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Reducing Risk and Preparing for Food Safety Regulations with Improved Produce Washing Methods for Vegetable Farms

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Abstract

Vegetable farmers are looking for practical ways to address food safety risks. This interest stems in part from passage of the Food Safety Modernization Act (FSMA), increased demand on the part of produce buyers for growers to follow Good Agricultural Practices (GAPS), and a growing awareness that food safety is a key consumer concern. Reducing levels of bacteria in vegetable wash water is one way to reduce food safety risks, specifically the risk of cross-contamination whereby one contaminated item leads to the spread of a pathogen to other items being washed in the same water. Leafy greens in particular warrant concern about cross contamination because large volumes of these crops are often washed in the same water, the crops are exposed to splashing soil which can contain pathogens, and they are typically consumed raw.

An on-farm research study evaluated the effect of multiple rinses, and use of an organically-approved sanitizer, on the level of generic E. coli in leafy greens wash water on Vermont farms. Water samples were collected weekly or biweekly from 3 farms in 2012 and 4 farms in 2013. These were analyzed by the Vermont Dept. of Health Laboratory. The results demonstrated that the highest labeled rate of sanitizer in the first wash was most effective in reducing E. coli levels (99.8% reduction). Triple washing without sanitizer was also very effective (96.9% reduction). Double washing or using a half-rate of sanitizer reduced E. coli but were not as effective.

Farmers were informed about the research findings results via presentations, extension newsletters and individual consultations (100 farms). A fact sheet was developed and a YouTube video was produced to encourage growers to improve their washing systems by using multiple rinses and/or an approved water sanitizer. Growers were recruited to take their own water samples to test leafy greens wash water during summer of the 2014 season. Pre-paid test kits from the Vermont Dept. of Health were provided for this purpose to 55 farms.

Forty-three farms submitted a total of 80 pairs of wash water samples which represented the first and final rinses from their leafy greens wash system. These were tested by for generic E. coli level. Thirty-four of these farms also completed surveys that estimated an aggregate of 447,000 pounds of leafy greens were washed, with a market value of over $2 million. Multiple rinses reduced the E. coli levels in wash water across all farms and wash system types. Several farms had very high E. coli levels in their first rinse, which were only reduced to zero after sanitizer treatment regardless of the number of rinses used. This suggests that the addition of sanitizer is a grower's best method of reducing cross contamination in rinse water.

Background

Commercial vegetable growers are interested in practical techniques for reducing food safety risks. This interest is motivated in part by the growing attention being paid to risks associated with fresh produce, as evidenced by a new federal food safety law and the increase in buyers that require food safety audits. Reducing levels of bacteria in vegetable wash water is one way to reduce food safety risks, specifically the risk of cross-contamination whereby one contaminated item leads to the spread of bacteria to other items being washed in the same water. Leafy greens in particular warrant concern about cross contamination because large volumes of these crops are often washed in the same water, the crop is exposed to splashing soil which can contain pathogens, and they are typically consumed raw.

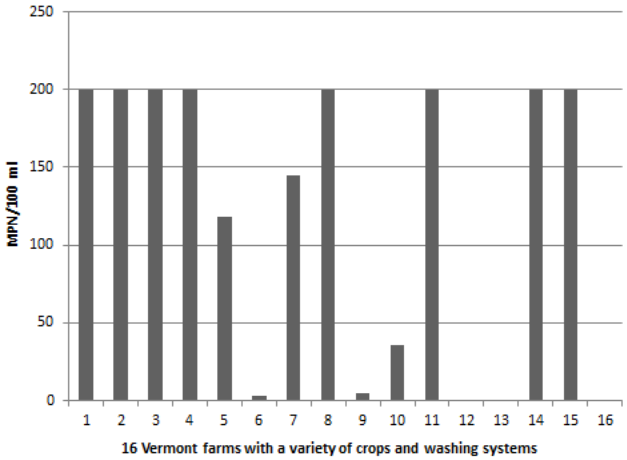
Generic *E. coli* is the most widely accepted indicator of bacterial contamination in agricultural water, including vegetable wash water. (Agricultural water is defined by the Food and Drug Administration as that which comes in contact with the edible portion of a crop.) While it is not a direct measure of pathogenicity, the level of generic *E.coli* is used in GAPS (Good Agricultural Practices) food safety audits and will also be used as part of FSMA (Food Safety Modernization Act) as a proxy for the level of risk posed by pathogens in agricultural water. Little is known about the level of *E. coli* and other bacteria in vegetable wash water on farms, or the effectiveness of post-harvest treatments in reducing those levels.

