VIRUS AND VIRUSLIKE DISEASES OF GRAPES

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Several diseases of grapes are caused by agents that invade and become systemic in plant tissues. These are infectious agents that have a common viruslike characteristic and are transmitted by grafting and therefore spread by nursery stocks. For most, natural spread in the field is very slow, lower than the rate of normal vineyard replacement. In other words, a healthy vineyard planted in clean soil would remain free of many of these diseases during the normal productive lifespan of the planting. However, if the grower introduces the disease with his planting stock, the vineyard is diseased and remains affected until it is pulled and replanted. Some of the pathogens that cause these obscure diseases are viruses; others are mycoplasmalike organisms and rickettsialike bacteria; still others have defied characterization.

The propagator could control these diseases easily if he could recognize diseased mother vines and eliminate them as a source of scions or cuttings for nursery stock production. Recognition of disease in vines where the disease agent is unknown or is not inciting obvious symptoms is not simple. It is, however, possible if healthy indicator plants in which disease symptoms are expressed clearly are available for tests of infectivity. If the indicator develops symptoms after it is grafted with buds or otherwise inoculated from the mother candidate, the presence of disease can be demonstrated. Testing infectivity by grafting or mechanical transmission of disease is called indexing.

Indexing is a tedious process because, with grapes and most other fruit crops, graft inoculation is required. The subsequent build-up of the pathogen to a point that it expresses symptoms in the indicator generally requires one or more growing seasons. It is, however, usually more accurate than any other infectivity test, provided that the indicator plant is initially healthy and disease symptoms that develop are distinct and specific.

Selecting a suitable indicator for reliable indexing requires considerable effort. We spent 10 years and examined numerous cultivar and hybrid clones until we had reliable indicators for indexing leafroll, corky bark and several other transmissible grape diseases at Davis. The effort paid off. Indexing permits us to certify that mother vines obtained from selection and heat therapy programs are free from specific diseases. We still lack good indicators for some graft-transmitted diseases. Lack of suitable indicators and indexing tests hampers understanding of grape diseases in other parts of the world.

Diseases that are transmitted with nursery stocks can only be controlled if they are detected. I will review the literature to the present on transmissible grape diseases. I will not organize my review by pathogen because that has obvious limitations for discussion of diseases for which the pathogens are not known. Rather, I will arrange my paper under the following headings: grape diseases transmitted by grafting; viruses associated with diseases in which infected grapes show no symptoms or with disease complexes; diseases that produce viruslike symptoms; and the control of graft-transmitted diseases. I will then conclude with a discussion of problem areas and the direction of future research.

GRAFT-TRANSMITTED GRAPE DISEASES

Graft-transmitted diseases are infectious diseases and are not to be confused with environmental or genetic problems. For characterization of each disease it is important to know 1) the symptomatology and effect on the host; 2) geographical distribution; 3) the causal agent; 4) natural spread; 5) effect of thermotherapy; and 6) a method for indexing. For control, the most important considerations are therapy and indexing. Disease identification by indexing depends on the recognition of specific symptoms in the indicator.

Indicator plants used in indexing or the stability of the disease to heat treatments might be logical points upon which to base discussion. However, I have chosen to group diseases by their specific effect on the grape plant. The effect is not always clear-cut, but in a general way the graft-transmitted diseases are either 1) lethal, 2) degenerative or 3) semilatent. The importance of each disease and, to a degree, its control depends on this effect.

Lethal diseases are devastating, but eliminate themselves from clonal propagation because potential mother vines are killed before becoming available as sources of scions or cuttings. Degenerative diseases are important because they cause yield losses, but they will not usually be clonally propagated unless symptoms do not show at the time when mother vines are selected. Some of the similatent diseases are extremely important because they produce chronic yield and quality losses and are easily transmitted or perpetuated during propagation.

Lethal diseases

Survival of the causal agent of such diseases does not depend upon grape vines but upon alternative host plants and efficient insect vectors. The diseases are rarely, if ever, clonally propagated. Two diseases, Pierce's disease and infectious necrosis, belong in this group.

