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Status of IPM Practice Adoption in Vermont Apple Orchards in 2017

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Abstract

Apples are among the most important agricultural crops produced in Vermont. Despite research on and advances in IPM implementation in northeastern U.S. apple systems, pesticide applications remain a primary practice. Adoption of IPM implementation by Vermont apple growers was evaluated in a 2017 survey. Questions covered topics including farm demographics, self-reporting of IPM knowledge and status, relative importance of arthropod posts and diseases, practices that impact pollinators and crop pollination, use of electronic IPM decision support systems, scouting practices used in orchards, and tolerance of pest damage on fruit sold to alternative markets. Respondents reported apple scab (*Venturia inaequalis* ((Cooke) Wint.) and fire blight (*Erwinia amylovora* (Burrill)) as their most important diseases and apple maggot (*Rhagoletis pomonella* (Walsh)) and codling moth (*Cydia pomonella* (L.)) insect pests of concern. A mean 10.9 and 5.7 fungicide and insecticide applications were made to manage pests and diseases. Growers reported high adoption of pollinator protection practices, and over half of respondents reported reliance of wild pollinators. All respondents used the regional NEWA decision support system and rated its usefulness highly overall. However, on-farm pest monitoring programs showed lower levels of adoption, and respondents indicated a lack of comfort with protocols for monitoring certain key pests. Survey response information may be useful in tailoring educational and outreach materials to improve IPM practice adoption and reduce grower risk.

Keywords: survey, farmer perception, pollinator protection, decision support systems, pest damage tolerance.

Background

Apples are the second-most economically valuable specialty crop in Vermont, with annual farm gate crop value of $12-20 million US generated from approximately 1600 acres of orchards in the state (Vermont Sustainable Jobs Fund 2013, NASS 2016). Because apples are a perennial crop and orchards typically are continuously cropped for two decades or more, and possibly up to a century, pest management programs cannot rely on crop rotation as a regular practice. Over eighty each of insect pests and diseases of tree fruit are present in the northeastern U.S. (Agnello et al. 2006, Northeast IPM Tree Fruit Working Group 2016), and many of them if left unmanaged may destroy an entire crop. Although the New England tree fruit industry is historic and well-established, changes in orchard systems, cultivars grown, invasive and exotic pests, pesticide registrations, pest and disease resistance development to pesticides, and increased disease pressures as a response to climate change require constantly newer pest management strategies to avoid significant crop loss (Bradshaw 2013, Cooley et al. 2013, Simmons et al. 2014, Cooley et al. 2015, Cox 2015). As the effects of climate change have become more evident at the farm-level in the past decade, increasing pest and disease pressures have become one of the greatest concerns for farmers in one recent study (Niles et al. 2013). Implementation of IPM programs ideally includes orchard monitoring, weather data collection, use of pest models, pollinator protection, and pest damage tolerance considerations, and these complex and often interacting components may present challenges to increasing adoption of advanced IPM systems that reduce pesticide inputs while maintaining or improving crop quality and quantity.

Apple growers have long been among primary users of pesticide inputs in northeastern U.S. agricultural systems. Merwin and Pritts (1993) outlined several components of modern orchard production systems that affect overall system sustainability. While several factors including a general lack of soil-disturbing tillage, low fertilizer requirements, and cultural heritage were identified as improving sustainability of fruit production systems, the reliance on pesticides for crop protection was highlighted as reducing sustainability. Since the 1970s, tree fruit growers have used IPM protocols to manage disease, insect, and weed pests while maintaining fruit quality and minimizing chemical inputs (Whalon and Croft 1984). Practices used in apple IPM programs include: insect and disease modelling to time management practices and minimize unnecessary pesticide applications; disease resistant cultivars; scouting programs that quantify pest and beneficial predator populations; orchard sanitation to reduce disease, insect, and weed pest inoculum; and orchard architecture and training systems to more efficiently manage pests within the planting (MacHardy 2000). Increased IPM adoption presents several benefits to farmers, consumers, and the environment. In grapes and peaches (both perennial crops with similar pest management needs to apples and other tree fruit), farmers who followed IPM principles applied fewer insecticides and fungicides than non-IPM adopters, while maintaining or increasing crop yield and/or productivity (Fernandez-Cornejo 1998, Fernandez-Cornejo and Ferraioli 1999). In a survey of New York apple growers after approximately one decade of IPM implementation in that state, IPM adopters reduced chemical applications substantially and improved profitability on their farms (Kovach and Tette 1988).

Within the United States, farmer attitudes, monitoring techniques, cost effectiveness, source and credibility of information, farmer age and education all positively influence IPM adoption (Waller et al. 1998). The majority of work on tree fruit IPM was conducted in the 1980s and 1990s before the prevalence of digital information sources, social media, and the Internet (for example: (Kovach and Tette 1988, Fernandez-Cornejo et al. 1994, McDonald and Glynn 1994, Fernandez-Cornejo and Castaldo 1998, Hubbell and Carlson 1998)). This is a major limitation of existing literature as increasingly, information sources are myriad (Lubell et al. 2014) and with the increased use of the Internet and social media, farmers may also be utilizing novel technologies and resources for assessing and understanding pest management issues and adoption of on-farm practices.

The implementation of IPM is dependent on knowledge of constantly changing orchard conditions, including crop and pest phenology, pest populations, beneficial insect and pollinator activity, previous pesticide applications, cultural management, and weather. Extension-based crop management guides may provide recommendations and options for IPM implementation (Bradshaw et al. 2017), but leave the complex task of actually integrating several types of data into an IPM decision to the grower. New England tree fruit growers have begun to use decision support systems to make this task easier. Presently, these systems combine past and forecast weather data with pest management models to advise growers regarding the risk presented by important diseases and insect pests, and when an application is likely to be most effective, treating problems only when they present potential economic risk, insuring that high risk periods are recognized, minimizing negative impact on pollinator insects and other beneficial organism, and avoiding pesticide drift and optimizing coverage in the tree canopy.

The Cornell Network for Environment and Weather Applications (NEWA) has been active in New York since 1995, and Vermont joined the network in 2010 (Carroll 2013). Presently, there are 17 NEWA sites in Vermont consisting of both on-farm and airport weather stations providing site-based weather data and pest and horticultural model output to growers. Specific data and model outputs that are useful to apple producers include: weather data (e.g., daily and hourly observations, degree day calculations); disease (e.g., apple scab (*Venturia inaequalis* ((Cooke) Wint.) ascospore maturity and infection potential, fire blight (*Erwinia amylovora* (Burrill)) infection potential); insect pests (e.g., codling moth (*Cydia pomonella* (L.)), plum curculio (*Conotrachelus nenuphar* (Herbst)) and other pest's life cycle models); and horticultural parameters (e.g., irrigation scheduling, carbohydrate deficit prediction). In prior unpublished surveys, Vermont growers have rated the NEWA system highly, but specific measurements for use of the system have never been published in the literature.

