SLIDE 1
This Steve Johnson, University of Maine Cooperative extension bringing you this brief update on *Dickeya* efforts from the recent past.

SLIDE 2
Dickeya is a seed issue. It comes on the seed. *Dickeya* doesn't do well in the soil

SLIDE 3
Dickeya centers around minimizing the bacterial contamination of the seed. The plants in the photo are infected with *Dickeya*. I have never seen *Dickeya* go top down, *Dickeya* goes bottom up starting with the seed. Seed can look great and have no problems on delivery, it may be infected or infected with *Dickeya*.

We have confirmed plants with *Dickeya* using PCR. There might be 4 tubers under the plant and one of them was mush. The other 3 tubers that looked beautiful and 2 of them were confirmed to have *Dickeya* internal to the tuber. You can't tell by looking at them. I'm not particularly thrilled with seed screening. A positive *Dickeya* test will tell you have it, but not the level you have. With a negative test, there is no assurance *Dickeya* is not present, as the sampling and grouping is not statistically set up to answer that question. A false negative may be dangerous.

SLIDE 4
Starting with *Dickeya*-free seed is what we need to do and everyone else needs to do going on with it.

Field loss without visible seed problems occurs.

Every time we'd get a hot spell, boom, another 3 to 4 percent a week would show symptoms.

It likes it hot above 75 degrees we had some of those conditions in May we got over 80 degrees. Yield reductions are as high as 100%.

It can invade root tissue one day and be found in stolons in 2 weeks.

SLIDE 5
I can't duplicate this level of lack of emergence. None of my research colleagues can, we have tried and tried to do this, but we can't. We have no idea how to get this.

I inoculated tubers with vacuum infiltrate 10 million bacteria were sucked it into the tubers. I still can't get this to happen. There's a lot of things we didn't know, but a few thing's we've learned on the way.

SLIDE 6
And so some of the things that were identified as key needs:

How to identify lots that have Dickeya?

How is it spreading within the grower, between growers, between states, how is it spreading?

What level of Dickeya in the seed is a concern, is 1%, is it 10% problem?

Chemical control, what do we have? What can we do to slow it down?

And lastly, how do we get it in the seed system?

I know how to get it out, but I don't know how it got in. If we don't know how it got in, we can't keep this from happening again.

I was gone the last three winters to in Australia working with the seed production authority. While I was there, Dickeya showed up as well as Pectobacterium parmentieri. Within less than a year, they identified the primary source, addressed it and limited secondary spread to the point it is no longer an impact in their system. It can be done, Science does work.

SLIDE 7
These are some things we have produced. These are available online; search for UMaine potato program and click on publications. There is also a Dickeya and Pectobacterium parmentieri fact sheet as well as the presentations from a November 2017 Dickeya summit.

SLIDE 8
Identifying seed lots with Dickeya, this is a publication that was an outgrowth of local Dickeya efforts. Questions continue: How we're going to deal with it? What are you going to do? How do you identify it? Because really no one wants to have it, no one wants to send it down the road.

SLIDE 9
We did a first report of Dickeya in Maine. We identified it, we went through primers, we went through several different proofs of pathogenicity, and published it in a professional journal. So at that point, we knew no longer question what the pathogen is. Jay has uploaded the type strain that's used for primer development for PCR work across many Universities and private research labs.

SLIDE 10
So how is Dickeya spreading?
It appears to be transferred by mechanical means of the seed lots. And the first question is oh, it's got to be seat cutter. That was the first thought.

SLIDE 11
And so we're looking at seed cutting as well as other area. Well, we spent a lot of time colleagues across the country discussing this, coming up with ways to try and solve that problem.

And so I took Dickeya infected seed, which were either naturally infected or I infected them myself. So I know that they were, and they were tested as such. And so I cut them, I cut an infected seed and I cut a clean seed. And I did irrigated and dry land, and the bottom line was I had zero transfer on seed cutting from the infected seed to a clean seed.

This was met myself included, with a lot of skepticism. That doesn't sound like a bacteria, that doesn't act like any other bacteria, that doesn't act like a Pectobacterium. The Pectobacterium and the Dickeya are in the Pectobacteriaceae group. They're a water group, they pretty much act the same, except for Dickeya doesn't always act that way.

SLIDE 12
So at this point, I had done clean infected, I had done them whole, I had mixed them together. I couldn't get them to transfer. And so my answer is no. Well, I needed to do more than one year of these studies, and so I did it a second year. And so this is where I had seed that was clean and cut compared to Dickeya-infected seed which was cut through and then clean seed cut.

First thoughts were the spread occurs like ring rot. If so, Dickeya would have been all over the place and it was not. And I had no difference in the bigger and statistically speaking no difference in the emergence. Again, this is second year data and I did irrigated, non irrigated on this, so this is four different trials on this.

