Integrated Cranberry Pest Management

Hilary A. Sandler

INTRODUCTION

Integrated pest management (IPM) was formally introduced to the cranberry industry in 1983 through support of a scouting program by the University of Massachusetts-Amherst. In 2007, estimates indicate private consultants, company personnel, and individual growers combine to scout more than 80% of Massachusetts' cranberries (>10,000 acres). During the past 25 years, IPM has come to mean much more than simply sweep netting for insect pests and installing pheromone traps. Successful modern cranberry growers must have a working knowledge of insect biology, weed ecology, plant physiology, and disease life cycles. They must know how to apply products with novel chemistry, have proficiency with several pesticide-delivery systems, integrate traditional cultural practices into modern horticulture, select new varieties, cost-effectively renovate out-dated farms, and adjust to the pressures stemming from the encroachment of urbanization.

IPM IN MASSACHUSETTS

In Massachusetts cranberry production, IPM involves pest monitoring by using sweep nets, pheromone traps, and visual inspection. Cultural, chemical, and biological control strategies are used to develop a broad-based approach to controlling the most economically threatening pests. Cultural practices, such as flooding, the application of a thin layer of sand, and the use of resistant varieties, can reduce the severity of a pest problem. Pesticides remain a vital part of cranberry IPM programs, tempered by their compatibility with other control measures and their consistency with IPM philosophy. Although economical and logistical constraints often hamper wide-scale adoption, biological controls can be successfully utilized to manage pests in specific situations (Mahr 1999).

Fig. 1. Using a sweep net to monitor for insects. Courtesy J. Mason.

Historically, many cranberry farmers who used IPM could reduce the number of spray applications made in a growing season. More recently, applications of broad-spectrum organophosphates have declined and the use of target-specific, reduced risk compounds has become more prevalent. To achieve efficacy with these newer chemicals, multiple applications are often needed. Thus, the traditional benchmark of success in IPM - reduction in the number of pesticide applications - is no longer appropriate. Success in cranberry IPM in the 21st century will likely be measured by such parameters as seasonal and long-term reduction in pest pressure and damage, promotion of sustainable vine health and crop yield performance, and promotion of environmental stewardship.

HISTORY OF CRANBERRY IPM IN MASSACHUSETTS

Significant federal support for IPM extension, research and field programs began in 1972, with major contributions coming from the EPA, USDA, and the National Science Foundation (National Research Council 1989). Since 1973, IPM administered through the Extension Service has focused primarily on promoting the implementation and development of workable programs among growers' organizations, consultants, and private industry. The IPM program for the Massachusetts cranberry industry was initiated in 1983 at the UMass Cranberry Station, which is part of the College of Natural Resources and the Environment at the University of Massachusetts-Amherst. Subsequently, the Cranberry Station has been looked upon as a leader in the development and dissemination of IPM techniques and information by the cranberry producing regions in the United States, Canada, and other countries.

In its first year, approximately 16 acres were scouted under the UMass IPM program. The number of acres covered by the program peaked in 1985 at just over 600 acres, hovered around 400 acres through the 1989 season, and returned to the initial year's coverage through the early 1990's. Prior to the economic collapse of the cranberry industry in 1999, as many as six private scouting businesses (IPM consultants) provided services for Massachusetts cranberry growers. One of the primary goals of any University-based IPM program is to encourage the adoption of IPM programs by the private sector and to slowly withdrawal from providing scouting services. Progressing along this continuum, the UMass Cranberry Station discontinued its fee-for-service program in 1995. The total number of cranberry acres managed using IPM philosophy has increased in the last two decades from several hundred acres to more than 10,000 acres. Most growers, in Massachusetts and other growing regions in the U.S., scout their farms themselves (Weber 1997). A small segment of growers pay private IPM consultants to scout their farms; costs vary but typically fall between of $75-100 per acre. Persons employed by individual cranberry companies scout the remainder of the acreage.

A basic cranberry IPM program consists of: sweep net sampling for 6-10 weeks; use of pheromone traps for *Sparganothis* fruitworm (*Sparganothis sulfureana*), cranberry girdler (*Chrysoteuchia topiaria*), and black-headed fireworm (*Rhopobota naevana*) moths to aid in the timing of insecticide sprays; inspection of berries in July-August for cranberry fruitworm (CFW; *Acrobasis vaccinii*) eggs; scouting for dodder (*Cuscuta gronovii*) seedlings to time management strategies; use of soil and plant tissue analyses and crop observations to develop and implement nutrient management plans; determination of crop phenology for fungicide and insecticide applications; and mapping of weeds. Maintaining proper sanitation, judicious use of irrigation, planting resistant varieties, and use of various cultural techniques are additional examples of the many components found in an integrated management program for cranberries (Lasota 1990).