The University of Vermont (UVM) Apple Program (UVMAP) has provided support to industry partners for over 100 years through research and outreach services that address grower needs. Similar to many institutions, UVM faculty and staff dedicated to providing IPM support services has declined with the loss of state and federal funding (Gadoury et al. 2009) but the UVMAP still provides IPM and related support services including electronic communications, site visits, meetings and workshops, and diagnostic services to state and regional growers (Chandran 2014, Bradshaw 2017a, b). Grower communications by UVM faculty and staff rely heavily on output from the NEWA system and observations made through formal monitoring of UVM apple orchards in South Burlington, VT, since direct and regular observations of commercial orchards in the state are limited by time and budgetary constraints. IPM communication notices typically are sent at weekly intervals during the first half of the active apple growing season (approximately from April to mid-July), with more irregularly scheduled notices (2-3 per month) generated during the remaining part of the year. Since 2011, all support for IPM outreach has been provided with limited, competitive funding, and with Extension support via the UVM Plant Diagnostic Clinic (Bradshaw 2013). The intent of this research is to ascertain grower uses of IPM information and adoption of IPM practices in order to further guide program efforts for the future.

Survey Methods

A survey was developed by the UVMAP to quantify adoption rates of certain IPM practices in Vermont apple orchards. Survey questions were divided generally into topical sections covering implementation of use of particular IPM practices, including self-certification of IPM adoption; use of available IPM support output from UVMAP; identification of pests of importance; number of pesticide applications made against particular pests; implementation of pollinator protection practices; use of electronic NEWA in IPM implementation; orchard monitoring practices used; programming recommendations to increase adoption and effectiveness of orchard monitoring programs; and use of increased pest damage tolerance suited to particular fruit markets.

The survey was advertised on the UVMAP electronic communications list on January 17, 2017, and a follow-up announcement made January 27. Queried growers were instructed to submit one response per farm. The survey was closed on February 1. Survey responses were collected online via Survey Monkey (www.surveymonkey.com) in order to preserve subject anonymity. The survey was determined exempt from human subjects oversight by UVM Institutional Review Board under project CHRBSS: 17-0299. Responses were checked for completeness, and one incomplete survey was removed from the dataset because it contained only qualitative responses and did not answer the majority of survey questions. Of the remaining responses, not all questions were answered, so total *n* for each response is not equal. Responses were exported into Microsoft Excel for descriptive statistical analysis, no further data processing was performed.

Survey Results and Discussion

Response rate and respondent demographics.

Fifteen responses were collected through the survey. Presently, the 'VT Apple Grower' email list maintained by the UVMAP includes 154 stakeholder subscribers, which suggests a response rate of under 10%. However, list subscribers include multiple managers or employees from a single farm, other regional academic and Extension faculty, home orchard hobbyists, and nursery professionals. The Vermont Tree Fruit Growers Association includes membership of 35-40 farms in any given year which represents the majority of commercial orchards in the state, and indicates that potentially 30-40% of commercial Vermont orchards responded to the survey. All but one respondent was from Vermont (Table 1), with that respondent being from neighboring Massachusetts. That grower subsequently contacted program staff and is located within twenty miles of the state border and within a shared watershed, and thus the farm was considered a Vermont orchard for the purposes of the survey. Growers reported a mean of 32.6 years of commercial orchard production experience, and a range of 8-99. For the maximum value, it is assumed that the grower selected the largest value available in the survey instrument to indicate that their farm had produced apples commercially for 100 years or more, which would be reasonable for a multi-generation farm as is common in the Vermont apple industry (Bradshaw 2013). Mean orchard acreage was 57.4, with a range of 2-225 and a median of 32. The difference between mean and median for this parameter reflects the bifurcated nature of the industry, in which a small number of large producers grow the majority of commercially-produced fruit in the state and a large number of smaller farms produce fruit primarily for pick-your-own and other direct to consumer markets. This characteristic has also been identified in prior industry surveys (VTFGA 2011, Becot et al. 2016). Also, the total combined reported orchard area was 861 acres, which accounts for approximately half of the commercial orchard acreage in the state. Therefore, it is assumed that the respondents, while arguably low in number, represent a reasonable representative sample of apple growers in Vermont.

General IPM practices used and the value of IPM education by growers.

Few respondents (15.4%, Table 2) used certified organic practices in their orchards, which is not surprising considering the documented difficulties (e.g., high insect and disease pest pressures, low crop yields, and biennial bearing tendencies) with producing apples commercially using such practices, especially in the Midwest and eastern U.S., (Friedrich et al. 2003, Delate et al. 2008a, b, Merwin and Peck 2009, Peck et al. 2010, Cromwell et al. 2011, Granatstein et al. 2014, Bradshaw et al. 2016a, b, Bradshaw et al. 2016c, Peck et al. 2017). All respondents reported using IPM on their farms. In this survey, IPM was intentionally not defined, however, the UVMAP and other regional University Extension programs have used the "IPM" designation since the 1980s or earlier, and thus, the term is in common usage among the grower community (MacHardy 2000). All respondents also reported using the UVMAP website to find information, and indicated a high level of use and utility of IPM information reported by the UVMAP, with 92.3% reporting use of the information to make IPM decisions and over 84% reporting that the information was "somewhat" or "highly" useful. Of more tangible importance, all respondents who reported an economic impact of IPM use on their farms (92.3%) indicated that the impact was positive. In a review of impacts of the regional NEWA IPM implementation system by Carroll et. al. (2007), New York apple growers reported savings of over $19,000 per year and avoidance of crop damage in excess of $250,000 per year from use of the service. The NEWA system is integral in UVMAP outreach efforts, and includes not only access to the system for all stakeholders, but also interpreted results sent in timely postings to the UVMAP email list.

Open ended text comments on the value of the information provided by UVMAP to respondents were universally positive. Three of five commenters reported that IPM practices reduced pesticide use on their farms, and another three referenced increased quantity and quality of fruit sold. Two commenters also expressed improved timing of pesticide applications, and one specifically referenced fire blight as a disease that was previously difficult to manage without information provided by the UVMAP.