Pierce's disease causes scalding and burning of leaf blades. It usually starts on a single cane but ultimately involves all the leaves on a vine. Canes showing leaf symptoms do not mature normally, and the fruit clusters on such canes wilt and dry. As the disease progresses, affected shoots show delayed growth in spring and dwarfing. Cuttings from affected vines, however, rarely root. All shoots on the vines ultimately become affected and, after 1 to 5 years, affected vinifera and labrusca grapes die (36). Several *Vitis* spp. in the southeastern U.S. are highly tolerant or immune (48). The disease occurs in the southeastern U.S. and in adjacent Mexico and in California (36, 25). Incidence varies from infection of 100% of vinifera and labrusca vines in the Southeast to an occasional diseased plant in many areas of California. Pierce's disease is spread by several species of insects; the principal one in northern California is *Hordnia circellata* (36). In areas in which a vector is favored, the disease can prevent grape production. The disease agent was considered for many years to be a virus that was limited to xylem tissues in grapevines and other hosts (36). Recently, examination of ultrathin sections of leaf tissues under an electron microscope revealed a rickettsialike bacterium in xylem elements of affected but not healthy vines (28, 40). The bacterium has not been cultured from the host plant (53). A claim that *Lactobacillus* sp. was the causal agent (1) could not be confirmed (53).

The agent is easily inactivated by immersing entire plants in water at 45°C for 3 hrs, at 50° for 20 min or at 55° for 10 min (28). Transmission to healthy vinifera plants from infected ones by leafhoppers is the best indexing test for the disease. The disease can also be transmitted by grafting, but with difficulty (36). The presence of rickettsialike bacteria in the lumen of leaf xylem vessels in thin sections can be used to confirm the diagnosis (25).

Infectious necrosis is less well characterized than Pierce's disease. Rootstock vines derived from American *Vitis* spp., and vinifera and hybrid cultivars as well, show a necrotic pattern in the areas between the principal leaf veins. The leaves are asymmetric. The necrotic pattern is preceded by a greenish-yellow spotting. As the disease progresses, shoot vigor is reduced and fewer shoots are formed. The disease is reported only from Czechoslovakia.

Cuttings from infected vines produce diseased plants that show symptoms the first season. The disease also spreads with grafts from diseased to healthy plants (20). A rickettsialike bacterium has been found in differentiating cells of young lateral roots from diseased vines, but not in the petioles or midribs of leaves from the same vines. The bacterium is not present in healthy vines. Penicillin treatments bring about a remission of symptoms on newly developed shoots. Tetracycline treatments do not (63). Heat treatments have apparently never been tried for the disease (20). High magnesium levels bring out the symptoms in infected vines (63).

Degenerative diseases

The etiological agents of most of the diseases in this group are viruses and mycoplasmalike organisms (MLO). Several serologically distinct nematode-borne polyhedral outline (NEPO) viruses cause similar symptoms, but the symptoms may vary with different viruses. Often more than one distinct virus is found in the same diseased planting. I propose that diseases caused by those NEPO viruses in grapes originating in Europe or Asia be called infectious degeneration viruses and those originating in North America, grape decline viruses.

The diseases caused by MLO are less well known and still need clarification. I agree with Caudwell et al. (10) that the diseases associated with MLO in Europe should be called grape yellows rather than 'flavescence doree' or 'bois noir'. In India, little leaf (58) appears to be associated with an MLO and this disease is distinctly different from the grape yellows of Europe. Asteroid mosaic, one of the degenerative diseases, is graft transmissible but has not become widely distributed in grape stocks and no specific pathogen has been associated with it.

Infectious degeneration (ID) produces many different and confusing symptoms in vines. This has led to separate descriptions for fanleaf, veinbanding, yellow mosaic, court-noue, Reisigkrankheit, Hungarian chrome mosaic and urticado, to list a few of many early names applied to manifestations of this disease. The disease brings about various color changes and asymmetry in leaves; early names often reflected the symptom types. Canes and shoots grow irregularly with double nodes, short internodes, fasciation and other alterations of shoot development. Vigor is usually, but not always, reduced. Fruit set is affected so that clusters are uneven with large and small berries, or, in extreme cases, no fruit at all in some cluster forms. Yields may be reduced to 25% of yield from comparable vines (42). In woody shoots, xylem vessels usually show trabeculae (69).

