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Effect of Market Channel, Farm Scale, and Years in Production on Mid-Atlantic Vegetable Producers' Knowledge and Implementation of Good Agricultural Practices

Sasha C. Marine
University of Maryland

David A. Martin
University of Maryland - Baltimore County

Aaron Adalja
Cornell University School of Hotel Administration, aaa362@cornell.edu

Sudeep Mathew
University of Maryland

Kathryne L. Everts
University of Delaware

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Abstract

Foodborne illnesses associated with fresh produce have dramatically increased within the last decade. Good Agricultural Practices (GAP) were developed to address potential sources of pre-harvest microbial contamination, but certification remains low. The majority of mid-Atlantic vegetable farms are fresh market, but limited information is available about what on-farm production practices are being utilized to mitigate food safety risks. Our goal was to assess Maryland and Delaware vegetable producers' understanding and implementation of GAP. An electronic survey on pre-harvest production practices was administered at commercial grower meetings in 2010 and 2013. A total of 313 surveys were analyzed, and Probit regression was used to estimate the average marginal effects of farm scale, years in production and market channel on the probability of using different on-farm food safety practices. Generally, food safety practices did not differ across farm scale or years in production. However, market channel did influence a grower's decision to implement some food safety practices. Growers who marketed their produce primarily through wholesale channels were more likely to: have written policies for how they grew and handled their produce, test their irrigation water at least once a year for microbial contamination, or be GAP-certified. Economic constraints were not reported as the primary obstacle for GAP implementation in either survey. While more research is needed to better understand how market channel influences decision-making activities including on-farm food safety practices, this study highlights the complexity of the issue and the need for GAP educational programs to expand beyond a one-size-fits-all approach.

Keywords

good agricultural practices, mid-Atlantic vegetable producers

Disciplines

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Comments

EFFECT OF MARKET CHANNEL, FARM SCALE, AND YEARS IN PRODUCTION ON MID-ATLANTIC VEGETABLE PRODUCERS' KNOWLEDGE AND IMPLEMENTATION OF GOOD AGRICULTURAL PRACTICES

Sasha C. Marine*
Department of Plant Science and Landscape Architecture
University of Maryland
Lower Eastern Shore Research and Education Center
Salisbury, MD
**Corresponding author.*
E-mail address: scmarine@umd.edu

David A. Martin
University of Maryland Extension
Baltimore County
Cockeysville, MD,

Aaron Adalja
Department of Agricultural and Resource Economics
University of Maryland
College Park, MD

Sudeep Mathew
University of Maryland Extension
Dorchester County
Cambridge, MD

Kathryne L. Everts
Carvel Research and Education Center
University of Delaware
Georgetown, DE

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Abstract

Foodborne illnesses associated with fresh produce have dramatically increased within the last decade. Good Agricultural Practices (GAP) were developed to address potential sources of pre-harvest microbial contamination, but certification remains low. The majority of mid-Atlantic vegetable farms are fresh market, but limited information is available about what on-farm production practices are being utilized to mitigate food safety risks. Our goal was to assess Maryland and Delaware vegetable producers' understanding and implementation of GAP. An electronic survey on pre-harvest production practices was administered at commercial grower meetings in 2010 and 2013. A total of 313 surveys were analyzed, and Probit regression was used to estimate the average marginal effects of farm scale, years in production and market channel on the probability of using different on-farm food safety practices. Generally, food safety practices did not differ across farm scale or years in production. However, market channel did influence a grower's decision to implement some food safety practices. Growers who marketed their produce primarily through wholesale channels were more likely to: have written policies for how they grew and handled their produce, test their irrigation water at least once a year for microbial contamination, or be GAP-certified. Economic constraints were not reported as the primary obstacle for GAP implementation in either survey. While more research is needed to better understand how market channel influences decision-making activities including on-farm food safety practices, this study highlights the complexity of the issue and the need for GAP educational programs to expand beyond a one- size-fits-all approach.

Keywords: Good Agricultural Practices Mid-Atlantic Vegetable producers

Effect of market channel, farm scale, and years in production on mid-Atlantic vegetable producers' knowledge and implementation of Good Agricultural Practices

1. Introduction

In 1998, the Food and Drug Administration (FDA) published *The Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables*, which outlined production practices and intervention strategies that could be implemented on farms for use in the production of unprocessed or minimally processed fresh fruits and vegetables (U.S. FDA, 1998). The 1998 guide also sought to increase awareness of potential food safety hazards among growers, packers, and shippers of fresh produce. Growers were advised to focus on risk reduction strategies, not risk elimination, as elimination of all potential food safety hazards associated with fresh produce that would be eaten raw is not technologically or economically feasible (Gravani, 2009).

However, in the years following release of the *Guide*, outbreaks associated with enteric pathogens (such as *Escherichia coli* O157:H7 and *Salmonella enterica*) and on-farm contamination events have been steadily increasing (DeWaal, Tian, & Bhuiya, 2008). Between 1998 and 2008, the consumption of fresh fruits and vegetables was implicated in 46% of foodborne illnesses and resulted in an estimated 21,000 hospitalizations and 334 deaths (Painter et al., 2013). Although research has identified several microbial risk factors (reviewed in Mandrell, 2009; Olaimat & Holley, 2012), eliminating enteric pathogens from fresh produce remains difficult due to microbial adhesion (reviewed in Berger et al., 2010) and their ability to persist as epiphytes or endophytes within the plant microbiota (reviewed in Critzer & Doyle, 2010). In 2002, the United States Department of Agriculture (USDA) developed a voluntary audit/ certification program known as "Good Agricultural Practices” (GAP) to verify conformance to the 1998 guide. This program seeks to minimize fresh produce contamination by recommending science- based "best practices” in areas such as irrigation water quality, manure management, wildlife management, worker health and hygiene, and post-harvest handling (USDA, 2014b). University of Maryland Extension programming has traditionally relied on the knowledge-deficit approach for GAP education, which emphasizes a one-way model of communication and attributes noncompliance to lack of information (Parker, Wilson, LeJeune, Rivers, & Doohan, 2012). Full-day trainings include presentations on the four W's (water, waste, wildlife and workers), sanitation, auditing programs, and writing a food safety plan (D. Pahl, personal communication). Following training, the GAP audit is conducted by a public or private third-party certifier, and a grower must score 80% or better on each of the seven sections to become certified. Growers are also responsible for bearing the costs of the training and audit.