Most respondents were familiar with the concept of FRAC and IRAC codes and used them in developing IPM programs on their farms (Table 3). These terms reference Fungicide and Insecticide Resistance Action Committees within CropLife International, a consortium of pesticide manufacturers whose charge is to develop and promote strategies to manage development of pest resistance to pesticides (Russell 2009, Sparks and Nauen 2015). As registered pesticides have shifted from primarily broad-spectrum, protectant-based (e.g., preventative and applied prior to pest damage occurrence) materials to more narrow-spectrum, biologically specific materials, the likelihood of resistance development in arthropod and disease pest populations has increased in recent years (Beckerman et al. 2015, Grigg-McGuffin et al. 2015). In one particular case, the development of the sterol-inhibiting (SI) class of fungicides for use against apple scab and other diseases presented a new means of management of that disease because those materials were highly effective in suppressing disease when applied after the initiation of infection as opposed to prophylactically during the growing season. As a result, the 'four-spray SI apple scab program' was promoted in the late 1980s and early 1990s as a means to reduce pesticide applications against scab from eight to twelve applications of protectant materials to four post-infection sprays (Wilcox et al. 1992). As a result of reliance on single-mode fungicides on rapidly increasing populations, SI fungicides were made ineffective within about five years due to resistance development in local *V. inaequalis* populations. Most orchards in Vermont do not have resistant populations (Frederick et al. 2014) because the previous Extension plant pathologist (1983-2014) highlighted in grower outreach materials resistance management as a key factor in pesticide timing and selection during the time that such materials were released and initially used (*Berkett, pers. comm.*). The use of resistance management codes in selecting and using appropriate pesticides by Vermont apple growers is an indicator of effective communication by the UVMAP and other educational programs in recent decades.

Disease and arthropod pests of importance.

Respondents were asked to rank the top five within lists of disease and arthropod pests for their importance in pest management on their farm where 1= the greatest threat, 2= the next greatest, etc (Table 3). Rankings for diseases were largely similar among respondents, with apple scab the highest ranked by all but one, followed by fire blight. Apple scab has long been considered the most important disease of the crop in the northeastern U.S. (MacHardy 1996). Its continued high ranking among important diseases by growers suggests that, despite improvements in management, including orchard sanitation for inoculum reduction; use of expert systems to model ascospore development and predict infection; quantification of potential ascospore dose to time early-season sprays; improved management of fungicide resistance; and development of cultivars with lower susceptibility to the disease (Carisse and Dewdney 2002, Reardon et al. 2005, Holb 2008, Berkett et al. 2009, Biggs et al. 2009, Carisse et al. 2009, Holb 2009, Gessler and Pertot 2012, Clements and Cooley 2013), it will continue to be a significant pest of apple producers in the region for the foreseeable future. Prior to about 2000, fire blight was not typically a serious problem in Vermont orchards, based on previous UVMAP surveys (T.L.B., unpublished data). A combination of changing climate which has brought generally warmer spring weather and a shift toward planting cultivars such as 'Gala' and 'Honeycrisp' which have greater susceptibility to the disease than the historically dominant cultivar 'McIntosh' (Beckerman 2006, VTFGA 2011, Bradshaw 2013) has increased its incidence in recent years. Growers in this survey reported fire blight as the second-most threatening disease of apples on their farms. The remaining listed diseases, including cedar apple rust (*Gymnosporangium juniperi-virginianae* (Schwein)), powdery mildew (*Podosphaera leucotricha* (Ellis & Everh.) Salmon), fruit rots (*Botryosphaeria* spp. and *Colletotrichum* spp.), and sooty blotch (caused by the complex of *Peltaster fructicola* (Johnson, Sutton, Hodges), *Geastrumia polystigmatus* (Batista & M.L. Farr), *Leptodontium elatus* ((G. Mangenot) De Hoog,) and *Gloeodes pomigena* ((Schwein) Colby))- and flyspeck (*Zygophiala jamaicensis* (E. Mason)), did not rank consistently among the respondents. Those diseases of secondary concern are typically controlled while managing apple scab unless a particular cultivar susceptibility or management consideration, e.g., use of scab-resistant cultivars preventing need for fungicides in managing apple scab, indicates specific treatment for those diseases (Rosenberger 2003).

Among arthropod pests, codling moth, apple maggot (*Rhagoletis pomonella* (Walsh)), and plum curculio were among the highest-ranked by respondents (Table 3), followed by mites (*Panonychus ulmi* (Koch) and *Tetranychus urticae* (Koch)), European apple sawfly (*Hoplocampa testudinea* (Klug)), and tarnished plant bug (*Lygus lineolaris* (Palisot de Beauvois)). Despite their presence as a major pest in the mid-Atlantic and, increasingly, southern New England and the Hudson Valley (Leskey et al. 2012) stink bugs including the invasive brown marmorated stink bug (*Halyomorpha halys* (Stål)) were consistently ranked last as a pest of importance. This overall-ranking of arthropod pests was relatively similar as that established in a survey of the Northeast IPM Tree Fruit Working Group (Northeast IPM Tree Fruit Working Group 2016), with the exception that stink bug had a higher ranking among that group of professionals, which includes membership from states where brown marmorated stink bug is a significant agricultural pest.

Apple growers typically manage pests using a number of pesticide applications in addition to cultural and other IPM practices as proscribed in an overall IPM program (Table 4). In this survey, growers applied an average of 10.9 fungicide applications against all disease, with over half targeting apple scab. This is similar to use patterns described in other assessments of IPM programs in New England (MacHardy 2000, Moran et al. 2016). The number of discrete applications made to manage other fungal diseases was variable, and likely reflects choice of specific materials applied during apple scab primary ascospore release that have specific activity against particular diseases while also protecting against scab. For fire blight, which as previously mentioned was not considered a common disease of tree fruit in Vermont as recently as ten to fifteen years ago, all growers reported making applications of pesticides to manage the disease in their orchards (range 1-3 applications). Most growers likely applied a delayed-dormant copper application to reduce overwintering bacterial inoculum, which is strongly recommended by all plant pathologists and IPM specialists in the region (Clements et al. 2015, Cooley et al. 2015). Weather conditions conducive to development of fire blight infection do not occur annually, and modelling, e.g., use of NEWA and other expert systems, and pest alert dissemination via regional outreach programs typically help growers to decide on need to apply an antibiotic during bloom to further manage the disease. In 2016, the year prior to this survey being collected, conditions were highly favorable for disease incidence and thus an effort was made by regional specialists including the UVMAP to encourage growers to treat their orchards in that year. Little damage was reported in orchards that had been treated, but an informal survey of growers indicated that the small number who had conditions for infection but did not treat suffered from disease, which was extensive in some cases.

