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DISEASES OF GRAPEVINES:

Commonly found in the vineyards of California; the cause, symptoms, nature, and control.

by

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Contents

	Page
Introduction	1
The Diseased Grapevine; signs and symptoms	1
Plant pathogens	2
Dispersal	4
Weather and grapevine diseases	5
Infection	5
Control	6
Diseases; tabulated	8
Diseases,; described	11
References	28

INTRODUCTION

The vineyards in California in general have a mode of good health. This is because: (1) the climate favors good health, it is relatively dry, there are few rains during the growing season and the relative humidity is generally low; (2) there are available some fairly good control techniques, fungicides and pesticides; and (3) growers keep vineyards in good production and relatively free from contagious diseases of the area.

However, there are a number of diseases of grapevines and grapes in the vineyards of California. It is important to the individual grower, his neighbors, the community, the county, the area, and the industry of the state that each and all keep the diseases under good control. When a contagious disease is not kept under control, it will spread and some may spread rapidly to other vineyards in the area and elsewhere. Diseases that spread or have the potential to spread rapidly must therefore be kept under good control.

Each year unless kept under good control limits, some diseases have the potential to cause loss in crop, reduce quality and market acceptability, and damage or weaken the vines. Losses in any season have varied from some 3% to 28% of the crop, whereas losses in individual vineyards and even areas have ranged from nil to complete loss in crop.

In general, the degree of control obtained in a season will effect the potential for control of the disease in the following season. The greater the disease carry over from season to season the greater will be the inoculum and the more difficult it will be to control the disease and conversely the smaller the disease carry over from season to season, the less will be the inoculum and easier will be the control.

Recognition of disease in very early stages of development, understanding the factors of environment and culture that favor disease development, understanding the principles of control, and the integration of control techniques and proper control measures into modern farming are cardinal to the production of a marketable crop and the making of a profit.

This outline provides information on the nature, cause, epidemiology, and control of most of the important diseases found in vineyards of California.

THE DISEASED GRAPEVINE; Signs and Symptoms

Disease is in direct contrast to health. Grapevines are either healthy or they are sick. Disease is an alteration from the normal, usually expressed as changes in morphology, color, function and/or death. Disease is the result of an antangonistic interaction between the pathogen (the cause of the disease) and the grapevine tissue; it is the result of a continuous irritation of the grape tissue. When the cause of the disease (the pathogen or antangonist) is removed or abated, your irritation stops and the grapevine will recover.

The entire grapevine or any part of it is subject to disease. Disease

is recognized by signs and symptoms. Signs indicate the presence of a pathogen. For example, the presence of mushrooms of the fungus Armellaria mellia about the base line of the trunk of the grapevine is a sign that the vine may have oak root fungus disease; and dripping juice from a cluster of grapes in the vineyard is a sign that the cluster may have bunch rot disease. Symptoms are an observable change in the parts of the entire grapevine. For example, leaf spots, chlorotic leaves, wilting, weak growth, death of tissue, presence of gall, etc.

Many pathogens cause only certain kinds of symptoms or affect only certain parts of the plant. For example, the fungus Uncinula necator, the cause of the powdery mildew disease, infects and develops white powdery growth only on the surface of green tissue of the grapevine. It causes symptoms; they are changes in shape (morphology) leaves, shoots, grapes and often reddish stains on the barks and canes. A musty odor in the vineyard and the white powdery growth on the surface of green tissues are signs of the presence of the disease. Many diseases have signs and symptoms that develop in sequence characteristic of the disease. Together, they constitute a syndrome and are used in diagnosis.

PLANT PATHOGENS

Diseases are caused by pathogens. They may be abiotic (not of biology or a biological entity) such as nutritional excesses or and/or deficiencies, etc., or they may be biotic (of biology) - a biological entity.

Some of the common abiotic pathogens of grapevines found in California are: mineral nutritional excesses and/or deficiencies, including boron, calcium, copper, magnesium, manganese, nitrogen, phosphorus, potassium and zinc; air pollutants, including ozone excesses, smog, etc.; diseases caused by pesticide and fungicide, growth regulators, and herbicides. Diseases caused by environmental factors include high temperature that result in fruit spot, cane blast, leaf and shoot blast, and low temperature that cause freezing and spring fever, and deficiency of light and damage by lightening.

Biotic causes of grapevine diseases of importance are among the viruses, mycoplasma-like organisms, rickettsial-like organisms, bacteria, fungi, nematodes, insects and mites.

Viruses: Viruses are sub-microscopic infectious, biological entities that multiply only in living host cells and they may cause disease. Viruses are not visible under the light microscope but may be pictured morphologically by the electron microscope. Plant viruses are composed of some protein and mucleic acid (ribonucleic acid-RNA and some contain double stranded deoxyribonucleic acid - DNA). Most viruses have a characteristic protein coat, however, some have no coat and exist only in the nucleic acid state in plant tissues.

The nucleic acid is the infectious part of the virus. It contains the genetic code for virus replication that takes place only in the host plant cells.

Virus that infect grapes are numerous, about 27, some are airborne;

they are vectored by insects, some are soil-borne, vectored by certain nematodes, and some are transmitted by man in grafting and/or budding.

Microplasma: Microplasma-like organisms (MLOs) are small sub-microscopic ranging in size from 70 to 1000 milimicrons, usually elipsoid, have a layered surface membrane, contain deoxyribonecleic acid, various organels, and occur intracellular in tissues of the phloem.

The MLOs are sensitive to chemotherapy with tetracycline compounds, but not to penicillin.

Flavescence dorée (FD) is caused by an MLO. The disease is known in Europe for the great damage to vineyards in southwestern France. It is spread by a North American leafhopper vector, Scaploideus littoralis, but the disease has not been observed in the U.S.A.

Though diseases caused by MLOs have not been reported in California, a disease with symptoms of FD was recently reported in a New York vineyard.

Bacteria: A rickettsial-like bacteria causes Pierce's disease (PD) of grapevines, alfalfa dwarf disease and almonds scorce disease and diseases of many other plants. The bacterial-like organisms is gram-negative, rod shaped (0.25-0.50 µm wide and 1.0-4.0 µm long), has a rigid cell wall; the outer portion is corrugated like the RLOs of vertebrates and invertebrates. In plants the Pierce's disease rickettsial-like bacteria are confined to xylem tissue, mostly vessels. They are transmitted by some 25 species of sharpshooter leafhoppers and by some spittle insects, most all of which occur in North America. The bacterial pathogen has a very wide host range, some 75 species of plants including monocotyledonous dicotylodous plants, grasses, herbs, shrubs and trees.

In California, the only other bacteria of importance in diseases of grapevines is Agrobacterium tumefaciens, the cause of crown gall.

Bacteria have no chlorophyll; they are single celled organisms, often grouped and sometimes occur in chains. They have a rigid cell wall, plasma membrane, nucleus and other cytoplasmic organelles. Those that cause diseases of agricultural plants are true bacteria, broad shaped, about 0.5 µm wide and 1-3 µm long. Bacteria reproduce by fission. During unfavorable seasons, many bacterial plant pathogens live in disease host tissue, such as blighted twigs, etc. The crown gall organisms overwinter or lives through unfavorable periods in the gall cells and also in the soil.

Fungi: The greatest number of plant pathogens that cause diseases of grapevines in California and perhaps over the world are fungi. They are a diverse growth of pleomorphic microorganisms.

They have a rigid wall composed of chittin but in some there is also cellulose in the wall. The vegetative body of the fungus (thallus) of some lower order fungi are single cell, however, the thallus of most fungi is composed of filament cells. Filaments are like threads. Some of the fungus filaments (hyphae), for example, the water mold fungi, do not have cross walls. However, most of the fungi are multi-cellular; that is the hyphal

filaments do have cross walls. The cytoplasm, nucleus, and nucleoli have a double layered membrane. Cells of many fungi have more than one nucleus, whereas some have only one.

