Consumer Perceptions of Plant Production Practices that Aid Pollinator Insects' Health

Hayk Khachatryan¹ and Alicia Rihn

Food and Resource Economics Department and Mid-Florida Research and Education Center, University of Florida, 2725 South Binion Road, Apopka, FL 32703

Additional index words. food crop plants, growing practices, landscape plants, ordered probit model, ranking, pollinator friendly plants

Abstract. Declining pollinator insect populations has become an important environmental concern in recent years. Despite widespread awareness, consumer perceptions of production practices (i.e., natural and organic) and effects on pollinator health are not well understood. This study assessed consumer perceptions of pollinator-friendly plant production practices in nursery production systems for food crop plants and landscape plants. Understanding consumer perceptions of horticultural production practices related to pollinator health is important because this impacts consumers' product selection (e.g., landscape and food crop plants), sales, and the availability of pollinator-friendly products in the residential landscape. We used an online survey of 1243 U.S. consumers who ranked the importance of 11 different production practices for both food crops and landscape plants. Results were analyzed using an ordered probit model and showed that plant type influences perceived importance of the production practices. For food crop plants, *grown without pesticides* practice was perceived as the best production method for pollinator health, whereas *grown outside* practice was ranked the highest for landscape plants. *Grown using synthetic pesticides* practice was ranked the least beneficial method regardless of plant type. Results contribute new insights into consumers' perceptions of pollinator-friendly production practices relative to plant type (i.e., landscape vs. food crop plants) which green industry stakeholders can use as they assess production methods or marketing strategies.

Insect pollinator services are important to the global economy and environment. World pollinator services have been valued at €153 billion per year (\$171 billion USD; Gallai et al., 2009) and pollinate ≈70% of global food crops (Klein et al., 2007). Environmental benefits of pollinator services include increased biodiversity, abundance of wild flowers and trees, bird food availability, ecosystem services (such as pest population reduction), soil protection, water quality (runoff mitigation), and aesthetics (Hanley et al., 2015; Wratten et al., 2012). However, recently, global pollinator insect populations have been declining (Hanley et al., 2015; Klein et al., 2007) which is concerning from an economic, environmental, and food availability standpoint (Gallai et al., 2009).

Governmental agencies and researchers have responded to this concern through increasing their efforts to identify potential causes of pollinator population declines (U.S. EPA, 2016a). However, results indicate there is not one central cause but many that contribute to the problem, including parasites,

disease, pesticides, habitat loss, urbanization, poor nutrition, monoculture agriculture, and climate change (Fairbrother et al., 2014; Hanley et al., 2015). Urbanization and management of residential landscapes serve as potential problem areas especially because these landscapes are often managed by inexperienced homeowners (O'Hara, 2010; Templeton et al., 1998; Winfree et al., 2009). In 2012, urban areas covered 67.8 million acres of the United States (Cox, 2012). Ninety million U.S. households (78% of all households) had yards, landscapes, and gardens that could be used to aid pollinators if properly managed (Kiesling and Manning, 2010). Research has shown that pollinators can thrive in urban environments and provide ecological benefits (i.e., pollination services and biodiversity) (Frankie et al., 2005; McIntyre and Hostetler, 2001). O'Hara (2010) found that widespread urbanization is negatively impacting pollinator insect populations, whereas increased access to pollinator-friendly plants in the urban environment can mitigate some of that damage. Consequently, homeowners' property management strategies could influence pollinator health (Frankie et al., 2005; McIntyre and Hostetler, 2001). This is especially important because 85 million U.S. households were actively gardening in 2012 (Hovhannisyan and Khachatryan, 2016; National Gardening Association, 2013). Plant selection

is one small but integral part of property management. However, to date, literature on consumer perceptions of landscape management practices that aid pollinators is limited. Understanding consumer perceptions is important because their perceptions influence decision-making, plant selection, and demand (Campbell et al., 2014, 2015; Lusk et al., 2004; Rihn and Khachatryan, 2016). The success of products (in general) largely depends upon consumer perceptions and acceptance. Unfortunately, consumers' perceptions are not always accurate (Campbell et al., 2013, 2015). Therefore, it is important to understand existing perceptions and factors that influence those perceptions to educate consumers and take corrective actions where needed. The present study investigates consumer perceptions of alternative production practices (e.g., grown using organic pesticides) in the U.S. green industry (i.e., nursery crops) with regard to their impact on insect pollinator health.

Several production practices are more beneficial to pollinator insects than conventional practices. For instance, production practices that increase biodiversity and forage crop availability (including planting natives, environmentally friendly, and natural practices) are beneficial to pollinator insects (Frankie et al., 2005). Integrated pest management (IPM) strategies (Kiesler et al., 1984) and organic production practices also aid pollinator insects through increased biodiversity and bee abundance (Gabriel and Tschantke, 2007; Morandin and Winston, 2005). Whereas alternative production practices can aid pollinator insects, implementing alternative production methods requires substantial financial and labor inputs from producers (Uematsu and Mishra, 2012). Furthermore, consumer perceptions of alternative production practices vary widely and are not always accurate (Campbell et al., 2013). Thus, it is imperative to understand consumer perceptions before implementation of different production practices to reduce producers' risks (e.g., increases in labor, financial, and other resource requirements). This leads to the following questions: how do consumers perceive different production practices in terms of their impact on pollinator health? Do those perceptions of production practices vary by end product (i.e., landscape vs. food producing plants)? Lastly, how do their perceptions influence their purchasing behavior?

Studies on consumer perceptions of production practices' effects on pollinators are limited; however, research does indicate that consumers recognize the need to aid pollinator insects (Breeze et al., 2015; Diffendorfer et al., 2014; Mwebaze et al., 2010; Wollaeger et al., 2015). For example, UK consumers are willing to pay £13.4/year (individually) for a pollinator conservation policy (Breeze et al., 2015) and £1.77 billion/year (cumulatively) to protect bees (Mwebaze et al., 2010). U.S. consumers are willing to pay \$4.78–6.64 billion/year to purchase beneficial plants and support a butterfly conservation program

Received for publication 22 Sept. 2016. Accepted for publication 18 Feb. 2017.

This manuscript is also included in the 2016 Florida State Horticultural Society conference proceedings.

¹Corresponding author. E-mail: hayk@ufl.edu.