In 2011, the Food Safety Modernization Act (FSMA) was signed into law. FSMA directs the FDA to establish a uniform set of produce safety standards and aims to ensure a safe U.S. food supply through prevention of microbial contamination (U.S. FDA, 2013). The proposed produce safety standards have received substantial input from scientists, industry stakeholders and consumers, and tens of thousands of comments have been submitted during the public comment periods. As a consequence of this widespread media attention, most growers and packers are now aware of their obligation to reduce the microbial hazards and risks associated with the production of fresh produce. Although FSMA represents the minimum requirements, compliance is mandated by law, and implementation is expected to begin in 2016. In contrast, GAP certification remains voluntary, so rates remain low and implementation remains inconsistent (Gravani, 2009). In a recent survey of diversified fruit and vegetable growers in Oregon, more than half indicated GAP certification resulted in competitive market benefits, but only 25% (4 of 16) of surveyed growers had active GAP certification (Prenguber & Gilroy, 2013). A study in Vermont also found 22% of surveyed produce farms had active GAP certification, but that GAP compliant farms were generally larger in terms of acreage than non-certified farms (Becot, Nickerson, Conner, & Kolodinsky, 2012). In a Minnesota survey, more than 65% of vegetable growers — the majority (230 of 237) of whom were small-scale — reported compliance with GAPs (Hultberg, Schermann, & Tong, 2012). However, the authors did not provide data on the number of respondents with active GAP certification. And in the Midwest, the majority of surveyed vegetable growers agreed GAP could reduce the risk of fresh produce contamination, but only 40% implemented GAP at a level of consistency to do so (Ivey, LeJeune, & Miller, 2012).

Since GAP certification is not codified regulation, growers reported buyer expectations and maintaining sales and customer accounts as the primary incentives for GAP certification (Becot et al., 2012; Bihn & Gravani, 2006; Prenguber & Gilroy, 2013). Wholesale buyers, such as supermarket chains, have used their purchasing power to exert pressure on growers to adopt more stringent food safety standards (Fulponi, 2006) even designating which third-party certifier should be used in some cases (Hatanaka, Bain, & Busch, 2005). Although small-scale growers (defined as those less than 4 ha in size (Newton, 2014) or with gross cash farm income less than $349,999 (Hoppe & MacDonald, 2013)) rarely reported barriers to GAP implementation when asked directly about economic feasibility (Ivey et al., 2012), they were less supportive of the program than large-scale growers and indicated they would side step GAP certification by avoiding wholesale market channels or retailers that required certification (Prenguber & Gilroy, 2013). Small-scale growers also tend to rely on direct-to- consumer marketing channels (Low & Vogel, 2011; Martinez et al., 2010), such as selling produce through Community Supported Agriculture programs (CSAs), which allow them to establish a direct relationship with their customers. Within the local food system, direct-to-consumer produce farms generate almost half of all local food sales (Low et al., 2015). Farmers markets in the mid-Atlantic are also some of the most profitable in the U.S., as 15.4% of vendors have annual sales of $25,000 or more (USDA, 2009). However, these direct-to-consumer channels may also differ substantially in terms of fresh produce food safety standards. For example, less than 12% of farmers market managers surveyed in Georgia, Virginia and South Carolina asked participating vendors about on-farm food safety practices, such as manure use or worker hygiene (Harrison et al., 2013). Taken together, the data suggest a grower's primary market channel may be an important factor in on-farm food safety decision-making.

Previous research also indicates that grower response to food safety risks is influenced by the extent they perceive the risks to be within their control (Parker, Wilson, LeJeune, & Doohan, 2012). The role of irrigation water quality in produce food safety has been well documented in recent reviews (Beuchat et al., 2006; Suslow et al., 2003), but agricultural water testing remains low. Growers often indicate that preventing aerial wildlife from accessing (and potentially contaminating) irrigation water sources is not feasible (Ivey et al., 2012; Parker, Wilson, LeJeune, Rivers, et al., 2012), but growers may lack access to municipal or groundwater irrigation sources. In a 1998 survey of fruit and vegetable growers in New York, 72% (118 of 163) reported using surface water (including streams, ponds, lakes, or open canals) as an irrigation source, but only 15% reported testing the water in any way (Rangarajan, Pritts, Reiners, & Pedersen, 2002). In a more recent survey, more than half (48 of 84) of New York fruit and vegetable growers reported using surface water to irrigate their crops, but less than 19% of those who applied surface water overhead reported testing the water for any indicators of fecal contamination (such as generic *E. coli*) (Bihn, Smart, Hoepting, & Worobo, 2013). For growers who do have access to groundwater irrigation sources, the percentage that routinely test for fecal contamination is also low. In a survey of fruit and vegetable growers in six New England states, 73% (217 of 297) used wells as a primary source for irrigation water but only 18% reported testing the water annually (Cohen, Hollingsworth, Brennan Olson, Laus, & Coli, 2005). The discrepancy between knowledge and behavior may be further explained by the low percentage of producers (19%) who believe contamination is likely to occur on the farm (Ivey et al., 2012).

In Maryland, there are 789 vegetable farms, which produce a wide range of crops including: cantaloupe, cucumbers, potatoes, pumpkins, snap beans, sweet corn, tomatoes and watermelons (USDA, 2014a). The majority of vegetable farms (708 of 789) are fresh market, and more than half of those (391 of 708) are less than 2 ha in size. Surprisingly, only 8 vegetable farms currently have completed a USDA GAP or Produce GAPs Harmonized audit (USDA AMS, 2013). The Maryland Department of Agriculture (MDA) has also offered a state GAP certification program for direct marketers since 2011 (also referred to as "Maryland GAP”) (D. Baldwin, personal communication), and 11 vegetable farms currently have MD GAP certification (MDA, 2013). In Delaware, the situation is similar, as the majority of vegetable farms (163 of 222) are fresh market, more than a third are small-scale (72 of 163) (USDA, 2014a), and very few (4 farms) currently have USDA or Produce GAP certification (USDA AMS, 2013). Since the cost of implementing food safety programs is often farm scale-dependent, the smaller operations may lack the capital resources required and elect to forgo GAP certification. However, for mid-Atlantic vegetable farms not involved in GAP, there is limited information available about what on-farm production practices, if any, are being utilized to mitigate food safety risks for their fresh market crop(s).