Fungi reproduce by spores, formed asexually with nuclei from mitotic division and sexually through plasmogamy, karyogomy, or miotic division of the nucleus. Asexual or imperfect spores (conidia) are produced on specialized, often characteristic, branches called conidiophores. Conidia (spores) are usually produced in great abundance and are adapted to rapid dispersal, that is scattering. Some fungi form fruiting structures or spoilating structures in close association with the host tissue. For example, the dead-arm fungus, Phomopsis viticola produces asexual spores in flask shaped structures imbedded in the epidermal tissues of diseased grape tissue. Whereas, some other fungi produce asexual spores on specialized branches, for example, the fungus Botrytis cinerea, produces conidia on tree-like structures that grow out into the air where the wind may pick up the spores and scatter them.

Nematodes: Plant parasitic nematodes may be classed into two major groups; endoparasitic and ectoparasitic. In general they are parasites of roots. They dwarf plants, induce stubby roots, root necrosis and some cause root galls. Members of the genera Xiphinema, Longidorus, and Trichodorus are vectors of some plant viruses. Nematodes also interact with some other soil-borne plant pathogens in infection and disease.

Insects and Mites: Although not infectious in the classical way, some insects and mites cause diseases in plants. To mention only a few, the mite Tetranychus pacificus causes one of the red-leaf diseases of grapevines in the red varieties, silver leaf in some of the white varieties and a leaf scorce and scald in others. Some Eriophyde miles induce big bud, blisters, erinose galls on leaves of the grape.

DISPERSAL

The plant pathogens that cause diseases of grapevines are spread in different ways; some have builtin mechanisms of movement, others are spread by vectors such as insects and nematodes, and many are spread by wind, rain and running water.

In general, many of the viruses of the grapevine are spread through propagative methods. The soil-borne viruses of grapes are spread by nematodes and Olpidium fungi. They are not known to be spread through the seed of grapes, though some viruses that infect grapevines are seed-borne in weed hosts. Some are spread in pollen. Man in his transfer of plants and in the nursery practices, has been responsible for the spread of the virus and other diseases of the grapevine over the world.

Bacteria are spread by insects, rain, wind blown rain, some are seed-borne, and some are carried on or in seed and pollen. Bacteria are often spread with plant materials used in the propagation and in contaminated soil. The crown gall bacterium of grape is spread, usually by man and is carried with grafted material and on the roots of plants. It is also transported in water. The bacteria that causes Pierce's disease is

vectored by a large number of sharpshooter leafhoppers.

Fungus plant pathogens are spread in many ways. Fungus spores are carried in splashing water drops, in rain drops, blown by winds, and wind-blown dust, plant debris and many are carried by insects, birds, and by man in his transport of plant material, seed bulbs, etc. Conidia of Uncinula necator, Botrytis cinerea, and several of the bunch rot organisms are wind blown. The conidia of Diplodia natalensis, the cause of the summer bunch rot disease, are wind blown along with vineyard soil dust. Spore of the dead-arm fungus, Phomopsis viticola as well as spores of Botrytis cinerea are carried in splashing rain drops and in wind blown drops. Spores of the powdery mildew fungus are wind blown, those which do land in water or come in contact with water actually absorb water until they burst. This fungus is a dry weather fungus.

There are few plant pathogens that are spread by implements in the processes of pruning and other vineyard operations. Crown gall is notorious for its spread by pruning shears and implements of cultivation.

Weather and Grapevine Diseases:

Weather (moisture, temperature and wind) has a profound influence in many diseases of the grapevine. For example, in California at least Botrytis rots of grapes and Botrytis shoot and blossom blight of grapevines, grapevine dieback caused by Eutyparmeniacae and dead-arm, caused by Phompsis viticola are wet weather diseases. In great contrast, the powdery mildew fungus, Uncinula necator, is a dry weather fungus and produces disease during dry weather.

Botrytis diseases, dead-arm, dieback, and powdery mildew, are all cool weather diseases. Whereas, many of the bunch rot fungi are favored by high temperature. Cool weather favors the development of symptoms of many of the grapevine virus diseases. Whereas hot weather has a damaging affect upon the virus, slows down its development and the symptoms seem to disappear. The symptoms of Pierce's disease of grapes, the bacterial disease, are favored by high temperature, causing leaf scald and berry wilt and various forms of can dieback.

INFECTION

Infection is an action of entering the host tissue and becoming established as a parasite. Penetration may be active or passive. It may take place directly through the cuticle and epidermas, through natural openings or wounds, or by placement. Natural openings are stomata, hydathodes, lenticels, gland pores, leaf scars, eruptions in the cortex of roots, and growth cracks. Placement is accomplished by insect vectors and feeding. They place the pathogen on or in plant tissues. Active penetration is common among fungi. Some examples are: a) the growth of the fungus spore germtube through a stomata, or other natural openings, b) enzyme action in the dissolving of the cuticle and softening the intracellular materials as with species of Alternaria, c) direct mechanical penetration through the cuticle by an infection peg from an appressorium is accomplished by Botrytis cinerea and the hystoria of the powdery mildew fungi, and d) active and

forceful penetration by the rhizomorph of Armellaria mellia, an example of mass affect penetration. The rhizomorph (a root-like structure) of the fungus is composed of many hypha that force their way into the bark of the plant. Some examples of passive penetration are: a) the fungi that are placed in wounds and various ruptures, b) in blossoms by insects from feeding, c) by winds, and d) water or rain.

After penetration of host tissue, the pathogen must become established and grow. The pathogen may progress by growth inter or intracelluarly or both. The interval between infection and the earliest symptom is known as the incubation period. Symptoms develop in response to pathogens-host interaction; they usually have a progressive sequence from the first occurrence to those at disease maturity, and are usually characteristic of the disease. The display of signs and symptoms and the sequence of development, all in all are known as the symptom syndrome and are important in the diagnosis. Consequence of infection may range from simple parasitism and no disease expression, to severe reaction and disease. Many pathogens colonize only special parts of the host. Some only certain tissue. For example, the powdery mildew fungus will infect only the epidermus, while other pathogens infect only flowers, fruits, seeds, leaves, wood, etc.

CONTROL

The principles of control of plant diseases follow closely those of man, animal, orthopods, nematodes and even weeds. Control most often is aimed at the pathogen or pest. Methods of control may be organized in different ways, usually for convenience in reference and discussion. They are commonly organized under the following headings: evasion (avoidance), exclusion, eradication, protection, therapy, resistance, and biological control.

Evasion - is to escape or avoid a disease. One of the basic principles in disease control is to plant clean materials in clean soil. In viticulture this is a very practical way to control the viruses and virus-like diseases of the grape.

Exclusion - is to shut out or keep out. The method is fundamental to plant quarantine. It is very important to California viticulture to exclude eastern and European forms of grape downy mildew fungus. This disease does not occur on Vitis vinifera grapes grown in California. It does however occur on the wild grapes of California. These physiological forms on wild grapes do not cause disease on cultivated vines in the state. Should the eastern form of the disease develop in California and become wide spread, necessary treatment would increase control practices greatly.

Eradication - is to destroy. This is usually complete destruction. However, the term is also commonly applied to partial destruction of the pathogen. Methods include chemical soil treatment. Some examples are: a) application of soil fumigants to kill out oak root fungus and nematodes, b) eradicant spray chemicals, their application of eradicant spray to destroy established powdery mildew fungus, and c) heat treatment to eliminate viruses and the Pierce's disease pathogens in grapes and to kill nematodes in nursery plants.

Protection - is shielding, defending, keeping down infection or preventing the disease from developing. This is without a doubt the most universal of the control measures. Methods include application of chemicals to prevent infection, control of insect vectors, adjustment of the soil reaction, etc.

Therapy - is to cure. Methods include: a) heat therapy which is used to cure plant viruses or to cure virus diseases in free plants of viruses, b) surgery to remove diseased parts, and c) chemotherapy treat with chemicals (to cure by chemicals).

