# 2020 Center for Produce Safety Research Symposium
# Session 3
# July 7, 2020

As a result of the ongoing Coronavirus pandemic, the 11th Annual CPS Research Symposium is being conducted virtually over the course of five consecutive weeks. In Session 1 held on June 23, 2020, we explored the use of computer-based modeling to help address two burning issues for the produce industry: understanding potential *Listeria* growth and persistence in whole produce commodities and the development of sampling strategies to support microbial testing needs (Key Learnings Session I). In Session 2 conducted on June 30, 2020, we expanded our knowledge base on *Listeria monocytogenes* and its persistence and growth on specific commodities and fresh-cut products and examined novel methods to control *Listeria* growth on food contact surfaces (Key Learnings Session II). In Session 3 we reviewed three final reports and one interim report on produce safety research projects examining mitigations for frogs that intrude on produce fields, the potential cross-contamination risks posed by co-managed farms where cattle and poultry are raised in close proximity to fresh fruits and vegetables, and the risks posed by *Cyclospora* when resident in irrigation water. An executive summary and the key learnings from these outstanding presentations and the discussions that followed are described below.

**Executive Summary**:

- ***A strategic fence can be good for everyone***. Intrusion by frogs and other amphibians into produce fields can be impeded by using fences equipped with a lip that prevents the frogs from climbing over. It is important that the fence be constructed of a material that is rigid enough to withstand high winds and tall enough so the frogs cannot just jump over the fence.
- ***Environmentally sound solutions can be found that fit with produce safety goals***. Employing fencing to control frogs is an example of a holistic, biological systems approach to solving a produce safety challenge. The biology of the frogs' toe pads and the recognition of the mating behaviors of frogs and their movements following rainfall events guided the researchers to develop an effective barrier and the ability to position the barrier strategically to prevent entry into fields. In this way, frogs remain an important part of the ecosystem and the grower has a solution to manage the risk of contamination.
- ***Vegetative buffer zones can be leveraged to control the movement of airborne pathogens***. Rapid growth vegetative buffer zones can be an effective tool in controlling airborne pathogens. A four-level vegetative buffer zone constructed with different height trees, shrubs, and grasses was shown to trap pathogens emanating from an adjacent poultry and dairy cattle operation on an experimental co-managed farm. Over the course of the two-year project, 11 produce samples were positive for STEC or generic *E. coli* and only one produce sample was positive for *Salmonella*, whereas 77 samples positive for STEC, generic *E. coli* or *Salmonella* were detected in the vegetative buffer zone, air, soil, and on manure in

the poultry and dairy cattle areas. This indicates that vegetative buffer zones can help control pathogen movement into produce fields.

- ***Once again, a "one size fits all" approach will not work***. Since no two co-managed farms can be identical in terms of risk, the deployment of vegetative buffer zones needs to be tailored to the specific characteristics of the operation. Animal types, densities, distances to produce fields, wind patterns, weather and other factors need to be considered when constructing buffer zones.
- ***Improved testing for Cyclospora***. New detection methods for *Cyclospora* have made it easier to detect in irrigation water sources. Over the course of three years of testing, an average prevalence of 7% *Cyclospora* positive samples was observed in Yuma area irrigation canals. Importantly, new DNA-based testing methods for *Cyclospora* do not distinguish between live oocysts and dead oocysts so the public health risk of a positive *Cyclospora* test is not clear. Since *Cyclospora* must pass through humans, the prevalence rate means that wastewater from sewage treatment plants or other sources containing human wastes are likely infiltrating the canal system. Adherence to good agricultural practices like inspection of irrigation water sources to make sure they are not compromised by effluents from sewage treatment plants and monitoring the health of workers and providing facilities and enforcing strict handwashing practices remain important tools for controlling this risk.