Growers applied a mean of 5.7 insecticide applications, but standard deviation of 5.4 suggests that the range was wide. Plum curculio received the highest number of treatments (2.3), but the raw data indicated that most growers applied a single or second spray, while two growers applied five and six applications. For other insect pests, between 0.4 and 1.7 pesticide applications were made on average. Many insecticide applications are commonly targeted at multiple target pest species, so the counts for applications made to each may reflect the overall importance of each pest to growers. Questions about relative importance of insect pests and the number of sprays targeted at each mistakenly did not include the same pests in all cases (apple maggot was left off of the 'most important' insect pests question, and stink bugs replaced), and therefore no conclusions can be elucidated between those two questions. Most of the insects listed in both questions have either trap- or degree day-based action thresholds (Clements et al. 2015), which helps growers to identify not only the specific target pest for a particular application, but also to better time applications for maximum efficacy.

In some cases, biological controls may be used to minimize or eliminate pesticide applications in orchards. Against phytophagous mites, growers applied an average of 0.9 horticultural oil treatments and 0.4 miticide applications. This suggests that most growers rely on a single application of early-season oil with infrequent follow-up applications of miticide to manage those foliar sap-feeding pests. This is on contrast to twenty or more years ago, when orchards were commonly-treated with non-oil miticides, but advances in conservation and classical biological control have led to increasing populations of predacious mites, especially *Typhlodromus pyri* and *Amblyseius fallacis*

(Prokopy et al. 1997, Nyrop et al. 1998). Research leading up to the implementation of orchard- and area-wide biological control programs designed to reintroduce these predator species to commercial orchards indicated that two classes of pesticides in particular, EBDC fungicides and pyrethroid insecticides, negatively impacted natural populations of those species, and that organophosphate (insecticide)-resistant mites could be reintroduced from orchards within the region to provide effective control of mite pests in most orchards, except for occasional spot treatments based on quantitative monitoring thresholds (Hardman et al. 1991, Bower et al. 1995, Bostanian et al. 1998, Bostanian et al. 2003). Despite work completed on conserving or promoting generalist predator species for management of other orchard insect pests in the region, limited application of target-specific pesticides remains a critical, if not primary, means of crop protection in apple production (Prokopy 1993, Prokopy et al. 1996, Brown 2012).

Although use of pesticides in northeastern U.S. orchard systems is common, with the implementation of the 1992 U.S. EPA Worker Protection Standard (WPS) and 1996 Food Quality Protection Act (FQPA), many chemical pesticides underwent re-review and a re-registration process which included more strict assessments of risk tolerance for workers and consumers. As a result, pesticide risk to workers and consumers from applications to U.S. orchard crops has dropped substantially (Benbrook 2012). Despite recorded decreases in overall toxicity of pesticide use in orchards, updated registrations including loss of older compounds, development of new materials, changing pest complexes, and management of pest or pathogen resistance development to pesticides has contributed to a stable or sometimes increasing number of pesticide applications made to New England orchards over the past decade (Agnello et al. 2009, Cooley et al. 2013). The nature of many materials applied to orchards has changed as growers have shifted from use of broad-spectrum materials that pose generally greater risk to non-target organisms including humans to more highly-specific compounds that target specific pests and life cycle stages.

Pollinator management and protection

Table 5 presents summaries of responses to questions about orchard pollination and pollinator protection. As a heterozygous flowering/fruiting crop, apples are highly dependent on adequate pollination in order to set a commercial fruit crop. Concerns about pollinator health in and around orchards and other surrounding landscapes has increased with recent evidence of declines in both wild pollinators and in the health of managed honeybee hives (Spivak and Le Conte 2010, Bartomeus et al. 2013, Kennedy et al. 2013). Use of migratory honeybees during bloom is considered routine in the apple industry, yet only 54.5% of growers reported using them in this survey, and one respondent was unsure, possibly indicating that the wording of the question was confusing. The same percentage (54.5%) of respondents reported reliance on wild pollinators for crop pollination, although the questions were not mutually exclusive. Only one respondent reported keeping managed honey bees on the farm year-round, which is understandable because the use of pesticides in IPM programs may be incompatible with on-farm beekeeping unless mitigation measures are considered to reduce bee exposure to chemicals. One grower reported use of nest boxes to encourage on-farm wild pollinator habitat, and 72.7% reported using reduced tillage practices which may improve habitat for ground-nesting pollinator species. However, cultivation is not commonly used in most commercial orchards in the northeast, and it is not expected that growers minimize its use primarily as a means to promote pollinator health.

The paradox surrounding apple pollination and crop protection that producers must manage is that every flower that is desired to develop into a fruit requires beneficial pollinating insects, yet every developing fruit requires protection from damaging insect and other pests. Thus, arguably the most important insects in the orchard ecosystem, pollinators, are highly desired and heavily discouraged within the course of a few days. The window of time between bloom and ‘petal fall’ is quite narrow, and in a given orchard, trees may be in both stages depending on cultivar, elevation, slope aspect, and other factors. The time period after bloom is a critical period for the most common and damaging insect pests, including codling moth, European apple sawfly, and plum curculio in orchards in the northeast U.S. (Clements et al. 2015). All respondents to the survey reported not applying insecticides during bloom, and slightly less than half reported not applying insecticides when no blooming plants were present in the orchard. While a single grower reported use of herbicides to reduce the incidence of flowering weeds in the orchard groundcover to discourage pollinator presence during critical pest management activities, 72.7% reported mowing flowering groundcover prior to insecticide application. In contrast, 27.3% of growers reported promoting flowering groundcover in the orchard, which may be detrimental to pollinators as it attracts them into the orchard when pesticides may be applied, but could promote populations of beneficial predator insect species (Risch et al. 1983, Wyss 1996, Campbell et al. 2017). The promotion of flowering habitat within orchard systems to improve pollinations and pest management services is not completely compatible with some pest management practices including the use of broad spectrum insecticides and insecticides highly toxic to bees (Mogren and Lundgren 2016). However, maintenance of refuge areas that contain diverse, flowering plants at field edges has reduced negative impacts on pollinator health from pesticide application in apple orchards (Biddinger and Rajotte 2015, Kammerer et al. 2015, Joshi et al. 2016), and 27.3% of the respondents in this survey indicated that they did so on their farms.

