

# Methods for Sampling X-Disease *Colladonus* spp. (Hemiptera: Cicadellidae) Leafhopper Vectors in Orchards



## Summary of Sampling Methods

- Sticky cards are a low-cost, effective method for sampling leafhopper adults over time and allow vectors to be identified and quantified.
- Sweep nets are used for sampling of nymph and adult leafhoppers in the ground cover, but the sweep netting is more difficult to standardize for users than sticky traps or modified leaf vacuums.
- Modified leaf vacuums allow nymph and adult leafhoppers in a standardized sampling area to be captured and counted, but the up-front equipment costs are higher than sticky traps or sweep nets.

## The X-Disease System

X-disease is a widespread plant disease critically impacting cherries and other stone fruit (genus *Prunus*) in the United States' Pacific Northwest region. First identified in Washington State in 1946, X-disease's prevalence has dramatically increased in Washington over the last decade (Harper et al. 2023). X-disease is caused by the phytoplasma *Candidatus* *Phytoplasma pruni*, which infects the phloem of cherry trees and causes fruit to be small, bitter, and unmarketable (Figure 1) (Harper et al. 2023; Wright et al. 2021).

The “Ca. *P. pruni*” phytoplasma also has a wide host range in non-*Prunus* species and has been reported in 52 different species (Harper et al. 2023). Detection of Ca. *P. pruni* was significant in six plant families commonly found on the orchard floor and along the borders, including Asteraceae (dandelion), Malvaceae (mallow),

Amaranthaceae (white goosefoot, pigweed), Polygonaceae (knotweed), Brassicaceae (flixweed, tumbled mustard, hoary bittercress, shepherd's purse), and Plantaginaceae (broadleaf plantain) (Harper et al. 2023).



Figure 1. X-disease symptoms on sweet cherry (*Prunus avium*) in Washington State. Photo: L.E. Flandermeyer.





Figure 2. Adult *Colladonus montanus reductus* leafhoppers with light (left) and dark (right) pigmentation (not to scale). Photo: L.E. Flandermeier.

Leafhoppers (Hemiptera: Cicadellidae) are the only known vector of X-disease phytoplasma (Harper et al. 2023). There are six confirmed vector species of X-disease; however, *Colladonus montanus reductus* (Van Duzee) and *Colladonus geminatus* (Van Duzee) are the two key vector species in Washington (Figures 2 and 3) (Harper et al. 2023; Marshall et al. 2024). These small insects utilize non-*Prunus* broadleaf weeds in the ground cover as developmental hosts, while cherry trees are a less preferred long-term host for the leafhopper. They acquire the pathogen while feeding on infected trees or weedy hosts like dandelion, mallow, and plantain, which act as pathogen reservoirs on the orchard floor (Clarke 2021; Cooper et al. 2022). The phytoplasma replicates for

approximately 30 days within the leafhopper before it can be transmitted during subsequent feeding through the salivary glands (Namba 2019). Leafhoppers in their nymphal and adult stages can acquire and transmit X-disease phytoplasma between trees, root suckers, and weedy hosts over the entire growing season in an orchard. Since leafhoppers feed on leaves and not fruit, disease spread continues postharvest, and it is critical to continue monitoring for vectors postharvest when pathogen titer and leafhopper abundance are high.

It is important to monitor for the presence of X-disease vector leafhoppers in cherry and stone fruit orchards to determine appropriate management strategies. Three common leafhopper sampling methods include sticky

traps, sweep nets, and vacuum tools like a modified leaf vacuum or Dietrick Vacuum Sampler (DVAC) (Harper et al. 2023; Purcell and Elkinton 1980). This publication describes each sampling method, along with previous research, techniques, advantages, and disadvantages, to improve decision-making.



L. Nottingham, WSU Extension

Figure 3. Adult *Colladonus geminatus* leafhopper. Photo: L. Nottingham.

## Sticky Card Traps

Sticky card traps (Figure 4) provide a passive sampling method that allows growers to trap adult leafhoppers and other insects and reduce variability caused by weather, sampling timing, and user technique. While sticky cards do not capture nonflying nymphs, they can be employed at different heights to track adult leafhopper populations in the ground cover and tree canopy.