Resistance - is to resist infections commonly used to connote degrees of resistance to disease. Possessing degrees of freedom from disease, some grape varieties are more resistant to powdery mildew than are others. Grapes of Cabarnet sauvignon appear to be more resistant to Botrytis rot than are those of the White Riesling.

Biological - is to control by use of biological entities. Though not used greatly in the past on diseases in viticulture, the techniques have much promise. Methods might include using a high population of a mild form of a parasite or competitive organism to swamp out a virulant form. For example, the use of a non or mild pathogenic strain of Agrobacterium to swamp out the crown gall bacteria, Agrobacterium tumefaciens and thus reduce the disease. This is being done. Another would be to infect a plant with a mild strain of a virus to prevent the development of a severe form of a disease, and another would be to use a pathogen to cause disease of another pathogen. There should be in some place, like in the southeastern United States, a pathogen that will infect the grape powdery mildew fungus.

Detecting Pathogens in Plant Materials:

Methods include the culture of the pathogen in vitro, the use of the light mycroscopy to examine the tissue, the use of the electron microscope, serology for detecting viruses and indexing by inoculation of susceptible indicator plants.

Vine Disease Control:

The control of most virus and virus-like diseases in vineyards in California can be obtained by planting only virus-disease free grapevines. Vineyards propagated with wood from the best selections of grapevines available, of both rootstocks and varieties, will have the greatest potential to develop into vineyards of high quality and production, whereas, vineyards propagated with wood gathered indiscriminately from vineyards will usually be less productive than the mother vineyard. Likewise, vineyards propagated with wood from vineyards containing virus diseases without selection often contain more virus diseased plants than did the mother vineyard, and vineyards propagated with wood from vineyards containing soil-borne viruses without careful selection are seldom economically productive for more than 8 to 12 years. Grapevines of the latter case will grow very well the first 4 to 5 years and then degenerate.

Grapevines that have a good crop of quality fruit can usually be found

in most any vineyard. Selections of choice grapevines only once just before harvest will insure much better propagating wood than no selection, but selections will often include virus diseased grapevines. It is possible by repeated careful selection in a vineyard over a period of 3 or so years to choose grapevines with high quality and productivity. Though not always so, grapevines which have been carefully selected over a sequence of years for production and quality of fruit may be free of virus diseases and certainly are free of serious virus diseases. It is best to choose virus-disease free propagating wood. The wood is freed of virus diseases by heat therapy in a high temperature room or meristem culture.

For control procedures of most other diseases it is suggested one obtain the latest information on disease control for grapes from the University of California Division of Agricultural Sciences, Experiment Station and Extension Service.

DISEASES: Tabulated

The diseases are first listed in tabular form under the kind of pathogen and in order as they may occur on the major parts of the grapevine. The tabulation is followed by a brief description of the characteristic symptoms of each of the most commonly observed diseases. A listing of references to some useful literature is provided. References are in alphabetical order by author and numbered, each number in the table and text refers to items in the list of references.

Following is a tabulation of the diseases of grapevines listed by kind of pathogen and/or parts of the grapevine affected, and some references to literature. Not all diseases are tabulated, only those which are found regularly and descriptions are only given for the most important diseases.

A. DISEASES CAUSED BY FUNGI: - or associated with fungi, 41, 80

1. On grapevine roots, crown, trunk and arms

Armellaria mellia (oak root fungus), 45, 89, 90
Cephalosporum wood rot, 6, 7
Crown canker (collar rot), 90
Dematophthora root rot
Dead-arm disease, 43, 72, 73, 74
Dieback disease, 65, 66
Diplodia trunk canker, wood rot, 3, 84
Fomes (F. igniarius) wood rot, 6, 7
Sterium (S. hirsutum) wood rot, 6, 7
Rootlet decay, 8
Rhizoctonia root decay, 8

2. On grapevine foliage, shoots and canes, 90

Apoplexy, 6, 7, 40
Black measles, 6, 7, 40, 68, 90
Dead arm, 41, 62, 63, 64
Dieback disease, 65, 66

Diplodia cane blight, 45
Downy mildew (Vitis californica)
Powdery mildew, 16, 43, 90
Scurf

3. On grapes and cluster stems in vineyards and in storage

Apoplexy, 6, 7, 40, 68
Aspergillus rot, 47
Blue berry of Zinfandel grapes (see water berry)
Botrytis rot, 38, 39, 47, 69, 70, 90
Black measles, 6, 7, 40, 68, 90
Cladosporium spot, 16, 47
Dead-arm, 43, 72, 73, 74
Diplodia rot (see summer bunch rot), 3, 45, 47, 84
Early Botrytis rot, 38, 39, 47, 63, 64, 70
Flower cluster rot (forms) see scurf and Botrytis
Gray mold (Botrytis rot) see text
Powdery mildew, 16
Rots of grapes - various, 47
Slip skin (Botrytis rot)
Summer bunch rot, 45, 47, 90

B. DISEASES CAUSED BY BACTERIA AND RICKETTSIAL-LIKE BACTERIA

1. Crown, trunk, cane, leaves, fruit, and on roots

Black knot (crown gall), 45, 90
Pierce's disease, 15, 18, 19, 20, 21, 22, 23, 42, 50, 55, 80, 81, 90, 91, 93

C. DISEASES CAUSED BY VIRUSES, MYCOPLASMA-LIKE ORGANISMS, ETC., 41, 43, 44, 45, 54, 67, 90, 92

1. On grapevine trunk, arms, spurs

Corky bark, 41, 48, 90
Wood and bark pitting, 1, 58, 92
Wood rot, trunk rots, 6

2. On grapevine foliage, 41, 43, 44, 46, 54, 67, 92

a. soil-borne (by nematode vectors), 14, 24, 57, 75, 76, 77, 92

enation, 14, 25, 49, 82
fanleaf, 13, 14, 25, 41, 51, 57, 75, 76, 92
vein banding, 14, 25, 33, 92
yellow mosaic, 13, 14, 25, 41, 92
yellow vein, 13, 35, 41, 92

b. mode of spread not determined, 54, 92

asteroid mosaic, 41, 52, 92
corky bark, 5, 41, 48, 54, 92
fleck, 41, 53, 92

leafroll, 30, 31, 32, 34, 36, 37, 92
vein clearing, 92
yellow speckle, 92

3. On grapes and/or clusters, 54, 67, 92

Fanleaf, 13, 14, 24, 25, 41, 51, 57, 75, 76, 77, 92
Leafroll, 30, 31, 32, 34, 36, 37, 92
Vein banding, 13, 14, 25, 33, 92
Yellow mosaic, 13, 14, 25, 92
Yellow vein, 18, 24, 35, 41, 92

D. DISEASES CAUSED BY MINERAL; DEFICIENCIES AND EXCESSES

1. Mineral deficiencies, 11, 12, 43, 90

Boron deficiency, 4, 10, 79
Copper deficiency (Exanthema), 49
Iron chlorosis
Little leaf (zinc deficiency), 9, 41, 50, 56, 90
Potassium, 82
Water berry (calcium deficiency), 2, 60, 90

2. Mineral excesses, 11, 12

Boron toxicity, 79
Nitrogen burn
Salinity damage
Alkali burn

E. DISEASES CAUSED BY ABNORMAL TEMPERATURES

1. High temperature damage, see text

Almeria spot (see heat spot in text)
Heat spot (see text)
Internal browning of shoots (see text)
Leaf burn
Sun scald

2. Low temperature damage

Frost or freezing damage (see text)

F. DISEASE CAUSED BY LIGHTENING

Lightening - blight of canes, killing of vines

G. AIR POLLUTANTS

1. Ozone damage (oxident stipple), 78

H. SOME COMMON DISEASES CAUSED BY AGRICULTURAL CHEMICALS

1. Arsenic damage - bud kill, 68
2. Bordeaux mixture
3. Growth regulators, 2,4-D and related compounds, 85, 86, 87, 92
   Gibberellins, 85, 88
4. Sulfur
5. Lime sulfur
6. Weed control chemicals, 61, 83, 85, 86, 92

I. DISEASES WITH THE CAUSE NOT DETERMINED: may be associated with a pathogen

1. Foliage - leaves, canes

   Apoplexy, 6, 7, 40, 68
   Black measles, 6, 7, 40, 68
   Spindle shoot, 41, 90
   Spring fever

2. Grapes - including flower cluster and cluster stem

   Black measles, 6, 7, 40, 68
   Cluster stem know

DISEASES: Described

Diseases caused by fungi or associated with fungi:

Apoplexy: (6, 7) In the spring vines develop sudden and severe symptoms. Diseased vines often drop most of their leaves and the canes die back from the tips. This early season form of the disease has been called apoplexy. Such vines often recover and symptoms will not appear again until another season.

