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

cultivar or species affected, and diseased vines often express no clear symptoms. We developed a testing system—indexing—whereby healthy indicator plants are inoculated by buds or pressed sap from a candidate selection and held for development of symptoms. Three standard grape indicators, St. George, Mission, and LN-33 and the herbaceous test plant, *Chenopodium quinoa*, will identify all the serious virus diseases that we have found in grapevines. We have established further that a candidate being tested is free of such diseases if symptoms do not develop within 18 months when the standard indicator plants are held in a proper environment for symptoms to express. Indexing has allowed us to prove that some candidates were diseased, but, more important, it has permitted us to establish that others were healthy and thus suitable as mother vines.

A problem developed in the programs when we found that all available materials of some cultivars were affected by disease. We solved this with heat treatments. Prolonged, continuous exposure to temperatures of 38° C or higher eliminated diseases from affected vines or from buds and stems tips of affected vines. By careful attention to plants exposed to heat, we were able to reestablish healthy explant lines from the disease-free plant parts that developed in the heat chamber. Meristem or tip culture is often necessary in addition to the heat treatment to free plants from leafroll or corky bark.

In recent years we have used thermotherapy routinely to process cultivars that come from foreign countries as insurance against accidental importation of a disease or pest that is not present in this country. Explant lines developed by heat treatments are reindexed to the standard indicators to be sure that disease has been eliminated before the treated cultivars are released to the registration program.

The healthy plants obtained by indexing or produced by heat treatments and indexing become the source for the initial increase of nursery materials. These must remain disease-free while they produce cuttings and buds for further increase. We accomplish this in an isolated foundation vineyard where we plant only vines that have passed the indexing tests. Here the vines are cared for by the Foundation Seed and Plant Materials Service, a service organization created within the University of California to maintain and distribute clean seeds and plant materials developed in the research programs.

Each plant in the foundation vineyard is carefully inspected for viruslike symptoms, once in the spring and again at harvest time, as long as it remains in the planting. If off-type symptoms show, the plant is reindexed before it is registered. Each vine in the foundation vineyard is also held until it fruits so that it can be checked for trueness to variety. When this is accomplished, the plant is registered with the California Department of Food and Agriculture as a source for further increase.

Cuttings and buds from the few vines of each cultivar registered in the foundation vineyard are not sufficient to supply the grape industry's demand for propagating materials. To further increase the wood, we have permitted cooperating nurseries to establish increase blocks from the foundation materials under the supervision of the California Department of Food and Agriculture. This step in the registration program is voluntary, but nurseries that wish to grow a registered increase block and distribute certified nursery materials are required to produce them in compliance with regulations spelled out in the California State Agricultural Code. The regulations ensure that materials remain free of serious virus diseases. In addition, the California Department of Food and Agriculture inspects the mother plants in the registered increase blocks once and occasionally twice each year for cultivar purity and freedom from disease. That agency maintains careful records of the total nursery materials produced by vines in each registered increase block.

The final step is release of clean plant materials to growers who wish to plant new vineyards. Each cutting from the nursery can be traced by registration of source vines back to the original mother vine that was indexed for disease freedom and identified for trueness to type for the specific cultivar. When the nursery delivers materials to the grower, the California Department of Food and Agriculture issues a tag certifying that the plant material was produced in compliance with the regulations of the Registration and Certification Program.

In the approximately 20 years that the program has operated, almost 70 million certified grape plants have been produced and sold to the California grape industry. Spread of leafroll, fanleaf degeneration, and corky bark by nursery stocks is no longer a serious problem. The grape industry cooperates with the program when growers request and receive certification tags with nursery stock delivered for planting new vineyards.

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