. The ones that are on the right have been dipped into some sort of fungicide and the ones on the left weren't. The ones on the right were protected, and they blasted billions of spores on these leaves and they were killed. The ones on the left, you know what happened. And the spore gets in, the spore penetrates, the spore starts to suck nutrients out of the leaf. It's very simple. You can kill the spores or you can have the spores kill their foliage.

The fungicides that are used today are very, very effective. These are strip trials in Georgia peanut leaf spot. And you can see non-treated, there are no green leaves on those peanuts. Peanut leaf spot have destroyed all the leaves. You can see where they've been treated and you have nice green foliage because the fungicide has killed the fungi. And the difference is 2,000 pounds per acre of peanuts. And you get a ton more if you spray with fungicides.

And so the fungicides that are registered now and used by our growers, they are very, very effective. I showed you mummyberry in blueberries and it's not something that you have to worry about because the fungicides that are registered and being used kill 98-99% of the fungus. Efficacy has to be very high because you got so many spores out there. The efficacy has to be way up there in the 90s.

Okay, one of the big agriculture stories in the last 10 years has been the rise of organic farms, and the press often refers to these organic growers not using pesticides at all. The reality is that these organic growers actually do use fungicides. So this is episode 5, the dark side of organics, but you know, there are people in the agrichemical industry that don't view it that way. I'm going to talk about why organic growers use these.

This is a picture of apple scab in the northeast. And again, there are apple scabs in every orchard in the NE, and the organic growers need to do something. They can bring their apples in looking like that, so Rutgers University did a nice study of what's going on in apple orchards in the NE. Organic farmers are spraying 10 gallons/acre of lime sulfur and 12 pounds per acre of wettable sulfur. These are permissible because these are natural and not synthetic chemicals. Now, we don't have yield data, we don't know how much yield they are losing because they are spraying lime sulfur. Let's not kid ourselves. You're not going to grow organic apples in the NE without spraying fungicides.

Organic wine grapes out in CA. This is powdery mildew. The University of California has done a nice budget for organic wine grapes out in CA, and they estimate that they use 66 pounds of sulfur per acre. I showed you that picture of the helicopter spraying the grape vines, that could have been an organic grower.

How about organic strawberries? For powdery mildew, the University of California estimates that every acre of organic strawberries is sprayed with 45 pounds of sulfur. Why? Well, when we look at this, we see a whitish, powdery growth, but it's very nasty, it's very dangerous to the strawberry plant. With no fungicide control, the organic growers would lose 35-60% of their strawberries.

Now one disease that the organic growers do not have a control for is gray mold. We've probably all bought a pint of strawberries home from the store and they look fine, but after leaving them in the fridge for a few days, they get this fungal growth. Well, the organic growers do not have any sort of fungicide spray to control gray mold. What they do is remove diseased fruit from the field. It's like from the old days in Georgia where the organic strawberry growers send workers and they spend 225 hours per acre, and they pull the diseased fruit off of the plant. 3 out of 4 strawberries don't make it because they

are infected and that fourth one does. They are spending about $2,000 an acre just to removed the diseased fruit because they don't have any fungicide like copper or sulfur to control this problem.

How about potatoes? I mean, those A1 and A2 mating types are out there in the organic fields as well. Again, let's not kid ourselves. The national sustainable agriculture information service's website says that organic potato growers can use copper to kill the late blight fungus, but copper isn't as efficacious so they have to spray more, about 9 to 15 times in our conventional fields, a lot of fungicide use there. But the organic farmers probably spray more than 9 to 15 times. That's probably something that doesn't sink into the general population, but it is a fact. Organic potato growers have to kill this fungus, and they spray more frequently than conventional growers.

This was quite a scandal in the United Kingdom a couple of years ago. The BBC said "Oh my gosh, we just found out in our own research that organic potato growers are spraying copper." This was really shocking to them. They said that consumers assume that sprays are not used on organic farms. It was a shocking front page story for them.

Let's leave this discussion of organics with this: The American public needs to be better informed about the fungicide spraying practices of organic growers. Somebody out there in the press, some pictures of organic growers, let's just be real straight about how important these things are, and not mislead the public and say that they don't use pesticides because they do!

Now many crops have been grown in the United States free of certain fungal pathogens, but weather has changed over the years. We've got long range transport of fungi and changes in the fungal populations. I've got examples of fungi marching across America and causing problems.

So I have Eddie Brant's favorite problem. Hops are Eddie's favorite crop. Out of those hop cones comes the flavor. We grow enough hops in the United States in the NW to flavor 9 million billion gallons of beer, and we export them too to Germany. Well, the center of hop production in the United States used to be in NY, but uncontrollable mildews wiped out NY's hop production. They had no defense back in the 1800s, and what they did was move the hop production to the Pacific NW. Let's get it out of the east and they don't have these fungal problems in the Pacific NW, and let's grow the hops out there.