Young leaves of vigorously growing grapevines show degrees of russet, malformation and develop burned areas. Chlorotic areas develop in the blades of older leaves on otherwise vigorous shoots, cane tips dry and die back. After yellowing leaves and flower clusters drop from the shoots. Diseased vines at this stage often have only green canes with necrotic tips. Later the necrotic areas of the canes drop. Side buds on the remaining portions of green canes start growth. The vines recover and grow normally the remainder of the season.

Apoplexy seldom occurs in the same grapevine in successive seasons. The disease is believed to be a form of the black measles disease and is associated with wood rots of trunks and arms.

Armellaria root rot (oak-root fungus): (45, 89, 90) The fungus pathogen of this disease is Armellaria mellia. The first indication of oak-root fungus in vines is usually a decline in vigor of the grapevine. Dwarfed growth is usually followed by death of spurs, arms and eventually the entire vine. The disease usually occurs in vineyards in spots or areas that often increase in size.

The appearance of clumps of mushrooms at the crown of plants in the fall or early spring is a sign of the disease. Rot of roots, crown and trunk seldom extend much above the ground level. The appearance of white to cream mats of fungus mycelium, often fan shaped in growth, extend along the cambium and in layers of the bark. The fungus has a strong mushroom odor which is good evidence of the disease. At times the fungus will produce rhizomorphs (dark brown round shoe string-like structures), that grow in and out of the bark. They are about 1 millimeter in diameter with shiny crusty surface. The interiors of the rhizomorphs are light in color. They do not always form on grapevines but are good signs of the presence of the fungus.

The fungus lives in host plant tissue in soils in old roots of many species of trees. Infection spreads from vine to vine in vineyards by contact through the root system. The disease is spread naturally over distances by flood waters and the movement of infected materials or roots.

Aspergillus rot: (47) There are some 5 different species of Aspergillus that have been recovered from rotting grapes in California. Aspergillus niger is the most common species causing rot of grapes. The fungus is recognized by the excessively large number of brown or black spores that cover cracks in the rotted areas of the fruit. The fungus does not infect grapes through the unbroken skin. It enters grapes only through wounds such as bird pecks, worm damage and cracks occuring around mildewed spots, etc. Often only a single grape of a cluster may have Aspergillus rot. However, it may also be involved in the rot of several grapes and associated with other rots.

Black measles: (6, 7, 40, 68, 90) The cause of black measles is not known, however, it is known to be associated with rots of the grapevine wood in trunks and arms. The disease is characterized by black spotting of the skin of grapes along with interveinal burn of leaves. Spots on the fruit are usually small, round and characteristically bordered by a halo and a ring of dark tissue. Diseased grapes often appear as though mottled in varying shapes. In severe cases the entire crop on the vine may be affected. Measled berries often crack, wither and dry up on the vines and some cracked berries develop rots.

Symptoms on leaves and grapes are most conspicuous on white or light colored grapes. They may appear on only a few canes or over the entire vine. Vines may have the disease one season but not the next. Leaf symptoms usually develop on canes which have diseased fruit, occasionally on canes on which fruit is apparently normal. The interveinal browning and drying of the leaf tissue typical of black measles starts as small, yellowish spots between the primary veins that gradually enlarge and become necrotic in the center. Leaves of colored varieties of grapes develop red margins around the burned necrotic areas. In extreme cases only narrow bands of greenish tissue may remain along the five large veins of the leaf. The green veins are generally bordered by yellowish tissue that becomes brown and dry.

Botrytis rots: (38, 39, 47, 63, 64, 69, 70, 90) Botrytis rot, a well known rot of grapes, is characterized by brown rot of grapes covered by

buff colored fungus spore masses. The skins crack, the sporophores of the fungus grow out through the cracks and produce the spores on branched stalks. This form of rot usually develops after two or more periods of rainy weather.

Early Botrytis rot is an early form of the disease. Grapes rot, turn brown, shrivel and dry in the cluster in mid season during the dry season without rains. The disease may involve anywhere from one individual grape to several in a clusterette or as much as 60 to 75% of the cluster. Rotting of the grapes in July to September prior to rains characterizes the disease. The fungus will often produce numerous spore structures that extend into open spaces amongst the rotting grapes producing masses of tan to brownish spores that disperse rapidly into the air if disturbed.

Early Botrytis rot is a result of bloomtime infection of the style of the grape. The fungus grows into the style and stylar end of the grape at flowering time and there becomes dormant early as the grape develops. The fungus remains latent in this area until the physiology of the grape changes to permit resumption of growth. The time that rot may develop will vary with the variety and to some extent with the locality. In many wine grape varieties such as Grenache, Riesling, Chenin blanc, Colombard, etc., the grapes will start to rot in late June and early July, whereas in some table grape varieties as Emperor, Tokay, and Calmeria, the grapes may not rot until quite late or even in storage after harvest.

Gray mold: Another form of Botrytis rot. In late seasons most often following rains grapes in clusters become covered with whitish to gray mold growth of the fungus Botrytis cinerea. This form of Botrytis rot usually follows rains in the vineyard.

Slip skin is an early symptom of the disease. It is characterized by the light colored, somewhat circular areas in the skin that when handled break and slip from the grape pulp. The skin has become loosened from the pulp by fungus action and growth between the skin and pulp. Slip skin will usually develop within 4 days following a rain that has wet the grapes and has kept them wet for some 20 to 30 hours or longer.

Cladosporium spot: (15, 47) The fungus Cladosporium herbarum will cause a small circular spot some 1/4 to 3/4 of an inch in diameter in grapes. The fungus can infect grapes directly through the skin but requires a relatively long period of high moisture. The disease is not of major importance though it does occur in seasons following early fall rains. The spots are blackish, often covered with metallic greenish masses of spores of the fungus. When the spores are rubbed from the surface of the diseased spot the grape epidermal cells are usually dark to black in color. Tissue under the spot becomes soft and the skin may slip from the grape under pressure. Cladosporium spot is most often found on grapes in storage. However, it has been observed on varieties held on the grapevine late in the season. The fungus is common in vineyards. It often affects damaged portions of leaves and invades the bark of the grape canes. It is one of the principal fungi causing mold and rots of raisins.

Crown and/or collar rot: (90) The disease is caused by water mold fungi species of Phytophthora and Pythium. Necrotic areas develop in the

cambium tissue of the trunk just at or below the ground level. The bark over the canker will dry and peel from the vine. Diseased areas may occur in only a part of the trunk but most often girdle the vine. Grapevines with collar rot may develop pre-mature color in the leaves, or the vines may die. Grapevines at all stages of development are susceptible to the disease. However, young vines in the nursery row or vineyard are most commonly affected. Excessively wet soil at the crown over sustained periods contributes to disease development.

