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Use of Surface Water in the Production of Fresh Fruits and Vegetables: A Survey of Fresh Produce Growers and Their Water Management Practices

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ABSTRACT

Currently, there are no national surface water quality standards for water used in the production of fresh produce, although the proposed rule resulting from the Food Safety Modernization Act (FSMA) and several commodity groups have adopted standards based on the Environmental Protection Agency's Ambient Water Quality Standards. A survey was conducted in the winter of 2008–2009 to assess current surface water management practices by fruit and vegetable growers in New York State. This survey was developed to better understand current irrigation water sources, how surface water sources are applied to fresh produce crops, whether water sources are being tested, and whether adjacent land uses are commonly assessed for produce safety risks. Eighty-four questionnaires were completed by growers in fifteen different counties throughout New York State. Survey data revealed that growers frequently utilize surface water sources and apply it overhead to grow a wide range of fresh produce commodities but that testing for microbial quality indicators and risk assessment of adjacent land are not common practices. Thirty-seven percent of growers who responded to the survey reported that fresh produce buyers had inquired about food safety practices on their farms. With continued food safety pressure from buyers and the FSMA proposed produce rule, more growers will need to adopt produce safety practices. This study highlights the need to understand current produce safety practices on the farm.

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INTRODUCTION

The production of fresh fruits and vegetables is impacted by many environmental variables, such as temperature, sunlight, rainfall, and soil type. Fresh produce growers modify the growing environment to ensure crop quality and productivity. The farm environment and common practices provide many opportunities for contamination of fruits and vegetables to occur. Soil amendments (i.e., manure, compost and compost teas), direct contact with wildlife, airborne deposition from off-farm activities such as cattle/dairy and manure/composting operations, and water (irrigation or flooding/runoff from adjacent land) all represent potential vehicles for contamination by foodborne pathogens such as *E. coli* O157:H7 and *Salmonella (1, 2, 3, 5)*. Much fresh produce is consumed raw and therefore does not receive any treatment step that would kill foodborne pathogens that may have contaminated the fresh produce during production and packing.

Over the past several decades, the consumption of fresh fruits and vegetables that were contaminated with human pathogens has resulted in foodborne illness outbreaks *(16, 20, 22)*. Four specific human pathogens, *E. coli* O157:H7, *Salmonella*, *Cyclospora*, and Hepatitis A virus, have accounted for 96% of the outbreaks and 95% of the illnesses in reported produce-related outbreaks from 1996 to 2007 *(22)*. Contamination of fresh fruits and vegetables with human pathogens can occur at any point in the supply chain and, depending on the commodity, it is difficult if not impossible to remove because of phenotypic and physiological traits of produce *(2, 7, 9, 18)*.

Water is an important natural resource and is critical to the production of fresh fruits and vegetables. The application of irrigation water, water for frost protection, and topical protective sprays are just a few of the practices that growers utilize during the growing season to promote crop growth and productivity. The water used for these practices can come from multiple sources, including surface water, well water and municipal water. Water from these multiple sources can be applied in several different ways such as through drip tape, furrows, overhead sprinklers, and spray machinery, and the type of delivery will often determine the volume of water needed as well as the pressure *(4)*.

Many growers use surface water, including streams, ponds, and lakes, as their water source to irrigate and apply pesticide sprays to fresh produce. In many instances, little may be known about the quality of this water because water testing is not implemented and there are not clear, consistent, universally accepted recommendations to guide farmers through the water monitoring process. Concern about the quality of water used to grow fresh produce is directly related to the concern about the foodborne illness risks it may present. Safety concerns arise when water is applied directly to the edible portion of the crop, thereby depositing any contamination that the water may contain directly onto the crop. Many human pathogens of concern carried in water, including *Salmonella enterica*, Shiga-toxin producing *E. coli*, *Campylobacter jejuni*, and *Cryptosporidium*, could be spread through irrigation and topical spray applications, especially when they are applied directly to the edible portion of the crop *(6, 13)*.