Our goal was to assess Maryland and Delaware vegetable producers' understanding and implementation of GAP. To do so, we designed a survey to assess pre-harvest production practices (including manure and compost application and irrigation water source management) as well as food safety training. The objectives of our survey were to: 1) establish growers' baseline GAP knowledge and utilization, and 2) assess changes in growers' implementation of GAP following targeted workshops and distribution of GAP-related training materials. We hypothesized that production practices and food safety perspectives would differ across market channel, farm scale and years in production. Survey results were used to guide GAP training and continue to be incorporated into University of Maryland Extension educational programs for growers.

2. Materials and methods

2.1. Questionnaire development

In 2010, we developed a survey on farm demographics and fresh produce food safety. Growers were asked about fruit and vegetable acreage, years in operation, and produce marketing channels. Growers were also asked about GAP certification, pre-harvest production practices including: GAP training, irrigation and pesticide spray water management, manure use and livestock management, and wildlife management; and harvest production practices including: harvest container and produce sanitation (Supplemental Table 1). The 2010 survey also included questions on nutrition grant programs and U-pick operations, which are not discussed in this manuscript. In 2013, the survey was revised: questions that did not pertain to food safety were removed, and questions related FSMA were added. The revised survey addressed the same topics as before and had a similar survey completion time. Despite these changes, the questions related to farm demographics and on-farm food safety practices that comprise the data for the analysis remained consistent between survey years. Based on the intended audience, units of measurement within the survey were presented in the U.S. customary, non-metric system. All survey questions were non-weighted and discrete (yes or no, "select one response" or "select up to 3 responses"). Both surveys were pretested by Extension specialists and researchers, and reviewed by the University of Maryland Institutional Review Board and deemed exempt (project #413818-1).

2.2. Questionnaire delivery

The survey was administered at six commercial fruit and vegetable grower meetings in Maryland between January and April in 2010, and at seven commercial fruit and vegetable grower meetings in Maryland and Delaware between January and February in 2013. Responses were recorded anonymously using Response- Card RF electronic clickers (Turning Technologies, Youngstown, OH). Participation in the survey was completely voluntary; no compensation was provided. Meeting registration lists were used to determine the percentage of attendees present at both the 2010 and 2013 meetings, among the total number of attendees present.

2.3. Data analysis

Probit regression was used to estimate the average marginal effects of farm scale, years in production and market channel on the probability of using different on-farm food safety practices. Some levels of each aforementioned independent variable were aggregated to reduce the frequency of errors due to collinearity (which occurs when one or more independent variables in the model is a perfect linear combination of the others), but levels were chosen that maintained distinctions meaningful to the data. Probit regression is commonly applied to survey data, as the model analyzes qualitative binomial response variables based on the cumulative normal probability distribution (Finney, 1971). Descriptive statistics were also calculated for the demographic data. Chi-square tests were used to compare the frequency of a particular response across the two surveys. All cross-tabs, probit regressions and other statistical tests were conducted using Stata v. 13.1 for Windows 7 (StataCorp, College Station, TX). Data were considered to be statistically significant at a 95% confidence level (a = 0.05) unless otherwise noted.

3. Results

3.1. Survey response and grower demographics

A total of 415 surveys were completed, and 313 surveys were analyzed (130 surveys from 2010, to 183 surveys from 2013). A total of 102 surveys were excluded from analysis because respondents either lacked vegetable acreage (65 surveys) or had vegetable acreage but failed to answer at least 60% of questions discussed in this manuscript (37 surveys). Overall, the greatest percentage of respondents produced vegetables on less than 2 ha of land (52.9%) and had been in production 20 years or more (53.6%) (Table 1). When asked about market strategy, 7.2% of all growers sold their produce primarily through wholesale channels (such as supermarkets), while 40.9% of all growers sold their produce primarily through direct channels (such as farmer's markets). Interestingly, more than a third (38.8%) of all growers reported using a combination of wholesale and direct market channels. Although only 13.5% of attendees were present at both the 2010 and 2013 Maryland meetings, no statistically significant differences exist in grower demographics between the 2010 and 2013 samples (vegetable acreage, p = 0.164; years in production, p = 0.416; market channel: wholesale, p = 0.746; market channel: direct, p = 0.436). In the 2013 survey, growers were also asked to classify their farm system. The majority (66.7%) reported use of conventional farming practices, with only l.6% of growers being certified organic. The remaining growers reported use of "other” farming practices, including 24.0% who employed primarily organic or sustainable farming practices (such as excluding use of synthetic pesticides and intentionally improving soil quality) but were not certified.

3.2. GAP preparation and implementation

Specific survey questions were included to determine growers' compliance with GAP. The majority of all growers (72.2%) surveyed reported they did not have written policies for how they grew and handled their produce. However, there was a significant increase (χ^2 (1) = 13.28, $p < 0.001$) in the percentage of growers who reported having written policies, from 16.4% in 2010 to 35.6% in 2013. Interestingly, growers who marketed their produce primarily through wholesale channels were 26.7%

more likely to have written policies for how they grew and handled their produce ($p < 0.001$), as compared to growers who marketed their produce primarily through other channels in the 2013 survey (Table 2).[2]

Growers were also asked if they had obtained third-party GAP certification. Although the majority of all respondents (90.6%) were not GAP-certified, there was a significant increase (χ^2 (1) = 12.04, $p < 0.001$) in the percentage of growers who reported having successfully completed a third-party audit, from 2.4% in 2010 to 14.3% in 2013. Growers who produced vegetables on 2-20 ha or who marketed their produce primarily through direct channels were less likely to be GAP-certified ($p = 0.014$ for both) than those with larger acreage or growers who marketed wholesale or through other channels in the 2013 survey (Table 3). When asked if buyers (such as retailers, processors, customers, etc.) had asked for GAP certification, significantly more growers answered in the affirmative in 2013 as compared to 2010 (χ^2 (1) = 15.60, $p < 0.001$). Growers who marketed their produce primarily through wholesale channels were 23.4% more likely to have been asked by their buyers to obtain GAP certification ($p = 0.003$), as compared to growers who marketed their produce through other channels in the 2013 survey (Table 4). Larger vegetable operations (i.e. more than 20 ha) were also more likely to have pressure from buyers, but the effect was only marginally significant ($p = 0.076$).