The disease has been distributed to all grape growing countries, along with vinifera cultivars. It possibly originated with the vinifera grape itself in Asia Minor (35, 69). It is soil-borne and transmitted by nematodes of the genus, *Xiphinema,* the commonest and most widely distributed of which is *X. index.* As previously stated, the disease is caused by a number of serologically distinct but apparently closely related viruses. Although they do not have similar serological reactions, these viruses have similar physical and chemical properties. They are isodiametric particles, 26 to 30 $m\mu$ in diameter, with single-stranded RNA in those that have been studied in detail (44, 54). Serologically distinct viruses isolated from infectious degeneration in Europe are grape fanleaf virus, arabis mosaic virus, tomato black ring virus, grapevine chrome mosaic virus, raspberry ringspot virus, strawberry latent ringspot virus and one or more isolates that may still prove to be serologically distinct (44, 60).

Heat lability appears to be one of the physical properties common to all NEPO viruses found in grapes. Grape fanleaf, arabis mosaic, tomato black ring and grapevine chrome mosaic viruses were each inactivated in the shoot tips of infected grapevines held in a heat chamber at 35-39°C for 4 weeks (59). A similar heat treatment inactivated fanleaf in grapes in California (27). Infectious degeneration can be indexed by grafts to woody indicators, especially *V. rupestris* Scheele cv. St. George (69), by mechanical transmission to *Chenopodium amaranticolor* Coste & Rein or *C. quinoa* Willd. (67), by anatomical examination of plant material for the presence of trabeculae and by serology (69).

Grape decline, the name that I propose for the disease associated with NEPO virus from North America, resembles infectious degeneration. As in infectious degeneration, symptoms of grape decline vary. Generally, vine growth in spring is delayed, leaves on affected vines show mosaic patterns and asymmetry, trunk and shoot growth is reduced, fruit set is poor, especially in primary clusters, and yields are reduced (16, 30, 55, 64, 66). Sometimes vines die. In other cases growth is not seriously affected (30). In New York affected vines of 'Cascade' show stem pitting and grooving in the trunks and canes (65).

The disease occurs in California, New York, Michigan and Ontario. Cuttings from infected vines root and produce infected daughter vines. The disease also is transmitted through buds to healthy vines of susceptible cultivars. *Xiphinema americanum* is apparently a vector, but the role of nematodes in disease epidemiology is not well understood. As with infectious degeneration in Europe, several serologically distant viruses have been isolated from grape decline-infected vines: peach rosette mosaic virus (16, 55), tomato ringspot virus, tobacco ringspot virus (66), grape yellow vein virus (30) and Joannes-Sayve virus (15). Although serologically distinct, all of these viruses have very similar morphology and physico-chemical properties.

The yellow vein virus is inactivated in shoot tips in plants held in heat chambers continuously for over 7 weeks (27), but heat inactivation procedures for the other viruses found in vines affected by grape decline have not been determined. Indexing by grafting in grape indicator plants is difficult because the decline viruses move very slowly, even in susceptible grape cultivars. Pressed sap inoculation to *Chenopodium quinoa* is a quick and reliable indexing test for the presence of the disease (30).

Grape yellows causes stunting of the trunk, shoots and leaves of he vine. The leaves become hardened, brittle and rolled downward. n the case of flavescence doree, its common form as it occurs in 'Baco Blanc', the leaf blade shows a golden-yellow patch in the parts exposed to the sun (13). Creamy yellow spots develop along the veins and these generally become necrotic. The shoots do not mature properly but remain green with black pustules arranged in longitudinal lines along the bark surface. Flower clusters may dry up without setting fruit and, if fruit does set, it is bitter and unusable (13).

The disease is distributed throughout grape growing regions of Europe. In southwest France it is called flavescence doree and is spread by the leafhopper, *Scaphoides littoralis* (13). In eastern France the disease is called bois noir, but in this region natural spread does not occur (12). The same disease occurs in Germany, where it is called Vergilbungskrankheit (45), in Switzerland (7) and in Italy (2). Natural spread apparently does not occur outside of southwest France. In France, mycoplasmalike organisms were associated with the disease (21). In Germany, Mendgen (45) did not accept the work of the French authors. He reported similar structures in both affected and nonaffected vines, in vines with diseases other than yellows, and in potato and tobacco plants as well. He found viruslike threads in the phloem tissues of yellow vines, but his conclusion that these particles might be the virus that causes yellows is as circumstantial as the evidence of the French workers. Another study (41) of the disease in Germany revealed both rickettsialike bacteria and virus particles in affected vines, but this study was not completed and the pathogenicity of the suspected agents was not established.