Water applied to fruits and vegetables not only impacts the safety of the crop, but can also impact the safety and water quality in local watersheds. The impact to local watersheds occurs through both the use (removal of water) and the return (application) of the water to the crop land (environment). Growers not only have to manage the safety of the crops they produce but also must manage their environmental impact to both land and water.

The safety of fresh produce and environmental impacts should be a concern to all fresh produce growers because of the ramifications to their customers as well as to the financial viability of their operations from both a liability and economic standpoint. Following well publicized produce-associated foodborne illness outbreaks, many retail buyers now require fresh produce growers to test their irrigation water prior to use and develop a water management plan to reduce food safety risks. In addition to the impact on markets, foodborne illness outbreaks have resulted in commodity groups adopting new practices and requirements in an attempt to control risks *(8, 23)*. Currently there are no federal irrigation water quality standards, but the Environmental Protection Agency Ambient Water Quality Standards have been adopted by the Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce as the irrigation standards required during production *(21, 23)*. The use of these standards is interesting because they were developed for recreational waters, not production agriculture. Because of the lack of national, science-based irrigation water quality standards, these EPA standards are the current benchmark used by several fresh produce commodity groups and proposed in the FSMA produce rule.

Depending on the year, New York is either first or second in cabbage production, second in apple production, and eighth in strawberry production in the nation. In addition to these crops, New York farms produce a diverse array of fresh fruits and vegetables from asparagus to zucchini. These crops are marketed locally, statewide, nationally, and internationally. Thus the safety of New York grown produce impacts many consumers every day.

This survey was developed to better understand current irrigation water sources and water management practices, including delivery methods, being used by fresh produce growers in New York. Questions were designed to assess whether testing of water sources was common and the types of water tests being conducted as well as the frequency of testing. Participants were also asked about environmental factors near their farms, including adjacent land use and manure application practices, that could impact the safety of their water sources and the produce they grow. Additional questions were included to determine if fresh produce buyers are inquiring about food safety practices and if New York growers are actively engaged in developing farm food safety plans.

The resulting data allows for the assessment of current water management practices by New York growers to help determine how the industry may be affected if federal standards are mandated regarding irrigation water delivery or water quality. Although this survey was conducted only in New York, the information obtained is relevant to growers beyond New York, because many of the commodities grown and management practices utilized are common in other states. Results from the survey will assist in the development of educational materials and extension training aimed at encouraging risk assessment and the implementation of food safety practices on fresh produce farms to reduce risks and meet market demands for food safety.

MATERIALS AND METHODS

A survey containing 18 questions, including questions on basic demographic information, was developed for fresh fruit and vegetable growers and distributed throughout New York State. The survey contained questions to determine current irrigation water uses, sources, and management practices, as well as questions pertaining to commodities grown and possible risk factors related to adjacent properties *(Table 1)*. In addition, questions were included to help determine if buyers' demand for food safety programs exist, and if so, what growers are doing to meet these demands. Participants were asked three questions on demographics: age, county where they reside, and size of their entire farm.

The survey questionnaire was produced in both an electronic and paper format to encourage participation. Growers were provided access to the survey through direct mailings, e-mail list-serves and monthly newsletters written by extension educators throughout the state of New York, including *Muck and Mineral*, *VegEdge*, *Fruit News*, and *New York Berry News*. Circulation of these newsletters accounted for approximately 1,183 homes. Some of the newsletters contained both the paper format and the link to the electronic format, while others contained only the link to the electronic format. A mailing list that contained 197 addresses of growers or farm operations was used to send a copy of the paper format, along with a stamped, addressed return envelope, as well as the link to the electronic survey. Responses were analyzed to determine sources of irrigation water, methods of application, use of water testing, commodities produced using surface water irrigation, and average acreage irrigated, as well as adjacent land uses that might represent risks to surface water sources or to fresh produce fields.

