Challenges and Successes in the Management of Three Key Insect Pests of Highbush Blueberries in New Jersey

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Highbush blueberry, *Vaccinium corymbosum* L., production in New Jersey (USA) is predominantly in the southern portion of the state, in an area referred to as the Pinelands or Pine Barrens. New Jersey highbush blueberry production brings in an estimated $85 million annually for the state and it is ranked regularly among the top six producers in the United States (NASS 2019). Of the approximately 16 insect pests of highbush blueberries in New Jersey (Figure 1), plum curculio (*Conotrachelus nenuphar* (Herbst)), aphids (multiple species), and spotted-wing drosophila (SWD, *Drosophila suzukii* (Matsumura)) are of important concern. These insect pests are present from late flowering (plum curculio and aphids), during fruit maturity (plum curculio, aphids, and SWD), and at harvest (SWD) (Figure 1). Both plum curculio and SWD directly damage the fruit (Tewari et al. 2014; Michel et al. 2015), whereas aphids act as vectors of viruses such as blueberry scorch virus (Morimoto and Ramsdell 1985; Martin and Tzanetakis 2018). As a result, there is little-to-no tolerance for these insect pests in blueberries.

Integrated pest management (IPM) strategies for these insect pests have their own unique challenges. Currently management for all three is reliant on insecticide applications (Van Timmeren and Isaacs 2013; Tewari et al. 2014; Rodriguez-Saona et al. 2019). Here, we describe the biology, damage, and management strategies for plum curculio, aphids, and SWD, and identify challenges and successes associated with their control.

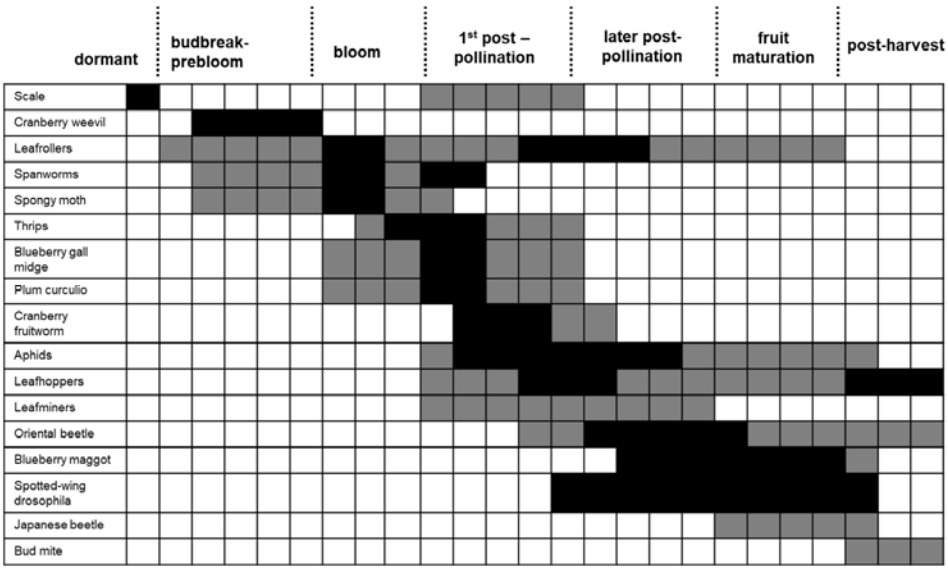

Figure 1. Seasonal activity period of blueberry insect and mite pests in New Jersey. Bars show period when scouting (grey color) and management (black color) of the pest is most important.