Specific pesticide material selection to both promote beneficial insects while adequately managing crop pests is a complicated and often-changing task. Neonicotinoid insecticides (NNIs) were developed in the 1990s and promoted as a replacement to broad-spectrum organophosphates, carbamates, and pyrethroids that were either losing registrations for use after FQPA and WPS implementation, or were being replaced by materials deemed less toxic to mammals and other non-target species (Jeschke and Nauen 2008). However, the high efficacy of NNIS against insects at relatively low concentrations and the systemic nature of their movement in plants presents significant potential for adverse effects on pollinators and other beneficial species (Blacquiere et al. 2012). Research on field-level impacts of NNIs and impacts on pollinator health has been primarily focused on annual field crops where application of the insecticide is made to seeds which uptake the pesticide upon germination and growth (Pilling et al. 2013, Thompson et al. 2013, Dively et al. 2015, Rundlof et al. 2015). Other research has generally focused on laboratory assays with sometimes questionable dose treatments that may overestimate impacts of NNIs on pollinator health (Blacquiere et al. 2012, Carreck and Ratnieks 2014).

Despite the lack of scientific certainty on the effects of orchard applications of NNIs and other crop protection materials on beneficial insect populations, growers must protect their crops from damage soon after trees end the bloom period. In this survey, all growers reported avoiding use of NNIs prior to bloom, likely because of potential for harmful residues in nectar or pollen as a result of the systemic nature of NNIs. While 81.8% of respondents reported avoidance of pesticides rated '"highly toxic to bees," only 63.6% reported avoidance of NNIs specifically. Explanations for those questions were intentionally not included in the survey. However, educational materials widely and extensively used by Vermont and surrounding states' growers, including the regional management guide (Clements et al. 2015) and regular newsletters, web postings, and workshops by UVM Apple and surrounding state programs regularly and prominently include information on relative toxicity of materials to bees and other beneficial insects, and growers may incorporate that information into their programs without making a discrete effort when making pesticide applications. Nearly all respondents reported avoidance of the use of demethylase inhibitor fungicides which have recently been implicated as having either direct or synergistic (with NNIs) negative impacts on orchard pollinators (Biddinger et al. 2013, Pettis et al. 2013). However, the results of that work have not been widely disseminated, and all fungicides presently are listed as having 'low' impact on bees in the regional Extension production guide (Clements et al. 2015). Conclusions from responses to that question are therefore difficult to draw.

Decision Support System Use in Implementing IPM

In previous, unpublished stakeholder surveys, the NEWA network and UVMAP's facilitation of its use in Vermont through network support and station maintenance has been highly rated, and is consistently held as among the most important services that UVMAP provides to growers. All respondents in this survey reported familiarity with the system (Table 6), and 80% reported using NEWA at least once per week in making management decisions on their farms; half of those reported using NEWA four or more times per week. This may be explained especially in the mean usefulness rating used in the survey questions where 1= not at all useful and 5= highly useful. Mean respondent rating for "helping to make management decisions for apple scab" was 4.44. In the spring, when ascospores are potentially released from overwintering inoculum over a six to eight week period (MacHardy 1996), timing of fungicide applications is critical to both minimize chemical use and prevent infection. Many commonly-used fungicides against apple scab are protectant materials that must be present in susceptible tissue before an infection occurs, but application too early can result in degradation, dilution by new growth expansion, and weathering prior to infection initiation that can reduce efficacy during infection events. Apple scab infection is a function of available, mature ascospore inoculum, susceptible tissue presence, and leaf wetness and favorable temperatures. The NEWA system integrates those factors and presents a user-friendly output that aids growers in determining whether or not an infection period occurred after a leaf wetting event, as well as a prediction for future infection within five days of the present. Favorable pesticide application windows are dependent on many factors, most notably wind and precipitation conditions, but also on ground conditions, presence of a temperature inversion, and specific orchard characteristics such as proximity to sensitive neighboring locations and time required to spray an orchard prior to infection. Besides helping to time pre-infection fungicide applications, NEWA apple scab models may also help to best determine the severity of infection periods where protectant fungicide coverage was suboptimal. For infection periods where protectant fungicide residue is in question, decision support models may improve timing of post-infection, selective fungicide application to reduce pathogen resistance development to fungicides and improve disease management (Cooley et al. 2013, Beckerman et al. 2015). Fire blight is another disease whose infection potential may be modeled in NEWA. While similar to apple scab in that disease may only occur when susceptible tissue conditions (open blooms or open trauma wounds from hail or other events) is present, conditions for infection from the bacteria may develop more rapidly than scab and may change substantially within the same day based on predicted vs. observed weather. Respondents rated the usefulness of NEWA for managing fire blight as 4.33 overall.

Another highly-rated function of NEWA was the calculation of growing degree days (4.44), which may be applied to multiple models, either those included in NEWA or stand-alone models such as those reported in Extension news bulletins. Codling moth, which had been managed up until approximately the past decade with regular applications of organophosphates, pyrethroids, and other relatively inexpensive broad-spectrum insecticides, is now increasingly managed with more expensive, selective materials including insect growth regulators, insecticidal virus, and mating disruption pheromones (Witzgall et al. 2008, Jones et al. 2010). Such practices and materials require greater information on pest development, and thus, degree-day models coupled with in-orchard scouting procedures have been developed that can predict critical management periods for this pest (Knight and Light 2005). The codling moth management model in NEWA was also highly rated (4.00) by respondents. Overall usefulness of other NEWA models and functions ranged between 3 (neutral) and 4 (somewhat useful), which may reflect that many other pests and management considerations may utilize other information to optimize management practices. However, no NEWA function scored a mean negative (below 3) rating, and the service was rated 4.10 out of 5 for its usefulness in overall orchard management.

Orchard Monitoring

Among the key practices used in IPM is crop and pest monitoring to track pest population and development in comparison to weather conditions and crop phenology. In New England apple orchards, formal, research-based monitoring programs to guide IPM practices have been used since the 1980s (Coli et al. 1985). In recent years, as weather-based monitoring systems like NEWA have seen increasingly utilized by fruit growers (Agnello and Reissig 2010), the implementation of on-farm, regular field scouting as a source of information for use in guiding IPM decisions has potentially decreased. Scouting may be considered the primary monitoring method used in orchard systems, and typically includes regular, methodical assessment of pest populations through trapping and visual crop assessment by trained workers in order to assess pest populations against known action thresholds, life cycle models, or other information which may guide management decisions (Moon and Wilson 2009). Among the respondents to this survey, half reported scouting weekly using traps and sampling of foliage and fruit to monitor pests (Table 7), 30% reported scouting as needed but using traps and foliar and fruit sampling, and 20% reported scouting as needed using general observations. No respondents reported that they did not scout at all in their orchards.

