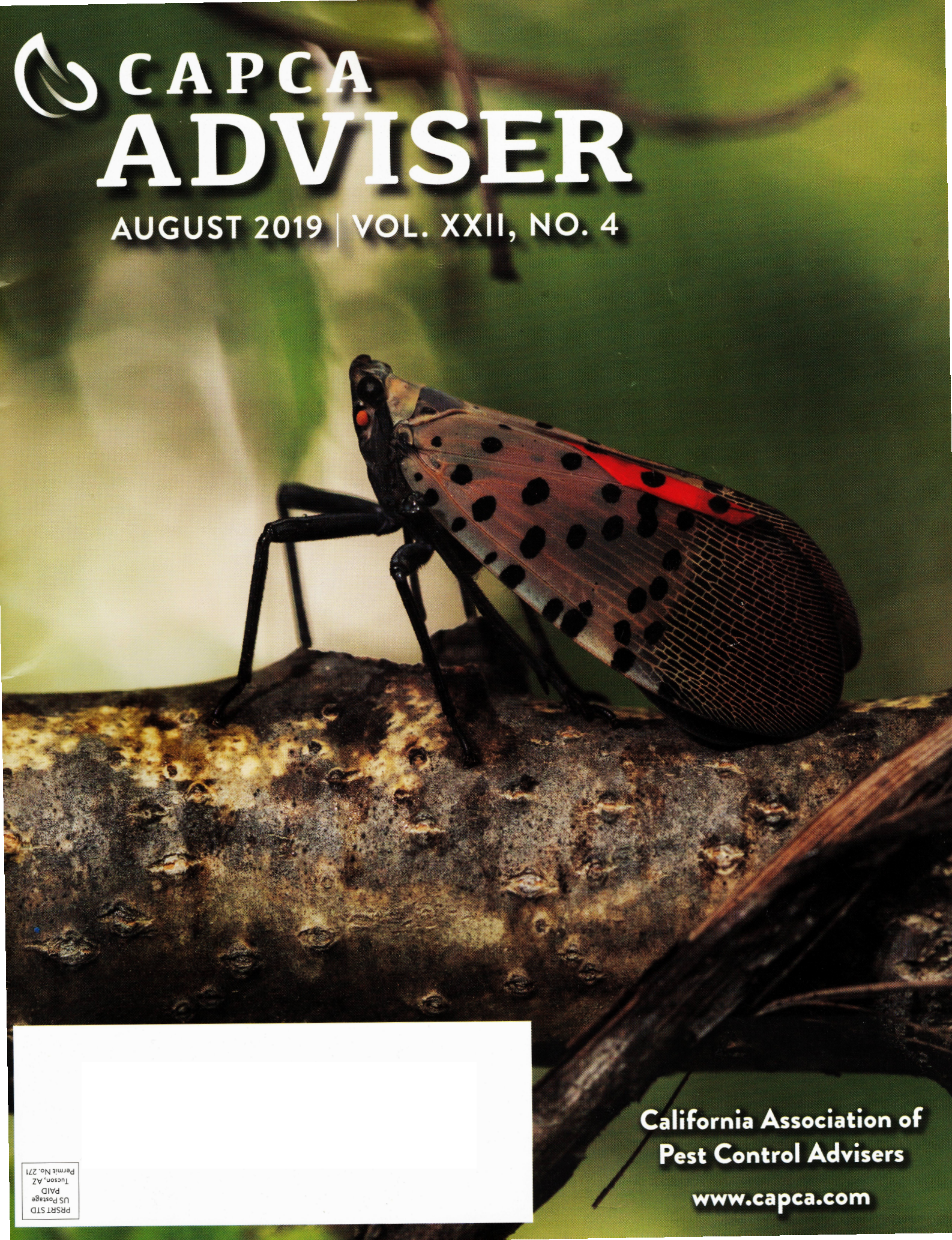

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Update on the area-wide IPM program for Virginia creeper leafhopper in the North Coast

