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A Mixed Methods Approach to Context Specific Curriculum Design for Very Small and Small Strawberry Growers in the Southeastern United States

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A Mixed Methods Approach to Context Specific Curriculum Design for Very Small and Small Strawberry Growers in the Southeastern United States

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by

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Abstract

Outbreaks of foodborne illness due to fresh produce are a continued threat to both the public health and the economy in the United States. Though there are many factors which influence the perpetuation of foodborne pathogens, the inability of the food industry to curtail this issue indicates systemic failure of interventions aimed at improving food safety practices. In this dissertation, we detail the efforts made over the past few decades to provide training to food producers and food handlers as well as recommendations that have been made for improvement based on these studies. By borrowing from more advanced fields of study such as implementation science, we will outline and evaluate a novel method for approaching context and commodity specific education for the food industry.

Dedication

My dissertation is dedicated to the family and friends with whom I couldn't have done this without. I am fortunate to have a mom who provides unyielding support, and a dad and stepmom who always offer sage advice. I have also been blessed with friendships that span decades as well as those made new. I love you all to the moon and beyond.

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Chapter 2: Yeargin, T. A., Fraser, A. M., & Gibson, K. E. (2021). Characterization of risk management practices among strawberry growers in the southeastern United States and the factors associated with implementation. *Food Control*, *122*, 107758. (Published)

Chapter 1

A Review of Literature Related to the Implementation of Risk Management Practices on Produce Farms and the Factors Holding Influence

Abstract

Foodborne illness related to the consumption of fresh produce has been on the rise for more than three decades. Though patterns of consumption and methods for pathogen detection have both increased in the concurrent timeframe, there is still a notable increase in foodborne illness. Similarly, there has been the proliferation of food safety education and training for produce growers for which there has been little overall observed effect. To overcome these challenges, food safety researchers must advance and incorporate those skills outside of those gained through laboratory research. In this dissertation, we outline those advanced methods; primarily those associated with social sciences and theories of behavioral change to demonstrate their application in food safety research for produce

1. Introduction

Outbreaks due to the consumption of contaminated fresh produce have been on the rise since the 1970's with recent estimates of single-etiology outbreaks indicating that leafy vegetables and fruit-nuts caused the 1st and 3rd most illnesses linked to a single commodity at 22% and 12%, respectively (Painter et al., 2013). Fruits and nuts along with five other produce commodities were linked to 46% of outbreaks, only outweighed by "all plant-commodities" of which they were included (Painter et al., 2013). The continued prevalence of produce-associated outbreaks is likely influenced by many factors including changes in produce consumption and pathogen distribution. Between 1970-2009, it was reported that consumption of fresh fruit and vegetables in the U.S. increased 25% and 31% respectively (USDA, 2009). Between 2000-2008, the U.S. Centers for Disease Control and Prevention (CDC) reported human norovirus was responsible for 58% of all foodborne illnesses, of which 49% were attributed to fresh produce. The following year, the CDC launched Calicinet, a national norovirus surveillance system (Painter et al., 2013, Scallan et al., 2012). These data can help us understand the current trends in produce related outbreaks but do not discount the continued need for improved food safety.

Recognizing the burden of foodborne illnesses, the U.S. government has enacted two major provisions to enhance the safety of our food supply. First, in 1997 the "Initiative to Ensure the Safety of Imported and Domestic Fruits and Vegetables" was announced. As part of this initiative the U.S. Food and Drug Administration (FDA) published the "Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables" (FDA, 1998). This guide was the first of its kind to introduce science-based standards for growers meant to reduce the risk of produce contamination. These standards provided recommended practices centered around eight main areas, now commonly referred to as good agricultural practices (GAPs) **(Table 1.1).**

Since the introduction of GAPs, the U.S. has continued to see outbreaks linked to produce, especially fruits and leafy greens, which have varied in their scale and severity. Between 1996 to 2010, there were 131 outbreaks associated with 20 types of fresh produce leading to 14,350 illnesses and 34 deaths. These outbreaks likely occurred early in the production process before reaching retailers or consumers (FDA, 2018). As a result, a great deal of research has been initiated to determine the sources of microbial contamination as well as the survival, transfer, and elimination of pathogens on fresh produce (Olmait & Holley 2012). Elimination of pathogens on fresh produce has been especially problematic due to their ability to adhere to the produce surface or, in some cases, internalize into the plant stomata (Berger et al., 2010; Critzer & Doyle, 2010). As fresh produce is highly susceptible to physical and to a lesser extent nutritional degradation, there are not many options to remove or inactivate pathogens without affecting the quality of the food. Because of this, many in the scientific community began to advocate for prevention-based controls, much like the Hazard Analysis and Critical Control Points (HACCP) used in meat processing and food manufacturing facilities, to be implemented in on-farm produce production (Soon. 2010). Currently, the FDA and U.S. Department of Agriculture (USDA) provide guidance on HACCP; however, the guidance is commodity and industry specific. Moreover, the Hazard Analysis and Risk-Based Preventive Controls approach is recommended for all FDA-regulated products to meet the requirements of the Preventive Controls for Human Foods Rule under the Food Safety Modernization Act (FSMA).

In 2011, President Obama signed into effect the FSMA which tasked the FDA with developing a new set of minimum standards for ensuring food safety through every point in the food supply chain. Along with input from growers, government entities, research and extension groups, the FDA established seven rules using evidence-based research that focus on risk reduction through prevention. The FSMA rule most related to produce safety, shown in **Table 1.2**, are the "Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption" also known as the Produce Safety Rule (PSR). The PSR addresses 5 main areas related to on-farm food safety. These areas are 1) agricultural water, 2) biological soil amendments of animal origin, 3) employee health and hygiene, 4) control of wildlife and domestic animals, and 5) sanitation of equipment, tools, and buildings. Also relevant to the produce industry is the rule for "Accreditation of Third-Party Certification Bodies to Conduct Food Safety Audits and To Issue Certifications". The FDA established this rule to enforce the FSMA through a two-tier process. This voluntary program would recognize accreditation bodies and grant them the power to accredit third-party organizations. It is then the responsibility of the third-party certification bodies to perform random audits. The rule on accredited third-party certifications contains instructions for both bodies to follow in order to monitor, assess, and document their respective duties. The FDA in turn may review these documents at any time and reserves the right to revoke recognition for both parties, and in on occasion, if they find necessary, directly accredit a third-party certification body.

Because the scope of the PSR combined with the shift to mandatory audits away from market-driven audits, some produce growers may be faced with making large scale changes. This could be especially true for very small and exempt growing operations as defined by the PSR.

Because of their revenue and market channel, these growers may not have been using risk management practices (RMP) to the same extent as larger growers (Adalja and Lichtenberg, 2018; Shinbaum et al., 2016). Before enforcement of the PSR, two national surveys were conducted in the U.S. to characterize on-farm food safety practices related to the five areas addressed in the PSR. A study of this scale had not been conducted since the "1999 Fruit and Vegetable Agricultural Practices" survey commissioned by the USDA National Agricultural Statistic Service (NASS) (USDA NASS, 2001) and, as such, presents a major update to our understanding of the current use of RMP by produce growers. Astill et al. (2018) presented data collected from 4618 growers surveyed from 2015 to 2016 and found that farm size was significantly associated with the implementation of some RMP. For example, growers with revenues between US$25,000 and US$500,000 (covered, i.e., these growers must comply with the PSR unless they meet the definition of qualified exempt) as well as those earning <$25,000 (exempt, i.e., these growers do not have to comply with the PSR) were less likely to collect agricultural water samples and less likely to follow an approved method to test for *Escherichia coli* in pre-harvest agricultural water samples compared with medium, large, and very-large growers. Meanwhile, a study by Adalja and Lichtenberg (2018b) focused on implementation challenges relative to the size of the farm—as specified by the PSR—as well as those growers identifying as 'sustainable' (e.g., use of biological soil amendments, grazing livestock, integrated farming systems, etc.). The authors surveyed 394 growers and reported that farm size as well as commodity and region impacted implementation of RMP. For example, berry and fruit/tree nut growers were less likely than leafy greens growers to collect agricultural water samples. In addition, growers in the western U.S. were more likely than growers in other regions to document RMP. Overall, both survey studies concluded that while the degree of change may vary based on the farm, all growers need to make changes to their current RMP to comply with the PSR.

To help facilitate implementation, the FDA along with Cornell University established the Produce Safety Alliance (PSA). Together they have developed two courses—one for growers and one for food safety educators—designed to explain the concepts behind the PSR along with the minimum required and recommended RMP. The "Grower Training" also satisfies the PSR requirement for managers and employees to receive food safety training. Meanwhile, the "Train-the-Trainer" has increased the number of experienced trainers to meet the demand of the industry. However, in a survey of 2359 produce growers in the southeast region of the U.S. who attended PSA Grower Training, Danyluk et al. (2018) found that 52% and 42% of growers indicated knowledge and perceptions towards FSMA, respectively, were a significant barrier to making changes to their practice. This was even after demonstrating a significant increase in knowledge from a median score of 65.2% to 84% between pre-test and immediate post-test. Furthermore, in a three-month post-test when asked 11 questions about actions taken on the farm since training, responses ranged from 30-85%. Growers were most likely to have written a food safety plan and least likely to implement new methods for transporting produce.

These results are similar to what has been reported for previous food safety training initiatives. Most food safety training programs, whether plainly stated or not, rely on the passive diffusion of information. The passive diffusion approach assumes that the more an individual is exposed to a given content, the more likely they will adopt it, leaving no alternatives to individual preferences (Milli et al., 2018). Many also follow the Knowledge, Attitude, Practice model (KAP) (Viator et al., 2015). In KAP, knowledge is transferred from the educator to the learner with the assumption that upon acquiring new knowledge, one will change their attitude which will then lead to action. KAP-focused training has been shown to increase knowledge but has largely been ineffective at influencing and/or sustaining attitude and practices (Insfarn-Rivarola et al., 2020; Young et al., 2020). Participants of food safety training typically show significant improvement in food safety knowledge based on pre/post training evaluation; however, a significant and sustained change in knowledge implementation is rarely observed (Insfarn-Rivarola et al., 2020; Zanin et al., 2017). The influence of context—defined as the environment or setting in which the shared knowledge is to be implemented—is receiving increased attention. As context differs between settings and can change over time, understanding the application context and addressing it in training is more likely to lead to improved training outcomes (May et al., 2007).

There are several ways to understand how context can be applied on the farm. As discussed, the PSR does utilize economic scale and commodity type as the criteria for determining inclusion within the rule. Farms can also be characterized by acreage, years in production, market channel, region, and/or professional grower organizations (Adalja & Lichtenberg, 2018; Marine et al., 2015). These characterizations are frequently used to provide descriptive statistics and are especially helpful for identifying trends in RMP. For example, Adalja and Lichtenberg (2018) found that growers located in the western U.S. and growers who identify as using conventional production practices are significantly more likely to keep written records than growers in other regions and those who identify as sustainable. Similarly, growers of fruit and tree nuts are significantly more likely to conduct routine water testing than those who grew vegetables/row crops berries. When it came to economic scale, Adalja and Lichtenberg (2018) found that small growers, whose revenue is between $250,001 to $500,000 in produce sales, were significantly more compliant than growers of any other scale with water testing, field monitoring, as well as training regarding employee health and hygiene.

Many growers, however, have diverse operations and will need to make a step-by-step assessment to determine if the PSR applies to their on-farm practices and what criteria must be met (Parker et al., 2012). For example, if a grower is harvesting produce that is considered likely to be consumed raw but selling it to a “qualified-end user”, who will further process the produce, then the growers will be exempt. Growers who are not exempt will also need to use the same scrutiny when deciding if and how to implement the individual guidelines in the PSR. In many cases, there are caveats or approved deviations. An example of this could be in the process of composting. The PSR gives two approved methods of composting which, if followed by the grower, do not require microbial sampling. Instead, growers are required to keep records on time, temperature, and turning to ensure they are following the method as described. Growers also have the option to use their own method; however, in this case microbial sampling is required to ensure that it meets the same criteria as the approved method. Another example would be the standards for pre-harvest agricultural water testing which have different regulatory requirements based on the source. Water from a municipal source does not require testing, but growers will need to have a copy of the public testing record. Ground and surface waters require testing 4 times a year for one year and 20 times a year for 2-4 years, respectively. Since growers can often use multiple sources of irrigation water (Ivey et al., 2012), providing some additional context for

PSR decision making (i.e., which regulatory requirement the grower must comply with) could be beneficial.

While considering every aspect of a grower's operation would not be practical, it stands to reason that focusing on those aspects related to the adaptive capacity of the land would provide the appropriate level of environmental context. Economic scale is a limited resource in terms of capital while commodity type and region would have a significant influence on production practices. By considering the five principles of the PSR within the context of a specific model rather than an entire industry, more directly applicable recommendations can be made. To support this claim, growers' current practices and opinions related to GAPs and PSR, as well as incorporation of context in food safety training and assessment will be discussed.

2. On-Farm Food Safety Standards

2.1 Summary of Reported Practices

There are a few useful pieces of information that can be gathered by looking at the implementation of GAPs leading up to FSMA. One can estimate which practices growers have prioritized in the past as well as the practices that will need the most improvement and if there are any trends in implementation. This was the aim of a national survey of produce growers recently published by Adalja and Lichtenberg (2018). The authors surveyed 394 growers to determine their current GAPs, framing the questions around 5 areas of the PSR including 1) agricultural water 2) biological soil amendment 3) employee health and hygiene 4) animal intrusions and 5) sanitation of equipment, tool, and buildings. By analyzing their results as well as those of previous regional surveys, a summary of the current practices is presented here as well as an analysis of how these practices have changed**.** The following information pertains to growers practicing *at least one* preventative measure in a given area. A preventative measure is a practice or set of practices designed to mitigate the risk of produce contamination with foodborne pathogens. Adalja and Licthenberg (2018) found in their national survey that growers (n=394) were practicing GAPs related to agricultural water, biological soil amendment (BSA), employee health and hygiene, animal intrusion, and sanitation of equipment/tools and harvest container, 51, 68, 80, 47, 68, and 86% of the time, respectively (**Table 1.3**). Employee health and hygiene is the area growers are most prepared whereas water testing and animal intrusion will need the most improvement.

2.2 Trends in Implementation

2.2.1 Agricultural Water

The 30% of produce growers identified by Adalja and Licthenberg (2018) practicing water testing particularly may be attributed to several things. First, Ivey et al. (2012) and Parker et al. (2012) demonstrated that only approximately 30% of growers agree that water testing is an important preventative practice. Second, compliance with the PSR is expected between 2018-2020 for most regulations; however, these dates have been extended by 4 years for regulations regarding water testing (FDA, 2018). Lastly, since there are several exemptions for participating in water testing based on factors such as water source and irrigation methods, growers who reported not doing water testing may not need to. For example, Astill, Minor, and Thornsbury (2019b) observed a shift to non-contact irrigation methods (drip irrigation) (44.4% to 69.1%) as well as use of less risky water sources with a 4.1% decrease in the use of surface water and 4.6% increase in the use of municipal water. Astill et al. (2018) found only 42.3% of growers applied ground or surface water that contacts produce; however, of these growers, 66.1% were already testing their water. This was up from 32% of growers in Maryland and Delaware who reported testing water at least once a year and 27% of growers in Iowa who routinely tested well water used for irrigation (Marine et al. 2015, Shaw et al. 2015).

2.2.2 Animal Intrusion

The reported practice for preventing animal intrusion is surprisingly low compared to previous studies; however, this is likely due to how the question was asked across various surveys. Adalja and Lichtenberg (2018) specifically asked growers if they monitor fields for animal intrusion. The question was possibly worded this way because the PSR does require field monitoring for animal intrusion but does not provide specific recommendations on how to do so. Focusing on monitoring as a specific practice may account for the low 47% report in practice. When asked more generally if growers are taking measures to prevent wildlife intrusion, 68% of growers in Maryland and Delaware and 70% of growers in Minnesota indicated yes (Marine at al., 2015; Hultberg et al., 2012). Additional results reported by Marine et al. (2015) as well as those by Becot et al. (2012) suggest there is less agreement among respondents when specific practices are addressed. In each study, a maximum of 50% of respondents reported using the same practice for animal intrusion—hunting and fencing. According to Astill et al. (2019), the use of fencing specifically increased from 10.6% to 42.7% of growers. Similarly, Astill et al. (2018) found that 69.9% of all growers were monitoring for animal intrusion, and 71% were using at least one method of prevention.

2.2.3 Biological Soil Amendments

Approximately 50 to 60% of produce growers use BSA, and of those, 60-70% report using some sort of treatment method (**Table 1.3**). The most common method of treatment mentioned is composting; however, growers appear to use other management practices commonly associated with the use of soil amendments such as an application interval or physical distancing. This was observed for the 55% and 68% of growers surveyed by Hultberg et al. (2012) and Harrison et al. (2013), respectively, who reported using a 120-day application interval. Furthermore, 71% of Minnesota growers reported using barriers to physically contain BSA (Hultberg et al., 2012).

According to Astill (2019), there has been an 11.7% increase in the use of raw manure products specifically; however, the authors also indicated that only 12.1% of growers use BSA of animal origin (BSAAO) (compost or untreated). For those who did use BSA, 71.0% used and documented an approved method. In their survey, Adalja and Lichtenberg (2018) found only 33% of growers were keeping records of the soil amendment application dates which is markedly lower than the 75% of PSR covered growers reported by Astill et al. (2018) to be keeping the same documentation. However, their question was asked in reference to BSA application and not treatment. Growers do appear to support the process for risk management as reported by Ivey et al. (2012). The study authors found raw manure application intervals to be one of only five things that >50% of Midwestern produce growers strongly agreed on and was seen as more important than banning their use.

2.2.4 Employee Health and Hygiene

The highest reported rates of compliance seen by Adalja and Lichtenberg (2018) were those related to employee health and hygiene with 80% practicing education and 91% providing adequate facilities to support employee hygiene. This is a marked improvement from what has been reported in the past with lowest reports of training and proper facilities in Iowa at 48% and 61%, and the highest being 77% and 85% in Minnesota, respectively (Shaw et al., 2015; Hultberg et al., 2012). This increase in reported practices may have been driven by anticipation of FSMA requirements; however, it could be the result of attention being placed on food handlers. Numerous scientific as well as media reports have pointed to food handlers being a significant source of foodborne illness throughout the food chain (Grieg et al., 2007). While food handlers certainly play an important role in FBI outbreaks, the level of focus by growers suggests they may be overly focused on this message. For instance, when asked about the importance of 32 on-farm preventative practices, employee training in personal hygiene had the second highest agreement with 60% of Midwestern growers that “strongly agree”. As mentioned with BSA, this is one of only 5 statements that had >50% of growers who strongly agree where the majority of other results found <30% agreement (Ivey et al., 2012). In the same region, Parker et al. (2012) found that when asked what the most important effective preventative measure was, the highest response was individual health. Despite this, Astill et al. (2018) found that among covered growers only 46.8% of harvest workers were providing food safety training to harvest workers.

2.2.5 Sanitation

Both Adalja and Lichtenberg (2018) and Hultberg et al. (2012) reported similar results in terms of sanitation. In their studies, greater than 60% and 80% of growers were sanitizing tools/equipment and harvest containers, respectively. Growers from the national survey also reported 51% compliance with building sanitation; however, this measure was not asked in other studies. These results are much improved from those seen by Shaw et al. (2015) and Harrison et al. (2013) whose growers only sanitized surfaces and harvest container 18% and 39% of time, respectively. However, those results may be regional as Parker at al. (2012) found that, across farms of all scale, 41 to 57% of growers agreed facility and equipment sanitation were important preventative measures. Additionally, though all these sanitation practices are mentioned in the PSR, sanitation of harvest containers (or food-contact surfaces) has its own set of regulations, which may explain why adherence to that practice was the highest. According to Astill et al. (2019b), the frequency of cleaning and sanitizing of harvest equipment, tools, and bins is one of the most improved areas of risk as the authors observed a 28.1% increase in the share of growers who sanitize their tools daily or weekly. In their 2018 survey, Astill and coauthors found this resulted in 60% and 43.1% of growers who cleaned and sanitized daily, respectively.

3. Factor Influencing Implementation

Many growers recognize the importance of on-farm RMP; however, a portion of growers may choose not to implement them because the perceived barriers outweigh the perceived benefits. The most common barriers cited by growers are time, cost, and lack of knowledge/skill though the degree to which these barriers are prioritized can vary. For example, produce growers in Kentucky as well as those in the Mid-Atlantic and New York reported time and cost as the two biggest barriers for implementing GAPs. However, Kentucky growers ranked time and cost barriers almost equally (68% and 67%) whereas Mid-Atlantic and New York growers indicated that time (86.6%) was a greater barrier than cost (53.6%) (Sinkel, 2015; Nayak, 2016). Even though cost is often assumed to be a major barrier to implementation, many growers indicated that cost was not a significant barrier and even expressed a belief that implementation of GAPs is economically feasible (Ivey et al., 2012; Parker et al., 2011; Marine et al., 2015). This is likely because cost is only one of the factors which influence a farms adaptive capacity.

3.1 Capacity

There are several factors which influence a farms adaptive capacity mainly labor, environment, revenue, and skill. These same factors are those which we use to describe context and, in the case of the PSR, to set inclusion criteria. The PSR relies on economic revenue to consider growers as "covered" or "not covered" as well as further delineate farms as being very-small, small, and all other sizes. In their USDA study, Astill et al. (2020) further stratified the category of "all other" to include large and very large farms. Distinct trends were observed by Astill and colleagues regarding implementation of RMP as related to coverage status and farm scale. Discussing these trends further demonstrates the many ways that revenue impacts adaptive capacity and thus implementation.

First, there was a linear trend in the implementation of RMP based on farm scale. When it came to training of harvest workers, only 25.7% of not covered growers offered training which increased to 66.8% for very large farms. This trend was also observed not only for total implementation but implementation per PSR standard. For example, for pre-harvest agricultural water, very large growers were not only three times more likely than not covered growers to be collecting samples, but they were also more likely to be analyzing those samples using an established numerical standard.

Second, Astill (2020) also identified that the same upward association was found between current spending on food safety measures and size. One way that this could be observed was via labor as 66.4% of very large growers versus 20.5% of not covered growers had a designated food safety person on staff. In addition, up to 50% of covered growers had an additional two to six food safety persons on staff compared to the 38% or less of not covered growers. This could be one reason for the differences in training we described in 2.2.4 as well as the reported differences in the implementation of documentation and recordkeeping. Farm food safety personnel are reported to spend up to 43% of their time on monitoring and documenting RMP (Calvin et al., 2017). Therefore, growers with a higher labor force of qualified food safety personnel have more resources to allocate per RMP. In addition, these same large and very large growers who were spending more were likely to have undergone a third-party audit and have a food safety plan. This means the growers as well as their employees may have more experience in dealing with food safety standards via third-party certification systems which are notoriously robust.

Lastly, it has been identified that an inverse trend exists when it comes to the cost of implementation. The cost per acre was highest for not covered growers and declined until reaching very large growers in which it increased again. This is not surprising as several authors have demonstrated that implementation of RMP is an economy of scale (i.e., implementation becomes cheaper with more land). Furthermore, regarding the PSR, Bovay, Ferrier, and Zhen (2018) demonstrated that cost is impacted by state and commodity-group. Specifically, the study authors found that the share of revenue required to implement RMP increased as the scale of the farm decreased and that this fixed cost would raise the cost/share of revenue per state and per commodity group depending on the farm-scale ratio. Of particular relevance to this dissertation, the estimated cost/share of revenue for strawberries is 1.31%. While 1.37% is on the lower end of the range per commodity, very small and small farms have the highest cost/share at 6.77 and 6.05%, respectively. Additionally, there is further variation by state for cost/share ranges from 1.31 to 3.67%, with Alabama being the highest within this range and the second highest in the U.S.

3.2 Motivation

There are two types of motivation—external and internal—that influence a grower's decision to implement RMP. External motivation can come from many sources including cultural values or community values; however, the external factors cited most by growers are related to buyer demands, access to markets, and anticipation of regulations (Tobin et al., 2013). This was observed by Prenguber and Gilroy (2013) who found that 71%, 29%, and 14% of Oregon produce growers intended to become GAPs certified to keep customers, prepare for FSMA, and add customers, respectively. Similarly, 69.8% and 45.9% of growers (n=220) in Pennsylvania indicated that they would obtain food safety certification to maintain produce sales to current customers and meet new demands from buyers, respectively (Tobin et al., 2013). Meanwhile, only four growers (1.8%) from the Tobin et al. (2013) study did so in anticipation of FSMA. Becot et al. (2015) determined that, of growers who complied with GAPs, 88% did so due to buyer requirements and 6% for new customers. Internal motivation to provide safer foods has been reported; however, it is less prevalent and often observed in growers who are exempt from buyer requirements. For internal motivation, Tobin and co-authors (2013) reported that the highest response was from small and medium growers (n=81) of which 43% indicated they had a desire to produce safer foods. However, this value of 43% is much higher than the 6 to 20% that has been reported in previous studies (Ivey et al., 2012; Parker et al., 2012, Marine et al., 2015, Shaw et al., 2015).

3.3 Risk Perception

3.3.1 Sources of On-Farm Contamination

Based on previous studies, growers are generally able to correctly identify sources of on-farm contamination; however, the level of agreement on the associated degree of risk may vary individually, based on region, size, or specific RMP. Interestingly, the most frequently cited sources of contamination are associated with RMP in which growers are most compliant. Ivey et al. (2012) found that at least one-third of growers (n=210) strongly agreed that animal droppings, raw manure, and worker handling of produce could be sources of pre- and post-harvest contamination. The highest agreement was among 50% who identified raw manure for pre- and post-harvest and 42% who identified wash water for post-harvest handling. Sinkel (2016) observed similar results with 58, 65, and 75% of growers (n=160) identifying worker hygiene, animal manure, and animal intrusion, respectively, as sources of microbial contamination on Kentucky farms. In addition, small, medium, and large growers in the lower Midwest all identified worker hygiene as their primary concern for contamination (71, 100, and 71%, respectively); however, there was less than 49% agreement in all other areas. The exception to this was for medium farms of which 57% also identified wildlife as a primary concern. Small and medium growers also identified irrigation methods and soil amendment use as potential sources of contamination; however, these were not mentioned by large growers. Sinkel (2016) also reported that 51% of growers identified irrigation water as a potential source of microbial contamination whereas only 30% or less identified it in either Ivey et al. (2012) or Parker et al. (2012). Parker and co-authors (2012) suggested that growers may be overly focused on things which have been drilled into them from the news media or food safety campaigns as a possible reason for this trend.