A grower survey conducted in 1999 indicated that 80% of Massachusetts cranberry growers identified themselves as frequent IPM practitioners and 16% as occasional practitioners (Blake et al. 2007). Practices frequently used by >75% growers included scouting with sweep net, inspecting fruit for cranberry fruitworm eggs, calculating % out-of-bloom activities (important for CFW management), scouting for dodder seedlings, raking dodder, mowing weeds, sanding, cleaning ditches, and scheduling irrigation to minimize leaf wetness. Most growers practiced IPM because they agreed with IPM philosophy (80%) and believed it had environmental benefits (73%). More than half of all growers who returned surveys were satisfied with its effectiveness and believed that IPM saved money. More than 90% agreed that the use of IPM could reduce pesticide residue in food and the environment and protect beneficial insects.

MANAGING CRANBERRY PESTS IN MASSACHUSETTS

The principle challenge for managing pests in cranberries is simply the vast number of organisms that can cause damage to the vine or the fruit or both. Over 20 insects cause injury to the cranberry and three are direct fruit pests (Averill and Sylvia 1998). Fruit rot is the most serious yield-limiting disease problem for Massachusetts and is associated with more than 10 causal agents (Oudemans et al. 1998; Caruso 2008). The large number of pathogens makes understanding the biology of this disease complex challenging. More than 80 species of weeds have been described by several cranberry researchers (Beckwith and Fiske 1925; Demoranville 1984; Demoranville 1986; Sandler 2004).

Management of these numerous pests combines knowledge of the biology of the pest complex with practical application of control strategies. In practice, IPM is the implementation of pest control strategies founded on ecological principles and biological data that capitalize on natural mortality factors (e.g., natural enemies, unfavorable soil conditions, etc.) while minimizing the disruption of these factors. Pest management revolves around optimizing control, rather than maximizing it. Consequently, current control tactics are aimed at the suppression of a cranberry pest rather than its eradication.

Although many other factors come into consideration, monitoring continues to be the tool by which growers collect information to determine when control decisions should be made. The use of sweep nets, pheromone traps and visual inspections are the main methods by which growers monitor insect populations. Action thresholds (AT) are available for many cranberry insects. The action threshold is a practical estimate of the economic threshold, the density at which control measures should be applied to prevent an increasing pest population from reaching the economic injury level (Stern et al. 1959). AT are typically based upon the average number of insects gathered at a particular sampling time. Examples of AT currently established for insect pests in cranberry production include: 4.5 cutworms, 4.5 cranberry weevils, and 18 spanworms per set of 25 sweeps (Averill and Sylvia 1998).

AT do not exist for weed and disease pests. However, cranberry growers use phenology and other biological indicators to make pest management decisions. For example, weeds are prioritized based on their ability to spread, reduce yield, and susceptibility to control measures (Else et al. 1995). Growers can then make decisions based on the assigned priority level. Weed mapping provides a historical catalogue of weed location, growth, and control over the years. Mapping can help identify populations of weeds that serve as points of invasion into the farm (Sandler et al. 2006). For fruit rot management, growers make fungicide applications based on the percentage of open bloom as well as the keeping quality forecast (KQF). A strong relationship between various weather factors and the quality of fruit was documented in the late

1940's (Franklin 1948) and the KQF procedure has been used to recommend fungicide applications ever since (see Weather chapter).

Chemical control is a critical component of pest management for cranberries. According to a recent summary report, 32 different pesticides were used in Massachusetts in 2003. These included seven fungicides, nine herbicides, and 16 insecticides (J. DeVerna, pers. comm.). Chlorothalonil was the most widely used fungicide (in terms of producing acres that received at least one application), followed by the ethylenebisdithiocarbamate (EBDC) fungicides and the copper fungicides. For postemergence herbicides, glyphosate was applied to 55% of the production area; clopyralid was used on only 8%. The top two preemergence herbicides used were pronamide (46%) and dichlobenil (23%). Diazinon was the most widely applied insecticide (84%), followed by carbaryl (72%) and thiamethoxam (54%).

