

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

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## Abstract

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2  
3 Foodborne illnesses associated with fresh produce have dramatically increased within the last decade.  
4 Good Agricultural Practices (GAP) were developed to address potential sources of pre-harvest microbial  
5 contamination, but certification remains low. The majority of mid-Atlantic vegetable farms are fresh  
6 market, but limited information is available about what on-farm production practices are being utilized to  
7 mitigate food safety risks. Our goal was to assess Maryland and Delaware vegetable producers'  
8 understanding and implementation of GAP. An electronic survey on pre-harvest production practices was  
9 administered at commercial grower meetings in 2010 and 2013. A total of 313 surveys were analyzed,  
10 and Probit regression was used to estimate the average marginal effects of farm scale, years in production  
11 and market channel on the probability of using different on-farm food safety practices. Generally, food  
12 safety practices did not differ across farm scale or years in production. However, market channel did  
13 influence a grower's decision to implement some food safety practices. Growers who marketed their  
14 produce primarily through wholesale channels were more likely to: have written policies for how they  
15 grew and handled their produce, test their irrigation water at least once a year for microbial  
16 contamination, or be GAP-certified. Economic constraints were not reported as the primary obstacle for  
17 GAP implementation in either survey. While more research is needed to better understand how market  
18 channel influences decision-making activities including on-farm food safety practices, this study  
19 highlights the complexity of the issue and the need for GAP educational programs to expand beyond a  
20 one- size-fits-all approach.

21

22 **Keywords:** Good Agricultural Practices Mid-Atlantic Vegetable producers

23

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

26

27 **1. Introduction**

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

36 However, in the years following release of the *Guide*, outbreaks associated with enteric pathogens  
37 (such as *Escherichia coli* O157:H7 and *Salmonella enterica*) and on-farm contamination events have been  
38 steadily increasing (DeWaal, Tian, & Bhuiya, 2008). Between 1998 and 2008, the consumption of fresh  
39 fruits and vegetables was implicated in 46% of foodborne illnesses and resulted in an estimated 21,000  
40 hospitalizations and 334 deaths (Painter et al., 2013). Although research has identified several microbial  
41 risk factors (reviewed in Mandrell, 2009; Olaimat & Holley, 2012), eliminating enteric pathogens from  
42 fresh produce remains difficult due to microbial adhesion (reviewed in Berger et al., 2010) and their  
43 ability to persist as epiphytes or endophytes within the plant microbiota (reviewed in Critzer & Doyle,  
44 2010). In 2002, the United States Department of Agriculture (USDA) developed a voluntary audit/  
45 certification program known as "Good Agricultural Practices" (GAP) to verify conformance to the 1998  
46 guide. This program seeks to minimize fresh produce contamination by recommending science- based  
47 "best practices" in areas such as irrigation water quality, manure management, wildlife management,  
48 worker health and hygiene, and post-harvest handling (USDA, 2014b). University of Maryland Extension  
49 programming has traditionally relied on the knowledge-deficit approach for GAP education, which

50 emphasizes a one-way model of communication and attributes noncompliance to lack of information  
51 (Parker, Wilson, LeJeune, Rivers, & Doohan, 2012). Full-day trainings include presentations on the four  
52 W's (water, waste, wildlife and workers), sanitation, auditing programs, and writing a food safety plan (D.  
53 Pahl, personal communication). Following training, the GAP audit is conducted by a public or private  
54 third-party certifier, and a grower must score 80% or better on each of the seven sections to become  
55 certified. Growers are also responsible for bearing the costs of the training and audit.

56         In 2011, the Food Safety Modernization Act (FSMA) was signed into law. FSMA directs the  
57 FDA to establish a uniform set of produce safety standards and aims to ensure a safe U.S. food supply  
58 through prevention of microbial contamination (U.S. FDA, 2013). The proposed produce safety standards  
59 have received substantial input from scientists, industry stakeholders and consumers, and tens of  
60 thousands of comments have been submitted during the public comment periods. As a consequence of  
61 this widespread media attention, most growers and packers are now aware of their obligation to reduce  
62 the microbial hazards and risks associated with the production of fresh produce. Although FSMA  
63 represents the minimum requirements, compliance is mandated by law, and implementation is expected to  
64 begin in 2016. In contrast, GAP certification remains voluntary, so rates remain low and implementation  
65 remains inconsistent (Gravani, 2009). In a recent survey of diversified fruit and vegetable growers in  
66 Oregon, more than half indicated GAP certification resulted in competitive market benefits, but only 25%  
67 (4 of 16) of surveyed growers had active GAP certification (Prenguber & Gilroy, 2013). A study in  
68 Vermont also found 22% of surveyed produce farms had active GAP certification, but that GAP  
69 compliant farms were generally larger in terms of acreage than non-certified farms (Becot, Nickerson,  
70 Conner, & Kolodinsky, 2012). In a Minnesota survey, more than 65% of vegetable growers — the  
71 majority (230 of 237) of whom were small-scale — reported compliance with GAPs (Hultberg,  
72 Schermann, & Tong, 2012). However, the authors did not provide data on the number of respondents with  
73 active GAP certification. And in the Midwest, the majority of surveyed vegetable growers agreed GAP  
74 could reduce the risk of fresh produce contamination, but only 40% implemented GAP at a level of  
75 consistency to do so (Ivey, LeJeune, & Miller, 2012).