RESULTS

Demographics

A total of eighty-four questionnaires were completed and submitted by growers. Seventy-five (paper) copies were submitted through the United States Postal Service and nine were completed online and submitted through the Checkbox survey collection site. Responses from growers living in fifteen counties throughout New York (Dutchess, Erie, Genesee, Monroe, Niagara, Ontario, Orange, Orleans, Schuyler, Steuben, Suffolk, Tioga, Tompkins, Wayne, and Yates) were received *(Fig. 1)*. Suffolk and Niagara counties had the highest number of participants, with each having 12 respondents who participated and identified their county. Fifteen respondents chose not to provide their county. Respondents were from 20 to over 70 years of age, with 31%

TABLE 1. Irrigation water management questions included in the survey

Questions
1. How many acres are you irrigating with surface water?
2. What is (are) your source(s) of irrigation water?
3. What method of irrigation do you use?
4. What crops are you irrigating with surface water?
5. Describe the frequency at which you irrigate your cabbage/crucifers in a "normal" year.
6. Do you apply topical/pesticide sprays that are mixed with surface water?
7. If you use surface water to mix topical/pesticide sprays, what is the source of your surface water?
8. Are you currently testing your surface water source?
9. If you are testing surface water, what are you testing for?
10. How often do you test your surface water?
11. Have you done an environmental impact of the area surrounding your irrigation water source to determine potential contamination factors?
12. Do you have a written farm produce safety plan?
13. Have any buyers of your commodities/crops ever inquired about food safety practices on your farm?
14. Have you ever had a third-party audit of your farm to verify food safety practices?
15. Do you have any adjacent land uses within 1 mile of your fields that may present a microbial risk?