(Diffendorfer et al., 2014). U.S. consumers are also willing to pay \$0.17–1.01 more for plants grown using “bee-friendly” production practices (Wollaeger et al., 2015). All of these studies accentuate consumer awareness of the value of pollinator insects. However, they do not reflect what consumers perceive as “beneficial” to pollinator insects.

Furthermore, many existing consumer preference studies on plant production practices do not incorporate consumer perceptions of how those practices influence pollinator health but instead focus on differences related to plant type. Yue et al. (2011) demonstrated that consumers’ are more interested in organic annuals, herbs and vegetables, and indoor plants than organic perennials, shrubs, and trees. However, Schimmenti et al. (2013) found that consumers have a propensity to purchase organic potted plants if they are available. Both studies suggest using production practices as a means of differentiating ornamental plants but that plant type influences the effect on consumer choices. Similarly, Rihn et al. (2016) and Khachatryan et al. (2016) recently reported that consumers’ were willing to pay price premiums for organically grown ornamental plants and organic fertilizers. One would expect production practices that are associated with human health (e.g., organic production reducing consumers’ pesticide exposure) to be more important for products that are potentially consumed (Yue et al., 2011). Consequently, the impact of product end-use (e.g., purely aesthetic vs. food producing) may influence consumer perceptions of production practices that benefit pollinator insects. Cumulatively, the pollinator insect studies and production method studies demonstrate consumer interest in both topics but they do not combine the two subjects. Our article addresses this research gap. We hypothesize that the importance consumers assign to different production practices will vary based on the plant type. Specifically, production practices that reduce pesticide use will be preferred for food crops and less so for landscape plants. For instance, Hawkins et al. (2012) determined consumers were willing to pay a higher premium for organically produced vegetable and herb plants than for organic ornamental plants. In the following sections, we cover the experimental design (questionnaire and sampling procedure), econometric model, results for food crop plants and landscape plants, and finish with a conclusion.

This research is unique in that it incorporates end consumer perspectives on production practices (e.g., organic practices, IPM, and conventional practices) and product end-use with regard to benefiting pollinator insects. As consumers become more conscious of pollinator population declines, there may be more demand for products that aid pollinator insects. Results could be beneficial to green industry stakeholders (i.e., growers, wholesalers, marketers, and retailers) as they determine the best strategies to aid pollinators and minimize (alternative) production

risks. Specifically, knowledge about current consumer perceptions could help producers align their product offerings and production practices with positive consumer perceptions. Retailers and intermediary wholesalers could benefit through developing promotional materials and product lines that educate consumers about production practices that aid pollinators and coincide with consumers’ existing perceptions. In addition, the long-term benefits to pollinator insects and the environment could be substantial if more beneficial products are widely available in stores and in residential landscapes.

Materials and Methods

U.S. consumers were surveyed using an online questionnaire. An online questionnaire was desirable because of the ability to efficiently reach consumers across the United States (McDaniel and Gates, 2010). The questionnaire was distributed through a third party contractor, Qualtrics Online Survey Software (Qualtrics, LLC, Provo, UT). Participants were screened to ensure that they had purchased plants within the past 12 months and were 18 years or older at the time of the study.

In the questionnaire, participants were asked to rank 11 production practices from the least important (1) to the most important (11) with regard to their impact on insect pollinator health for both food crops and landscape plants. Specific question wording was as follows: “When considering landscape plants grown for aesthetic purposes, please rank the following production practices from least important (1) to most important (11) in regard to their impact on insect pollinator health,” and “Rank the following food crop plant production practices from least important (1) to most important (11) in regard to their impact on pollinator health.” The production practices were developed by researchers from consulting with green industry (i.e., horticulture) experts and from existing research (Frankie et al., 2005; Gabriel and Tschamtko, 2007; Kiester et al., 1984; Morandin and Winston, 2005). The list of production practices are related to production location (i.e., grown in a greenhouse and grown outside), production method (i.e., grown using organic practices, grown using IPM strategies, and grown using conventional practices), pesticide use (i.e., grown using natural pesticides, grown using organic pesticides, grown using synthetic pesticides, and grown without pesticides), and pollinator use (i.e., grown using commercial honey bees and grown using native pollinators). No additional information was provided to participants about the definitions of the production methods. Thus, they relied upon their own perceptions of what the production methods meant. Specific production method definitions can be viewed in Supplemental Appendix 1. The production practices were randomized to eliminate any order effect. In addition, standard sociodemographic questions were included in the survey. All of the

questions and experimental procedures were approved by the Institutional Review Board.

U.S. consumers were surveyed in Jan. 2015. Upon completion of the questionnaire, participants were compensated with online rewards points (distributed by Qualtrics). Of the 2766 people who started the survey, 1243 (45% of all respondents) completed the questionnaire, passed the validation question (which read as: “to ensure you are reading the statements, please select four as your answer”), and were included in the analysis.

Econometric model. Stata/IC 11 Software (StataCorp, LP, College Station, TX) was used to analyze the data. Because the production practices were discrete and ordinal, an ordered probit model was used to assess consumers’ perceptions. Each production practice was assigned a level of importance. The levels ranged from “1” being the least important to “11” being the most important. This method was previously used to successfully identify producers’ levels of importance for cherry traits (Yue et al., 2014a), peach traits (Yue et al., 2014b), apple traits (Yue et al., 2013), and strawberry traits (Yue et al., 2014c).

Following Yue et al. (2013), consumers’ rankings were assumed to depend on their underlying utility derived from their perceptions of the different production practices. Consumers know what their perceptions of the different production practices are with regard to pollinator health; however, the researcher does not. Each participant ranked the production practices based on his or her perceptions of which provided greater benefits (i.e., utility) to pollinators. Assuming that U_{ij} is the utility that participant i obtains from production method j , U_{ij} can be expressed as:

$$U_{ij} = \alpha + \alpha_1 \text{greenhouse}_i + \alpha_2 \text{outside}_i + \alpha_3 \text{organic}_i + \alpha_4 \text{ipm}_i + \alpha_5 \text{conventional}_i + \alpha_6 \text{natural_pesticide}_i + \alpha_7 \text{organic_pesticide}_i + \alpha_8 \text{synthetic_pesticide}_i + \alpha_9 \text{no_pesticide}_i + \alpha_{10} \text{honeybee}_i + \alpha_{11} \text{natives}_i + \beta_1 \text{age}_i + \beta_2 \text{gender}_i + \beta_3 \text{education}_i + \beta_4 \text{income}_i + \beta_5 \text{household}_i + \epsilon_{ij}; \\ i = 1, \dots, 1,243(n)$$

where α_j is the participant i ’s marginal utility from plants grown with the different production practices j ; β_j is the vector of participant i ’s sociodemographic characteristics (including age, gender, education, income, and household size); ϵ_{ij} is the error term not captured by the independent variables which follows a normal distribution (mean zero and standard deviation σ_{ϵ}). To analyze food crop plants and landscape plants separately, two ordered probit regressions were used.

