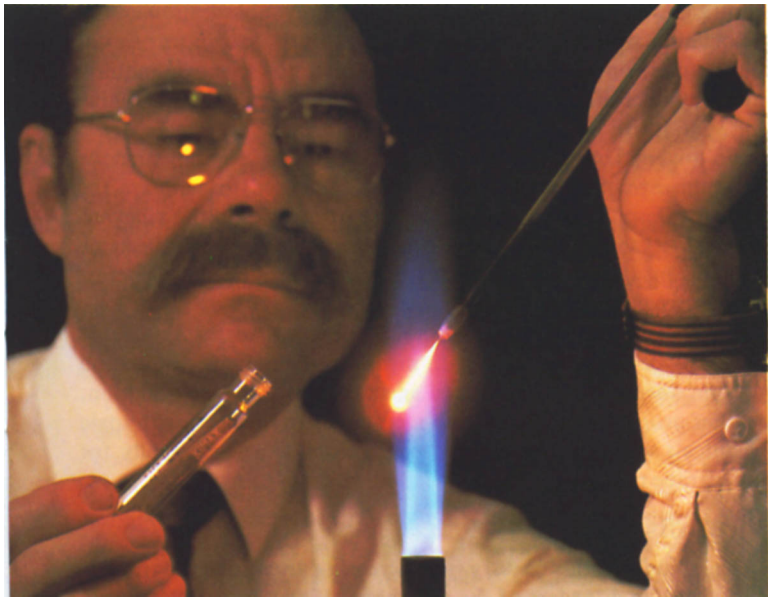

The use of pure yeasts as starter cultures, recommended by U. C. enologists, was a major step for California vintners. Ralph Kunkee sterilizes loop before inoculating a growing medium with one of the many yeasts in the University collection.

able for this: use of diethylpyrocarbonate (now banned); addition of sorbic acid; or sterile filtration followed by sterile bottling. Research at the University was carried out on each of these methods to make them practical for the California wine industry. For the sterile process, a method for quick detection of faulty procedures was developed.

Summary

The results of University research in wine microbiology during the past century have led to the widespread application in the wine industry of several important technologies: submerged culture flor sherry production; the use of pure yeast starter cultures in active dry form; the elimination of spoilage in dessert wines by *Lactobacillus trichodes*; controlled alcoholic fermentations including refrigeration; the ability to induce or inhibit malo-lactic fermentations; and quality control procedures for monitoring aseptic bottling of table wine containing residual sugar. These authors look forward to continued significant contributions in wine microbiology at the University of California during the next 100 years.

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Milestones in grape pathology

William J. Moller

microclimate, coupled with some unusual weather patterns, might still create a suitable environment for the disease, and growers need to keep it in mind. A strain of downy mildrew occasionally occurs on the state's wild grape, *Vitis californica*.

California vineyards still have their mildew—the powdery form (*Uncinula necator*)—first recognized in a northern grape district as early as 1859. Pierce reported on its "rapid spread" in the 1860s to southern California vineyards. Oidium, as it is sometimes called (a generic term for all the surface mildews), needs little moisture; in fact, it is favored by a warm, dry climate. Frederic Bioletti once wrote that (powdery) mildew "is the only serious fungus disease of the vine in California." Some 65 years later, his statement is still close to the mark.

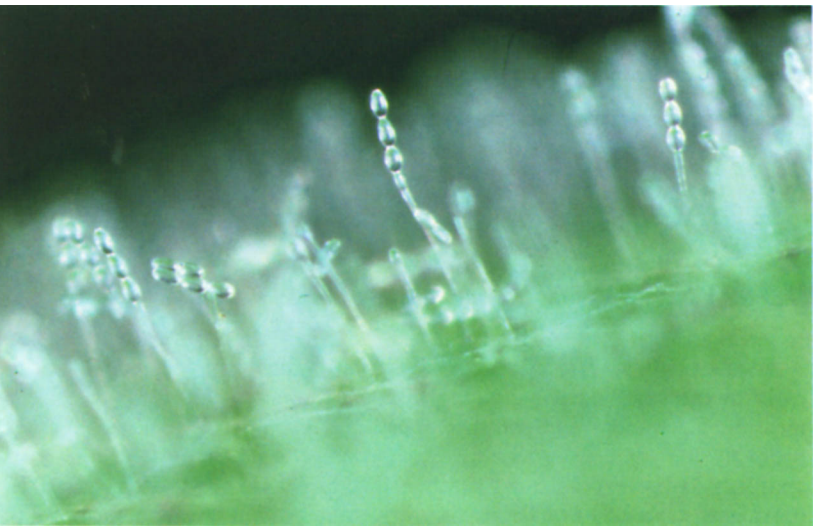
Other important fungal diseases of grapevines have since been recognized, but powdery mildew is the most widespread and economically significant. Few serious growers neglect routine mildew treatments, and table grapes might receive as many as 12 treatments each season.