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**Key Learnings**:

1. **Using the biology of the system to identify farm-level solutions.** The subject matters for the research projects presented in Session 3 are varied but three of the four share a common theme in systems biology. Systems biology is an approach that focuses on the complex interactions within biological systems and relies on a holistic approach to experimentation and interpretation of results. Indeed, this theme of biological system complexity and the interactions between the production environment, weather, the specific microorganism's genetics and physiology, commodity characteristics and other variables has surfaced in previous CPS Key Learnings reports (Key Learnings Session I, Key Learnings Session II)

   We have all seen the pictures on the internet when a consumer opens a fresh-cut salad and finds a frog in the mix. There is no escaping the "yuk factor" but there may also be a pathogen contamination risk as amphibians have been shown to harbor *Salmonella* and STECs in previous CPS-funded research projects (Michele Jay-Russell 2011). Growers of leafy greens and other commodities have been frustrated in their efforts to control frogs from gaining access to fields responsibly, and with many of these crops harvested by machine, it is inevitable that some may get swept up in the harvested product and infrequently may find their way into finished products. ***Michelle Green*** from the University of South Florida, St. Petersburg, presented her project *"Engineering and ecological approaches reduce Pacific tree frog intrusion into leafy green agriculture"* dealing with novel approaches to control tree frogs by leveraging their biology to thwart or control their movements at the farm level (Michelle Green 2019) insert link to final report on CPS website). Key learnings from this project include:

   - Installation of a fence, even if it is just a standard silt fence, will significantly impact the movement of small vertebrate animals and frogs in a growing area.
   - Testing extensively at multiple sites in the Salinas Valley in California, a new fence design using lengths of standard aluminum flashing equipped with a 10-cm overhanging lip at the top prevented all frogs from climbing over the top of the fence 100-percent of the time. This novel fence design can be used to surround a water reservoir to prevent frogs from entering or exiting the space or can be used as a field barrier. The fence is rigid enough to hold up to wind. A standard silt fence commonly employed on farms costs approximately $0.35/linear foot while the aluminum flashing is $0.85/linear foot, so there is a cost differential. The key factor is the over-hanging lip that physically prevents the frog's toe pads from gaining a grip against the forces of gravity to get over the lip. No matter what material is used for the fence, the lip or overhang cannot make the fence top heavy or it will likely topple over if it encounters windy weather conditions; an advantage of using the more durable and rigid aluminum construction. It is recommended that the fence be at least 20 inches high so that frogs are not simply able to jump over the fence. A photo of the aluminum fence can be found below.

*Photo courtesy of Michelle Green, University of South Florida, St. Petersburg*

- Thermal imaging cameras (FLIR) were testing as a tool for tracking movement of frogs in production environments but proved to be ineffective.
- Acoustic interventions hold promise for redirecting frogs away from production environments and into designated breeding areas. However, these observations on acoustic interventions were made on a small sampling and not in synchrony with the optimal breeding season for frogs, so more study is necessary. Frog calling (males calling females for breeding) began in late January and was closely tied with winter rainfall. Rainfall or water availability is the key factor driving frog movements. Peak calling occurred shortly after the rains ceased at the end of March. Variation in rainfall and frog activity suggests that some regions may exhibit a delay to this general breeding pattern and that the breeding season may extend longer into the summer under wet conditions. Dispersing juveniles that were born in the spring or early summer underwent extensive egress from wetlands starting in May, with major exodus events in June, July, and August. It is important to examine region-specific rainfall and cover characteristics to ascertain likelihood of frog breeding and movements within the region.
- A picture-based field guide for amphibians in the Salinas Valley was developed for use by growers so they can immediately identify which species of frogs or other amphibians they are observing in their fields. For example, the Pacific tree frog was the target intruder of this study and a prolific climber, but other frog species are not as adept at climbing, and adjustments to fencing might be required or tolerated.