In such specifications, a variable must be excluded from the estimation to avoid perfect

multicollinearity (Greene, 2008). Here, the variable used as the base for estimation was “grown using conventional practices” (i.e., *conventional*). Consequently, all of the coefficient estimates and their significance are relative to conventional production practices. Thus, a significant positive estimate indicates participants place that production practice as more important to pollinator insects’ health than conventional production practices, whereas a significant negative estimate demonstrates less importance than conventional practice. Non-significant estimates are not statistically different from conventional production practices. Marginal effects were also estimated to show the incremental changes in predicted probabilities for the production practices at each ranked importance level.

Results and Discussion

Sample summary. The mean age of participants was 52 years, in which 42% were male (Table 1). Forty-six percent of participants had completed their bachelor’s degree or higher at the time of the study. The 2013 average household income was \$58,570. The mean household size was between 2 and 3 people, and 67% were in a relationship or married. Compared with the U.S. population, the study participants were older and had a higher percentage of females (U.S. Census Bureau, 2014). This is consistent with core plant consumers and may reflect the study topic and screening questions (Mason et al., 2008). People who had obtained a higher level of education were under-represented in the sample.

Food crop production practices. Food crop plants are dual-purpose products that can be used for aesthetic and consumption purposes. The ordered probit model estimates for food crop plants are shown in Table 2. The significance is relative to respondents’ perceptions of conventional production practices’ impact on pollinator insect health. When considering the broad topic categories, pesticide use was the most impactful, followed by production location, pollinator use, and then production method. Overall, consumers perceived *grown without pesticides* as the most beneficial to pollinators, followed by *grown outside*, *grown using native pollinators*, organic practices, natural pesticide use, organic pesticide use, and commercial

honey bee use. IPM strategies and synthetic pesticide usage were perceived as less beneficial to pollinators than conventional production practices.

Within the pesticide use category, consumers perceived pesticide-free (as indicated by the “grown without pesticides” option) production practices as the most beneficial to pollinators (Table 2). They also perceived the use of natural and organic pesticides as more beneficial to pollinator insects than conventional production practices. Conversely, the use of synthetic pesticides was viewed as the most detrimental to pollinator insects’ health when compared with conventional production practices. Because pesticides (i.e., insecticides) are often used to control insect pests (Pimentel, 2005), likely respondents intuitively connect pesticide use to poor insect health. They may have also heard of large garden retail centers (e.g., Home Depot) phasing out purchasing plants grown using certain pesticides (i.e., neonicotinoids) that may be detrimental to pollinator insects (Drotleff, 2015). Consequently, respondents likely connected reduced pesticides or “safer” pesticides (i.e., organic or natural) as being less hazardous to pollinator insects. Often the terms “organic” and “natural” are perceived as “safer” than conventional products (Campbell et al., 2014, 2015; Saba and Messina, 2003; Thilmany et al., 2006).

Regarding production location, food production plants that were grown outside were perceived as more beneficial to pollinator insects than those grown using conventional production practices (Table 2). Grown in a greenhouse was not significantly different from conventional production practices indicating a similar perceived level of importance with regard to their impact on pollinator insects’ health. Likely respondents viewed plants grown outside as being more accessible to pollinator insects than plants grown within structures.

When considering pollinator use, respondents perceived the use of native pollinators as more beneficial to pollinator insects than conventional production practices (Table 2). The use of commercial honey bees was also perceived as more beneficial than conventional production practices. These results are not surprising because the use of pollinator insects in production indicates that the plants being produced are beneficial (i.e., nutrient

sources) to pollinators because they are required during production. In addition, if pollinator insects are used to grow the plants, the firm’s other production strategies are less likely to harm pollinator insects because the firm would not want to harm the pollinator insects they are currently using.

Different production methods were perceived to have varying levels of impact on pollinator insect health as well (Table 2). Organic practices were perceived as the most beneficial production method when compared with conventional practices. Conversely, IPM strategies were viewed as negatively impacting pollinator health more so than conventional production methods. Similar to the discussion on pesticide usage, organic production methods are often perceived as being more environmentally friendly because of less pesticide usage (Campbell et al., 2014, 2015; Saba and Messina, 2003). Research has also shown that organic production methods benefit pollinator insects through increased biodiversity and bee abundance (Gabriel and Tschamtk, 2007; Morandin and Winston, 2005). Interestingly, although IPM strategies aid pollinators (Kiestler et al., 1984), respondents perceived them as being less beneficial than conventional methods. This may indicate consumer confusion about what IPM strategies encompass.

Marginal effects were used to compare how the predicted probability changed at each importance level (Table 3). Conventional production practice was used as the base for comparison. In the production location category, outside production had an increasing probability of selection (0.039 to 0.134) for the highest rankings (i.e., 9 to 11 range) when compared with conventional production. Greenhouse grown was not significantly different from conventional production. Regarding production methods, organic production had an increasing probability of selection (0.035 to 0.107), whereas IPM had a decreasing probability of selection (−0.007 to −0.012) for the highest rankings (9 to 11). For pesticide use, no pesticide use, natural pesticides, and organic pesticides had increasing probabilities of selection (0.043 to 0.185, 0.030 to 0.083, and 0.016 to 0.036, respectively) for the highest rankings (9 to 11), but synthetic pesticide use had a decreasing probability of selection (−0.052 to −0.072)

Table 1. Sociodemographic statistics of U.S. consumers from a 2015 survey ($n = 1,243$).