3.3.2 Routes of transmission

Despite demonstrating adequate knowledge about sources of produce contamination, growers have largely indicated that produce contamination will most likely happen in the home as opposed to on the farm. Ivey et al. (2012) found that growers believe contamination happens: in the home (50%), during processing (43%), during retail handling (38%), and on the farm (19%). Though the authors state that the level of agreement across these statements was low, it is similar to the 51% reported by Sinkel (2016) and much lower than what was reported by Parker et al. (2012). Parker and co-authors elicited responses from both small, medium, and large growers of which 86, 100, and 94% identified "consumer behavior" as the primary source of contamination, respectively. Interestingly, when Parker et al. (2012) paired the results from growers with industry experts (i.e., scientists, policy makers, growers, and produce retailers), the result was still an overwhelming 94% who agreed that consumer behavior was the biggest issue.

4. Food Safety Education

Food safety education has been practiced since the late 1980's when public health and knowledge of foodborne illness awareness increased (Motarjemi, Y. 2013). Initially intended for those in food service, education programs have since proliferated to accommodate all sectors of the food industry from agriculture, food processing, retail, food service, and consumers. Similar to GAPs training, these programs are offered by a variety of entities including government agencies, universities, third-party certifiers, non-profit organizations, and professional organizations. While the PSA Grower Training (Perry et al., 2021, Clements & Bihn 2019) course is the most relevant example here—and the only FDA approved curriculum to meet the PSR training requirement—the most substantial body of work on food safety education is of those aimed at food handlers. Despite nearly four decades of food safety education and the associated research, there has yet to be a demonstrable impact on the incidence of foodborne illness. Considering that FBI are believed to be largely preventable using practices as simple as handwashing, it is apparent that more work needs to be done around food safety education. There are many factors which contribute to FBI outbreaks, and thus, the responsibility cannot be placed on food safety education alone.

With respect to produce growers, there have been relatively few reviews detailing the efforts or effects of food safety education. Most recently, Chen et al. (2021) performed a comprehensive review of food safety education for produce growers in which they identified 43 studies conducted between 2000 and 2019 that focused on food safety knowledge, attitudes, and behavior change. The authors found growers to be most knowledgeable about employee health and hygiene and least knowledgeable about agricultural water and BSA. Produce growers also understood the importance of RMP but were mostly motivated by customer demands when it came to implementation of RMP. In addition, growers face barriers to implementation such as time, cost, and perceived knowledge. Out of the 43 studies reviewed, there were 13 interventions which conducted evaluations including 4 which assessed behavior change. Unfortunately, due to the evaluation measures used and small sample sizes, Chen at al. (2021) were unable to find significant support for the effect of these educations, aside from an increase in knowledge.

The results reported by Chen et al. (2021) are not novel. A multitude of other studies have been conducted to 1) assess the outcome of education programs; 2) survey grower practices; and 3) review farm audits; however, the decoupled nature of these activities has provided little data on the relationship between education and grower practices. The effectiveness of food handler training has been the most well studied by the authors who have performed knowledge syntheses such as systematic reviews and meta-analysis on the topic. Among the most comprehensive reviews detailing food handler education are those by Egan et al. (2007), Soon et al. (2012), Fraser and Miller (2014), and Viator et al. (2015), which examined 46, 9, 23 and 19 studies, respectively. Each of these reviews make similar conclusions and state that, overall, the studies reviewed lacked a rigorous and systematic approach to experimental design. The review by Viator et al. (2015), in agreement with previous authors, pointed to three main areas for improvement within food safety education research: design, implementation, and evaluation.

Some of the issues raised, especially concerning rigor, may be due to issues of resource. For example, an ideal experimental design for evaluating an educational intervention would involve a randomized controlled trial performed in replicate environments. In addition, sufficient pretesting would be performed to ensure internal and external validity of methodology and instrumentation. However, conditions such as these require a great deal of both financial as well as time commitments. Fraser and Miller (2014) note that limitations in resources, time, and access make it so that the conditions needed for a randomized control trial are not always possible. These limitations may have been a factor in the many studies which utilized a single unrandomized group. For example, only 5 out of 45 studies reviewed by Egan et al. (2007) utilized randomized control trials.

Within the systematic reviews, Fraser and Miller (2014) and Eagan et al. (2007) describe more than 5 different research designs and at least 10 evaluation measures used in the design of educational interventions focused on food safety. Likewise, Medeiros et al. (2009) found that food safety education programs were offered from as short as 1 hour to as long as 3 days. The variety of methods reported further support the need for more rigor used in experimental design. Alternatively, the consensus among researchers to take the same approach to the type of intervention itself suggests a better understanding of behavioral change is needed. Most current models of food safety education, whether explicitly stated or not, also rely on the concept of diffusion as they follow the KAP model. In this model, knowledge is transferred from an expert to an assumed novice with the expectation that upon acquiring new knowledge an individual will experience a change in attitude which will motivate a change in practice. The result of KAP-based training programs while generally found to improve knowledge has been found to be largely ineffective at changing food safety practices (Insfarn-Rivarola et al., 2020, Young et al., 2021). By doing an in-depth analysis of the KAP model, we can better understand why this approach has not been wholly successful at changing practices in the food industry.

4.1 Knowledge, Attitudes, and Practices Model

The core principles of the KAP model are relatively simple but have a significant impact on experimental design. These principles may best be described as ‘expert-novice’ and ‘knowledge-diffusion', the first being related to design and implementation, and the second linked to implementation and evaluation. In the first instance, 'expert-novice' relies on the researcher to determine the core content of the training and assumes they will be received as a credible and trustworthy educator. The second principle 'knowledge-diffusion' assumes that the recipient of this expert knowledge—through a credible source—will undergo a change in attitude and that this change in attitude will ultimately lead to a change in practices. By this same reasoning, the success of food safety interventions conducted in this manner are determined through measuring the change in knowledge, attitudes, and to a lesser extent, practices. The measurement tool is usually a questionnaire administered as a pre-test and post-test whereas actual observed behavior or recorded practices are much less reported. Typically, these data are collected as intended behaviors or self-reported practices, both of which can lead to skewed data (Soon, Baines, & Seaman. 2012, Green et al., 2005, Ganster, Hennessey, & Luthans. 1983). On occasions where more quantitative instruments have been applied, a variety of different metrics have been measured including microbial data, audit reports, review of records, or manager observation. While these are useful indicators of performance, their ability to support significant results is again undermined due to an absence of rigor. Egan et al. (2007) found that only 8 of the 55 studies reviewed provided information on the development or validation of their instruments used for data collection.

The KAP approach typically results in a lecture-style education program that is broad spectrum, heavy in scientific detail with little consideration of practical needs. Though typically grounded in evidence-based practices, the KAP model often precludes the participant which Tobin et al. (2013) suggest is why some growers don't feel confident in their skills regarding implementing changes on their farm despite having participated in training. The larger problem, however, is in the inability of knowledge to effect motivation. A previous study reported significant gains in knowledge with this approach, but it was also shown that knowledge gain did not lead to significant changes in behavior (Tobin et al. 2013). When determining the relationship between knowledge, attitude, and confidence in actions taken regarding implementation of RMP, Tobin et al. (2013) found that only confidence was a significant predictor of intentions related to implementation. Additionally, in the same 6-month follow-up, Tobin et al. (2013) found that the reported gain in knowledge was not sustained.

In their review on strategies for training food handlers, Stedfelt et al. (2015) suggest that lack of efficacy observed for KAP-based training may be due in part to attitudinal ambivalence (AA) among individuals. Attitudinal ambivalence is the collection of positive and negative feelings an individual has about a practice or behavior. Two important influencers of AA often cited in agricultural-related research are risk perception and optimism bias. Risk perception influences the degree to which individuals associate possible negative outcomes with their behaviors whereas optimism bias is referring to the illusion that an individual's actions are lower risk than another. With respect to optimism bias, Parker et al. (2012) observed a "scale-dependent" optimism bias among growers. More specifically, the authors found that small and large growers both indicated that the other groups practices were riskier than their own. For example, large growers often see the use of raw manure by small growers as a risk—a similar bias that organic growers face. Meanwhile, small growers alternatively thought that large growers have a greater environmental impact and expressed concerns over runoff containment. Risk perception is usually viewed as "loss of life and limb" by growers as they associate specific negative outcomes related to their livelihood. Likewise, food safety risk perception is influenced not only by how severe of an illness you believe you will get but also by how likely you think you are to get it. For growers, if the grower has not experienced specific action or consequence related to food safety, then their food safety risk perception may be low. This results in an underestimation of risk regarding foodborne pathogens and an overestimation around practices being implemented on farm—one of the many things leading to a behavior-intention gap.

4.2 Implementation Science

Attitudinal ambivalence is an example of one behavioral construct which helps to understand the flaws of the KAP model. Regardless of the amount or accuracy of knowledge one is exposed to, there still exists an underlying collection of beliefs which ultimately influence decision making. Other behavioral constructs that have been linked to implementation of RMP and food safety risks include motivation and perception. To adequately understand these factors and their complex interactions, behavioral constructs have been organized into theories of behavioral change (TBC). Theories of behavioral change attempt to characterize and explain the interrelationship of psychological factors that influence individual behavior (Young et al., 2018) (**Table 1.4**).

Many fields of study, including food safety, are just beginning to incorporate social and behavioral science methods into their research. However, there is another field called implementation science which has already taken a more critical approach ensuring that the theories of behavioral change are being appropriately used. Implementation science is a field of research which is interested in the actual transfer of evidence-based findings into observed practice. The belief is that a significant barrier to implementation is the lack of or incorrect use and explication of the TBC. Researchers who are unfamiliar with TBC may choose the wrong theory from the start or do not implement them using appropriate methodology (Michie, Stralen, and West, 2011; Young et al., 2017). Additionally, many of the theories have overlapping constructs which can make it difficult to select the appropriate TBC and to determine which construct is significant.

To address this issue, implementation science researchers have developed the Theoretical Domains Framework (TDF). To do this, Cane et al. (2012) integrated 38 theories and 128 key theoretical constructs associated with behavioral change. These data were synthesized and mapped to what resulted in 14 theoretical domains each comprised of their own set of constructs (**Table 1.5**). A significant characteristic of the TDF is that it includes domains for internal influences as well as external influences of behavior while the TBC have mostly only considered internal influences and individual behaviors. The importance of external influences, especially environmental context, has been especially emphasized in implementation science research. Context plays a crucial role in decision making because it represents the current circumstances of an individual which either encourages or discourages the development of skills, independence, social competence, and adaptive behavior (Michie et al., 2011). Along with the TDF, Cane et al. (2012) created a list of example questions that are linked to each domain that can be used to identify important behavioral influences of a population related to a specific action, context, and goal.

While the TDF is mainly utilized in the early stages of experimental design, its main purpose was to make TBC more accessible for future research. A variant of the TDF known as the Capability Opportunity Motivation and Behavior (COM-B) Model is part of continued work by Michie et al. (2011) that seeks to completely integrate every part of experimental design (**Table 1.6**). The COM-B model is a framework which has simplified the TDF into 3 constructs each with two levels. Capability, Opportunity, and Motivation are represented as physical and psychological, physical and social, and reflective and automatic, respectively. The COM-B model is also the center of a larger framework referred to as the Behavioral Change Wheel (BCW) (**Table 1.6**). The BCW links each part of the COM-B model to an intervention function and a type of policy which would support it. Interventions are described as a function instead of a category because interventions may serve multiple functions. For example, an intervention may rely on persuasion and education, or education and coercion. The policy categories which could support either of these include training, regulation, communication, and guidelines. Using the BCW provides a systematic approach to intervention design and implementation which links each aspect to a mechanism of action. Because of these mechanisms of action have been well defined the links provided by the BCW can be useful in determining why interventions fail or succeed.

Making this determination is part of another recommended practice developed from implementation science know as process evaluation. Evaluation should not be focused solely on measuring the success of the outcome but how each step in the experimental design either contributed or detracted from the success. This is another reason why studies which mimic the KAP model are considered of poor experimental design. While knowledge does represent a distinct construct on both the TDF and COM-B model, attitude and practice are more complex concepts which could be affected by physical, psychological, social, and automatic influences. Saunders et al. (2005) suggest that process evaluation should measure fidelity, dose, reach, recruitment, and context which are in **Table 1.7**. This 6-step process may be used in real-time to guide and improve intervention design, or as is described in its nomenclature, to evaluate the overall process.

4.2.1 Considering Context

Because of its complexity, the farm environment provides us with several ways to consider context. Economic scale has received a lot of focus as one of the main barriers to implementation of RMP. Parker et al. (2011) identified farm structure to be one of 10 interacting constructs which ultimately influenced fruit and vegetable growers' decisions related to RMP. The characteristics the authors used to determine farm structure were labor, land size, technology/equipment, and marketing. Of the 10 constructs, Parker and co-authors also determined the interactions between the farm characteristics and found that social and cultural factors influenced farm structure of which both influenced the adaptive capacity of the farms. Adaptive capacity, along with awareness and understanding, then influenced risk perception which was the final point in their model leading to growers' actions. However, the results presented by Parker et al. (2011) may still be too broad to serve our purpose of enhancing food safety education for fresh produce growers. This is because the adaptive capacity of the farm is not only determined by financial and labor capital but also the existing physical and natural capital of the land. A grower's capability would certainly be limited by access to financial capital, but the other tenants of adaptive capacity would be much more influenced by their production system and environment and its relation to RMP. Consider, for example, a small-scale strawberry grower in the northeastern U.S. who follows organic practices. The temperature and soil type in the northeast region could influence their cultivar selection, bed preparation, and harvest schedule whereas the organic classification would also impact their methods of soil treatment and pest control. Furthermore, each of these decisions would be nested within a particular production system, which would be dictated by the crop type.

5. Conclusions

To make significant improvements in the public health burden due to foodborne illness, a different approach is needed for food safety education. In order to develop a context specific education, our objectives are to describe and characterize the strawberry industry in the southeastern U.S. In addition to this, we will utilize both qualitative and quantitative methods to collect data from the sample in multiple environments and over multiple time points. This research will be guided by the use of TBC which in turn will be used for evaluation. Our hypothesis is that a theory driven food safety curriculum will result in a significant improvement in practices of strawberry growers who undergo food safety education.

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TABLES

Table 1.1
Principle and Requirements of Good Agricultural Practices

Principle	Recommendations
Principle 1	Prevention of microbial contamination of fresh produce is favored over reliance on corrective actions once contamination has occurred.
Principle 2	To minimize microbial food safety hazards in fresh produce, growers, packers, or shippers should use good agricultural and management practices in those areas over which they have control.
Principle 3	Fresh produce can become microbiologically contaminated at any point along the farm-to-table food chain. The major source of microbial contamination with fresh produce is associated with human or animal feces.
Principle 4	Whenever water comes in contact with produce, its source and quality dictates the potential for contamination. Minimize the potential of microbial contamination from water used with fresh fruits and vegetables.
Principle 5	Practices using animal manure or municipal biosolid wastes should be managed closely to minimize the potential for microbial contamination of fresh produce.
Principle 6	Worker hygiene and sanitation practices during production, harvesting, sorting, packing, and transport play a critical role in minimizing the potential for microbial contamination of fresh produce.
Principle 7	Follow all applicable local, state, and Federal laws and regulations, or corresponding or similar laws, regulations, or standards for operators outside the U.S., for agricultural practices.
Principle 8	Accountability at all levels of the agricultural environment (farm, packing facility, distribution center, and transport operation) is important to a successful food safety program. There must be qualified personnel and effective monitoring to ensure that all elements of the program function correctly in the event of a recall

Table 1.2

Standards and Provisions Associated with the Produce Safety Rule

Standard	**Provisions**
Agricultural Water	No detectable generic *E. coli* are allowed for certain uses of agricultural water in which it is reasonably likely that potentially dangerous microbes, if present, would be transferred to produce through direct or indirect contact.
Biological Soil Amendments	Treated biological soil amendments of animal origin, such as raw manure, must be applied in a manner that does not contact covered produce during application and minimizes the potential for contact with covered produce after application
Domesticated and Wild Animals	At a minimum, this requires all covered farms to visually examine the growing area and all covered produce to be harvested, regardless of the harvest method used.
Equipment, Tools, and Buildings	Required measures to prevent contamination of covered produce and food contact surfaces include, for example, appropriate storage, maintenance and cleaning of equipment and tools.
Worker Training and Health	Measures to prevent contamination of produce and food-contact surfaces by ill or infected persons, for example, instructing personnel to notify their supervisors if they may have a health condition that may result in contamination of covered produce or food contact surfaces.

Table 1.3
Growers Reported Use of *at least* 1 Preventative Practice (%)

Study	Region	Food Safety Measure					
		Water Testing	BSA	Employee Health Training	Hygienic Facilities	Sanitation of Equipment & Tools	Sanitation of Harvest Containers
Adalja and Lichtenberg (2018)	National	51	68	80	91	68	86
Marine et al. (2015)	Delaware, Maryland	32	n/a	56	n/a	n/a	n/a
Shaw et al. (2015)	Iowa	27	37	48	61	18	n/a
Harrison et al. (2013)	Georgia, Virginia, South Carolina	n/a	55	41	50	n/a	39
Hultberg et al. (2012)	Minnesota	n/a	69	77	85	66	84

Table 1.4
Theoretical Domains Framework and Associated Constructs

Domain	Definition
Knowledge	Awareness of the existence of something
Skills	Ability or proficiency acquired through practice
Social/Professional Role and Identity	Coherent set of behaviors and displayed personal qualities of an individual in a social or work setting
Beliefs about Capabilities	Acceptance of the truth, reality or validity about an ability, talent, or facility that a person can put to constructive use
Optimism	The confidence that things will happen for the best or that desired goals will be attained
Beliefs about Consequences	Acceptance of the truth, reality, or validity about outcomes of a behavior in a given situation
Reinforcement	Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus
Intentions	A conscious decision to perform a behavior or a resolve to act in a certain way
Goals	Mental representations of outcomes or end states that an individual wants to achieve
Memory, Attention and Decision Process	The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives
Environmental Context and Resources	Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behavior
Social Influences	Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviors
Emotion	A complex reaction pattern, involving experiential, behavioral, and physiological elements, by which the individual attempts to deal with a personally significant matter or event
Behavioral Regulation	Anything aimed at managing or changing objectively observed or measured actions

Table 1.5
Components of The Behavioral Change Wheel

Influence	Subcomponent	Definition	Intervention strategy
Capability	Physical	Physical skills, strength or stamina	training, enablement
	Psychological	psychological skills, strength or stamina to engage in a mental process	education, training, enablement
Opportunity	Physical	opportunity afforded by the environment involving time, resources, location	training, restriction, environmental restructuring, enablement
	Social	opportunity afforded by interpersonal influences, social cues and cultural norms	training, restriction, environmental restructuring, modelling, enablement
Motivation	Automatic	emotional reactions, desires, impulses, inhibitions, drive state, and reflex response	persuasion, intervention, training, environmental restructuring, modeling, enablement
	Reflective	Self-conscious intentions and beliefs	education, persuasion, intervention, coercion

Table 1.6
Six Step Evaluation Components for Interventions

Component	Purpose
Quality	extent the intervention was implemented as planned
Completeness	amount or units of intervention delivered
Exposure	extent to which participants engaged
Satisfaction	participation satisfaction
Participation Rate	proportion of intended proportion
Recruitment	process to approach participants
Context	aspects of the environment that may influence intervention

Chapter 2

Characterization of Risk Management Practices among Strawberry Growers in the Southeastern United States and the Factors Associated with Implementation.

Abstract

Strawberries, the fifth most preferred fresh fruit in the United Sates, are one of several fresh produce commodities in the U.S. linked to outbreaks of foodborne disease. However, the industry is not well characterized. Additionally, in the southeastern U.S. (SEUS), very small strawberry-growing operations are particularly common, presenting unique challenges to implementation of risk management practices (RMP). A 45-item survey was developed to collect data regarding each strawberry grower's location, farm characteristics, and RMP. The majority of SEUS growers harvested strawberries on less than 5 acres with 2.00-4.99 acres being most common (41%) and reported a revenue based on strawberry production of US$25,001-250,000 (68%). Implementation of a pre-harvest policy and animal intrusion monitoring were both highly prevalent whereas testing of pre-harvest agricultural water was least common. Growers also reported using RMP but were less likely to document them. For example, 76.6% of growers reported their employees had attended food safety training; meanwhile, only 38.9% had documented training. The frequency of use and documentation of RMP were also found to be impacted by certain farm characteristics, most notably acreage, revenue, presence of third-party audit, and presence of a written food safety plan. Based on these results, strawberry growers, particularly in the SEUS, may benefit from additional education tailored to align with farm scale that includes instruction on documentation.

1. Introduction

The Food Safety Modernization Act (FSMA), the first major update to United States (U.S.) federal food safety regulation since the adoption of the Federal Food, Drug, and Cosmetic Act in 1939, was signed into law in 2011. One unique attribute of FSMA is that it now allows for U.S. Food and Drug Administration (FDA) oversight of the produce industry. This oversight is detailed in the Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption, 21 CFR Part 112, commonly known as the Produce Rule (PR) (U.S. FDA, 2015). The PR addresses five areas related to on-farm food safety: 1) agricultural water, 2) biological soil amendments of animal origin, 3) employee health and hygiene, 4) control of wildlife and domestic animals, 5) sanitation of equipment, tools, and buildings and 6) sprouts. The rule also addresses the documentation required for each of these five areas of food safety. Growers earning more than US$25,000 in annual sales (3-year average adjusted for inflation) of covered produce (i.e., produce which is likely to be consumed raw) must comply with the PR or meet the criteria for qualified exemption (U.S. Department of Health and Human Services, 2015). For farms earning more than US$500,000, compliance with the PR began in 2018; however, due to the scope of the rule, very small (US$25,001-US$250,000) and small farms (US$250,001-US$500,000) were given longer to comply. Regardless of scale, all farms were required to comply with the PR by January of 2020 with the exception of those standards related to agricultural water for which the dates have been extended out through 2024 (U.S. FDA, 2019;U.S. FDA, 2017a; Wall et al. 2019).

Before enforcement of the PR, two national surveys were conducted to characterize on-farm food safety practices related to the five areas addressed in the PR. A study of this scale had not been conducted since the "1999 Fruit and Vegetable Agricultural Practices" survey commissioned by the U.S. Department of Agriculture (USDA) National Agricultural Statistic Service (NASS) (USDA NASS, 2001) and as such presents a major update to our understanding of the current use of risk management practices (RMP) by produce growers. Astill and colleagues (2018) presented data collected from 4,618 growers surveyed from 2015 to 2016 and found that farm size was significantly associated with the implementation of some RMP. For example, growers with revenues between US$25,000 and US$500,000 (covered, i.e., these growers must comply with the PR unless meet the definition of qualified exempt) as well as those earning <$25,000 (exempt, i.e., these growers do not have to comply with the PR) were less likely to collect agricultural water samples and less likely to follow an approved method to test for *Escherichia coli* in pre-harvest agricultural water samples compared with medium, large, and very-large growers. Meanwhile, a study by Adalja and Lichtenberg (2018b) focused on implementation challenges relative to the size of the farm—as specified by the PR—as well as those growers identifying as 'sustainable' (e.g., use of biological soil amendments, grazing livestock, integrated farming systems, etc.). The authors surveyed 394 growers and reported that farm size as well as commodity and region impacted implementation of RMP. For example, berry and fruit/tree nut growers were less likely than leafy greens growers to collect agricultural water samples. In addition, growers in the western U.S. were more likely than growers in other regions to document RMP. Overall, both survey studies concluded that while the degree of change may vary based on the farm, all growers need to make changes to their current RMP to comply with the PR.

To facilitate compliance with the PR, a multi-center partnership known as the Produce Safety Alliance (PSA) was formed. Their primary aim is to develop and deliver training to produce growers. PSA grower training, which is currently the only FDA-recognized curriculum, has been delivered to nearly 36,000 growers across the U.S. as of June 2020 (PSA, 2020). Because of the diversity in agricultural practices as well as the complex nature of microbial contamination on farm, the FDA has also emphasized the importance of developing commodity-specific training and education (U.S. FDA, 2018; U.S. FDA, 2017b). Commodity-specific training has been developed in the past for the leafy green, tomato, and cantaloupe industries, which have previously implemented commodity-specific RMP due to a history of associated foodborne disease outbreaks (FBDO) (Painter et al., 2013). However, these are mainly available through the work of industry interest groups. Strawberries are another commodity attributed to FBDO over the past 20 years and may benefit from commodity-specific training as well (Palumbo, Harris, & Danyluk, 2013). Strawberries are typically consumed raw, grown on the vine close to the ground, have an exposed edible portion during the growth and harvesting period, and are harvested by hand—all risk factors associated with microbial contamination and subsequent infectious disease transmission (Ceuppens et al., 2015; Delbeke et al., 2015; Macori et al., 2018). Despite these risk factors, the strawberry industry has yet to be well characterized within the context of food safety (Christman & Samtani, 2019; Freidrich et al., 2016, Howe, 2019; Samtani et al., 2019).

