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Grower perceptions of native pollinators and pollination strategies in the lowbush blueberry industry

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Abstract

Pollinator declines and dependence on insect pollination, particularly in fruit and vegetable crops, creates a pressing need to understand growers' interactions with pollinators and factors affecting pollination strategies. At present, many growers are dependent on commercial honey bees (*Apis mellifera*), but diversified strategies may be necessary to secure adequate crop pollination in the future. As of yet, little social science research exists on pollination practices. This article presents the results of a survey of lowbush blueberry growers in Maine. The survey was part of a five-year pollination security study focusing on four fruit and vegetables crops in the Northeast US. The survey assesses grower perceptions of native pollinators' effectiveness and their perceptions of native pollinators' contribution to fruit set. Results indicate a widespread perception among growers of native pollinators' importance. While native pollinators are not effective enough to replace rented honey bees for three-quarters of the industry, they are broadly seen as an important form of insurance in poor weather when honey bees' effectiveness is reduced. The main obstacle to greater utilization of native pollinators found in this study was uncertainty over native pollinators' contribution to yield and the associated difficulty monitoring native pollinators' population size. Scientists and extension experts must work to reduce these obstacles before more widespread use of native pollinators will occur.

Key words: pollination, perceptions of pollinators, agricultural diversity, Maine agriculture, blueberries

Introduction

Pollinator declines around the world have raised concerns about the sustainability of current crop pollination practices[1,2]. In the US, Colony Collapse Disorder (CCD) and the rising price of commercial honey bees are a threat to farmers[3–5]. Both wild pollinators and commercially raised honey bees have experienced declines[6,7]. Pollinators' economic value has been placed at over US$200 billion worldwide[8], and while this ecosystem service is difficult to measure, many common crops are completely dependent on insect pollination, including many fruits and vegetables[2]. Some crops are self-pollinated and others are wind pollinated, including most grains, but insects pollinate about 75% of crop species worldwide to some degree and roughly one-third of all crops species are wholly dependent on insect pollination[9,10]. In the US, commercial honey bees' contribution to crop pollination is valued at approximately US$14 billion annually and over 35% of US crops by value receive some degree of insect pollination[11,12]. US acreage dependent on pollinators is also increasing[13,14]. Native pollinators increase the diversity and stability of crop systems[15–17], and given the importance of insect pollination and the instability of commercial and wild pollinator populations, there is a need to understand the obstacles to adopting practices beneficial to native pollinators.

This paper reports on a survey of pollination practices and perceptions of the effectiveness of native pollinators in the lowbush blueberry (*Vaccinium angustifolium*) industry. It is part of a larger, US Department of Agriculture (USDA)-funded, interdisciplinary project involving a team of researchers, including entomologists, toxicologists, landscape ecologists, anthropologists and economists at several universities in the Northeast US. The project's goal is to enhance pollination security by improving use of both native pollinators and honey bees, focusing on apples, cranberries, blueberries and cucurbits (pumpkin and squash). The latter three crops are native

US species, which means they co-evolved with native pollinators, and apples have a long residency in the region. All four are close to 100% dependent on insect pollination[11]. This combination makes the crops likely candidates for greater use of native pollinators as a way to enhance pollination security through diversification of pollination sources.

While there is a growing literature on the economics of pollination[12,18], there are few studies of factors affecting growers' pollination strategies[19–22]. An extensive literature on adoption of agricultural crops, technologies and techniques shows the importance of factors such as values, attitudes and perceptions[23–25]. The survey presented here examined growers' perceptions of native pollinators' effectiveness and their certainty about native pollinators' contribution to yield. More fundamentally, it assessed whether perceptions of effectiveness and uncertainty are obstacles to greater use of native pollinators. 'Greater use' means anything from attempting to increase native pollinator populations to relying on them for a greater contribution to yield, and greater use of native pollinators is usually accomplished in combination with commercial honey bees, not as a replacement for them. Growers are less likely to use native pollinators more extensively, or implement conservation strategies for them, if they see them as ineffective or are uncertain of their contribution to yield.