Preliminary On-Farm Assessments

In 2008, an on-farm assessment was conducted in collaboration with members of the Vermont Vegetable and Berry Growers Association. Sixteen farms across the state volunteered to collect water samples from their wash water prior to use (clean water) and after washing vegetables (used water.) These farms took one to three paired samples over the course of the growing season.

The data found that the majority of farms used clean water that was potable (contained no *E. coli* or coliforms), and that generic *E. coli* was commonly found in the used water after washing vegetables (Figure 1). One farm that treated the vegetable wash water with a sanitizer (chlorine) consistently had no detectable *E. coli* in the water after washing vegetables.

Figure 1. Generic *E. coli* levels in used vegetable wash water on 16 Vermont farms, July 2008



A number of challenges related to on-farm testing of vegetable wash water were revealed during the course of this assessment. First, there were concerns that raising the issue of *E. coli* in vegetable wash water could have negative market consequences if the results were improperly interpreted. Second, inconsistent water sample collection and handling raised concerns about the quality of the data. (Water samples must be properly collected, kept cool, and delivered to the lab within 30 hours in order to get an accurate reading of *E. coli* levels. It was not always clear whether farmers achieved this.) Third, the testing lab initially used had an upper limit of 200 MPN (most probable number) when measuring generic *E. coli*, and in cases when the water samples after washing vegetables exceeded this level the true extent of wash water contamination could not be determined. Fourth, a wide variety of vegetable crops and washing systems are found on farms, complicating interpretation of the data.

By 2011 some new conditions emerged that warranted additional study of vegetable wash water. A new, non-chlorine sanitizer had become commercially available which was approved for use in wash water on organic farms (Sanidate 5.0). This was of interest because Vermont has many farms required to, or that desire to, follow organic practices and this material would give them a practical way to treat their wash water. Second, the Vermont Department of Health Lab introduced a new test kit for higher levels of generic *E. coli* than in the past. Third, the passage of FSMA and recent food safety outbreaks associated with leafy greens increased grower interest in practical ways to reduce food safety risks.

Figure 2. SaniDate® 5.0 is manufactured by BiosafeSystems, LLC. It is a sanitizer/ disinfectant containing the active ingredients hydrogen peroxide (23%) and peroxy acetic acid (5.3%) which is OMRI-labeled and thus acceptable for use on organic farms. At the time of these pilot studies, SaniDate® 5.0 was labeled for post-harvest use in fruit and vegetable processing water at a rate of 0.5oz (15 ml)/10 gallons (38 L) of water, a 1:1000 dilution.

In 2011 samples were collected from one Vermont farm in August as a preliminary assessment of the efficacy of Sanidate 5.0, as well as the efficacy of triple washing in reducing generic *E. coli* levels in leafy greens wash water. Twenty-four heads of lettuce were washed in 10 gallons of water in stainless steel sinks and *E.coli* levels in the water were measured after one, two and three rinses, and after the addition of 0.5 fluid oz. Sanidate 5.0 to the 'dirty' first rinse. The results were: >200, 25, 2 and 0 MPN of *E. coli*, respectively.

In 2012, with funding from the Vermont Agency of Agriculture, a pilot study was conducted on three farms to further evaluate triple washing and/or the addition of Sanidate 5.0 for effectiveness in reducing generic *E. coli* in wash water of leafy greens and other vegetables. The farms were vegetable farms using organic practices and representing different scales of production and geographic location across Vermont. All farms used composted manure on their soils within the last year to improve soil fertility, and all farms had an un-chlorinated but potable water supply for washing vegetables.

The research team collected weekly or bi-weekly samples, from mid-June through mid-September, depending on the farm. The Vermont Department of Health Lab conducted the analyses (Table 1.)

