VitisGen3 Variety Trial Enhances Biopesticide Management

Richard Carey

There is a reason that many articles are being written about biopesticides these days: across all sectors of agriculture, we are seeing diminishing disease control via conventional fungicides as pathogen populations become more resistant. Compounding the issue is the reduced number of conventional materials in the pipeline due to the cost of development, slow registration pathways, and environmental concerns. New suppliers of non-conventional agents, such as biopesticides, have been looking for new and improved ways to combat plant pathogens to reduce the need for traditional chemical control, lengthen the useful lifespan of conventional solutions, while reducing the overall environmental impact of vineyard disease management.

The Green Revolution introduced chemical herbicides, insecticides, and fungicides into the grower's arsenal that dramatically improved global food security. These chemistries were powerful, effective, and reasonably inexpensive. In the years since, we have come to understand their significant environmental and human health consequences. Environmental regulations have put greater scrutiny onto the commercial development process and pipeline and have slowed the speed of development while increasing its cost. With fewer new compounds coming onstream, vineyard managers are looking for alternative materials to protect crops.

Dr. Katie Gold, assistant professor of grape pathology at Cornell Agritech, part of Cornell's College of Agriculture and Life Sciences (CALS), and David Combs, Cornell Grape Pathology research support specialist, have been testing the efficacy of several newly released biopesticides on wine, hybrid, and juice grapevines since 2020. The Gold lab team has made several presentations over the last few years about their work. In December 2021, Alice Wise, viticulture specialist with Cornell Cooperative Extension on Long Island, published a report on a project that evaluated one of the earlier biological pesticide products, Regalia, in combination with Stargus, regarding the success of these products on grapevines in Suffolk County, New York.[1]

Cornell Grape Pathology's latest project is funded by the USDA NIFA SCRI VitisGen3 project, which will support the evaluation of several disease-resistant varieties under conventional and biopesticide management programs in commercial-style production. The grant, awarded in 2022, is the third in this series focused on breeding powdery mildew-resistant grape varieties. These new trials mark the first time VitisGen-developed varieties will be evaluated in the field under commercial-style management. More information about the VitisGen3 project is available at *vitisgen3.umn.edu/about-vitisgen3*.

Scientists and grape growers have known that relying too heavily on conventional pesticides leads to an increase in pest resistance to those products. Mutations occur naturally within all organismal populations, including plant pathogens, and sometimes one of those randomly occurring mutations confers increased fitness, such as fungicide resistance. These mutations can impart partial or total resistance to a compound used to control the pest, and then quickly propagate throughout the entire population due to the increased survival likelihood the trait confers.

Integrated Pest Management (IPM) is a management philosophy developed in reaction to the Green Revolution and the environmental impact of pesticides developed during that time. The goal of IPM is to create protocols to reduce the amounts and effects of conventional pesticides through systems thinking.

Recently, IPM has undergone a revitalization and update in its strategy and implementation. An article in Evolutionary Applications (2020) provides insight into the newer implementation of IPM.[2] The authors present the concept of an evolutionary framework, a change that will encourage testing the efficiencies of control measures and predict long-term consequences of any measures taken on the specific ecosystems in which they are used. The prior protocol of IPM was based more on reaction to a problem presented, while the new protocol will anticipate the problem and develop preventative measures.

These authors emphasize that environmental resistance is part of a normal mutation. However, in an agricultural setting, where the maximization of certain traits is paramount for production demands, including quantity, resistance traits have either consciously or unconsciously been lost from many commercial varieties. The VitisGen3 project is specifically designed to deal with this problem as part of an integrative solution to reduce the reliance on conventional pesticides via increased innate disease resistance and optimized chemical control.

A strong push is now underway to educate grape growers about the necessity of embracing IPM strategies—with the additional emphasis on prevention—to benefit grape growers worldwide. The May 2023 issue of *Wine Business Monthly* included an article by Dr. Pam Marrone, owner of Invasive Species Corporation. Her article, "New Biological Products Prove More Effective, Meet Sustainability Needs," (the first in a series of articles) is an in-depth article that includes a good description of many of the biological pesticide product types and their modes of action.