Diplodia blight and canker: (3, 45, 47, 84) The fungus Diplodia natalensis causes blight of canes, cankers in trunks and arms and rot of wood. The fungus also rots grapes and imitiates the disease summer bunch rot. Cane blight usually starts at the tip of a cane and proceeds back toward the arm or crown of the vine. Blighted areas are often bordered with darkish brown tissue. The main portion of the blighted areas are generally light brown to white in color with numerous black pimple-like structures of pycnidia that push through the bark. When wet or put in moist chambers overnight the pycnidia extrude masses of black spores which tend to clump or mass; when wet, however, they become sticky and slimy. Spores are dark with two cells and have longitudinal stridations.

The fungus will produce rotting of wood in the trunk of grapevines, grows from the infected canes into the trunk and may even kill the vines. Wood necrosis often extends longitudinally from point of entry into the vine and in cross section develops a wedge shaped necrotic black rot of the trunk. Decayed wood is firm, often has a black to brownish color. It is difficult to distinguish from other rots except that fruiting structures or pycnidia may be found in the wood and/or bark in cambium regions where separation has occurred.

Dead-arm disease: (43, 72, 73, 79, also refer to dieback disease) The fungus pathogen of the disease in California vineyards is Phomopsis viticola. Small dark necrotic spots on young leaves with translucent halos characterize the early stages of the disease in young leaves in the spring. The spots may be numerous, scattered and/or clustered on the leaf blade and are often found along the veins. As the leaves age the spots become more pronounced and the centers darker black. When spots are numerous, infected areas in the leaf blade may fail to expand with growth and the leaves tear leaving open holes in the leaf blade. In older leaves at the base of the cane, infected tissues may turn yellow, later die and turn brown. Spots often develop in numbers on leaf veins and leaf petioles. Necrosis may extend along the veins in the leaf for several millimeters.

Black spots often are found on the petioles and on the shoot tissues. The halo effect is not pronounced on the petiole and stem or shoot tissues. Spots may be few or many, scattered and/or clustered. Necrotic spots on the petiole and shoot stem tissues may enlarge to varying sizes with irregular margins. Some spots coalesce to form cankers of 1/8 to 1/2 inch long and 1/8 to 1/4 inch wide. The epidermis of cane tissues in or about cankers may split and expose the cortex tissue. The shoots, leaves and flower forms may be dwarfed and badly distorted when infections are numerous.

The disease is named from the killing of spurs and arms which are usually most evident when shoots fail to push on them in the spring.

Spurs, arms and trunk wood may be affected showing dark streaks extending in projections from dead areas. Spurs and canes show irregular whitish areas with dark brownish margins forming patches in the canes. The exterior surface of diseased areas are usually covered with numerous small pimple-like extrustions called pycnidia which produce spores of the fungus. When moist or wet the pycnidia extrude white thread-like structures that curl or if excessive moisture is present become a creamy white sticky mass of fungus spores.

The cluster stems of the pedicels of grapes are often infected and show similar symptoms. Diseased areas in cluster stems may grow into the berries and there cause rotting of the fruit.

Dieback - Eutypa dieback (dying arm): (65, 66) The disease is caused by the fungus Eutypa armeniacae. The same fungus causes limb dieback of apricots. Dieback (death of spurs and arms) has been present in California vineyards for many years. In some areas, as for example in Lodi, the disease has been considered to be a part of the dead arm disease. In Napa Valley and most other north coast vineyard districts, however, the dead arm disease was either not known or not considered to be a problem in most of the wine grape varieties. In these coastal areas the cause of dieback of spurs and arms of the older hand pruned vines had not been determined until the disease was recently recognized (57d). The dieback disease has become a serious problem in the newer plantings and in particular in vineyards under sprinklers. The dead arm disease is of importance in table (Tokay, Olivette blanche, Kandahar, Cornichon) and raisin grape varieties from Lodi south into the San Joaquin Valley.

The symptoms of dieback and dead arm on shoots, leaves, canes, and fruit are distinctly different. However, the dead spurs and arms or wood decay, dieback stages of the two diseases, have symptoms in common and may be confused.

Dieback is characterized by delayed foliation, the presence of small diameter shoots with small leaves. The leaves are often malformed, the basal leaves may have tatter-holes, leaves may yellow, the margins burn and the leaves drop from the shoots. Leaves are often rough, have bronzing of the surface and some shoots and leaves blight. Clusters often blight and shatter. The canes are usually scurfy (rough bark). Spurs and arms fail to leaf out, dry and dieback. When cut open, the wood will show degrees of decay, usually from a pruning wound. The wood decay may look like that found on many vines caused by various fungi (6, 65, 66, 73, 74).

Powdery mildew: (16, 43, 90) Spring and Summer: Powdery mildew is caused by the fungus Unicinula necator. The fungus is an obligate parasite and causes disease only in Vitis spp. It causes dwarfing, curling and twisting of leaves and young shoots. It forms a white cobweb-like growth on the surface of green tissues often radiating from centers (fungus mycelium). Colonies of the fungus become powdery white, denser at centers, lighter on margins. The name powdery mildew comes from white powdery-like masses of sporophores and spores. Powdery colonies may become creamy to tan with age. Under the microscope or hand lens one finds numerous small stalks (conidiophores) with chains of white to pearly white spores (conidia)

extending from the end of the stalks. The spores will glisten in the sun. Musty odor can be noted in walking in the vineyard if abundant. Powdery mildew colonies may occur in spots scattered and later become general on young green tissues, leaves, petioles, shoots, flower clusters and grapes. When powdery mildew colonies, the cobweb-like growth, is rubbed from the surface of affected tissue the epidermal cells will show a dark to brownish black netting. The discoloring of the cells is due to the growth and development of haustoria into the cells and a subsequent formation of gum and tanning within the cell. Haustoria serve the fungus by anchoring it to the surface of the grapevine cells and most important the extraction of nutrients from grapevine cells.

Young succulent green tissue is most susceptible to the disease. There is usually more powdery mildew on leaves, shoots, and grapes growing in the shade than in the sun. Older leaves have little or no powdery mildew in the summertime. The grapes become less susceptible to powdery mildew as they begin to mature. Seldom are new powdery mildew colonies found on grapes when the sugar approaches 10%.

Late season - September: Old leaves, petioles, cluster stems become susceptible to powdery mildew in the fall. White web-like fungus growth is much more dispersed on tissues in the fall than in early season or in summer. The conidiaspores and conidia are less dense. Often in late September small yellowish specks develop within the dispersed colonies of the fungus. These specks turn orange and then black when mature. They are called "cleistothecia". They are spherical shells in which the perfect spore stage of the fungus forms in spring of the following year. Infected tissues, leaves, petioles and cluster stems may become densely populated with the black cleistothecia.

The fungus overwinters in two ways as mycelium in the buds and as cleistothecia. The place or importance of the cleistothecia is overwintering the fungus in grapevines in California has not been determined.

Dark reddish to brown stains show on the canes after the bark is formed and the canes turn brown. The stained bark may be noted in the dormant season and is a sign of the disease; it has no part in overwintering of the fungus.

Root and rootlet decay: (8) Species of Pythium and Phytophthora cause varying degrees of decay of rootlets. Rhizoctonia solani has also been found to produce decay of small roots in grape. The degree of killing of roots has been found to vary with soil type.

Pythium and Phytophthora species are often found to rot rootlets of grapevines growing in sandy to sandy loam soil. Vines in affected areas may be dwarfed or slowed in growth compared to vines in non-affected areas. These fungi produce water soaked areas in the cortex of feeder roots and often kill root tips and result in excessive branching. The decay of rootlets often shows most pronounced within 3-4 days after an irrigation. Growth of new roots will usually follow as the soil becomes dryer. Rootlet decay will very often follow each irrigation. Successive rotting of small roots results in slowed vine growth and low vigor.