Case Study: Lowbush Blueberries in Maine

Lowbush blueberry is particularly interesting because it is a little-altered native plant, many of whose natural pollinators are still present. Blueberries are one of Maine's most valuable crops, with an annual yield averaging 33.7 million kg sold for an average value of US$45.1 million per year over the past decade, and with a direct and indirect impact of US$250 million in Maine[26]. Blueberries are divided into highbush and lowbush, with highbush being much more widespread and lowbush being geographically limited mostly to Maine and neighboring Canada. The highbush blueberry has numerous cultivars, whereas lowbush blueberry is essentially an uncultivated, semi-wild crop. Cultivars have been developed, but these are very rarely used[27]. Instead, lowbush blueberries are not planted; forest is cleared and they colonize cleared areas. Growers reduce the pH of cleared fields with sulfur to encourage colonization by lowbush blueberries and to inhibit growth of competitor plants. Fields need to be weeded after establishment and growers manage on a 2-year cycle, mowing or burning their fields every other year to keep plants compact, reduce weeds, and encourage fruiting in the second, harvest year. Lowbush blueberry is thus highly unusual in that it is an unimproved, unplanted crop. Maine growers take advantage of this by marketing their product as a 'wild blueberry.'

Lowbush blueberries are 100% insect pollinated[28], therefore, an insect must pollinate a flower for it to produce fruit. The blueberry flower is an upside down oval tube, preventing pollen exchange by wind. Although flies and wasps do provide some pollination, bees provide almost all lowbush blueberry pollination[28]. Over 210 bee species are native to Maine and over 75 have been found on lowbush blueberry[29]. However, a given field may have only a dozen or so bee species that are important and these species vary from field to field.

Most lowbush blueberry growers use commercial honey bees (*Apis mellifera*) for pollination, although some use bumble bees (*Bombus impatiens*), which are more efficient on a bee-per-bee basis but more expensive and live in much smaller colonies[29–31]. Leafcutter bees (*Megachile rotundata*) have also occasionally been used in the past. The use of commercial honey bees in the Maine lowbush blueberry industry has increased significantly, from around 500 colonies in 1965 to over 60,000 in 2000[32]. The annual yield for the state has grown from 6.8 to 24.0 million kg over the same period, while harvested acreage only expanded from about 12,000 to 18,000 hectares[33]. Other factors have contributed to yield gains, but greater pollination from increased commercial honey bees has certainly played an important role[32]. Honey bee hive prices have increased recently, however, and are a concern for growers[34]. Not all growers use commercial bees. Many rely exclusively on native pollinators and others use both commercial and native bees to varying degrees.

Methods

The survey of Maine wild blueberry growers aimed to understand views of 'early adopters' that will first use innovations in pollination science[35]. It contained 34 questions in four sections covering four themes: pollination practices, grower perceptions of native pollinators, economics of pollination, and grower and farm characteristics. It asked about practices for that year (2012) except where growers needed to provide information for the past 2 years (2011–2012) for a 2-year crop (e.g., honey bee rentals were combined for the past 2 years). The survey was conducted at the 'Wild Blueberry Summer Field Day,' hosted by the University of Maine Cooperative Extension at Jonesboro, ME on July 18, 2012. The Summer Field Day is the largest grower meeting devoted to blueberries in Maine. Growers attend extension meetings to keep current on agricultural science and to earn pesticide credits needed to maintain licenses. Surveys were distributed to all of the approximately 50 US growers in attendance and completed in a 20-min time slot during the meeting. Forty-eight surveys from US growers were returned. Twenty-nine additional surveys were completed by growers who did not attend this meeting but who did attend other extension meetings

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Table 1. Grower and farm characteristics, Maine lowbush blueberry, 2012.

Grower and farm characteristics	*N*	Mean
Years growing blueberries	76	24
Percent time at paid work growing blueberries	70	40
Percent of income from blueberries	69	28
Number of extension meetings attended annually	72	2.8
Yield (average past 10 years)	67	3012 kg ha^{-1}
Price (2011 crop)	65	US$3.44/kg
Hectares managed	77	172 ha
		Percentage
Vocational/technical degree or higher	74	69
Pest management style	77	
IPM		60
Organic		17
Traditional		18
No-spray		5

Table 2. Grower pollination strategies, Maine lowbush blueberries, 2012. ($N = 77$).

Pollination strategy	Percentage
Rent honey bees	77%
Own honey bees	18%
Rent bumble bees	23%
Own bumble bees	16%
Honey bee stocking density (mean, $N = 61$)	5.7 hives ha^{-1}
Actions to improve native pollinator populations	
Leaving deadwood standing	68%
Alerting pesticide use to aid native pollinators	63%
Avoiding mowing wildflowers	55%
Using nest boxes or other nesting items	22%
Planting wildflowers for pollinators	15%
One or more of the above strategies	86%
Other actions	
Limit floral competition during bloom by cutting wildflowers or trees	18%
Renting fewer bees due to pollination from neighbor's hives	18%

in 2012. These were collected individually and the growers were chosen through purposive sampling to make the survey more representative. The 77 total respondents possessed similar demographic and farm characteristics to the most recent industry-wide mail survey (Rose 2010)[34] characterizing Maine blueberry growers. Both the present survey and Rose (2010)[34] likely over-sampled growers who are early adopters of recent pollination science, as these are the individuals who are likely to complete voluntary surveys and attend extension meetings.