The majority (72%) of acreage dedicated to strawberry production in the U.S. is in California and Florida; however, this represents merely 10% of the total number of strawberry farms in the U.S. and is more indicative of large acreage farms (e.g., >15 acres per farm) (USDA

National Agricultural Statistics Service, 2017). Most strawberry farms (65%) in the U.S. use 0.9 acres or less for production. With respect to the focus of the present study, the southeastern U.S. (SEUS) has an estimated 1,894 strawberry farms (excluding Florida). The average farm acreage dedicated to strawberries in the SEUS ranges from 0.45 to 7 acres per farm with 92% of farms falling in the range of 0.45 to 2.31 acres (USDA NASS, 2017). Therefore, to determine the food safety needs of strawberry growers in the SEUS, the first step is to characterize current RMP, filling a gap in the current understanding of the use of RMP among produce growers. The results of the study can inform the development of a commodity-specific food safety curriculum for the strawberry industry to meet the operational strategy needs proposed by the FDA for complying with the PR. The four research questions informing this study are: 1) What are the characteristics of strawberry growers in the SEUS? 2) What are the RMP of strawberry growers in the SEUS? 3) What are gaps in the RMP of strawberry growers in the SEUS? 4) Is there an association between strawberry grower characteristics in the SEUS and on-farm implementation of RMP?

2. Methods

2.1 Instrumentation

The survey questionnaire was developed based on a review of the PR, the minimum requirements of the PR as well as PR inclusion criteria: RMP, Monitoring, and Revenue. More domains were added to include items designed specifically for the intended sample population. These domains were consent, criteria, and farm characteristics. The resulting questionnaire consisted of six domains and 54 items. To refine the questionnaire, the face and content validity were assessed by two separate panels of experts. The face validity was assessed by two experts in food safety and food safety education. The question stem of each item was reviewed for clarity. For content validity, a panel of five experts from academia and industry provided feedback on the relevance of each item concerning strawberry production. These included three extension associates with experience in food safety, one extension associates with experience in horticulture, and one industry associate working as a quality assurance specialist in the strawberry industry. The items were reviewed based on their feedback until no further rounds of comments were made. Based on their comments, nine items were removed. The final questionnaire contained 45 items and was organized into six domains as follows: informed consent (one item), inclusion criteria (two items), farm characteristics (21 items), RMP (15 items), documentation (three items), and revenue (three items). These items were presented as 4 free response, 5 matrix questions, 7 selects all that apply, 12 multiple choice, and 15 dichotomous questions

2.2 Distribution and Data Collection

The survey was administered online via Qualtrics™ Online Survey Software (Qualtrics, Provo, Utah) to participants recruited via email, postal mail, and in-person. Individuals receiving email or postal mail were identified through a combination of google maps, online listservs, professional organizations, and university extension associates. Before distribution, individuals were screened for eligibly to ensure the farms were currently in operation and growing strawberries. Next, individual farms were characterized by whether they had an available email or postal address. Individuals with an email address received invitations containing a description of the survey, the potential for incentive, an assurance of anonymity, the research team contact information, and a personalized link to the survey. Individuals with a postal address received a letter on official University of Arkansas letterhead with the same content; however, a nonpersonalized abbreviated link was provided to the survey. A total of 440 personal links and 369 anonymous links were distributed. Of the 440 personal links, two were removed as duplicates and 80 were undeliverable resulting in 358 net usable invitations. In-person recruitment was done at the 2018 North American Strawberry Growers Association annual meeting in Savannah, GA. A flyer containing a description of the survey, an abbreviated link, and a scannable QR code was placed on an announcement board adjacent to the conference registration area.

2.3 Statistical Analysis

Statistical analysis was performed using SPSS Version 26 (IBM, Armonk, New York). Descriptive statistics were performed on all variables to determine frequencies and distribution. Quantitative variables were also tested for their normality. Acreage variables were transformed into ordinal values for further analysis due to non-normal distribution. Inferential statistics were performed to determine associations between farm characteristics and the current implementation and documentation of RMP. These tests were performed by chi-square analysis using Monte Carlo adjustment to account for the small sample sizes. Tests were performed at alpha = 0.05.

Statistical analysis was also performed to address potential error due to non-response. A chi-square test of association was performed using five key variables of interest on two separate groups. The variables of interest were those that were significant based on the previously described statistical analysis and those that had a high rate of response. These variables included the use of a pre-harvest assessment, monitoring for animal intrusion, collecting pre-harvest agricultural water samples, documentation of measures related to employee health and hygiene, and documentation of measures related to equipment sanitation. Growers were assigned to groups for the analysis based on recommendations from Linder, Murphy, and Briers (2001).

First, the participants were assigned as either early respondents or late respondents using the median (n=45) as the cut-off point. Second, participants were assigned as either respondents or non-respondents based on whether they provided a usable response for determining revenue based on strawberry production. Tests were performed at alpha = 0.05.

3. Results

3.1 Demographics

3.1.1 Response Rate and Geographical Distribution

The geographical distribution of growers who completed the survey is shown in **Figure 2.1**. Of the 124 growers that completed the survey, a total of 34 growers were determined to be outside of the sampling frame and were excluded from analysis. For the 90 eligible growers the most represented states were North Carolina, Virginia, and Arkansas with 18, 13, and 12 growers, respectively. There were no respondents from Mississippi. The response, consent, and completion rate were 25.0%, 89.5%, and 76.0%, respectively (Ramanthan & Faulkner, 2015).

3.1.2 Farm Scale

The average acreage across all farms was 250.7 acres. An average of 234.4 and 16.9 acres was dedicated to crop and strawberry production, respectively (**Table 2.1**). For total and crop production, the majority of growers harvested 20-200 acres, whereas for acreage dedicated to strawberry production, the responses were more diverse, with 33% of the sample reporting 2.00-4.99 acres. The majority of growers were very small scale based on their total annual crop (43.0%) and strawberry production (62.0%). The median and mode for permanent employees were two and zero, respectively, with 69% of growers employing seasonal workers.

3.2 Agricultural Production

3.2.1 Commodity

Over half (56.7%) of growers grew crops and raised livestock (mixed production) while 36.7% of growers grew only crops (crop production) (**Table 2.2**). Of the 84 growers with crop production, 51.2% grew crops covered by the PR. Growers with mixed production were asked what type of livestock they raised. The categorical responses and their reported frequencies are presented in **Table 2.2** except "aquaculture" which received zero responses. For the 33 growers with mixed production, the two most common responses were cattle (72.7%) and swine (54.5%). The majority of growers who selected 'other' raised equine.

3.2.2 Production

The most common methods used among all growers were plasticulture systems for strawberry production and conventional practices for agricultural production representing 95.6% and 80% of the sample, respectively (**Table 2.2)**. The percent of respondents who were certified organic was relatively small (10%); however, 22% reported the use of organic practices without certification.

3.2.3 Soil Amendment Use

Less than one-third (32.3%) of growers in our survey used biological soil amendments (BSA). Of these growers (n=29), the most common BSA was stabilized treated compost as indicated by 72.4% of the sample (**Figure 2.2**). Aside from raw manure, all other BSA types (e.g., agricultural tea, non-fecal animal byproducts, yard trimmings) were used by eight growers or less. Growers who used stabilized compost were additionally asked if they produced compost on their farm of which eight growers responded yes.

3.2.4 Pre-Harvest Agricultural Water

Groundwater was the most common source of pre-harvest agricultural water (68.9%). Slightly more than 25% of growers used either surface water or public water sources. A majority of growers (81.1%) used only one source of pre-harvest water while 16.7 and 2.2% used two and three sources, respectively. While all water types were used for irrigation, both public water and groundwater were most commonly used for handwashing whereas surface water was most commonly used for frost protection (**Figure 2.3**).

3.2.5 Harvest and Packing

Field packing was the most common practice chosen by growers in our survey (71.1%). For harvest container type, growers were presented with five categorical responses, with accompanying images, and asked to select all that apply. For baskets and clamshells, both are non-reusable, small in size, and constructed of non-corrugated paper (green) and clear plastic, respectively. Boxes and bins were both larger and depicted as constructed from wood and plastic. **Figure 2.4** indicates that the majority of growers used “baskets” (56.6%) followed by clamshells (46.7%). Only one-third or less selected boxes or bins. For growers that answered ‘other’, the two most common responses were bucket or pale.

3.2.6 Market Channel

More than 70% of growers sold strawberries through farmer and U-Pick via general distribution. Meanwhile, only 48.9 and 26.7% of growers, respectively, used either of these markets for primary distribution. For the remaining market channels, there was a low overall response. **Figure 2.5** shows all market channels and their general and primary use by growers.

3.2.7 Key Measures of Food Safety

Though only 25.6% of growers responded ‘yes’ regarding the third-party audit, half (50%) of growers had a written food safety plan (**Table 2.4**). Out of the 45 growers who had a food safety plan, 97.8% indicated it had been tailored to their farm, and 57.8% indicated their plan received a review.

3.3 Risk Management Practices

3.3.1 Food Safety Training

Overall, 75.6% of growers had they themselves or an employee attended food safety training (distribution presented in **Table 2.5**). For both measures of scale, there was an increase in the prevalence of food safety training based on size of operation. For acreage, there was a general linear increase in the prevalence of food safety training; however, for revenue, 100% of both small- and large-scale growers had attended training. For commodity measures, more than 70% of growers with either crop or mixed production had attended food safety training. For growers of covered crops, more than 80% of growers had attended food safety training compared to approximately 50% of growers of non-covered crops. Significant differences were also observed for both measures of food safety (**Table 2.6**). More than 95% of growers with a third-party audit or food safety plan had attended food safety training as compared to 53% or less of those without.

3.3.2 BSA Application Guidelines

BSA application guidelines were followed by the majority of growers (55.3%). Most growers followed guidelines established by the NOP (24.1%), and an almost equal number of growers (20.7%) followed those established by the PSA which simply refer to the NOP guidelines. A common response for growers who followed “other guidelines” was the USDA GAPs. A similar trend was observed in the prevalence and use of established guidelines by BSA type (**Figure 2.6**). A further breakdown of adherence to any BSA application guideline by farm characteristic is shown in **Table 2.5**. For both measures of scale, there was a lack of an observable trend for growers who used application guidelines. For revenue, however, there was a statistically significant difference with 100% of exempt and large-scale growers using application guidelines as compared to none of the small-scale growers. For commodity measures, at least 50% of growers with either crop or mixed production followed application guidelines. However, 57.1% of covered growers adhered to application guidelines as compared to only 33.3% of non-covered growers. Significant differences were also observed for both measures of food safety. At least 75% of growers with a third-party audit or food safety plan followed application guidelines. Where over half (52%) of growers without a third-party audit also used application guidelines, only one-third of those without a food safety plan reported the same.

3.3.3 Pre-Harvest Agricultural Water Testing

Nearly half (47.8%) of growers collected samples which was the lowest response to any RMP for this survey **(Table 2.5)**. For those who did collect samples, more than half (58.1%) collected pre-harvest samples once per year with the remaining 41.9% collecting samples more than once per year. For collecting samples, there were significant differences in prevalence of testing based on revenue (Table 6). For frequency of testing, there was a decreasing linear trend based on revenue actually indicating an increase in the frequency of testing. For commodity measures, more than half (55.8%) of covered growers collected samples compared to less than one-third (30.8%) of non-covered growers. Significant differences were also observed for both measures of food safety for collecting samples. A total of 91.3% and 68.9% of growers with either a third-party audit or food safety plan, respectively, collected samples as compared to less than one-third of those without.

3.3.4 Wildlife and Animal Intrusion

Overall, 77.8% and 88.3% of growers indicated they monitored and took measures to prevent animal intrusion, respectively (**Table 2.5**). For revenue, 100% of both small- and large-scale growers reported monitoring for and taking measures to prevent animal intrusion. For commodity measures, more than 87% of growers with mixed production monitored for and took measures to prevent animal intrusion compared to 78.9% or less of growers with crop production. For both measures of food safety, at least 88% of growers with a third-party audit or food safety plan indicated the use of RMP related to animal intrusion. Significant differences were only observed based on a food safety plan (**Table 2.6**).

3.3.5 Pre-Harvest Policy

More than 95% of all growers had a pre-harvest policy—the highest reported response for any RMP in this survey, with prevalence of growers who used a pre-harvest policy increasing based on acreage (**Table 2.5**). For revenue, less than three-fourths of very small growers used a pre-harvest policy as compared to 91.7% of exempt growers. For both commodity measures, differences between groups were minimal as more than 82% of all growers had a pre-harvest policy. Significant differences were observed for both measures of food safety (Table 6). More than 95% of growers with a food safety plan used a pre-harvest policy as compared to 71.1% of those without (p=0.011).

3.3.6 Labeling

Over three-quarters of growers reported labeling their containers (**Table 2.5**). For measures of scale, there was an observable increase in the prevalence of labeling based on acreage and revenue. More than 50% of growers for both commodity measures reported labeling with minimal differences observed between groups. Significant differences were observed for both measures of food safety (Table 6). More than 75% of growers with a third-party audit and those with a food safety plan reported labeling. Growers without a food safety plan were the lowest for this RMP (35.6%).

3.3.7 Documentation

Most growers did not keep documentation related to RMP (**Table 2.7**). The exception to this were those RMP related employee health and hygiene and equipment sanitation for which 51 and 57% of growers reported some type of documentation, respectively. For all other RMP, the prevalence of documentation among growers ranged from 41-48%. We observed similar trends to those reported for RMP based on farm characteristics; however, overall, there were fewer significant differences. For both measures of farm scale, prevalence of documentation was found to be significant for both employee health and hygiene as well as pre-harvest agricultural water (**Table 2.8**). Additionally, there was a significant difference in the prevalence of documentation of RPM related to animal intrusion for acreage alone. For measures of commodity, a significant difference was only observed based on coverage status for which 62.8% of covered growers reported documentation related to equipment sanitation compared to less than one-third of non-covered growers. For measures of food safety, growers with either a third-party audit or written food safety plan were significantly more likely to report documentation for all RMP (**Table 2.8**). For example, more than 90% of growers with a third-party audit and more than 80% of growers with a written food safety plan documented RMP related to employee health and hygiene, wildlife intrusion, and equipment sanitation (**Table 2.7**). For growers without a third-party audit, only 13.3% reported documentation of RMP related to pre-harvest agricultural water.

3.4 Non-Response

There were two potential sources of non-response error in this study, unit non-response and item non-response (Barriball & While, 1999). As the overall response rate of our survey was 76%, our results may be prone to error due to unit non-response. In addition, more than 50% of our participants chose to not answer questions related to revenue, which is one of the two key factors used in this study to determine scale, and it is a primary criterion for determining PR compliance requirements. The result of the chi-square analysis indicates no significant associations between response timing or refusal to answer based on revenue and the five variables of interest: pre-harvest assessment, monitoring for animal intrusion, collecting pre-harvest agricultural water samples, documentation of measures related to employee health and hygiene, and documentation of measures related to equipment sanitation. Based on the statistical analysis, the results of the survey are not subject to non-response error.

4. Discussion

Compared to previous reports, the geographical distribution and production characteristics of the growers in this study align well. The majority of growers in our survey were exempt from regulations because they operated very small farms, which is common in the SEUS, with the exception of Florida (Samtani et al., 2019). Not surprisingly, the most common production practice reported was plasticulture which has been largely adopted by the industry due to the high quality and yield of strawberries, reduced water usage, and improved pest management as compared to the traditional matted row production system (Fernandez, Butler, & Louws, 2001; Poling, E.B., 2005; Rysin et al., 2015). Additionally, plasticulture methods utilize chemical fumigants that are not congruent with organic practices, which likely contributed to the 80% of growers utilizing conventional production practices.

Implementation of RMP reported in the present study is somewhat comparable to previous studies. For instance, less than half of all growers reported collecting pre-harvest agricultural water samples which is slightly lower than the 51 and 66.1% of growers reported in the studies by Adalja and Lichtenberg (2018b) and Astill et al. (2018), respectively. In general, these results follow the ongoing trend of an overall increase in water testing within the past decade (Cohen et al., 2005; Harrison et al., 2013; Marine et al., 2016). One reason for the apparent increase in water testing may be due to growers implementing the PR requirements; however, Marine et al. (2016) used data from a 2010 and 2013 survey for which the PR would not apply to the 2010 survey data. Meanwhile, Adalaj and Lichtenberg (2018b) attribute their high response to a greater proportion of survey respondents concentrated in the West for which agricultural water testing is more common. As the PR requirements for pre-harvest agricultural water are based on both source and application, more information about the farm characteristics may be necessary to adequately interpret the results from our study as well as the aforementioned studies. For example, in our study, growers applying pre-harvest agricultural water through sub-irrigation methods would be exempt from testing under the PR regardless of the water source as the water would not be in contact with the edible portion of the plant. Alternatively, for those in our study using surface water for frost protection, pre-harvest agricultural water testing would be required multiple times a year.

Notably, there were two RMP in the present study that were reported in much higher percentages than previous studies. We found a high prevalence (75%) in implementation of monitoring and preventative measures for wildlife and animal intrusion in our survey which is similar to Astill et al. (2018). Conversely, this level of implementation was much higher than that reported in the national survey by Adalja and Lichtenberg (2018b) for which the authors found only 47% of growers monitored for animal intrusion. The use of pre-harvest assessment was another highly prevalent RMP reported in this survey with 95% of growers adopting this practice. Meanwhile, only 24.4% of growers reported the same in the survey conducted by Astill and colleagues (2018). These differences may be attributed to the fact that our study focused specifically on growers producing strawberries. As indicated previously, strawberries are harvested by hand, often packed in the field, and receive minimal to no post-harvest processing, and thus the pre-harvest assessment may be one of the last points a grower has to identify and prevent contamination. Moreover, the pre-harvest assessment presents an opportunity to evaluate the effect of other RMP, particularly those related to preventing animal intrusion.

Implementation of RMP associated with employee training (i.e., food safety training) as well as documentation of employee health and hygiene training along with equipment sanitation were reported at a high prevalence in our survey. Here, more than 75% of growers reported implementation of employee training which is similar to the 80% of growers reported in the survey by Adalja and Lichtenberg (2018b). This high prevalence of employee training across multiple grower surveys may be driven by growers' perceptions toward on-farm sources of contamination as well as the effectiveness of a given RMP and potential ease of implementation. For instance, when asked about the importance of 32 on-farm preventative practices, Ivey at al. (2012) found that 60% of Midwestern growers strongly agree that employee training on personal hygiene was an important practice to prevent on-farm contamination. Interestingly, employee training on personal hygiene was the only RMP for which more than half of growers agreed was important aside from the timing of raw manure application (Ivey et al., 2012). In the same region surveyed as Ivey et al. (2012), Parker, Wilson, LeJeune, and Doohan (2012) observed that across all farms, regardless of scale, growers felt that employee hygiene and produce handling practices were the most likely sources of contamination on the farm while "individual health and hygiene" and "employee training" were found to be the most important preventative measures.

In our study, there were several factors associated with farm scale (i.e., acreage and revenue). There was a general increase in the reported implementation and documentation of RMP based on acreage. For revenue, there was often scale solidarity between the upper and lower classes. For example, 100% of small and medium/large-scale growers versus 50% or less of very small and exempt growers attended food safety training. Previous studies also identified significant differences in RMP implementation based on revenue. Similar to our results, Astill et al. (2018) reported an increase in the use of RMP among growers from exempt to the largest scale growers. Adalja and Lichtenberg (2018b) also found that large-scale growers were more likely to report and document RMP with the exception of monitoring fields for flooding, monitoring for wildlife intrusion, and measures for employee health and hygiene. Interestingly, the RMP not likely to be implemented by large-scale growers were more likely to be implemented by small-scale growers.

One reason for these observations could be caused by farm-scale capacity constraints. Though the relationship between acreage and revenue is difficult to establish due to differences in crop yield and farm expenditures, studies have shown that implementation is an economy of scale. Adalja and Lichtenberg (2018a) demonstrated that the cost of implementation per acre decreases as the farm revenue increases. Bovay, Ferrier, and Zhen (2018) further demonstrated that cost is impacted by state and commodity-group. Specifically, the study authors found that the share of revenue required to implement RMP increased as the scale of the farm decreased and that this fixed cost would raise the cost/share of revenue per state and per commodity group depending on the farm-scale ratio. For our sample the estimated cost/share of revenue as a commodity is 1.31%; however, very small and small farms have the highest cost/share at 6.77

and 6.05%, respectively. Additionally, for the 13 SEUS, the cost/share ranges from 1.31-3.67%, with Alabama being the highest within this range and the second highest in the U.S. Thus, the majority of the growers in the present survey, which were very small, could still face significant cost implementing RMP even on less than five acres.

Astill and coauthors (2018) also observed that the current food safety expenditures increased based on farm scale. While the authors are careful not to conflate this spending directly with the cost of implementation, a similar trend in response to other items related to RMP may further support how scale influences RMP. For example, farms with higher expenditures were more likely to have designated food safety staff and more likely to train all of their harvest workers. As reported by Calvin, Jensen, Klonsky, and Cook (2017), on farm food safety personnel spent up to 43% of their time on monitoring and documenting RMP. Based on this, it could be assumed that a larger number of trained employees may make implementing and maintaining RMP less burdensome.

Also increasing with scale were the number of growers with third-party audit and written food safety plans. As third-party audits have stringent food safety requirements, there is potential that growers have implemented RMP in preparation of that process and/or may be more familiar with RMP as they pertain to produce safety. Similarly, growers who indicated having a written food safety plan would have at least taken preliminary measures to consider the food safety aspects of their production practices as well as the process of documenting them (Astill et al. 2018). For example, Korlsun (2014) reported food safety plans were valued as tools by small fruit and vegetable growers in Minnesota in drafting standard operating procedures for employee training. Additionally, Tobin, Thomson, LaBorde, and Radhakrishna (2013) found that Pennsylvania growers who were confident in their skills in writing a food safety plan were more likely to conduct a self-audit and apply for a third-party audit. The majority of growers in our survey did not report a third-party audit or the use of a food safety plan. For those who did, a food safety plan was more common than a third-party audit. This is likely because a third-party audit comes at a considerable cost and is often undertaken based on buyer demands. (Becot, Nickerson, Conner, & Kolodinsky, 2012; Hardesty & Kunsunos 2009; Paggi, M.S., 2008).

4.1 Limitations

The limitations of this study are similar to those described in other survey-based research and are mainly due to sampling error, coverage error, and non-response. Both sampling and coverage error may be attributed to the fact that our sample is a hard-to-reach population. Despite the use of a custom sampling frame, we were unable to achieve adequate size for a representative sample. Similarly, as the response rate was less than 80% for those who agreed to participate in the survey, our results may be subject to non-response error. These three sources of error likely contributed to the non-normal distribution for quantitative variables of interest as well as unequal and often small sample sizes for the qualitative variables of interest. Despite these issues, according to our statistical analysis there was no error due to non-response. Future studies should carefully consider whether to allow optional response during the data collection procedures in an effort to avoid participant drop-out although this may also result in gaps in the data. For example, Adalja and Lichtenberg (2018b) found that of 140 respondents, 36% did not report revenue and 1% chose not to report their state. In their study of Midwestern growers, Ivey et al. (2012) reported that of the 210 mail surveys that were returned only 26.4% had at least

50% of the question completed whereas 21.9% provided no response. Lastly Hultberg, Schermann, and Tong (2012) reported a response rate of 32% and a participation rate of 43% from their mail survey of Minnesota growers; however, individual survey items had up to 31% non-response. A greater effort, especially among research focused on food safety, should be taken to address non-response. Though many of the previous surveys discussed in this paper had issues of non-response similar to what we reported here, they were rarely addressed outside of general limitations.

5. Conclusions

The majority of growers in our sample used RMP but did not document them. Because documentation requires significant labor, all growers may benefit from guidance on effort in the development of protocols as well as the keeping of records. We also found significant differences in the implementation and documentation of RMP based on farm characteristics, most notably acreage and revenue. Based on these results, strawberry growers, particularly in the SEUS, may benefit from additional education tailored to align with farm scale that includes instruction on documentation.

6. Acknowledgements

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TABLES

Table 2.1
Descriptive summary of growers by farm scale.

Measure	Count (N)	Percent (%)[a]
Acreage		
Total		
< 20.00	14	16.5
20.00 – 199.99	44	51.8
200.00 – 399.99	16	18.8
400.00+	11	12.9
Crop Production		
< 20.00	27	35.5
20.00 – 199.99	38	50.0
200.00 – 399.99	7	9.2
400.00+	4	5.3
Strawberry Production		
< 2.00	26	30.6
2.00 – 4.99	35	41.2
5.00 – 14.99	18	21.2
15.00+	6	7.1
Revenue		
Crop Production[b]		
$25,000 or less	9	22.0
$25,001 to $250,000	20	48.8
$250,001 to $500,000	6	14.6
Greater than $500,000	6	14.6
Strawberry Production[c]		
$25,000 or less	12	26.1
$25,001 to $250,000	29	63.0
$250,001 to $500,000	2	4.3
Greater than $500,000	3	6.5

[a] Row percentages reported as within group percentage
[b] 49 respondents (54%) chose not to answer the question
[c] 44 respondents (%) chose not to answer the question

Table 2.2
Farm production characteristics.

Context	Count (N)	Percent (%)[a]
System		
High Tunnel	16	17.8
Low Tunnel	7	7.8
Greenhouse	8	8.9
Plasticulture	86	95.6
Matted Row	6	6.7
Classification		
Conventional	72	80.0
Certified Organic	9	10.0
Non-Certified Organic	20	22.2
I am not sure	1	1.1
Commodity		
Strawberry	6	6.7
Mixed Crop	51	56.7
Mixed Livestock	33	36.7
Covered Crops[b]		
Yes	43	51.2
No	13	15.5
I do not know.	28	33.3

[a]Total percent may add up to >100% as respondents were asked to 'select all that apply'
[b]Covered Crops are those which are included in the PR

Table 2.3
On farm animal production.

Type	Count (N)	Percent (%)
Cattle	24	72.7
Poultry	9	27.3
Swine	18	54.5
Small Ruminants	8	24.2
Other	4	12.1

Table 2.4
Key food safety practices.