Scurf: The disease is caused by the fungus Alternaria tenuis. Scurf may be confused with dieback and also exanthema, a copper deficiency disease. Scurf is a wet weather disease and may be serious only when rains occur during early shoot growth. Scurf does not cause dieback of spurs and arms. In early season, dwarfing of shoots, twisting and deformity of leaves with small brownish flecks in the epidermal tissues characterizes the disease. As the shoots grow the affected tissues turn brown, become scaly or scurfy. It is from this the disease gets its name. Heavily infected leaves may drop leaving the shoot somewhat defoliated. The scabs or scurf may show on canes, petioles, leaves and the stems of flower clusters. Only young succulent tissue is susceptible to infection by the organism. Scurf areas may be found at intervals along canes, at positions and representing times of rainy periods. The most susceptible varieties are Perlette, Delight and Thompson Seedless. The disease in this form is seldom found in other varieties. However, in wine grape varieties the scurf disease may be observed as a form of blossom blight. This stage may occur on some varieties of wine grapes in the north coastal counties, but may be confused with exanthema.

Summer bunch rot: (45, 47, 90) This disease is initiated by the fungus Diplodia natalensis. However, the disease is a complex of microorganisms including adults and larvae of dried fruit beetles and fruit flies, many fungi, yeasts and bacteria. Sour dripping rot of the grape cluster before harvest time characterizes the occcurrence of this disease. It is most prevalent in Thompson Seedless grapes but has also been observed in Red Malaga, Ribier and Emperor. The disease has not been observed on the wine grape varieties. This form of sour rot is assocaited with Diplodia cane blight and is caused by the same fungus Diplodia natalensis. Infection by the fungus occurs during bloom time through the style of the grape. There the fungus becomes latent and usually remains until the grape approaches maturity or having about 11 to 14% soluble solids. The rotting of the grape by Diplodia is first pinkish and then turning to a wet rot. In early stages of rot the grapes crack and drip juice. The fungus will spread from grape to grape in the cluster. Fruit flies visit the cracked grapes and lay eggs, leave yeast and other fungi which start and develop the rot. Larva of the fruit flies will develop on the yeast in the grapes. The rot will generally proceed in the center of a cluster. There are often many fungi, yeast and bacteria involved, also, fruit flies and dried fruit beetles. The strong sour vinegar odor comes from the fermentation of the grape juices by vinegar bacteria.

Other sour rots: (47) Most of the rots of grapes have their origin through injured grapes. Some 70 different microorganisms in 30 genera have been isolated from rots of grapes. Grapes may be injured in a number of different ways. Sour rots usually develop in grapes when they approach maturity. Seldom do green grapes rot. Grapes affected with water berry often loosen at the cap stems and there become infected with rotting fungi and often infested with fruit fly larva. The bread mold fungus Rhizopus sp. when it becomes established in the injured grape in the upper shoulder or into the center may often spread to other grapes and induce a rot of the cluster very similar to summer bunch rot.

Injuries in grapes caused by black measles, powdery mildew, larva of

the grape leaf folder or orange tartrix or by birds or any other cause may lead to rot of the affected grapes.

Wood rots, trunks and arms: (6, 65, 90) Rot of grapevine wood, spurs, arms, trunk and roots is common. They are usually of two kinds, hard or soft and punky. Pruning wounds do not heal on grapevines as they do on many other woody plants. The wounds are thus open to infection by fungi and other pests. There have been found in California vineyards some 5 fungi associated with trunk and wood rots. They are a Cephalosporum sp., Fomes ignarius, Stereum hirsutum, Phomopsis viticola, (the dead-arm disease fungus) and Diplodia natalensis, (the same fungus that causes summer bunch rot disease and cane canker disease).

The rots of wood caused by these latter two fungi are described under the respective headings Dead-arm and Diplodia blight and canker.

Cephalosporium sp.: (6) This is a fungus that invades the wood tissue of the grape, trunk, arms and large roots there turning the wood darkish brown to black in color. The disease often occurs in irregular areas of the wood and in patches extending vertically as streaks into new wood. In cross section the diseased areas appear as darkish brown to black areas in the wood. It is a hard rot.

Fomes ignarius: (6) This fungus produces a brownish to tan or fawn colored rot of the wood that often becomes soft and punky. The fungus is often followed by another fungus Stereum hirsutum (6) which produces numerous bracket fruiting structures from the surface of rotted old wood on the trunk. The brackets often extend around the margin of an old large pruning wound. This latter fungus is not believed to be a primary pathogen but is often found in rotting wood of grapevine trunks and arms and causes a soft rot.

Cephalosporium and Fomes are believed to be involved with the black measles disease of the grapevine.

Disease caused by bacteria and rickettsial-like bacteria:

Crown gall: (black knot) The causal pathogen is Agrobacterim tumefaciens. This is the only bacterial disease of grapevines known in vineyards of California. Spherical callous-like, spungy overgrowth of cell, tissue soft, succulent, and later becoming hard characterizes the disease. Galls are found most commonly at crown and on roots of grapevines. Galls often develop in cracks of bark following winter kill and freezing injury.

Pierce's disease: (15, 18, 19, 20, 21, 22, 23, 42, 50, 55, 59, 71, 80, 81, 91, 92, 93) Pierce's disease is caused by a rickettsial-like bacterium. Rickettsial-like because of the morphology (see section under bacteria). The causal organism was not known until recently (15). Originally the California vine disease was thought to have been caused by a bacterium and was contrasted with the Mal-nero disease of Italy. However, the causal bacterium was not isolated by earlier workers perhaps for lack of more modern cultural media and technology. The bacterium causal agent of Pierce's disease is transmitted by a number of the sharpshooter leafhoppers. In California, the same bacterium also causes alfalfa dwarf and almond leaf

scorch. Though some 26 vectors of leafhoppers are known to vector the pathogen, the principal vectors of the disease pathogen are the sharpshooter leafhoppers, Dracucephala minerva, D. fulgeda and Hardina circelata. The disease kills grapevines. Primarily symptoms show in leaves and canes. A scald in areas about the margin of the leaf characterizes the disease in early stages. Leaf tissue dries while still green at most any time, most often after mid season into the fall. Scald is usually followed by browning at the scalded area. Margins of scalded areas turn yellow. Often the scalding and browning progress in patches or concentric zones or rings around the originally scalded area. Several scald and necrotic areas may develop about the margin of the leaf and extend progressively towards the petiole. Scalded, burned leaves often drop leaving the petioles attached to the cane. Early in disease development scald may occur on only one cane or on canes coming from one arm of the vine. As the disease advances, however, symptoms may show over much of the grapevine before fall.

Canes mature in irregular brown and greenish patches. In the fall and winter the green areas are subject to freezing damage and are killed. Brown areas in the wood are usually laden with starch, whereas green areas have little starch.

In the winter diseased vines may be identified by the patchy maturity of grape canes.

In the spring of the 2nd and in the spring of subsequent seasons of disease development, grapevines are usually delayed in growth or leafing out. Often, only parts of the vine will grow leaving dormant canes and spurs that dry out and die in the summer. The first 8 or more leaves of a shoot in the second season of development form interveinal chlorosis. The intensity of the chlorosis is usually more severe in the lower leaves and becomes less marked with each succeeding leaf. In hot areas diseased grapevines die within 2-3 seasons whereas in coastal regions they may live for some 4-5 years.

Diseases caused by viruses, mycoplasma-like organisms, etc.: (26, 27, 28, 29, 90, 92)

Asteroid mosaic: (41, 52, 92) This virus disease of grapevines is relatively rare. The mode of natural spread is not known. It has been found only in a few grapevines. Symptoms are usually pronounced and show mostly in the leaves. They may be variously deformed in many ways. The disease is characterized by numerous small lucid spots in third order veins of the leaf which often coalesce to form star-like spots in the blade. Some small veins may show degrees of vein clearing (translucent to transmitted light). In Vitis rupestris St. George the disease shows as pronounced cream colored portions of primary leaf veins. They may be only an occasional yellowed or creamy vein or there may be many on the leaf. The leaves may be cupped and irregular.