Update on Biopesticide Research

Cornell's VitisGen3 field trials evaluate how coupling resistant varieties with biology-driven disease management and biopesticide-focused management programs will improve sustainability in the U.S. wine and grape industry. Some, but not all, biopesticides are listed by the EPA as organic. Organic Materials Review Institute (OMRI) approval, the means of acquiring an organic label, is a separate registration pathway from EPA registration. According to the EPA, there are three classes of biopesticides:

1. Naturally occurring biochemical pesticide substances that control pests by non-toxic mechanisms from plant, animal, mineral, microbial

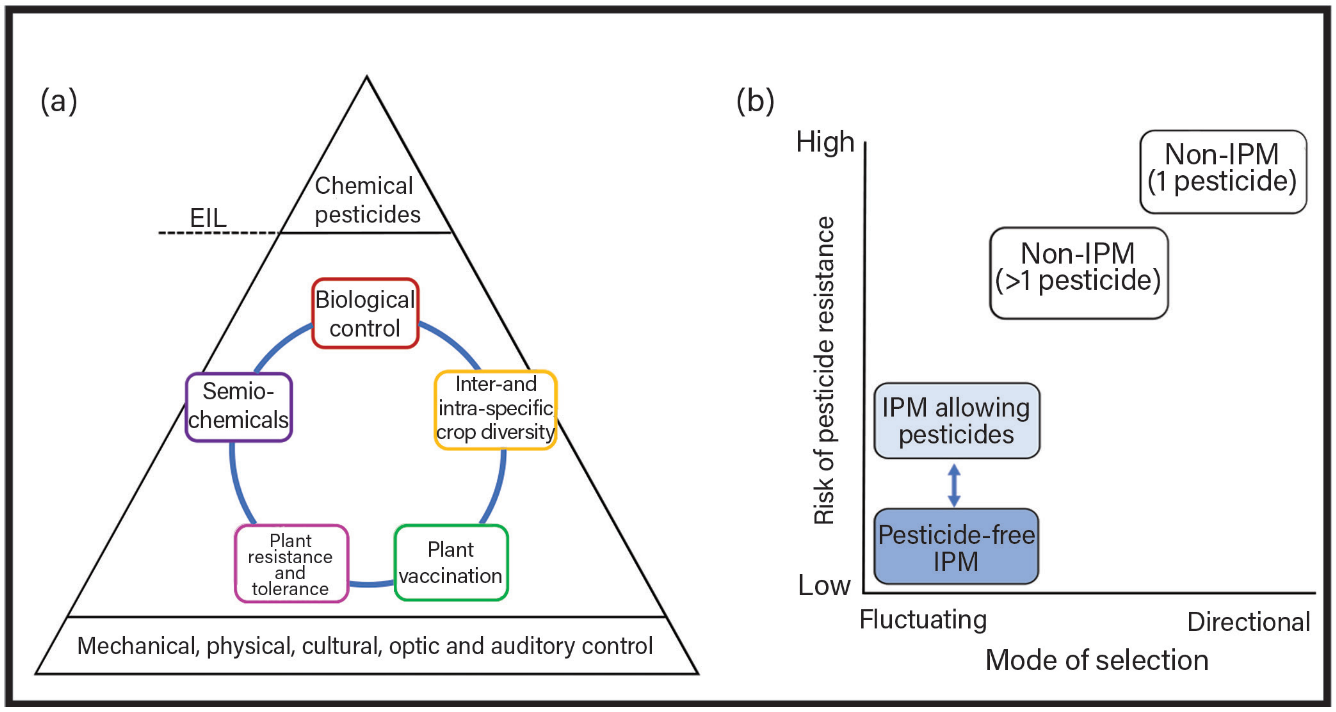

FIGURE 1: These diagrams show the importance of prevention and that it's an evolving process.

(a) Sustainable pathogen control begins with prevention based on disruption and delay of attack of the host. The more time, the more avenues, the more the plant can overcome the pathogen with its own defense mechanisms to keep a crop below its economic injury level (EIL).