Sticky card traps, typically cards covered with an adhesive material that traps the insect onto the card's surface, are produced by many companies. Insects fly or jump onto the cards and become stuck. Insects come in contact with cards haphazardly or due to an attractant on the card, usually either the card's color or the addition of an olfactory lure. Sticky traps are available in multiple sizes and colors. The trap size and color may depend on the target insect (Wilén et al. 2021). Sticky traps can also be made by coating surfaces like plastic or plywood with an adhesive that is capable of capturing the target insect, like Stikem Special (Seabright Laboratories, Emeryville, CA) and Tanglefoot Tangle-Trap Sticky Coating (The Scotts Company LLC, Marysville, OH).



Figure 4. Unbaited 5x7-inch yellow sticky card (ARBICO Organics, Oro Valley, AZ) utilized for leafhopper trapping in Washington. The figure shows an unused card (top) and *C. m. reductus* stuck to the sticky trap (bottom). Photo: L.E. Flandermeier.

Yellow sticky traps have been a primary method for leafhopper sampling for X-disease research as cited by numerous studies from the 1950s to the '70s; however, the method is commonly supplemented with another form of sampling, such as DVAC (an insect vacuum powered by a lawnmower engine) or sweep net methods (Purcell and Elkinton 1980). In 1980, sampling methods for X-disease leafhopper vectors were evaluated in California cherry orchards. Researchers captured the same leafhopper species using the sticky card, leaf vacuum, and sweep net methods but in different relative abundances (Purcell and Elkinton 1980). *C. montanus*, a primary vector of X-disease in Washington and Oregon, was captured in the greatest abundance by sticky traps, followed by DVAC and sweep netting (Purcell and Elkinton 1980). Unlike DVAC and sweep netting methods, sticky cards can be used to measure the relative abundance of leafhoppers in the tree canopy (Purcell and Elkinton 1980).

When collecting leafhoppers with a sweep net or DVAC, the insects captured represent a short period of time when the sampling was occurring. Sticky card traps provide a passive sampling method, where cards are set up, left for a set time, and then collected by a scout. As a result, sticky cards can capture adult leafhoppers over the length of time they are employed, allowing for a higher cumulative abundance of leafhoppers to be captured (Purcell and Elkinton 1980). These traps typically do not capture nymphs due to their inability to fly up to the trap (Purcell and Elkinton 1980). However, sticky cards placed close to developmental host plants in the ground cover may capture nymphs.

## *How to Use Sticky Cards*

Washington State University Extension recommends placing one trap approximately every two acres, two to four feet from the orchard floor throughout the block, in orchard borders two or three trees from the edge, or areas with suspected high leafhopper presence (DuPont et al. 2023). Sticky traps may be hung in trees or attached to stakes elevated from the ground (Figure 5). Plants may become stuck to the adhesive surface if traps are placed below two feet, making trapping more difficult. Avoid placing sticky traps in the direct path of sprinklers to avoid water damage or reduced adhesive efficacy.

A standardized protocol, including using consistent trap type (e.g., brand, size), is necessary to properly interpret sticky card sampling. Traps should be monitored or changed every one to two weeks, with shorter time periods allowing a more rapid management response to vector presence (DuPont et al. 2023). Scan traps and record vector numbers in the orchard or package to evaluate using a dissecting scope later. If transporting for counting later, the trap should be placed inside a clear bag or wrapped with cling film to preserve the insects and prevent the traps from sticking to other items. It is imperative to label traps with their location and deployment date to

accurately keep track of when and where leafhopper vectors are being collected.



Figure 5. Five-by-seven-inch yellow sticky cards attached to wooden stake. Photo: L.E. Flandermeyer.

## Considerations

Sticky trap placement will impact the number of leafhoppers captured (Purcell and Elkinton 1980). Avoid locations that will be directly affected by irrigation. Consider pre- and postharvest activities impacting sticky trap placement, deployment, and collection, such as mowing, spraying, pruning, harvesting, and others. Placing sticky cards closer to host plants may increase the probability of catching leafhoppers; however, putting a card too close may result in plant material adhering to the trap.