Growers were also asked about the primary obstacle hindering them from developing written policies for how they grew and handled their produce. About a quarter of all growers did not believe GAP applied to their size farm operation (25.6%) or did not believe they had enough knowledge about GAP to develop a food safety plan (24.3%) (Table 5). Concerns about economic feasibility appeared to be relatively minor, as only 8.6% of all growers reported cost as their primarily obstacle. In the 2010 survey, the greatest percentage of growers reported lack of knowledge as their primary obstacle (43.1%); however, in the 2013 survey, significantly less growers reported this as their primary obstacle (10.9%; χ^2

[2] For ease of exposition, average marginal effects are presented within the text and tables for the probit models for each of the food safety practices. The average marginal effect of a regressor is the amount by which the conditional probability of the outcome variable changes due to a one-unit increase in the regressor. The underlying probit regression coefficients are available upon request.

(1) = 42.73, $p < 0.001$). Surprisingly, in the 2013 survey, not being required to have written policies was the major reason (27.3%) growers selected for why they had not developed a food safety plan.

3.3. Pre-harvest production practices: irrigation and pesticide spray water management

When asked about their source of irrigation water, 48.5% of 2010 growers and 23.4% of 2013 growers indicated they used surface water (including ponds, rivers and streams) at least some of the time. Groundwater (including shallow and deep wells and municipal) was used for irrigation at least some of the time by the majority of all growers. More than 76% of all growers did not test their irrigation water at least once a year for indicators of fecal contamination. However, there was a significant increase (χ^2 (1) = 16.48, $p < 0.001$) in the percentage of growers who reported testing their irrigation water at least once per year, from 11.5% in 2010 to 31.9% in 2013. Growers who marketed their produce primarily through wholesale channels were 23.5% more likely to test their irrigation water at least once a year ($p = 0.001$) relative to growers marketing through other channels in the 2013 survey (Table 6). Growers were also asked about their source of pesticide spray water. More than 91% of all growers used groundwater for pesticide applications — the majority of which originated from deep wells - with only 6.4% of growers indicating they used surface water.

When asked how their vegetable acreage is irrigated, the majority (70.6%) of all growers reported using trickle (drip) irrigation at least some of the time. Interestingly, there was a significant decrease (χ^2 (1) = 4.73, $p = 0.030$) in the percentage of growers who reported using trickle (drip) irrigation for more than half of their vegetable acreage, from 52.3% in 2010 to 39.9% in 2013. Growers were also asked what other types of irrigation they use on their fresh produce. Overhead or sprinkler irrigation was used by 23.5% of growers in the 2013 survey, followed by furrow and flood irrigation (1.1% each).

3.4. Pre-harvest production practices: manure use, livestock on farm and access to crop fields

The majority of all growers (60.4%) reported applying manure, compost or bio-solids to their vegetable acreage. However, not all growers had on-farm sources of manure or compost. In the 2013 survey, more than half of growers (56.8%) indicated they did not have livestock or poultry on their farm. Of those with domestic animals, poultry (free range and confined; 21.3%) and cattle (beef and dairy; 18.0%) were most frequently reported. Some growers did report raising small ruminants (sheep and goats; 8.2%) and swine (4.4%) on their farm. When asked if their livestock or poultry had access to their crop fields during the year, the majority of growers (70.3%) answered “no”. More than 14% of growers allowed domestic animals to enter crop fields after harvest, and two growers allowed domestic animals to enter crop fields during the growing season.

3.5. Pre-harvest production practices: wildlife access to crop fields

The majority of all growers (80.9%) reported that wildlife accessed their production fields daily during the growing season. However, a significantly lower percentage of growers answered in the affirmative in the 2013 survey (76.6%), as compared to the 2010 survey (86.7%) (χ^2 (1) = 4.85, p = 0.028). Growers who marketed their produce primarily through wholesale channels were more likely report daily wildlife access in their fields (p = 0.013) as compared to growers who marketed their produce primarily through other channels in the 2010 survey (Table 7), while growers who produced vegetables on more than 2 ha were more likely to report daily wildlife access in their fields in the 2013 survey (Table 7). Growers were also asked what preventative measures they use to control wildlife access. In the 2013 survey, the greatest percentage of growers reported using crop damage permits or hunting (50.8%), followed by fencing (36.1%), chemical repellents (16.4%), domestic guard dogs (15.9%) and netting (12.6%). Interestingly, 18.0% of growers reported not employing any preventative measures to control wildlife access to their production fields.

3.6. Pre-harvest production practices: GAP training for self and workers

In the 2010 survey, more than half of growers (59.3%) indicated they had not received any food safety or GAP training in the last 3 years. However, growers who had been in operation more than 20 years were more likely to report having attended a training session within the last three years ($p < 0.001$), as compared to those who had been in operation less than five years (Table 8A). Of those who reported attending a food safety or GAP training in the 2010 survey, the largest percentage had done so within the last year (21.5%). In the 2013 survey, the percentage of growers without recent food safety or GAP training was significantly less (27.6%; χ^2 (1) = 29.66, p < 0.001), and almost half of all growers reported attending a training session within the last year (45.4%). Growers were also asked if their hired workers had received any food safety or GAP training in the last three years. Half of all growers reported that their employees had not attended a recent training session. However, the percentage of hired workers without any recent food safety or GAP training was significantly less (χ^2 (1) = 4.04, p = 0.045) in the 2013 survey (43.2%) as compared to the 2010 survey (60.0%). Again, growers who had been in operation more than 20 years were more likely report that their employees attended a training session within the last 3 years (p < 0.001) in the 2013 survey (Table 8B). Although growers who produced vegetables on 2-20 ha were 21.5% less likely to report any recent food safety or GAP training for their hired workers, this effect was only marginally significant (p = 0.106).

3.7. Harvest production practices: field packing activities

Growers were also asked about field harvest production practices related to sanitization of containers and cleaning of vegetables. The majority of all growers (84.2%) surveyed reported they did sanitize their harvest containers at least once during the season. There was also a significant increase (χ^2 (1) = 10.85, p < 0.001) in the percentage of growers who reported sanitizing their harvest containers, from 75.4% in 2010 to 90.0% in 2013. No independent variable (i.e. farm scale, years in production or market channel) significantly impacted the likelihood of this on-farm production practice (Table 9). Growers were also asked what cleaning method(s) and sanitizer(s) they used on their crop prior to sale or storage. In the 2010 survey, the largest percentage of growers reported washing their produce by hand (39.2%), followed by use of spray washers (6.9%) and flumes (5.4%). In the 2013 survey - which included additional response options - the largest percentage of growers reported washing their produce with plain water (47.0%), followed by wiping with a cloth (29.5%), and cleaning with chlorinated water

(18.6%) or water containing another disinfectant (such as soap) (3.8%). About one quarter (24.9%) of all growers reported not cleaning their crop prior to sale or storage.