The vigor of the Dickeya cut seed then the clean cut seed were not different – 93 vs 94% vigor

The emergence was 18.5 out of 20 seed pieces for the clean and 16.8 out of 20 seed pieces for the Dickeya.

SLIDE 13
So I performed it, I redid it, I redid it again. This was redone in North Dakota, it was redone in a commercial lot in Florida, and it was re-redone in a commercial a lot in Florida. And we've still not had any transfer whatsoever during the seed cutting operation. And frankly, I'm not going to do it anymore.

I've got three years doing it and I can't get it to transfer. The odd thing is when you cut the seed, you can get the bacteria transferred across the seed, but the seed never becomes infected or expresses symptoms. So technically, we're probably transferring the bacterium the pathogen, but we're not seeing the disease. We're not seeing any results from the seed cutting.

So the colleagues I have moved on as we are not getting Dickeya transfer during seed cutting.

SLIDE 14
Are there ways it's spreading?

Well, it's not spreading during the seed cutting, but is spreading. So what is it doing? How is it coming in?

SLIDE 15
I looked at rough handling, sometimes the recipients of seed do not live, breathe, and dream about potatoes, the way Maine growers do, and their handling, at times, can make me shutter a bit.

So I rough handled clean seed. I cut them, I cut them and rough handled them just as a check, and I did get some reduced growth. I had emergence going through this, so I can rough handle and I can beat at the potatoes and I can affect how they come out.

SLIDE 16

I continued the rough handling on Dickeya-infected seed. I had very good emergence, but when the Dickeya infected seed was cut and rough handled, I had a problem. The yield was substantially less when they were rough handled, and the emergence was substantially less as well too.

So at that point, the rough handling looks like it's a key going in through there. It appears that if Dickeya-infected seed are not handled like eggs, the disease will become more severe.

SLIDE 17
I have a concern with seed that are stripped out, small sizes that are in seed lots that are not grown to be small sizes. They're grown to be bigger sizes and these small ones they may be small because they're sick, they may have Dickeya, they may have Rhizoctonia, they may have PVY, they may have something else as well.

And so I'm not a big fan of growing a crop from these off-type potatoes. These are often handled more times, possibly leading to increased field symptoms similar to rough handling.

So, I planted strippers that were stripped out of a known problem load, and you can see on the emergence on 6/28/17 and 6/23/17. There's substantial difference. This seed is from the same infected seed lot, just small seed versus big seed. Since this was an infected seed lot, the smaller seed is smaller for a reason. And yes, the seed size difference carried onto emergence, vigor, and yield. So smaller seed that is infected and rough handling are going to exasperate the problem.

SLIDE 18
I was fortunate to have a hailstorm go through my plots one year. This is what the plots look like. You can see they're pretty well shattered and tattered. I was expecting a huge amount of aboveground spread, as occurs with traditional *Pectobacterium* blackleg, That was not the case. I've never seen Dickeya spread with windblown rain. If there was no aboveground spread with hail, rest assured that above ground-spread does not enter the epidemic. So, seed is still the source, and the pathogen is not spreading above ground, it's spreading below ground.

SLIDE 19
This is from an area that was flooded – I believe an end cap blew off the pivot. Weeds are the only green you see in the affected area. This was 4 to 5 days after the flooding. Before the flooding, the field had *Dickeya* symptoms in some plants

here and there, but not a total wipe out. The rest of the field went down soon after this photo was taken. The pathogen spread in the water from the infected plants to healthy plants. *Dickeya* is a very fast-growing pathogen in warm conditions.

SLIDE 20
There's a lot of work in Europe looking at that, and gone into spread dynamics up and down the role, and in Israel as well too. And so that's one way it is spreading. We're all forgetting all these big numbers. We've been told it's in the rainwater, it's in the rainwater. This is 2018, this is 2019. These are separate rain events that I collected rain from, and every one of them was run through for Dickeya and guess what? It's not there.

We're not getting it through rain. I'm done doing this as well too. I'm not going to collect rain for another year. Okay, that was a thought it's a good thought and we didn't have an answer to it. Now here's two years worth of an answer that we're not getting it through the rain. There was also comments it's coming in on moon dust. I can collect rain, I struggle with moon dust. I can't test it.

So at this point, it may be coming from someplace else, but it's not the rainwater. We also have sampled lentic and lodic moving in still water, all the way through Aroostook County for three years now. We've looked at the riparian zone, we've looked at the weeds, we've looked at all that we don't find Dickeya.

We don't find *Dickeya dianthicola*, we find some other *Dickeya* species, *Dickeya* aquatic and some of these that are water Dickeya. More aquatic ones but not *Dickeya dianthicola*. One exception it was a field in particular, that there was a containment a runoff pond in that field, and it was a massive Dickeya dianthicola problem.