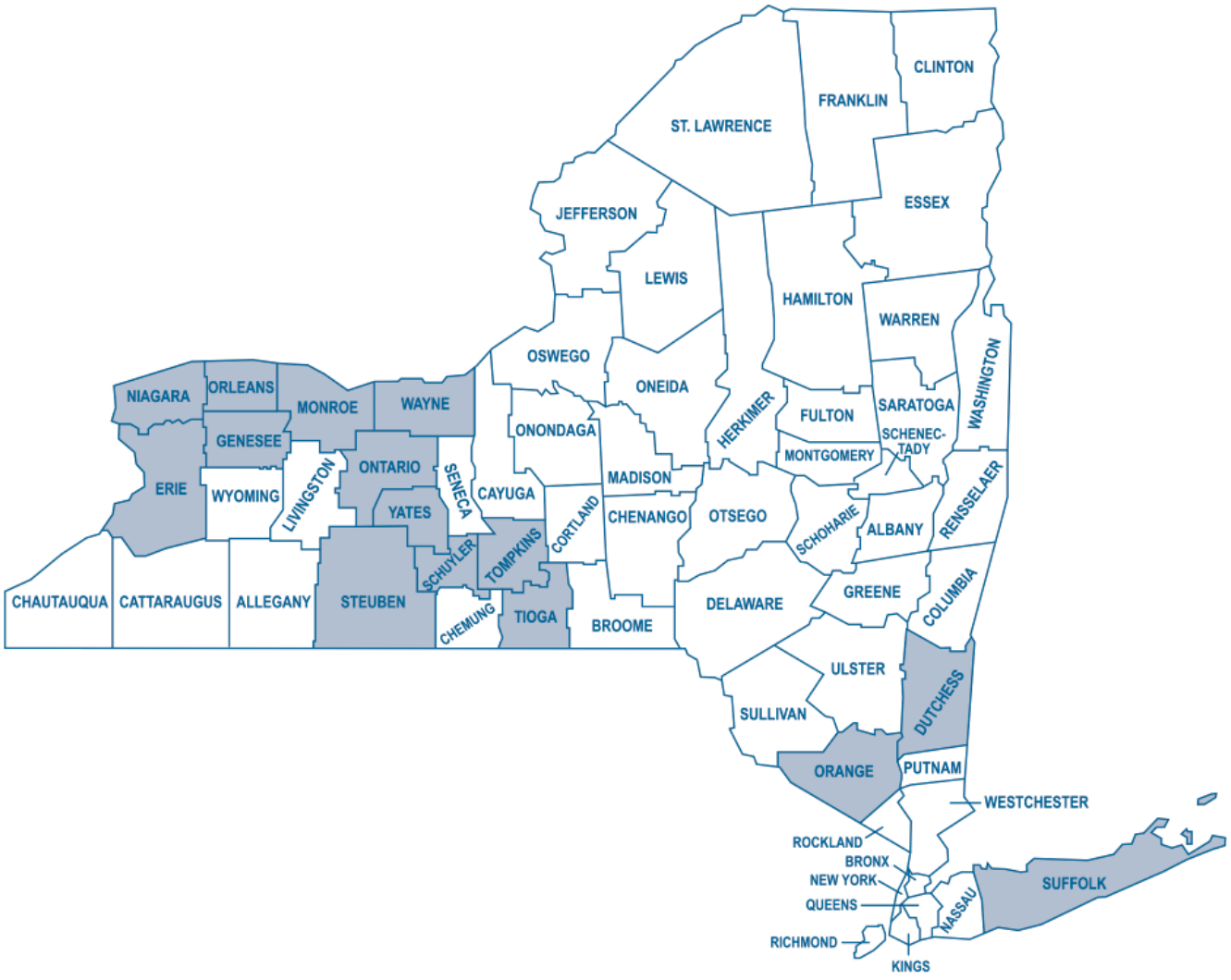

FIGURE 1. Counties with fruit and vegetable growers who participated in the survey are shaded.

(26 of 84 respondents) being in the 50–59 age range, accounting for the highest percentage of respondents *(Fig. 2)*. This supports 2007 census data from the National Agricultural Statistics Service that found the average age of principal farm operators in New York to be 56 years of age *(19)*.

Participating growers indicated that their farm sizes were from one acre to more than 1,000 acres. The option of less than one acre was provided but was never selected. The largest response rate was from growers who indicated farm size as 11–50 acres, providing 20 of the 84 responses (24%) *(Fig. 3)*. The average farm size in New York is 195 acres, according to the 2007 census data from the National Agricultural Statistics Service *(19)*. In this survey, 17 respondents (20%) reported having farms that ranged from 101–200 acres.

Distribution rates among counties, ages, and farm size, as well as commodities grown, was very good, indicating that a diverse set of state growers participated in the survey. These farmers represented diverse sized farms growing a range of commodities. Given the size of farms and commodities produced, it is likely that these farms represent a variety of marketing practices, including direct marketing to consumers and wholesaling, although specific information on this was not collected. Two specific production regions of New York were represented in the survey, namely western and southeastern NY.

Surface water use, method of delivery, management and testing

Data collected revealed that 48 of 84 growers (57%) use surface water to irrigate their crops, while 15 of 84 (18%) report applying topical/pesticide sprays that are mixed with surface water. Of the 48 growers who report using surface water to irrigate, 41 (85%) report that they apply the water overhead as one of their delivery methods or their only delivery method. Crops irrigated with surface water that is applied overhead and/or to which topical sprays mixed with surface water are applied include all of the crops identified as high risk by the Food and Drug Administration (berries, green onions, herbs, leafy greens, netted melons, and tomatoes) as well as apples, beans, beets, broccoli, cauliflower, corn, cucumbers, eggplant, garlic, pears, peppers, potatoes, shallots, smooth melons, squash, and sweet corn. Of the growers who reported using surface water to irrigate and applying the water overhead, only 11 of 41 (27%) indicated that they were testing this water in any way, with 8 of 11 (72%) specifically indicating that