3.8. Modifications to production practices since 2010

In the 2013 survey, growers were asked what on-farm production practices they had modified or implemented in the last three years in response to concerns about food safety. About a quarter of growers reported improving their record keeping (24.6%), improving the food safety or GAP training their hired workers received (24.0%), or implementing preventative measures to restrict wildlife access to their production fields (26.8%). More than one-third of growers reported increasing their use of trickle (drip) irrigation (38.8%) or increasing how often they cleaned their harvest containers (39.3%). Additionally, 29.5% of growers indicated they had started testing their irrigation water source(s) for indicators of fecal contamination.

4. Discussion

This report on vegetable growers' knowledge and on-farm implementation of GAP is, to our knowledge, the most extensive survey of its kind carried out in the mid-Atlantic region to date. For the most part, production practices and food safety perspectives did not differ across farm scale or years in production. This finding is similar to previous GAP research in Pennsylvania that found no significant relationship between farm scale and a grower's likelihood to write a food safety plan or apply for third-party certification (Tobin, Thomson, LaBorde, & Radhakrishna, 2013). However, we found market channel did influence a grower's decision to implement some food safety practices. Less than 10% of all surveyed growers reported marketing their produce primarily through wholesale channels, but in our 2013 survey, this group was significantly more likely to: have written policies for how they grew and handled their produce, test their irrigation water at least once a year, or be GAP-certified. In contrast, the largest proportion of all surveyed growers reported marketing their produce primarily through direct channels, and this group was significantly less likely to be GAP-certified. Although direct-to-consumer sales in the

U.S. currently account for less than 2% of total fresh produce sales (Cook, 2011), they are a fast-growing segment of agricultural sales (Low et al., 2015) and a focus of current U.S. policy (Johnson, Aussenberg, & Cowan, 2013), due in part to consumer demand for locally produced foods (reviewed in Martinez et al., 2010). With its densely populated urban areas, the mid-Atlantic region has some of the most successful farmers markets, in terms of sales and number of customers per week (USDA, 2009). Previous studies have found consumers' willingness to pay is greater for local versus non-local fresh produce (Adams & Adams, 2011) but similar for organic versus locally grown tomatoes (Yue & Tong, 2009). There is also evidence that local food systems support regional economic growth, as Brown, Goetz, Ahearn, and Liang (2014) found a positive financial association between the level of direct sales in community-focused agriculture and growth in total farm sales in certain regions including Maryland.

Unfortunately, few publications have investigated the impact of market channel on growers' certification decisions and implementation of produce safety practices. When asked about potential solutions to marketing challenges, organic produce growers in California ranked "food safety regulations accounting for marketing methods" as one of the top recommendations (Cantor & Strochlic, 2009), yet surprisingly, research has shown that fruit and vegetable growers who reported direct marketing as the most economically important channel had significantly less certified organic acreage (Monson, Mainville, & Kuminoff, 2008; Veldstra, Alexander, & Marshall, 2014). Market channel was correlated with produce safety measures in a recent survey by Lichtenberg and Tselepidakis (unpublished data), who found the share of fresh vegetables sold to retail or foodservice establishments was positively, albeit marginally, associated with the probability of testing water, soil amendments or crop samples for indicators of fecal contamination. In our survey, very few growers who sold their produce exclusively through direct channels had been asked by their buyers (such as farm market managers or CSA members) to obtain GAP certification. In contrast, growers who sell their produce through wholesale supermarket chains are increasingly required to provide evidence of compliance with food safety standards through third-party certification (Hatanaka et al., 2005) or GAP (Tobin, Thomson, LaBorde, & Bagdonis, 2011) in order to maintain the business relationship. This de facto mandatory practice is appealing to wholesale operations, which account for an estimated 57% of total fresh produce sales (Cook, 2011), as it shifts the responsibility and liability for produce safety from wholesale operations onto third-party certifiers and suppliers (Hatanaka et al., 2005). Further data is needed to assess the impact of direct-to-consumer marketing on on-farm food safety practices, as a production decision to implement GAP and a marketing decision to certify are likely interrelated, but separate, business decisions.

In this survey, only a quarter of all growers tested their irrigation water at least once a year for generic *E. coli*, an indicator of fecal contamination. Previous surveys in other regions have reported similarly low routine testing of irrigation water, both from groundwater sources (18% in Cohen et al., 2005) and surface water sources (19% in Bihn et al., 2013). Growers may decide not to test an irrigation water source for a myriad of reasons including concerns about cost and limited control over the water source. Adjacent land use (such as grazing cattle or applying animal manure) and runoff from nearby livestock or poultry operations have been shown to impact the prevalence and concentration of bacteria in the aquatic environment (Chen & Jiang, 2014; Harmel, Karthikeyan, Gentry, & Srinivasan, 2010; Thurston-Enriquez, Gilley, & Eghball, 2005). Growers may also lack alternative water sources. In the mid-Atlantic region, vegetable growers primarily reported irrigating their crops with groundwater, but about 30% reported irrigating with surface water some of the time. Surface water has been identified as a predominant *Salmonella* reservoir in the eastern U.S. (Micallefet al., 2012; Strawn et al., 2013), and in 2005, a *Salmonella* Newport strain isolated from a pond used to irrigate tomatoes on the eastern shore of Virginia was matched to the outbreak strain (Greene et al., 2008). This is of particular concern for growers who use overhead or sprinkler irrigation systems, as non-pathogenic *E. coli* strains have been consistently recovered from field-grown leafy greens following overhead irrigation with contaminated water (Wood, Bezanson, Gordon, & Jamieson, 2010; Fonesca, Fallon, Sanchez, & Nolte, 2011). However, the absence of generic *E. coli* does not mean the water is free of foodborne pathogens, and the lack of the predictive correlation between this indicator and pathogenic *E. coli* (and other human pathogens) in fresh produce has been well documented (reviewed in Busta et al., 2003). Since agricultural water is an important potential source of pre-harvest microbial contamination, the proposed produce safety standards within FSMA do include requirements related to routine water testing. However, the Tester-Hagen Amendment exempts small- scale and local food growers, and other growers may be exempt from the regulation due to their water source, irrigation system used or the crop(s) grown (U.S. FDA, 2013). Since fresh market vegetable production within Maryland and Delaware is predominantly small-scale and qualifies for the statutory exemption, routine testing of irrigation water in the mid-Atlantic is likely to remain low.