However, despite most growers reporting at least some level of scouting their orchard using traps and other quantitative sampling methods, many did not report trapping specific pests that have established methods and thresholds for management. The insect pest most-trapped in Vermont orchards was apple maggot fly, which 70% of respondents monitored with traps, followed by codling moth, at 60%. All other pests listed were monitored with traps by less than half of respondents. Respondents reported a range of comfort levels with scouting protocols for key insect pests. While only one respondent reported they were 'not at all comfortable' with protocols for management of only one pest, codling moth, the data skewed toward 'neutral' regarding comfort with protocols for monitoring all insect pests listed. In no case were more than 33% of respondents 'very comfortable' with scouting protocols for any pest.

When provided a list of potential resources that may improve or enhance adoption of scouting programs on grower farms, two general trends were apparent (Table 8). Growers rated practices on a 1-5 scale (1= not at all useful; 2= somewhat useful; 3= neutral; 4= often useful; 5= highly useful), and two practices, "weekly postings via newsletters or blogs of scouting activities on area farms" and "access to an IPM consultant (at no cost to [the grower]) to assist in developing a scouting program" were rated 4.75 and 4.88, respectively. Other support practices with mean rating above 4 included "explanations of best scouting practices at winter meetings" (4.13) and "online descriptions of scouting protocols and step-by-step methods for implementation" (4.38). Listed practices with mean ratings below 4 included: "a one-time on-farm training in deploying a scouting program", "a seasonal on-farm training program at my farm or one near mine", and "access to an IPM consultant (paid by [the grower]) to assist…in developing a scouting program."

Table 9 presents mean response values for changes in market and resulting tolerance for cosmetic blemishes that may affect IPM implementation. Most growers (70-90%) reported sales via alternative markets (compared to wholesale fresh fruit) and dispensation routes, including pick-your-own, farm stand, and cider sales. Among those that reported using those markets, 40% reported reducing both insecticide and fungicide applications and eliminating applications of pesticides targeted solely at pests that cause cosmetic damage. Half of all respondents reported —selling culled fruit from packing house grading lines to cideries; managing blocks of dessert cultivars specifically for cideries; and managing blocks of specialty cider cultivars specifically as cider apples. Although not defined in the question, the management of fruit intentionally as cider apples indicates that fruit are managed from the beginning of the season with the intention of selling to cideries, as opposed to managing for production of maximum yield of higher-valued dessert fruit and selling the lower-quality grades for cider. The management and marketing strategy specific for cideries has been discussed at multiple venues since 2014 attended by most cider apple producers in the state (outlined at http://go.uvm.edu/cidermtgs) and thus is not likely to be misunderstood by the respondents. Among the growers that reported selling apples to cideries (n=7), 71-86% adjusted labor practices by harvesting all fruit from trees at once ('stripping') or adjusting grading standards in the field, as opposed to the commonly-used practice of selectively picking highest quality fruit multiple times during harvest. No growers reported using mechanical harvest for cider fruit. Fifty-seven percent of respondents reduced both fungicide and insecticide inputs in apples grown for cider, but only 29% reduced labor costs by reducing or delaying pruning activities.

Conclusions and Practical Implications

Metrics for assessing adoption of IPM practices on farms are relevant for crediting farmers for adopting conservation measures, for assisting service providers to adapt and develop appropriate training and support programs, and for regulators to provide guidance for policy making that affects farmer livelihood. Commercial producers of apples are reliant on IPM programs to produce sufficient quantity and quality of annual, marketable crops. After forty-plus years of development, IPM in northeastern U.S. apple production is considered a 'mature' system, but, as it is based within a changing crop and pest complex, will always require innovation to maximize its benefits to farmers, consumers, and the environment. Respondents in this survey selfreported a high rate of IPM use on their farms, and answers to subsequent questions generally affirmed that characterization to be accurate. Few respondents practice certified organic management of their orchards, but adoption of advanced IPM practices is arguably more sustainable for perennial, pest-ubiquitous production systems like those used for growing apples in the humid/wet northeastern U.S.

Specific pests of concern for Vermont apple growers were similar to previous surveys, which indicates that, generally, regardless of the specific farm, the pest complex in the region is stable and relatively predictable. This has allowed for development of biologically-based, information-intensive management models whose use have been promoted in outreach communications and through automated, online decision support systems. Growers report a high level of use and utility of the NEWA system. However, orchard-level scouting programs were not fully implemented by most growers, and for many specific pests, growers reported low levels of comfort with scouting protocols. For apple maggot fly where scouting was most-used to make IPM decisions, specific characteristics of its management likely increased implementation. Apple maggot fly is an easily-identified, relatively-large (i.e., viewable without magnification) insect, and traps used in monitoring are easily handled and unique to that pest. It is present in most Vermont orchards to at least some degree, but the variability in its population levels makes it a pest that is not always necessary to manage in every orchard or in every year. Because the use of organophosphate insecticides with long residual activity has declined following implementation of FQPA, apple maggot is typically managed separate from other insect pests as opposed to the complex of pests managed at petal fall or soon after when a broad-spectrum insecticide is commonly used against multiple target pests. If appropriately timed by use of monitoring traps, one or two applications of an insecticide with relatively low non-target impacts may manage this pest in most orchards.

In contrast, prebloom pest insects were monitored less frequently by survey respondents. Many such pests, including European apple sawfly and tarnished plant bug, may also be sufficiently managed at petal fall, but extended bloom period or high populations may increase potential for fruit damage if practices are not applied prebloom. Adjustments to postbloom pesticide application to manage plum curculio or codling moth may also be adjusted to better target those pests' specific management requirements if a prebloom insecticide is applied. The interrelated, somewhat conflicting, and at times complementary needs for managing these insects highlight the complex decision-making process growers face in implementing IPM, especially in the present when broad-spectrum insecticides with long residual effect are decreasing in use.

This indicates that there is need for continued training in orchard monitoring programs. Resources highlighted for improving scouting adoption and usefulness include coordinated postings of weekly scouting activities on farms across the state, access to a public IPM consultant to assist in program implementation, and online instructions for implementation of scouting programs. Such activities will be important to include in UVMAP and other support programs. Metrics for impacts of adoption of orchard scouting programs should be developed to quantify their effect on pesticide use, pest management effectiveness, and farmer quality of life.