The National Agricultural Statistics Services (NASS) lists 577 lowbush ('wild') blueberry farms in Maine from the 2007 Census of Agriculture, but this includes landowners who do not manage their land and lease it to a grower, which is a common practice. Cooperative Extension's Maine blueberry specialist estimates there may be 500 growers who manage land, with companies considered as 'one' grower (David Yarborough, pers. comm.). The present survey therefore had responses from no less than 15% of growers. However, respondents reported managing 13,000 hectares, and as the NASS lists 18,200 hectares of lowbush blueberry in Maine, the survey covered over 70% of the crop's total acreage[33]. Larger growers are thus overrepresented, and as they rent more honey bees than smaller growers the survey likely reports higher levels of commercial bee use than would be the case in a random sample of growers[34].

Results

Grower and farm characteristics

Table 1 presents results for the survey's five questions concerning grower characteristics and four concerning farm characteristics. Years growing blueberries is highly variable among the sample population, ranging from 1 to 75 years. However, 51% of respondents have been growing blueberries for more than 20 years. Fifty-three percent of respondents spend 25% or less of their time at a paid job growing blueberries. Sixty-four percent of respondents make less than 25% of their annual income from blueberries and only 12% of respondents make more than 75% of their income from blueberries. Although responses were highly varied, the majority of respondents can be characterized as educated growers who regularly attend extension meetings, and who have long experience in the industry but who spend more time and make more money on other enterprises.

Pollination strategies

Table 2 presents results of survey questions on growers' pollination strategies. Despite honey bees' proven value[32], 23% of growers surveyed did not rent or own commercial bees. Of the remaining 77% who relied on rented or owned commercial bees to some extent, the majority, 66%, said that 100% of their land is pollinated with rented or owned commercial bees. None of these growers relied exclusively on their own beehives; all rented commercial bees. All growers who indicated that they do not rent commercial bees for pollination manage 10.1 hectares (25 acres) of blueberries or fewer. This is consistent with Rose (2010) who found that larger growers tend to be 'high input' growers[34]. Fifty-one percent said they stock between 2.5 and 6.25 honey bee hives per hectare and 19% stock more than 6.25 hives per hectare. Stocking density was calculated by dividing

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Table 3. Growers' perceptions of native pollinators, Maine lowbush blueberries, 2012.

Question	*N*	Responses
How important do you think native bees are for pollinating blueberries in Maine?	76	Very important: 61% Somewhat important: 33% Neither important nor unimportant: 0% Somewhat unimportant: 4% Very unimportant: 3%
What percent of your fruit set do you feel comes from native bees?	*Growers who rent bees* $N = 60$ *Growers who do not rent bees* $N = 17$	*Growers who rent bees* Range: 5–80% Mean: 27% *Growers who do not rent bees* Range: 40–100% Mean: 82%
What percent decrease in fruit set do you think you would see if you rented no bees?	46	*Grower who rent bees* Range: 12–95% Mean: 52%
What percent increase in fruit set do you think you would see if you rented bees?	15	*Growers who do not rent bees* Range: 0–300% Mean: 50%
How would you rate the habitat for native pollinators with a half-mile of your fields?	77	Very good: 17% Good: 40% Fair: 39% Poor: 4% Very poor: 0%
How often would you get sufficient fruit set from native pollinators alone?	*Growers who rent bees* $N = 58$ *Growers who do not rent bees* $N = 16$	Never: *Renters* 66%; *Non-renters* 6% 1 year in 4: *Renters* 9%; *Non-renters* 6% 2 years in 4: *Renters* 14%; *Non-renters* 13% 3 years in 4: *Renters* 5%; *Non-renters* 31% Every year: *Renters* 7%; *Non-renters* 44%
Monitoring the size of my native pollinator population would be easy to do.	76	Strongly agree: 5% Agree: 20% Neither agree nor disagree: 46% Disagree: 28% Strongly disagree: 1%
Identifying native pollinators in my fields would be difficult to do.	76	Strongly agree: 4% Agree: 18% Neither agree nor disagree: 21% Disagree: 47% Strongly disagree: 9%

total hives used by total acres pollinated per year. Thirty percent of growers who rent or own commercial bees indicated that they use commercial bumble bees. The average stocking density for bumble bees was 1 quad per hectare. Bumble bees are sold in 'quads' where each field unit contains four hives.