Plum curculio

Biology. Plum curculio, *C. nenuphar* (Figure 2), is a native pest of blueberries in North America (Chapman 1938; Lampasona et al. 2020). It is predominantly univoltine (Chapman 1938),

Figure 2. Plum curculio adult and oviposition scar (Photo Credit: Dean Polk).

although some mid-Atlantic states exhibit evidence of multivoltine populations (Leskey 2008). In New Jersey, adults overwinter in leaf litter and become active in April–May when they move to blueberry fields and mate. Peak activity is typically observed at the end of flowering and beginning of fruit set. Females lay eggs on the fruit and create a crescent-shaped scar at the oviposition site. One larva develops inside the fruit until they are ready to pupate at which time they drop to the soil and emerge as adults in July and August (Crandall 1905; Lampasona et al. 2020). Newly emerged adults may feed on mature fruit before moving to overwintering sites.

Damage. Adults feed on both the flowers and developing fruits (immediately following petal fall). Fruit damage is both cosmetic when the adult female oviposits and leaves a scar (Figure 2), as well as internal as the larvae feed inside the fruit. The larval feeding also causes fruit to develop prematurely and drop to the ground (Antonelli et al. 1992). In early-maturing varieties, fruit may be harvested prior to drop and result in rejections as there is a zero-tolerance for plum curculio in blueberries.

Management. Insecticides targeting the adults are applied as soon as commercial honeybees have been moved off blueberries. In New Jersey, the primary insecticides recommended for plum curculio control in blueberries are indoxacarb (Avaunt®) or phosmet (Imidan®) (Besançon et al. 2022).

Challenges and Successes in Management. Plum curculio can be challenging to manage because it is active during bloom when insecticides are not possible because of the presence of honeybees (Deutsch and Guédot 2018). This is especially a challenge in early maturing varieties.

Behavioral and biological control alternatives have recently been tested to target the adult and immature stages of plum curculio, respectively. An odor-baited "trap bush" approach has been evaluated to aggregate plum curculio adult injury (Rodriguez-Saona et al. 2019). This approach consists of using attractive baits such as the aggregation pheromone grandisoic acid and benzaldehyde to lure plum curculio adults to specific sections of the field (i.e., bushes along the perimeter) and then apply control measures only to these sections. Thus, under this "trap bush" approach, insecticides could be targeted only at a few (perimeter-row) bushes within fields rather than entire fields.

Entomopathogenic nematodes (EPNs) are a group of nematodes that cause death to insects and infect many types of insects living in the soil. In addition to broad infection, they are found in diverse habitats and can be readily used in blueberry fields. Four commercially available EPNs were recently tested against plum curculio: *Steinernema feltiae*, *S. carpacapsae*, *S. riobrave*, and *S. scarabaei* at a rate of 50 infected juveniles (IJs)/cm^2. Emergence traps baited with plum curculio infested berries indicated that *S. riobrave* was the most successful at reducing adult emergence and that it was able to persist in the soil for 21 days in the field (Sousa et al. 2021). Further testing of *S. riobrave* at a high rate of 50 IJs/cm^2 and low rate of 25 IJs/cm^2 demonstrated significant reduction from an untreated control and similar rates of suppression (Sousa et al. 2021). Future studies will evaluate the persistence and efficacy of *S. riobrave* against plum curculio in commercial blueberry farms.

Aphids

Biology. Adult aphids (Figure 3) are about 2 mm in length and, for species attacking blueberries, range in color from light to dark green. Nymphs are similar in color and appearance to adults but are smaller in size and wingless. Several aphid species attack highbush blueberries in New Jersey, including *Illinoia azaleae* (Mason), *Aphis fabae* Scopoli, *Ericaphis fimbriata* (Richards), and *Myzus persicae* (Sulzer), with *I. azaleae* being the most abundant. Aphids generally overwinter as eggs that hatch in the spring and populations begin to build in June. Immature aphids feed using a stylet (piercing-sucking mouthparts) on new growth, often on the undersides of leaves at the top or bottom of blueberry bushes. Adults reproduce through parthenogenesis for most of the growing season where females produce offspring clonally. In the fall, males and egg-

Figure 3. Aphids on a blueberry leaf (Photo Credit: Dean Polk).

laying females are produced. Aphids have multiple generations each growing season.