Description		Sample Mean	U.S. ^a Mean
Age	Age (in years) of participant	51.605	37.6
Gender	1 = male 0 = female	0.421	0.490
Education	Highest level of education completed 1 = Bachelor’s degree or graduate school/degree 0 = otherwise	0.460	0.509
Income	2014 gross household income	\$58,570	\$51,939
Household	Number of people in household	2.599	2.54
Relationship	1 = in relationship or married 0 = otherwise (divorced or separated, single, and widowed)	0.672	0.501 (only married, does not include “in a relationship”)

^aSource: U.S. Census Bureau (2014).

when compared with conventional production. The use of honey bees and native pollinators had increasing probabilities of selection (0.015 to 0.033 for honey bees and 0.035 to 0.109 for native pollinators) for the highest rankings when compared with conventional production. Overall, the marginal effect estimates indicate that pesticide free had a statistically significant increased probability of selection as the most

important production practice to pollinators at each importance level when compared with conventional. Grown outside was next, followed by native pollinators, organic practices, natural pesticides, organic pesticides, and commercial honey bees. Synthetic pesticides and IPM had a decreasing probability of selection. Greenhouse grown was not significantly different.

Landscape plant production practices. Landscape plants are those grown in a landscape primarily for aesthetic reasons. The landscape plant ordered probit model estimates are presented in Table 4. Regarding the overall categories, production location was the most impactful, followed by pesticide use, pollinator use, and then production method. Overall, consumers perceived grown outside as the most beneficial production practice to pollinators, followed by grown without pesticides, grown with native pollinators, natural pesticides, organic practices, commercial honey bees, and organic pesticides when compared with conventional production practices. Consumers perceived synthetic pesticide usage on landscape plants to be detrimental to pollinator insect health. Grown in a greenhouse and grown using IPM strategies were not significantly different from conventional.

Within the production location category, grown outside was perceived as positively impacting pollinator insect health when compared with conventional production practices (Table 4). Being grown in a greenhouse was not significant indicating a similar level of importance when compared with conventional production practices. Contrary to the food crop plants, the production location category appears to be more important for landscape plants when considering the impact on pollinator health. This may be due to landscape plants primarily being grown for aesthetic purposes (vs. food crop plants also being grown for edible portions), which frequently include flowers (Brand and Leonard, 2001; Kendal et al., 2012). Flowers provide pollinators with nutrient sources (nectar and pollen; Wratten et al., 2012), but only if the pollinator insects can access the flowers. Being grown outside has potential to increase pollinator access to nutrients supplied by the landscape plants, whereas being grown in a greenhouse may limit access because of entry barriers (e.g., screens).

Within the pesticide use category, grown without pesticides was perceived as having

Table 2. Ordered probit coefficient estimates of the perceived importance of food crop production practices with regard to insect pollinator health ($n = 1,243$).

	Coef. (SE)	
Production location		
Grown outside	0.670 (0.041)	***
Grown in a greenhouse	-0.042 (0.041)	
Production method		
Grown using organic practices	0.564 (0.041)	***
Grown using integrated pest management strategies	-0.090 (0.041)	*
Grown using conventional practices	Base	
Pesticide use		
Grown without pesticides	0.848 (0.041)	***
Grown using natural pesticides	0.455 (0.041)	***
Grown using organic pesticides	0.229 (0.041)	***
Grown using synthetic pesticides	-0.851 (0.042)	***
Pollinator use		
Grown using native pollinators	0.571 (0.041)	***
Grown using commercial honey bees	0.210 (0.041)	***
Sociodemographics		
Age	0.000 (0.000)	
Gender	0.001 (0.018)	
Education	-0.000 (0.006)	
Income	0.000 (0.003)	
Household	0.000 (0.007)	
Threshold parameters ²		
_cut1	-1.240 (0.047)	
_cut2	-0.758 (0.046)	
_cut3	-0.420 (0.045)	
_cut4	-0.137 (0.045)	
_cut5	0.121 (0.045)	
_cut6	0.371 (0.045)	
_cut7	0.626 (0.046)	
_cut8	0.901 (0.046)	
_cut9	1.226 (0.046)	
_cut10	1.686 (0.047)	
Number of obs.	13,519	
Log likelihood	-31,220.464	
LR chi ² (15)	2,393.36	
Prob > chi ²	0.0000	

***, **, * indicate significance with P values ≤ 0.001 , 0.010, and 0.050, respectively.

²Cut-off values for the ordered probit model.

Table 3. Estimated marginal effect estimates of the relative importance of food crop production methods for U.S. consumers ($n = 1,243$).

	Ranking (1 = least important; 11 = most important)										
	1	2	3	4	5	6	7	8	9	10	11
Production location											
Outside	-0.060***	-0.061***	-0.052***	-0.041***	-0.029***	-0.016***	-0.001	0.017***	0.039***	0.070***	0.134***
Greenhouse	0.006	0.005	0.003	0.002	0.001	-0.000	-0.001	-0.002	-0.003	-0.004	-0.006
Production method											
Organic	-0.054***	-0.053***	-0.044***	-0.034***	-0.023***	-0.011***	0.002	0.017***	0.035***	0.060***	0.107***
IPM	0.013*	0.010*	0.007*	0.004*	0.002**	-0.000	-0.003*	-0.005*	-0.007*	-0.009*	-0.012*
Conventional	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base
Pesticide use											
No pesticide	-0.069***	-0.072***	-0.064***	-0.053***	-0.040***	-0.024***	-0.006***	0.015***	0.043***	0.085***	0.185***
Natural pesticide	-0.047***	-0.045***	-0.036***	-0.027***	-0.018***	-0.007***	0.004***	0.016***	0.030***	0.049***	0.082***
Organic pesticide	-0.027***	-0.024***	-0.018***	-0.013***	-0.007***	-0.002*	0.004***	0.010***	0.016***	0.024***	0.036***
Synthetic pesticide	0.182***	0.090***	0.044***	0.014***	-0.008***	-0.026***	-0.040***	-0.052***	-0.062***	-0.069***	-0.072***
Pollinator use											
Honey bee	-0.025***	-0.022***	-0.017***	-0.013***	-0.007***	-0.002*	0.004***	0.009***	0.015***	0.022**	0.033***
Native pollinators	-0.054***	-0.054***	-0.045***	-0.035***	-0.024***	-0.012***	0.002	0.017***	0.035***	0.060***	0.109***

***, **, * indicate significance with P values ≤ 0.001 , 0.010, and 0.010, respectively.

Conventional production practices were used as the base for comparison. All marginal effect estimates were statistically significant (P value ≤ 0.050) except "greenhouse grown."

the most positive impact on pollinator health relative to conventional production practices (Table 4). Grown using natural pesticides or organic pesticides were also perceived as having positive impacts on pollinator insects. Conversely, respondents viewed the use of synthetic pesticides on landscape plants as being detrimental to pollinator insect health when compared

with conventional production practices. Although consumers still perceive no pesticides, organic, and natural pesticides as more beneficial to pollinator health than conventional production methods, the pesticide use category was less important on landscape plants than on food crop plants likely due to not being consumed (Yue et al., 2011).