Chemigation remains the delivery mechanism of choice for insecticides and fungicides in Massachusetts. However, cranberry growers are not reliant solely upon chemical pesticides. Other pest management options are biological control (Mahr 1999), pheromones, cultural management, and nutrient management. Many options require the application of a material, even if it is biological product, such as beneficial nematodes, stomach poisons for caterpillars, or fungi for dodder control. The value of these options will be impacted not only by the products' efficacy but by the precision of the delivery system (e.g., chemigation, boom applicator) and cost.

RESEARCH AND DEVELOPMENT OF PEST MANAGEMENT PRACTICES

Massachusetts cranberry industry and research scientists have good relationships with several chemical manufacturers as well as federal and state agencies that regulate and register new pesticides. These relationships are critical for the maintenance of currently registered compounds and well as future registrations. The cranberry industry has been very successful over the past decade in securing Specific and Crisis Exemptions (called Section 18 permits) from EPA. Section 18 permits enable growers to manage pests, such as cranberry weevil, dodder, and *Phytophthora cinnamomi*, with pesticides that have not yet received (but are in the process of obtaining) a full EPA registration. The outbreak of organophosphate-resistant weevils in the early 2000's would have caused severe economic loss for many growers if not for the granting of a Crisis Exemption for the use of an insecticide that was pending registration (Averill and Sylvia 2002). UMass Cranberry Station scientists have also obtained special local needs (SLN or 24c) labeling by conducting field trials to demonstrate efficacy, and subsequently working with state officials and registrants to incorporate the needed label changes.

BIOLOGICAL PRODUCTS

***Bacillus thuringiensis* (B.t.) Products**. Several products containing the bacterium, *Bacillus thuringiensis* (B.t.), have been registered to control lepidopteran pests of cranberries. These products are effective for control of the small larval (caterpillar) stages of cutworms, spanworms, and gypsy moths. These insect pests feed primarily on the leaves and buds of cranberry vines. B.t. products are very low in mammalian toxicity, specific to caterpillars and are not harmful to bees, wildlife, or beneficial insects. Growers can apply these products by air or chemigation.

According to the survey by Blake et al. (2007), B.t. products were not frequently used by Massachusetts growers at the close of the 20th century. In fact, less than 10% of the respondents said they frequently used B.t. products while over 50% said they never used them. This response fits fairly well with that reported for North American cranberry growers by Weber (1996). Only one-third of the respondents reported that they had tried B.t., and almost half of those growers had fair or negative experiences.

Beneficial Nematodes. Biological control of black vine weevil, strawberry root weevil, and cranberry girdler is possible with use of beneficial nematodes. Nematodes are microscopic worms that parasitize and kill the larval (immature) stages of the above-mentioned cranberry pests. Beneficial nematodes target specific soil-inhabiting insects and should not be confused with the plant-parasitic nematodes, which are considered plant pathogens. Beneficial nematodes do not harm the cranberry plant, whereas the plant-parasitic nematodes do feed on or infect roots and runners.

A biological insecticide (Biosafe-N, BioSys, Inc.) that used the nematode, *Steinernema carpocapsae* as the active ingredient, was registered for use in cranberry farms in the mid-1980s. Projects researching the efficacy of this product began in 1985. The product is nontoxic to plants, animals, and most beneficial insects and does not contaminate groundwater supplies. The cranberry industry was the first food crop in North America to employ beneficial nematodes as a biological control agent on a commercial basis. Use recommendations for managing soil insects have been developed for cranberry and other small fruit crops (Polavarapu 1999; Booth 2000).

Growers in Massachusetts and in other cranberry regions have been using nematodes for black vine weevil and strawberry root weevil control since 1988. Good control was observed in Massachusetts (S. Roberts, pers. comm.) and Washington (Booth et al. 2002). The two primary targets of beneficial nematodes (black vine and strawberry root weevils) are not significant pests in Massachusetts. The lack of pest pressure and sporadic availability of commercial product in the Northeast has limited the incorporation of beneficial nematodes into standard IPM programs in Massachusetts.