Trap color may impact capture. Previous research demonstrated that X-disease vectors, notably *Colladonus montanus* (subspecies unclear), were visually attracted to yellow (Nielsen 1968) or yellow-orange color (Alverson et al. 1977; Purcell and Elkinton 1980). Researchers in Washington and Oregon use unbaited, yellow, 5×7-inch sticky cards for trapping and monitoring *Colladonus* spp. leafhoppers (Figure 4). Growers in Washington have reported successfully capturing X-disease vectors with chartreuse sticky cards, but we recommend using the same color consistently to account for any differences in attraction by color.

Trap height will affect capture. Several researchers have evaluated the effect of trapping height on relative leafhopper abundance. Purcell and Elkinton (1980) found the relative abundance of leafhoppers collected from the orchard floor was the same across sampling methods (i.e., yellow sticky cards, DVAC, and sweep net); however, sticky cards placed 1.8 m above the ground had lower relative abundance compared to DVAC and sweep net samples from the ground cover. Purcell and Elkinton (1980) further evaluated the effect of trap height on average leafhopper catch. They found that the number of leafhoppers captured decreased as the height of the sticky trap increased, suggesting leafhoppers more abundantly populate lower strata. *C. montanus* was caught in the highest abundance on traps 20 inches above the ground, then abundance decreased with height; however, *C. montanus* was trapped within the tree more than other X-disease vectors (Purcell and Elkinton 1980). In 1988, Van Steenwyk and colleagues found trap capture of *C. montanus* to be highest at 1.8 meters mid-season and higher in traps at 4.9 meters in spring and fall (Van Steenwyk et al. 1990). However, relative abundance was only studied over one season in an untreated orchard that would allow leafhoppers to reach higher numbers in trees compared to an insecticide-treated orchard (Van Steenwyk et al. 1990).

Capture will be affected by leafhopper phenology. A study by Marshall et al. (2024) examined cultural control strategies and demonstrated that there are three generations of *C. m. reductus* leafhoppers per season in Washington. Trapping with sticky cards revealed the highest adult abundance of *C. m. reductus* in June,

August, and September through October (Marshall et al. 2024). It is critical to monitor *C. m. reductus* continuously throughout the growing season (particularly postharvest when phytoplasma titers are highest in plants) to know when each generation begins and ends. If you happen to only sample between generations, you may inaccurately assume vector presence or lack thereof in your orchard. In California life history studies, *C. m. reductus* and *C. geminatus* had generation times of approximately 56 days from egg to adult (Severin and Klostermeyer 1950). The generation time for *C. geminatus* was nine days longer in Oregon life history studies, and two generations were completed in the field on alfalfa (Nielsen 1968).

The trap's sun exposure may affect leafhopper capture. In a mark-release-recapture study of *C. montanus* leafhoppers in California cherry orchards, researchers suggest the sun's position relative to the leafhoppers influenced the movement or attraction to the yellow sticky traps (Purcell and Suslow 1982). In April and October, leafhopper recapture on sticky traps was highest to the north and east of the release location despite wind directions from the west and northwest (Purcell and Suslow 1982). Sun position may influence movement, since leafhoppers did not move directly into or with the wind after release (Purcell and Suslow 1982).

Leafhoppers may be difficult to identify on sticky cards, depending on their orientation, and may be affected by predation. For example, a distinguishing feature of *C. geminatus* is the patterning on the thorax, but *C. geminatus* that gets stuck to the adhesive on its dorsal side may be difficult to identify accurately (L.E. Flandermeyer, personal observation). Additionally, birds and yellow jackets have been observed eating insects from sticky cards, and some leafhopper specimens are missing abdomens (A.E. Clarke, personal communication; T.D. Melton, personal observation).

## Sweep Nets

Sweep nets, similar to butterfly nets but with tougher net material, are tools commonly used to collect insects (Figure 6). Sweep netting is a cost-effective, direct sampling method that provides estimates of leafhopper abundance at a particular time and place (Purcell and Elkinton 1980). Sweep nets capture both leafhopper nymphs and adults in the ground cover. This method is not recommended for use in the tree canopy because the proper technique cannot be executed (Purcell and Elkinton 1980).