Flavescence doree was eliminated in 80% of the cuttings from an affected source by holding them in warm water (30°C) for 3 days (9). Heat lability, spontaneous remission of disease symptoms and leafhopper transmission (13) are characteristics that it shares with peach X-disease, which is believed to be caused by a MLO (22). In Switzerland, vines infected with grape yellows produced corky bark symptoms in 3 of 37 inoculated indicator vines of LN-33 (7). Corky bark is one of the most heat stable diseases found in grapes (unpublished). Perhaps the grape yellows disease of Europe is a mixture of several unrelated diseases.

In southwest France, grafts or leafhopper transmission to 'Baco 22A' indicator vines is the best indexing test for grape yellows (13). Recent experiments (11) indicated that leafhopper transmission to broad bean, *Vicia faba* L., may be a more rapid test for the disease. A good test for the 'bois noir' form of the disease has not been published.

Little leaf causes vines to be small, with stunted roots, shoots and leaves. As the name implies, the leaves become exceedingly dwarf and deformed. They are yellow instead of green and somewhat cupped. The canes are weak and spindly with shortened internodes. Affected vines produce neither fruit forms nor fruit (58).

The disease is found only in India. It is transmissible by buds and grafts but not mechanically by pressed sap. Diseased cuttings soaked in a solution of oxytetracycline hydrochloride for 24 hr produced plants with temporary remission of symptoms (58). The agent is presumed to be mycoplasmalike. Hot water treatments for unspecified times applied to affected cuttings also produced plants with temporary remission of symptoms. Grafting or budding onto healthy Emperor cuttings can be used as an indexing test. Following inoculation by such means, the disease was observed within 40 to 50 days (58).

Asteroid mosaic reduces vine growth. Leaves are covered with small, starshaped spots in the lamina, which often contain a small, necrotic center. The spots may fuse, especially along veins, so that leaves show a netlike veinbanding. The leaves are asymmetric, twisted and puckered alone the veins. Diseased vines produce little or no fruit (56).

The disease occurs only in California and its distribution is limited to a few plants. It is transmitted by grafting or budding only. Neither a vector nor a pathogenic agent has been found associated with affected plants (unpublished data).

The disease can be eliminated by heat treating affected plants at 38°C for 42 or more days, followed by rooting explants from small shoot-tip cuttings under mist (27). Grafting or budding to *V. rupestris,* cv. St. George indicator plants is a good indexing test. In 'St. George' a cream-yellow vein banding symptom is produced irregularly along the major veins in late summer and is diagnostic for the disease (56).

Semilatent Diseases

Two of the most important graft-transmitted diseases, leafroll and corky bark, are semilatent in grape cultivars. They are widespread in vines grafted to phylloxera-resistant rootstocks, especially *V.*

rupestris cv. St. George, because they do not interfere with rooting or grafting and both affected and healthy vines of the rootstocks have been used at random as sources for propagating wood. A number of unrelated leaf mosaics are also nearly latent in grape cultivars.

Leafroll causes a slight reduction in vine growth. Affected vines leaf out somewhat later than healthy ones, but during most of the spring season, diseased and healthy vines look very similar. In early summer leaves on the diseased vines roll downward starting at the base of canes. By late summer, those on dark-fruited cultivars turn red between the veins and on light-fruited ones, yellow. Gradually all of the leaves on a cane show the rolling and discoloration, with the exception of the leaves at the tips of the canes or shoots. In a few cultivars, affected leaves do not roll, but they burn, especially in areas between the veins. The most characteristic symptom of leafroll shows in the late autumn, at which time the main veins stand out as green ribbons against a red, yellow or burned background. Compared with healthy vines, fruit clusters are smaller on diseased vines, but the berry size is usually slightly larger. Affected fruits have less pigmentation in the berry skin and ripening is delayed, sometimes to a degree that fruit maturity is never achieved. The disease affects cation uptake as well as carbohydrate nutrition. Most rootstock cultivars show no symptoms whatsoever, but all common ones can carry the disease (24).