The powdery mildew fungus made it out there. Here, you see these hop cones, they have this reddish glow to them. They are infected with the mildew, totally unacceptable for brewing. They produce off flavors in beer, that's a total loss. Powdery mildew first appeared in the NW in 1997, and, again, I'm sure that many of you are familiar with growers needing section 18s to deal with this problem and right now 100% of U.S. hops are treated with fungicides. It's a problem that they simply have to have a chemical to kill the fungus.

Eastern filbert blight. All the eastern filbert trees were killed in the 1920s. We grew filberts out here in the East. It's a nasty disease. It's coming down the tree. Look at those branches, it's killing the tree. Filbert production moved out to Oregon in the 1920s and the fungus wasn't there. They also changed the name. They tried to fool the fungus by changing the name to hazelnuts. The fungus caught on and got out to Oregon in the 1970s. In the state of Oregon, I think I picked this up in a section 18 request to the Agency. Without fungicide use, 75% of Oregon hazelnut trees would be killed within the next 20 years.

I love this disease: bacterial fruit blotch. I love to linger on this picture because it's so nasty. It's a disease the first appeared in 1989. We never had this disease before. It turns the inside of a watermelon into a slimy mess. Growers have to use fungicides in order to kill the fungus before it gets into the watermelon.

Ok, we'll talk about some of the non-chemical methods of controlling plant diseases. And again, the plant pathologists have been using crop breeding for centuries, producing a crop that's resistant to the fungi.

There have been terrific successes. We have disease resistant beans on the left and disease susceptible beans on the right. Again, they blast billions of spores into this field and the beans on the left don't get the disease for whatever reason. Their cuticles might be a little thicker, maybe it's some sort of chemical that they are producing. The ones on the right get destroyed and the ones on the left don't. The problem is that the pathogen eventually evolves and eventually overcome the plant's defenses and so now you have a treadmill of crop breeding. The crop breeders have got to stay at work, and they are constantly producing new crop varieties just to stay ahead of the fungi.

And there have been some terrific failures that the EPA's had to step in and do something about. From 1960-1976, plant resistance took care of lettuce downy mildew. There was no reason to have fungicides for the lettuce downy mildew because the plants killed the fungi. In 1977, that broke down and fungicides had to be used. Plant breeders came out with new disease resistant varieties in 1988 and they worked for 4 years until 1992. And then it broke down again in 1989, and since then we've been using fungicides as a primary mechanism to deal with downy mildew. So there have been spectacular failures of crop breeding over the years as a main mechanism for dealing with these diseases.

We'll wind up by saying that fungicides have been used for centuries to kill plant disease. Our general impression is that the country doesn't really understand too much about these chemicals. The people of this nation don't really understand the value of these chemicals. Not too many people take plant pathology classes, and so now we say that it's time for a reality check. Let's look at the data, and trust what the data is telling us.

Well, first thing is that we've been using fungicides for 100 years. I don't have data that goes back where I can draw a timeline. There weren't that many pesticide use surveys back in the 1900s. What can I tell you?

American farmers produce enormous quantities of food. These are unheard of kinds of numbers. 44 billion pounds of potatoes every year. 27 billion pounds of tomatoes. 10 billion pounds of lettuce. Enormous quantities of fruits and vegetables.

And most of these acres are treated every year. Once again, it didn't start yesterday. It didn't start 5 years ago. It's been going on for 100 years. 94% of our potatoes are sprayed every year. 85% of the lettuce. 83% of the onion and on and on. These are numbers that you see in USDA surveys and it's been going on for a long time. And in our study, we estimate what would happen to yields of these crops without fungicides. The data are pretty clear, study after study. The report from the USDA says that there would be a significant reduction in fruit production. And so potatoes going down by 43%. We wouldn't be getting 44 billion pounds of potatoes, we get 22 billion pounds. That's still a lot of potatoes, but that would represent a 50% yield loss. Another way to think about this is that this represents the value of fungicides right now.

You can look at a plant, you can see a little black dot, a little brown dot. Well, do a cross section and be there when the spores come out, and it's an implacable foe. These are life forms that infect plants so that they can complete their life cycle. That's what they do. There's 20,000 species out there that infect crops. Fungicides are a main XXX against their spread.

And we wind up with this slide and simply say that there's a role for EPA and for Congress to think about that if the fungicides are so valuable, shouldn't the United States have policies that U.S. farmers have the fungicides that they would need in the future. That's something that the EPA will have a lot to say about. I think you know that certainly it's getting more companies to bring fungicides to the market and is that something that the Congress or USDA need to look at and say what fungicides do we make that we need to make sure that we have in the future.

All of this material is on our website. Our press conference will be on September 13th and we'll have press releases and all of the study with hundreds of estimates of use. We also did a major literature survey, about 900 references from the literature, where we talk about each one of the 50 crops and we tell you its history and biology of the fungi. That'll be going up on our website on September 13th.