(b) Varying non-pesticide measures, coupled with propholactic biopesticides, results in a longer delay and the lower amount of the final arrow in the quiver – conventional pesticides.

or other origin. In terms of grape disease control, the most common biochemical pesticides are plant extracts and microbial extracts.

2. Microbial pesticides consisting of microorganisms (a bacterium, fungus, virus, or protozoan) as the active ingredient. The subcategory of biofungicides describes formulations of living organisms used to specifically control the activity of plant pathogenic fungi.
3. Plant Incorporated Protectants (PIP) that are genetically incorporated into a plant's genome to ward off attacks to a plant (**TABLE 1**).[3] These are uncommon in plant disease control.

* The New York Grape and Wine Foundation sponsors the B.E.V. NY conference every winter. In her 2022 presentation at this conference, Gold emphasized that the industry is going to need to rethink their current standards of practice given the reality of increasing fungicide resistance in pathogen populations. Gold conceptualized vineyard fungicide resistance management as a house, encouraging vineyard managers to consider knowledge of the risks and problems faced in the vineyard as the foundation of their disease control programs. The pillars of the house are early detection and proactive prevention. This is the prevention part, and the place where most of the work needs to be focused. Biopesticides play an important role in proactive prevention of fungicide resistance development. Integrating biopesticides into disease management programs can reduce the overall use of conventional chemistries while retaining satisfactory disease control, thus slowing resistance development by reducing selective pressure for fungicide resistance (**FIGURE 1**).

Biopesticides have been present for years; but until now they have not been adopted as a significant percentage of the pesticides used. Today, they are the fastest segment for growth in the grapevine sector and represent 5% of the global market.[4] Some examples are:

1. Regalia (formerly Milsana) is an extract of giant knotweed. Coupled with benzothiadiazole (BTH), it was commercialized in 1990 for powdery mildew protection. However, subsequent BTH was discontinued due to lack of efficacy.

2. Romeo is another plant extract that is a foliar application made from yeast. It was discovered in 2006 and was released into the European market by Lesaffre in 2017/18.

3. Lifegard WG is a defense-activating biofungicide which has a unique mode of action amongst fungicides: it acts upon the plant to activate innate defense, rather than upon the pathogen.

4. Pseudomonas chlororaphis is the active ingredient in the Howler biofungicide.

Demand for these products has grown significantly in recent years.

Currently, the EPA has registered 390 compounds listed as biopesticides. Producers of these biological materials are scavenging for natural products that can have utility against processes or organisms that reduce the target plant's ability to grow and to produce a high-quality crop. There is a much lower threshold to get the new biological products to market, because the environmental risk and the health and safety of the products are much less of a concern for regulatory departments. Several of the more common biopesticides and their primary class of action are shown in **TABLE 2**. Two articles are available online for more in-depth information on biological pesticides, plant protectants, and insecticides.[5, 6]

Recently I had a conversation with Steve Bogash, the Northeast and Mid-Atlantic territory manager of ProFarm Group. He indicated that many of the biological pesticide companies have thousands of compounds that are being catalogued as potential materials for use "at some point." The problem in bringing these compounds to market is a combination of the cost of production, the ability to grow an organism at scale, and producing that product at scale. There also are shelf-life issues, even if the product has a high probability of being useful.

The opposite is true for the conventional pesticide market, as that industry is declining, and manufacturers don't see enough profitability after research and development as consumer demand tends toward reducing the amount of conventional chemicals introduced into the environment.

TABLE 1: BIOPESTICIDE CLASSES

1. Biochemical pesticides are naturally occurring substances that control pests by non-toxic mechanisms. Biochemical pesticides include substances that interfere with mating, such as insect sex pheromones, as well as various scented plant extracts that attract insect pests to traps. Because it is sometimes difficult to determine whether a substance meets the criteria for classification as a biochemical pesticide, EPA has established a special committee to make such decisions.
2. Microbial pesticides consist of a microorganism (e.g., a bacterium, fungus, virus or protozoan) as the active ingredient. Microbial pesticides can control many different kinds of pests, although each separate active ingredient is relatively specific for its target pest[s]. For example, there are fungi that control certain weeds and other fungi that kill specific insects.
3. Plant-Incorporated-Protectants (PIPs) are pesticidal substances that plants produce from genetic material that has been added to the plant. For example, scientists can take the gene for the Bt pesticidal protein and introduce the gene into the plant's own genetic material. Then the plant, instead of the Bt bacterium, manufactures the substance that destroys the pest. The protein and its genetic material, but not the plant itself, are regulated by EPA.