Leafroll occurs in all grape growing regions of the world, especially in areas where plants must be grafted to rootstocks for phylloxera or nematode control. The disease spreads from affected scions to healthy rootstocks upon which they are grafted and vice versa. It also is perpetuated by cuttings taken from diseased mother vines (70). Slow natural spread may occur in some grape regions (18) but no vector is known. Most spread occurs during propagation (70). A virus was reportedly recovered from infected vines growing in a greenhouse in Israel (61), and an MLO was observed in tissues of an affected vine in Portugal (46), but adequate proof that either can be graft-transmitted to healthy indicator vines and produce leafroll symptoms is lacking.

Leafroll is heat stable but can be inactivated by prolonged thermotherapy (27). Heating infected buds grafted to healthy rootstocks at 38^{o}C for 2 months has been used to eliminate leafroll from certain desirable cultivars and selections (26). Grafting to healthy indicators of dark-fruit cultivars, such as 'Mission', 'Pinot Noir', 'Cabernet Sauvignon', 'Cabernet Franc' and 'LN-33', is the best index test for the disease. In the indexing nursery, mild forms of the disease sometimes do not express leaf symptoms in indicator plants until the end of the second growing season (24).

Corky bark causes severe stunting in many scion cultivars, but in several others the disease does not cause reduced growth. Leaf symptoms are similar to those of leafroll, with the exception that discoloration covers the entire leaf, including veins. In late fall, leaves do not drop after frost but remain attached to the vine long after the leaves on healthy or leafroll-affected ones fall. Canes grow downward and bend easily. The bark at the base of the cane may split and the base of the cane appears bluish-purple (6). In 'French Colombard' and 'LN-33', the xylem of canes and trunks is pitted and grooved (unpublished). Most rootstock species, as in the case of leafroll, are symptomless when infected.

Corky bark is widely spread in grape stocks, especially *V. rupestris* cv. St. George rootstocks (6). The disease is transmitted by buds and grafts and is perpetuated in cuttings. It does not spread naturally in California vineyards and is not mechanically transmitted in expressed sap. The causal agent is unknown (6).

The disease is heat stable; heat treatments will separate corky bark from the less stable leafroll (unpublished). It can be inactivated, however, by prolonging the same treatments that are used for leafroll inactivation (27). The rootstock 'LN-33' is a good indicator for the disease. In this indicator, corky bark causes extensive proliferation of secondary phloem tissues so that canes appear swollen and cracked. The growth in the indicator is severaly reduced and, during winter months, the indicators die because no mature wood is produced (6).

Leaf mosaics make up a group of 6 latent or semilatent diseases described in grape, probably caused by unrelated agents, and all transmissible by grafting. The symptoms of these diseases in vines are not well documented, but none affect either fruit quality or production. Each produces a distinctive foliar pattern in one or more grape cultivars. At times the foliar symptoms may be masked. Specific diseases are fleck or marbrure (39, 43), yellow speckle (62), vein mosaic (43, 51), vein necrosis (43), alfalfa mosaic in grapes (4, 8, 50), and Bratislava mosaic (52).

Fleck and yellow speckle are distributed worldwide, vein mosaic is reported from Romania and France, vein necrosis is recognized in France, alfalfa mosaic in grapes is found in vines in central Europe, and Bratislava mosaic is found in Czechoslovakia. In addition to graft transmission, which is common to all the mosaics, alfalfa mosaic is transmitted by mechanical inoculation to *C. quinoa* and by aphids, which normally do not colonize grapevines (32). Alfalfa mosaic in grapes is caused by the alfalfa mosaic virus (4); no agent has been established for the five other diseases.

The mosaics differ widely in heat stability. Fleck is moderately stable (27), yellow speckle is extremely stable (unpublished) and alfalfa mosaic in grapes in labile (8). The heat stability of the other three is unknown. Fleck (30) and alfalfa mosaic (8) can be indexed by grafting to 'St. George'. Yellow speckle is difficult to detect by indexing because the appearance of symptoms is erratic (62). However, it can be indexed in 'LN-33' in growth chambers (47). Vein mosaic and vein necrosis are best indexed by grafting to *Vitis riparia* Michx, and *V. rupestris* Scheele × *V. berlandieri* Planch cv. 110R, respectively (43). Bratislava mosaic transmits mechanically to *C. quinoa* (52).