76           Since GAP certification is not codified regulation, growers reported buyer expectations and  
77 maintaining sales and customer accounts as the primary incentives for GAP certification (Becot et al.,  
78 2012; Bihn & Gravani, 2006; Prenguber & Gilroy, 2013). Wholesale buyers, such as supermarket chains,  
79 have used their purchasing power to exert pressure on growers to adopt more stringent food safety  
80 standards (Fulponi, 2006) even designating which third-party certifier should be used in some cases  
81 (Hatanaka, Bain, & Busch, 2005). Although small-scale growers (defined as those less than 4 ha in size  
82 (Newton, 2014) or with gross cash farm income less than \$349,999 (Hoppe & MacDonald, 2013)) rarely  
83 reported barriers to GAP implementation when asked directly about economic feasibility (Ivey et al.,  
84 2012), they were less supportive of the program than large-scale growers and indicated they would side  
85 step GAP certification by avoiding wholesale market channels or retailers that required certification  
86 (Prenguber & Gilroy, 2013). Small-scale growers also tend to rely on direct-to-consumer marketing  
87 channels (Low & Vogel, 2011; Martinez et al., 2010), such as selling produce through Community  
88 Supported Agriculture programs (CSAs), which allow them to establish a direct relationship with their  
89 customers. Within the local food system, direct-to-consumer produce farms generate almost half of all  
90 local food sales (Low et al., 2015). Farmers markets in the mid-Atlantic are also some of the most  
91 profitable in the U.S., as 15.4% of vendors have annual sales of \$25,000 or more (USDA, 2009).  
92 However, these direct-to-consumer channels may also differ substantially in terms of fresh produce food  
93 safety standards. For example, less than 12% of farmers market managers surveyed in Georgia, Virginia  
94 and South Carolina asked participating vendors about on-farm food safety practices, such as manure use  
95 or worker hygiene (Harrison et al., 2013). Taken together, the data suggest a grower's primary market  
96 channel may be an important factor in on-farm food safety decision-making.

97           Previous research also indicates that grower response to food safety risks is influenced by the  
98 extent they perceive the risks to be within their control (Parker, Wilson, LeJeune, & Doohan, 2012). The  
99 role of irrigation water quality in produce food safety has been well documented in recent reviews  
100 (Beuchat et al., 2006; Suslow et al., 2003), but agricultural water testing remains low. Growers often  
101 indicate that preventing aerial wildlife from accessing (and potentially contaminating) irrigation water

102 sources is not feasible (Ivey et al., 2012; Parker, Wilson, LeJeune, Rivers, et al., 2012), but growers may  
103 lack access to municipal or groundwater irrigation sources. In a 1998 survey of fruit and vegetable  
104 growers in New York, 72% (118 of 163) reported using surface water (including streams, ponds, lakes, or  
105 open canals) as an irrigation source, but only 15% reported testing the water in any way (Rangarajan,  
106 Pritts, Reiners, & Pedersen, 2002). In a more recent survey, more than half (48 of 84) of New York fruit  
107 and vegetable growers reported using surface water to irrigate their crops, but less than 19% of those who  
108 applied surface water overhead reported testing the water for any indicators of fecal contamination (such  
109 as generic *E. coli*) (Bihn, Smart, Hoepting, & Worobo, 2013). For growers who do have access to  
110 groundwater irrigation sources, the percentage that routinely test for fecal contamination is also low. In a  
111 survey of fruit and vegetable growers in six New England states, 73% (217 of 297) used wells as a  
112 primary source for irrigation water but only 18% reported testing the water annually (Cohen,  
113 Hollingsworth, Brennan Olson, Laus, & Coli, 2005). The discrepancy between knowledge and behavior  
114 may be further explained by the low percentage of producers (19%) who believe contamination is likely  
115 to occur on the farm (Ivey et al., 2012).