Pollination is a critical need in apple production since without fertilization of ovules, there is no fruit. Vermont apple growers reported using several conservation practices at varying levels of adoption to improve pollinator health and abundance, including avoidance of certain pesticide uses at critical times, managing groundcover to improve pollinator habitat, and management of surrounding habitat to increase pollinator populations. These practices were performed in addition to the use of managed bees in most orchards. It was surprising, however, that one-third of growers reported not using managed honeybees for orchard pollination, which suggests that wild or other pollinator populations may be sufficient to provide adequate pollination services for commercial apple production. Further research is necessary to assess diversity and abundance of wild pollinator species in Vermont and their quantitative effects on crop yield and quality.

An important component of IPM that is commonly overlooked is the adjustment of damage thresholds based on market requirements in order to minimize need for pesticide applications. Survey respondents reported high levels of retail and processing markets that may have increased tolerance for fruit damage and therefore, may present opportunity to reduce pesticide use. However, those alternative markets may be complementary to wholesale or other markets that have low tolerance for pest damage, and thus, increasing sales to alternative markets to reduce pesticide use may compromise profitability if the prices paid by processors or direct retail customers are lower than those paid for unblemished fresh fruit. That conclusion was reached by Becot et. al. (2018) where increased sales of fruit from wholesale-market growers to cideries resulted in decreased profitability. A careful assessment of the actual costs of IPM practices compared to potential reduction in farm revenue must be completed before recommending that producers shift markets in order to incrementally reduce pesticide inputs.

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Tables

Table 1. Demographic statistics of survey respondents

	Vermont	Massachusetts			n[a]
In what state are you located?	93.30%	6.7%			15
	Mean	**Median**	**Mode**	**Min**	**Max**
For how many years have you grown apples commercially?	32.6 ± 24.0	25	8	8	99
How many acres of apples do you grow?	57.4 ± 70.8	32	60	2	225

[a]Number of respondents for each question.

Table 2. General IPM management practices by respondents and value of UVM outreach program

	Yes	No	Unsure	n[a]
Do you practice Certified Organic management in any of your orchard?	15.4%	84.6%	0.0%	13
Do you practice IPM in your orchard?	100%	0.0%	0.0%	13
Have you used the UVM Apple IPM webpages to get information?	100%	0.0%	0.0%	12
Have you used the IPM information provided in decision-making?	92.3%	7.7%	0.0%	13
Have the IPM practices that you have implemented had an overall economic impact in your orchard operation?	92.3%	7.7%	0.0%	13
If Yes, has the economic impact produced a (n=12):				
Net economic benefit (i.e., benefit from better yield (quality and/or quantity) and/or reduce risks, etc.)	100.0%			
Net economic loss (i.e., cost outweighed any benefits)	0.0%			
Are you familiar with FRAC and IRAC codes for use in resistance management?	80.0%	20.0%	0.0%	10
Do you use FRAC and IRAC codes in developing your IPM program?	80.0%	10.0%	10.0%	10
Have you found the IPM information (i.e., either the IPM Alerts, articles, presentations, website, and/or one-on-one education) provided by the UVM Apple IPM Program (n=13)				
Highly useful	53.8%			
Somewhat useful	30.8%			
Useful	15.4%			
Rarely useful	0.0%			
Never useful	0.0%			

[a]Number of respondents for each question.

Table 3. Disease and arthropod pests of importance to survey respondents

Rank the most important pests you manage in your orchard (1= greatest threat, 2= next greatest, etc.)		
Diseases	Mean rank	n[a]
Apple scab (*Venturia inaequalis* ((Cooke) Wint.)	1.07	15
Cedar apple rust (*Gymnosporangium juniperi-virginianae* (Schwein))	4.9	10
Fire blight (*Erwinia amylovora* (Burrill))	2.21	14
Fruit rots (*Botryosphaeria* spp. and *Colletotrichum* spp.)	5.17	12
Powdery mildew	4.31	13
Sooty blotch/flyspeck (Multiple spp.; *Zygophiala jamaicensis* (E. Mason))	3.79	14
Arthropods		
Apple maggot (*Rhagoletis pomonella* (Walsh))	2.58	12
Codling moth (*Cydia pomonella* (L.))	2.67	12
European apple sawfly (*Hoplocampa testudinea* (Klug))	4.29	14
Mites (*Panonychus ulmi* (Koch); *Tetranychus urticae* (Koch))	3.92	13
Obliquebanded leafroller (*Choristoneura rosaceana* (Harris))	5	12
Plum curculio (*Conotrachelus nenuphar* (Herbst))	2.85	13
Stink bugs (Multiple spp.)	7	11

[a]Number of respondents for each question.

Table 4. Mean number of pesticide applications made by Vermont apple growers targeted at specific pests

In a typical year, how many pesticide applications do you make to manage the following pests:(Please indicate applications made to manage the primary pest, i.e. an apple scab spray that also targets cedar apple rust would be counted as an apple scab spray).

	Mean[a]	n[b]
All diseases	10.9 ± 6.3	7
Apple scab	6.8 ± 2.6	9
Fire blight	1.6 ± 0.7	9
Cedar apple rust	0.8 ± 1.2	6
Powdery mildew	2.3 ± 1.6	6
Fruit rots	3.0 ± 3.3	6
Sooty blotch/flyspeck	1.8 ± 1.3	6
All insects	5.7 ± 5.4	9
Tarnished plant bug	0.4 ± 0.5	5
European apple sawfly	1.4 ± 1.5	8
Codling moth	1.7 ± 0.7	7
Plum curculio	2.3 ± 1.9	8
Obliquebanded leafroller	1.6 ± 1.9	8
Mites (oil)	0.9 ± 0.6	8
Mites (other miticide)	0.4 ± 0.5	7

[a]Mean number of applications targeted toward a specific pest, ± standard deviation. Applications made targeting multiple pests were recorded for the most important pest for that application.

[b]Number of respondents for each question.

Table 5. Practices employed to improve crop pollination or reduce impacts on pollinators in respondent's orchards

	Yes	No	Unsure	n[a]
Use of migratory honey bees during bloom	54.5%	36.4%	9.1%	11
Keeping honey bees on the orchard property year-round	9.1%	90.9%	0.0%	11
Use of purchased bumble bees in the orchard	20.0%	80.0%	0.0%	10
Reliance on wild bees for pollination	54.5%	45.5%	0.0%	11
Use of nest boxes to encourage wild bee populations	9.1%	81.8%	9.1%	11
Minimum tillage to improve ground bee habitat	72.7%	18.2%	9.1%	11
Not spraying insecticides during apple bloom	100.0%	0.0%	0.0%	11
Not spraying insecticides when any plants are blooming in the orchard	45.5%	45.5%	9.1%	11
Mowing to reduce flowering weeds prior to spraying	72.7%	27.3%	0.0%	11
Herbicides to reduce flowering weeds prior to spraying	9.1%	72.7%	18.2%	11
Maintaining flowering habitat within the orchard to encourage pollinators	27.3%	63.6%	9.1%	11
Maintaining flowering habitat outside but near the orchard to encourage pollinators	81.8%	9.1%	9.1%	11
Avoiding use of neonicotinoid insecticides	63.6%	36.4%	0.0%	11
Avoiding use of neonicotinoid insecticides before bloom	100.0%	0.0%	0.0%	11
Avoiding use of pesticides rated highly toxic to bees	81.8%	18.2%	0.0%	11
Avoiding use of demethylase/sterol inhibitor fungicides (e.g. Inspire, Rally, Procure, etc.) during bloom	90.9%	9.1%	0.0%	11

[a]Number of respondents for each question.