Continuing along the same general focus on controlling pathogen spread on the farm, ***Sid Thakur*** from North Carolina State University presented his project, *"Establishment of vegetative buffer zones to reduce the risk of STEC and Salmonella transmission from animal operations to fresh produce on co-managed farms*". This project is an extension of an earlier project by the same research team (Siddhartha Thakur 2015) where the team measured pathogen movement from animal production areas (APAs) on an experimental research farm that produces fresh fruits and vegetables in close proximity to poultry and dairy cattle operations. In this current project (Siddhartha Thakur 2019), the research was focused on constructing a vegetative buffer zone (VBZ) that growers could practically implement to impede the movement of STECs and *Salmonella* from animal areas to produce fields. Key learnings from the final report of this project include:

- Rapid growing vegetative buffer zones or VBZs can be constructed with multiple species of plants to act as barriers to airborne transmission of human pathogens. A figure taken from Dr. Thakur's slide presentation is included below to help you visualize how these VBZs can be constructed and the layout of the experimental farm employed in this project. The VBZ employed in this project consisted of four areas: one row of rapid growing hardwood trees (poplars), one row of evergreen trees (Loblolly pines), one row of shrubs (giant arborvitae) and a rye grass strip.

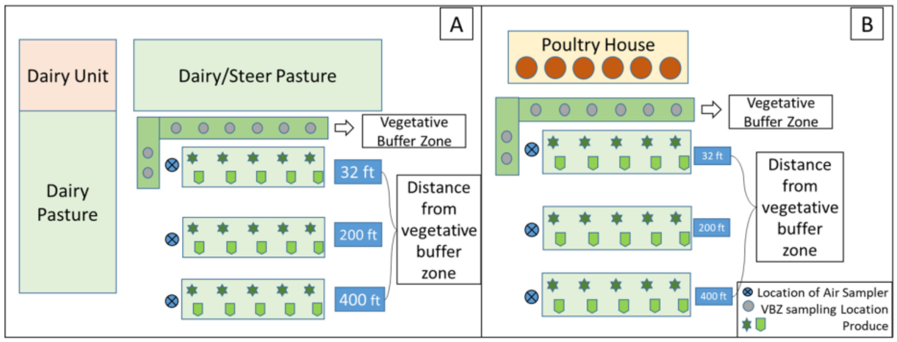


*Diagram reproduced courtesy of Sid Thakur, North Carolina State University*

- Soil, air, plants in the VBZ, and the crop in the adjacent fields (either tomatoes or romaine) were sampled and tested for *Salmonella*, STEC and generic *E. coli* at varying distances from the poultry house or the dairy building. Of the 1,133 samples taken, 7 were positive for *Salmonella* (0.6%) and from these samples 19 *Salmonella* isolates were recovered. Over the two years of the study, only one produce sample tested positive for *Salmonella*. In total, 82 samples tested positive for generic *E. coli* and 53 for STEC, but over the two years of the study, just 11 produce samples tested positive for generic *E. coli* or STEC. Interestingly, there was a seasonality to *E. coli* or STEC positives, with all positives commencing in April and ending in early June. This may be the result of changes in farm management at the experimental farm, but seasonality in STEC positives has been observed in several different production locations around the country. The VBZ had the highest number of positives followed by soil samples. These data demonstrate the ability of the VBZ to capture pathogens before they can reach the produce fields.
- Data analysis from a challenge study using dry chalk inoculated with *Salmonella* and *E. coli* O157:H7 further suggests that a VBZ can be used to mitigate the transmission of STEC and *Salmonella* from APAs to adjacent fresh produce fields. Despite the fact that the challenge study was performed late in the year when the deciduous trees of the VBZ had already lost their leaves, challenge inoculums with genetically marked *E. coli* O157:H7 and *Salmonella* strains showed that only one of the presumptive-positive *E. coli* O157:H7 isolates recovered had a similar banding pattern to the rifampicin-resistant avirulent *E. coli* O157:H7 lab strain used in the challenge inoculum. This result confirms that growers can use VBZs as barriers to pathogen transmission to produce fields on co-managed farms.