Practice	Count (N)	Percent (%)
Third-Party Audit		
Yes	23	25.6
No	67	74.4
Food Safety Plan		
Yes	45	50.0
No	45	50.0

Table 2.5
Response of Growers to Dichotomous questions related to risk management by farm context.

	Reported Practice (%)[a]							
	Employee Training	**Biological Soil Amendment**	**Pre-harvest Agricultural Water**		**Wildlife Intrusion**		**Harvest and Packing**	
Classification	**Food Safety**	**Apply Interval**	**Collect Samples**	**Per Annum**	**Field Monitoring**	**Preventative Measures**	**Pre-harvest Assessment**	**Label Container**
Acreage								
< 2.00	18 (69.2)	9 (64.3)	9 (34.6)	7 (77.8)	20 (76.9)	19 (73.1)	22 (84.6)	11 (42.3)
2.00 - 4.99	27 (77.1)	3 (33.3)	17 (48.6)	8 (47.1)	25 (71.4)	29 (82.9)	28 (80.0)	21 (60.0)
5.00 - 14.99	15 (93.3)	1 (33.3)	10 (55.6)	7 (70.0)	16 (88.9)	17 (94.4)	15 (83.3)	13 (72.2)
15.00+	6 (100.0)	3 (100.0)	5 (83.3)	2 (40.0)	6 (100.0)	6 (100.0)	6 (100.0)	5 (83.3)
Revenue[b]								
$25,000 or less	7 (58.3)	3 (100.0)	3 (25.0)	2 (66.7)	7 (58.3)	9 (75.0)	11 (91.7)	3 (25.0)
$25,001 to $250,000	22 (75.9)	2 (28.6)	12 (41.4)	7 (58.3)	20 (69.0)	23 (79.3)	21 (72.4)	15 (51.7)
$250,001 to $500,000	2 (100.0)	0 (0.0)	2 (100.0)	1 (50.0)	2 (100.0)	2 (100.0)	2 (100.0)	2 (100.0)
Greater than $500,000	3 (100.0)	2 (100.0)	3 (100.0)	1 (33.3)	3 (100.0)	3 (100.0)	3 (100.0)	2 (66.7)
Commodity								
Crop	44 (77.2)	8 (61.5)	28 (49.1)	16 (57.1)	41 (71.9)	45 (78.9)	47 (82.5)	31 (54.4)
Mixed Livestock	24 (72.7)	8 (50.0)	15 (45.5)	9 (60.0)	29 (87.9)	30 (90.9)	28 (84.8)	20 (60.6)
Covered Crops[c]								
Yes	36 (83.7)	8 (57.1)	24 (55.8)	13 (54.2)	35 (81.4)	35 (81.4)	36 (83.7)	24 (55.8)
No	7 (53.8)	1 (33.3)	4 (30.8)	3 (75.0)	11 (84.6)	12 (92.3)	11 (84.6)	7 (53.8)
Third-Party Audit								
Yes	22 (95.7)	3 (75.0)	21 (91.3)	10 (47.6)	21 (91.3)	22 (95.7)	20 (87.0)	19 (82.6)
No	46 (68.7)	13 (52.0)	22 (32.8)	15 (68.2)	49 (73.1)	53 (79.1)	55 (82.1)	32 (47.8)
Food Safety Plan								
Yes	44 (97.8)	11 78.6)	31 (68.9)	15 (48.4)	40 (88.9)	42 (93.3)	43 (95.6)	35 (77.8)
No	24 (53.3)	5 (33.3)	12 (26.7)	10 (83.3)	30 (66.7)	33 (73.3)	32 (71.1)	16 (35.6)
Total	**68 (75.6)**	**16 (55.3)**	**43 (47.8)**	**25 (58.1)**	**70 (77.8)**	**75 (88.3)**	**75 (95.6)**	**51 (77.8)**

[a] Row percentages reported as within group percentage
[b] 49 respondents (54%) chose not to answer the question
[c] Covered Crops are those which are included in the PR

Table 2.6
Association Between Farm Characteristic and Risk Management Practices.

Query	Farm Characteristic (p-value)					
	Acreage	**Revenue**	**Commodity**	**Covered**	**Third-Party Audit**	**Written Safety Plan**
Have you or any of your employees attended food safety training?	3.13 (0.372)	3.33 (0.343)	0.23 0.635)	5 (0.025)	6.76 (0.009)	24.1 (<0.001)
Do you use application guidelines for soil amendment?	5.22 (0.156)	6.12 (0.047)	0.39 (0.534)	0.56 (0.453)	0.74 (0.39)	5.99 (0.014)
Do you collect samples for pre-harvest water testing?	5.28 (0.152)	8.22 (0.042)	0.11 (0.737)	2.5 (0.114)	23.5 (<0.001)	16.1 (<0.001)
How often do you collect sample?	7.2 (0.303)	10.7 (0.097)	0.17 (0.919)	0.95 (0.623)	3.1 (0.212)	4.77 (0.092)
Do you monitor for animal intrusion?	3.91 (0.272)	2.91 (0.406)	3.06 (0.079)	0.07 (0.791)	3.27 (0.071)	6.43 (0.011)
Do you take measures to prevent animal intrusion?	4.82 (0.186)	1.47 (0.69)	2.15 (0.142)	0.88 (0.348)	3.38 (0.066)	6.48 (0.011)
Do you conduct a pre-harvest assessment?	1.52 (0.677)	3.36 (0.339)	0.09 (0.769)	0.01 (0.939)	0.29 (0.589)	9.68 (0.002)
Do you label you produce containers with your farm information?	5.77 (0.123)	5.29 (0.152)	0.33 (0.566)	0.02 (0.90)	8.47 (0.004)	16.3 (<0.001)

Table 2.7
Distribution of Growers with at least one type of documentation related to RMP by farm context.

	Risk Management Practice (%)[a]						
Context	**Employee Health and Hygiene**	**Biological Soil Amendment**	**Pre-Harvest Water**	**Post-Harvest Water**	**Wildlife Intrusion**	**Equipment Sanitation**	**Transport to Buyer**
Acreage							
< 2.00	10 (38.5)	12 (46.2)	10 (38.5)	9 (34.6)	8 (30.8)	11 (42.3)	10 (38.5)
2.00 - 4.99	19 (54.3)	15 (42.9)	13 (37.1)	11 (31.4)	15 (42.9)	16 (45.7)	11 (31.4)
5.00 - 14.99	14 (77.8)	8 (44.4)	9 (50.0)	9 (50.0)	10 (55.6)	10 (55.6)	10 (55.6)
15.00+	6 (100.0)	5 (83.3)	6 (100.0)	5 (83.3)	6 (100.0)	6 (100.0)	5 (83.3)
Revenue[b]							
$25,000 or less	3(25.0)	4 (33.3)	5 (41.7)	4 (33.3)	4 (33.3)	5 (41.7)	4 (33.3)
$25,001 to $250,000	17(58.6)	9 (31.0)	9 (31.0)	8 (27.6)	14 (48.3)	14 (48.3)	12 (41.4)
$250,001 to $500,000	2 (100.0)	2 (100.0)	2 (100.0)	2 (100.0)	2 (100.0)	2 (100.0)	2 (100.0)
Greater than $500,000	3 (100.0)	2 (66.7)	3 (100.0)	2 (66.7)	3 (100.0)	3 (100.0)	2 (66.7)
Commodity							
Crop	34 (59.6)	24 (42.1)	27 (47.4)	23 (40.4)	30 (52.6)	33 (57.9)	28 (49.1)
Mixed	17 (51.5)	16 (48.5)	14 (42.4)	14 (42.4)	13 (39.4)	13 (39.4)	11(33.3)
Covered Crops[c]							
Yes	29 (67.4)	21 (48.8)	23 (53.5)	22 (51.2)	25 (58.1)	27 (62.8)	23 (53.5)
No	6 (46.2)	5 (38.5)	6 (46.2)	6 (46.2)	5 (38.5)	4 (30.8)	4 (30.8)
Third-Party Audit							
Yes	22 (95.7)	15 (65.2)	19 (82.6)	17 (73.9)	22 (95.7)	21 (91.3)	17 (73.9)
No	29 (43.3)	25 (37.3)	22. (32.8)	20 (29.9)	21 (31.3)	25 (37.3)	22.(32.8)
Food Safety Plan							
Yes	41 (91.1)	28 (62.2)	34 (75.6)	31 (68.9)	37 (82.2)	38 (84.4)	31 (68.9)
No	10 (22.2)	12. (26.7)	7 (15.6)	6 (13.3)	6 (13.3)	8 (17.8)	8 (17.8)
Total	**56.7**	**44.4**	**45.6**	**41.1**	**47.8**	**51.1**	**43.3**

[a] Row percentages reported as within group percentage
[b] 49 respondents (54%) chose not to answer the question
[c] Covered Crops are those which are included in the PR

Table 2.8

Association Between Farm Characteristic and Documentation of Risk Management Practices

Management Practice	Farm Characteristic (p-value)					
	Acreage	Revenue	Commodity	Covered	Third-Party Audit	Written Safety Plan
Employee Health and Hygiene	11.5 (0.009)	8.58 (0.035)	0.56 (0.453)	1.93 (0.165)	19.1 (<0.001)	43.5 (<0.001)
Soil Amendment	3.48 (0.324)	5.05 (0.168)	0.34 (0.557)	0.43 (0.511)	5.39 (0.02)	11.5 (<0.001)
Pre-Harvest Water	8.85 (0.031)	8.37 (0.039)	0.21 (0.65)	0.22 (0.643)	17.1 (<0.001)	32.7 (<0.001)
Post-Harvest Water	6.83 (0.076)	5.77 (0.123)	0.04 (0.847)	0.1 (0.752)	13.7 (<0.001)	28.7 (<0.001)
Wildlife Intrusion	10.3 (0.016)	6.37 (0.095)	1.47 (0.226)	1.55 (0.213)	28.4 (<0.001)	42.8 (<0.001)
Equipment Sanitation	7.08 (0.069)	5.29 (0.152)	2.86 (0.091)	4.14 (0.042)	20 (<0.001)	40 (<0.001)
Transportation to Buyer	7.28 (0.063)	3.81 (0.283)	2.12 (0.145)	2.06 (0.151)	11.8 (<0.001)	23.9 (<0.001)

Figure legends

Figure 2.1: Geographical distribution of respondents

Figure 2.2: Distribution of soil amendment use by type

Figure 2.3: Application of pre-harvest agricultural water by source

Figure 2.4: Frequency of harvest container use by type for n=90 respondents.

Figure 2.5: Distribution of market channels for n=90 respondents

Figure 2.6: Response to BSA application guideline compliance

FIGURES

Figure 2.1 Geographical distribution of respondents. Growers were asked to provide either a 5-digit zip code or select from a list of states. Growers who were outside the sampling frame or provided unusable response were removed.

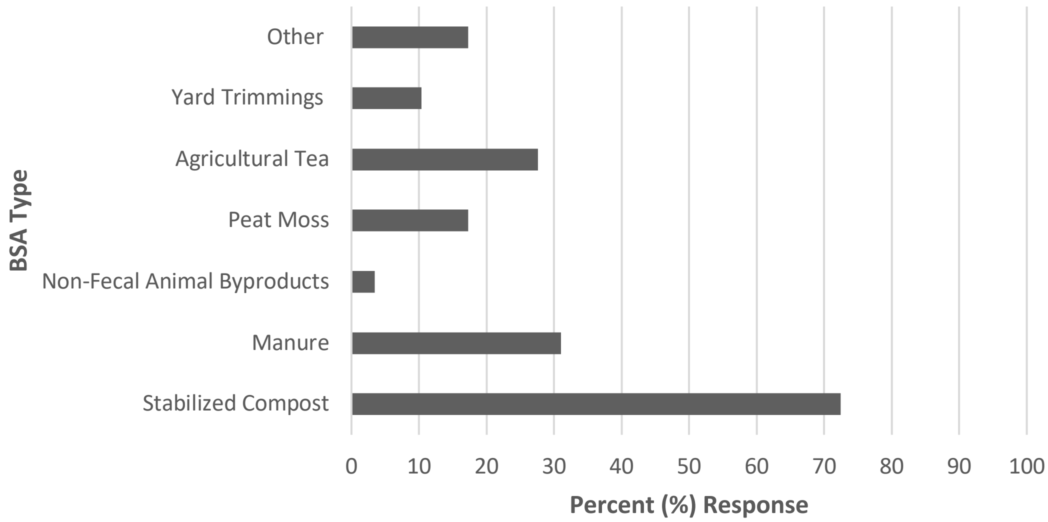

Figure 2.2. Distribution of soil amendment use by type. The n=49 growers using biological soil amendments were asked to 'select all that apply' from seven categorical options.

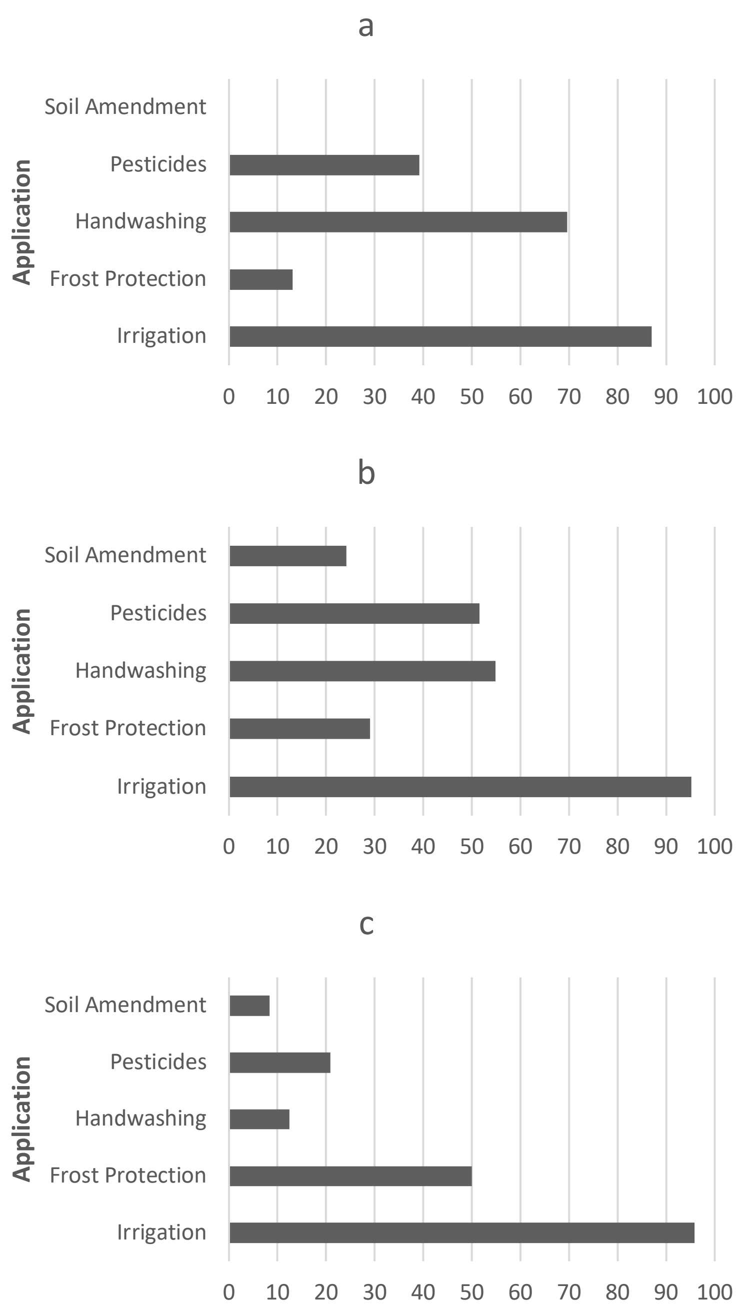

Figure 2.3. Application of pre-harvest agricultural water by source. Growers were asked to indicate their use of a) public water b) groundwater and c) surface water from which they were presented with their elected choice(s) to specify application.

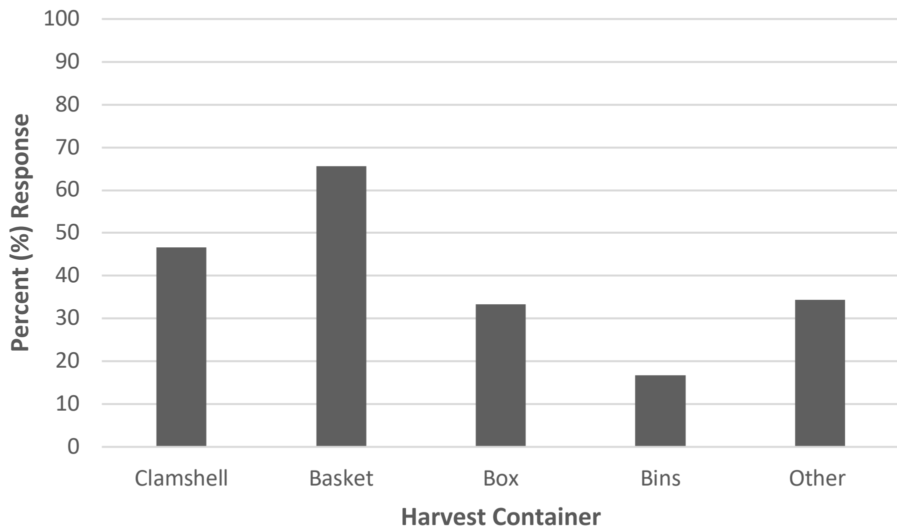

Figure 2.4. Frequency of harvest container use by type for n=90 respondents. Growers were asked to 'select all that apply'.

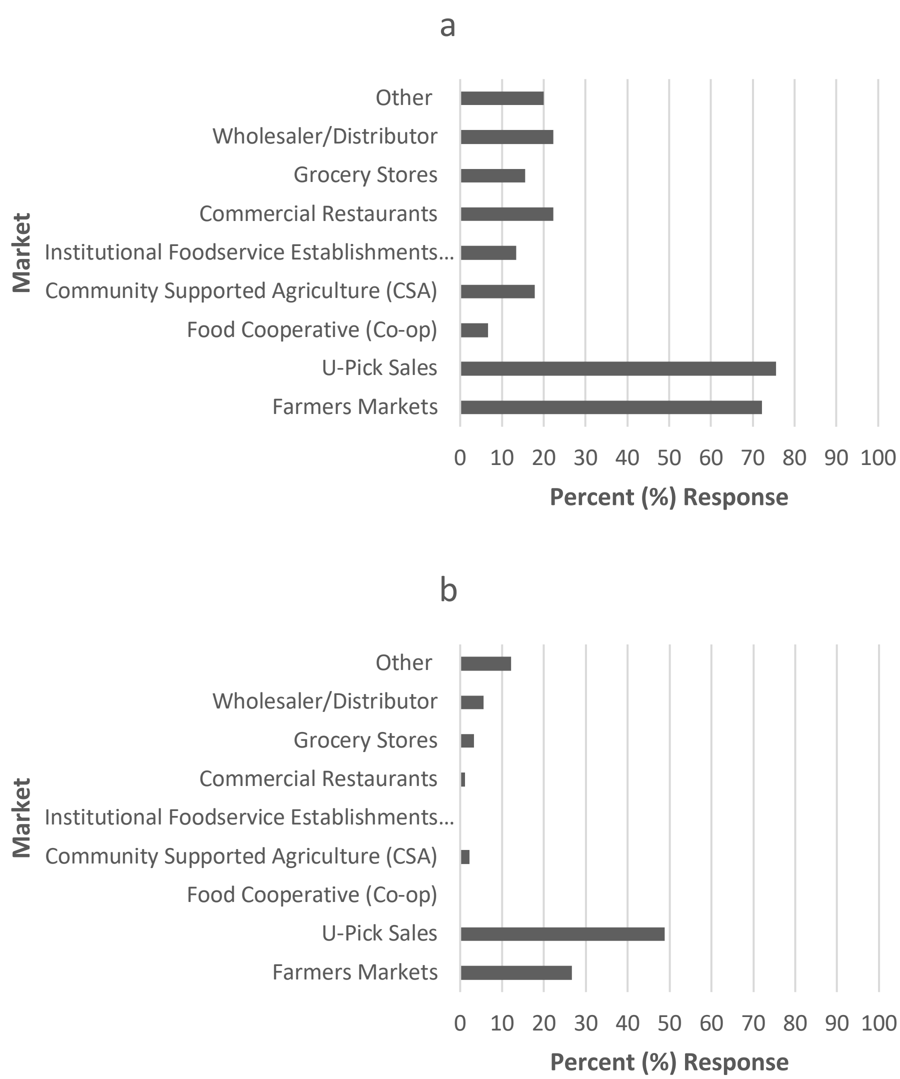

Figure 2.5. Distribution of a) all and b) primary market channels for n=90 respondents. Growers were asked to 'select all that apply' from 10 categorical options from which they were presented their selected choice.

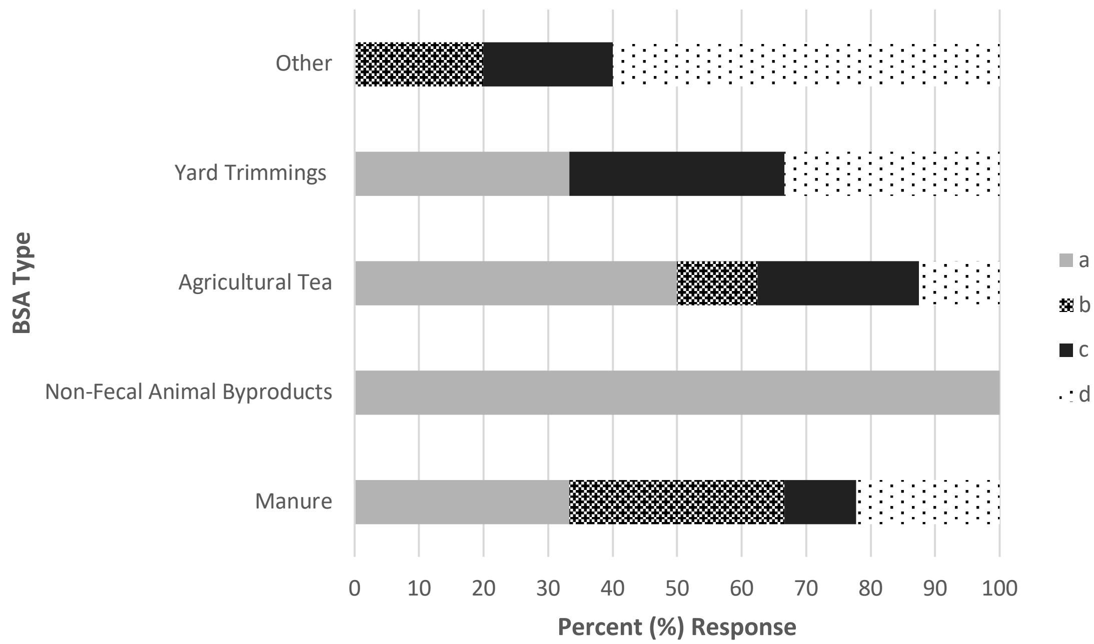

Figure 2.6. Response to BSA application guideline compliance. For n=49 growers who use BSA, with stabilized compost and peat moss removed for growers following NOP, PSA, Other, None.

Chapter 3

Triangulation of Factors Influencing the Implementation of Risk Management Practices Among Strawberry Farms in the Southeastern United States

Abstract

The strawberry industry is one which has had little attention paid to characterization outside of horticultural practices. In this dissertation, we utilize a case study approach to conduct a qualitative assessment of the factors which may or may not inhibit strawberry growers from implementing risk management practices related to FDA's Produce Safety Rule. We interviewed a total of n=9 strawberry growers from the southeastern United States utilizing between one-quarter to 15 acres for strawberry production. In addition, we utilized an on-farm environmental assessment collecting quantitative measures regarding growers' food safety risk management practices. We found that there were both scale dependent and scale independent issues encountered for implementing risk management practices related to the Produce Safety Rule.

1. Introduction

As of January 2020, all farms which meet the inclusion criteria for coverage under the Produce Safety Rule (PSR) are required to have documented the implementation of risk management practices (RMP) applicable to the specific operation (except for agricultural water). Since the passage of Food Safety Modernization Act (FSMA), researchers have seen the need to characterize the current use of RMP by the produce industry (FDA, 2015). The most ambitious example of this effort was completed by Astill et al. (2018) who set out to determine the rate at which growers are implementing the provision of the FSMA as well as the factors influencing implementation such as coverage status, farm size, and farm expenditures. Collecting quantitative data such as these is essential as they help determine not only the current use of RMP but also the amount of potential change faced by growers.

As these data are typically self-reported via survey, some information may be slightly skewed. There are several behavioral factors that can contribute to this skew including a more favorable perception of one's internal motivation, overconfidence in efficacy of one's own (excellent to spell out up front) practices, observed bias compared to another's practices, or a lack of understanding of reporting requirements. In the case of growers implementing RMP, overconfidence and/or a lack of understanding have been observed in self-reporting regarding implementation of a given practice. For example, in a 2012 survey, Hultberg et al. found that at least 65% of growers reported implementing RMP related to employee health and hygiene, sanitation of harvest equipment and tools, treatment of irrigation water, safe storage of biological soil amendments of animal origin (BSAAO) and taking measures to prevent animal intrusion. However, in a follow-up study conducted by Hamilton et al. (2015) in which on-farm visits were conducted, the researchers found that growers self-reported practices only aligned with observed on-farm practices for 2 out of 14 questions related to RMP. For example, 81% of growers self-reported safely storing BSAAO in such a way that it could not contaminate vegetable crops where only 27% of the growers were found to be adequately doing this on-farm. Additionally, 92% and 81% of growers reported taking measures to prevent wildlife from entering packing facilities and harvest fields, while only 45 and 70%, respectively, were properly implementing these practices on the farm. Lack of understanding may also impact observer bias which has been documented amongst farmers as well as food handlers. For example, Parker et al. (2012) observed in their study that large and small growers often viewed each other's practices as disproportionately unsafe for both conventional and organic growers. In the case of food handlers, observer bias is especially present as demonstrated by Rodrigues et al. (2020). In their study of food handlers' knowledge attitude and practice towards food safety, the researchers found that food handlers regularly ranked their practices as safer than their peers and indicated they believed family members less like to become ill through food they prepared as compared to their peers. On an even larger scale, this problem of self-reporting practices versus actual practices plays a role in food safety via hand hygiene. In 2021, Lawson, Vagnay-Miller, and Miller found that, across the European Union, 92.57% of the population ranked hand washing as very important for food safety; however, only 53.45% reported washing their hands after every time they went to the bathroom, and only 18.24% indicated they performed all 8 steps for successful handwashing.