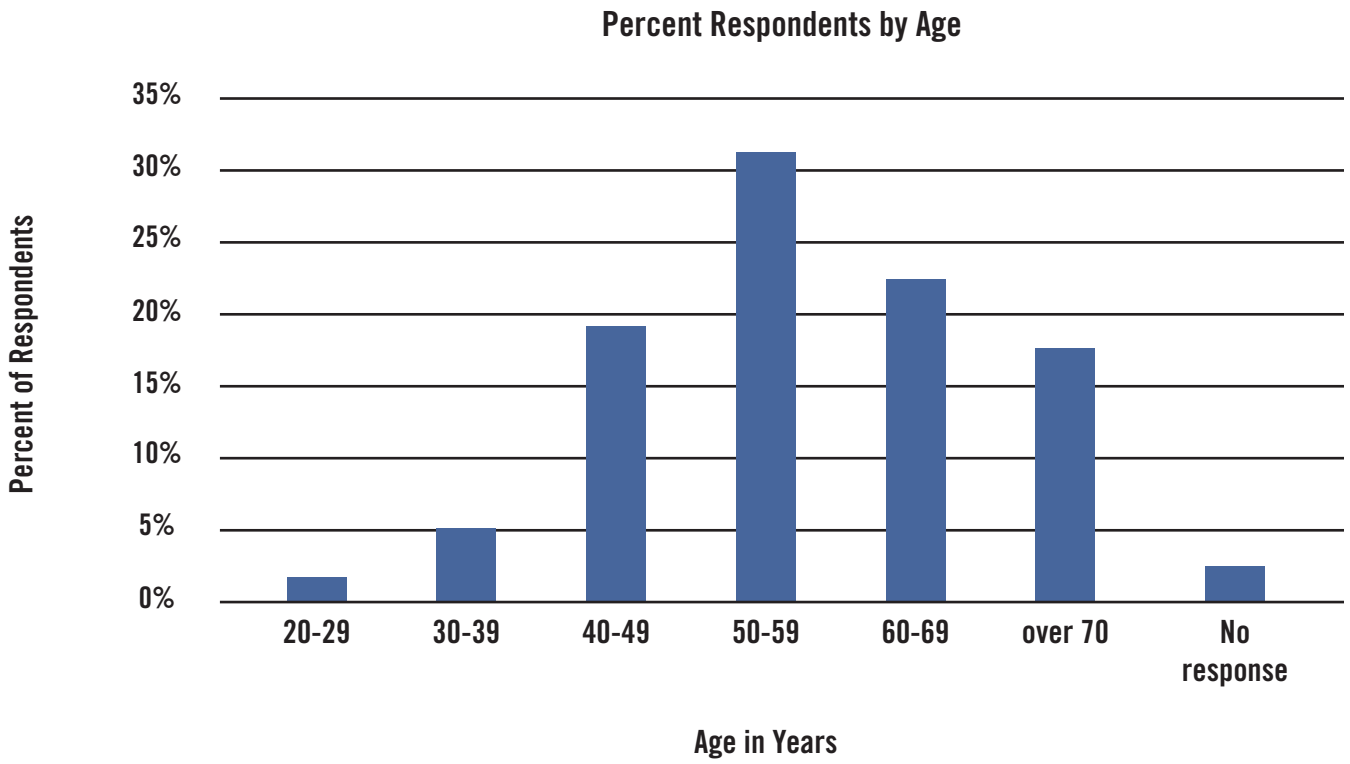

FIGURE 2. Growers in the range of 50–59 years of age accounted for the highest level of participation, reflecting the average age of 56 for growers in New York.