Purcell and Elkinton (1980) found that capture of X-disease leafhopper vectors with sweep nets was lower than with sticky traps or a DVAC, but the relative rate of capture using a sweep net can be increased with additional sampling effort. Sticky traps are locationally fixed in an orchard while sweep nets or modified leaf vacuums are mobile throughout an orchard. Sweep netting

is a valuable tool for exploratory monitoring as the technique and sampling location can be adjusted to identify insect abundance and distribution in an area rapidly.

Sweep nets come in various sizes and are often mesh or canvas (Figure 6). When collecting numerous samples, it is imperative to use sweep nets with the same diameter opening to ensure comparable results (Figure 7).

## *How to Sweep Net*

Proper sweep netting technique should be used to ensure sample numbers collected on one date or by one individual can be compared to another (Figure 8). A standardized protocol is required to properly interpret sweep netting results. Hold the sweep net by the handle, with the opening close to the ground. As you walk through the orchard, swing the net from one side to the other in a 180-degree arc (Figure 8). Moving the net each time you take a step can be helpful. It is critical to maximize contact with the ground cover to collect leafhoppers that live on the orchard floor. Maintain contact with ground cover for most of each sweep. If collecting live specimens (such as for bioassays), do not sweep too aggressively or too long. In addition, mesh sweep nets preserve live leafhoppers better than canvas sweep nets.

After sweeping the desired area, shake the contents to the end of the net, close the mouth of the net, and carefully transfer the contents to a storage container (zip-top bag, insect cage, jar, etc.). Label each sample with a date, time, and location. If you are sweeping a particularly large area, it is helpful to complete only 10 to 15 strokes at a time to avoid losing contents from the sweep net as you go.

Count leafhopper vectors in the net using a hand lens to identify which species are present, or bring samples back to a central location to count. Due to the rapid movement of adult leafhoppers, it is advised to freeze samples or store them in ethanol for easier evaluation.

## *Considerations*

When and where scouts sample, the material of the sweep net, and the size of the net opening can impact the number of leafhoppers captured. Time of day, temperature, and ground wetness may impact sweep netting efficacy (DeLong 1932). Sweep netting is suitable for estimating relative leafhopper abundance in ground cover but not the tree canopy (Purcell and Elkinton 1980). Choose the sweep net material based on the type of ground cover you are sweeping. Canvas is more durable than mesh, which tends to snag or tear. If collecting live specimens, however, the mesh sweep nets reduce water accumulation and physical damage to insects, allowing higher survivorship (A.E. Clarke, personal observation).



Figure 6. Canvas sweep net (left) and mesh sweep net (right) with 36-inch handles. Photo: L.E. Flandermeyer.

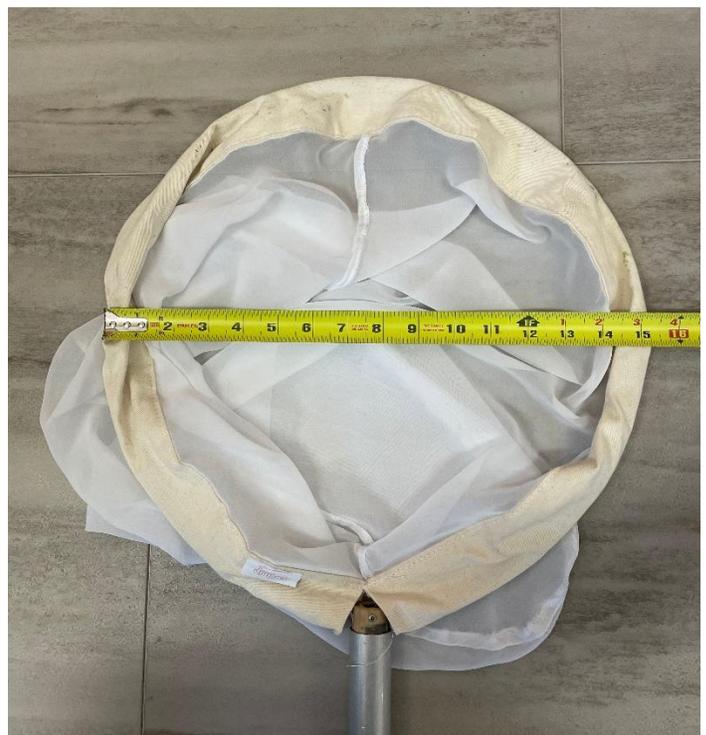


Figure 7. Measuring diameter of 15-inch mesh sweep net. Photo: L.E. Flandermeyer.