Table 1. Mean and (range) Percent Reduction of *E. coli* by Wash and/or Treatment in 2012

Farm / Produce Type	**Double Wash**	**Triple Wash**	**Double Wash + Half-rate SaniDate**	**Single Wash + Half-rate SaniDate**	**Single Wash + Full-rate SaniDate**
Farm 1 n=10	88.54 (51.7 - 98.2)	97.9 (94.9 - 100)	98.7 (96.3 - 99.9)	--	99.9 (99.2 - 100)
Farm 1 greens only n=7	93.8 (80.2 - 98.7)	98.1 (94.9 - 100)	98.7 (96.3 - 99.9)	--	100 (99.9 - 100)
Farm 1 non-greens n=3*	76.2 (51.7 - 99.2)	97.2 (96.4 - 98.1)	--	--	99.7 (99.2 - 100)
Farm 2 n=8	88.0 (73.9 - 98.8)	97.0 (89.6 - 99.6)	--	90.8 (79.9 - 99.8)	100 (100 - 100)
Farm 3 n=3	85.9 (74.3 - 94.1)	93.4 (88.0 - 97.0)	97.7 (96.9 - 99.4)	--	99.0 (96.9 - 100)
All Farms all produce n=21	87.9 (51.7 - 98.8)	96.9 (88.0 - 100)	98.3 (96.3 - 99.9)	90.8 (79.9 - 99.8)	99.8 (96.9 – 100)
All Farms Greens Only n=16	90.9 (73.9 - 98.8)	97.5 (94.9 - 100)	98.7 (96.3 - 99.9)	90.8 (79.9 - 99.8)	99.8 (96.9-100)
All Farms Non-greens n=5	78.5 (51.7 – 99.3)	95.0 (88.0 – 98.1)	97.7 (96.0 – 99.4)	--	99.8 (99.2 – 100)

The results demonstrated that the highest labeled rate (full dose) of sanitizer in the first wash was most effective in reducing *E. coli* levels (99.8% reduction). Triple washing without sanitizer was also very effective (96.9% reduction). Double washing or using a half rate of sanitizer reduced *E. coli* but were not as effective. However, the number of samples was not sufficient to confidently establish Extension recommendations. The study team decided that additional data were needed.

Project results

In 2013, with funding from the USDA Risk Management Education program, the study team collected weekly samples from four farms from mid-June through mid-October. Included were two farms from the 2012 study plus two additional farms so that two of the test sites were in the north of the state and two were in the south. The farms included a small-scale and a large scale CSA, as well as two farms with a mix of retail and wholesale markets. Samples were collected only from leafy greens washing systems.

In 2013, as in 2012, the addition of sanitizer or the use of triple washing proved most effective in reducing *E. coli* levels in wash water. Double washing was not as effective but still greatly reduced *E. coli* compared with an untreated single rinse. The data from both years of sampling were merged to provide a more robust analysis (Table 2).

Table 2. Percent Reduction of *E. coli* by Wash and/or Sanitizer Treatment Compared to Single Wash. Data combined from 2012 and 2013.

	Double Wash n=33	**Triple Wash n=33**	**Full Rate Sanitizer in First Wash n=53**	**Full Rate Sanitizer in Second Wash n=9**	**Half Rate Sanitizer in Second Wash n=21**
Minimum	56.6	89.6	55.3	98.1	94.6
Average (mean)	90.6	98.0	99.1	99.6	99.5
Maximum	100	100	100	100.0	100

Seasonal trends were observed during both the 2012 and 2013 seasons, with spikes of *E. coli* more common in mid-summer (Figure 3). *E. coli* levels were moderately correlated with the high temperature of the day(s) before harvest.

Figure 3. Level of generic *E. coli* level in the first, second and third wash water rinse on one farm over the 2013 growing season. Each sample of water was taken after rinsing 24 heads of lettuce in 10 gallons of water.