The potential role of wildlife in pre-harvest contamination of fresh produce also remains unclear. Although migratory birds (such as geese, ducks and gulls) are thought to be involved in the dispersal of human pathogens (reviewed in Hubalek, 2004), several studies examining the prevalence of *E. coli* O157:H7 in Canadian geese failed to identify the pathogen (reviewed in Langholz & Jay- Russell, 2013). This is fortuitous for the mid-Atlantic, which lies within a major bird migration route known as the Atlantic Flyway (U.S. Fish and Wildlife Service, 2012). In the rare case where a direct link between wildlife and a foodborne illness outbreak could be established, *E. coli* O157:H7 isolated from feral pigs was matched to the outbreak strain associated with spinach in 2006 (Jay et al., 2007), *Campylobacter jejuni* isolated from Sandhill cranes was matched to the outbreak strain associated with peas in 2008 (Gardner et al., 2011), and *E. coli* O157:H7 isolated from deer was matched to the outbreak strain associated with strawberries in 2011 (Laidler et al., 2013). In this survey, the majority of our surveyed growers reported daily intrusion of wildlife into production fields during the growing season, but approximately one-fifth of growers did not employ any preventative measures to minimize or prevent access. Previous studies have documented growers' concerns that the food safety risk(s) posed by wildlife are beyond their control (Parker et al., 2012b), or that preventative strategies are not economically feasible (Ivey et al., 2012) or contradict environmental regulation designed to protect wildlife and growers' desire to be responsible "stewards of the land” (Beretti & Stuart, 2008; Lowell, Langholz, & Stuart, 2010). Concerns about the impact of food safety practices on land-use are supported by a recent study in California, which documented the degradation and/or elimination of more than 13% of riparian habitat in a major produce-growing region in the 5-year period following the 2006 *E. coli* O157:H7 outbreak associated with spinach (Gennet et al., 2013). The FDA has also responded to public concern that the produce safety standards may promote practices that adversely affect wildlife and animal habitat by proposing a new provision that clarifies FSMA's compliance with the Endangered Species Act and encouragement of environmental stewardship (U.S. FDA, 2014). However, growers may also have a more *laissez-faire* attitude regarding wildlife as they believe most fresh produce contamination occurs within the home (Ivey et al., 2012; Parker et al., 2012a), and the consumer has greater responsibility for ensuring raw meat food safety than they do (Erdem, Rigby, & Wossink, 2012). A national survey of U.S. consumers found only 53% of respondents always wash their hands before they handle produce and only 28% of respondents separated fresh produce from raw meat within a shopping bag (Li-Cohen & Bruhn, 2002), which helps explain why growers across all farm scales expressed concerns about consumer behavior and in-home food preparation (Parker et al., 2012b).

In this survey, less than 10% of all growers indicated that financial constraints were the primary obstacle for GAP implementation. This finding is similar to what Ivey et al. (2012) reported for Midwestern vegetable growers, who agreed on-farm food safety practices were generally economically feasible. However, the cost of implementing these preventative measures is often scale- dependent, and growers may underestimate the total expenditures required for GAP certification. Larger operations also tend to have lower production costs per pound, whereas smaller operations may be capital and/or labor poor. A study looking at fresh market strawberry production and the adoption of five food safety practices (including routine irrigation water testing) across different farm scales estimated that the additional cost per hectare for smaller growers would be four times more than that for larger ones ($720 per hectare versus $165 per hectare; Woods & Thornsbury, 2005). More recently, Becot et al. (2012) used data obtained from online surveys and in-depth interviews to analyze the costs of GAP certification (i.e. infrastructure, equipment and labor) for diversified, small- and medium-scaled farms in Vermont. They estimated the average cost for GAP certification per farm ranged between $2599 and $3983, but found no significant difference in spending based on primary market strategy (<50% of produce sold through wholesale channels versus >50%; Becot et al., 2012). Produce food safety costs also occupy a greater percentage of gross farm cash income for growers with lower sales. Among GAP-certified fruit and vegetable growers in Oregon, for example, those with gross farm cash incomes of $2758 per hectare spent about 12% on food safety, whereas those with gross farm cash incomes of $23,718 per hectare spent less than 2% (Prenguber & Gilroy, 2013). Interestingly, a recent survey on the cost of on-farm produce safety measures in the mid-Atlantic found only a handful of practices (such as employee training and sanitizing harvest containers) were likely to be financially burdensome for smaller operations (Lichtenberg and Tselepidakis, unpublished data). One possible explanation for the low rate of GAP implementation, despite the perceived low economic burden, is the lack of evidence that the financial investment for GAP results in sustained profits, access to new markets or other benefits (Parker et al., 2012a; Tobin, Thomson, & LaBorde, 2012). Furthermore, economic incentives (such as higher prices or reduced storage costs) are dependent on the ability of the marketing system to segregate GAP-certified from non-certified produce (Hobbs, 2003). Hardesty and Kusunose (2009) found that California leafy greens growers did not receive a price premium for implementing the compliance requirements of the Leafy Greens Marketing Agreement (LGMA), but LGMA does differ from other food safety programs as it has nearly 100% grower adoption. And although Ribera, Palma, Paggi, Knutson, and Masabn (2012) found that the compliance costs incurred by growers to demonstrate food safety assurance are much lower than the costs incurred during a produce-associated outbreak (i.e. declining sales and unsaleable product), it is unlikely that the growers with GAP certification are buffered from the volatile market during an outbreak.