To determine if stocking density was being affected by the rising price of hives, a honeybee hive demand and demand elasticity analysis was conducted. Demand elasticity is defined as the responsiveness of changes in quantity demanded to changes in price. The analysis showed that growers' hypothetical consumption of hives, while influenced by a range of price level scenarios (US$40, US$120, US$200, US$280), is not responsive to current rental rates facing Maine growers, which are between US$90 and US$150 at present. Hive stocking density is also not affected by current price levels. The demand elasticity for honeybee hives is highly inelastic with an elasticity coefficient of 0.1. This confirms the initial hypothesis that honey bee hives are essential to many blueberry growers in Maine for commercial production due to relatively few substitutes (i.e., bumble bee quads) and constituting a manageable (at least for now) proportion of both costs and revenues.

The final pollination strategy the survey asked about was grower actions to improve native pollinator populations. Eighty-six percent of growers practiced at least one of the five methods for improving native pollinator populations listed in the survey, which indicates that growers see native pollinators as valuable. The most common strategies were those where growers avoid taking an action, whereas the less common methods involved active creation of something. This suggests that future scientific advice requiring

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avoidance strategies will be adopted more readily than recommendations based on more labor- or land-intensive management.

Perceptions of native pollinators as potential obstacles to adoption

Table 3 presents results of survey questions pertaining to growers' perceptions of native pollinators. The survey sought to assess how growers perceive the effectiveness of native pollinators and their contribution to fruit set to determine whether such perceptions were an obstacle to more extensive utilization of native pollinators. Ninety-four percent of growers responded that native pollinators were either *somewhat important* or *very important* for pollinating blueberries in Maine. Growers were also asked under what conditions they thought native bees were important. Responses were grouped into themes. The most common circumstance reported was weather (47%). Lowbush blueberries in Maine bloom for about one month in late April to May, a period with frequent inclement weather. Honey bees fly less or not at all in wet, cold weather, and so poor weather conditions can greatly reduce their effectiveness. Twenty-one percent of respondents stated that native bees are always important. Between 8 and 11% percent stated that native bees were important for each of the following: ecosystem health, when cost becomes a concern, and as an insurance or supplement to honey bees. Only 5% responded that native bees are important due to CCD. Growers may have also given a high rating to native pollinators' importance because: they know that many growers do not rent bees; they know others rent *Bombus impatiens*, a native species; because lowbush blueberries are a native plant; or because scientists have provided 10 years of outreach on native pollinators to the industry.

Growers were asked what percentage of their fruit set they believed came from native pollinators. 'Fruit set' is a term for the number of flowers that set fruit and it is a more accurate measure of pollination than yield because fruit is often damaged or lost prior to harvest. A number of growers relying on native bees, and renting no commercial honey bees or bumble bees at all, answered that 100% of their fruit set came from native bees. However, most (59%) perceived that a lower percentage (between 40 and 99%) of their fruit set came from native bees. Presumably these growers felt their neighbors' honey bees accounted for the additional percentages. Responses from growers renting commercial bees indicate that they see native pollinators as a valuable source of pollination with a significant impact on yield. The average perceived decline in fruit set if these growers rented no bees indicated that these growers believe that if they reduced their reliance on commercial bees, native bees would be able to meet an even larger amount of their pollination needs than they currently do. This could be due to a perception of reduced competition between native and managed honeybees or to an unwillingness to think pessimistically about a worst-case scenario. Either way, native bees represent an important form of insurance in the minds of most bee-renting respondents.

Among growers who rent commercial bees, most respondents reported being uncertain of their perception of percentage of fruit set from native bees. When viewed together with the responses on the fruit set contribution from native bees, this shows that although growers saw native pollinators as a valuable source of pollination, they were generally uncertain or lacked knowledge regarding the significance of native pollination services. Uncertainty is thus a potential obstacle to greater use of native pollinators.

Growers reported positive views of the native pollinator habitat surrounding their fields, and therefore growers' perception of habitat quality is not an obstacle to greater utilization of native bees. Future research will assess the accuracy of grower perceptions against the project's findings to judge whether growers are overly optimistic about their adjacent pollinator habitat.