Corky bark: (5, 41, 54, 90, 92) A transmissible disease of grapes. The vector is not known. The disease has been found in several varieties of grapes, many of which do not show distinct symptoms. These are often referred to as latent carriers of the virus. The disease gets its name from the rather thick, often spongy rough cracked bark. Canes of diseased vines are limber or rubbery in character, that is, they bend easily and droop from the vine. The bark at the base portion of canes is often cracked. Canes

mature their wood irregularly in brown and green patches. The leaves of black and red varieties of grapes may show premature coloring in various patterns. Diseased vines often have dead spurs and arms. The virus has been observed to spread in vineyards of the north coast counties and there on occasion kill quite a few grapevines.

Enation: (92) The disease is caused by a strain of the grapevine fanleaf virus. It has been observed in Flame Tokay and in several of the wine grape varieties in California. Leaves at the base of the cane for the first 6 to 8 nodes on diseased grapevines are thick and leathery in texture. The backs of the leaves may or may not show the enations - the outgrowths of leaf tissue usually along the major veins. Leaves may be otherwise deformed, the large vein in some leaves may fail to grow and open normally. These leaves usually have several enations scattered along the veins on the under side. Grapevines with enation are generally less vigorous than the normal vines and will degenerate with age.

Fanleaf: (13, 14, 25, 41, 51, 57, 75, 76, 92) Symptoms are generally pronounced in the early season growth and become less distinct as the season advances. This is particularly so in the hotter regions. Leaves show varying degrees of deformity. The margins may be deeply lobed with sharp vein tips. The petiole sinus opens in some cases to as much as 200 degrees giving the leaf veins the effect of a closing fan. It is from this symptom the disease was named. Mottling in the leaves shows up in shades of green, veinlet clearing, speckling, chlorotic rings in various patterns over the leaf's surface. The canes of fanleaf diseased vines may show such symptoms as weak growth in advanced cases of the disease, zig-zag type of growth bending at the nodes, short internodes and double nodes. The double nodes and short nodes occur most frequently at the 8th to 11th internode space and may repeat at intervals along the cane. Flower clusters of diseased vines are often smaller than normal. They shell badly after bloom and set straggly clusters with many seedless or shot berries. The disease causes degeneration of grapevines.

Fleck: (41, 53, 92) Symptoms of the fleck virus show only in Vitis rupestrus St. George. The virus is latent in many varieties of grapes. Its presence in grapevines is determined by indexing or grafting a portion of the plant to the variety St. George. Leaves of St. George carrying the virus will show varying degrees of vein break or short fleck-like spots in the veins. Flecks may be few or they may be numerous, apparently depending somewhat on the strain of the virus. Leaves may be crinkled and puckered in severe cases of disease. It is believed to be one of the important viruses carried in grapes and may be involved with low production.

Leafroll: (30, 31, 32, 34, 36, 37, 90, 92) A virus disease, the vector or modes of natural spread are not known. The disease is transmitted by grafting. It becomes evident in mid season. The lower leaves of the cane begin to turn or roll down at the margin. As the season advances, the degree of roll increases. Leaves on some varieties are often rough or rugose in the upper surface and become leathery and brittle when squeezed with the hand. Leaves of red and black varieties turn prematurely red, whereas leaves of the white varieties may become silvery in appearance. In the interior valley and also in abnormally hot seasons leaves of affected vines of some

varieties may scald. Vines affected with leafroll often have less fruit and lower concentrations of sugars than do fruit on normal vines.

Soil-borne viruses: (14, 24, 57, 75, 76, 77, 92) In California vineyards some 5 diseases of the grapevine are known to be carried in the soil. They are fanleaf, yellow mosaic, vein banding, enation and yellow vein. They are spread in soil by the dagger nematodes Xiphinema species. When healthy vines are planted in infested soils these viruses will transmist to the healthy grapevine and show symptoms within the second to third year after planting. Grapevine fanleaf, yellow mosaic, vein banding and enation are diseases caused by different strains of the grapevine fanleaf virus. The vector is X. index and X. italae. Yellow vein is caused by a different virus, the grapevine strain of tomato ringspot virus. This virus is spread to plants by X. americanum. It is believed to spread the virus to grapevines but not readily.

Vein banding: (13, 14, 25, 33, 92) This strain of the fanleaf virus is recognized by pronounced green to yellow bands along the larger leaf veins. Symptoms become pronounced in mid to late season. This is in contrast to the yellowing of veins by the yellow mosaic strain which show early in the season. The symptoms commonly associated with fanleaf and yellow mosaic may also be a part of vines carrying this strain of the virus.

Wood and bark pitting: (1, 48, 58, 92) The disease is prevalent throughout many of the European grape growing regions. It has been found only recently in California. The virus that causes the disease has not been determined, however, it will transmit by grafting. There is some indication that the disease may be soil-borne. The disease is recognized by the presence of pits in the bark and wood. The pits may be seen easily by stripping a piece of the bark at the cambium from the trunk. Pits may be numerous and the trunks of the vine deformed or there may be only a few pits with slight change in trunk character. The disease is known to show only in certain varieties and to be latent in others. Wood pitting and corky bark index very similarly when graft transmitted to the grapevine indicator variety LN33. The two diseases may have the same pathogen (48).

Yellow mosaic: (13, 13, 25, 41, 92) The disease is characterized by yellow shoots that stand out in contrast to normal green foliage in the early season. The shoots, leaves, stems and blossom clusters are often yellow in varying degrees. Other symptoms associated with the disease are blossom shelling and leaf mottling of different kinds. Leaves may show only a few yellow spots along the veins or as leaking from veins or the veins may become yellow producing a yellow vein effect. Veins are often bordered by yellow tissue. It is not uncommon that the leaves and shoots on the vine in early spring will be strong yellow. As yellow leaves age they fade to cream color, then bleach to nearly white and burn and turn brown. Vines with yellow mosaic, like those containing fanleaf virus, usually degenerate with age and become nonproductive.

Yellow speckle: (92) This disease we have sometimes called "speckle mottle". It occurs in several varieties but expresses symptoms only under certain conditions. It is latent in many of the varieties in California but shows distinct symptoms in the same varieties or even the same wood of

the same varieties when grown in Australia. The disease is recognized by the presence of chrome yellow spots speckled over the leaf's surface. The number of spots may vary from an occasional one on one or so leaves to many spots scattered over several leaves. They often accumulate along the major leaf veins. In California leaves of the variety Mission have been observed to show a few speckled spots on occasional leaves. More precise methods of assay and indexing for the presence of this virus are needed before the impact of the disease on vine vigor, yield, etc., can be determined.

Yellow vein: (13, 24, 35, 41, 92) A primary symptom is a faint chlorotic mottle and line pattern which may form in rings or in lines across the leaf. The most common symptom are chrome yellow spots scattered along the margin of the large veins giving the impression of yellow veins. In the variety Emperor, however, the veins become distinctly yellow. Numerous yellow spots may also occur scattered over the leaf blade. Diseased vines have straggly clusters, that is, with poor fruit set and numerous small seedless grapes or shot berries. The diseased vines are often more vigorous than are normal vines. This effect is in contrast to that caused by the fanleaf viruses which degenerate grapevines. Varieties of grapes commonly known to carry yellow vein are Carignane, Grenache, Emperor and Valdipenas. It may also occur in other varieties.

Mineral deficiencies: (11, 12, 43, 90)

The most common mineral deficiency diseases which have been observed in vineyards of California are those induced by deficiencies in boron, copper, iron, potassium and zinc.