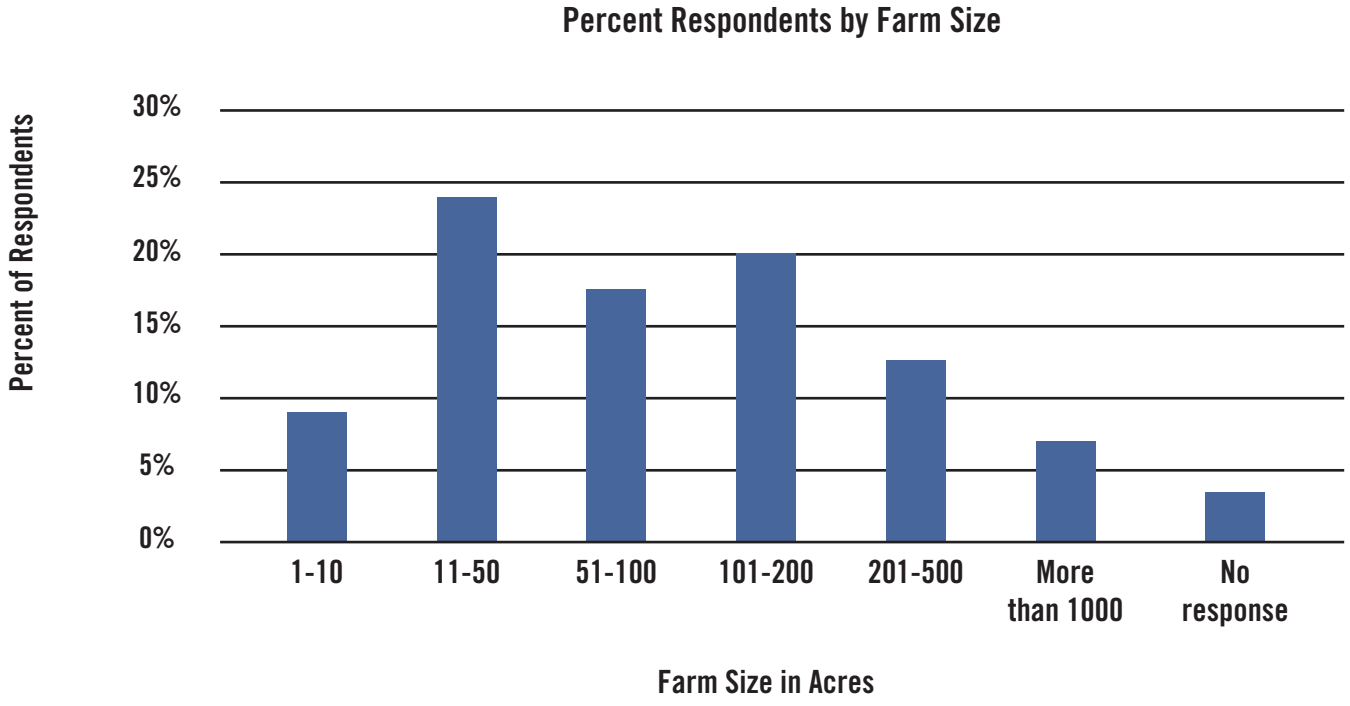

FIGURE 3. All farm sizes were represented in the survey, with distribution not dominated by any one size. The average farm size in New York is 195 acres (19).

they were testing for generic *E. coli*. The distribution of acreage being irrigated with surface water and the percentage of these operations using overhead application as a delivery method are provided in *Table 2*.

Environmental assessment

To determine the extent to which growers were considering the impact of environmental conditions to water quality and produce safety, they were asked several questions regarding land and activities adjacent to their water sources and farms. When asked whether they "have done an environmental impact of the area surrounding your irrigation water source to determine potential contamination factors," noting that this included surveying the area around the water source to see if there was wild or domestic animal activity or man-made activity that could impact the microbial safety of the water source, 20% of the 84 respondents responded Yes, 55% responded No, and 25% did not respond. Twenty-three percent of respondents (19 of 84) report adjacent land uses within one mile of their fields that may present a microbial risk, including confined animal operations, landfills, dairy farms, horse farms or inadequate home leach fields/septic systems, while 17% (14 of 84) report using manure as a soil amendment within one year of harvest.