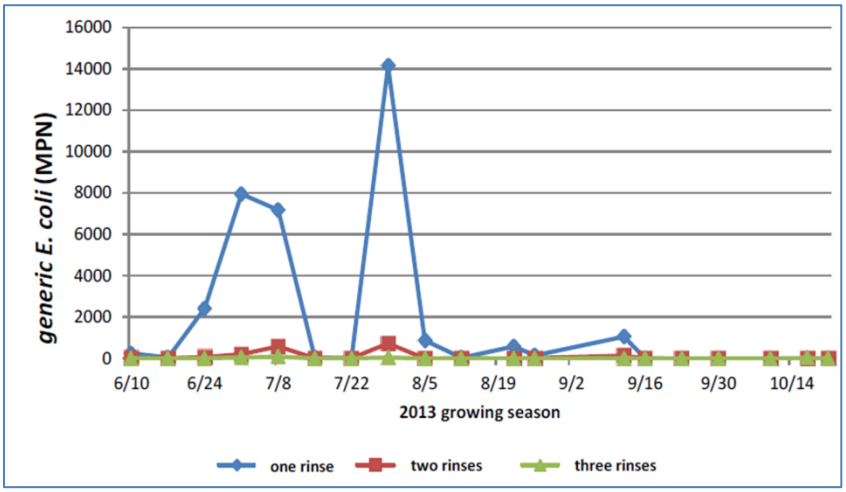
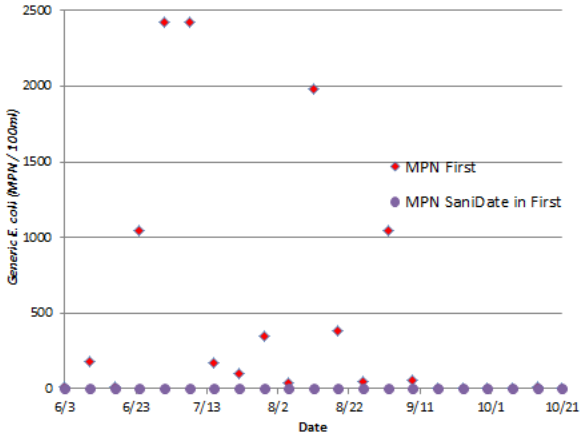


Figure 4. Level of generic *E. coli* level in the first rinse (red points) and in the first rinse after the addition of the full rate of Sanidate 5.0 (blue dots) on one farm over the 2013 growing season. (On dates when the first rinse had a very low level of *E. coli* the blue dot covers the red point.) The volume of water and amount of produce washed varied throughout the season.



Outreach efforts shared these findings with growers; individual discussions also took place around wash system design and suitability of different treatment options. During the winter of 2013-14, approximately 1,700 farmers were informed about the project results via presentations at the New England Vegetable and Fruit Conference in Manchester, NH (200 farmers attending,) the annual meeting of the Vermont Vegetable and Berry Growers Association in Montpelier, VT (160 farmers), the Northeast Organic Farming Association of Vermont winter conference in Burlington, VT (40 farmers), the Vermont vegetable and berry grower extension newsletters (700 farmers), as well as through individual consultations (100 farms).

A fact sheet was developed and a YouTube video (500+ views) was also produced to encourage growers to improve their washing systems by using multiple rinses and/or an approved water sanitizer.

Growers were recruited to take their own water samples to test leafy greens wash water during summer of the 2014 season. Pre-paid test kits from the Vermont Dept. of Health were provided for this purpose to 55 farms (including one in each of MA, NH and NY). Forty-three of these farms submitted a total of 80 pairs of samples representing a first rinse and a 'final' rinse' that was the last in a series of multiple rinses, a sanitized rinse, or some combination. Twelve farms tested once (12 test pairs), 31 farms tested twice (62 test pairs) and 2 farms tested 3 times over the season (6 test pairs).

Based on surveys completed by 34 of these farms prior to testing their own wash water we estimate the quantity of leafy greens washed by farms participating in this project to total 446,485 pounds. These leafy greens included some combination of lettuce, kale, mesclun mix, spinach and other similar crops. By taking an average of the typical 'direct wholesale' price (e.g. sales direct to stores) and the retail price (at farm stands, farmers' markets, etc.) for each crop (see: http://www.uvm.edu/vtvegandberry/factsheets/vegetableberryprices.pdf), and by assuming equal amounts of the four crops above were washed, the estimated average value of leafy greens washed was $4.49 per pound or just over $2 million worth of leafy greens in the aggregate.

All farms submitting samples in 2014 had adopted multiple rinses and/or use of sanitizer. The majority of farms participating in the 2014 water testing program had made changes to their washing system as a result of this project's outreach efforts. Twenty-six farms had either increased the number of rinses and/or started using sanitizer (Table 3.) Four of the farms planned to make a change in the coming season. Four farms had already adopted one of the practices prior to this project and did not plan any changes.