Figure 8. Sweep netting in an orchard. Photos: A.E. Clarke.

## Modified Leaf Vacuums

Although they are rarely used by growers, vacuum insect sampling devices are commonly used by researchers as a direct sampling method for X-disease leafhopper vectors that can be used on various types of vegetation. These devices can capture both adults and nymphs at a given time point (Figure 9) (Purcell and Elkinton 1980). These vacuum tools use suction to trap insects and are suitable for sampling in various vegetative habitats. Modified leaf vacuums capture leafhopper nymphs and adults and have been successfully used to sample leafhopper vectors of X-disease in Oregon and Washington (Harper et al. 2023). In a 1980 study, the relative rate of leafhopper capture was lower with DVACs than sticky cards, but capture increased with additional sampling effort (Purcell and Elkinton 1980).



Figure 9. Electric Ryobi 40 Volt Blower/Vacuum (model RY404015). Photo: L.E. Flandermeyer.

## *How to Create a Vacuum Insect Sampling Device*

Common household leaf blowers with a vacuum setting can be easily modified for insect trapping (Figure 9). These leaf vacuums are available in electric (battery-powered) and gas-powered forms.

To modify the leaf vacuum for insect trapping, first you must prepare your leaf vacuum according to manufacturer requirements. Some models may require assembly or part changes if the tool has both vacuum and blower functions.

Next, create a barrier between the air intake and the motor to prevent unwanted material from being sucked into the motor. For each leaf vacuum being modified, you will need four screws at least one inch long, fender washers, nuts, plastic mesh netting, and a power drill (Figure 10). Drill into the top, bottom, and each side of the lower tube approximately one to one-and-a-half feet from the end (Figure 11). Installing the barrier far enough from the end is important to provide sufficient trapping space. Cut the plastic mesh netting into a piece that is wider than the diameter of your leaf vacuum's lower tube but two times as long. Fold the mesh lengthwise, overlapping some to create more barriers without inhibiting airflow (Figure 12). Place one washer on each screw and insert the screws into the drilled holes. Place the plastic mesh netting into the lower tube and wrap the mesh around the base of

each screw multiple times (Figure 12). Ensure the mesh netting is tight so it cannot be pulled into the motor. Place the fender washers onto each screw and secure tightly with a nut.

Once the barrier is complete, a five-gallon paint strainer bag can be placed into the lower tube and secured by rubber tubing (Figure 13). The mesh netting barrier should stop the bag when suction is applied. The paint strainer bag will collect all insects and debris and can be emptied and reused numerous times. When damaged, the paint strainer bag should be replaced so target insects do not escape.

## *How to Use a Modified Leaf Vacuum*

Use proper personal protection when operating a modified leaf vacuum. The operator should evaluate the need for hearing protection (earplugs, headphones, etc.). According to the National Institute on Deafness and Other Communication Disorders, repeated exposure to sounds at or above 85 A-weighted decibels can lead to hearing loss.



Figure 11. Leaf vacuum tube with washers, nuts, and screws installed. Photo: L.E. Flandermeyer.