Pathogens. *Alternaria destrucens* has been identified as a pathogen of dodder (Bewick 1987). The commercial availability of the mycoherbicide based on this organism has been hampered by many production problems over the past 20 years. However in 2006, a manufacturer in Pennsylvania (Sylvan BioProducts) registered the product, Smolder, for dodder control on cranberries in Massachusetts. Two formulations were registered: a preemergence granular and a postemergence wettable powder. In conjunction with scientists from Wisconsin, USDA, and Sylvan, field trials were initiated in 2006 at the UMass Cranberry Station and continued into 2007. Early results indicated that timing and application procedures need to be more clearly defined to maximize the performance of Smolder (Bewick and Cascino 2007). Results from 2007 studies in WI and MA indicated that Smolder did not perform reliably in the field. The future use of this product for control of dodder in cranberry is unknown as of this writing. *Colletrotrichum gloeosporioides* has also been identified as a pathogen of dodder (Mika and Caruso 1999), but no attempts have been made to commercialize this fungus.

Predators and Parasitoids. Published research on the potential use of parasites and parasitoids in cranberry production has focused on those infecting black-headed fireworm (BHF) and cranberry fruitworm (CFW). Indigenous *Trichogramma* sp. nr. *sibericum* (now *T. sibericum*) and, to a lesser extent, *T. minutum*, parasitize BHF eggs (Li et al. 1994). Other species (a tachinid fly and several parasitic wasps) have been reared from BHF larvae (Fitzpatrick et al. 1994). It has been noted that spiders will prey on BHF moths in field cages (Fitzpatrick and Troubridge 1993) and on certain larvae of known cranberry pests (Bardwell and Averill 1996).

Other Products. An agricultural decontaminant foam, alkyl dimethyl benzyl ammonium chloride (ADBAC), was tested as a growth deterrent for the field and storage rot pathogen, *Physalospora vaccinii* (Tubajika 2006). At least 100 ppm ADBAC was needed to affect mycelial growth and complete inhibition was achieved at 1,000 ppm. The authors contend this product would fit well into an integrated program for fungal control. Biological fungicides containing *Pseudomonas syringae*, when applied in combination with carnauba wax, effectively reduced fruit decay in cranberry (Chen et al. 1999), but more research is needed to determine the range of pathogens affected. Several nontoxic household cleaners (e.g., vinegar, soap) have been evaluated for postemergence control of dodder (Morrison et al. 2005). Cryolite bait has been used by many growers in the Pacific Northwest for control of black vine weevil and strawberry root weevil (Weber 1997). Its use has been limited in Massachusetts (due to low pest pressure) and its production was discontinued in 2004 (Averill and Sylvia 2008).

PHEROMONES, TRAPS, AND MATING DISRUPTION

Research on the identification of sex pheromones for several cranberry pests has led to the incorporation and adoption of pheromone traps into standard IPM programs as monitoring tools (Brodel 1985). The effectiveness of pheromone traps for monitoring populations of cranberry girdler (Corliss 1990; Kamm et al. 1990), BHF (Shanks et al. 1990; Cockfield et al. 1994), and *Sparganothis* (Cockfield et al. 1994) has been evaluated by many cranberry scientists across North America. Traps are regularly used by more than half of the Massachusetts growers (Blake et al. 2007). Trap catches are monitored to determine the beginning of the moth flight or peak flight, after which sprays can then be timed (Kamm and McDonough 1982; Averill and Sylvia 2008).

Fig. 2. Example of a pheromone trap used to monitor black-headed fireworm moths. Photo courtesy: A. Averill.

Applied research on mating disruption is another outcome stemming from the identification of sex pheromones. A sprayable formulation of BHF pheromone (3M Canada Company) was tested and registered for use in the U.S. and Canada (Fitzpatrick, unpublished data). However, due to the availability of chemicals that give good control of BHF and other cranberry pests, use of mating disruption for BHF has not been incorporated into Massachusetts IPM programs.

CULTURAL CONTROL OPTIONS

Flooding. Cranberries evolved in a wetland setting and as such are able to withstand periodic flooding without sustaining injury. Growers use flooding for many management purposes including harvesting, frost protection, and winter protection (see Flooding and Water Use chapters). Holding a late water flood (i.e., reflooding the bog from mid-April to mid-May) can decrease the inoculum potential of the fruit rot fungi, cause a general reduction of annual weeds, suppress the spread of *Rubus* spp. as well as suppress populations of certain insects and mites (Averill et al. 1994; Averill et al. 1997).

Short spring floods can control BHF (Cockfield and Mahr 1992) and dodder (Sandler 2003; Sandler and Mason 2004). Short (3 to 7 days) late summer floods can also be used for management of cranberry girdler (Beckwith 1925; Fitzpatrick 2007), and longer floods (held for 3-4 weeks after harvest of the fruit) can reduce CFW emergence from hibernacula and suppress growth of dewberries (DeMoranville et al. 2005). Flooding for pest management is not always successful in terms of reducing pest populations. In New Jersey, data collected from short flooding experiments for management of *Sparganothis* were not promising (Teixeira and Averill 2006). The authors concluded that flooding will not replace the control seen with chemical control or mating disruption.