The final presentation of systems biology focused on farm-level mitigation research was an interim report delivered by ***Daniel Karp*** from the University of California, Davis. His project, *"Towards a decision-support tool for identifying and mitigating on-farm risks to food safety"* is geared toward providing growers with tools to help them assess the efficacy, feasibility, and costs of various produce safety practices. Examples of practices that have become de facto buyer requirements to reduce contamination risks, but are largely understood biologically in terms of actual benefit or adverse effects on the environment and produce safety, are the use of rodent traps around production fields, vegetation removal in crop-bordering areas to reduce harborage sites, wildlife fences around fields, and the reduced use of composts to reduce pathogen levels in soils. Karp's research will also examine microbial communities found in produce production environments where composts and cover crops are used to enrich soils and how they might be leveraged to control pathogen transference to crops. The project is now in year two, and the following learnings were shared:

- In looking at soils where composts and cover crops were employed, soil bacterial communities thrived and suppressed *Listeria* and *Salmonella*. For example, 5-percent of *Listeria* remained in nutrient poor soils after 10 days whereas <0.01-percent was recovered from nutrient rich soil.
- Similarly, depending on the composition of the soil bacteria, *Salmonella* levels either grew by 75-percent or were reduced to 4-percent of initial levels after 10 days.
- At the beginning of a growing season, five-times more *Salmonella* persisted after 10 days in soils without composts relative to composted soils.

***Why are these results important to the produce industry?*** Throughout our produce safety journey there has been a constant conflict or concern by growers over the impact of produce safety practices and finding proper environmental balance. Wildlife fences, rodent traps in fields, clearing vegetation from adjoining spaces to fields, and other well-intentioned and perhaps effective produce safety mitigations change the environment. Our fields are biological systems and any perturbation can create a positive or negative impact or alteration in the balance of that system.

The Green, Thakur and Karp projects share the desire to find solutions to important, field-level produce safety challenges while prioritizing environmental balance, animal conservation, economics, and public health. For example, Green's project on control of Pacific tree frogs leveraged the mating behaviors of the frogs and the basic biology of tree frog toe pads to devise a fencing design designed to control frog movements into adjacent produce fields and thus eliminate the potential for tree frogs to show up in bagged salads or transmit human pathogens. The production environment benefits from removal of a potential risk and the overall environment is preserved.

The Thakur program on the study of vegetative buffer zones (VBZs) to control pathogen transmission from animal operations on co-managed farms is another example of trying to find the right biological and environmental balance and gaining a greater understanding of aerial pathogen transmission on the farm. This has been a hotly debated topic in recent years and one that is devoid of clear answers owing to the difficulty of conducting meaningful experiments because the variables that exist in real-world production environments. The data suggest that VBZs can be an effective tool in managing aerial transmission of pathogens. Frankly, this is a produce safety challenge where growers on co-managed farms do not have a lot of options, so the VBZ tool is welcome. But caution must also be taken. A "one size fits all" approach is not warranted here. Each co-managed farm is different. The topography of the land, prevailing direction of the wind, the density, management and type of farm animals, the distance from the animals to the fruit and vegetable areas, rainfall frequency, soil types, equipment used on the farm, and crops being grown all need to be considered when developing a strategy for how to design and construct effective VBZs. It is also important to note that while VBZs look to be part of a solution to manage pathogen transmission, the pathogens are still there on the farm. Their capture by the VBZ means they are still there and could be transferred by other mechanisms, e.g. water runoff, animals, insects, etc. Certainly, manures from farm animals still need to handled carefully and validated composting protocols must be carried out and verified before recycling back to the land.

Lastly, Karp's project on examining soil nutrition and suppression of human pathogen persistence and growth is an obvious example of trying to find the right balance to achieve of produce safety goal, i.e. suppression of pathogens while building and maintaining healthy, nutritious soils. Though the project is just getting started, the correlation between soils that have been subject to cover crops and routine additions of composts are better positioned to suppress *Salmonella* and *Listeria* populations. But much remains to be learned about this suppression effect. The role of the soil microbiome in supporting or suppressing human pathogens was one of the early CPS funding priorities and it proved elusive to understand (Maria Marco 2010, Trevor Suslow 2010, and Gitta Coaker 2010) to the point where application to growing operations were clear. However, soil amendments and other treatments promoting microbially diverse populations in agricultural soils to boost yields and create soil health is an industry all to itself. Today's analytical and genetic tools are advanced from a decade ago and so it will be interesting to see where the Karp project takes us.