116         In Maryland, there are 789 vegetable farms, which produce a wide range of crops including:  
117 cantaloupe, cucumbers, potatoes, pumpkins, snap beans, sweet corn, tomatoes and watermelons (USDA,  
118 2014a). The majority of vegetable farms (708 of 789) are fresh market, and more than half of those (391  
119 of 708) are less than 2 ha in size. Surprisingly, only 8 vegetable farms currently have completed a USDA  
120 GAP or Produce GAPs Harmonized audit (USDA AMS, 2013). The Maryland Department of Agriculture  
121 (MDA) has also offered a state GAP certification program for direct marketers since 2011 (also referred  
122 to as "Maryland GAP") (D. Baldwin, personal communication), and 11 vegetable farms currently have  
123 MD GAP certification (MDA, 2013). In Delaware, the situation is similar, as the majority of vegetable  
124 farms (163 of 222) are fresh market, more than a third are small-scale (72 of 163) (USDA, 2014a), and  
125 very few (4 farms) currently have USDA or Produce GAP certification (USDA AMS, 2013). Since the  
126 cost of implementing food safety programs is often farm scale-dependent, the smaller operations may lack  
127 the capital resources required and elect to forgo GAP certification. However, for mid-Atlantic vegetable

128 farms not involved in GAP, there is limited information available about what on-farm production  
129 practices, if any, are being utilized to mitigate food safety risks for their fresh market crop(s).

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

139

## 140 **2. Materials and methods**

### 141 *2.1. Questionnaire development*

142 In 2010, we developed a survey on farm demographics and fresh produce food safety. Growers  
143 were asked about fruit and vegetable acreage, years in operation, and produce marketing channels.  
144 Growers were also asked about GAP certification, pre-harvest production practices including: GAP  
145 training, irrigation and pesticide spray water management, manure use and livestock management, and  
146 wildlife management; and harvest production practices including: harvest container and produce  
147 sanitation (Supplemental Table 1). The 2010 survey also included questions on nutrition grant programs  
148 and U-pick operations, which are not discussed in this manuscript. In 2013, the survey was revised:  
149 questions that did not pertain to food safety were removed, and questions related FSMA were added. The  
150 revised survey addressed the same topics as before and had a similar survey completion time. Despite  
151 these changes, the questions related to farm demographics and on-farm food safety practices that  
152 comprise the data for the analysis remained consistent between survey years. Based on the intended  
153 audience, units of measurement within the survey were presented in the U.S. customary, non-metric

154 system. All survey questions were non-weighted and discrete (yes or no, "select one response" or "select  
155 up to 3 responses"). Both surveys were pretested by Extension specialists and researchers, and reviewed  
156 by the University of Maryland Institutional Review Board and deemed exempt (project #413818-1).

157

## 158 *2.2. Questionnaire delivery*

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

166

## 167 *2.3. Data analysis*

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

179

### 180 3. Results

#### 181 3.1. Survey response and grower demographics

182 A total of 415 surveys were completed, and 313 surveys were analyzed (130 surveys from 2010,  
183 to 183 surveys from 2013). A total of 102 surveys were excluded from analysis because respondents  
184 either lacked vegetable acreage (65 surveys) or had vegetable acreage but failed to answer at least 60% of  
185 questions discussed in this manuscript (37 surveys). Overall, the greatest percentage of respondents  
186 produced vegetables on less than 2 ha of land (52.9%) and had been in production 20 years or more  
187 (53.6%) (Table 1). When asked about market strategy, 7.2% of all growers sold their produce primarily  
188 through wholesale channels (such as supermarkets), while 40.9% of all growers sold their produce  
189 primarily through direct channels (such as farmer's markets). Interestingly, more than a third (38.8%) of  
190 all growers reported using a combination of wholesale and direct market channels. Although only 13.5%  
191 of attendees were present at both the 2010 and 2013 Maryland meetings, no statistically significant  
192 differences exist in grower demographics between the 2010 and 2013 samples (vegetable acreage,  $p =$   
193 0.164; years in production,  $p = 0.416$ ; market channel: wholesale,  $p = 0.746$ ; market channel: direct,  $p =$   
194 0.436). In the 2013 survey, growers were also asked to classify their farm system. The majority (66.7%)  
195 reported use of conventional farming practices, with only 1.6% of growers being certified organic. The  
196 remaining growers reported use of "other" farming practices, including 24.0% who employed primarily  
197 organic or sustainable farming practices (such as excluding use of synthetic pesticides and intentionally  
198 improving soil quality) but were not certified.