For produce growers, there are also external factors which may influence the implementation of RMP, the nuances of which cannot be captured from survey alone. For example, time and cost are the most common barriers to implementing RMP; however, growers have often cited lack of available labor, capital resources, and lack of knowledge as well (Nayak, 2016). To determine specifically how these factors interact with each other, Parker et al. (2011) conducted an expert elicitation to determine how these factors influence a grower's decision to implement RMP. What the authors found was that a lack of time and cost of conducting the required surveys impact growers' decisions as they represent the farms adaptive capacity. Moreover, adaptive capacity along with knowledge was one of 9 other factors (i.e., factors which influence risk perception) which influence growers' decisions to adopt RMP. Elements of adaptive capacity as well as knowledge and experience were explored by Minor et al. (2019) in a case study conducted with growers from five different commodity groups: apple, cantaloupe, strawberry, onion, and tomato. Minor et al. (2019) observed that growers who self-reported many years of experience with food safety were more comfortable and confident in implementing RMP despite changing standards. These higher confidence growers tended to operate large farms with past experience undergoing food safety audits as well as selling to national supply chains. Minor and co-authors also found more similarities by farm size as defined by the PSR criteria than by commodity type. For example, small farms regularly reported both financial and time constraints for implementing RMP, particularly related to documentation and recordkeeping. Alternatively, large farms typically were able to hire a food safety person to manage documentation and recordkeeping and thus found it less burdensome.

The case study approach, which was utilized by Minor et al. (2019), is useful in exploring an issue or problem using the case as a specific illustration to establish the real-life context surrounding a phenomenon (Yin, R.; 2009). This approach was also used by Vaughan et al.

(2018) to examine the methods used for food safety education of small and limited resource farmers in Alabama. The authors' goal was to identify challenges that produce growers face in obtaining certifications and determine the best intervention methods to overcome them. In their study, Vaughn and co-authors identified three main challenges to obtaining food safety certification including need of motivation, need of information clarification, and need of resources.

To identify both the internal and external factors that influence growers to implement RMP on the farm, we chose to take a mixed-methods approach. The use of mixed methods facilitates a deep understanding of a subject via triangulation. Triangulation entails the use of multiple theories, researchers, data collection methods, and spaces of time to obtain data with the most rich and detailed description of a sample. For the researcher, this can help to explain different aspects of the sample population or a confounding result. As such, triangulation increases the reliability and validity of the results. In this study, we chose to conduct in-depth interviews as well as on-farm environmental assessments. These two approaches were completed using different data collection methods, different data collectors, and different periods of time. The in-depth interviews will be treated as a case study and provide the qualitative portion of the data, whereas the on-farm environmental assessments provide both qualitative and quantitative data.

2. Methods

2.1 Telephone Survey

2.1.1 Questionnaire

Questions for the telephone survey were developed by an expert in food safety education. The questions were focused on factors which either facilitate or inhibit the implementation of RMP. Growers were first asked to indicate what three main barriers they faced to produce safe food followed by specific questions for eight (if the number is less than 10, needs to be spelled out) RMP on strawberry farms. If the grower needed explanation as to what type of barriers, there were a set of related barriers for each RMP. The goals of these interviews were to develop food safety education, we also asked about their experience and preferences for food safety education. Specifically, what an ideal food safety education course would like for them, and if applicable, their employees. The guided interview questions can be seen **Table 3.1**. The questionnaire along with distribution methods were approved by the University of Arkansas International Review Board under protocol 2107345681.

2.1.2 Recruiting and Distribution

For recruiting and distribution, our goal was to reach n ≥ 9 growers. The sample size was based upon the response received during a previous survey by Yeargin et al. (2021) for which we wanted to conduct a follow up with at least 10% of the sample size obtained from the original survey. To recruit the n=9 participants sought for this interview, multiple approaches were used. For the first wave, an invitation was sent to the participants (n=76) from the Yeargin et al. (2021) survey who provided an email address for follow-up to claim an incentive. The invitation included the goal of the project, a statement explaining privacy and consent, as well as a description of an incentive to be received upon completion. For this initial wave of contact, we obtained n=5 responses. Due to the low response, the second wave of recruitment was done through snowball sampling. Snowball sampling was facilitated by extension associates and strawberry growers, particularly ones who completed the telephone interview during the first contact. For recruiting participants an invitation to participate in the telephone interview was sent via email. Participants were emailed a document with the list of questions to be used for the interview as well as a consent form. For distribution of the incentive, a combination of email and postal mail were utilized. Individuals who opted for an Amazon Gift Card received them directly via email, whereas individuals who opted for either Walmart or Sam's Club were sent via U.S. postal mail.

2.1.3 Interview

Interviews were conducted over Zoom (5.9.1, San Jose, CA). Interviews were scheduled at a time convenient to the grower with an estimated 45 minutes to completion. At the beginning of the interview, the researcher confirmed consent from the grower and reviewed the university policy regarding protecting their anonymity. Before starting the interview, the grower was then asked if they had received and reviewed the list of questions for the interview. Lastly, the location and acreage of the farm used for strawberry production were documented. Immediately following the interview, the recording was downloaded from the Zoom server and moved to a secure folder.

2.1.3 Transcription Analysis

Interviews were transcribed using Microsoft Stream via Office 365 to generate the full text of the recording. The in-depth interviews were to be analyzed using within- and cross-case analysis to identify aligning and opposing patterns within the interview responses. Following this, thematic analysis was done to generate categories for barriers to implementing RMP. These categories were then mapped to behavioral constructs based on the identified themes, which were then matched to their respective domains of the Theoretical Domains Framework (Cane & Michie, 2012; Thaivalappil et al., 2018; Syeda et al., 2021)

2.2 Environmental Assessments

<u>2.2.1 Instrumentation</u>

The environmental assessment tool was informed by literature review and content analysis. A systematic literature review was performed by Jayawardhana et al. (2020) to identify studies which had conducted on-farm environmental assessments. Content analysis was done on the Produce Safety Rule, GAPs (Good Agricultural Practices) harmonized audit standard, and Food and Drug Administration (FDA) On-Farm Readiness Review (OFFR) guidance. Similar to the OFFR, we sought to create a document more focused on capturing what growers were doing rather a comprehensive checklist of what was not being performed. Face and content validity were assessed by experts in academia and industry. Experts in food safety and food safety education provided initial feedback on the question stem and clarity of each item. For content validity, experts in cooperative extension and industry were asked to ensure that questions would be relevant to our intended population. Lastly, the instrument was pilot tested on 2 farms in Florida which was facilitated by one of the industry reviewers. Following validity check and pilot testing, specific changes were made.

Questions were separated into categories for “ask” and “observe” to ease data collection. Similarly, questions that may be related to postharvest practices were moved to a “postharvest addendum” as they did not/would not apply to all growers. The resulting tool was 37 pages of total text consisting of 28 pages for all main questions and 9 pages pertaining to the post-harvest addendum. Additional documents that were include were a grower consent form, data collector checklist, and 0.2 cm grid paper for sketching farm layouts.

2.2.2 Recruiting

To facilitate collection of data across the 13 Southeastern United States (SEUS), 14 professionals in the fields of agricultural extension and food safety were recruited. Individuals who agreed to serve as data collectors were expected to identify two farms meeting our case criteria in their sate (i.e., production of 2 acres or less of strawberries) as well as conduct the on-farm environmental assessment. To ensure proper data collection, a 30-minute training session was held via webinar to explain the objectives of this project, the expectations of the data collectors, and the proper methods for recording data. This included instructions for how to fill out the forms and capture farm layout. In addition, data collectors were responsible for obtaining the final consent from the farms participating in the study. The consent form explained the purpose of the research, an assurance of confidentiality and anonymity, and description of incentive upon completion. Data collectors were also sent a recording of the webinar including a question-and-answer portion. A total of 14 data collectors agreed to participate of which 10 were able to collect data.

2.2.3 Data Collection and Analysis

The 10 data collectors performed n=20 site visits between June 2020 and October of 2020. Each data collector was responsible for data collection at 2 farms in their state. Data collectors were responsible for collecting farm level demographic information needed from growers as well as generating a unique identification (as described in training to protect privacy). In addition to the checklist items, data collectors used a Zozen Measuring Wheel (model) to determine the shortest and longest distance between potential contamination sources. Researchers were also asked to sketch a layout of the farm on 0.25 cm grid paper, when possible. Following data collection, a final checklist was used to secure complete data collection. Data collectors' final responsibility was to mail back the content packet using prepared and addressed envelopes. Assessment data were entered into Excel by study researchers during simultaneous coding. Coding was used to generate a score based on the physical attributes of the farm as well as to perform descriptive statistics using JMP software (JMP, 14.1, SAS Institute Inc., Cary, NC). Thematic analysis was also conducted based on identifiable qualitative information taken from the farm layout and all text and comments recorded by data collectors.

3. Results

3.1 In-Depth Portrait

In 2018, Yeargin et al. (2021) conducted a survey to characterize the RMP of very small and small strawberry growers in the southeastern U.S. (Chapter 2). In addition to characterizing the RMP, the researchers also identified five ways to describe the context of farms to determine if there was an association between these factors and the implementation of RMP. Upon conclusion of this research, the researchers also sought to identify any barriers that strawberry growers may face when implementing these RMP. Our sample population, which is further described in Section 3.2, is known to have less external motivation for implementing these RMP, less access to capital, and may have less formal experience with food safety. Our goal, in addition to providing a better understanding of how growers face these barriers, was to determine how food safety education may overcome these barriers.

3.2 Interviews

3.2.1 Context-Case Description

Several criteria were used to determine the bounds for this case study. Growers needed to reside in one of the 13 southeastern U.S. An additional criterion which was used for sampling but not enforced for screening was participation in the 2018 strawberry grower survey (Yeargin et al. 2021). In short, individuals who participated in the survey were contacted first. After that list was exhausted, we resumed snowball sampling. These efforts resulted in n=9 interviews with strawberry growers in Alabama, Arkansas, Georgia, North Carolina, Oklahoma, and Georgia. **Table 3.2** provides information related to acreage for strawberry production, location, and primary reported barrier for the 9 interview participants.

3.2.2 Within-Case Descriptions

For multi-focus case studies, it can be recommended to provide an in-depth description of individual cases. This not only allows the researcher to become familiar with each case, but also begins the process of refining data analysis. For example, when describing each case, similarities and differences should begin to emerge which can then be aggregated into patterns and themes. For the telephone interviews, the cases that will be described are of the strawberry growers with the largest and smallest acreage. Acreage was found to be a factor significantly related to the implementation and documentation of RMP by Yeargin et al. (2021) (Chapter 2). This criterion was used as it was the only piece of identifying information collected at time of interview.

Described below are *Case 1* and *Case 2* which are farms with 15 and 0.14 acres of strawberry production, respectively.

Case 1

The first case we will discuss was a farm with 15 acres of strawberry production. Their top three challenges were wildlife intrusion, domestic animal intrusion via U-pick customers with pets, and traceability of strawberries being sold into retail…?. When it came to employee health and hygiene, the grower was not concerned about offering training because they were fluent in Spanish but had more concern about the time associated with training. This was both in terms of the time of year and the time allotted. The grower expressed that if the workers start mid-season, then there would be no opportunity to train them. In addition, workers may lose interest after about 15 minutes. For sampling of pre-harvest agricultural water, this grower struggled most with finding where to submit the samples for testing. They indicated having to search around and encountered prices that were high. In addition, the grower indicated that most labs they contacted were not familiar with the testing specified by the PSR. While that was their only issue with physical sampling, they also expressed interest in more remediation techniques if water sampling leads to an unfavorable result. This grower also expressed issues with animal intrusion despite having a chain-link fence. This was regarding wild animals as well as domesticated animals brought onto the farm. For example, the growers have asked U-pick customers not to bring pets but has not been able to enforce it. Additionally, this grower had people abandon animals on their farm. In the case of other domesticated animals, the grower did not have an issue as they kept their chickens in a coop.

The grower did not express concern over the use of BSAAO as they never used raw amendments and purchased their BSAAO from a local supplier. Likewise, there was a low level of concern over container sanitation as the grower used single use containers and does not perform any washing or packing on the farm. They did indicate potential issues with vehicle sanitation for the limited times that they transport strawberries to the farmer's market. Outside of sanitation of vehicles, the grower also indicated that establishing and maintaining records in general was an issue for sanitation and traceability. Their primary concern was the time that it would take as well as the process of establishing a protocol. The grower primarily expressed the desire to have something they could "build off of". In regard to time, the grower also felt that having the workers take part in traceability would take away from their wages as they get paid by the hour. The grower also indicated having only 3 year-round staff, so in terms of documentation and recordkeeping, they felt continually "strapped".

Case 2

The second case was a farm with 0.14 acres for strawberry production. When asked the top three barriers to producing safe food, the grower indicated time, labor, and resources. In terms of time and resources, the grower did link the two saying not having enough time is related to their lack of having someone else to help the manager complete tasks. For resources, however, the grower differentiated this as resources related to training. The grower indicated the need for one centralized database where small growers could go and get information without having to read through lengthy documents.

When asked about barriers to employee health and hygiene, the grower indicated that they did not have any concerns at the time of the interview as they did not have hired workers in the strawberry fields. However, they did indicate that they had plans to expand next year and would have some concerns about training mainly due to a potential language barrier, because of their lack of fluency in the language of the workers. The grower did emphasize that they rely on past experience as most of their workers come from an agricultural work background and have had training related to food safety practices. However, they also indicated that their workers spoke Burmese and that finding training material and handwashing information in that language was not available. They also explained they felt they would be able to hold the attention of the workers for a maximum of 5 minutes. The grower also expressed minimal concern when it came to pre-harvest agricultural water testing. In this case, the grower had previous experience getting their agricultural waster tested for a cottage food law, so it was a process they were familiar with. The grower did, however, have questions regarding an on-farm inspection in which the inspector told them to put mouse traps around their well heads for extra safety. These growers were organic and so were not open to the use of baited traps.

The grower did employ the use of BSAAO; however, as they were organic, they were already familiar with the National Organic Program (NOP) rule of doing a 90-day application window between application of BSAAO and harvest date. The grower indicated they do discuss and track BSAAO application dates for strawberry plots as well as nearby plots to account for cross-contamination. The grower also produced compost via chicken manure on farm but indicated that the strawberries are located uphill which created a physical barrier for cross-contamination.

Animal intrusion was a concern for the grower despite having an electric fence. They indicated that if animals were to get into the strawberry fields it could be devastating due to possible contamination. The grower also mentioned the natural fauna that are associated with farmlands such as skunks, armadillos, and rabbits. For the rabbits, the grower indicated that it would be nearly impossible to go around and find all of the burrows, so once the animals are there, they can be especially hard to remove without using lethal methods. Lastly, the grower also mentioned there was a neighbor who often brought their dogs to the strawberry U-pick fields despite being asked multiple times not to.

Sanitation related to harvest and packing was not a great concern for the grower as they field packed their strawberries into single use containers. The grower did mention that they have separate tools for handling compost such as a tractor and hand tools. In addition, the process associated with application of compost or raw manure doesn’t happen around harvesting season so there is no contact. When asked about traceability, the grower said they wouldn’t know where to start. When pressed further, they indicated that they have some idea in terms of inclusion of certain things like packing date or lot numbers but did not have a clear idea of what actual implementation of a traceability system would look on their farm. They also indicated that implementing a traceability program may not be practical for their small farm because of the labor associated with establishing and continuous implementation of that type of system. For documentation and recordkeeping, the grower indicated the use of a more informal system keeping track of data in notebooks. They indicated that as documentation and recordkeeping related to food safety was not the first thing on their mind and that the requirements are quite arduous. However, in terms of things like soil amendment application and record of rainfall, the grower thought they were doing a very sufficient job. Returning to food safety, the grower indicated they didn't necessarily know what implementing food safety recordkeeping systems would look like in terms of the quantity and quality of data needed.

3.3.2 Cross-Case

For the cross-case analysis of all n=9 cases, we begin with those elements which can be carried over from our within-case description. For example, all growers expressed an issue with animal intrusion despite having measures for prevention (i.e., fences). The primary concern was towards deer due to the possibility of cross-contamination with fecal material and/or destruction of crops however smaller wildlife were also mentioned. Additional issues that were discussed regarding animal intrusion were the need for employee training as well as the frequency of recordkeeping. All but one grower lamented over the time associated with regular documentation and record keeping; however, there were differences in the way this was presented. For most growers, the burden related to documentation and recordkeeping was an overall issue of time due to lack of labor; however, one grower expressed more concern with the perceived frequency of recordkeeping that would be required. Additionally, many small growers expressed the need for templates that were tailored to small farms. These same sentiments were expressed when it came to traceability as growers either did not see it feasible time wise to label every container or did not know how to adequately start a traceability program from scratch.

One distinct difference observed in the cases described was related to pre-harvest agricultural water. For example, the grower described in *Case 1* faced trouble finding competent labs and felt they were lacking in remediation strategies. The grower described in *Case 2* does not express concerns with sampling of pre-harvest agricultural water and cited their previous experience with the subject as the reason. This trend was repeated in that growers who cited no barriers to meeting pre-harvest agricultural water standards had multiple years of experience implementing the practices on their farm. There were also differences in the needs expressed related to employee training or employee health and hygiene. Growers with farms$\geq$5 acres of strawberry production expressed needs specifically for worker training whereas growers with smaller farms did not express the same need. All growers with U-pick discussed issues with customer behavior. Lastly, there were also differences in the level of concern held by growers related to sanitary harvest and packing procedures. For growers that field-packed into single use containers, there was generally no concern as they do not have any reusable food contact surfaces on their farm either for harvest containers or harvest equipment. Alternatively, for growers that had reusable containers, the frequency of sanitation was repeatedly discussed. Growers were often under the impression that containers MUST be sanitized after each use and did not see it feasible based on the size of their harvest and/or workforce. Furthermore, one grower using reusable plastic pails with plastic liners for the purpose of U-pick felt they had been presented with inconsistent recommendations from different food safety trainings.

3.3.3 Thematic Analysis

Thematic analysis was done by mapping categorical barriers to the implementation of RMP to the relevant constructs and subsequent domains of the Theoretical Domains Framework. The results of this analysis are presented in **Table 3.3**. The first domains we will discuss are knowledge, skills, and behavioral regulation. Knowledge in this instance refers to both the awareness of information as well as the procedural knowledge to apply information. Skills refers to the physical skills which one gains proficiency through training. For behavioral regulation, these refer to the actions taken to manage or change a behavior. For many growers, they felt they had the knowledge related to a given RPM but did not have the skills to implement them. This was most discussed in terms of implementing traceability plans; however, overall growers also felt they did not have adequate tools for monitoring or managing RMP. These barriers most often resulted from a lack of understanding, lack of physical resources, and lack of training.

The domains "belief about capabilities" and "belief about consequences" also appeared to play a major role in implementation. "Beliefs about capabilities" refers to one's belief about their ability or talent to put to constructive use and includes the constructs perceived behavioral control and self-efficacy. These constructs presented themselves in two different ways in this context. For certain growers, who did not perceive barriers to implementing specific RMP, they exhibit a high degree of perceived behavioral control and self-efficacy. These growers were confident in their ability to implement RMP and did not find that time or motivation influenced their abilities. These examples were primarily individuals with previous years of experience in the food industry and mainly associated with pre-harvest agricultural water. However, other growers who were less confident in their abilities to implement RMP often indicated that there were other things that were higher on their list of priorities to complete. The domain "beliefs about consequences" refers to one's belief about the severity of outcome related to a behavior. The constructs related to this domain are attitude and outcome expectancies in which differences were observed mainly related to RMP rather than the individual grower. For example, with testing of pre-harvest agricultural water, most growers felt that it was a useful practice as well as important to food safety. However, for other practices such as documentation related to harvest container sanitation and sanitation of buildings, growers acknowledged that it was important for food safety, but did not find the current requirements useful. In this instance, a lack of agreement presents one barrier which may be facilitated by lack of perceived benefit as well.

Lastly, the domain "Environmental context and resources" played a major role in the decision to implement RMP. "Environmental context and resources" include any characteristic of the environment or innovation that encourage or discourage a behavior. In this context, the environment represents both the physical environment and financial capital the farm. The innovation would be the PSR and includes the degree to which that innovation fits in with daily practice as well as the level of support one is given to implement the innovation. For many, grower resources such as time and money were the major barriers to implementing RMP. This was usually due to a lack of labor, lack of skilled labor, or perceived cost of initial implementation. However, many growers also felt that for certain RMP the requirements were not compatible with their daily practice. This again usually related to time especially the frequency of documentation of RMP. Finally, although all growers took measures to prevent wildlife and animal intrusion, many growers felt there was a lack of solution to this issue due to the farm environment. This was due to the presence of wildlife associated with the farm as well as domestic animals (pets) in some instances.

3.3.4 Growers Preferences of Food Safety Educational Methods?

We also asked growers what an ideal food safety education program would look like for them and, if applicable, their workers. For the grower who did employ workers, they felt that the training would have to be between 15 to 20 minutes maximum. Although, as described in the Section 3.3.1, the grower in *Case 2* indicated that training should be as little as 5 minutes. This was both due to the attention span of the workers as well as the potential impact on their wages due to time not spent harvesting. In addition, the growers indicated that the messaging should be concise in communicating only the most important reason for implementing a RMP rather than a lengthy list. Other specific wants related to employee training mention by growers were training material in different languages and training on animal monitoring. Q: were workers paid for the training time?

For the growers themselves, there were several points on which they were aligned and a few in which they were split. A majority of growers (n=7) also indicated they would prefer a shorter training i.e., a maximum of 2 hours. Growers with this viewpoint were in favor of virtual training which would be accompanied by physical resources. These resources were identified as both physical documents and videos the grower could go through at their own pace. For the growers that favored in person training, they recommended no more than 5 hours. In addition, these growers indicated they would be more likely to attend an in-person training at a professional conference due to time associated with travel. Additionally, growers felt they did not want to sit through lengthy PowerPoint presentations recapping information they had previously seen. They wanted the material to be stimulating as well as new and offering practical solutions. One grower suggested taking a poll in advance of the training to determine the content for a given session. In addition, using the verbiage of the PSR, growers indicated the wanted to know what they *must* do, not everything they *should* do.

Lastly, there were several ways that growers expressed the want for context specific education or resources provided from other strawberry growers. For example, one grower felt that food safety education should be conducted on-farm where another grower thought peer lead training would be very effective. Both centered these ideas around learning from a strawberry grower who is already implementing RMP in order to understand how they are incorporated into daily activities. Alternatively, there were several other growers that felt physical resources provided from another strawberry grower would suffice. These physical resources were most often a food safety plan or documentation and records related to RMP.

3.4 Environmental Assessments

3.4.1 Context – Case Description

As with the in-depth interviews, there were ideal criteria for selection of growers to participate in the environmental assessment. These growers had to be within the 13 southeastern United States and harvest strawberries on ≤5 acres of land. Of the 20 farms included in this study, they included 10 of the 13 SEUS: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia.

3.4.2 Within-Case

There were two growers who had an extensive amount of information regarding standard operating procedures for equipment sanitation where there were others with relatively little information. These farms were chosen for the within case analysis because, despite having a rich description of information regarding sanitation, there was still a varying degree in the accuracy in the methods that were reported.

Case 1

This first case described is a 15-acre farm with 2 acres dedicated to strawberry production. The grower employed between 5 to 9 employees which were a combination of part-time and family workers. All workers were provided with personal protective equipment (PPE) for harvesting, packing, and soil amendment handling. The PPE provided to the workers included gloves, face mask, and apron. In terms of employee hygiene facilities, the only functioning toilet was inside the home which at its greatest distance was 435 ft. from the strawberry production. The bathroom was fully stocked with a lidded trash can, potable water, soap, and paper towels. Aside from the in-house bathroom, there were two hand washing stations which at their greatest distance were 436 ft. from the strawberry production area. The handwash stations were also fully stocked with potable water, hand soap, and single-use paper towels.

Strawberries were grown via plasticulture methods and received irrigation through below ground drip lines. There was one on-farm reservoir of groundwater which was used for both irrigation and fertigation. Alternatively, for pesticide application and handwashing, the grower utilized municipal water. The grower did not treat the water; however, there were backflow prevention devices. In addition, the grower collected pre-harvest agricultural water samples 1 to 4 times per year since 2009. Biological soil amendments of animal origin were used for strawberries. The BSAAO utilized by this grower was in the form of stabilized compost which was purchased form a supplier rather than being produce on-farm. For transport of the compost, the grower rented a commercial vehicle; however, there were no designated tools or structure for the handling or storage of BSAAO on the farm. The grower did, however, store the compost as a covered pile away from high foot traffic areas. When measured, the shortest distance from the compost pile to the strawberry U-pick fields, water reservoir, or well house was 50, 115, and 113 ft., respectively. There were no signs of animal intrusion in the strawberry production area which was enclosed by a fence. In addition, there were no other type of domestic animal or livestock seen or reported

For harvest and packing of commercial strawberries, the grower utilized a harvest cart, plastic buckets, and plastic trays. For strawberry U-pick, the grower utilized wooden boxes and reusable plastic bins. Harvest tools and plastic bins were daily using municipal water was used for cleaning all food-contact and nonfood-contact surfaces. In addition, food-contact surfaces were sanitized using bleach. To prepare bleach for sanitation of equipment and tools the grower combined 1-2 tbs of bleach with municipal water in a spray bottle. Food contact surfaces were sanitized in a designated place using plastic bins to contain them. No formal documentation or recordkeeping for sanitation practices were observed.