***Why are these results important to the research community?*** Generally, these projects are a reminder of the value on bringing broad expertise together to address industry challenges. Scientists with expertise in soil biology, animal husbandry, materials science, microbiology, fruit and vegetable production, environmental science and so on are needed to address produce safety challenges in a holistic way that provides practical solutions or routes to solutions that are practical on the farm.

The potential use of VBZs to control pathogen transmission on co-managed farms represents opportunities to better understand the complexities of these systems. Everything from alternate pathogen vectors from the VBZ to the fields to composition of the VBZ and how it might be affected by animal density and remediation methods for the VBZ and soils are important areas to better understand.

During the question and answer period following the presentations, the question of distance that pathogens can travel by air arose. Is it 400, 600, 1,200 feet or further? Human behavior dictates that we seek safe haven distances we can plug into our produce safety programs and move on. In fact, naming a single minimum distance that would be “safe” is not likely. Selecting an unnecessarily long distance is undesirable because of the valuable land it would take out of production. While selecting an insufficient distance frees up land for production, it can compromise the safety of the resulting crop. The answer is being able to evaluate the risks each situation presents and that means every operation needs to have tools to help them understand the risks animal operations represent and devise distances that mitigate those risks. But the truth is, we don’t have those tools today. VBZs are likely a part of the answer for some types of operations in some locations around the world. For example, a VBZ may be effective on a small, 150-head dairy/vegetable production farm and would be overwhelmed by a 150,000-head feeding operation. Clearly our knowledge base needs more depth. CPS has prioritized development of tools to detect fecal contamination in the environment, and projects are currently underway. During Session 1 of the 2020 CPS Research Symposium we heard about the use of computer-based modeling to address the question of *Listeria* growth and persistence on fruit and vegetable commodities. Modeling was a viable approach because there were data on *Listeria* and growth characteristics and growth on some products to help build the model. The challenge was using that information to create a model that could be extended to commodities where research was yet to be done in a world where market and public health demands require it now. One is left to wonder if there might be an opportunity to employ computer-based models to begin addressing our need to provide the industry with better decision-making tools to guide decisions on the risks animals represent to fruit and vegetable crops? Certainly, we have a knowledge base on pathogen persistence in soils and water sources, mechanisms of transmission of bacteria and aerial dispersion of other types of particles that can fuel initial model development.

Lastly, these projects are reminders of just how difficult it is to conduct experimentation on working farms. Collaboration between the produce industry and the research community is critical. The Green project was highly reliant on having access to farms in the Salinas Valley, and the expertise of growers influenced their approaches. The Thakur project pointed out that even when the farm is under the control of a research institution, stuff still happens! The VBZ developed for the project did not extend to cover the dairy area completely leaving a window where transmission could skirt around the VBZ, farm management was changed in the middle of the project, the poultry house was depopulated during the project, and the area was subject to a hurricane; all in just two years. This is not a criticism; it is an example of the reality of farm operations, whether it be at a university or a commercial operation. Changes happen to accommodate the business and those changes can introduce additional complexities and change the outcomes of experiments. Still, collaboration and access to produce operations remain a critical component to produce safety research.

***Why are these results important to regulators?*** This work is important to the regulatory community not only because it offers potential solutions to real, on-farm contamination risks but also to create awareness that mitigation strategies can be developed using principals of systems biology. There is a need to be open to these approaches and support the research needed to prove efficacy. To the extent that FDA and USDA can work with the industry and industry groups like CPS to identify and fund research needs to explore systems approaches, the more flexibility growers will have as they seek solutions that fit their operation-specific needs. This will also result in greater willingness to pursue research to demonstrate efficacy by researchers.