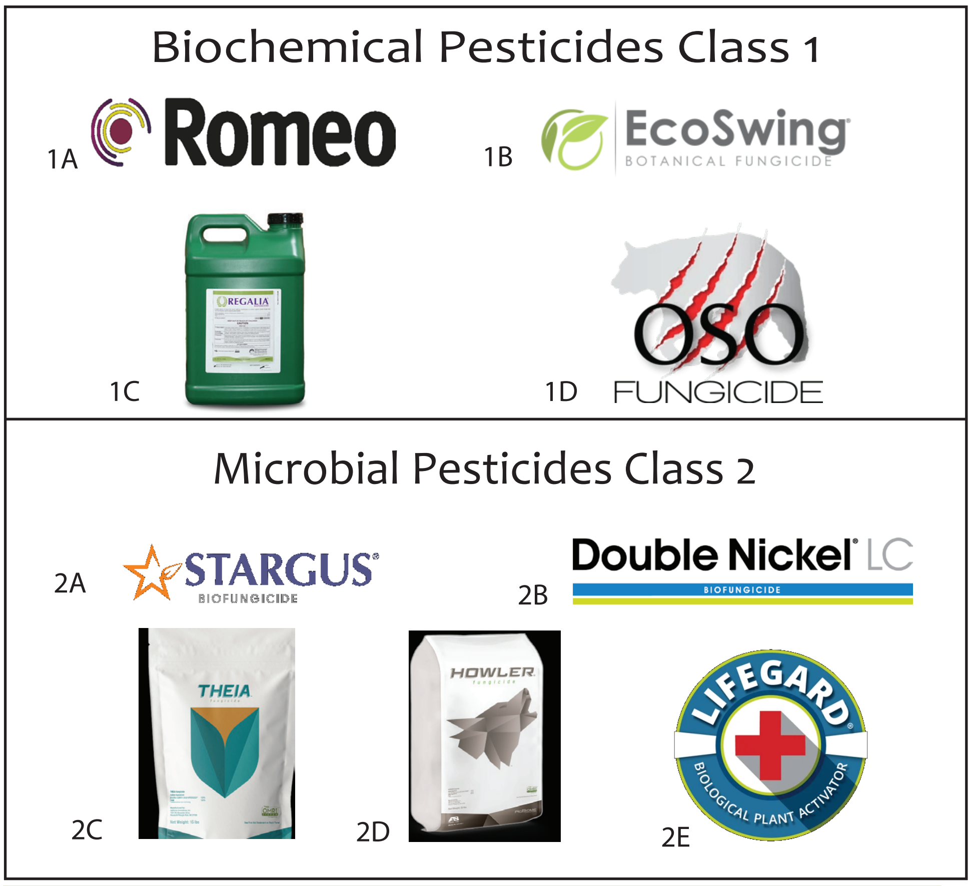

TABLE 2: Two of the three EPA classes of biological pesticides are important for grapevines and are some of the more common biological and microbial pesticides on the market. The following list gives the brand names of the companies that sell them:

1A – Wilbur-Ellis Agribusiness – *www.wilburellisagribusiness.com*
1B - Gowan Company – *www.gowanco.com*
1C – Pro Farm Group – *www.marronebio.com*
1D – Certus Biologicals – *www.certusbio.com*
2A – Pro Farm Group – *www.marronebio.com*
2B – Certus Biologicals – *www.certusbio.com*
2C – AgBiome – *www.agbiome.com*
2D – AgBiome – *www.agbiome.com*
2E – Certus Biologicals – *www.certusbio.com*

The goal of the grape industry is to change the direction for vineyard health and sustainability for the positive. One of the driving forces in this change will be finding compounds that have as high a degree of control efficacy as conventional pesticides with fewer environmental and health issues.