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Vineyard Leafhoppers in California

There are three closely related species of leafhopper (Cicadellidae) that are considered pests in vineyards – the Western grape leafhopper (*Erythroneura elegantula*), variegated leafhopper (*Erythroneura variabilis*) and Virginia creeper leafhopper (*Erythroneura ziczac*). While the Western grape leafhopper (WGLH) is native to California, the variegated leafhopper (VLH) and Virginia creeper leafhopper (VCLH) both arrived in California sometime in the 1980s. WGLH can be found in vineyards throughout most areas of the state, including the Central Valley, Central Coast and North Coast. VLH is mostly found in the San Joaquin Valley, southern Sacramento Valley and in Southern California, although small populations are occasionally found in the North Coast. In contrast, VCLH is limited to the Sacramento Valley and Sierra Foothills regions, as well as the North Coast, where it was recently introduced.

These leafhoppers have pierce-suck mouthparts and feed on grape leaves, which produces leaf stippling that can lead to reduced vine vigor, yield and/or fruit quality. Additionally, the seasonal timing of leafhopper development can result in large populations of adults right around harvest, which can be a major nuisance to workers manually harvesting grapes. Leafhopppers overwinter as adults in reproductive diapause, typically residing in and around the vineyard in leaf litter and/or on nearby winter vegetation. In the spring, as grape vines begin to develop shoots, leafhoppers will move back onto the vines to feed on mature grape leaves. As they feed, they will break their diapause, mate and then begin to oviposit into grape leaves. When the immature leafhoppers (i.e. nymphs) emerge from their eggs, they primarily reside on the underside of the grape leaves, where they feed. Nymphs pass through five immature stages (i.e. instars) before molting into an adult, at which point they can fly and migrate to other areas of the vineyard. Leafhoppers have multiple generations, typically 2-5 per year depending on the region (more generations in warmer areas, fewer generations in cooler areas). At the end of the season, when the photoperiod decreases and grape vines senesce, the leafhopper adults move onto the vineyard floor and enter reproductive diapause for the winter.

While generalist predators like minute pirate-bug (*Orius* spp.), green lacewings (*Chrysopa* spp., *Chrysoperla* spp.) and spiders are all known to attack vineyard leafhoppers, biological control is primarily the result of egg parasitism by a group of closely related parasitoids – *Anagrus erythroneurae*, *Anagrus daanei*, and *Anagrus tretiakovae* (Mymaridae). WGLH eggs are attacked by *A. erythroneurae* and *A. daanei*, VLH eggs are attacked by *A. erythroneurae* and *A. tretiakovae*, and VCLH eggs are attacked by *A. daanei* and *A. tretiakovae*. More specifically, these parasitoids lay their own egg inside a healthy leafhopper egg, which is subsequently consumed by the parasitoid larva. This larva then completes its develop and emerges as an adult from the leafhopper egg, leaving a circular exit hole on the upper surface of the egg. These parasitoids complete multiple generations per year and under good conditions can rapidly build up their populations in vineyards, resulting in adequate biological control of leafhoppers. These *Anagrus* parasitoids require leafhopper eggs in order to successfully overwinter. Since WGLH, VLH and VCLH all overwinter as adults, the *Anagrus* parasitoids must leave the vineyard at the end of the season and locate an alternate leafhopper host for the winter. These alternate hosts are typically found on blackberry (*Rubus* spp.) and coyotebrush (*Baccharis pilularis*), and it has been shown that the timing and abundance of *Anagrus* activity in vineyards is related to the area and proximity of habitats that contain these plants surrounding the vineyard.