Table 3. Responses to the question on intake form prior to water testing in 2014: "Over the past several years have you made changes to your leafy green wash system as a result of information you received from UVM Extension?"

Farm Change	**(n=34)**
Farms that increased the number of rinses	20 (59%)
Farms that added sanitizer	3 (9%)
Farms that increased rinses and added sanitizer	3 (9%)
Plans to add sanitizer and/or an additional rinse	4 (12%)
Farms that did not make any changes	4 (12%)*

* Two farms were already triple rinsing; one double rinsing; and one single or double rinsing depending on the mix. Note: This sample should not be considered representative of all Vermont produce farms.

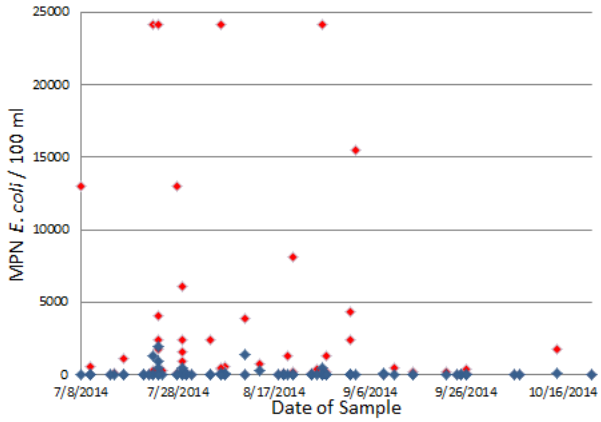
A survey of growers conducted in winter 2013-14 found that most had not been evaluating the water used in leafy greens wash systems. Only 5 of the 62 farms responding said they had tested wash water for bacterial levels (Table 4.) Some of this test may have been for potable water prior to washing.

Table 4. Responses to the question on winter 2013-14 grower survey: "Did you evaluate the effectiveness of your leafy greens wash system in 2013?"

Evaluation	**(n=62)**
Monitored sanitizer levels in wash water	1 (2%)
Tested wash water for bacteria count	5 (8%)
Other methods	4 (6%)
No I did not evaluate the system	49 (79%)
No answer	2 (3%)

The 43 farms that submitted water samples to test their leafy greens wash water used a variety of washing systems and treatments. Across all of these there was notable reduction in generic *E. coli* in wash water after multiple rinsing and/or use of sanitizer, compared to a single untreated wash (Figure 4.) In 2014 there were some unusually high levels of *E. coli* measured in the first rinse on a few farms.

Figure 4. Incoming load of generic *E.coli* in first rinse (red points) and the load of generic E. coli in the 'final' rinse (blue points) on all farms in 2014. Data combines all wash systems and treatments used on 43 farms.



The highest reductions were observed in single wash systems with sanitizers +/- bubblers and triple wash with sanitizer in the third wash (Table 5.) Percent and log reductions for double and triple washes, with the exception of triple wash with sanitizer in the third rinse, were lower than seen in the more controlled 2012 and 2013 studies. With the exception of triple wash without sanitizer, the number of paired observations in each category is small (<5), resulting unstable estimates.

Table 5. Percent and log Reduction of generic *E. coli* from first to final rinse by treatment and type of leafy greens washing system. These growers used a variety of washing systems and wash water treatments. One farm had a hydrocooler for washing, three farms had a bubbler system (air forced into wash tank), and the remaining 39 farms used either a single, double, or triple wash system with or without sanitizer.

Wash system/treatment combination (n)	**Percent reduction mean (range)**	**Log reduction mean (range)**
Hydrocooler + sanitizer (1)	100	2.7
Single rinse + Sanitizer + Bubbler (2)	100	3.9 (3.4, 4.5)
Single rinse + Sanitizer (3)	100	3.0 (2.3, 3.9)
Double rinse + Bubbler (1)	99.6	2.4
Double rinse (3)	63.4 (17.9, 100)	1.1 (0.1, 2.8)
Double rinse + Sanitizer in second rinse (4)	87.3 (64.1, 100)	2.1 (0.8, 4.2)
Triple rinse (21)	92.1 (46.9, 100)	1.7 (0.3, 2.9)
Triple rinse + Sanitizer in the second rinse (5)	96.2 (81.0, 100)	2.7 (0.7, 4.7)
Triple rinse + Sanitizer in the third rinse (3)	100	3.4 (2.0, 4.4)

Excludes sample pairs with incoming loads with MPN < 50; a test with abnormal appearance in the lab; and pairs with an MPN greater than the limit of detection of the test with or without dilution.