199

#### 200 3.2. GAP preparation and implementation

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

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

209 Growers were also asked if they had obtained third-party GAP certification. Although the  
210 majority of all respondents (90.6%) were not GAP-certified, there was a significant increase ( $\chi^2 (1) =$   
211 12.04,  $p < 0.001$ ) in the percentage of growers who reported having successfully completed a third-party  
212 audit, from 2.4% in 2010 to 14.3% in 2013. Growers who produced vegetables on 2-20 ha or who  
213 marketed their produce primarily through direct channels were less likely to be GAP-certified ( $p = 0.014$   
214 for both) than those with larger acreage or growers who marketed wholesale or through other channels in  
215 the 2013 survey (Table 3). When asked if buyers (such as retailers, processors, customers, etc.) had asked  
216 for GAP certification, significantly more growers answered in the affirmative in 2013 as compared to  
217 2010 ( $\chi^2 (1) = 15.60$ ,  $p < 0.001$ ). Growers who marketed their produce primarily through wholesale  
218 channels were 23.4% more likely to have been asked by their buyers to obtain GAP certification ( $p =$   
219 0.003), as compared to growers who marketed their produce through other channels in the 2013 survey  
220 (Table 4). Larger vegetable operations (i.e. more than 20 ha) were also more likely to have pressure from  
221 buyers, but the effect was only marginally significant ( $p = 0.076$ ).

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

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<sup>2</sup> 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.

229 (1) = 42.73,  $p < 0.001$ ). Surprisingly, in the 2013 survey, not being required to have written policies was  
230 the major reason (27.3%) growers selected for why they had not developed a food safety plan.

231

### 232 ***3.3. Pre-harvest production practices: irrigation and pesticide spray water management***

233 When asked about their source of irrigation water, 48.5% of 2010 growers and 23.4% of 2013  
234 growers indicated they used surface water (including ponds, rivers and streams) at least some of the time.  
235 Groundwater (including shallow and deep wells and municipal) was used for irrigation at least some of  
236 the time by the majority of all growers. More than 76% of all growers did not test their irrigation water at  
237 least once a year for indicators of fecal contamination. However, there was a significant increase ( $\chi^2$  (1)  
238 = 16.48,  $p < 0.001$ ) in the percentage of growers who reported testing their irrigation water at least once  
239 per year, from 11.5% in 2010 to 31.9% in 2013. Growers who marketed their produce primarily through  
240 wholesale channels were 23.5% more likely to test their irrigation water at least once a year ( $p = 0.001$ )  
241 relative to growers marketing through other channels in the 2013 survey (Table 6). Growers were also  
242 asked about their source of pesticide spray water. More than 91% of all growers used groundwater for  
243 pesticide applications — the majority of which originated from deep wells - with only 6.4% of growers  
244 indicating they used surface water.

245 When asked how their vegetable acreage is irrigated, the majority (70.6%) of all growers reported  
246 using trickle (drip) irrigation at least some of the time. Interestingly, there was a significant decrease ( $\chi^2$   
247 (1) = 4.73,  $p = 0.030$ ) in the percentage of growers who reported using trickle (drip) irrigation for more  
248 than half of their vegetable acreage, from 52.3% in 2010 to 39.9% in 2013. Growers were also asked what  
249 other types of irrigation they use on their fresh produce. Overhead or sprinkler irrigation was used by  
250 23.5% of growers in the 2013 survey, followed by furrow and flood irrigation (1.1% each).

251

### 252 ***3.4. Pre-harvest production practices: manure use, livestock on farm and access to crop fields***

253 The majority of all growers (60.4%) reported applying manure, compost or bio-solids to their  
254 vegetable acreage. However, not all growers had on-farm sources of manure or compost. In the 2013

255 survey, more than half of growers (56.8%) indicated they did not have livestock or poultry on their farm.  
256 Of those with domestic animals, poultry (free range and confined; 21.3%) and cattle (beef and dairy;  
257 18.0%) were most frequently reported. Some growers did report raising small ruminants (sheep and goats;  
258 8.2%) and swine (4.4%) on their farm. When asked if their livestock or poultry had access to their crop  
259 fields during the year, the majority of growers (70.3%) answered “no”. More than 14% of growers  
260 allowed domestic animals to enter crop fields after harvest, and two growers allowed domestic animals to  
261 enter crop fields during the growing season.