It is important to understand that these biological compounds have different chemistries than their conventional counterparts. Gold uses the analogy of a lock on your door; a good lock will prevent an opportunistic or weak thief, but the determined, strong thief can still break through. These products require more in both quantity and frequency of use because they are acting in a way that doesn't necessarily kill the organism. Instead, the product makes it harder for the pest to grow so, in many ways, the plant can develop a defense against a low-level attack, keeping the "honest thieves" at bay.

In the case of Regalia, the giant knotweed extract stimulates a multitude of plant protective measures on application of the material. It thickens the epidermal plant tissue, making it harder for the plant pathogen to penetrate the outer cell layers.

Over the years, Cornell Grape Pathology has evaluated several different types of biopesticides in their seasonal spray trials. For both powdery and downy mildew, they evaluated control on leaves and on grape clusters separately. Overall, they find that many newly released biopesticides have comparable performance to conventional products. However, it is important to note that biopesticides are sensitive to biological pressure. The greater the pressure, the more difficult it will be to maintain control of downy and powdery mildew, especially on foliar spray (**FIGURES 2** and **3**).

Earlier this year, AgBiome Innovations released a new microbial called Theia. They have incorporated a new strain of *B. subtilis AFS032321*, which now adds a new tool that covers many current grape diseases. Theia is listed as an OMRI product and works to control black rot, downy mildew, Botrytis gray mold, Phomopsis, powdery mildew, and several soil diseases. Agbiome's literature claims the *B. subtilis* will block fungal, bacterial, and oomycete pathogen and activate grapevine natural defenses.

There are other products that can be used in a tank mix to provide the same type of protection. Biological pesticides do not have a high probability of incurring resistance to these materials; however, it will be prudent to continue mixing materials of different modes of action to protect against that possibility in the coming years.