Case 2

The second case described is a 5-acre farm with 0.1 acres dedicated to strawberry production. Aside from themselves, the grower also employed 2 full time workers. In addition, the grower sometimes had “summer helpers” which were local young adults. Regarding employee hygienic facilities, the toilet was located in the home for which the longest distance to the strawberry production area was 678 ft. The bathroom was fully stocked with a trashcan, potable water, disposable towels, and a melaleuca oil-based hand soap. There was also an “employee sick kit” on farm consisting of gloves, a hairnet, and Tough and Tender ® melaleuca oil-based cleaner. Aside from this the workers did not use any sort of PPE nor was there food safety signage.

Strawberries were grown via plasticulture using drip irrigation. There was one on-farm reservoir for groundwater which was pump operated ad fit with a backflow device. The groundwater was used for irrigation, pesticide application, and handwashing. The grower did test their pre-harvest agricultural water 1-4 times per year by collecting samples and sending the samples to an accredited lab. Strawberries on this farm were also fertilized with BSAAO which was a mixture corn and chicken manure. For storage, the BSAOO were piled 20 ft. from the strawberry field so long as strawberries were not in season which ensured that no edible portion of the crop could be cross-contaminated. To determine the maturity of the pile, the grower reported relying on smell. Separate equipment and tools are used to handle and plow BSAOO into the field, but \there is no designated storage space for tools. The grower utilized their own waste for the pile from their own chickens (n=20). Aside from chickens, the grower also had domestic animals on the farm such as dogs (n=4).

For harvesting, the grower did not field pack but rather utilized a packing house. Strawberries were initially harvested by hand into 5-gallon buckets which were transported to the packing house for sorting and packing. After sorting, strawberries were packing into pint size fiber cups. For harvest containers the grower reported cleaning and sanitizing weekly. Sanitizing or harvest containers was done with the same cleaning agent used in the spill kit (Tough and Tender). The grower did not specify or report regularly scheduled cleaning of other food-contact surfaces (i.e., those in the packing house). There were documented procedures or records reported for cleaning and sanitation of food-contact surface.

3.4.3 Cross-Case

The most common factors across all cases (n=20) were the use of plasticulture (n=20), drip irrigation (n=20), and fencing (n=19) for the prevention of animal intrusion. In addition, other commonalities were the operation off U-pick (n=14) and field packing (n=13). As per our inclusion criteria, all farms operated less than two acres for strawberry production; however, there was variation within that. The average acreage of strawberry farms was 1.2 acres, ranging from 0.1 to 2 acres. Of the 20 farms there were 19 with adequately stocked bathrooms and handwash stations; however, only 18 were conveniently located. There were n=9 growers for which the bathroom was located in the house. Relatively few growers used BSAAO; however, of the 4 growers who reported using BSAAO, three used compost while only one used raw manure. Additionally, 3 of the growers using BSAAO had separate tools and equipment with established decontamination procedures. For pre-harvest agricultural water, most growers used multiple sources depending on the application. For pre-harvest agricultural water, most growers used ground water; however, only 8 of the 16 growers who required to collect water samples were doing so.

Most growers used the field packing method; however, there were also 6 farms that used in-house packing. In addition, more than half (n=14) growers utilized U-pick operations while an additional 4 farms conducted further strawberry processing. The majority of growers (n=19) harvested in pails, followed by boxes (n=6), and non-reusable plastic containers (n=5). However, only 10 growers that indicated they engaged in in post-harvest practices had physical attributes to conduct post-harvest sanitation practices. For example, 9 of 10 farms reported sanitization of harvest containers. While all (n=9) used sanitizers on food-contact surfaces, not all were EPA approved. Moreover, while growers described their practice's often with an immense level of detail a written standard operating procedure were only reported on 10 farms with most (n=6) having operating procedures for cleaning and sanitization.

4. Knowledge Synthesis

There were 4 main goals during data analysis and interpretation. First, we sought to identify barrier(s) to implementation of RMP for which we could reasonably address in an educational intervention. Second, we sought to identify RMP for which growers had the greatest need or greatest desire for educational assistance. Third, we sought to understand growers' previous experiences with food safety education particularly elements they liked and disliked. Lastly, in our goal to present a context specific education, we sought to utilize all these data to create a curriculum that is presented based on the environment it will be implemented.

From the in-depth interviews, it was concluded that growers would best benefit from an education focused on the documentation and record keeping of RMP. Determining the subject matter was again determined not only based on the results of the interviews, but also an understanding of our capabilities as educators. For example, in **Table 3.2,** it is shown that the most common issue cited by growers is animal intrusion. The most common method employed for preventing animal intrusion is physical exclusion; however, this was already being performed by all growers. While there are unique/novel methods to be employed to improve this practice, this need was not expressed by growers. Instead, growers expressed frustration with the perceived need to document *every* instance of animal intrusion. This same sentiment was expressed often regarding the perceived required frequency for documentation and recordkeeping. For example, some growers were under the impression that cleaning and sanitation for buildings must be performed and documented daily. Though the growers did not cite documentation specifically, growers also had concerns over the perceived frequency of sanitation of harvest containers as it related to their overall workload. Frequency of documentation and recordkeeping was also discussed in regard to environmental sanitation and traceability which further lead us to believe that an overview of documentation and recordkeeping within the scope of cleaning and sanitizing could be most useful for growers in familiarize themselves with the requirements of the PSR when it comes to documentation and recordkeeping. Additionally, sanitation of equipment, tools, and buildings is one of the few areas of risk management for which the PSR gives requirements rather than a recommendation, making it less up to interpretation.

The other element raised by growers which lead us to focus on documentation and recordkeeping was the desire for templates. Though the growers were aware that there are a multitude of online resources, there were several issues raised with the materials currently available. First, the materials are generic and not commodity specific. Second, the available templates are typically not designed for small farms. This is because of the lack of specificity of online materials which often results in growers wading through information to determine what is useful or applicable for their farm. Lastly, because of the varying requirements for documentation and recordkeeping based on RMP, some growers still faced uncertainty about what information should be documented, even when growers did have a good idea of what information should be recorded. For example, when considering traceability, the growers still did not know what a formal traceability plan would look like.

5. Conclusion

In this study, we sought to gain better insight into the challenges and barriers that very-small and small strawberry growers in the southeastern U.S. face in implementing RMP. By conducting in depth interviews as a follow-up to our characterization, our goal is to develop context and commodity-specific education that both addresses growers need and meets requirements. In carrying this research forward, we will utilize this data to establish theory driven methods for the development and evaluation of curriculum targeting strawberry growers. It is our opinion that this approach can serve as a framework for designing food safety education for other lesser served commodities, thus bridging one potential gap in the food safety practices in the food industry.

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TABLES

Table 3.1
Interview Guide Developed for In-depth Telephone Interview

Environmental Assessments to Customize Food Safety Training for Very Small to Small Strawberry Producers in the Southeastern United States

INTERVIEW DISCUSSION GUIDE

BEFORE THE INTERVIEW BEGINS
When the interviewer confirms the scheduled interview, at least one week before the scheduled interview, they will send: (1) demographic survey, (2) confirmation email, and (3) list of the eight risk management practices and corresponding preventive measures. The interview cannot start until the participant confirms in an email that they have reviewed the confirmation email (consent form).

CONDUCTING THE INTERVIEW
The interviewer (Dr. Angela Fraser) will introduce herself. She will share with the individual the purpose of the study, make statements about confidentiality, describe how the interview will be conducted. NOTE: All of this information will be included in the confirmation email.

Opening — participant gets acquainted and feel connected

As you know, food safety has been in the news particularly in terms of eating fresh produce. One way to keep produce safe is to implement risk management practices on the farm. The USDA has identified eight risk management practices. Implementation of risk management practices is very important so we want to learn more about the challenges that you face in terms of implementing recommended practices. Before this interview, you receive a list of these practices and corresponding preventive measures. Did you have a chance to review the list?

Introductory — begins discussion of topic and makes them comfortable with sharing their experiences and thoughts about food safety on strawberry farms.

Identify three challenges you believe <u>*you*</u> *have to safely growing strawberries on your farm.*

Key — obtains insight on areas of central concern in the study.

I would now like to talk to you about what barriers you believe you have to implementing the risk management practices that are on the list we sent to you. Examples of barriers include but are not limited to financial constraints, infrastructure problems, workforce limitations, lack of skills and expertise to implementing recommended practices

Ask about risk management practices for each of the eight areas:

- *Worker health and hygiene*
- *Agricultural water*
- *Soil amendments*
- *Domesticated and wild animals*
- *Harvesting and packing activities*
- *Storage and transportation activities*
- *Equipment, tools, and building*

Table 3.1
Interview Guide Developed for In-depth Telephone Interview

- *Traceability procedure*

In addition, what challenges do you have in terms of documenting and maintaining records for the eight risk management practices we just discussed.

Ending — helps researchers determine where to place emphasis and brings closure to the discussion

If you could design a training course for you and your workers about how to implement these practices, what would that training course look like?

Summary Question — interviewer gives a short oral summary (2 or 3 minutes) of the key questions and the big ideas that emerged from the interview. After the summary, the participants are asked about the adequacy of the summary.

How well does that capture what you said?

Final Question — to ensure that critical aspects have not been overlooked.

Is there anything that we should have talked about but did not?

Thank you for participating in this interview.

Table 3.2
Demographics and Food Safety Barriers of Participants

Location	Acreage	Top Barrier
AL	3.0	Weather
AR	5.0	Gloves
GA	0.14	Time
GA	0.25	Livestock
GA	5.0	Bird Control
NC	15.0	Wildlife Intrusion
OK	1.0	Pest Control
OK	1.0	Animal Droppings
VA	1.0	Animal Contamination

Table 3.3
Thematic Analysis of Factors Influencing Implementation of RMP

Domain	Construct	Category
Knowledge	Procedural Knowledge	Lack of Knowledge
Skills	Psychical Skills	Lack of Understating
Behavioral Regulation	Action Planning	Lack of Understanding Lack of Physical Resources
Beliefs About Consequences	Attitude	Lack of Agreement
	Outcome Expectancies	Lack of Benefit
Beliefs about Capabilities	Perceived Behavioral Control	Lack of Confidence
	Self-efficacy	Lack of Priority
Environmental Context and Resources	Environment	Lack of Solution
	Resources	Lack of Financial Capital Lack of Physical Resources
	Innovation Characteristic	Lack of Time Lack of Training Lack of Compatibility

Table 3.4
On-farm Attributes Related to Food Safety

Practice	Attribute	N	Percent (%)[a]
Employee Health and Hygiene	Adequate Bathroom	18	90
	Adequate Handwash	19	95
Pre-harvest Agricultural Water	Non-Contact Irrigation	20	100
	Water Sampling	8	50
Animal Intrusion	Physical Barrier	20	100
	Livestock Containment	6	66.7
BSAAO	Composting	3	75
	Designated Handling	3	75
Harvest and Packing	Non-Reusable Container	5	25
	Cleaning of Equipment and Tools	7	87.5
	Sanitizing Equipment and Tools	2	25

[a]Percentages calculated within row total (n)

Figure Legend

Figure 1 Diagram for Case and Thematic Analysis of Telephone interviews and Environmental Assessments.

FIGURES

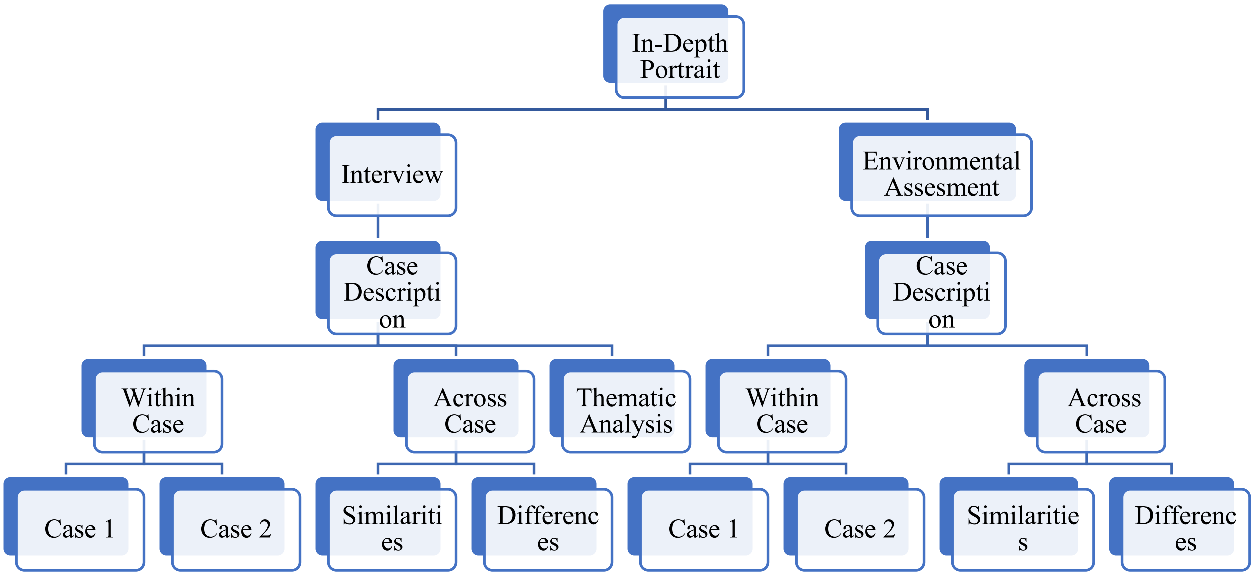

Figure 3.1 Diagram for Case and Thematic Analysis of Telephone interviews (left) and Environmental Assessments (right).

Chapter 4

A Pilot Scale Test of Context Specific Education Tailored Towards the Strawberry Industry

Abstract

Strawberries are a produce commodity linked to several significant instances of foodborne illness outbreaks for which there has yet to be a set of published industry guidelines. This may be partially attributed to a lack of characterization which has been the primary focus of this dissertation. Upon synthesizing the knowledge pertaining to the implementation of risk management practices among strawberry growers, we developed a context specific education as well as a novel framework for evaluation. While we did not detect a significant difference in the pre- and post-test scores of participants, we did observe several positive increases in the perception of growers towards Action Planning, Perceived Behavioral Control, Attitude, Environmental Context and Resources, and Intentions.

1. Introduction

Strawberries are one of the top five consumed produce commodities. They have also been linked to several outbreaks of foodborne illness (FBI). Unlike other highly consumed produce commodities which have also been linked to foodborne illness outbreaks (i.e., leafy greens, melon, tomato), the strawberry industry has received considerably less attention. This has led to a lack of characterization of the strawberry industry and its production practices. This is especially apparent in comparison to other commodity groups such as leafy greens and melons, (Leafy Greens Marketing Association. 2007, Rocky Ford Growers Association. 2011, Minor et al. 2019, Calvin et al. 2017, Calvin, L. 2013).

Experts in food safety education have recognized the need for education that is more tailored to the user and the environment in which the user is working. The environment in which an individual is working includes their physical environment but also pertains to other factors including interpersonal interactions, intrapersonal interactions, and organization level interactions. These four factors provide what is referred to as context and are understood to represent the whole system in which an individual is expected to perform a task. A “context specific” approach to education has been the focus of many studies on education and implementation, both within and outside of the food industry. For example, experts in implementation science have indicated that a failure to consider the learners’ context is why nearly 50% of evidence-based research fails to be implemented (Green et al., 2009). Similarly, Young et al. (2018) and others have reported a rate of 50% or less in implementation of food safety practices following food safety education.

For produce growers, context may include their commodity type, labor resources, access to capital, revenue, acreage, and geographical location. In the case of the Produce Safety Rule (PSR), growers are classified by both commodity type and revenue. In addition, growers themselves often cite time, labor, and finances as major barriers to implementation. Though researchers cannot directly impact those aforementioned barriers, a focus on context would ideally result in educational or training material which is designed to promote the adoption of a specific behavior even given those barriers.

Aside from a failure to consider context, researchers have also highlighted issues regarding methods and content surround food safety curriculum. Reynolds and Dolasinski (2019) noted in their review of food safety training topics and modalities that, at present, there is a lack of innovation in terms of mode of delivery for food safety training. In addition, Young et al. (2018) reported that most food safety trainings for retail and food service workers were conducted as a lecture style, in-person training (86%), predominantly covering topics related to personal hygiene (88%) and cross-contamination (87%). In their paper on a new approach to food safety education, Yeargin, Gibson, and Fraser (2021) also highlight these design related factors as major barriers to implementation of RMP due their impact on knowledge sharing. Knowledge sharing is proposed by Becheikh et al. (2010) to be a 6-step process: generation, adaptation, dissemination, reception, adoption, and implementation. Similarly, Zanin et al. (2020) notes that the translation of knowledge into practice is influenced by many factors including attitude, risk perception, and experience. To understand these factors, food safety research needs longitudinal strategies to fully understand context. Our goal was to adapt and disseminate information collected from survey, in-depth interviews, and environmental assessments of strawberry growers in the southeastern U.S. to develop context specific food safety education.

To guide the development of the curriculum as well as our evaluation, we utilized the Theoretical Domains Framework (TDF). The TDF was developed by (Caine et al. (2011) as an attempt to unify the more than 180 theories of behavioral and subsequent constructs. Since development of the TDF, it has undergone multiple validations which have resulted in refinement of the framework to what is now 18 constructs. The approach to this framework is said to be novel in that it includes internal, external, individual, and group influences. In addition, the framework has several constructs which are meant to address context, which is of particular relevance to this study. Along with validations of the framework, several questionnaires have been assessed for their use in healthcare settings. Most recently, Hujig et al (2014) has validated a 99-item questionnaire which can be used to adapt the TDF in multiple settings. For example, each item contains an action (A) context (C) time (T) and target (Ta).

2.Theories of Behavioral Change and Their Application in Food Safety

Theories of behavioral change (TBC) are modules utilized to understand decision making processes. Young et al. (2018) found that studies informed by a theory of behavioral change had a larger effect size when it came to changing food safety behaviors. Using TBC provides a structured format to identify and incorporate successful strategies for promoting or changing certain behaviors. The applicability of TBC is broad and can be used to understand individuals as well as organizations. For example, in studies involving food handlers, it has been found that food safety culture as well as moral norms, which are organizational and person factors, respectively, can have an influence on food handler practices.

2.1 Review of Studies Utilizing Theories of Behavioral Change Amongst Food Handlers

The main behavioral models applied to understand food handler behaviors are the Knowledge Action Practice (KAP) model, the Health Belief Model (HBM), and the Theory of Planned Behavior (TPB) (**Table 4.1)**. The KAP model is one which has been widely utilized as well as widely criticized. This model suggests that for an individual to change their practices they need to receive knowledge, which in turn will influence their attitude. The change in attitude is supposed to have an influence on intentions and thus the likelihood that an individual would change their behavior. In their review of 36 articles, Young et al. (2020) found that 50% of articles demonstrated no translation of knowledge into a change in attitudes or practices. While the authors did note that KAP are important elements to be used in the evaluation of food safety training, additional elements should be considered in order to change behaviors. Meanwhile, Insfran-Rivarola et al. (2020) performed a systematic review and meta-analysis on 31 articles measuring KAP. To perform their analysis, the authors determined the effect size for interventions utilizing the KAP. Effect size is used to perform comparisons of studies which are done under different conditions, particularly with varying sample size, and is a measure of what percent of the control group is below the experimental group. In regard to knowledge, the Insfran-Rivarola and co-authors found there was a large effect size of 1.24 which indicates a significant impact of food safety educational interventions on knowledge. This is not surprising as an increase in knowledge is typically observed after participation in food safety education. For attitude, the Insfran-Riveraola et al. (2020) reported an effect size of 0.28 which indicates a positive significant effect as a result of training; however this effect size would be interpreted as only moderate. Lastly, for practice, the authors reported the effect size for two different measures: self-reported practices and observed practices. For self-reported practices, the effect size was large (0.8); however, when assessing observed practices that number fell to 0.45. The authors concluded that while food safety education does have a positive effect on KAP of food handlers, only 25% of food safety educational interventions translated into behavioral change.

To overcome the challenges presented in the use of the KAP model, researchers have implemented more complex theories of behavioral change such as the HBM and TPM. These models are more complex as they include a broader range of constructs that focus on more individual factors. The HBM focuses mainly on the influence of perception regarding a specified outcome, especially perceived risk, perceived barrier, and perceived benefit. For individual risk perception, the HBM suggests that this is influenced by the individual's perceived susceptibly to a risk and perceived severity of an outcome. In addition, their decision to choose a behavior will be facilitated by a perceived benefit or impeded by a perceived barrier. Conversely, rather than focusing on the outcome of a behavior, the TPB is more focused on the personal beliefs of an individual which may influence an individual's intentions to perform a behavior. The constructs included in the TPB are attitude, perceived behavioral control, and subjective norm. Attitude and perceived behavioral control are beliefs about a behavior as well as the belief in one's ability to perform a behavior. Subjective norms are also focused on beliefs; however, these are individual beliefs about how others view a behavior.

Young et al. (2018) conducted a systematic analysis of theories of behavioral change among food handlers, and the authors found that the TPB (n=9) was most employed followed by the HBM (n=4). Among the 19 studies reviewed it was determined there was wide variability in the predictive capabilities for both the HBM and TPB. In the case of the HBM, Young and co-authors found that at least one construct was a significant predictor of behaviors in each study, but only perceived benefit was significant in all studies. For the TPB, there was no clear pattern in the significant constructs identified, and in one case, none of the constructs were found to be significant. The TPB was also utilized by Soon and Baines (2012) in their study of produce workers. The authors found that the model explained 57% if the variance in handwashing. Of the constructs, perceived behavioral control was identified as the most significant indicator of intention regarding handwashing. Soon and Baines (2012) explain that because there was a perceived barrier for workers in getting to handwash stations, that when that perceived barrier was removed handwashing was performed more regularly.

2.2 Review of Studies Utilizing Theories of Behavioral Change Amongst Produce Growers

In Chapter 3, we utilized qualitative information obtained from interviews with strawberry growers to identify potential domains of the TDF and their related construct which may influence the decision of a produce grower to implement risk management practices (RMP). Here, we will provide further support for the application of the TDF through identification of relevant peer-reviewed research publications, specifically with produce growers, that have utilized the theories of behavioral control. These studies are summarized **in Table 4.2** along with the relevant domains.

In their review of food safety education on produce farms, Chen et al. (2019) found that of 13 studies only 3 specified behavioral learning models. One of these studies was previously reviewed by Soon and Baines (2012) in the section on food handlers as that study focused on agricultural workers. The other model employed was Bennet's Hierarchy which was utilized by Tobin et al (2013) and Nayak et al. (2015). Bennet's Hierarchy is a 7-step tool meant for design and evaluation of food safety education. Both studies utilized the model to determine growers' knowledge, attitude, and skills as well as behavior related to Good Agricultural Practices (GAP). Tobin et al. (2013) found no significant influence of knowledge on a grower's intentions towards implementing GAP related activities such as writing a food safety plan, conducting a third-party audit, and conducting a self-audit. Attitude was found to be significant as they reported that growers with a more positive attitude towards food safety practices were more likely to conduct GAP activities. Similarly, growers who had a positive attitude toward the availability of resources showed the same trend. Regarding GAP activities, Both Tobin et al. (2013) and Nayak et al. (2015) found that attitude and confidence were significantly correlated to actions taken. In the case of Tobin et al. (2103), while it was found that knowledge, attitudes, and confidence increased as a result of participation in training, the same level of improvement was not found in a delayed 6 month follow up.

The role of knowledge was further explored by Becot et al. (2020) who elicited a novel framework in order to understand growers' willingness to implement RMP versus being financially able. For example, Becot et al. (2020) found that growers for which there was an average knowledge score of 77.1%, only 41% reported knowledge as a barrier to implementing RMP. However, when determining what factors could be significant predictors including a grower's financial ability and willingness to invest, the authors found knowledge to not be significant. In a study of lettuce growers in Iran, Rezaei et al. (2018) also assessed knowledge via validating the use of an adapted version of the TPB which utilized the constructs of knowledge and moral norms. The authors found that while all of the original components of the TPB were significantly associated with a grower's decision to implement RMP the inclusion of knowledge and moral norms, both of which were statically significant, increased the predictive capacity of the model from 45.6% to 57.4%. In addition, Rezaei and co-authors found that with the inclusion of moral norms, social norms were not a significant predictor in their model. The authors concluded that rather than being influenced by social pressure, growers were more influenced by their own morals (i.e., producing safe food because it it's the right thing to do). Rezaei et al. (2018) also determined that of all the constructs, attitude was the most significant predictor of intentions.

In another study utilizing the same sample, Rezaei and Mianaji (2019) further explored the use of an adapted theory of behavioral change, in this instance the HBM. In addition to the original components of the HBM, the researchers also assessed constructs for cues to action and self-efficacy. In this instance, they found that two of the components of the original model (i.e., perceived severity and perceived susceptibly) were not significant predictors of growers' intentions to implement RMP. Of all constructs assessed, Rezaei and Mianaji (2019) found that perceived barrier was the most reliable predictor of intentions, noting that it had a significant negative effect on growers' intentions to implement practices. The authors also included that among the main predictors of positive impact on growers' intentions were perceived benefit, self-efficacy, and cues to action.

Lastly, in work performed by Parker et al. (2013), they elicited a novel framework via the mental models approach. Using the mental models approach they defined 10 domains, each informed by individual constructs which influenced growers' decisions to implement RMP. Of interest for the present study are those results pertaining to environmental context/resources, procedural knowledge, and social support.