2. ***Cyclospora* can be found in Yuma Valley canal water, but is it a public health risk?** Since 2000 there have been 42 illness outbreaks in the United States involving *Cyclospora cayetanensis.* 80-percent have occurred in what is becoming known as the "Cyclospora season" of April through July, and 40% of those outbreaks have been associated with the consumption of imported or domestic fresh fruits and vegetables. In 2019, there were 2,408 laboratory-confirmed cases reported in 37 states associated with a number of commodities, and just last month an outbreak attributed to consumption of bagged salads has made more than 500 people sick and the investigation is ongoing. ***Gerardo Lopez***, University of Arizona, presented the timely results of his project: "*Cyclospora prevalence in irrigation water in fresh produce growing regions in Arizona*" (Gerardo Lopez 2020). This project assessed the prevalence of *C. cayetanensis* in agricultural water in the Yuma Valley of Arizona. The newly developed FDA BAM 19b method for detection of *Cyclospora* was used for DNA isolation, purification, and quantitative PCR (qPCR) assays. The key learnings from this final report include:
   - Modifications were made to fine tune FDA BAM Chapter 19b method to permit detection of *Cyclospora* in irrigation water samples. This is a DNA-based detection method and permits more rapid sample analysis. Historically, *Cyclospora* detection was only possible with tedious microscopic protocols.
   - *C. cayetanensis* was found in 6/196 water samples from the Yuma Valley growing region collected between February 2019–February 2020, which represents a prevalence of 3-percent. There seems to be a seasonality to these positive samples as they were found in December (2), January (3), and February (1), and all other samples in all other months were negative.
   - The 2019–20 results demonstrate an overall lower prevalence from previous years (2017 to 2018) when 15/119 samples tested positive (13-percent) for *C. cayetanensis*. The three-year average from the combined studies shows a 7-percent prevalence (21/315) for *C. cayetanensis*.

- Four of the six positive samples from 2019–20 were from unlined canals (4/103) and two samples were from lined canals (2/93). There was no statistically significant difference in *C. cayetanensis* gene copies/liter values between lined and unlined canals.
- The value of gene copies/liter is an estimation of what could be found per liter of agricultural water since only less than 1 mL was used for DNA extraction from sample volumes ranging from 5–15 mL. The number of gene copies per liter was less than one.
- These findings suggest that the risk of fresh produce contamination by *C. cayetanensis* from agricultural water in this produce growing region seems to be relatively low, given that no *C. cayetanensis* outbreaks have been associated with fresh produce grown in the Yuma Valley and given the volume of raw agricultural commodities irrigated with these agricultural waters.

***Why are these results important to the produce industry?*** It is important that the produce industry begins to understand the risks associated with *Cyclospora*. In an important fruit and vegetable production region like the Yuma Valley, *Cyclospora* was found at an average 7-percent prevalence rate. Leaving aside whether that prevalence rate represents a public health risk, it means that human fecal contamination is making its way into agricultural waters used to irrigate crops. The research team advised irrigation districts and growers to continue to implement and practice current water quality safety measures, good agricultural practices (GAPs) and good management practices to reduce the incidence of contamination of agricultural water and subsequently fresh produce irrigated with that water.

It is important to note that the modifications to the FDA BAM Chapter 19b method for detection of *Cyclospora* will permit more research attention to the question of water transmission of *Cyclospora* to fruit and vegetable crops. Indeed, in 2019, CPS funded three additional research projects exploring *Cyclospora* prevalence in different regions of the US and to help us better understand how it moves in our production environments (Kalmia Kniel abstract, Mia Mattioli abstract, and Ynes Ortega abstract– all funded n 2019). Improved detection protocols along with the yearly occurrence of *Cyclospora* outbreaks means that *Cyclospora* has joined STECs, *Salmonella* and *Listeria* as points of focus. In addition to water as a vector, we know humans infected with *C. cayetanensis* can transmit the oocysts into the environment and perhaps onto fresh fruits and vegetables. Workers that routinely travel to areas of the world where *Cyclospora* is endemic and return to your operation to work seasonally may be an important consideration. Therefore, at any point in the supply chain where workers handle products it is important that they are trained and practice good hygiene and sanitation practices to minimize the potential of cross contamination.