VCLH Arrives in the North Coast

VCLH first appeared in northern California vineyards sometime in the 1980s. Since its introduction, populations of this insect have primarily been limited to the Sierra Foothills and Sacramento Valley areas. More recently, starting around 2011-2012, wine grape growers in Mendocino and Lake County began to experience severe and persistent outbreaks of VCLH in their vineyards. These outbreaks were especially devastating in certified organic vineyards, where control options are more limited. In some extreme cases certified organic growers found it necessary to resort to synthetic chemical controls for VCLH, thereby losing their organic certification status. WGLH is the dominant leafhopper in the North Coast region and the unexpected arrival of VCLH quickly became a serious problem.

Initial surveys conducted in August 2013 revealed a total absence of VCLH parasitism in the North Coast. Even more surprising was the finding that the primary VCLH parasitoid *A. daanei* was actually present and abundant throughout the region – but it was simply not attacking VCLH! Meanwhile, WGLH was found to be regularly attacked by both *A. erythorneurae* and *A. daanei*. As such, it seemed that the *A. daanei* in the North Coast had apparently lost preference for VCLH, even though it is a known reproductive host for this parasitoid.

As mentioned, WGLH is the dominant leafhopper pest in the North Coast and growers are very accustomed to effectively managing this insect. With the arrival of VCLH though, early observations indicated that some adjustments would be needed to the timing of monitoring and treatment.

While VCLH and WGLH are very similar in many ways, there are some important differences in the timing of their development. When the overwintering adult WGLH first begin to feed on grape vines in the spring, they require approximately two-weeks of feeding before they begin to oviposit. This is in contrast to the overwintering adult VCLH, which begin ovipositing on mature grape leaves almost immediately once they become available. This earlier egg deposition means that VCLH nymphs will appear on grape leaves earlier than WGLH, and so growers must initiate monitoring efforts for this pest sooner in the year than they are accustomed to for WGLH.

Furthermore, when monitoring for VCLH nymphs it is important to note that early stage nymphs (i.e. 1st – 2nd instar nymphs) of WGLH and VCLH appear very similar and are difficult to distinguish (see inset box for details on leafhopper identification).

VCLH also appear to have a strong preference for grape varieties with more glaborous leaves (i.e. leaves that are smooth on the underside, without a lot of trichomes or tomentum), such as chardonnay and grenache. In this way, growers can prioritize VCLH monitoring efforts in more susceptible blocks that contain these varieties – although it is still strongly recommended that growers monitor for VCLH in all vineyard blocks.

Earlier oviposition by VCLH has implications for the timing of chemical controls as well. While many grape growers rely on AIs with systemic activity for leafhopper control, such as imidacloprid, it is critical that, when treatment is warranted, those growers utilizing contact products time their applications to coincide with the most vulnerable leafhopper life-stage. For most contact products, this is typically when a majority of the population is in the earlier developmental stages (i.e. early instar nymphs). Please consult your PCA for specific product recommendations, rates and timing.

Finally, due to the absence of biological control in the North Coast, early season treatment of VCLH is essential. This is in contrast to WGLH, where biological control is fairly consistent and as a result many North Coast growers can afford to wait until later in the year to make a treatment decision.

More information on vineyard leafhopper identification, monitoring procedures, management options and product selection can all be found at the UC IPM website (http://ipm.ucanr.edu/).

Area-wide IPM Program for VCLH

In 2013, responding to the growing severity of VCLH outbreaks, UC Cooperative Extension (UCCE) advisors Glenn McGourty (UCCE Mendocino) and Lucia Varela (UCCE North Coast IPM Advisor) brought together a team of entomologists to address the problem, this included Kent Daane (UC Berkeley), Houston Wilson (UC Riverside) and Serguei Triapitsyn (UC Riverside). Shortly thereafter, this group developed the Virginia Creeper Leafhopper Area-wide IPM Program, a coordinated research and extension effort to help get these regional VCLH outbreaks under control.