Damage. Aphids excrete a sugary liquid, called honeydew, that can form a sticky layer on leaves. This can promote the development of sooty mold when there are high levels of aphid populations. This is, however, a minor concern for blueberry growers because aphid populations are generally controlled so as not to reach high levels. A primary concern is the ability of aphids to act as vectors of viruses, such as the blueberry scorch virus (Schloemann and Piñero 2020).

Management. Aphids can appear during bloom, but insecticide application should not occur until after honeybees are removed (Schloemann and Piñero 2020). In New Jersey, treatment is recommended if greater than 10% of terminals are infested with live aphids. Insecticides typically used for aphid control in blueberries are predominantly neonicotinoids, such as acetamiprid (Assail®), imidacloprid (Admire® Pro), and thiamethoxam (Actara®) (Besançon et al. 2022).

Challenges and Successes in Management. There are concerns on the use of neonicotinoids because of the possibility of non-target effects (Hladik et al. 2018), causing restrictions on their usage. New insecticides with different modes of action have been registered in blueberries including: Movento® (spirotetramat), Sivanto® (flupyradifurone), and Senstar® (pyriproxyfen + spirotetramat). These new insecticides were tested alongside Assail® (acetamiprid) as well as an untreated control. Aphid mortality after 5 days of exposure to these insecticides indicated significant reductions in live aphids (Rodriguez-Saona and Holdcraft 2022). Limited commercial use has shown that spirotetramat and flupyradifurone can yield improved aphid control compared to standard neonicotinoids (Polk and Mansue, unpublished IPM field data).

Spotted-wing drosophila

Figure 4. A male spotted-wing drosophila (SWD) (Photo Credit: Elvira de Lange).

Biology. Spotted-wing drosophila (SWD), *D. suzukii* (Figure 4), is an invasive pest first found in New Jersey in 2011 (Michel et al. 2015). The adults attack a wide range of thin-skinned fruits including blueberries, strawberries, raspberries, and cherries (Kanzawa 1935; Kanzawa 1939). This pest overwinters as an adult. Eggs are laid into ripening berries and multiple larvae can be present in each berry. Larvae take 5–7 days to develop and pupation an additional 4–15 days either inside or outside of the fruit. SWD populations in New Jersey become active in June and increase as the season progresses, so later ripening varieties are more susceptible to damage. There are several generations per growing season (Michel et al. 2015).

Damage. SWD causes direct damage to the berry through feeding by the larvae (Michel et al. 2015). Berries infested by larvae originally have no apparent damage but begin to shrink and become less sound and misshapen as the larvae develop.

Current Management. SWD is primarily controlled through calendar-based insecticide sprays that occur almost weekly during fruit ripening (Tait et al. 2021; Besançon et al. 2022). Several modes of action are present in registered insecticides, and it is recommended to rotate IRAC classes to avoid resistance. Resistance to insecticides is of concern as it has been observed on populations in California (Gress and Zalom 2018). Sanitation is also recommended because, although SWD females prefer to oviposit in ripe fruit, they will also use rotting fruit as an oviposition site. Keeping rows clean, covering fallen berries, and completely harvesting rows are all cultural control tactics recommended to reduce SWD populations in blueberry fields (Michel et al. 2015; Leach et al. 2018).

Challenges and Successes in Management. Because of its wide host range, rapid development, and multiple generations it is difficult to control and suppress SWD populations. In addition, biological control agents in the invaded regions not effective at controlling this

pest. Efforts are current underway to develop effective behavioral control and biological control strategies.