In the pollinator use category, both using native pollinators and commercial honey bees were perceived as being better for pollinator insects than conventional production methods (Table 4). Likely this is due to respondents' intuition that the plants and production methods used to grow those plants are beneficial to pollinators because they are being used in the production practices (as discussed in the food crop plant results section).

Lastly, for the production method category, organic production practices were perceived as being beneficial to pollinator insects' health when compared with conventional production methods (Table 4). IPM strategies were not significant. The perceptions that organic production being safer for pollinator insects may be related to the pesticide use results. Specifically, respondents may perceive organic production as using no or low pesticides and thus having less pesticide residue on the plants which could harm pollinator insects (Campbell et al., 2013; Smed, 2012).

The marginal effect estimates for the landscape plant production practices are shown in Table 5. Regarding production location, outside production had an increasing probability of selection (0.41 to 0.186) for the top rankings (9 to 11) when compared with conventional production. Grown in a greenhouse was not significant. Under the production method category, organically grown had an increasing probability of selection from 0.022 to 0.055 for the top rankings (9 to 11) when compared with conventional, whereas IPM was not significant. Regarding pesticide use, no pesticide, natural pesticides, and organic pesticides had increasing probabilities of selection (0.034 to 0.113, 0.023 to 0.059, and 0.009 to 0.020, respectively) compared with conventional production for the top three rankings. Conversely, synthetic pesticide use had a decreasing probability of selection for the top three rankings (−0.052 to −0.067). Both of the pollinator use categories (honey bees and native pollinators) had increasing

Table 4. Ordered probit coefficient estimates of the perceived importance of production practices for landscape plants with regard to insect pollinator health ($n = 1,243$).

	Coef. (SE)	
Production location		
Grown outside	0.835 (0.042)	***
Grown in a greenhouse	−0.007 (0.041)	
Production method		
Grown using organic practices	0.319 (0.041)	***
Grown using IPM integrated pest management strategies	0.005 (0.041)	
Grown using conventional practices	Base	
Pesticide use		
Grown without pesticides	0.573 (0.041)	***
Grown using natural pesticides	0.337 (0.041)	***
Grown using organic pesticides	0.126 (0.041)	**
Grown using synthetic pesticides	−0.708 (0.042)	***
Pollinator use		
Grown using native pollinators	0.524 (0.041)	***
Grown using commercial honey bees	0.140 (0.041)	***
Sociodemographics		
Age	−0.000 (0.000)	
Gender	0.000 (0.018)	
Education	−0.000 (0.006)	
Income	0.000 (0.003)	
Household	0.000 (0.007)	
Threshold parameter ²		
_cut1	−1.235 (0.046)	
_cut2	−0.773 (0.046)	
_cut3	−0.447 (0.045)	
_cut4	−0.173 (0.045)	
_cut5	0.078 (0.045)	
_cut6	0.322 (0.045)	
_cut7	0.571 (0.045)	
_cut8	0.843 (0.046)	
_cut9	1.165 (0.046)	
_cut10	1.622 (0.047)	
Number of obs.	13,519	
Log likelihood	−31,526.167	
LR chi ² (15)	1,781.96	
Prob > chi ²	0.0000	

***, **, * indicate significance with P values ≤ 0.001 , 0.010, and 0.050, respectively.

²Cut-off values for the ordered probit model.

Table 5. Estimated marginal effect estimates of relative importance of landscape plant production methods for U.S. consumers ($n = 1,243$).

	Ranking (1 = least important; 11 = most important)										
	1	2	3	4	5	6	7	8	9	10	11
Production location											
Outside	−0.073***	−0.070***	−0.061***	−0.050***	−0.038***	−0.024***	−0.007***	0.014***	0.041***	0.083***	0.186***
Greenhouse	0.001	0.001	0.001	0.000	0.000	−0.000	−0.000	−0.000	−0.000	−0.001	−0.001
Production method											
Organic	−0.038***	−0.032***	−0.025***	−0.018***	−0.011***	−0.004***	0.004***	0.012***	0.022***	0.034***	0.055***
Integrated pest management	−0.001	−0.001	−0.000	−0.000	−0.000	0.000	0.000	0.000	0.000	0.001	0.001
Conventional	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base
Pesticide use											
No pesticide	−0.059***	−0.053***	−0.044***	−0.034***	−0.023***	−0.012***	0.001	0.016***	0.034***	0.060***	0.113***
Natural pesticide	−0.040***	−0.033***	−0.026***	−0.019***	−0.012***	−0.004***	0.004***	0.012***	0.023***	0.036***	0.059***
Organic pesticide	−0.017***	−0.013**	−0.010**	−0.007**	−0.004**	−0.001	0.002***	0.006***	0.009***	0.013**	0.020**
Synthetic pesticide	0.148***	0.074***	0.039***	0.015***	−0.003*	−0.018***	−0.031***	−0.042***	−0.052***	−0.062***	−0.067***
Pollinator use											
Honey bee	−0.018***	−0.014***	−0.011***	−0.007***	−0.004**	−0.001	0.003***	0.006***	0.010***	0.015***	0.022**
Native pollinators	−0.055***	−0.049***	−0.040***	−0.031***	−0.021***	−0.010***	0.002*	0.015***	0.032***	0.056***	0.101***

***, **, * indicate significance with P values ≤ 0.001 , 0.010, and 0.010, respectively. Conventional production practices were used as the base for comparison. All marginal effect estimates were statistically significant (P value ≤ 0.050) except "greenhouse grown" and "integrated pest management."

probabilities of selection for rankings 9 to 11 (0.010 to 0.022 for honey bees, 0.032 to 0.101 for native pollinators). Overall, grown outside had a significant increasing probability of selection as the most important production method to pollinators at each importance level when compared with conventional. Grown without pesticides was next, followed by grown with native pollinators, natural pesticides, organic practices, commercial honey bees, and organic pesticides. Synthetic pesticides had a significant decreasing probability of being chosen as the most important production practice to pollinators when compared with conventional. IPM strategies and grown in a greenhouse were not significantly different from conventional practices.