262

### 263 ***3.5. Pre-harvest production practices: wildlife access to crop fields***

264 The majority of all growers (80.9%) reported that wildlife accessed their production fields daily  
265 during the growing season. However, a significantly lower percentage of growers answered in the  
266 affirmative in the 2013 survey (76.6%), as compared to the 2010 survey (86.7%) ( $\chi^2 (1) = 4.85, p =$   
267  $0.028$ ). Growers who marketed their produce primarily through wholesale channels were more likely  
268 report daily wildlife access in their fields ( $p = 0.013$ ) as compared to growers who marketed their produce  
269 primarily through other channels in the 2010 survey (Table 7), while growers who produced vegetables  
270 on more than 2 ha were more likely to report daily wildlife access in their fields in the 2013 survey (Table  
271 7). Growers were also asked what preventative measures they use to control wildlife access. In the 2013  
272 survey, the greatest percentage of growers reported using crop damage permits or hunting (50.8%),  
273 followed by fencing (36.1%), chemical repellents (16.4%), domestic guard dogs (15.9%) and netting  
274 (12.6%). Interestingly, 18.0% of growers reported not employing any preventative measures to control  
275 wildlife access to their production fields.

276

### 277 ***3.6. Pre-harvest production practices: GAP training for self and workers***

278 In the 2010 survey, more than half of growers (59.3%) indicated they had not received any food  
279 safety or GAP training in the last 3 years. However, growers who had been in operation more than 20  
280 years were more likely to report having attended a training session within the last three years ( $p < 0.001$ ),

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

294

### 295 ***3.7. Harvest production practices: field packing activities***

296 Growers were also asked about field harvest production practices related to sanitization of  
297 containers and cleaning of vegetables. The majority of all growers (84.2%) surveyed reported they did  
298 sanitize their harvest containers at least once during the season. There was also a significant increase ( $\chi^2$   
299  $(1) = 10.85, p < 0.001$ ) in the percentage of growers who reported sanitizing their harvest containers,  
300 from 75.4% in 2010 to 90.0% in 2013. No independent variable (i.e. farm scale, years in production or  
301 market channel) significantly impacted the likelihood of this on-farm production practice (Table 9).  
302 Growers were also asked what cleaning method(s) and sanitizer(s) they used on their crop prior to sale or  
303 storage. In the 2010 survey, the largest percentage of growers reported washing their produce by hand  
304 (39.2%), followed by use of spray washers (6.9%) and flumes (5.4%). In the 2013 survey - which  
305 included additional response options - the largest percentage of growers reported washing their produce  
306 with plain water (47.0%), followed by wiping with a cloth (29.5%), and cleaning with chlorinated water

307 (18.6%) or water containing another disinfectant (such as soap) (3.8%). About one quarter (24.9%) of all  
308 growers reported not cleaning their crop prior to sale or storage.

309

### 310 ***3.8. Modifications to production practices since 2010***

311 In the 2013 survey, growers were asked what on-farm production practices they had modified or  
312 implemented in the last three years in response to concerns about food safety. About a quarter of growers  
313 reported improving their record keeping (24.6%), improving the food safety or GAP training their hired  
314 workers received (24.0%), or implementing preventative measures to restrict wildlife access to their  
315 production fields (26.8%). More than one-third of growers reported increasing their use of trickle (drip)  
316 irrigation (38.8%) or increasing how often they cleaned their harvest containers (39.3%). Additionally,  
317 29.5% of growers indicated they had started testing their irrigation water source(s) for indicators of fecal  
318 contamination.

319

## 320 **4. Discussion**

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

333 U.S. currently account for less than 2% of total fresh produce sales (Cook, 2011), they are a fast-growing  
334 segment of agricultural sales (Low et al., 2015) and a focus of current U.S. policy (Johnson, Aussenberg,  
335 & Cowan, 2013), due in part to consumer demand for locally produced foods (reviewed in Martinez et al.,  
336 2010). With its densely populated urban areas, the mid-Atlantic region has some of the most successful  
337 farmers markets, in terms of sales and number of customers per week (USDA, 2009). Previous studies  
338 have found consumers' willingness to pay is greater for local versus non-local fresh produce (Adams &  
339 Adams, 2011) but similar for organic versus locally grown tomatoes (Yue & Tong, 2009). There is also  
340 evidence that local food systems support regional economic growth, as Brown, Goetz, Ahearn, and Liang  
341 (2014) found a positive financial association between the level of direct sales in community-focused  
342 agriculture and growth in total farm sales in certain regions including Maryland.