Two separate systems which used bubblers had very high levels of *E. coli* in the first rinse after washing a relatively small amount of produce. One farm used a single rinse with bubbler and sanitizer to wash 24 lbs. of leafy greens. The water sample taken after the rinse/bubbler had an MPN of 15,531. This was reduced to 0 following the addition of sanitizer (log reduction 4.49). A second farm used a double rinse without sanitizer with the bubbler in each rinse to wash 3 lbs. of greens. The first and second rinses sample yielded MPNs of 24, 192 and 91, respectively, resulting in a log reduction of 2.42. We hypothesize that bubblers may dislodge organic matter and bacteria off the greens, resulting in higher counts in the water. In the case of the first farm, sanitizer was able to neutralize these high levels. At the second farm, a higher than usual reduction was observed for a double rinse without sanitizer system. It is possible that the bubbler dislodged a higher percentage of the organic in the first rinse, resulting in a lower bacterial load in the second rinse.

Several farms using sanitizer had very high *E. coli* levels in their first rinse, which were reduced to 0 after sanitizer treatment regardless of the number of rinses used. This suggests that the addition of sanitizer is a grower's best method of reducing cross contamination in rinse water.

Two farms had consistently high *E. coli* levels, often exceeding the upper limits of the test even after dilution. Conversations with these farms did not yield an obvious source for the *E. coli*. One of these farms tested for a third time in October, when *E. coli* levels generally fall dramatically. While the levels were reduced compared with summertime levels, they were still higher than what we would expect for that time of year. These two farms reinforce the unpredictability of *E. coli* levels on farms. Both of these farms used a triple rinse without sanitizer, suggesting that while triple rinse can be effective at reducing *E. coli* with lower incoming loads, it may not be sufficient for higher levels.

Conclusions

Use of the sanitizer (disinfectant) Sanidate 5.0 and/or multiple rinses appears to reduce the risk of bacterial cross contamination when washing leafy greens. These practices can be implemented in variety of ways that meet the needs of individual farms, their products, markets and washing systems. However, there are obstacles to adopting these practices, identified by growers in the 2013-14 winter survey and 2014 summer intake form (Table 6.)

Table 6. Grower-Identified Obstacles to Multiple Rinses and/or Sanitizer for Leafy Greens Washing.

Obstacles	**Winter/spring survey (n=62)**	**Summer intake (n=34)**
I do not have the infrastructure (equipment or space) for multiple washes	15 (24%)	4 (12%)
I do not use sanitizer due to production practices, environmental or other reasons	15 (24%)	--
Improvements to my wash system would be too costly	4 (6%)	3 (9%)
Multiple rinsing takes too much time	8 (13%)	4 (12%)
Multiple rinsing reduces produce quality and/or shelf life	5 (8%)	--
Sanitizer use reduces produce quality and/or shelf life	4 (6%)	--
Testing water for *E. coli* is too costly and/or time consuming	10 (16%)	1 (1%)
Other	12 (19%)	16 (47%)
No barriers	11 (18%)	9 (15%) (no or blank)

"Other" barriers listed by farmers included: What about good microorganisms on food and use of sanitizer?; I plan to make changes but don't know which improvements would be most cost effective, fearful of making changes now that will need to be changed again with FSMA; Limited space available; Being a very small farm and knowing customers well - better to advise they wash and most do; Cost of stainless steel; Fear of consumer resistance to taste, chemicals; Not familiar with sanitizer options and costs; Triple washing uses a lot more water; General concerns about sanitizer (and the NOP-approved sanitizer is not cheap); Just haven't gotten there as a relatively new farm, will continue to make improvements; Inability to find equipment; concerned about smell of SaniDate; cost of SaniDate is too high based on manufacturers rates; Triple rinsing inconvenient; Need to build a better washing station/pack shed.

The main benefit of using a disinfectant in water is to reduce the population of organisms that can lead to cross contamination within the wash vessel. Similarly, the presence of disinfectant in wash water can protect produce quality if there is a temperature-generated pressure differential that forces wash water into crop tissues. Secondary effects may include the reduction of microbes on the surface of the produce. The use of disinfectants does create additional expense for purchase and application. Their level in wash water should be monitored over time, an issue not addressed by this project. Sanitizers also raise human and environmental health concerns if improperly used or disposed. Growers need education about proper methods of handling sanitizer, including how to safely measure out the volume of the material needed for addition to wash water system from a larger container of sanitizer.