2.3 Evaluation Framework

Based on the review of qualitative and quantitative data, we identified the following constructs for the use in evaluating the effect of the intervention: Action Planning, Attitude, Perceived Behavioral Control, and Self Efficacy. Due to the size and the scope of the framework and subsequent questionnaire, it was our goal to narrow down the constructs for both the development of our educational content and the evaluation of our training. To do this, we conducted a literature review of food safety education based on either established or novel frameworks. The results of this review are contained in **Table** 4.**2.**

3. Materials and Methods

3.1 Curriculum Development

The results of the strawberry grower survey demonstrated that the majority of growers were not performing documentation and recordkeeping required by the food safety RMP. When conducting the follow up interview, it became apparent that there could be several reasons contributing to this trend. First, there was a common misconception that documentation and recordkeeping for activities must be performed daily. While there are some RMP for which daily documentation and recordkeeping may be beneficial, the RMP often mentioned by growers were those related to sanitation or animal intrusion. Second, in regard to documentation, there was a perceived lack of time to develop, implement, and regularly maintain documentation and recordkeeping. This is likely related to the previous issue regarding confusion about the required frequency of documentation but may also be related to a third theme identified which was the need for templates.

There were other issues identified by growers including those related to identifying content for employee training as well as the frequency of sampling for agricultural water; however, these were expressed by some but not all growers. There were more frequent and numerous reports of discrepancy between information received in regard to container sanitation. These were also in regard to frequency of cleaning and sanitizing as well as other related practices such as the use of plastic liners for lining of U-pick buckets. Finally, documentation and recordkeeping related to sanitation procedures were one of two areas of risk management for which more than 50% of strawberry growers were implementing suggest this is an area of risk management of importance to growers.

For these reasons, we decided an educational curriculum focused on documentation and recordkeeping may be most beneficial to strawberry growers in the southeastern region of the U.S. Because documentation and recordkeeping requirements vary throughout the PSR, we chose to focus on one are of risk management. The area of risk management we chose was Sanitation of Equipment, Tools, and Buildings. This choice was informed by our research findings, published research studies, as well as extension communication reports which have also suggested that documentation and recordkeeping related to sanitation is an area of need and interest in the industry.

The developed curriculum went through multiple rounds of refinement utilizing the feedback of one extension associate with expertise in producer education at the University of Arkansas System Division of Agriculture, one expert in food safety education at Clemson University, and one expert in food safety at the University of Arkansas System Division of Agriculture. Refinement of the curriculum primarily involved development of learning objectives as well as alignment of the objectives, content, and exercises. The resulting curriculum was composed of the following 4 modules: Importance of Food Safety; Cleaning and Sanitizing Terminology; Standard Operation Procedures for Cleaning and Sanitizing Surfaces; Documentation Recordkeeping and Monitoring.

3.2 Instructional Design

Our approach to designing the curriculum was to utilize a sequential design incorporating knowledge sharing, problem-based learning, and practical skills application. These elements were delivered through the use of PowerPoint, video examples, and in-training discussions. Elements for knowledge sharing were derived based on required elements for the Produce Safety Rule for sanitation, documentation, and recordkeeping. Both problem-based learning and skills application were focused on the identification of food-contact surfaces as well as navigation of a Produce Safety Alliance Excel tool for selection of U.S. Environmental Protection Agency approved sanitizers.

An additional integral part of our approach was to also incorporate feedback from extension educators. This was based on Shaw, Strohben, & Naeve (2015) and their approach which is described as “know, show, go”. In this systematic approach to on-farm food safety, training is broken down into three different sessions in where growers first received the knowledge, then received guidance in how to apply that knowledge, and finally observe the use of this knowledge on-farm. Our approach is much more condensed due to time considerations; however, we believe that we have maintained the core elements.

3.3 Implementation

A pilot study was conducted to implement and evaluate our context specific food safety education. An online course of approximately 3 hours was developed and offered over Zoom Video Communications, Inc. (San Jose, CA). Course contents include four training modules focused on covering importance of food safety, terminology related to cleaning and sanitizing, SOPs for cleaning and sanitizing, documentation, recordkeeping and monitoring. Individual modules were followed by an educational engagement activity and a break. Participation was elicited from growers with respect to the modules being discussed. This included identification of food contact surfaces on their farm as well as an invitation to discuss their sanitizing practices related to harvesting, packing, storage, and transportation.

3.4 Participant Recruiting

Extension associates at the University of Arkansas recruited n=20 individuals involved in the strawberry industry. This was done through a combination of email, flyers, and social media announcements.

3.5 Evaluation

3.5.1 Questionnaire Development

The questionnaire was adapted from work initiated by Cane et al. (2012) on the TDF and measured questions related to specific behavioral constructs on a Likert scale. The TDF is a classification scheme developed to integrate the multitude of existing behavioral theories and individual constructs which Cane et al. (2012) felt were too simple, overlapping, and often misunderstood. An evaluation of the framework by Huijg et al. (2014) in the healthcare setting performing discriminate content validity found that the overlapping of constructs still occurs in 2 out of the 14 proposed domains and suggested a refined version resulting in 18 domains. Based on their results and the needs of this research project, our proposed questionnaire focused on 7 main constructs using 19 questions. The 27-item questionnaire was adapted from Huijjg et al. (2014) and focused on documentation and recordkeeping of RMP. These are presented in **Table 4.3.** Face and content validity were assessed by an expert in food safety as well as an expert in food safety education after which the items were remodeled to focus specifically on cleaning and sanitation. Additionally, as significant statistical power would be needed to validate a 10-construct behavioral model, the construct was reduced by half from 10 to 5 total constructs. These remaining constructs were the most relevant to this sample as well as having the most support from other published studies. This questionnaire displayed in **Table 4.4** utilizes items pertaining to Action Planning, Environmental Context and Resources. Perceived Behavioral Control, Attitude, and Intention.

3.5.2 Statistical Analysis

Statistical analysis was performed using SPSS (IBM, Cary, NC). Descriptive statistics were calculated for demographic variables as well as individual questionnaire items. To determine if there a significant effect of training on the post-training scores, both parametric and nonparametric methods were employed. These included the paired t-test, Wilcoxon signed-rank test, and sign test. In addition to assess construct validity, Spearman's Rho was calculated for constructs containing ≥3 related items for both the pretest and posttest. All statistical tests were run at alpha=0.05.

4. Results

4.1 Demographics and Descriptive Statistics

There was a total of n=17 participants of which n=14 provided both pretest and posttest data. The demographics of these participants is presented in **Table 4.5**. For both pretraining and post-training, nearly all had undergone food safety training and a majority identified as female. There was a relatively even distribution among the age groups with those being 25-45, 25-54, and 55-64 making up nearly 80% of the sample. When asked about their role, the two most common responses from participants were farm owner (35.7%) and educator (35.7%). For those that selected other (n=3) text response included auditor, quality and safety, and assistant.

For the remaining variables results are presented for those that owned or operated a farm as this same logic was applied to those participants were presented with Likert scale items related to on-farm food safety practices. In **Figure 4.1a** it is shown that the majority of growers (n=50%) had less than 1 acre dedicated to strawberry production, whereas in **Figure 4.1b** you can see that post training the majority of growers utilized 1-5 acres for strawberry production. There was not a great observable difference for those utilizing 6-10 acres; however, those utilizing more than 10 acres were notably absent post training. As can be seen in **Figure 4.1**, for both and pre- and post-training, >70% of the sample utilized 5 acres or less for strawberry production.

In **Figure 4.2**, the participant response to items related to action planning are shown for both pre and post training. For both cleaning and sanitizing, there is an observable shift in the individuals who somewhat agree to those who strongly agree that they have a plan for implementing RMP. For the construct "Environmental Context and Resources", the barriers that growers felt they faced for cleaning and sanitizing, both pre- and post-training, are presented in **Figure 4.3.** The results were widely distributed; however, most commonly growers strongly disagreed they had the time, finances, technical knowledge, and/or staff for implementing these practices. While the percent of growers that strongly disagreed decreased to less than 20% for both cleaning and sanitizing post-training, a similar increase was not seen in positive agreeance items. For example, even post-training, the majority of individuals somewhat disagreed that they had the time, financial resources, technical knowledge, or staff that they needed.

For items related to "Perceived Behavioral Control and Attitude" (**Figure 4.4**), the scale responses were again relatively widespread; however, in this instance, growers tended to have more positive agreeance with at least 50% of growers somewhat agreeing that documenting and recording their cleaning and sanitizing practices was easy, possible, worthwhile, and simple. Additionally, as opposed to the previous comparison of Environmental Context and Resources, between 80 and 100% of growers exhibited an increase in Attitude as they strongly agree the practices were worthwhile. For items related to Perceived Behavioral Control there was an increase from 20% of participants who strongly agreed to 80% of participants who strongly agreed that cleaning practices were easy possible and simple, however the same incase was not seen for sanitizing practices.

Finally, for measures of Intention **(Figure 4.5)** to complete a standard operating procedure (SOP) and recordkeeping for cleaning, there was in increase between pre- and post-training for those that indicated they strongly agree; however, the percent of individuals who somewhat agreed decreased. Additionally, there were 15% of individuals who indicated they strongly agreed on an intention to implement recordkeeping. For sanitation, a similar trend was seen in that the percent of individuals that strongly agreed they would document and record sanitizing somewhat decreased post-training.

4.2 Statistical Analysis

To determine the appropriate use of statistical measures, the Shapiro wilks test for normality was performed on the different scores for each construct. The results of this analysis, which are presented in **Table 4.5**, indicate that the differences are not normally distributed for n=7 items. For the n=24 items that were normally distributed, the paired t-test was performed. The results of the paired t-test **(Table 4.6)** did not indicate there was a significant difference between the pre- and post-test scores for any of the items measured. For those n=7 samples that were not normally distributed, a measure of central tendency was again used to assess the appropriateness of non-parametric methods. A histogram of the median difference revealed the distribution to be asymmetric, thus violating the assumptions needed for the non-parametric Wilcoxon Signed-Rank Test. Finally, the sign test was performed on pairs that did not meet assumptions of normality or symmetry which were also found no to be t significant.

5. Discussion

We did not observe a significant increase in differences of scores between pre- and post-test evaluation. There may be several reasons contributing to this result. First, there was a small sample size (n=17) which was reduced to n=5 matched pairs for statistical analysis. In addition, there was a decrease in the predictive capability for some constructs as indicated by the pre- and post-test reliability based on Spearman's Rho. This would indicate in such a short time frame there is an issue with the test-retest reliability of these constructs, and as such, the constructs should be reworded or otherwise reconsidered. There was also dropout of four participants between the pre-test and post-test which further decreased the sample size available for matched pairs. As it is also suggested to do delayed follow-up to training, to allow for maturation and incorporation, a 3 or 6 month follow-up may reveal different results.

Aside from statistical analysis, we did gather positive feedback from participants. Based on feedback from participants, growers were made more aware of food safety resources such as extension programming and the PSA Excel tool for Disinfection. In addition, though not statistically significant we did, we did see a positive increase in growers agreeance of items related to documentation and recordkeeping of RMP. For example, there was a 60% increase in a grower who strongly agreed that implementing documentation and cleaning practices were worthwhile. We also saw a similar increase in the percent or growers who felt that implanting practices for cleaning were possible.

For the remaining constructs, the following trends were also observed. For the distribution of responses from pre-training evaluation they results were widely distributed. Though there were slight skews toward positive agreeance items, there was rarely >50% of participants with positive opinions and at least 10-20% of participants exhibiting negative opinions.

In the post-training results, however, there was an observable shift towards positive response items. This was most observable in the shift of participants who somewhat agreed with items related to cleaning and sanitizing RMP to those who strongly agreed. In addition, there was an observable decrease in the percent of participants who strongly disagreed to a response of somewhat disagreed. Furthermore, as the distribution of responses were more conserved from pre- to post-training, it could be suggested that--regardless of positive or negative connotation--participants of the training had a higher level of understanding as to the implementation of these practices on their farm.

6. Conclusions

The results of this education did not indicate a significant change for n=5 matched pairs which were tested. Based on the small sample size as well as difference in the predictive capacity of our constructs between pre-training and post-training, there are multiple ways the experimental design that could be modified in order to make more conclusive results. These include a larger sample size, randomized controlled trials, postponed follow-up, and increased construct validity.

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TABLES

Table 4.1
Theories of Behavioral Change and their Application in Food Handler Research

Reference	Models	Sample	Analysis	Studies	Results
Young, I., Thaivalappil, A., Greig, J., Meldrum, R., & Waddell, L. (2018)	TPB HBM	Food handlers	Systematic Review	19	• Most common theories were TPB (n=9) and HBM (n=5). • Wide variability in predictive capability of models 0.34-.61 r2 • TPB useful but could not elicit which construct had predictive effect. • HBM at least one or more constructs were significant in all studies but perceived benefit significant in all four studies reviewed
Lin, N., & Roberts, K. R. (2020)	TPB	Food service workers	Systematic Review Meta-Analysis	46	• Effect size of 0.282 at p<0.001 indicated that TPB is a useful predictor of food safety intentions for food service workers. • Subjective Norm was the most influential construct with a medium to large effect size • Between study heterogenicity low and non-significant suggesting findings may be applicable in in various food service environments • Larger samples yielded stronger Individual Norm to Intention Prediction
Zanin, L. M., da Cunha, D. T., de Rosso, V. V., Capriles, V. D., & Stedefeldt, E. (2017)	KAP	Food handlers	Integrative Review	36	• Of the included studies 4 failed to translation knowledge into practice, 7 failed to translate attitudes into practice, 3 that did not translate knowledge into attitudes OR practice, and 4 in which knowledge AND attitudes failed to translate into practice.
Insfran-Rivarola, A., Tlapa, D., Limon-Romero, J., Baez-Lopez, Y., Miranda-Ackerman, M., Arredondo-Soto, K., & Ontiveros, S. (2020)	KAP	Food Handlers	Systemic Review and Meta- Analysis	31	• For the observed studies knowledge, attitudes, and practice showed an effect size of 1.24, 0.28, and 0.65, respectively. • When assessing self-reported vs observed practices the effect sizes were 0.45 and 0.8.

Table 4.2
Application of Theories of Behavioral Change Among Produce Growers

Domain	Construct	Framework	Result	Reference
Knowledge	Knowledge	Novel Framework	77% score with 42% indicating knowledge as barrier however Knowledge as a perceived barrier r was not statistically significant at predicting willingness or financial to adopt RMP	Becot, F., Parker, J., Conner, D., Pivarnik, L., Richard, N., & Wright-Hirsch, D. (2020).
	Procedural knowledge	Elicited	Knowledge was 1 of 6 MCA related to grower decision making, awareness and understanding 7-10	Parker, J. S., Wilson, R. S., LeJeune, J. T., Rivers III, L., & Doohan, D. (2012
		TPH	Knowledge increased TPB predictive e by 16.4%	Rezaei, R., Mianaji, S., & Ganjloo, A. (2018).
Beliefs about capabilities	Self-efficacy	HBM	Self-efficacy predictor intentions to engage on farm lettuce products	Rezaei, R., & Mianaji, S. (2019).
	Perceived behavioral control	TPB	perceived behavioral control was significant	Rezaei, R., Mianaji, S., & Ganjloo, A. (2018).
		TPB	perceived behavioral control was sig	Rezaei, R., Seidi, M., & Karbasioun, M. (2019).
Beliefs about consequences	Attitudes	TBP	Attitude most important predictor of lettuce grower intention	Rezaei, R., Mianaji, S., & Ganjloo, A. (2018).
		TPB	Attitude perceived significant PPE	√ Rezaei, R., Seidi, M., & Karbasioun, M. (2019).
	Outcome expectancies	HBM	Perceived threat not Significant	Rezaei, R., & Mianaji, S. (2019).
		TPB	Perceived susceptibility and severity increased by 109% predictive capability	Rezaei, R., Seidi, M., & Karbasioun, M. (2019).

Table 4.2 (cont.)
Application of Theories of Behavioral Change Among Produce Growers

Domain	Construct	Framework	Result	Reference
Environmental context and resources	Resources/material	Elicited	Adaptive Capacity, Farms Structure	Parker, J. S., Wilson, R. S., LeJeune, J. T., Rivers III, L., & Doohan, D. (2012
		HBM	Perceived barrier was the most reliable predictor	Rezaei, R., & Mianaji, S. (2019).
		Novel Framework	Only 24% of participants financially able to invest and 54% willing based on cost 74% said financial was a barrier to implementation which was sig predictor for module om financially able	Becot, F., Parker, J., Conner, D., Pivarnik, L., Richard, N., & Wright-Hirsch, D. (2020).
Social influences	Social support	Novel Framework	Subjective norm likely not for growers because of scale solidarity and observer boas and altitudinal amiable	Parker, J. S., Wilson, R. S., LeJeune, J. T., & Doohan, D. (2012).
	Subjective norm	TPB	Subjective norm was a significant predictor of behaviors until moral norm added	Rezaei, R., Mianaji, S., & Ganjloo, A. (2018).
	Descriptive norm			

Table 4.3
Relevant Construct and Questionnaire Items Determines by Triangulation of Research with Produce Growers

Construct	Item
Procedural knowledge	I am aware of how to document RMP[a].
	I know how to document RMP.
	I am familiar with how to document RMP.
Skills	I have been trained how to document RMP.
	I have the proficiency to document RMP.
	I have the skills to document RMP.
	I have practiced documenting RMP.
Action planning	I have a clear plan of how I will document RMP.
	I have a clear plan under what circumstances I will document RMP.
	I have a clear plan when I will document RMP.
	I have a clear plan how often I will document RMP.
Innovation characteristics	It is possible to tailor documentation of RMP to professionals' needs.
	Documenting RMP takes little time.
	Documenting RMP is compatible with daily practice.
	Documenting RMP is simple.
Innovation strategies	FDA[b] provides professionals with a training to document RMP.
	FDA provides the possibility to experience documenting RMP before professionals need to commit to it.
	FDA provides sufficient intervention materials.
	FDA provides assistance to professionals with documenting RMP.
	FDA organizes meetings for professionals.
	FDA provides sufficient financial reimbursement to professionals for document RMP.
	FDA provides insights into results of documenting RMP.
Self-efficacy	I am confident that I can document RMP following the guidelines.
	I am confident that I can document RMP following the guidelines even when other strawberry growers do not.
	I am confident that I can document RMP following the guidelines even when there is little time.
	I am confident that I can document RMP following the guidelines even when not motivated.
Perceived behavioral control	I am confident that if I wanted, I could document RMP.
	How much control do you have over document RMP?
	For me, documenting RMP is… (Very difficult – very easy).

Table 4.3 (cont.)
Relevant Construct and Questionnaire Items Determines by Triangulation of Research with Produce Growers

Construct	Item
	For me, document RMP is… (Impossible – possible).
Attitude	For me, documenting RMP following the guidelines is (not useful at all – very useful).
	For me, documenting RMP following the guidelines is (not worthwhile at all – very worthwhile).
Outcome expectancies	If I document RMP following the guidelines, documentation of RMP will be most effective.
	If I document RMP following the guidelines, this will strengthen the collaboration with strawberry growers.
	If I document RMP following the Guidelines, I will feel satisfied.
Intention	I intend to document RMP following the guidelines in the next three months.
	I will definitely document RMP following the guidelines in the next three months.
	How strong is your intention to document RMP following the guidelines in the next three months?

[a]; Risk Management Practice
[b]; Food and Drug Administration

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Table 4.4
Evaluation Items for Strawberry Grower Pilot Study

Construct	Item
Action Planning	I have clear plan how I will document my cleaning practices
	I have a clear plan how I will document my sanitizing practices
	I have a clear plan how I will record my cleaning practices
	I have a clear plan how I will record my sanitizing practices
Environmental Context and Resources	I do not have time to document and record my cleaning practices
	I do not have financial resources to document and record my cleaning practices
	I do not have the technical knowledge to document and record my cleaning practices
	I do not have staff to document and record my cleaning practices
	I do not have time to document and record my sanitizing practices
	I do not have financial resources to document and record my sanitizing practices
	I do not have the technical knowledge to document and record my sanitizing practices
	I do not have staff to document and record my cleaning practices
Perceived Behavioral Control	For me documenting ad recording my cleaning practices is easy
	For me documenting ad recording my cleaning practices is possible
	For me documenting ad recording my cleaning practices is simple
	For me documenting ad recording my sanitizing practices is easy
	For me documenting ad recording my sanitizing practices is possible
	For me documenting ad recording my sanitizing practices is simple
Attitude	For me documenting ad recording my cleaning practices is worthwhile
	For me documenting ad recording my sanitizing practices is worthwhile
Intentions	Within the next three month, I plan to create my cleaning standard operating procedures
	Within the next three month, I plan to create my sanitizing standard operating procedures
	Within the next three month, I plan to create my recordkeeping log for cleaning
	Within the next three month, I plan to create my recordkeeping log for sanitizing

Table 4.5
Demographics of Training Participants

		Pretest		Posttest	
Query	**Response**	**Count (N)**	**Percent (%)**	**Count (N)**	**Percent (%)**
Prior Food Safety Training	Yes	16	94.1	13	92.9
	No	1	5.9	1	7.1
Farm Role	Farm Owner	6	35.3	5	35.7
	Farm Manager	1	5.9	0	0.0
	Farm Operator	1	5.9	1	7.1
	Educator	6	35.3	5	35.7
	Other:	3	17.6	3	21.4
Gender	Male	4	23.5	6	42.9
	Female	12	70.6	8	57.1
	Prefer Not to say	1	5.9	0	0.0
Age	18-24 years old	1	5.9	1	7.1
	25-34 years old	4	23.5	2	14.3
	35-44 years old	1	5.9	2	14.3
	45-54 years old	4	23.5	2	14.3
	55-64 years old	5	29.4	4	28.6
	65+ years old	2	11.8	3	21.4

Table 4.6
Construct Validity

Construct	Item	Spearman's Rho	
		Pre	**Post**
Action Planning	I have clear plan how I will document my cleaning practices	0.929	0.717
	I have a clear plan how I will document my sanitizing practices		
	I have a clear plan how I will record my cleaning practices		
	I have a clear plan how I will record my sanitizing practices		
Environmental Context and Resources	I do not have time to document and record my cleaning practices	0.916	0.973
	I do not have financial resources to document and record my cleaning practices		
	I do not have the technical knowledge to document and record my cleaning practices		
	I do not have staff to document and record my cleaning practices		
	I do not have time to document and record my sanitizing practices		
	I do not have financial resources to document and record my sanitizing practices		
	I do not have the technical knowledge to document and record my sanitizing practices		
	I do not have staff to document and record my cleaning practices		
Perceived Behavioral Control	For me documenting ad recording my cleaning practices is easy	0.926	0.880
	For me documenting ad recording my cleaning practices is possible		
	For me documenting ad recording my cleaning practices is simple		
	For me documenting ad recording my sanitizing practices is easy		
	For me documenting ad recording my sanitizing practices is possible		
	For me documenting ad recording my sanitizing practices is simple		
Intentions	Within the next three month, I plan to create my cleaning SOP[a]	0.955	0.717
	Within the next three month, I plan to create my sanitizing SOP[a]		
	Within the next three month, I plan to create my recordkeeping log for cleaning		
	Within the next three month, I plan to create my recordkeeping log for sanitizing		

[a]= standard operating procedure

Table 4.7
Test of Normality

Construct	Item	Shapiro - Wilk	Significance (a=0.05)
Action Planning (2)	I have clear plan how I will document my cleaning practices	0.684	0.006
	I have a clear plan how I will document my sanitizing practices	0.881	0.314
	I have a clear plan how I will record my cleaning practices	0.881	0.314
	I have a clear plan how I will record my sanitizing practices	0.908	0.453
Environmental Context and Resources	I do not have time to document and record my cleaning practices	0.684	0.006
	I do not have financial resources to document and record my cleaning practices	0.902	0.421
	I do not have the technical knowledge to document and record my cleaning practices	0.881	0.314
	I do not have staff to document and record my cleaning practices	0.961	0.814
	I do not have time to document and record my sanitizing practices	0.833	0.146
	I do not have financial resources to document and record my sanitizing practices	0.914	0.490
	I do not have the technical knowledge to document and record my sanitizing practices	0.914	0.492
	I do not have staff to document and record my cleaning practices	0.881	0.314
Perceived Behavioral Control	For me documenting and recording my cleaning practices is easy	0.852	0.201
	For me documenting ad recording my cleaning practices is possible	0.771	0.046
	For me documenting ad recording my cleaning practices is simple	0.881	0.314
	For me documenting ad recording my sanitizing practices is easy	0.684	0.006
	For me documenting ad recording my sanitizing practices is possible	0.881	0.314
	For me documenting ad recording my sanitizing practices is simple	0.735	0.021
Attitude	For me documenting ad recording my cleaning practices is worthwhile	0.881	0.314
	For me documenting ad recording my sanitizing practices is worthwhile	0.881	0.314
Intentions	Within the next three month, I plan to create my cleaning SOP	0.552	0.000
	Within the next three month, I plan to create my sanitizing SOP	0.684	0.006
	Within the next three month, I plan to create my recordkeeping log for cleaning	0.768	0.044
	Within the next three month, I plan to create my recordkeeping log for sanitizing	0.684	0.006