343           Unfortunately, few publications have investigated the impact of market channel on growers'  
344 certification decisions and implementation of produce safety practices. When asked about potential  
345 solutions to marketing challenges, organic produce growers in California ranked "food safety regulations  
346 accounting for marketing methods" as one of the top recommendations (Cantor & Strohlic, 2009), yet  
347 surprisingly, research has shown that fruit and vegetable growers who reported direct marketing as the  
348 most economically important channel had significantly less certified organic acreage (Monson, Mainville,  
349 & Kuminoff, 2008; Veldstra, Alexander, & Marshall, 2014). Market channel was correlated with produce  
350 safety measures in a recent survey by Lichtenberg and Tselepidakis (unpublished data), who found the  
351 share of fresh vegetables sold to retail or foodservice establishments was positively, albeit marginally,  
352 associated with the probability of testing water, soil amendments or crop samples for indicators of fecal  
353 contamination. In our survey, very few growers who sold their produce exclusively through direct  
354 channels had been asked by their buyers (such as farm market managers or CSA members) to obtain GAP  
355 certification. In contrast, growers who sell their produce through wholesale supermarket chains are  
356 increasingly required to provide evidence of compliance with food safety standards through third-party  
357 certification (Hatanaka et al., 2005) or GAP (Tobin, Thomson, LaBorde, & Bagdonis, 2011) in order to  
358 maintain the business relationship. This de facto mandatory practice is appealing to wholesale operations,

359 which account for an estimated 57% of total fresh produce sales (Cook, 2011), as it shifts the  
360 responsibility and liability for produce safety from wholesale operations onto third-party certifiers and  
361 suppliers (Hatanaka et al., 2005). Further data is needed to assess the impact of direct-to-consumer  
362 marketing on on-farm food safety practices, as a production decision to implement GAP and a marketing  
363 decision to certify are likely interrelated, but separate, business decisions.

364         In this survey, only a quarter of all growers tested their irrigation water at least once a year for  
365 generic *E. coli*, an indicator of fecal contamination. Previous surveys in other regions have reported  
366 similarly low routine testing of irrigation water, both from groundwater sources (18% in Cohen et al.,  
367 2005) and surface water sources (19% in Bihn et al., 2013). Growers may decide not to test an irrigation  
368 water source for a myriad of reasons including concerns about cost and limited control over the water  
369 source. Adjacent land use (such as grazing cattle or applying animal manure) and runoff from nearby  
370 livestock or poultry operations have been shown to impact the prevalence and concentration of bacteria in  
371 the aquatic environment (Chen & Jiang, 2014; Harmel, Karthikeyan, Gentry, & Srinivasan, 2010;  
372 Thurston-Enriquez, Gilley, & Eghball, 2005). Growers may also lack alternative water sources. In the  
373 mid-Atlantic region, vegetable growers primarily reported irrigating their crops with groundwater, but  
374 about 30% reported irrigating with surface water some of the time. Surface water has been identified as a  
375 predominant *Salmonella* reservoir in the eastern U.S. (Micallef et al., 2012; Strawn et al., 2013), and in  
376 2005, a *Salmonella* Newport strain isolated from a pond used to irrigate tomatoes on the eastern shore of  
377 Virginia was matched to the outbreak strain (Greene et al., 2008). This is of particular concern for  
378 growers who use overhead or sprinkler irrigation systems, as non-pathogenic *E. coli* strains have been  
379 consistently recovered from field-grown leafy greens following overhead irrigation with contaminated  
380 water (Wood, Bezanson, Gordon, & Jamieson, 2010; Fonesca, Fallon, Sanchez, & Nolte, 2011).  
381 However, the absence of generic *E. coli* does not mean the water is free of foodborne pathogens, and the  
382 lack of the predictive correlation between this indicator and pathogenic *E. coli* (and other human  
383 pathogens) in fresh produce has been well documented (reviewed in Busta et al., 2003). Since agricultural  
384 water is an important potential source of pre-harvest microbial contamination, the proposed produce

385 safety standards within FSMA do include requirements related to routine water testing. However, the  
386 Tester-Hagen Amendment exempts small- scale and local food growers, and other growers may be  
387 exempt from the regulation due to their water source, irrigation system used or the crop(s) grown (U.S.  
388 FDA, 2013). Since fresh market vegetable production within Maryland and Delaware is predominantly  
389 small-scale and qualifies for the statutory exemption, routine testing of irrigation water in the mid-  
390 Atlantic is likely to remain low.