Knowing your water source and monitoring the path the water follows to be sure it is not contaminated by human wastewater or is not accessed by temporary encampments is important. Additionally, both wild and domesticated animals can act as vectors for *C. cayetanensis* oocysts if they move from areas where human waste or garbage might be located and into production fields. Therefore, it is important to monitor animal movements around production fields.

Lastly, it is difficult to determine if a 3-percent incidence rate in 2019–20 represents a true public health risk. The FDA BAM method of detection cannot distinguish live versus dead *Cyclospora* oocysts; currently, only a manual microscopic analysis for sporulation can determine oocyst viability. While during the question and answer period it was established that no *Cyclospora* outbreaks have been associated with produce from the Yuma region and this can be taken as a positive. There are certainly many incidents of cyclosporiasis each year where produce is suspected as the causative vector but not determined and therefore its origin is also unknown.

***Why are these results important to the research community?*** In many ways, the reaction of the produce industry and the research community to the emergence of *Cyclospora* in produce is similar to the emergence of *L. monocytogenes* a decade ago when a devastating outbreak shook the industry. While *Listeria* was known to the industry, it was not well understood biologically and control practices within everyday operations were rudimentary. *Cyclospora* is not new to the produce industry but its emergence in the last three years has had profound impacts and we are again left with more questions than answers. While breakthroughs in detection have been achieved, determining the sensitivity of the test, concentration of oocysts, and their infectivity still presents challenges. We do not know the triggers for oocyst sporulation, oocyst survivability in the production environment, the precise nature of transmission vectors, or what measures might be taken to remove oocysts from our environments, though we do know that common sanitizers in use in the industry are not effective. In the end, we do not know if water is even the primary transmission vector for *Cyclospora* or what the public health risk is when it is found. We are clearly in our infancy in terms of our understanding of this pathogen and the role of fresh produce in causing illness, and we hope that this project and the others underway right now will increase our knowledge base and encourage scientists to pursue much-needed studies on this parasite.

***Why are these results important to regulators?*** This research project has the same impact for regulators as it does for growers and researchers. *Cyclospora* can be in the growing environment and represents a potential public health risk, therefore we need to learn how to manage the risk more effectively. An important question arising from this research is why was it only the months of December, January, and February that yielded a low level of positive samples when outbreaks from produce seem confined to May, June, and July? Since there is a human factor in the *Cyclospora* life cycle, how are the oocysts moving from humans or human wastewater sources to agricultural waters? These spring to early summer months where outbreaks occur, especially in the mid-section of the US are also associated with heavy rainfalls and flooding. How are these factors accounted for in separating what might be food consumption spread versus environmental or drinking water transmission?

*Cyclospora* is a priority for FDA as it is for industry and FDA is certainly pursuing research and gathering learnings from outbreak investigations. It is important that FDA, CDC and the states continue to work together with industry to find solutions to this important produce safety risk.

***Acknowledgements**: The Center for Produce Safety would like to thank the researchers who made presentations during Session 3 of the 2020 Research Symposium. Their presentation of research results and their discussion of what that research might mean to the produce industry certainly informs the content of this paper. More detail on these research projects can be found at www.centerforproducesafety.org. This discussion of key learnings contained here is meant to inform and provoke thought with an eye towards inspiring readers to examine their own produce safety programs and to use the research to make improvements. It is not meant as a directive on what must be done to produce safe food. Produce safety needs to be determined on an operation by operation basis; there are no one size fits all solutions. If you have additional questions, please feel free to contact Bonnie Fernandez-Fenaroli (Bonnie@centerforproducesafety.org). Thank you.*