ASSOCIATED VIRUSES

Several viruses can be recovered from infected vines that show no symptoms of disease or that show symptoms only of infectious degeneration. These viruses have not been established as the primary cause of any described grape disease, and their role in disease complexes is unknown. Among these are tomato bushy stunt virus (3), sowbane mosaic virus (5), tobacco necrosis virus (14), tobacco mosaic virus (3, 17) and potato "x" virus (23).

VIRUSLIKE SYMPTOMS

A number of symptoms that are not associated with any specific grape disease are also found in vines. Either studies of their transmission have not been carried far enough to definitely associate the symptoms found in an indicator plant with a disease condition found in a grape cultivar or no transmission has succeeded, or the symptoms produced have been associated with two or more different diseases. Others may list these symptoms as separate grape diseases (34, 44); but, until an indexing test is developed or unequivocal association with a specific disease is established, they are better considered only as viruslike symptoms. Under this heading I include stem pitting (legno riccio), enation, grapevine linepattern, spindle shoot and flat trunk.

Stem pitting is widely distributed in Europe, South Africa and the U.S. However, transmission of the symptoms is circumstantial because neither an indexing test nor a healthy indicator has been discovered. In South Africa (19) no soil-borne viruses were found associated with the symptom, but the symptom was associated with vines having fleck and corky bark. In California, Hewitt (38) found the symptoms associated with corky bark disease; but in New York Uyemoto (65) found them associated with grape decline caused by tomato and tobacco ringspot viruses. In France, Legin (42) associated the symptom with a form of leafroll. Stem pitting appears to be a symptom associated with two or more grape diseases rather than with any specific disease.

Enation, likewise, is a widespread symptom with both erratic transmission and expression (31, 33). It seems to be associated with severe forms of infectious degeneration in California and Europe. Difficulties with establishing its graft transmission in Australia (70) made positive identification of a specific cause impossible.

Flat trunk in Calfornia (38) was found on certain indicator vines but it was not a specific disease associated with the mother vine from which buds were obtained for indexing. Line pattern (57) from the Soviet Union was not transmissible, but viruslike particles were found in vines showing these symptoms. Spindle shoot of Colombard grapevines (37) is a viruslike symptom that was not transmitted by grafting but was perpetuated in rooted cuttings.

CONTROL OF GRAFT-TRANSMITTED DISEASE

The spread of graft-transmitted diseases can be stopped by a system to prevent the propagation from diseased mother vines during the clonal increase of cultivars. Programs to produce clean nursery stock, such as the California Clean Stock Program, are based on vine selection, disease recognition, indexing, therapy, registration and certification. Such programs do not prevent disease transmission to mature vines by nematodes, insects or grafts made with noncertified scions but they do prevent transmission by scions or cuttings that are used for nursery stock production.

Selection is a basic step in the program for clean stock production. It determines that a specific clone possesses the desirable growth and yield characteristics of the cultivar and that the cultivar is correctly identified. Selection is a responsibility of viticulturists cooperating in the clean stock program.

Disease recognition, indexing and therapy are also basic steps in the program. The program is effective only when all serious graft-transmitted diseases can be recognized. Indexing tests must be able to establish that mother vines are free from recognizable diseases, even at the latent stage. Therapy eliminates diseases from any clonal material that is universally affected by a disease. For grapes, heat treatments and a combination of heat treatment and meristem culture are effective therapy for graft-transmitted diseases other than yellow speckle (26). Disease recognition, indexing and therapy are the responsibility of plant pathologists.

Registration is the step in the program that assures maintenance of clean mother plants and that provides for the increase of disease-free nursery materials. It regulates the planting site to assure freedom from disease and it monitors the increase of stock by cooperating nurserymen to assure propagation only from disease-free mother plants. Indexed mother vines planted in fumigated soil at sites a few hundred feet from adjacent, nonindexed vines have remained free from diseases for the past 15 years. In California, the Foundation Seed and Plant Material Service of the University of California and the California Department of Food and Agriculture manage the registration scheme. Certification is the last step in the program. Nursery stocks produced from registered sources by prescribed procedures are certified by the California Department of Food and Agriculture.