Beginning in 2014, the VCLH Area-wide IPM Program organized multiple field days, tailgate talks and other events to educate growers on VCLH identification, biology, seasonal development,

LEAFHOPPER NYMPH SPECIES IDENTIFICATION

Virginia creeper and Western grape leafhoppers are approximately the same shape, size (0.03 - 0.10 inch / 0.8 - 2.5 mm) and color (white/yellow) with the key exception that VCLH nymphs develop 4 distinct brown/red spots on their thorax as the nymphs mature. The spots don't appear until the nymph has molted at least once, so the early stage (1st instar) of both species is identical. The spots on VCLH nymphs are light orange on 2nd/3rd instars and become brown/red on the 4th/5th instar. Early in the season, leafhopper nymphs can be found on fully-expanded, mature leaves on nodes 1-5 and later in the season just above the fruit zone on nodes 4-6.

Western Grape Leafhopper

Virginia Creeper Leafhopper

and control options. Pest identification guides were developed as well, including a video that explained how to differentiate VCLH and WGLH. This and other relevant information were all aggregated on a project website (http://ucanr.edu/sites/VCLH) for growers and PCAs to reference. Furthermore, with the help of multiple growers and PCAs, a regional leafhopper monitoring effort was initiated as well. Monitoring data from multiple vineyards across Mendocino and Lake County were summarized and circulated weekly in order to provide updates on leafhopper development and identify population hot spots. Data were initially circulated via an email list-serve, but this eventually grew into a regional newsletter and blog.

In addition to these outreach, education and monitoring efforts, vineyard surveys for VCLH parasitoids were conducted across northern California, including the North Coast, Sacramento Valley and Sierra Foothill regions. The 2014 survey effort successfully identified a strain of *A. daanei* from the Sacramento Valley that would readily attack VCLH. Initial laboratory testing indicated that this Sacramento Valley strain (SV-strain) of *A. daanei* would indeed parasitize VCLH eggs, unlike the North Coast strain (NC-strain) of *A. daanei* which would not attack VCLH at all. Subsequently, small-scale field studies in 2015 demonstrated that releasing large numbers of the SV-strain *A. daanei* into a Mendocino County vineyard led to increased parasitism of VCLH. Starting in 2016, a large-scale rear-release program was initiated to introduce large numbers of the SV-strain *A. daanei* into Mendocino and Lake County vineyards in order to establish biological control of VCLH. Over the course of two years, more than 30,000 SV-strain *A. daanei* were released across 12 vineyard sites, primarily concentrated in areas with the most intense VCLH outbreaks. The results of this parasitoid augmentation program were mixed, with parasitism increasing at some sites but not all. This may be due to a variety of factors, including hybridization between the SV-strain and NC-strain of *A. daanei* (that is, when these two strains mate do their offspring retain a preference for VCLH eggs?).

While impacts of the parasitoid introduction effort were mixed, late season parasitism of VCLH appears to be slightly increasing year-over-year, and this even includes at some sites were parasitoids were not released. This may indicate that either the released SV-strain of *A. daanei* are migrating to other areas and/or that the local NC-strain of *A. daanei* is potentially starting to attack the VCLH. Regardless, biological control of VCLH still needs improvement and at present it is recommended that North Coast growers continue to monitor and treat VCLH populations early in the season.

Conclusions and Future Directions

Management of VCLH continues to be a priority for growers in the North Coast. While biological control remains limited, a combination of vigilant monitoring and appropriately timed sprays have greatly reduced the severity and persistence of VCLH outbreaks. Work is currently underway to improve biological control. This includes efforts to evaluate the genetics of the SV- and NC-strains of *A. daanei*, and to compare this with *A. daanei* populations from other regions across the West Coast. This molecular work is being combined with additional laboratory testing to evaluate the performance of hybrid offspring produced by mating the two strains of parasitoid. Finally, extension efforts will continue to emphasize the necessity and nuance of controlling VCLH while researchers continue to monitor VCLH parasitism throughout the North Coast. The goal is to establish more reliable biological control of VCLH in order to reduce the need for early season treatments.

Questions and inquiries can be directed to Houston Wilson: Houston.wilson@ucr.edu ■