The marketing benefit of triple washing, particularly for crops like leafy greens grown near the soil surface, is a cleaner crop with less grit. Triple washing may reduce or eliminate the need for the use of a disinfectant; however, there is a lack of studies on the effectiveness of triple washing without sanitizer in pathogen reduction. Our data suggest that triple washing is usually effective a reducing bacteria loads, but may not be able to achieve sufficient reduction when the incoming loads are very high. Triple washing requires more infrastructure (three vessels compared with one dump tank) and larger quantities of water.

These data suggest that additional research is needed in the following areas:

1) Further investigate incoming *E. coli* load and environmental variables including temperature, humidity, and soil load.

2) Monitor bacterial (ideally generic *E. coli* and pathogens) levels on/in greens, correlating these levels to rinse water. We are particularly interested in including a bubbler system in this analysis. Bacterial reductions on the surface of vegetables following various wash treatments have been observed, but the study did not correlate them with bacteria levels in the water.

3) Conduct research on best practices for the use of organic sanitizer, including a recommended dose of sanitizer (the manufacturer currently gives a wide range), the amount of greens that can be washed per unit of sanitizer, monitoring sanitizer levels in wash water, and safe methods of handling sanitizer.

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Testimonials

"At Jericho Settlers Farm in the past three years we increased our leafy greens production from 100 to over 500 lbs. of greens harvested per week. As we scaled up the leafy greens production on our farm we wanted to make sure we were using effective practices to ensure the safety of the greens we were selling. The Leafy Greens Wash Water study funded by the Risk Management Education program and conducted by Vern Grubinger and Lynn Blevins was instrumental in helping us evaluate if our wash system was effective. In fact, it helped us eliminate some redundancy in our greens wash line, thus improving our production efficiency while still maintaining high levels of food safety.

Three years ago we did not use a sanitizer in our greens washing system, but we did do a double wash, or if the greens were particularly dirt-covered we would do a triple wash. We had no idea what levels of E. coli might be present on our greens. We wanted to try using a sanitizer but had limited information on its effectiveness. We decided to implement and test the Cadillac of wash systems (at our small scale), which was comprised of a triple rinse with a sanitizer used in the second rinse. The results of the wash water study showed us three key things: 1) that E.coli was always present and often in high numbers in our greens (first rinse), especially during periods of warmer weather, 2) that the second rinse with sanitizer was always effective at bringing those E.coli levels down to zero or very close to zero, and 3) that is was not essential to do the third rinse after the second rinse with the sanitizer. Based on the results of the study we have officially adopted the use of a sanitizer for our leafy greens wash system, and we have settled on a two rinse system with the sanitizer in the second rinse, thereby saving labor by eliminating the third rinse. We are very thankful for UVM Extension and the Risk Management Education program making this information available and practical for our farm."

– Christa Alexander, Jericho Settlers Farm, Jericho VT

"Out of a desire to reduce potential food borne illness from our produce in the wake of Tropical Storm Irene, the Intervale Community Farm (ICF) worked with UVM Extension personnel to help identify a common sense and effective way to do that. After engaging in the research funded in part by the Risk Management Education program, ICF opted to change our approach to washing leafy greens. ICF harvests approximately 500 lbs. of baby greens weekly from June through October, and lesser amounts earlier and later in the season. On recommendation from Extension, we shifted from a single wash to a three tub wash without sanitizers for all of our baby greens, and most of our other leafy greens. With the use of large poly stock tanks and large fishing nets, this proved reasonably easy to do, adding about 3 hours a week to our wash schedule.

Over the summer months, this added about $1,000 in labor. As a result of this practice, we saw our final rinse E.coli numbers plummet and also found that we have better shelf life for our baby greens and other greens. While triple rinsing certainly adds to our costs, we made up for some of it with better product shelf life, and in the scheme of our annual labor budget in excess of $200,000, it isn't an unreasonable cost to bear for a substantial reduction in risk."

- Andy Jones, Intervale Community Farm, Burlington VT