DISCUSSION

With the development of healthy mother stocks, we have been able to control major diseases such as leafroll and corky bark that spread into new vineyards with vine propagation. We have not, however, eliminated the need for further research. Many graft-transmitted agents have not yet been identified. Likewise, the interaction between grapevines and pathogenic agents is often not well understood.

We have no information on the nature of the infectious agents in several diseases. This knowledge may not be important. We may never need to know the causal agent of some diseases; on the other hand, this knowledge might be valuable in indexing or in breeding for disease resistance. Reports that viruses, bacteria or mycoplasma-like organisms are associated with diseased vines, but do not also establish that such microorganisms are graft-transmitted to healthy indicator plants, obfuscate the literature and have little value.

Another problem concerns the mechanism for the natural spread of several diseases. Nematodes spread the soil-borne viruses and leafhoppers spread Pierce's disease and grape yellows in those areas in which it spreads. Aphids, other than Phylloxera, do not usually colonize vines. Recently, however, aphidborne alfalfa mosaic has been found in a few vines in one vineyard in Germany (5) and in a single vine in a collection in Switzerland (8). Alfalfa mosaic, however, has never become an important problem in grapes. Insect or nematode spread seems to be necessary for initial infections; afterwards, most spread seems to be by nursery stock.

Indexing has always been a problem. Healthy indicators are difficult to find among the ancient plant lines making up a cultivar. We have selected healthy indicator clones over the years. However, a routinely used indicator has occasionally caused embarrassment to our program when new tests with another indicator showed that our supposedly healthy mother plants were actually infected with a disease. Growth chambers and controlled environments will help with indexing. Recently Mink and Parsons (47) found a procedure using growth chambers effective for indexing grape yellow speckle.

Several of the obscure graft-transmitted diseases and latent viruses probably have little or no effect on production or quality. However, any effect they have should be tested. Diseased and healthy vines of a cultivar can be tested in replicated plantings. Such tests are expensive to conduct and, even with the obviously deleterious diseases leafroll and infectious degeneration, we have few good records concerning disease effect on yield and quality. Some of the responsibility for such tests rests with viticulturists who, like plant pathologists, have limited budgets.

Tests to establish any effect from disease on yields must be conducted before assuming that small and consistent growth or yield differences often found in clonal lines are genetic differences. Somatic mutations do occur and some may become established as chimaeras in grapes. Most such mutations are deleterious, but are any beneficial? I believe that thermotherapy may be a tool to help answer this question. If an obviously diseased vine is heat treated and results in an explant line that is free from disease and a superior clone, we have proven that disease was the cause of the decline. We have actually noted an improvement in some vines that developed as explants following heat therapy from mother vines that originally indexed apparently free from known diseases. This poses a new question: Are mutations heat labile?

What effect if any does heat treatment have on the host itself? This is another question concerning heat therapy. In France a method of heat therapy that was used for disease inactivation appeared to cause mutations (68). This disturbed the French industry a great deal, even to the point that thermotherapy was almost abandoned in the French clean grape stock program. The so-called mutants, however, reverted to normal vines after growing in the French foundation planting for a few seasons. The condition proved to be juvenility resulting from the method that was used for thermotherapy.

Not all obscure symptoms observed in grapevines are caused by insects or other graft-transmissible agents. The clean stock program permitted recognition of certain obscure fungus diseases, such as *Verticillium* in vines (29) and *Eutypa* dieback (49), which were overlooked because their symptoms overlapped with symptoms of the graft-transmitted diseases.

We have had problems with the registration and certification of grapes. The most vexing of these came with discovery of improved selections resulting from better indexing. We have also occasionally made clerical errors in registration and infrequently we have mixed cultivars during distribution. We try carefully to avoid such problems. The only sure way to resolve them once they occur, we have found, is to accept the better selection and withhold certification from the infected or misnamed materials. Nurserymen probably will remember these problems in our program even though they may forget our significant improvements.

The grape industry in California has accepted the clean stock program and certification. Since the first certified plant was offered to the grape industry in 1960, almost 65 million certified plants have been grown and sold. According to the California Department of Food and Agriculture, Nursery and Seed Service, 95% of all grapes sold in California in 1976 were of certified stocks.

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