5. Conclusions

Overall, mid-Atlantic vegetable growers' knowledge and on- farm implementation of GAP appears to be improving, as evident by the increased percentage of growers who reported microbial testing of irrigation water, attending a GAP training, having hired workers attend a GAP training, and sanitizing harvest containers. Between 2010 and 2013, University of Maryland Extension offered eleven educational workshops on food safety that were attended by more than 250 produce growers. It is probable the increase we observed for some on-farm GAP activities is connected to the extension programming. However, the effectiveness of the knowledge-deficit model (which attributes non-compliance to lack of information) in the context of food safety remains uncertain (Webster, Jardine, Cash, & McMullen, 2010; Parker et al., 2012a). For example, while pre- and post-evaluations from growers who attended GAP trainings offered by Penn State Extension did indicate an overall increase in technical knowledge, changes in on-farm food safety practices were largely absent, as only a minority of growers had written policies, conducted a self-audit, or applied for third-party certification six months later (Tobin et al., 2013). Additionally, food safety training has not generally been targeted at the farm level, but a previous study on hand hygiene among hired produce workers did show that perceived behavioral control (i.e. fewer barriers) was a significant predictor of handwashing intention (Soon & Baines, 2012). Consequently, field days focused on food safety and held at agricultural experiment stations or volunteer farms could be a valuable educational tool, facilitating discussion and peer-learning through demonstrations, mock GAP inspections and hands-on activities. In this study, we did not find a significant influence of farm scale or years in production on food safety practices, and economic feasibility does not appear to be the primary driver for growers who forgo GAP certification. However, market channel did impact a grower's likelihood to have written policies, test irrigation water, and obtain GAP certification, and strong differences were observed between wholesale and direct-to- consumer growers. While extension programming should continue to focus on supporting the needs of growers who elect to implement GAP, food safety outreach may benefit from expanding to involve farm market managers and personnel in intermediate market channels such as local food hubs. More research is needed to better understand how market channel works with other grower characteristics to influence decision-making activities including on-farm food safety practices. However, this new information further highlights the complexity of the issue at hand and the need for GAP educational programs to expand beyond a one-size-fits-all approach.

6. Study limitations

As in similar survey-based research, the main limitations included: coverage errors, non-response and measurement errors, and selection bias. The failure to track individual responses across the surveys was also a major limitation.

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Appendix A. Supplementary data

Supplemental Table 1. Analyzed questions from 2010 and 2013 surveys.

Topic	Question
Farm demographics	How long have you been growing vegetables and fruit?
	How many acres of vegetables do you produce?
	How is your produce marketed?
	How would you classify your farming operation? [*]
GAP implementation	Do you have written procedures and policies for how you grow and handle your produce?
	Have you completed a GAP third party certification?
	Have your buyers asked you to have a third party GAP certification?
	What obstacles are keeping you from developing a GAP plan for your operation?
	When was the last time you attended a GAP training?
	If you have hired workers, when was the last time your workers attended a GAP training?
Irrigation and spray water	If you use irrigation, what is/are the source(s) of the water?
	How often do you have all of your water sources tested for bacterial contamination?
	What is the source of water for pesticide spray applications?
	If you use irrigation, what percentage of your acreage is trickle or drip irrigated?
	If you irrigate your fruit or vegetables, what type(s) of irrigation do you use? [*]
Livestock and manure	What percentage of your fruit or vegetable acreage is fertilized with compost or manure?
	If you have livestock on your farm, what is/are the main animal type(s)? [*]
	Do you allow livestock animals to have access to your produce fields at any time during the year? [*]
Wildlife access and control	How frequently do domestic animals and wildlife access your crop fields during the growing season?
	If you use preventative measures to control wildlife access or damage to your produce crops, what types of measures do you use? [*]
Harvest practices	How often are harvest containers washed or sanitized?
	If you clean your vegetables prior to sale, what is the main cleaning method?
Other	Since 2010, what production practices have you changed or started? [*]

[*] Indicates question was only asked in 2013 survey.

Table 1. Descriptive summary of mid-Atlantic vegetable grower demographics.

Variable	Level	Distribution of responses (%)			
		2010	2013	Total	Census data for MD and DE[c]
Vegetable acreage[a]	<2 ha	54.5	51.8	52.9	46.5
	2–20 ha	34.1	28.8	31.1	32.9
	>20 ha	11.4	19.4	16.0	20.6
Years in production	<5 years	16.8	11.4	13.7	11.4
	5–20 years	32.0	33.1	32.6	–
	>20 years	51.2	55.4	53.6	–
Marketing channel[b]	Wholesale	7.1	7.3	7.2	
	Direct	42.5	39.9	40.9	
	Combination	39.8	38.2	38.8	
	Processing	10.6	14.6	13.5	

a. Acreage in hectares.

b. Respondents allowed to select “primarily wholesale”, “primarily direct”, “combination or wholesale and direct” or “processing”.

c. Combined USDA-NASS Census of Agriculture acreage data and principal operator tenure data for vegetable farms in Maryland (N = 789) and Delaware (N = 222) presented for farm scale and years in production comparisons. Due to differences in response scale between this survey and the USDA-NASS census, only <5 years is included in the table. Data not available for primary market channel of vegetable farms by individual state.

Table 2. Marginal effects of farm scale, years in production and market channel on the probability of having written policies for the growing and handling of produce by survey year.

Variable[a]	**2010 probit results**		**2013 probit results**	
	Average marginal effect[b]	**Significance level**[c]	**Average marginal effect**	**Significance level**
Vegetable acreage (**<2 ha**)				
2–20 ha	0.043		−0.015	
>20 ha	0.127		0.114	
Production years **(<5 years**)				
5–20 years	0.078		0.050	
>20 years	0.123		0.005	
Market channel **(other)**				
Wholesale market	0.045		0.267	****
Direct market	0.109		−0.075	

a. Reference categories are in boldface and shown in parentheses. Responses were significantly different ($p < 0.001$) by survey year.

b. Average marginal effects calculated from the probit regression coefficients.

c. *$P \leq 0.10$; **$P \leq 0.05$; ***$P \leq 0.01$; ****$P \leq 0.001$.

Table 3. Marginal effects of farm scale, years in production and market channel on the probability of having completed a GAP third party certification by survey year.

Variable[a]	**2010 probit results** [d]		**2013 probit results**	
	Average marginal effect[b]	**Significance level**[c]	**Average marginal effect**	**Significance level**
Vegetable acreage (**<2 ha**)				
2–20 ha	.		−0.154	***
>20 ha	.		−0.023	
Production years **(<5 years**)				
5–20 years	.		(not estimable)[e]	
>20 years	.		(not estimable)	
Market channel **(other)**				
Wholesale market	.		0.286	****
Direct market	.		−0.150	***

a. Reference categories are in boldface and shown in parentheses. Responses were significantly different ($p < 0.001$) by survey year.

b. Average marginal effects calculated from the probit regression coefficients.

c. *$P \leq 0.10$; **$P \leq 0.05$; ***$P \leq 0.01$; ****$P \leq 0.001$.

d. Probit model for 2010 survey data not estimable due to collinearity.

e. Production years omitted from the model due to collinearity.