And there was some in that pond in one sample, whether it moved through there and that pretty much is what most people in the world looking at this I've looked at this for this species for a while, it moves underground in the water, and that's how it got to that place. We drilled through the ice, we looked in the water, we looked for a long time, didn't find it. Don't think that's the source.

SLIDE 21
Again, we're trying to eliminate potential sources. Irrigation can it bring it in? Never found it in a borehole, we haven't found it into rivers, or the well water, we haven't found it in the rivers. So the answer is well, we don't think so. Will this

spread it? Will this make it worse? Yes and yes. Dickeya will spread when it is water soaked underground. It's not going to spread it above ground, we just don't get aboveground spread.

We'll get below ground spread certainly if it's saturated, and I've seen one in particular where the end cap blew off a pivot, and it just soaked a whole quarter. And it was a badly Dickeya infected field. And in 10 days, there was nothing but a couple of weeds in that area because it was underwater, and this is a water bacteria and it likes the water.

So it's not coming from rain, it's not coming from irrigation water, it's not coming from wells, it's not being transferred during seed cutting, and rough handling seed increases problems. We're right back to seed being the problem.

SLIDE 22
How much Dickeya in a seed lot is a problem? This is always the issue when trying to set up thresholds.

SLIDE 23
This is from field plots. I spiked the plots, putting in different amounts of Dickeya infected seed in a known ratio in there. And so I have a pretty good relationship between the more I put in, the more symptoms I get. Well, that's pretty intuitive. But again, it's a step that needs to be accomplished so we can move onto the next step in doing that, so sure.

SLIDE 24
This is yield loss from the same plots, without trying to explain the differences in here is this is where I mixed two varieties, and I separated them I looked at the yield. With the red line being clean seed and the blue line being Dickeya-infected seed. And interestingly, there was a rapid loss of yield at the low levels, and it tends to flatten out.

So at that point, just focus right here that low levels disproportionately reduce yields. I inoculated my plots again, in 2019. I vacuum infiltrated the seed to infect it. Unfortunately, Aroostook Farm was probably one of the driest areas around. There are some places got a lot more rain, some got a little bit more rain. We just missed every one of the showers went through. Bottom line, the season was extremely dry.

SLIDE 25

This is the one and only symptom above ground that I saw in my plots in 2019, and yet they were sick.

SLIDE 26
I made them sick, and you could see that they were sick sometimes going through there. So this is a sub lethal infection. They don't always do this, they're doing something to the plant. And again, a nonemergence is a catastrophic symptom.

So this is cut seed, this is 50% disease, 10%, 75, 25, 100% and 0, you can see some of the plots going through here just don't look good. And that's because they were infected. They didn't have any symptoms on the top, but they look like that.

SLIDE 27
So this is the yield in that same, where I started with 0, 10, 25, 50, 75 and 100% disease. And you can see that the bigger went down with more disease, and the yield went down with more disease as well.

Not a bad relationship at that point. So at what level is a problem? Well, that's what I'm not sure, this is the third year I've done this. I have a fourth year in the field in 2020.

SLIDE 28
So on this chart of the cut seed, the bottom are yield by size categories, it tends to have less big ones and more little ones, which it's intuitively obvious, but I need to go through and be able to defend that statement.

And again, we're back to the small strippers, the small potatoes coming out of there are probably they could be more likely from a Dickeya than a non Dickeya plant. So this is the overall yield going down with increasing Dickeya and this is plots per weight per plot. Typically, two to 400 bags per acre as seen in the field. This relates very closely to that, it's about 250 to 300 bags of loss during that period.

So this has been done in Michigan, it has been sampled in Massachusetts, among other places.

So we're getting loss without the symptoms.

SLIDE 29
This chart is of the yield going down with increasing infection. This is 10% it didn't seem to make that big of a difference. Potatoes they compensate very well at

eight to 11% stand loss, but start dropping off after that and you can see that very quickly at 25 going through there.

I had sub lethal infections and didn't have a lot of visible symptoms, we didn't have the catastrophic non emergence that we've seen in some areas. I just can't get that to occur.

SLIDE 30
The top row is a 20-plant plot harvest looks with no Dickeya, and the bottom row is a plot harvest with 100% Dickeya. One can see the disproportional numbers of tubers.

And the yields were low because we were so dry this year anyway. I thought things were looking good, I thought I was onto something.

SLIDE 31
And I also did this same plot on whole seed, not cut. And so this is 50, 10, 75, 25, 100 and 0. They don't look any different to me. And they didn't look any different in my ratings all the way through.

In fact, with the emergence, the plots with more Dickeya came up better with the whole seed. So with the whole seed it acted totally differently than did the cut seed. There was a reduction vigor, but the relationships aren't that tight with the more pathogen.