Two behavior-based products under evaluation to manage SWD are ACTTRA SWD and Combi-protec. ACTTRA SWD (ISCA Technologies Inc., California, USA) combines an attractive volatile blend (chemical cues) with visual cues and a phagostimulant in a formulation that can be mixed with an insecticide to attract and kill SWD flies and thus reduce fruit infestation. A recent study showed that ACTTRA SWD is effective at controlling SWD under laboratory conditions, but its efficacy is influenced by internal (i.e., the insect's physiological status) and external (i.e., the availability of host fruits) factors (Babu et al. 2022). Like ACTTRA SWD, Combi-protec (Andermatt Group AG, New Jersey, USA) is an adjuvant feeding stimulant that can be mixed with an insecticide, but it does not contain an attractant (Noble et al. 2021). Combi-protec has been tested under laboratory and semi-field conditions in New Jersey and other US states. When compared with an untreated control, adult mortality was comparable to full-rate insecticide applications without the feeding stimulant. Additionally, insecticide with Combi-protec applied at half-rate performed at similar levels to the full-rate insecticide (unpublished data). As of this writing, ACTTRA SWD and Combi-protec are in the process of registration in the USA.

A permit to release *Ganaspis brasiliensis* (Ihering), a parasitoid of SWD native to Asia, was recently approved in the United States. Unlike parasitoids already present in the USA, *G. brasiliensis* is well adapted to attack SWD larvae. In 2022, releases of *G. brasiliensis* wasps were conducted in wooded areas adjacent to blueberry fields in New Jersey, with the expectation that it will establish and successfully parasitize SWD in these areas. Research on *G. brasiliensis* overwintering biology and additional releases and monitoring of its establishment will be conducted in New Jersey.

Conclusions

New chemical, behavioral, and biological control tools are being evaluated to manage three key insect pests of highbush blueberries in New Jersey – plum curculio, aphids, and SWD (Figure 5). The EPN *S. riobrave* has shown to be effective against plum curculio larvae and future research will focus in combining this EPN with the "trap bush" approach to develop a multi-stage management program for plum curculio. New classes of insecticides show efficacy against aphids and can thus be used in rotation with neonicotinoid insecticides. Two behavior-based strategies, ACTTRA SWD and Combi-protec, show promise in reducing SWD infestation. The parasitoid *G. brasiliensis* is being released in New Jersey and other US states; whether this biological control agent and behavioral control strategies are compatible in managing SWD will be the subject of future research.

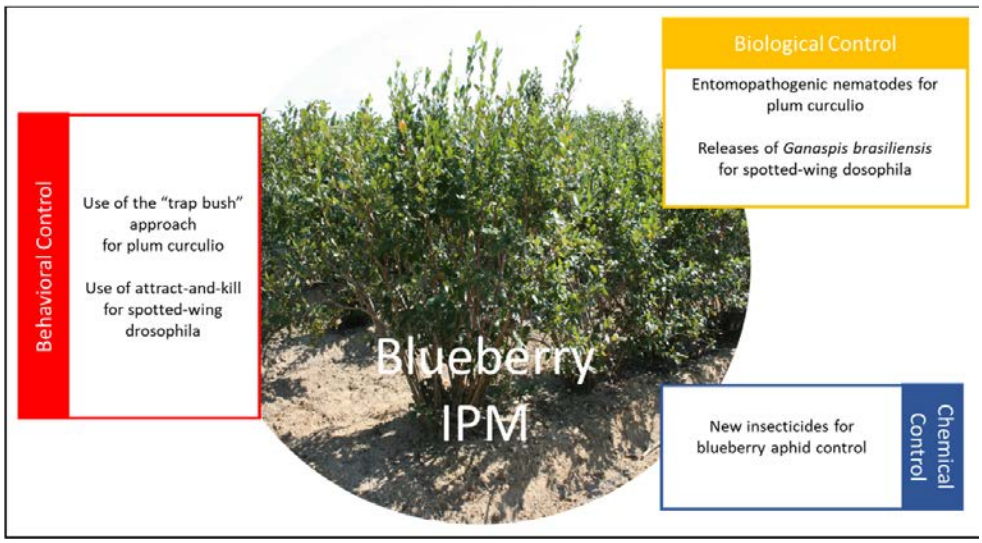

Figure 5. Research advances in blueberry integrated pest management (IPM).

Acknowledgments

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