DISCUSSION AND CONCLUSIONS

Assessment of water risks

This survey highlighted several important factors regarding the use of surface water in the production of fresh produce and the impact food safety requirements might have on fresh produce growers. In New York, many fresh fruits and vegetables are overhead irrigated or have protective topical sprays mixed with surface water applied to them. Less than 20% of growers who indicated that they apply surface water overhead have tested the water they are using for generic *E. coli*, a commonly used indicator of fecal contamination in the determination of the microbial quality of surface water. This is a concern because it impacts growers' ability to make informed water management decisions that impact produce safety.

Testing surface water allows growers to define their current surface water quality and make informed decisions about when to apply or not apply irrigation and topical sprays that use the surface water. Assessing water quality is one part of conducting a water management risk assessment that should include reviewing other management practices such as when water is applied in relationship to harvest and the method of delivery. Overhead application applied within two weeks of harvest during which the edible portion of the crop is contacted represents the highest risk practices if the quality of the water is poor *(11, 14)*. Without understanding water quality through testing, it would be difficult for growers to assess their risks. In addition, many topical sprays used in the production of fresh produce can be and are applied with a 0 day to harvest (DTH) interval. Sprays such as Cuprofix Ultra 40 Disperss (copper sulfate), Switch (cyprodinil/fludioxonil), Elevate (fenhexamid) and Bravo Ultrex (chlorothalonil) all have a 0 DTH interval for at least some commodities and may be applied very close to harvest. Pathogens present in poor-quality water can persist in pesticide mixes *(10, 15)*. The importance of good water quality increases as the plants near harvest because there is less opportunity for UV solarization, desiccation, and other environmental factors to reduce microbial pathogens that may be present in the water. Microbial risks

TABLE 2. Acreage irrigated with surface water and the percentage of farms using overhead irrigation as a delivery method

Land irrigated with surface water	# of Respondents	% of Respondents	% Using overhead delivery
Less than 1 acre	2	2%	50%
1–10 acres	10	12%	50%
11–50 acres	15	18%	93%
51–100 acres	8	10%	100%
101–200	10	12%	100%
201–500 acres	1	1%	100%
501–1000 acres	2	2%	100%
None	36	43%	0%

can be reduced by applying irrigation water in the morning to promote exposure to the sun and drying of the crop *(17)*. Again, making the best management decisions requires having the right data regarding water quality. Water testing would allow growers to better monitor source water quality for changes or contamination events and allow them to make management decisions based on water quality information.

Environmental assessment and adjacent land use

Adjacent land and riparian zones can represent a risk to the safety of both water sources and fruits and vegetables grown in nearby fields. Survey results indicate that only 20% of respondents are doing an environmental assessment of the areas surrounding their water sources, even though 23% responded that their fields are within one mile of potential foodborne pathogen contamination sources that may present a microbial risk, including confined animal operations, landfills, dairy farms, horse farms or inadequate home leach fields/ septic systems, while other respondents indicated they had significant wildlife presence that may represent a risk or that they were applying manure within one year of harvest. A more worrisome result was that 51% of respondents to the question "Do you have any adjacent land uses within 1 mile of your fields that may present a microbial risk?" who did not provide any response. It seems likely that if the answer was "none," they would have selected that answer, so it seems more likely that they did not know, had not considered it, or did not want to reveal adjacent land issues, all of which responses are of concern. Foremost, it is important that fresh produce growers consider adjacent land use in their risk assessment. In some cases, identified risks can be very difficult to manage because fields cannot simply be moved to a different location and other operations that represent risk cannot be asked to move or cease to exist. That said, the likelihood that something will be done to mitigate an adjacent land risk is much higher if the risk has been identified and is known, even though it may be difficult to fix. The survey results highlight a great opportunity to encourage growers to, at the very least, conduct an environmental assessment of adjacent land use as part of their farm food safety risk assessment.