Table 6. Use of Decision Support System in IPM program

	Yes	No
Are you familiar with the Network for Environmental and Weather Applications (NEWA) system managed by Cornell and used by the UVM Apple Program? (n=10)	100%	0%
How often do you use NEWA in making management decisions? (n=10)		
Often (4+ times per week)	40.0%	
Sometimes (once per week)	40.0%	
Rarely (1-2 times per month)	10.0%	
Very rarely (1-2 times per season)	10.0%	
How useful is the NEWA system in helping make management decisions for the following diseases, pests, and horticultural practices: (Scale 1-5, 1= not at all useful, 5= highly useful)	Mean rating	n[a]
Overall orchard management	4.10	10
Apple scab	4.44	9
Fire blight	4.33	9
Sooty blotch and flyspeck	3.88	8
Spotted tentiform leafminer	3.29	7
Oriental fruit moth	3.29	7
Codling moth	4.00	9
Plum curculio	3.88	8
Obliquebanded leaf roller	3.43	7
Apple maggot	3.89	9
San Jose scale	3.63	8
Carbohydrate deficit thinning model	3.56	9
Irrigation deficit	3.25	8
Evapotranspiration	3.38	8
Frost risk	3.71	7
Growing degree day calculation	4.44	9

[a]Number of respondents for each question.

Table 7. Scouting practices used in Vermont orchards

Do you follow a formal scouting program in your orchard (n=10)?					
Yes, I scout weekly for pests and beneficial arthropods using traps and foliar & fruit sampling.	50%				
Yes, I scout as needed for pests and beneficial arthropods using traps and foliar & fruit sampling.	30%				
Yes, I scout as needed by making general orchard observations.	20%				
No, I do not scout	0%				
Other (please specify)	0%				
Do you use traps for monitoring the following insects in your orchard? (n=10):	Yes	No	No answer		
Tarnished plant bug	10%	90%	0%		
Spotted tentiform leafminer	20%	80%	0%		
European apple sawfly	40%	60%	0%		
Codling moth	60%	40%	0%		
Obliquebanded leafroller	40%	50%	10%		
Oriental fruit moth	40%	50%	10%		
Redbanded leafroller	30%	60%	10%		
Apple maggot	70%	30%	0%		
How comfortable are you with protocols for scouting for the following pests (n=9)[a]:	1	2	3	4	5
Tarnished plant bug	0.0%	22.2%	66.7%	0.0%	11.1%
Spotted tentiform leafminer	0.0%	12.5%	75.0%	0.0%	12.5%
European apple sawfly	0.0%	11.1%	55.6%	11.1%	22.2%
Codling moth	11.1%	11.1%	33.3%	22.2%	22.2%
Plum curculio	0.0%	33.3%	33.3%	11.1%	22.2%
Obliquebanded leafroller	0.0%	22.2%	66.7%	0.0%	11.1%
Apple maggot	0.0%	22.2%	33.3%	11.1%	33.3%
Leafhoppers	0.0%	11.1%	55.6%	22.2%	11.1%
European and two-spotted mites	0.0%	22.2%	44.4%	22.2%	11.1%
Aphids	0.0%	22.2%	33.3%	22.2%	22.2%

[a]Rating scale: 1= not at all comfortable; 2= somewhat comfortable; 3= neutral;4= comfortable; 5= very comfortable

Table 8. Potential resources to increase adoption of scouting programs and improve program effectiveness

What resources would best assist you in using a scouting program in your orchard (n=8)?	Mean rating[a]
A one-time on-farm training in deploying a scouting program	3.50
A seasonal on-farm training program at my farm or one near mine	3.63
Weekly postings via newsletters or blogs of scouting activities on area farms	4.75
Explanations of best scouting practices at winter meetings	4.13
Access to an IPM consultant (at no cost to me) to assist me in developing a scouting program	4.88
Access to an IPM consultant (paid by me) to assist me in developing a scouting program	3.63
Online descriptions of scouting protocols and step-by-step methods for implementation	4.38

[a]Rating scale: 1= not at all useful; 2= somewhat useful; 3= neutral;4= often useful; 5= highly useful

Table 9. Increased tolerance for pest damage and defects based on market

Do you grow fruit for the following markets with higher damage tolerance? (n=10)	Yes	No
Pick your own	80%	20%
Farm stand	80%	20%
Bulk/ungraded sales (sales of whole fresh fruit to markets that do not require USDA grading, e.g., some co-ops, organic markets, etc.)	30%	70%
Processing fruit (pies, sauce, etc.)	40%	60%
Cider (sweet)	90%	10%
Cider (fermented)	70%	30%
If you grow for markets with higher damage tolerance, do you: (n=10)	**Yes**	**No**
Reduce insecticide applications	40%	60%
Reduce fungicide applications	40%	60%
Eliminate applications of pesticides targeted at maintaining cosmetic condition (e.g. sooty blotch, flyspeck, tarnished plant bug, etc.)	40%	60%
If you grow fruit intended for cider making, do you: (n=10)	**Yes**	**No**
Sell packinghouse culls to cideries	50%	50%
Sell drops to cideries	20%	80%
Intentionally manage blocks dessert of dessert fruit as cider apples	50%	50%
Intentionally manage blocks of specialty cider cultivars as cider apples	50%	50%
If you intentionally grow fruit for cideries, in order to reduce labor and management costs do you: (n=7)	**Yes**	**No**
Reduce fungicide inputs	57%	43%
Reduce insecticide inputs	57%	43%
Reduce pruning inputs	29%	71%
Strip pick trees to reduce labor costs	86%	14%
Instruct pickers with different picking standards (for color, bruising, etc.) to reduce labor costs	71%	29%
Mechanically harvest fruit	0%	100%