Conclusion

Research has shown that consumers are interested in conserving pollinator insects and plants grown with alternative production practices; however, to date, very few studies investigate consumers' perceptions of production practices with regard to how those products benefit pollinator health. The main objective of this research was to evaluate consumer perceptions of plant production practices that aid or impede pollinator health for aesthetic (i.e., landscape) and food-producing plants. Results indicate that grown without pesticides was perceived as the most beneficial production practice for food crop plants, whereas grown outside (i.e., without a greenhouse-like structure) was the most beneficial for landscape plants. These results are unique in that they demonstrate differences between consumer perceptions based on plant type, supporting our hypothesis. Differences may have occurred because of landscape plants being grown for aesthetic reasons (e.g., flowers) where outside production increases pollinators' access to the nutrients supplied by flowers. Food crop plants are dual-purpose and grown for edible (i.e., fruit, vegetables, and foliage) and aesthetic purposes. As a result, consumers may have viewed them as a source of nutrition for juvenile (i.e., larvae) pollinators. If so, pesticides would likely be used to protect the crops from predatory insects (i.e., pollinator larvae) which would be detrimental to pollinator insects. Alternatively, because the plants produced food for consumption, consumers may have associated pesticide free with being "healthier."

Knowing how consumers perceive different production methods and how that changes by plant type can be used in several ways to assist the green industry as they make production and marketing decisions. First, growers can use this information to align their production methods and product offerings with end-consumer needs. For instance, end consumers are interested in production methods that aid pollinator insects (Wollaege et al., 2015). In this article, outside production was perceived as the most beneficial to pollinators for landscape plants, whereas grown

without pesticides was the most beneficial for food crop plants. Growers specializing in either of these types of plants could adjust their production practices to align with these perceptions and then emphasize them in their companies' promotional messages. Overall, regardless of plant type, many end consumers perceive outside production, low or no pesticide use, organic practices, and using native pollinators in production as beneficial to pollinator insects. Therefore, when economically feasible, growers who specialize in landscape or food crop plants can incorporate these practices into their production strategies and share that information with supply chain members who interact with end customers (e.g., retailers). If these production strategies are already in use, it would be beneficial for growers (and retailers) to promote and market the products as aiding pollinators.

Wholesalers, marketers, retailers, and policymakers could also benefit from this information. For instance, wholesalers and marketers could benefit from sourcing plants that were grown using methods that benefit pollinator insects. They could assist in promoting these products by developing and distributing marketing materials to other supply chain members which emphasize why the product is beneficial to pollinators. Another key implication is that retailers could benefit from in-store promotions emphasizing that the products were produced using pollinator-friendly methods. In-store promotions are essential to inform and educate consumers about pollinator-friendly production methods and products because that information is not readily available simply by viewing a plant (i.e., pollinator friendly and production methods are credence attributes). There is an opportunity to use promotional strategies to connect products to pollinator-friendly attributes and influence consumers' product selection and ultimately demand. Lastly, policy and environmental groups could also benefit from this study. Results provide a base indication of consumer perceptions of various production methods that benefit pollinators. This gives these groups a launching point for educational efforts, labeling strategies, and policy development with respect to production methods that benefit pollinator insects.

Although the results provide interesting insights into consumer perceptions of production methods that aid pollinator insects, several limitations should be acknowledged. First, the study did not incorporate consumers' existing knowledge, awareness, or perceptions of the various production methods and pollinator insects. This information would be valuable in determining factors that influence consumer perceptions of how the various production methods influence pollinator health. Future studies could connect this information to provide additional insights into consumer perceptions of pollinator-friendly production strategies. Another limitation is that the study was conducted using an online survey instrument and thus was subject to bias in sampling (i.e.,

individuals with limited or no internet connection were not included). However, online surveys allow for national data collection, quick responses, and greater sample diversity which compensates for the potential sample bias drawback (McDaniel and Gates, 2010).

Literature Cited

- Brand, M.H. and R.L. Leonard. 2001. Consumer product and service preferences related to landscape retailing. *HortScience* 36:1111-1116.
- Breeze, T.D., A.P. Bailey, S.G. Potts, and K.G. Balcombe. 2015. A stated preference valuation of the non-market benefits of pollination services in the UK. *Ecol. Econ.* 111:76-85.
- Campbell, B., S. Mhlanga, and I. Lesschaeve. 2013. Perception versus reality: Canadian consumer views of local and organic. *Can. J. Agr. Econ.* 61:531-558.
- Campbell, B., H. Khachatryan, B.K. Behe, J.H. Dennis, and C.R. Hall. 2014. U.S. and Canadian consumer perceptions of local and organic terminology. *Intl. Food Agribus. Mgt. Rev.* 17:21-40.
- Campbell, B., H. Khachatryan, B.K. Behe, J.H. Dennis, and C.R. Hall. 2015. Consumer perceptions of eco-friendly and sustainable terms. *Agr. Resource Econ. Rev.* 44:21-34.
- Cox, W. 2012. New U.S. urban area data released. 9 Dec. 2014. <<http://www.newgeography.com/content/002747-new-us-urban-area-data-released>>.
- Diffendorfer, J.E., J.B. Loomis, L. Ries, K. Oberhauser, L. Lopez-Hoffman, D. Semmens, B. Semmens, B. Butterfield, K. Bagstad, J. Goldstein, R. Wiederholt, B. Mattsson, and W.E. Thogmartin. 2014. National valuation of monarch butterflies indicates an untapped potential for incentive-based conservation. *Conserv. Lett.* 7:253-262.
- Drotleff, L. 2015. The Home Depot says no to neonics. *Greenhouse Grower, Business Management.* 28 Oct. 2016.
- Fairbrother, A., J. Purdy, T. Anderson, and R. Fell. 2014. Risks of neonicotinoid insecticides to honeybees. *Environ. Toxicol. Chem.* 33:719-731.
- Frankie, G.W., R.W. Thorp, M. Schindler, J. Hernandez, B. Ertter, and M. Rizzardi. 2005. Ecological patterns of bees and their host ornamental flowers in two northern California cities. *J. Kans. Entomol. Soc.* 78:227-246.
- Gabriel, D. and T. Tschamtkke. 2007. Insect pollinated plants benefit from organic farming. *Agr. Ecosystems and Environ.* 118:43-48.
- Gallai, N., J.-M. Salles, J. Settele, and B.E. Vaissiere. 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecol. Econ.* 68:810-821.
- Greene, W.H. 2008. *Econometric analysis*. 6th ed. Prentice Hall, Upper Saddle River, NJ.
- Hanley, N., T.D. Breeze, C. Ellis, and D. Goulson. 2015. Measuring the economic value of pollination services: Principles, evidence and knowledge gaps. *Ecosyst. Serv.* 142:137-143.
- Hawkins, G., S.E. Burnett, and L.B. Stack. 2012. Survey of consumer interest in organic, sustainable, and local container-grown plants in Maine. *HortTechnology* 22:817-825.
- Hovhannisyan, V. and H. Khachatryan. 2016. Household level demand analysis of ornamental plants in the United States. *Agribusiness Intl. J.* doi: 10.1002/agr.21488.
- Kendal, D., K.J.H. Williams, and N.S.G. Williams. 2012. Plant traits link people's plant preferences to the composition of their gardens. *Landsc. Urban Plan.* 105:34-42.
- Khachatryan, H., Suh, D.H., G. Zhou, and M. Dukes. 2016. Sustainable urban landscaping:

- Consumer preferences and willingness to pay for turfgrass fertilizers. *Can. J. Agr. Econ.* doi: 10.1111/cjag.12129.
- Kiesling, F.M. and C.M. Manning. 2010. How green is your thumb? Environmental gardening identity and ecological gardening practices. *J. Environ. Psychol.* 30:315–327.
- Kiester, A.R., R. Lande, and D.W. Schemske. 1984. Models of coevolution and speciation in plants and their pollinators. *Amer. Nat.* 124:220–243.
- Klein, A.-M., B.E. Vaissiere, J.H. Cane, I. Steffan-Dewenter, S.A. Cunningham, C. Kremen, and T. Tschamtko. 2007. Importance of pollinators in changing landscapes for world crops. *Proc. Royal Soc.* 303–313.
- Kuepper, G. 2010. A brief overview of the history and philosophy of organic agriculture. 9 Dec. 2014. <<http://kerrcenter.com/wp-content/uploads/2014/08/organic-philosophy-report.pdf>>.
- Lusk, J.L., L.O. House, C. Valli, S.R. Jaeger, M. Moore, J.L. Morrow, and W.B. Traill. 2004. Effect of information about benefits of biotechnology on consumer acceptance of genetically modified food: Evidence from experimental auction in the United States, England, and France. *Eur. Rev. Agr. Econ.* 31:179–204.
- Mason, S.C., T.W. Starman, R.D. Lineberger, and B.K. Behe. 2008. Consumer preference for price, color harmony, and care information of container gardens. *HortScience* 43:380–384.
- McDaniel, C., Jr. and R. Gates. 2010. Marketing Research with SPSS. Wiley, Hoboken, NJ.
- McIntyre, N.E. and M.E. Hostetler. 2001. Effects of urban land use on pollinator (*Hymenoptera: Apoidea*) communities in a desert metropolis. *Basic Appl. Ecol.* 2:209–218.
- Morandin, L.A. and M.L. Winston. 2005. Wild bee abundance and seed production in conventional, organic, and genetically modified canola. *Ecol. Appl.* 15:871–881.
- Mwebaze, P., G.C. Marris, G.E. Budge, M. Brown, S.G. Potts, T.D. Breeze, and A. Macleod. 2010. Quantifying the value of ecosystem services: A case study of honeybee population in the UK. 12th Annual BIOECON Conference 'From the Wealth of Nations to the Wealth of Nature: Rethinking Economic Growth', Venice, Italy.
- Murray, T., C. Miles, and C. Daniels. 2013. Natural insecticides: A Pacific Northwest Extension publication. PNW649. 14 Dec. 2014. <<http://agresearch.montana.edu/wtrc/producerinfo/entomology-insect-ecology/Biopesticides/NaturalInsecticides.pdf>>.
- National Gardening Association. 2013. The National Gardening Association's comprehensive study of consumer gardening practices, trends, and product sales. National Gardening Association Inc., Williston, VT.
- National Pesticide Information Center. 2016. Organic Pesticide Ingredients. 1 Oct. 2016. <<http://npic.orst.edu/ingred/organic.html>>.
- National Resource Conservation Service. 2005. Native Pollinators. Fish and Wildlife Habitat Management Leaflet 34:1–10.
- O'Hara, B. 2010. The burbs and the bees: Improving native bee habitat in the suburban landscape. University of Guelph, Guelph, ON, Canada.
- Pimentel, D. 2005. Environmental and economic costs of the application of pesticides primarily in the United States. *Environ. Dev. Sustain.* 7:229–252.
- Rihn, A. and H. Khachatryan. 2016. Does consumer awareness of neonicotinoid pesticides influence their preferences for plants? *HortScience* 51:388–393.
- Rihn, A., H. Khachatryan, B. Campbell, C. Hall, and B. Behe. 2016. Consumer preferences for organic production methods and origin promotions on ornamental plants: Evidence from eye-tracking experiments. *Agr. Econ.* 47(6):599–608.
- Saba, A. and F. Messina. 2003. Attitudes toward organic foods and risk/benefit perception associated with pesticides. *Food Qual. Prefer.* 14(8): 637–645.
- Schimmenti, E., A. Galati, V. Borsellino, C. Ievoli, C. Lupi, and S. Tinervia. 2013. Behaviour of consumers of conventional and organic flowers and ornamental plants in Italy. *Hort. Sci.* 40:162–171.
- Smed, S. 2012. Information and consumer perception of the "organic" attribute in fresh fruits and vegetables. *Agr. Econ.* 43(s1):33–48.
- Templeton, S.R., D. Zilberman, and S.J. Yoo. 1998. An economic perspective on outdoor residential pesticide use. *Environ. Sci. Technol.* 32(17):416A–423A.
- Thilmany, D.D., W.J. Umberger, and W.J. Ziehl. 2006. Strategic market planning for value-added natural beef products: A cluster analysis of Colorado consumers. *Renew. Agr. Food Syst.* 21(3):192–203.
- Uematsu, H. and A.K. Mishra. 2012. Organic farmers or conventional farmers: Where's the money? *Ecol. Econ.* 78:55–62.
- U.S. Census Bureau. 2014. Top. Cogn. Sci. 17 Mar. 2015. <<http://www.census.gov/topics.html>>.
- U.S. Government Publishing Office. 2015. Electronic Code of Federal Regulations. 30 Nov. 2015. <http://www.ecfr.gov/cgi-bin/textidx?c=ecfr&sid=3f34f4c229aa8e6d9864cc2683cea02&tpl=/ecfrbrowse/Title07/7cfr205_main_02.tpl>.
- U.S. EPA. 2016a. Federal Pollinator Health Task Force: EPA's Role. 27 Oct. 2016. <<https://www.epa.gov/pollinator-protection/federal-pollinator-health-task-force-epas-role>>.
- U.S. EPA. 2016b. Introduction to integrated pest management. 1 Oct. 2016. <<https://www.epa.gov/managing-pests-schools/introduction-integrated-pest-management>>.
- Williams, P.R.D. and J.K. Hammitt. 2001. Perceived risks of conventional and organic produce: Pesticides, pathogens, and natural toxins. *Risk Anal.* 21(2):319–330.
- Winfree, R., R. Aguilar, D.P. Vázquez, G. LeBuhn, and M.A. Aizen. 2009. A meta-analysis of bees' response to anthropogenic disturbance. *Ecol.* 90:2068–2076.
- Wollaeger, H.M., K.L. Getter, and B.K. Behe. 2015. Consumer preferences for traditional, neonicotinoid-free, bee-friendly, or biological control pest management practices on floriculture crops. *HortScience* 50:721–732.
- Wratten, S.D., M. Gillespie, A. Decortye, E. Mader, and N. Desneux. 2012. Pollinator habitat enhancement: Benefits to other ecosystem services. *Agr. Ecosystems and Environ.* 159: 112–122.
- Yue, C., J.H. Dennis, B.K. Behe, C.R. Hall, B. Campbell, and R.G. Lopez. 2011. Investigating consumer preference for organic, local, or sustainable plants. *HortScience* 46:610–615.
- Yue, C., K.R. Gallardo, J. Luby, A.L. Rihn, J.R. McFerson, V. McCracken, D. Bedford, S. Brown, K. Evans, C. Weebadde, A. Sebolt, and A.F. Iezzoni. 2013. An investigation of U.S. apple producers' trait prioritization - Evidence from audience surveys. *HortScience* 48:1378–1384.
- Yue, C., K.R. Gallardo, J. Luby, A.L. Rihn, J.R. McFerson, V. McCracken, N. Oraguzie, C. Weebadde, A. Sebolt, and A.F. Iezzoni. 2014a. An evaluation of U.S. tart and sweet cherry producers trait prioritization: Evidence from audience surveys. *HortScience* 49:931–937.
- Yue, C., K.R. Gallardo, J. Luby, A.L. Rihn, J.R. McFerson, V. McCracken, T. Gradziel, K. Gasic, G.L. Reighard, J. Clark, and A.F. Iezzoni. 2014b. An evaluation of U.S. peach producers' trait prioritization: Evidence from audience surveys. *HortScience* 49:1309–1314.
- Yue, C., K.R. Gallardo, J. Luby, A.L. Rihn, J.R. McFerson, V. McCracken, V.M. Whitaker, C.E. Finn, J.F. Hancock, C. Weebadde, A. Sebolt, and A.F. Iezzoni. 2014c. An evaluation of U.S. strawberry producers trait prioritization: Evidence from audience surveys. *HortScience* 49:188–193.