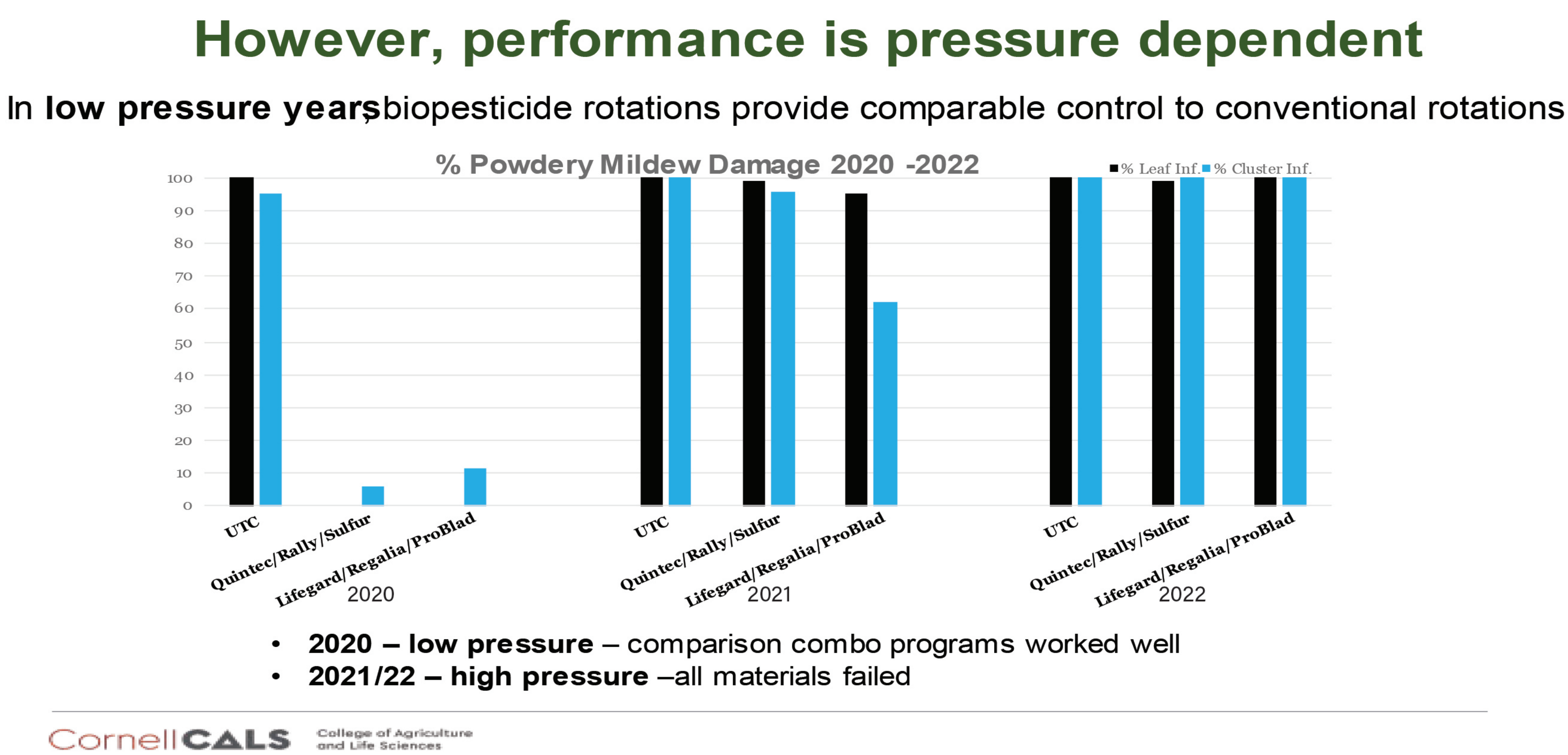

FIGURE 2: Biopesticide rotations provide comparable control when a low pressure year (2020) for control of powdery mildew is compared to a high pressure year (2021/2022).

However, performance is pressure dependent

In **high pressure years** we see control failures across the board (especially for DM)

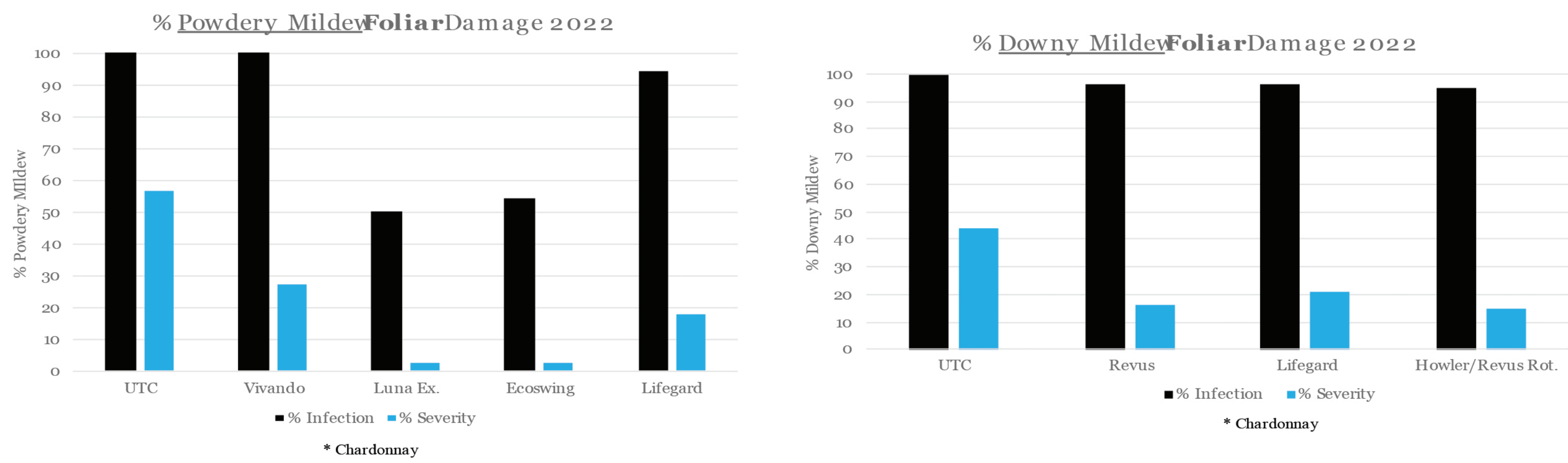

FIGURE 3: On foliar sprays, biopesticides show a pressure dependence that is better on powdery mildew than for downy mildew infection. Both diseases show that their efficacy is challenged by the pressure of infection.