Table 4.8
Test of Statistical Significance

Construct	Item	Test Statistic[ac]	Significance (a=0.05)
Action Planning	I have clear plan how I will document my cleaning practices	3.000	0.250
	I have a clear plan how I will document my sanitizing practices	0.881[a]	0.314
	I have a clear plan how I will record my cleaning practices	0.881[a]	0.314
	I have a clear plan how I will record my sanitizing practices	0.908[a]	0.453
Environmental Context and Resources	I do not have time to document and record my cleaning practices	0.001	0.250
	I do not have financial resources to document and record my cleaning practices	0.902[a]	0.421
	I do not have the technical knowledge to document and record my cleaning practices	0.881[a]	0.314
	I do not have staff to document and record my cleaning practices	0.961[a]	0.814
	I do not have time to document and record my sanitizing practices	0.833[a]	0.146
	I do not have financial resources to document and record my sanitizing practices	0.914[a]	0.490
	I do not have the technical knowledge to document and record my sanitizing practices	0.914[a]	0.492
	I do not have staff to document and record my cleaning practices	0.881[a]	0.314
Perceived Behavioral Control	For me documenting ad recording my cleaning practices is easy	0.852[a]	0.201
	For me documenting ad recording my cleaning practices is possible	3.000[c]	0.625
	For me documenting ad recording my cleaning practices is simple	2.138[a]	0.099
	For me documenting ad recording my sanitizing practices is easy	0.535[a]	0.621
	For me documenting ad recording my sanitizing practices is possible	1.000[a]	0.374
	For me documenting ad recording my sanitizing practices is simple	2.000[c]	0.625
Attitude	For me documenting ad recording my cleaning practices is worthwhile	0.881[a]	0.314
	For me documenting ad recording my sanitizing practices is worthwhile	0.881[a]	0.314
Intentions	Within the next three month, I plan to create my cleaning standard operating procedures	1.000[c]	1.000
	Within the next three month, I plan to create my sanitizing standard operating procedures	2.000[c]	0.500
	Within the next three month, I plan to create my recordkeeping log for cleaning	1.000[c]	1.000
	Within the next three month, I plan to create my recordkeeping log for sanitizing	2.000[c]	0.500

a= paired t-test; c= sign test

Figure Legends

4.1 Acreage Dedicated to Strawberry for Participants Pre- and Post-Training

4.2 Grower Perceptions Towards Action Planning Pre- and Post-Training

4.3 Grower Perceptions Towards Environmental Context and Resources Pre- and Post-Training

4.4 Grower Perceptions Towards Perceived Behavioral Control Pre- and Post-Training

4.5 Grower Perceptions Towards Attitude Pre- and Post-Training

4.6 Grower Perceptions Towards Intention Pre- and Post-Training

FIGURES

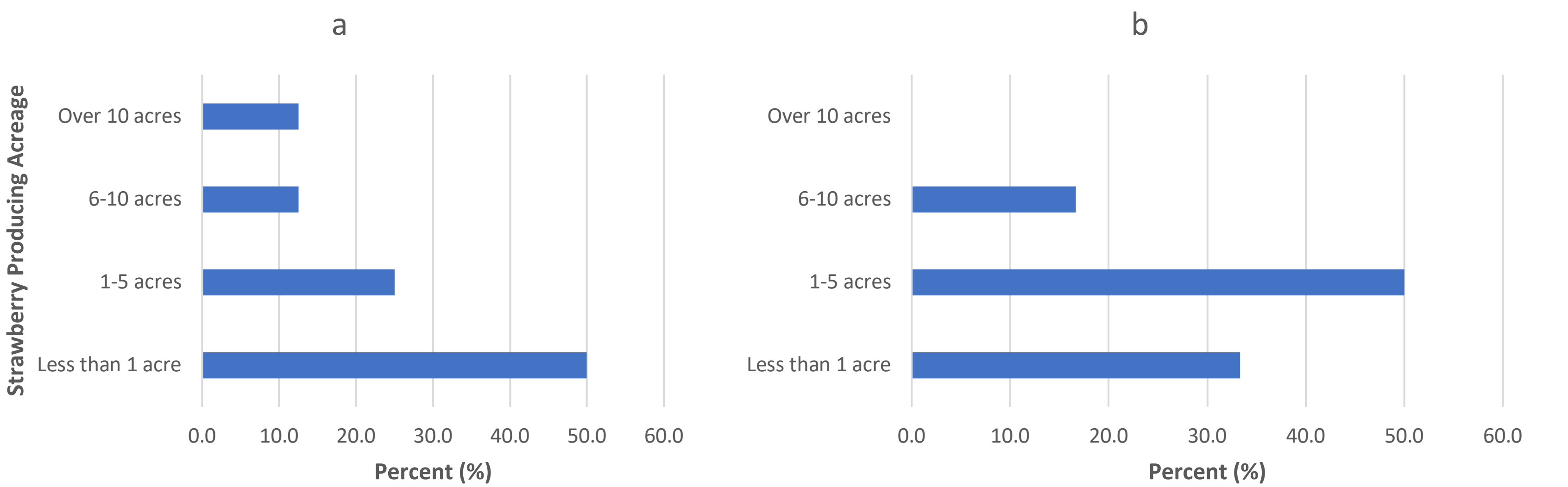

Figure 4.1 Acreage dedicated to strawberry production for a) pre-training and b) post-training

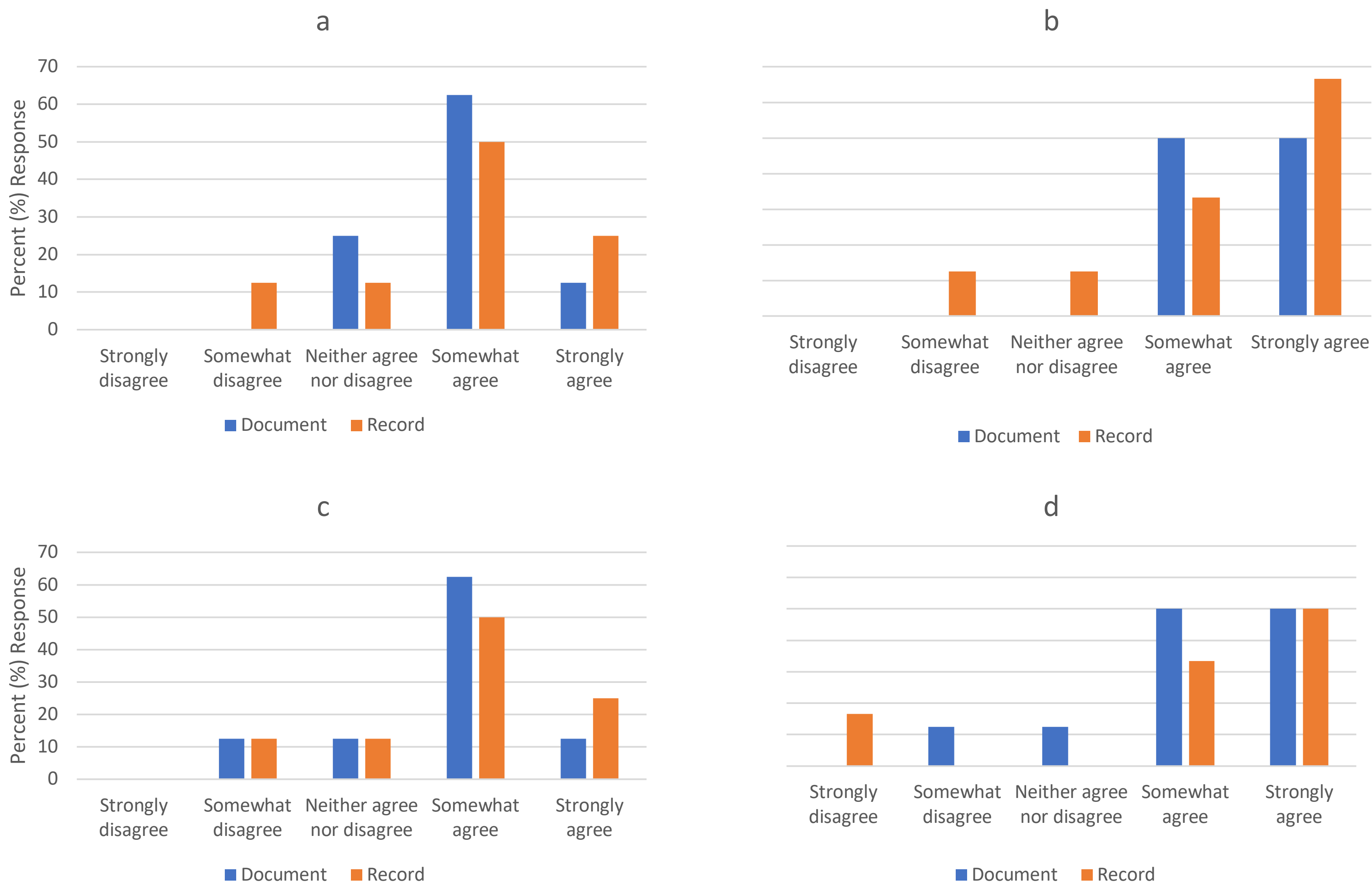

Figure 4.2 Grower Perceptions Towards Action Planning for cleaning via pre-test and post-test (a,c) and sanitizing via pre-test and post-test (b,d)

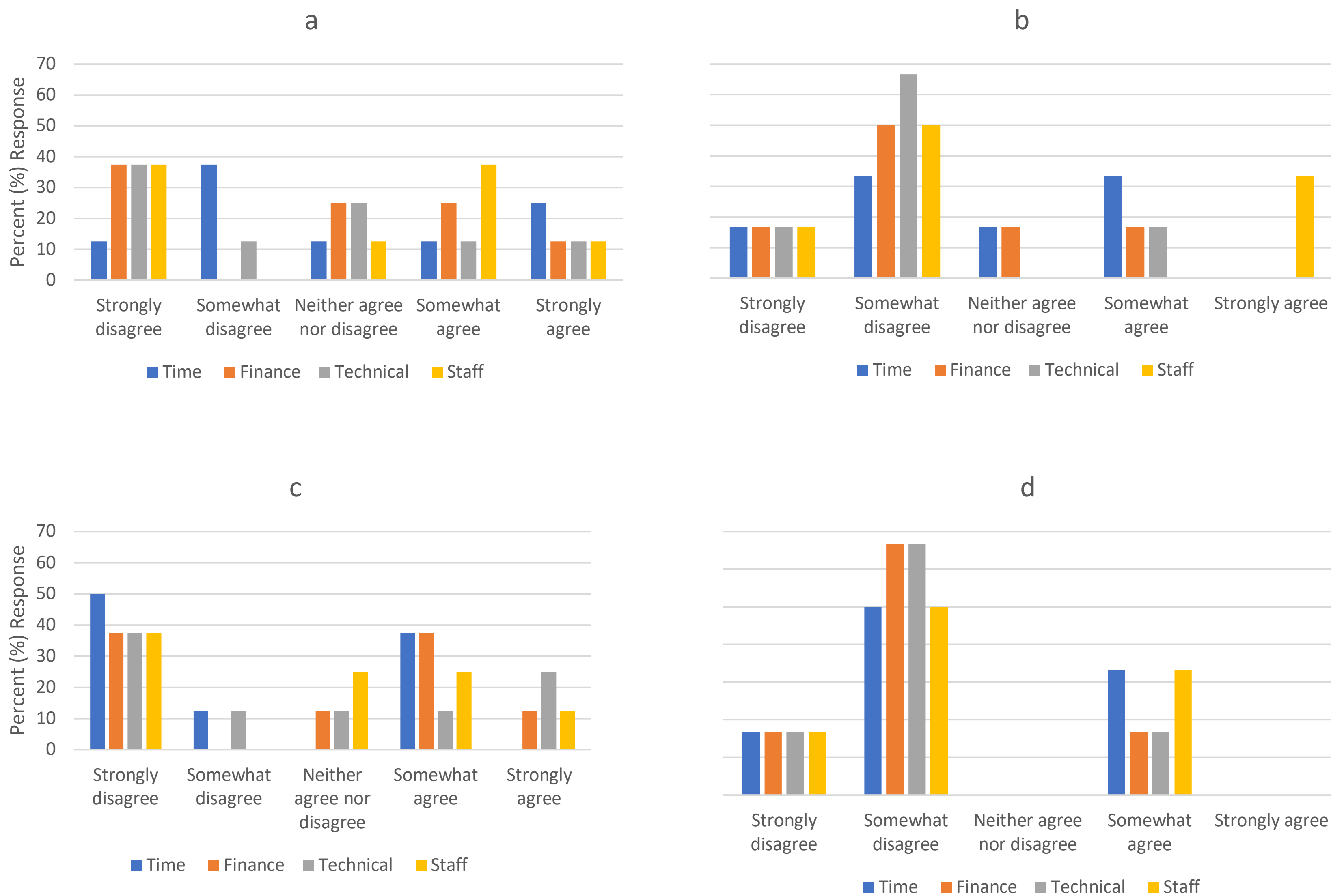

Figure 4.3 Grower Perceptions Towards Environmental Context and Resources for cleaning via pre-test and post-test (a,c) and sanitizing via pre-test and post-test (b,d)

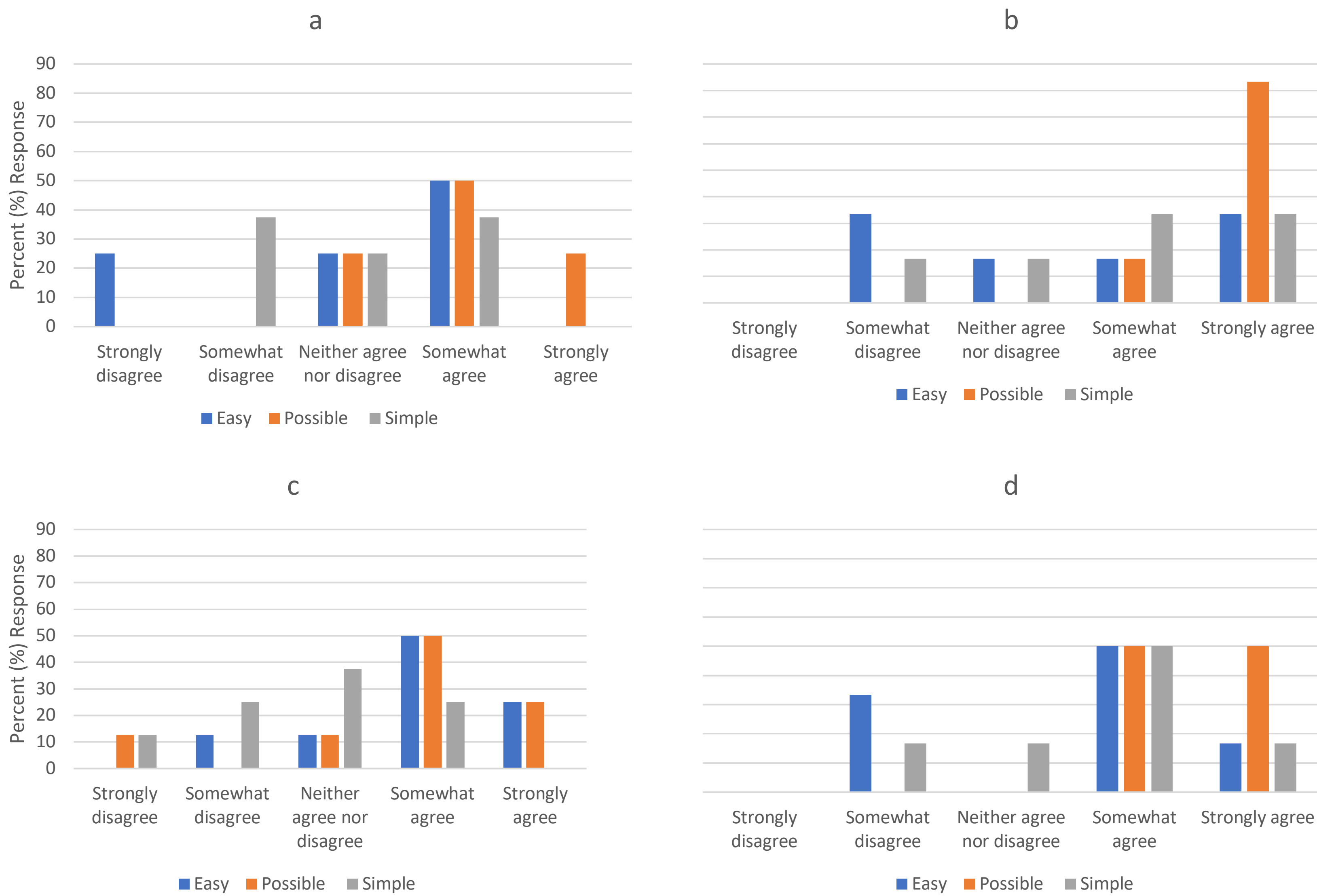

Figure 4.4 Grower Perceptions Towards Perceived Behavioral Control for cleaning via pre-test and post-test (a,c) and sanitizing via pre-test and post-test (b,d)

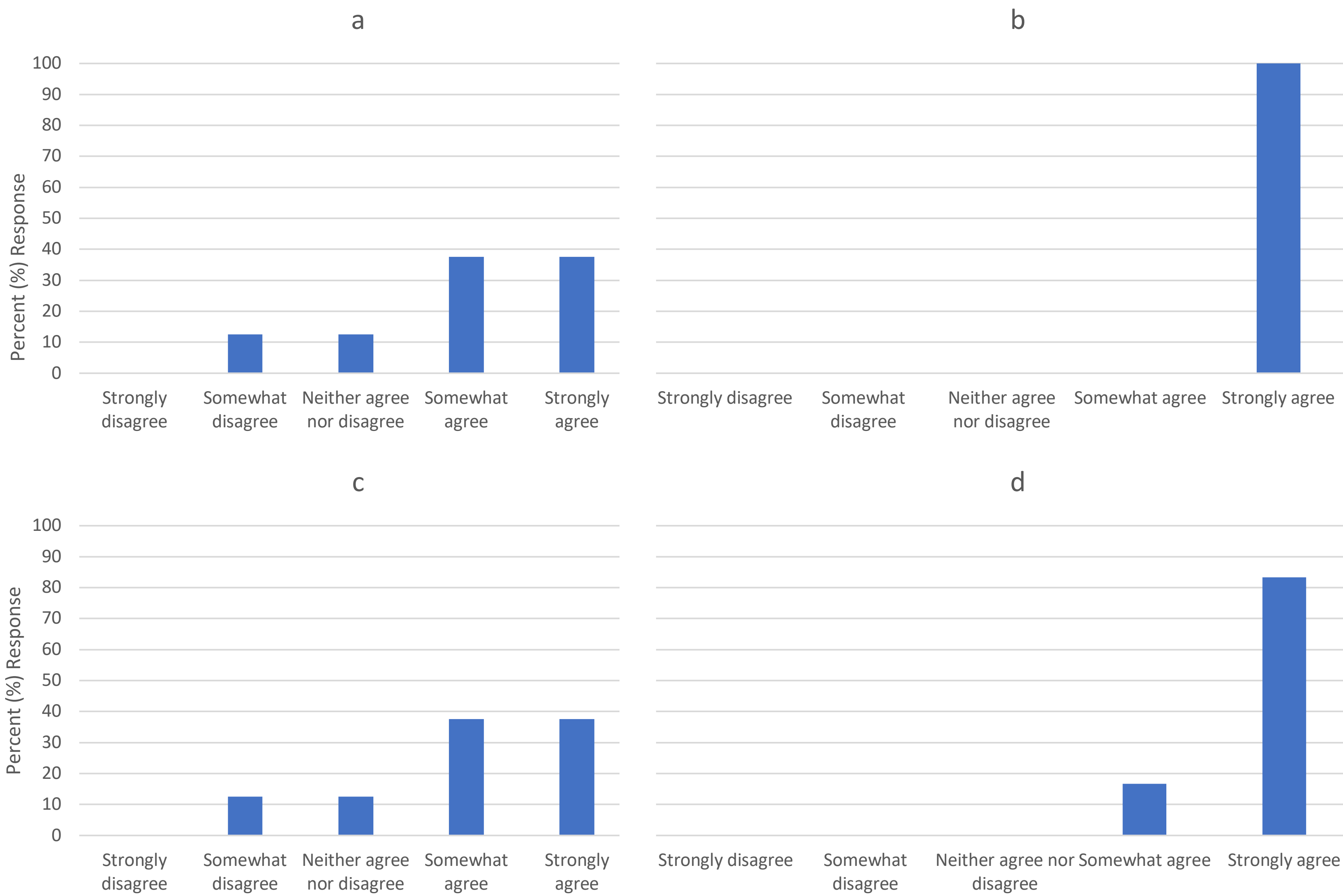

Figure 4.5 Grower Perceptions Towards Attitude for cleaning via pre-test and post-test (a,c) and sanitizing via pre-test and post-test (b,d)

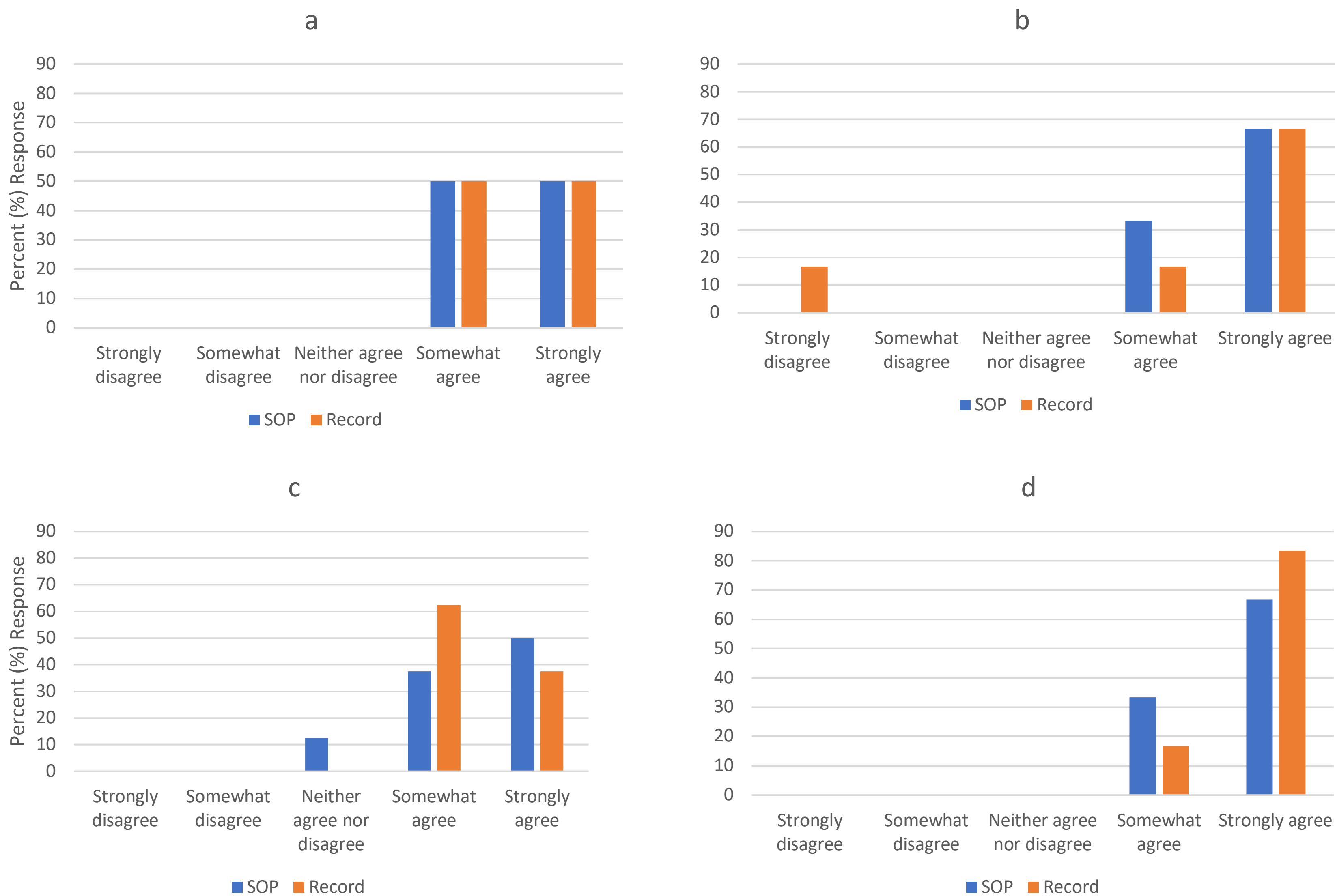

Figure 4.6 Grower Perceptions Towards Intentions for cleaning via pre-test and post-test (a,c) and sanitizing via pre-test and post-test (b,d)

Chapter 5

1. Conclusion

In this dissertation, we have investigated the factors which influence grower decisions towards implementing on-farm RMP. To gain an in-depth understanding of this subject, we chose to explore the implementation of RMP among strawberry growers in the SEUS. Upon initial characterization of the SEUS strawberry industry, we discovered that a vast majority of growers reported implementing RMP; however, less than half reported documenting or recording those practices. In the process of describing the practices of the SEUS strawberry industry, we also determined that there were significant differences in the trends of implementation based on acreage, revenue, and prior experience with food safety training.

To further our understanding of the SEUS strawberry industry, we also conducted follow-up studies in the form of telephone interviews and on-farm environmental assessments. The results from these data collection confirmed what was found from our initial characterization and furthered our understanding of those results. For example, there were distinct differences in the labor needs for growers based on acreage as well as a different level of understanding towards PSR requirements for those growers with multiple years of experience in the agricultural industry. We also gained clarification as to the barriers towards documentation and recordkeeping reported amongst strawberry growers. These barriers are most often reported as time, labor, and finances however in speaking with strawberry growers it can be understood that each of these barriers is a function of the other. For example, growers perceived they had a lack of time to commit to documentation and recordkeeping because they did not have any additional labor to perform the task. For those growers who did have additional labor this was relegated to harvesting and packing.

As many of the barriers described relate to the adaptive capacity of a farm, they cannot be overcome by training alone. Because of this we chose to focus our education on changing growers' perceptions as to the usefulness of RMP as well as their ability to implement them on their own farm. Our hypothesis was that growers Intention could be influenced by Action Planning, Environmental Context and Resources, Perceived Behavioral Control, and Attitude. More specifically, we supposed that providing context specific education would result in a significant increase in grower perception of those 5 constructs that would engender a change in Intentions. Despite seeing a positive shift in many of the constructs described, we did not detect a statistically significant difference between pre-test and post-test scores. Because this training was undertaken as a pilot study, we believe that further testing of this hypotheses with higher samples size and more rigorously tested constructs is needed.