Another potential obstacle to greater utilization of native pollinators is growers' ability to identify them in the field and monitor their population size. When asked about the two processes, most growers responded that identification would be easy to do but monitoring population size would be difficult. Growers routinely identify insect pests in their fields, so this is most likely the basis for their view that identification of native pollinators would not pose a problem. However, monitoring native pollinators' population size is seen as difficult and represents a much greater potential obstacle than pollinator identification. Growers were also asked if they currently monitored their native pollinator populations in any way and 35% responded that they did.

To assess growers' perceptions of variability, the survey asked how often growers expected to get sufficient fruit set from native pollinators alone. While almost every grower who did not rent bees felt they could sometimes receive sufficient pollination from native pollinators, there was a significant number who felt this was not always possible due to annual population variability. Most growers who rent bees answered that they would never receive sufficient pollination from native bees, which is expected given their higher yields. Native pollinator populations vary from year to year, and these results show that both groups of growers are aware of this. Interestingly, since 34% of growers who rent bees did respond that native bees would provide sufficient pollination in some years, it appears that these growers see annual variation as an obstacle to greater reliance on native bees.

Lastly, growers were able to provide written comments expressing their concerns about pollination. These comments were coded into broad themes. Nearly one-third of growers (31%) were concerned that weather will impact

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their crop pollination. Additionally, 23% percent were concerned about bee health, citing such threats as CCD. Twenty-three percent were also concerned about the quantity of bees available in the coming years. Twenty percent were concerned that they will not get adequate yield or fruit set and 16% percent are worried about the rising cost of renting bees.

Conclusions

One of the most important findings from this survey is that there is no barrier to use of native pollinators based on perception of pollinator effectiveness. Improved use of native pollinators can diversify pollination sources as a way of building security[15–17], and it can include everything from improving habitat or nesting sites to relying on them for a greater percentage of fruit set. At present, 93% of respondents see native pollinators as important, but perhaps more significant is commercial bee renters' view of native pollinators as an insurance policy. The 77% of growers who rent honey bees perceive that native pollinators are contributing 27% of fruit set now and could potentially contribute as much as 48% if they were unable to rent bees. Poor weather was the main concern and main circumstance in which native pollinators were seen as useful, indicating that this native bee insurance policy is especially important to commercial bee renters in cold, wet springs. Enhancing these current contributions, and this critical insurance policy, makes sense and explains why 86% of growers reported attempts to increase pollinator populations. It is important to note though, that 77% of respondents rent bees and price is not yet affecting their rentals substantially due to the highly inelastic demand for honey bee hives. Honey bees are more manageable and have been proven to reliably increase yields[28], and in the largest fields where alternative floral resources are scarce, sufficient pollination without honey bees is likely impossible. The survey results suggest that the overall perception of native pollinators among respondents who rent commercial bees is that they are valuable contributors now, and are especially important as an insurance policy in poor weather, but not a viable replacement for honey bees.

Despite their perceived usefulness, uncertainty seems to present the main obstacles to greater native pollinator use in this study. Growers reported a great deal of uncertainty over native pollinators' contribution to fruit set, and related to this, growers responded that monitoring pollinator population size would likely prove difficult. These findings raise the question of why growers would decide to invest time, effort or money into improving native pollinator populations if they are unable to obtain a clear sense of how these investments will impact yield. Indeed, while growers reported widespread adoption of easier avoidance-based strategies to improve native pollinator numbers they also reported less use of strategies requiring more money, time and effort (i.e., the building and planting strategies). Both uncertainty over fruit set and perceived ease of monitoring may be changeable, however. One of the major goals of the larger pollination security project will be to develop much-needed tools for growers to more accurately assess their pollinator population size, and factors affecting growers' adoption of these tools will need to be studied carefully.

This study raises a number of questions for future research. As the survey sought to sample early adopters of science pertaining to native pollinator utilization, it was biased toward that sub-population and did not represent the majority of growers. Growers who are 'late adopters' or who are less enthusiastic about innovations in pollination science may have quite different perceptions and may face a different set of obstacles, which the social science team hopes to explore later in the project. Another question is whether growers in Maine's 'wild' blueberry industry see pollinators and their habitat more favorably than growers in more developed landscapes or with more cultivated crops. The pollination security project will look at three other crops in New England to answer this question. In addition, growers need to be able to make more accurate assessments of the native pollinator habitat surrounding their fields, and the pollination security project is developing tools for growers to do this. Growers' adoption of these tools, and the accuracy of their habitat perceptions, will be important social science research questions moving forward.

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