Table 4. Marginal effects of farm scale, years in production and market channel on the probability of having been asked by buyers for GAP certification by survey year.

Variable[a]	2010 probit results [d]		2013 probit results	
	Average marginal effect[b]	**Significance level[c]**	**Average marginal effect**	**Significance level**
Vegetable acreage (**<2 ha**)				
2–20 ha	.		−0.065	
>20 ha	.		0.195	*
Production years **(<5 years**)				
5–20 years	.		(not estimable)[e]	
>20 years	.		(not estimable)	
Market channel **(other)**				
Wholesale market	.		0.234	***
Direct market	.		−0.087	

a. Reference categories are in boldface and shown in parentheses. Responses were significantly different ($p < 0.001$) by survey year.

b. Average marginal effects calculated from the probit regression coefficients.

c. *$P \leq 0.10$; **$P \leq 0.05$; ***$P \leq 0.01$; ****$P \leq 0.001$.

d. Probit model for 2010 survey data not estimable due to collinearity.

e. Production years omitted from the model due to collinearity.

Table 5. Primary obstacles hindering growers from developing a food safety plan for their farm.

Response	Distribution (%) and number of responses		
	2010	**2013**	**Total**
Lack of knowledge	43.1 (56)	10.9 (20)	24.3
Lack of assistance/personnel	16.9 (22)	8.7 (16)	12.1
Lack GAP training	22.3 (29)	–	22.3
Doesn't apply to my size operation	33.1 (43)	20.2 (37)	25.6
Requires too much time	16.2 (21)	7.1 (13)	10.9
Costs too much	10.8 (14)	7.1 (13)	8.6
I'm not required to do so	–	27.3 (50)	27.3

Data analyzed from 130 growers in 2010 survey and 183 growers in 2013 survey. Growers were allowed to select up to 3 answers. All responses except “costs too much” (p = 0.255) were significantly different between survey years ($p < 0.05$). – indicates response was not an option for that survey year.

Table 6. Marginal effects of farm scale, years in production and market channel on the probability of testing irrigation water annually for indicators of fecal contamination by survey year.

Variable[a]	2010 probit results		2013 probit results	
	Average marginal effect[b]	**Significance level[c]**	**Average marginal effect**	**Significance level**
Vegetable acreage (**<2 ha**)				
2–20 ha	−0.038		−0.107	
>20 ha	−0.015		0.033	
Production years **(<5 years**)				
5–20 years	0.077		0.072	
>20 years	0.079		0.184	
Market channel **(other)**				
Wholesale market	0.035		0.235	****
Direct market	−0.049		−0.402	

a. Reference categories are in boldface and shown in parentheses. Responses were significantly different ($p < 0.001$) by survey year.

b. Average marginal effects calculated from the probit regression coefficients.

c. *$P \leq 0.10$; **$P \leq 0.05$; ***$P \leq 0.01$; ****$P \leq 0.001$.

Table 7. Marginal effects of farm scale, years in production and market channel on the probability of daily wildlife access to production fields during growing season by survey year.

Variable[a]	2010 probit results		2013 probit results	
	Average marginal effect[b]	**Significance level[c]**	**Average marginal effect**	**Significance level**
Vegetable acreage (**<2 ha**)				
2–20 ha	0.056		0.178	**
>20 ha	0.047		0.306	****
Production years **(<5 years**)				
5–20 years	0.094		0.086	
>20 years	0.021		0.119	
Market channel **(other)**				
Wholesale market	0.197	***	−0.019	
Direct market	−0.028		0.022	

a. Reference categories are in boldface and shown in parentheses. Responses were significantly different ($p < 0.001$) by survey year.

b. Average marginal effects calculated from the probit regression coefficients.

c. *$P \leq 0.10$; **$P \leq 0.05$; ***$P \leq 0.01$; ****$P \leq 0.001$.

Table 8. Marginal effects of farm scale, years in production and market channel on the probability of food safety or GAP training of self (A) and workers (B) by survey year.

	2010 probit results		**2013 probit results**	
A) Variable[a]	**Average marginal effect**[b]	**Significance level**[c]	**Average marginal effect**	**Significance level**
Vegetable acreage (**<2 ha**)				
2–20 ha	−0.132		−0.087	
>20 ha	−0.097		−0.081	
Production years **(<5 years**)				
5–20 years	0.142		0.048	
>20 years	0.274	**	0.049	
Market channel **(other)**				
Wholesale market	−0.107		0.094	
Direct market	0.127		0.107	
	2010 probit results		**2013 probit results**	
B) Variable[a]	**Average marginal effect**	**Significance level**[b]	**Average marginal effect**	**Significance level**
Vegetable acreage (**<2 ha**)				
2–20 ha	0.109		−0.215	*
>20 ha	0.159		−0.109	
Production years **(<5 years**)				
5–20 years	0.038		0.289	*
>20 years	0.113		0.524	****
Market channel **(other)**				
Wholesale market	0.095		−0.035	
Direct market	0.240		−0.039	

a. Reference categories are in boldface and shown in parentheses. Responses were significantly different ($p < 0.05$) by survey year.

b. Average marginal effects calculated from the probit regression coefficients.

c. $*P \leq 0.10$; $**P \leq 0.05$; $***P \leq 0.01$; $****P \leq 0.001$.

Table 9. Marginal effects of farm scale, years in production and market channel on the probability of yearly sanitization of harvest containers by survey year.

Variable[a]	2010 probit results		2013 probit results	
	Average marginal effect[b]	**Significance level[c]**	**Average marginal effect**	**Significance level**
Vegetable acreage (**<2 ha**)				
2–20 ha	−0.029		−0.013	
>20 ha	−0.234		−0.038	
Production years **(<5 years**)				
5–20 years	0.018		0.138	
>20 years	−0.056		0.121	
Market channel **(other)**				
Wholesale market	0.011		−0.009	
Direct market	0.001		−0.063	

a. Reference categories are in boldface and shown in parentheses. Responses were significantly different (p = 0.001) by survey year.

b. Average marginal effects calculated from the probit regression coefficients.

c. $*P \leq 0.10$; $**P \leq 0.05$; $***P \leq 0.01$; $****P \leq 0.001$.

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