391         The potential role of wildlife in pre-harvest contamination of fresh produce also remains unclear.  
392 Although migratory birds (such as geese, ducks and gulls) are thought to be involved in the dispersal of  
393 human pathogens (reviewed in Hubalek, 2004), several studies examining the prevalence of *E. coli*  
394 O157:H7 in Canadian geese failed to identify the pathogen (reviewed in Langholz & Jay- Russell, 2013).  
395 This is fortuitous for the mid-Atlantic, which lies within a major bird migration route known as the  
396 Atlantic Flyway (U.S. Fish and Wildlife Service, 2012). In the rare case where a direct link between  
397 wildlife and a foodborne illness outbreak could be established, *E. coli* O157:H7 isolated from feral pigs  
398 was matched to the outbreak strain associated with spinach in 2006 (Jay et al., 2007), *Campylobacter*  
399 *jejuni* isolated from Sandhill cranes was matched to the outbreak strain associated with peas in 2008  
400 (Gardner et al., 2011), and *E. coli* O157:H7 isolated from deer was matched to the outbreak strain  
401 associated with strawberries in 2011 (Laidler et al., 2013). In this survey, the majority of our surveyed  
402 growers reported daily intrusion of wildlife into production fields during the growing season, but  
403 approximately one-fifth of growers did not employ any preventative measures to minimize or prevent  
404 access. Previous studies have documented growers' concerns that the food safety risk(s) posed by wildlife  
405 are beyond their control (Parker et al., 2012b), or that preventative strategies are not economically  
406 feasible (Ivey et al., 2012) or contradict environmental regulation designed to protect wildlife and  
407 growers' desire to be responsible "stewards of the land" (Beretti & Stuart, 2008; Lowell, Langholz, &  
408 Stuart, 2010). Concerns about the impact of food safety practices on land-use are supported by a recent  
409 study in California, which documented the degradation and/or elimination of more than 13% of riparian  
410 habitat in a major produce-growing region in the 5-year period following the 2006 *E. coli* O157:H7

411 outbreak associated with spinach (Gennet et al., 2013). The FDA has also responded to public concern  
412 that the produce safety standards may promote practices that adversely affect wildlife and animal habitat  
413 by proposing a new provision that clarifies FSMA's compliance with the Endangered Species Act and  
414 encouragement of environmental stewardship (U.S. FDA, 2014). However, growers may also have a more  
415 *laissez-faire* attitude regarding wildlife as they believe most fresh produce contamination occurs within  
416 the home (Ivey et al., 2012; Parker et al., 2012a), and the consumer has greater responsibility for ensuring  
417 raw meat food safety than they do (Erdem, Rigby, & Wossink, 2012). A national survey of U.S.  
418 consumers found only 53% of respondents always wash their hands before they handle produce and only  
419 28% of respondents separated fresh produce from raw meat within a shopping bag (Li-Cohen & Bruhn,  
420 2002), which helps explain why growers across all farm scales expressed concerns about consumer  
421 behavior and in-home food preparation (Parker et al., 2012b).

422         In this survey, less than 10% of all growers indicated that financial constraints were the primary  
423 obstacle for GAP implementation. This finding is similar to what Ivey et al. (2012) reported for  
424 Midwestern vegetable growers, who agreed on-farm food safety practices were generally economically  
425 feasible. However, the cost of implementing these preventative measures is often scale- dependent, and  
426 growers may underestimate the total expenditures required for GAP certification. Larger operations also  
427 tend to have lower production costs per pound, whereas smaller operations may be capital and/or labor  
428 poor. A study looking at fresh market strawberry production and the adoption of five food safety practices  
429 (including routine irrigation water testing) across different farm scales estimated that the additional cost  
430 per hectare for smaller growers would be four times more than that for larger ones (\$720 per hectare  
431 versus \$165 per hectare; Woods & Thornsbury, 2005). More recently, Becot et al. (2012) used data  
432 obtained from online surveys and in-depth interviews to analyze the costs of GAP certification (i.e.  
433 infrastructure, equipment and labor) for diversified, small- and medium-scaled farms in Vermont. They  
434 estimated the average cost for GAP certification per farm ranged between \$2599 and \$3983, but found no  
435 significant difference in spending based on primary market strategy (<50% of produce sold through  
436 wholesale channels versus >50%; Becot et al., 2012). Produce food safety costs also occupy a greater