Sulfur has been a safe, inexpensive, and reliable mildewcide on vinifera grapes since it was first used successfully in California in 1861. New chemicals have been regularly tested, and some have shown great promise, only to prove unacceptable because of cost or health hazards. Sulfur is still the mainstay of any grape mildew control program in California—either as a finely micronized wettable powder, or more commonly as a dust. Agricultural dusting is becoming less acceptable in many areas, however, and there are also increasing concerns about the energy required for a regular sulfur dust program. University researchers are hoping to improve forecasting of critical mildew periods, permitting more timely and less frequent chemical applications.

A widespread vineyard disease in low-rainfall districts appeared early in the state's grape-growing history. Known variously as measles, black measles, Spanish measles, and black mildew, it is probably the same disorder that Europeans refer to as esca or apoplexy. Over the years it has been ascribed to attacks of parasitic organisms, especially fungi entering via pruning wounds. Although there is general agreement on the symptoms of leaf burn and fruit

Striking autumn vineyard colors are caused by leafroll virus, the most common grape virus disease in California. Such colors are less often seen as growers use virus-free stock.

Above: Powdery mildew is the most economically important grape disease in the state. Severe infections lead to cracking, wilting, and rotting of the berries. Below: Microscopic view of mildew on a grape shows chains of fungus spores. Changes in humidity free the spores, which are carried by air currents to other grapes.



Below: Pure gray mold (*Botrytis cinerea*) infection on certain grape varieties in the coastal areas can be used for the sweet, aromatic dessert wines of the type highly prized in Europe.

spotting (which can be most harmful to quality table grapes) and its association with a soft, spongy wood rot in the crown or head of older vines, one aspect confuses and frustrates scientific inquiry: affected vines often exhibit almost complete recovery in the following years, with or without control measures.

Following University research in the 1920s, sodium arsenite solutions swabbed on dormant vines were used to suppress the disease. Despite the sporadic incidence of measles in the vineyard and the risks involved in using this hazardous chemical, the same control measures persist today, largely because no superior alternative has been found.

Extensive investigations in the 1950s consistently associated various wood-rotting fungi with measles-affected vines but could not pin down the specific causal agent. Without this information, further progress is unlikely, and measles and its control with toxic chemicals will continue to be a contentious issue—especially for table grape producers.

Virus diseases

The middle of this century saw increasing attention paid to virus and viruslike disorders of the grapevine. Vineyards still produced irregularly and inconsistently, even when other common diseases were under control, and decline sometimes began far earlier than expected. To prevent transmission of virus diseases through propagating wood, a foundation vineyard of virus-free, high-quality grape varieties has been established at U.C., Davis. Studies at

Austin Goheen grafts a candidate vine selection onto a healthy indicator plant. If, after 18 months, the selection proves to be disease-free, it will be certified for propagation.

Davis also revealed that soil-borne nematodes can serve as vectors of certain grape virus diseases.

Phomopsis, Eutypa, and deadarm

Another disease of grapes, caused by the fungus *Phomopsis viticola*, made its first California appearance in 1935 in the American River section of Sacramento County. By the 1950s it had become a consistent problem in the northern San Joaquin Valley. University researchers found that the dormant sodium arsenite treatment, by then in common use for measles, also eradicated the overwintering stage of *Phomopsis*, and other chemicals, like captan used at early growth stages, were effective protectants against shoot and leaf infection.