Supplemental Appendix 1. Definitions of various production methods.

Production method	Definition
Grown in a greenhouse	The plants or products were grown inside a greenhouse structure. Greenhouses are constructed of glass, plastic, polyethylene, or some other material, and the temperature, air circulation, and irrigation are controlled.
Grown outside	The plants or products were grown without a greenhouse-like structure. Irrigation and fertilization are provided as needed but the plants are more exposed to the local climate (e.g., temperature and rainfall) than those produced in a greenhouse.
Grown using organic practices	Organic practices were used in production. The overall goals of organic practices are to mitigate and correct soil problems (erosion and depletion), improve biodiversity, foster resource cycling, balance ecological services, and be grown without synthetic or prohibited substances (pesticides and fertilizers), genetic modification, ionizing radiation, sewage sludge, antibiotics, growth hormones, and nonorganic agricultural substances (Kuepper, 2010; U.S. Government Publishing Office, 2015).
Grown using IPM strategies	IPM strategies were used in production. IPM strategies focus on using multiple control methods (e.g., pest trapping, heat and cold treatments, physical removal, and pesticide application) based on site-specific information to control pests in an environmentally friendly manner (U.S. EPA, 2016b). IPM strategies prevent pest infestations by inspecting, monitoring, and reporting pest levels and taking corrective actions when needed.
Grown using natural pesticides	Natural pesticides were used in production. Natural pesticides can be chemical, mineral or biological in nature and are used to reduce insect, fungi, and other predator damage on crops (Murray et al., 2013). The term “natural” is not regulated by the government but often conveys a sense of “wholesomeness and safety” to consumers (Murray et al., 2013). Consumers often confuse “organic” and “natural” terms (Murray et al., 2013).
Grown using organic pesticides	Organic pesticides were used in production. Organic pesticides are typically not manmade and contain natural substances (National Pesticide Information Center, 2016). Organic production does not allow all natural chemicals (e.g., arsenic and tobacco) (National Pesticide Information Center, 2016).
Grown using synthetic pesticides	Synthetic pesticides were used in production. Synthetic pesticides are those that are manmade and manufactured.
Grown using commercial honey bees	Commercial honey bee hives were used in production to pollinate the plants. Pollination is often required when producing food crops [e.g., 70% of the world’s food crops depend upon pollinator insects (Klein et al., 2007)].
Grown using native pollinators	Native pollinators were used during production. Native pollinators are “adapted to local climate conditions, soils, and plant life” reducing their management and maintenance needs (National Resource Conservation Service, 2005). They include flies, beetles, butterflies, moths, bees, birds, bats, and small mammals.
Grown using conventional practices	Conventional production practices were used during production. Conventional production practices can use any commercially available product during production (including organic, natural, and synthetic pesticides and fertilizers). Often consumers perceive conventional production practices as the opposite of organic production practices (Williams and Hammitt, 2001).

IPM = integrated pest management.