SLIDE 32
And again the same sort of graph as before but this time with whole seed. Emergence improved with Dickeya levels, but vigor decreased. No idea and that's why this happened. I do know that the cut seed is banged it up more than whole seed. Perhaps rough handling comes into play, with the cut surfaces and edges sharp., damaged.

SLIDE 33
The yields on the whole seed was pretty much across the board, didn't make much difference whether it had Dickeya or not, the yields were low there, what with the dry year.

SLIDE 34

In chart form, there are no real differences in yield.

SLIDE 35
I have been beyond unsuccessful in chemical control of this disease. I managed to slow the pathogen down with I think 2000, 2800X material, which will never happen. There just doesn't seem to be a bactericide that has an effect on this pathogen.

UMaine is looking at some resistance in plants and trying to incorporate that in, but that has not been.

SLIDE 36
Dickeya development it is always related to the starting amount; the more at the start, the more at the end.

Lower levels of Dickeya are needed to cause problems than traditional *Pectobacterium*.

There is scant data on the sub-lethal infections and their effect on the crop. This is an area that could hold many secrets. The sub-lethal infections appear in a crop where it just doesn't look right. It doesn't grow right, you expected a bigger yield, it just isn’t there.. I get this from here, I get this from out of state in places more so the past few years.

SLIDE 37
Yield loss chart from Dickeya presence in a seed lot. This is a commercial trial from North Dakota where it ends up costing about 100 bags per acre. I have measurements from Michigan that was 300 bags, one from Massachusetts that was 200 bags. And again, these areas didn’t express blackleg symptoms or the nonemergence, they just didn’t look right.

SLIDE 38
In some years, we there is a lot of stand loss from Dickeya, and some years there isn’t. I don't have consistent results in my research class either. That's very frustrating because they have to be done redone, redone.

SLIDE 39
How did Dickeya get into the seed system? That’s the big question.

In Australia, the best explanation for their initial outbreak is a seed grower planted gladiolus, which were plowed up and put potatoes planted. Nothing was really seen that first potato year, but by the time the potatoes were grown for the third year, there was probably 60% emergence at best. Again this incident was where the pathogen transferred in a location that did bulbs, a known host, and potatoes.

The whole-genome sequencing of those pathogens showed that they were the identical pathogen. It's always been around, but it jumped to potatoes and flourished. The pathogen per se is nothing new, it's just new in potatoes.

I worked with the Australian seed group to help set up the procedure to get it out of the system, and they did in in a year and a half.

So, how did Dickeya get into the seed system? I'm not sure anyone really knows.

SLIDE 40
We do know disease development is related to seed and inoculum level. If the seed lot doesn't have it, highly unlikely the crop grown from that seed will have it.

Lower levels of Dickeya than Pectobacterium are needed to do the same amount of damage.

Spread occurs with handling, likely at harvest.

It builds up in subsequent seed generations and tends to be present in or near the lenticels.

It does not survive particularly well in the soil, I'm talking months. Two weeks to a month, but likely much less in our situation.

It does well in water; it's a water bacterium.

Loss can occur without visible or apparent symptoms on seed. In fact, seed can look beautiful, but be infested or infected

Warm environments and high yield reductions are possible.

We don't see right now the catastrophic losses from *Dickeya* that we did a few years ago.

SLIDE 41
Seed testing procedures have been improved and standardized.

New pathogens have been identified. This has helped explain some of the observations in the field.

More robust and accurate primers Have been and are being developed.

Breeding lines are now being screened as are varieties. Interesting to note that Caribou Russet shows good tolerance to *Dickeya* infection,

Seed cutting does not transfer *Dickeya*.

Dickeya does not stay in soil for an appreciable time.

Rainwater is not a source of *Dickeya* contamination.

Surface water is a negligible source of *Dickeya* contamination. Water will help spread the bacteria, but really doesn't bring it into a field.

Chemical control has been unsuccessful.

SLIDE 42
Dickeya is wider spread than we first thought and it's still out there. I don't think *Dickeya* is going to go away.

Dickeya is more aggressive to some varieties than others. Hopefully that will be used in breeding efforts.

Sub lethal symptoms can change year to year.

Sanitation still works, Quaternary ammonia does work.

SLIDE 43
We don't know what causes those catastrophic losses. We have some ideas, but we don't know for sure.

We don't know how *Dickeya* got into the system. The pathogen may be getting into the seed system early. *Dickeya* is seed borne and doesn't survive over seasons in the soil.

We don't know what the thresholds for certification That's what we're trying to work on. We just can't get consistent symptoms in the field.

We just don't know how important sub lethal infections are in the epidemiology of the disease. We know they're important in yield loss.

SLIDE 44
I don't do this alone. This are just some of the people that help and do this.

SLIDE 45
This Steve Johnson, University of Maine Cooperative extension bringing you this brief update on *Dickeya* efforts from the recent past.