Throughout their investigations, these workers, like others elsewhere in the world, did not question that the symptoms caused by *Phomopsis* were identical to those described earlier in the century in New York and Ontario under the common name "deadarm," even though the most obvious signs in California consisted of leaf, shoot, and rachis spotting with little, if any, killing of arms. Severe spring infections make the weakened canes more susceptible to freezing injury during the following winter, but it is uncommon to lose large portions of vines to *Phomopsis*.

Controlled inoculations, which we have made at Davis over the past five to six years, have confirmed that "deadarm" disease, particularly as described in North American literature over much of this century, is in fact a complex of two separate diseases. Dying and dead arms and large pruning-wound cankers are commonly caused by a fungus that invades pruning wounds—*Eutypa armeniacae*—whereas leaf, shoot, and rachis spotting, and sometimes berry rotting, is caused by *Phomopsis*.

Rotting bunches—the good and the bad

During the past 15 to 20 years, increasing attention has been paid to grape bunch rot diseases.

High-yielding, tight-clustered varieties—especially when grown under sprinkler irrigation—seem prone to bunch rot disease, and some vineyards have occasionally been badly damaged by *Botrytis* when unseasonal rains have occurred just before harvest.

The impression frequently prevails that *Botrytis*-rotted bunches are desirable, which is true if the gray mold invades late in the grape's maturity, and favorable conditions follow; such berries, harvested carefully, can be used to produce sweet, highly aromatic, dessert wines of the type prized in Europe. More commonly, however, under California environmental conditions, other fungus and yeast rots are involved as well as *Botrytis*, and the rotting turns into a nightmare rather than profitable vintage. Investigations by University researchers during the past ten years have shown the benefits of early-season *Botrytis* control with fungicides.

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The California clean grape stock program

Austin C. Goheen

Grape plants live for many years, and we might say, if we consider vegetative propagation, that they live for centuries. Vegetative propagation, which perpetuates the mother plant by cuttings or buds, is important for maintaining trueness of grape cultivars to type, because perennial woody species do not breed true from seed as is the case with annual crops.

Vegetative propagation, however, can also spread disease. Although a disease that spreads slowly may be of little consequence during the normal life span of an individual vineyard, it will continue to spread with vegetative propagation and to increase with subsequent propagations. To eliminate such diseases from cultivar lines and thereby control them in new vineyard plantings, we have devised the California Registration and Certification of Grapevines, a cooperative effort between the research and regulatory agencies and the grape industry.

Basic elements of the program are proof of cultivar and clone identity, recognition of systemic diseases that spread with stocks, a procedure to establish freedom from disease, an isolated vineyard to maintain healthy mother stocks, a method to increase healthy plant materials, and a scheme to distribute the clean materials. This requires close liaison among viticulturists, plant pathologists, regulatory officials, nurserymen, and the grape industry. Much of the program is centered on the Davis campus of the University of California.

University viticulturists are responsible for cultivar and clone identity. They also breed new cultivars and select clones of established ones. They must demonstrate to the grape industry that the clonal material is valuable and worth maintaining in the program.

Pathologists in the University and the Science and Education Administration of the United States Department of Agriculture provide identification of the grape diseases, indexing procedures that prove mother vines are free from serious diseases, and therapeutic treatments that eliminate diseases from clonal materials.

Several viruslike diseases have been identified in grapes, and in a few cases the causal virus has also been isolated and purified. Research has demonstrated that some diseases are important to vine growth and yield, while others are of little or no consequence. The serious diseases are grape leafroll, infectious degeneration caused by fanleaf virus, and corky bark. Decline, caused by a mixture of tomato and tobacco ringspot viruses, is important in French hybrid cultivars in eastern United States, and it would be a serious threat if vinifera cultivars were not generally immune to it in California. Grape yellow vein, a form of decline caused by the tomato ringspot virus, is occasionally found in old Carignane and Emperor vineyards in the San Joaquin Valley. We now know that Pierce's disease, which was once considered to be a virus disease, is caused by a bacterium that kills grapevines and consequently rarely spreads in nursery stocks. Fleck and yellow speckle, two other virus diseases frequently found in grape cultivars, seem to cause little or no damage to grape production.

Identifying healthy and diseased grapevines on the basis of symptom expression in commercial vineyards is not easy. The diseases produce an array of symptoms in vines, depending on the