437 percentage of gross farm cash income for growers with lower sales. Among GAP-certified fruit and  
438 vegetable growers in Oregon, for example, those with gross farm cash incomes of \$2758 per hectare spent  
439 about 12% on food safety, whereas those with gross farm cash incomes of \$23,718 per hectare spent less  
440 than 2% (Prenguber & Gilroy, 2013). Interestingly, a recent survey on the cost of on-farm produce safety  
441 measures in the mid-Atlantic found only a handful of practices (such as employee training and sanitizing  
442 harvest containers) were likely to be financially burdensome for smaller operations (Lichtenberg and  
443 Tselepidakis, unpublished data). One possible explanation for the low rate of GAP implementation,  
444 despite the perceived low economic burden, is the lack of evidence that the financial investment for GAP  
445 results in sustained profits, access to new markets or other benefits (Parker et al., 2012a; Tobin, Thomson,  
446 & LaBorde, 2012). Furthermore, economic incentives (such as higher prices or reduced storage costs) are  
447 dependent on the ability of the marketing system to segregate GAP-certified from non-certified produce  
448 (Hobbs, 2003). Hardesty and Kusunose (2009) found that California leafy greens growers did not receive  
449 a price premium for implementing the compliance requirements of the Leafy Greens Marketing  
450 Agreement (LGMA), but LGMA does differ from other food safety programs as it has nearly 100%  
451 grower adoption. And although Ribera, Palma, Paggi, Knutson, and Masabn (2012) found that the  
452 compliance costs incurred by growers to demonstrate food safety assurance are much lower than the costs  
453 incurred during a produce-associated outbreak (i.e. declining sales and unsaleable product), it is unlikely  
454 that the growers with GAP certification are buffered from the volatile market during an outbreak.

455

## 456 **5. Conclusions**

457 Overall, mid-Atlantic vegetable growers' knowledge and on-farm implementation of GAP  
458 appears to be improving, as evident by the increased percentage of growers who reported microbial  
459 testing of irrigation water, attending a GAP training, having hired workers attend a GAP training, and  
460 sanitizing harvest containers. Between 2010 and 2013, University of Maryland Extension offered eleven  
461 educational workshops on food safety that were attended by more than 250 produce growers. It is  
462 probable the increase we observed for some on-farm GAP activities is connected to the extension

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

486 **6. Study limitations**

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

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495 **Appendix A. Supplementary data**496 **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? *

497 \* Indicates question was only asked in 2013 survey.

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

Variable	Level	Distribution of responses (%)			
		2010	2013	Total	Census data for MD and DE <sup>c</sup>
Vegetable acreage <sup>a</sup>	<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 <sup>b</sup>	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	

499 a. Acreage in hectares.

500 b. Respondents allowed to select “primarily wholesale”, “primarily direct”, “combination or  
501 wholesale and direct” or “processing”.502 c. Combined USDA-NASS Census of Agriculture acreage data and principal operator tenure data  
503 for vegetable farms in Maryland (N = 789) and Delaware (N = 222) presented for farm scale and  
504 years in production comparisons. Due to differences in response scale between this survey and  
505 the USDA-NASS census, only <5 years is included in the table. Data not available for primary  
506 market channel of vegetable farms by individual state.

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

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

- 509 a. Reference categories are in boldface and shown in parentheses. Responses were significantly  
 510 different ( $p < 0.001$ ) by survey year.
- 511 b. Average marginal effects calculated from the probit regression coefficients.
- 512 c. \* $P \leq 0.10$ ; \*\* $P \leq 0.05$ ; \*\*\* $P \leq 0.01$ ; \*\*\*\* $P \leq 0.001$ .

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

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

- 515 a. Reference categories are in boldface and shown in parentheses. Responses were significantly  
 516 different ( $p < 0.001$ ) by survey year.
- 517 b. Average marginal effects calculated from the probit regression coefficients.
- 518 c. \* $P \leq 0.10$ ; \*\* $P \leq 0.05$ ; \*\*\* $P \leq 0.01$ ; \*\*\*\* $P \leq 0.001$ .
- 519 d. Probit model for 2010 survey data not estimable due to collinearity.
- 520 e. Production years omitted from the model due to collinearity.

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

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

523

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

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

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

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

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

530 **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

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

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

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

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

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

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

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

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

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

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

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

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

A) Variable <sup>a</sup>	2010 probit results		2013 probit results	
	Average marginal effect <sup>b</sup>	Significance level <sup>c</sup>	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	
B) Variable <sup>a</sup>	2010 probit results		2013 probit results	
	Average marginal effect	Significance level <sup>b</sup>	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	

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

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

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

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

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

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

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

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

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