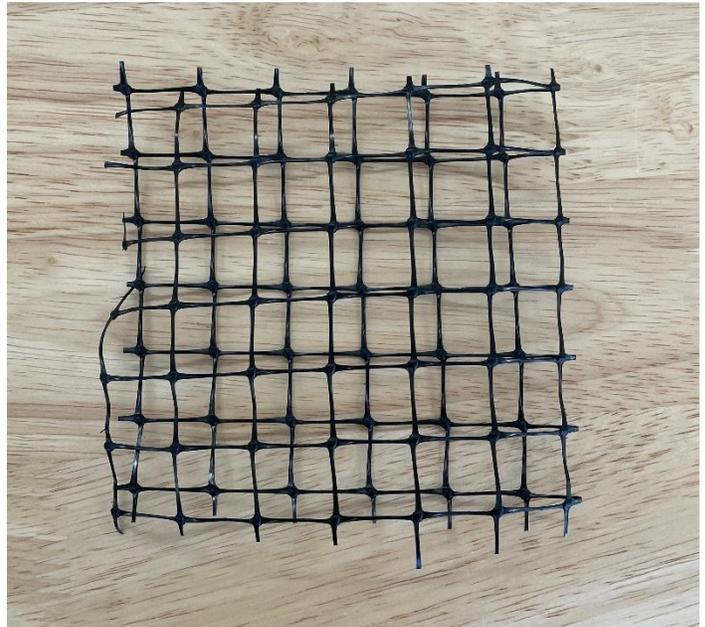


Figure 12. Plastic garden mesh netting with one square inch openings, folded to generate a motor barrier inside the leaf vacuum tube (top) and installed (bottom). Photo: L.E. Flandermeyer.



Figure 10. Hardware to install motor barrier screen in leaf vacuum, including a  $\frac{3}{8}$  and  $\frac{3}{16}$ -inch fender washer, #10-24 coarse machine screw nut, and 2-inch #10 machine screw. Photo: L.E. Flandermeyer.

Standardize the sampling area and device settings when making comparisons across sites and time. Determine a standard speed or throttle during sampling to maintain consistent suction. A one-by-one meter square or hula hoop with a known diameter are two simple tools to consider for standardizing an area. Sample the standardized area by vacuuming in and above the ground cover vegetation, and vacuum the entire area thoroughly (Figure 14).

Ensure consistent suction while sampling. With the vacuum on, shake large plant debris (i.e., leaves, grass) to release insects and remove the debris from the mesh bag. The vacuum should remain on until the top of the mesh bag has been pinched closed to avoid losing trapped insects when the suction stops. After removing the closed paint strainer bag from the vacuum, carefully transfer the contents into a container or zip-top bag for future sorting (Figure 14).

## Considerations

Vacuum sampling devices require assembly and maintenance and are affected by environmental conditions at sampling time. Like sweep nets, modified leaf vacuums require good sampling technique; however, vacuuming requires less physical effort than sweep netting.

Although these vacuums can be used in ground cover, leaf vacuums like those seen in Figure 14 have yet to be reported for use in trees. A modified leaf vacuum is an instantaneous sampling method, so the time of day, temperature, and ground wetness may impact sampling efficacy. Irrigation or rain may cause an accumulation of water in the ground cover, which will soak the paint strainer bag in the leaf vacuum, making leaves, debris, and insects stick together. Dampness increases sample sorting difficulty, so a leaf vacuum is best when used in dry conditions.

The type of ground cover sampled may yield different leafhopper species and quantities. Choosing a sampling area that is primarily broadleaf weeds may yield a larger number of *Colladonus* leafhoppers, known to preferentially feed on weedy hosts, compared to vacuuming grasses or bare ground.

It is important to remember that household leaf vacuums are designed with enough suction to collect leaves and other ground debris. Different leaf vacuum models will have variable settings and suction ability. Beware that suction will decrease as the paint strainer bag accumulates more debris, which reduces airflow. The operator should monitor and clear debris from the bag when necessary to maintain suction power and space for the target insect.



Figure 13. Five-gallon paint strainer bag and rubber tubing. Photo: L.E. Flandermeyer.



Figure 14. Using a modified leaf vacuum in a standard area within an orchard. Photo: A.E. Clarke.

## Other Considerations

### *Orchard Environment and Irrigation*

The sampling method chosen may depend on the environment of the orchard and the level of irrigation. Burs are challenging in drier environments, as they become tangled in sweep nets and tear the material. These burs will also stick to the paint strainer bag in the modified leaf vacuum, though the bag can easily be changed if damaged. Sticky traps are not placed on the ground, so burs are not an issue. In over-irrigated orchards, muddy conditions, standing water, and wheel ruts from tractors and orchard machinery make sweep netting and using a modified leaf vacuum more challenging. Orchards with excess water and strong weed banks may become overgrown if not regularly maintained. It may be more difficult to swing a sweep net through dense ground cover.