Flooding, even if successful in reducing pest populations, carries a certain degree of risk to the vines. Until the early 2000's, flooding was primarily viewed through the lens of pest management only. Recent research has shown that flooding at different times of year for various lengths of time can impact the total nonstructural carbohydrate (TNSC) concentration of the vines (Botelho and Vanden Heuvel 2006). TNSC are the energy currency of the plant. Carbohydrate resources are important (even crucial) to proper fruit set (Birrenkott and Stang 1990; Hagidimitriou and Roper 1994). Carbohydrate stress may be observed after prolonged periods of net respiration during flooding (Botelho and Vanden Heuvel 2005; Vanden Heuvel 2005). Botelho and Vanden Heuvel (2006) found that TNSC were generally unaffected by late water floods, winter floods, and short-term spring floods. However, fall floods often resulted in decreased TNSC. Thus, the use of fall floods for pest management may carry the risk of yield reduction.

Flood duration is also of importance with regards to water quality in the flood discharge, particularly around harvest (see Flooding chapter). Before discharging harvest water back to a stream, river, or pond, the flood is held for at least two days to allow organic matter or other particles, along with associated nutrients, to settle out. However, holding the flood for an extended duration can lead to movement of phosphorus from the bog soil into the flood water (DeMoranville 2006; DeMoranville et al. 2008). The use of flooding in cranberry production has numerous interactions and impacts that should be considered whenever utilizing this cultural option for pest management.

Sanding. Sanding, i.e., the application of a thin (0.5 to 2 inches) layer of sand on the production surface at 2 to 5 year intervals, is the most commonly used cultural practice in Massachusetts (DeMoranville et al. 1996). Sanding can suppress fruit rot inoculum by burying infected leaves (Tomlinson 1937). Uniform applications of sand on a regular interval may reduce infestations of cranberry girdler and green spanworm (Franklin 1913; Tomlinson 1937). Research is on-going to determine the impact of sanding on CFW (A. Averill, pers. comm.). Uniform sand applications can also inhibit emergence of dodder seedlings (Sandler et al. 1997).

Sanding may not always have positive pest management outcomes. Sand as the surface layer may shorten herbicide longevity (Sandler and DeMoranville 1999). Weed seeds of problematic plants can actually be introduced by the application of sand to the vines, increasing weed problems (Mason et al. 2006). Pest control (e.g., cranberry girdler, dodder) often depends on the deposition of uniform layers of sand. Growers will strive to apply a certain target depth, but recent research reported that the majority of measurements of sand depths actually deposited to the bog floor were much lower than the target depth (Hunsberger et al. 2006). In fact, deposition patterns were very irregular and would reduce the expectation of pest suppression that requires a uniform layer of sand (i.e., dodder).

Pruning. Pruning has indirect effects on pest populations but provides overall benefits to vine vigor and is an important cultural practice. Periodic pruning of vines improves aeration in the vine canopy and makes the environment unfavorable for fruit rot infection (Caruso and Ramsdell 1995).

Pruning is becoming more important to Massachusetts growers as local sand (available on-site) resources decrease and the cost of sand increases. Studies are currently investigating the incorporation of low-cost practices that have potential to increase fruit quality and contribute to pesticide reduction, such as pruning, irrigation scheduling, drainage management, bed sanitation, and integrated nutrient management.

Other cultural practices. Sanitation (removal of leaf trash after harvest) is very important for minimizing fruit rot inoculum (Caruso and Ramsdell 1995). Proper use of water is important to successful disease management and overall vine health. Improving drainage can help mitigate Phytophthora root rot (Caruso and Wilcox 1990). Minimizing the length of time that leaves remain wet will reduce the infection potential of fruit rot fungi. Proper maintenance and calibration of the sprinkler system and other equipment are important procedures that are practiced by cranberry growers. Adequate pressure and clean nozzles are critical to ensure that proper amounts of chemicals are delivered to the target area.