Meeting demands for food safety

In 2008–2009, many New York and national retailers, including Wegmans, Price Chopper, and Hannaford, were just beginning to require all their "Locally Grown" suppliers to have food safety practices in place and have them verified by third-party audits. These audits require that growers test their water sources, but the survey data indicates that many of the respondents are not participating in these third party audits. The survey results also indicate that the New York growers who responded were not engaged in meeting the demands of buyers. Although almost 37% of growers (31 of 84) self-reported that buyers have inquired about food safety practices on their farms, only 17% of respondents said that they have a farm food safety plan, while another 10% reported that their plans are "in progress." Even if these two groups are combined, only 27% of participating farmers have a farm food safety plan or are working on a plan, while 37% are being asked about their practices. This indicates a large gap between what is being asked about or required and what growers are delivering. This could represent a market opportunity for those growers motivated to write a farm food safety plan, implement it, and successfully pass an audit. Eleven of 84 respondents (13%) report having had a third-party audit to verify food safety practices on their farms. For those growers who continue to avoid the implementation of food safety practices, such as testing their on-farm water sources, this could represent a loss of market or the need to find markets that do not have food safety requirements.

Since this survey in 2008–2009, Good Agricultural Practices (GAPs) workshops have continually been offered to growers in New York. Survey results collected after these workshops indicate that more New York growers have completed a written farm food safety plan and are participating in third-party audits (unpublished data). The most recent survey included the question "Can you put a dollar value on the amount of business that would be lost if you had NO food safety certification or 3rd party audit?". The responses ranged from "none, just for customer peace of mind and the right thing to do" through "$1.5 million" with other amounts including $70, $500, $8,000, $15,000, $85,000, $200,000, and $500,000 (Kahlke, C.J. 17 January 2013. Draft of Smith-Lever Final Project Summary [Email: cjk37@cornell.edu]. Available from: Bihn, E.A. at eab38@cornell.edu). Pressure from buyers, as well as the release of the first ever proposed regulation of fresh produce by the Food and Drug Administration as part of FSMA, will likely increase the number of growers who develop written farm food safety plans and seek third-party audits.

Economic farm viability could be impacted not only by losing markets but by litigation should a foodborne illness result as a consequence of consuming fresh produce grown without food safety practices in place. Although it is unlikely that an individual farm would be indicated as the source of a produce-related foodborne illness, farms that are implicated have been found liable and responsible for the financial impacts of illnesses *(12)*. Due diligence is defined as "the care that a reasonable person exercises to avoid harm to other people." There is no way to guarantee that fresh produce is 100% safe because it is grown outside under open skies in the soil, but growers do have a responsibility to understand risks that exist and implement practices to reduce these risks. Fresh produce growers should be aware of this liability and actively address it through the implementation of farm food safety practices.

Survey assessment

One very important outcome of conducting this survey in both paper and electronic formats was noticing the stark contrast in the numbers of surveys returned through the postal service versus those submitted online. Only nine people completed the online survey, while 75 individuals completed the paper survey. As part of the mailing to 197 homes, stamped return envelopes were included, but some of those who completed the paper questionnaire paid for the postage to return it because they got it from a newsletter rather than from the project directly, indicating an additional investment of a stamp and an envelope over a free online submission. The exact return rate is impossible to determine; we are not certain how many surveys were distributed because of collaboration with extension educators who included information about the survey in their newsletters, but all news stories included the link to the electronic format although they may not have included the paper format. A review of the ages of those who submitted the electronic rather than the paper format was conducted to determine if age may have been a factor. Of the nine electronic surveys

submitted, 1 was from a 20–29 year old and 4 each from 40–49 and 50–59 year olds. Overall, participation in the survey occurred across a range of ages *(Fig. 2)*, so there is no evidence that the preferential use of the paper format was related to age. It is not clear why participants chose paper over electronic submission. However, it is very important to recognize the disparity, since it could heavily influence participation in other surveys. These data highlight the value of offering paper versions of surveys to encourage participation by fruit and vegetable growers.

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