Biopesticides can improve the health of our vineyards, and vineyardists will need to up their game with these different types of materials. It will be necessary to research the target organisms for each product in each vineyard, and whether one product works better than another in that location. A more rigorous schedule will need to be developed for biological pesticides to assure that the vineyard is protected early: The lag phase of infection is the easiest time to hit the pathogen with the most effective solution. The more infection is allowed to build up, the more passes required to lower the causative agent, especially when weather conditions may work against you. Tank mixing with different components will be a required procedure to maximize each pass through a vineyard. Mixing with conventional materials is also an option to find the best combinations. In this scenario, much lower levels of conventional pesticides can be used.

VitisGen3

New developments are incorporated into the USDA grant for the VitisGen3 project. A major component of this grant is a breeding program to find cultivars of hybrids from programs at several institutions participating in VitisGen3 (**TABLE 3**). An important part of the VitisGen3 project is extending the work from the previous two projects by expanding the process of disease control through a combination of the biopesticides discussed above, but also breeding grapes to include genetic resistance to pesticides. This is the best way to reduce the need for conventional control measures. In strong pressure times, this process may not completely protect a plant, but it certainly will make it easier to control during that time of stress.

VitisGen3 will employ the gene editing tool Crispr to select specific genes for disease resistance and insert them into vines and test the vine's ability to fend off the pathogen. A project goal will insert only the resistance gene and not change any other character traits to see if it will be possible to only need to

TABLE 3

VitisGen3 Grape Breeders		
Institution	**Breeder**	**Title**
Cornell AgriTech	Dr. Bruce Reisch	Professor of plant breeding and genetics
University of California Davis	Dr.Dario Cantu	Professor of Grape Genomics
University of California Davis	Dr. Luiz Diaz-Garcia	Assistant Professor Grape Breeding and Local Phenotyping
University of California Davis	Dr. Mélanie Massonnet	Assistant Scientist Grape Genomics
University of Minnesota	Dr. Mathew Clark	Project Director, Associate Professor of Grape Breeding and Local Phenotyping
University of Minnesota	Dr. Dan Voytas	Professor of Grape Genomics
Missouri State University	Dr. Chin-Feng Hwang	Professor of Grape Breeding and Local Phenotyping
North Dakota State University	Dr. Harlene Hatterman-Valenti	Professor Grape Breeding and Local Phenotyping
South Dakota State University	Dr. Anne Fennell	Professor Grape Genomics
USDA	Dr. Surya Sapkota	Research Geneticist, Grape Breeding and Local Phenotyping
USDA	Dr. Gan-Yuan Zhong	Research Leader, Grape Genomics
VitisGen3 Plant Pathologists		
Institution	**Breeder**	**Title**
Cornell AgriTech	Dr. Katie Gold	Assistant Professor Plant Pathology
University of Georgia	Dr. Phil Brannen	Professor of Plant Pathology
Virginia Tech University	Dr. Mizuho Nita	Assistant Professor of Plant Pathology, Physiology and Weed Science
USDA	Dr. Lance Cadle-Davidson	Co-Project Director and USDA-ARS Research Plant Pathologist