Renovation of older plantings to new (hybrid) varieties, along with installation of improved irrigation systems, is being more readily embraced by current cranberry growers than in the past. The age of the planting can influence the pest complex that must be managed (DeMoranville et al. 2001). Newly planted beds typically need less fungicide and insect inputs; but should be intensively managed for weed pests. Choice of vine density, nitrogen rate and weed management strategy interact to provide thorough colonization of newly planted vines (Sandler 2004). The most cost-effective production scheme for establishing new beds that minimizes weed infestation is to plant vines at a low density, use moderate amounts of nitrogen, and apply an annual application of a preemergence herbicide (Sandler et al. 2004). As vines age, additional pests may become established. Scouting should be performed routinely, and the process of integrating cultural, biological, and chemical controls becomes part of the regular pest management program.

Nutrient Management. Nutrient management is important when considering pest management in terms of the overall health of the plant. Sustainable nutrient practices have positive impacts on the environment as well as the plant. Use of organic fertilizers, slow-release fertilizers, and small split applications reduce leaching loss. Ammoniated forms of nitrogen are readily and preferably taken up by cranberry vines (Addoms and Mounce 1932; Greidanus et al. 1972; Dirr 1974) and protect the groundwater. Calcium-boron supplements improve pollination and increase yield potential (DeMoranville and Deubert 1987).

Inorganic fertilizers with various proportions of the major elements of nitrogen, phosphorus and potassium (NPK) are the most commonly used fertilizer products in cranberry since they provide quick vine response. However, growers are incorporating slow-release products and foliar fertilizers into their regular programs. Best management practices (BMP) for nutrient management recommend that growers use moderate application of nitrogen fertilizers (DeMoranville et al. 1996). From a pest management perspective, this practice helps in two ways. Using appropriate amounts of nitrogen limits overgrowth of vines that can encourage infection from fruit rot organisms (Davenport 1996). Secondly, lush vine growth can provide a suitable habitat for tipworm and flea beetle infestations (Averill and Sylvia 1998). Growers can reduce pest problems through judicious use of fertilizer.

Research on the organic product, fish hydrolysate (or fish fertilizer), was initiated at the UMass Cranberry Station in 1987 (DeMoranville 1992). Results indicated that fish hydrolysate may be a suitable alternative to inorganic soluble fertilizers. Growers first tried fish fertilizer, made using recycled products from the state's fishing industry, as a nutrient source in 1989. Fish fertilizer is an efficient material; it remains in the root zone longer than inorganic soluble fertilizers. Use of this slow-release, organic material is particularly well suited to areas that have a high leaching potential.

Phosphorus (Roper et al. 2004) and nitrogen (Davenport and Vorsa 1999; Hart et al. 2000) are important elements of interest in Massachusetts due to increased concern for protection of water quality, both on state and federal levels (DeMoranville 2006). The development of BMP for nutrient management was identified in the 1990s as a way to help address some of these concerns. Outcomes from the research initiative included that once established and consistently producing good fruit yields, cranberry vines need low rates of phosphorus to complete their life cycle and maintain a healthy vine canopy (Davenport et al. 1997; DeMoranville and Davenport 1997; Davenport et al. 2008; DeMoranville et al. 2008; Roper 2008). Another study that focused on the discharge of nitrogen and phosphorus from cranberry bogs concluded that discharge was primarily associated with flooding (Howes and Teal 1995). Data from DeMoranville (2006) showed that describing the flow and discharge of nutrients through the cranberry system can be complex and thus, the need to field test potential nutrient management BMP recommendations is an area for future research.

CONCLUSIONS

Integrated pest management implies more than the application of chemicals at the appropriate time against the correct target pest. Knowledge of the pest's life cycle, symptoms, as well as the conditions that predispose the cranberry to infection or infestation contributes to effective management of cranberry pest problems. Implementing cultural practices, such as flooding and sanding, broaden the baseline defense against crop loss due to pest pressures. Many biological control opportunities exist for cranberry pest management but logistical obstacles, such as problematic production and distribution of reliable commercial compounds, has prevented widespread incorporation of these strategies.

Cranberry growers and researchers face many challenges at the beginning of the 21st century. As environmental concerns continue to limit the availability and application of conventional (registered) pesticides, the incorporation of new chemistries and reduced risk compounds, along with biological and cultural control measures, into routine pest management programs will become even more crucial. Sustained population growth in the southeastern region of Massachusetts will put increased pressure on the farming community.

The future of IPM and the cranberry industry will be shaped by many factors including the physical transition of farms and the intellectual transfer of pest management knowledge and experience from the present generation to the next.

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