### *Orchard Cultivation and Management*

Orchards may be clean cultivated, sodded, or cultured. When comparing the effects of the ground cover environment, it is important to consider that capture rates on sticky traps are influenced by movement and abundance, whereas directly collecting leafhoppers with sweep nets or DVACs is only influenced by leafhopper abundance in the habitat. In 1977, the number of *C. montanus* leafhoppers caught on sticky traps in clean-cultivated orchards was higher than in sod-cultivated orchards, which may have been due in part to greater movement or relative attractivity to sticky cards in the absence of other host plants (Purcell and Elkinton 1980). In contrast, *C. montanus* species collected by DVAC and sweep netting methods in clean-cultivated orchards were similar to the number collected in sod or cultured orchards (Purcell and Elkinton 1980). In addition to *C. montanus*, the authors collected *C. geminatus* and other X-disease vectors and found that the species' identities were consistent across the different collection methods. This

finding suggests that the type of cultivation does not impact the ability to sample different leafhopper species with sticky trap, sweep net, or leaf vacuum methodology (Purcell and Elkinton 1980).

Orchards require management through pesticide sprays, mowing, or both. Scouts will need to plan around irrigation and pesticide sprays when retrieving and replacing sticky cards. Sticky cards do not need to be removed during pesticide applications or mowing if they are placed out of the way, so they are not run over, destroyed, or covered with grass clippings.

## *Ground Cover Barriers*

Ground cover barriers such as reflective mulches and fabrics may prevent certain sampling methods in an orchard. Limitations should be expected, whether the barriers are used for weed management or fruit coloring. For example, Extenday, a reflective plastic geotextile (DaySuperStartMax, Extenday, Yakima, WA), is primarily used for fruit coloring, but it has been shown to also reduce X-disease leafhopper vector populations on broadleaf weeds in orchards (Marshall et al. 2024). When the geotextile is properly deployed, the drive row is completely covered, so sampling via sweep net or modified leaf vacuum cannot be completed.

## *Budget*

The method(s) you choose to sample X-disease leafhopper vectors may depend on your budget and the experience of the person conducting the sampling. Sweep netting requires the least expensive equipment. However, it can be time-intensive and requires some training. For large orchards, it may require a trained labor force. Nonetheless, it can be an inexpensive way to quickly identify potential sources of leafhoppers when needed and is a useful supplement to other methods.

Depending on the vendor, size, color, and number of traps needed, sticky card sampling includes the most expensive supplies. Yellow sticky cards (5×7 inch) are approximately \$0.70 apiece (ARBICO Organics, Oro Valley, AZ) (Figure 4). If trap contents need to be identified instantly in the field, a technical expert, potentially with higher associated labor costs, may be required to complete the sampling. If traps are collected and returned to the lab for identification, however, the field collection does not require the same technical expertise as other approaches, and a technical expert can sort traps quickly within the lab environment.

The upfront cost for a leaf vacuum is higher than other methods, but the tool is durable and can be utilized for multiple seasons and purposes. Modified leaf vacuums also require either purchasing gas or access to electricity for charging. Battery-powered leaf vacuums are typically more expensive than gas but require less maintenance

and can be transported in an enclosed cab vehicle. Like sweep netting, vacuum sampling requires technical expertise. It can be more effective at collecting insects than a sweep net, yet leaf vacuums are larger and heavier than sweep nets, making them more difficult to keep handy in the field for sporadic use.

## *Schedule*

The sampling method you choose may depend on your schedule. Sticky traps require the least time commitment in the field and are easy to change but should be switched every one to two weeks. Sweep netting and vacuuming methods take longer to complete in the field, requiring several minutes per sample. Each method requires a similar amount of time to look through samples, quantify, and identify the adult leafhopper vectors.

## **Conclusion**

It is imperative to monitor and sample leafhoppers in your orchard to identify X-disease vectors. Sticky cards are a low-cost, effective method for sampling leafhopper adults. Vectors can be easily identified and quantified from traps. Instantaneous sampling by modified leaf vacuum provides a “snapshot” of insects in a standardized sampling area. While the modified leaf vacuum has a higher upfront cost, the method allows nymphs and adults to be captured and requires less physical effort when compared to sweep netting. Sweep nets may also be used for instantaneous sampling of adults and nymphs, but the user technique is more difficult to standardize.

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