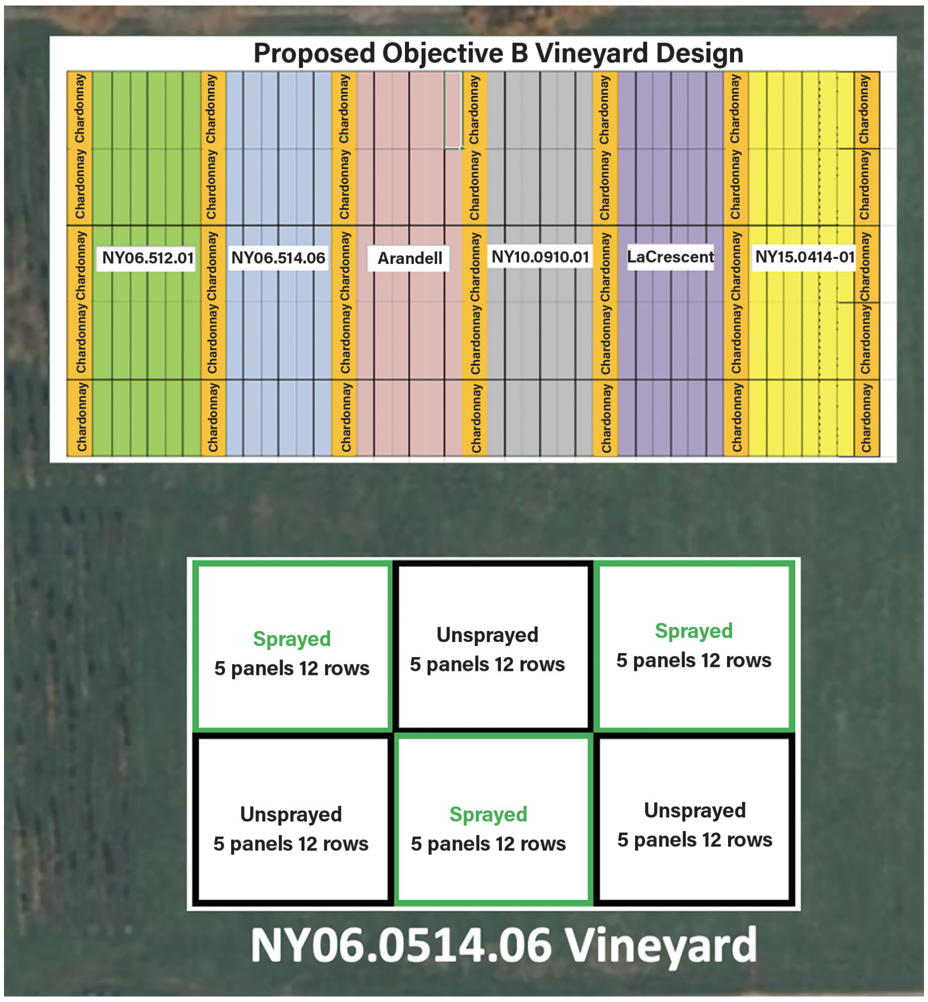

FIGURE 4: This diagram shows the proposed vineyard plot for the VitisGen3 trials for grape breeding against disease and for grapevine responses to several EPA biopesticides.

identify that the (Pick your name of Grape) "X cultivar Disease resistant" as an identifier for the variety of grape made into wine.

The VitisGen3 project will then develop control measures so that the lowest number of pesticides of any type can control the pathogens and produce high quality wine.

Combs described one of the plots as six replicated blocks with half as sprayed blocks and half unsprayed blocks (**FIGURE 4**). At the time of this writing, the blocks have been planted. The plan is to monitor everything from no or minimal spray to the extent possible, to varying levels of sprays of different types, with appropriate observations. Gold also plans to monitor these blocks with hyperspectral analysis and phytopatholobot robotic inspections, as well as the conventional visual inspection protocol. Vegetative barriers will exist between each block to minimize cross block contamination.

As a result of these trials, more definitive observational techniques are expected to be developed. These new tools will be available to vineyard personnel to manage their vineyards to produce consistent high-quality fruit for growers.

Conclusion

Even though the biological pesticide renaissance has been too long coming, most scientists and vineyardists in this field believe that now is the time for increased use of biological pesticides to happen. It may cost a bit more per acre, but the results will far outweigh the negatives, and will be a benefit to the health and safety of the vineyard personnel. Non-target organisms will thrive more, and there is even the prospect of more vineyards being able to achieve near organic levels on a regular basis, even if they are not certified as organic. **WBM**

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