Boron deficiency: (4, 10, 79) Depending on the variety, mild deficiencies in boron may result in light set of fruit with many flower clusters drying up. Some clusters may set many seedless or shot berries and apparently normal clusters may shatter severely. In more severe cases of boron deficiency leaves may show varying degrees of interveinal chlorosis. The chlorotic spots between the large veins tend to coalesce and become more generally an interveinal chlorosis as the leaves age. The tissues around the primary veins may remain darker green producing a vein banding effect. The terminals of shoots often die back and drop from the shoot and lateral buds grow which results in irregular shaped canes, often forked. In severe cases, the pith of shoots in large green canes turns prematurely brown. Canes may split at the base and result in open cankers. In the spring boron deficient vines leaf out late. The first few leaves at the base of the cane become variously deformed, thick with a leathery feel. They have prominent somewhat translucent veins and sharp marginal vein tips. As the new shoot grows the leaves become more nearly normal in shape and color. Later, leaves at the terminal end of the shoot will develop chlorotic spots between the large veins which enlarge to form the symptoms described above. Grapes on boron deficient vines are often round and the stylar ends tend to be flat, rather than oblong and in late seasons chlorotic leaves will burn at the margins and interveinal tissues.

Calcium deficiency: Water berry (pedicel shrivel) (2, 60, 90 and unpublished data, Hewitt) Water berry is a calcium deficiency disease, a lack of enough calcium at a critical period to serve as an antidote for excesses of bivalent heavy metals like magnesium and manganese as well as

take its part in cell membrance function. It is evident that as amounts of the bivalent heavy metals in grapes increase so must the amount of calcium; and conversely, as the bivalent heavy metals decrease in grapevine tissue, so can the amount of calcium. The balance in favor of calcium at critical periods in the rachus, pedicels, and fruit seems to be the key. A deficiency of calcium (lower than other bivalent heavy metals) results in a decay or leak in the cell membrane and death of cells. Pedicel shrivel, wilting and withering of the grape, single grapes or in clusterettes and often at the tip of the clusters in Thompson Seedless characterizes this disease. It is well known and occurs in many varieties in many parts of the world. In Zinfandel grapes the disease may be known as blue berry and berry drop. Here the grapes shrivel and may drop from the cluster. Diseased grapes, especially in tight clusters, often loosen at the cap stem and may become infected and rot by different organisms.

Exanthema (copper deficiency): A nutritional disease controlled by applying copper to the foliage of the grapevine or to the soil. The disease has been known on fruit trees, apple, citrus, pears, mostly in coastal areas of California for some time. The name "exanthema" refers to the rough, scaley, scurfy bark on canes, and leaf veins, and is thus similar to the disease in fruits.

Symptoms are similar in most varieties. However the severity of the disease varies greatly with the variety and location. Among the varieties observed to have exanthema, Merlot is very sensitive. Pinot Noir, White Riesling, Sylvaner, and Chardonnay are moderatly sensitive, whereas Cabernet Sauvignon seems tolerant. Often degrees of severity are evident in adjacent vines or groups of vines in the same vineyard area.

In general diseased vines are dwarfed, develop excessive lateral shoots, with smaller, often deformed leaves, have a poor crop (or no crop), leaves in general are rugose (rough) malformed, the cane bark is rough in spots and areas, and scurfy (has exanthema).

In the spring shoots may grow normally, the first leaves remain small, turn yellowish, burn at the tips and many will drop; also, later in the season, it is likely the leaves on a new flush of growth may turn yellowish, burn and drop. Leaves on exanthema vines are rough and variously malformed, parts of the petiole and large veins may turn greyish, puffed, appear water soaked and later become scurfy. Large veins so affected cause the leaf to curl. Canes on diseased vines may also develop grey to blackish areas, some appear water soaked and later dry and are scurfy.

Flower clusters appear to be normal until bloom when many of the caps turn to straw color and persist. Cluster parts may dry and drop from the vine.

About mid June developing leaves often have vein clearing (become translucent) that may show on most any leaf or parts of leaves. In later season many of the cleared veins turn yellowish and appear as though affected by a virus. Leaf petioles may range in copper from 1.8 to some 9 ppm. Normally they contain some 12-15 ppm.

Iron deficiency: (11, 12, 43, 90) The lack of iron in the grapevine will show in the foliage as interveinal chlorosis and give the vines a general yellow cast. As the season advances symptoms become more severe towards the shoot tips and in severe cases result in marginal burn of the leaves.

Potassium deficiency: (82) Symptoms usually begin to show in early summer in leaves about the middle of the shoots. The disease is characterized by marginal chlorosis, that is, fading of the green color from the margins of the leaves toward the center and petiole. Leaves appear to become thick, feel leathery and crisp and will crack when crumpled in the hand. As symptoms advance the leaves curl downward at the margins. In advanced cases margins of leaves will burn following the chlorosis. In the vineyard symptoms of potassium deficiency may vary from vine to vine; some vines appearing normal and others showing deficiency symptoms. Rootlet decay on vines will often induce potassium deficiency symptom in the leaves.

Zinc deficiency: (9, 41, 50, 56, 90) The disease is called little leaf, a characteristic common to zinc deficiency in many plants. Canes tend to produce large numbers of small leaves on excessive growth of side buds on shoots from the canes. Leaves will show varying degrees of mild to strong interveinal chlorosis with dark green veins. The petiole sinus remains open in some leaves to over one hundred degrees or more. Leaves are variously deformed. Symptoms become more severe towards the shoot tips. Clusters are often straggly with seedless or shot berries.

Mineral toxicity and excesses: (90)

The excesses of boron, salts and alfali are most common in vineyards of California. Sometimes excess nitrogen is observed to cause a marginal burn of leaves.

Boron toxicity: (79, 90) Leaves of affected vines are often cupped and variously wrinkled along the veins. This is apparently due to either very slow growth or failure of expansion at the leaf margins. Leaves of affected vines will also show varying degrees of black to brown necrotic areas sprinkled about the margins. The specks later become numerous and cover the entire margins of the leaves. Black speckling may extend to the petiole between the large veins.

Salinity injury: (90) Damage to grapevines caused by high salinity may develop from the continued use of irrigation water that is high in chlorides. Symptoms first appear as marginal burn followed by progressive necrosis of the leaf blade from the margins towards the petiole. The large veins often remain green. The striking feature of this disease is that the line of demarkation between the green and the brown tissues is usually quite sharp.

Alkali injury: (90) So-called alkali injury caused by high concentrations of total salts is difficult to distinguish. Grapevines growing in alkali soils are often small, shoots tend to have short internodes and the leaves are usually smaller than would be expected in normal soils. Leaves may show varying amounts of chlorotic to necrotic areas in the leaf blade

with fading of green color at the margins. Severely affected leaves may burn and drop from the vines. Vines growing in excessively high salt conditions in hot weather may dry up and die.

Abnormal temperature affects:

Grapevines appear to grow best at temperatures ranging from some 60° to 90°F.

High temperatures damage: Excessively high temperatures of over 104°F affect shoot elongation in many grape varieties. In hotter desert regions internodes may become very short and leaves small, thick and dark green. When temperatures moderate, growth gradually becomes normal. Grapes of some varieties such as Almeria, Thompson Seedless and Flame Tokay are quite susceptible to high temperatures. They develop internal breakdown or brownish areas under the skin known as heat spots. When the flesh temperature exceeds about 104°F, the internal tissue at points seems to disintegrate. The degree of internal browning and breakdown will vary with the variety and the duration of the high temperatures. Burn or brown necrosis of some varieties, blackish in color, often occurs on grapes exposed to direct sun during the high temperature periods. Other grapes become straw colored when exposed to direct sun for long periods of time.

Shoots, leaf petioles and cluster stems may under excessively high temperatures of 108°F or more also develop heat spots or internal breakdown. Conditions of this nature have been observed to develop in grapevines in late May when the temperatures after a period of cool weather climb rapidly within 3 or 4 days to an excess of 108°F. Internal breakdown of shoots is not uncommon in many varieties under these conditions; the variety Flame Tokay has been observed to burn very badly. Grapevines gradually conditioned to high temperatures withstand them without severe damage.

Freezing damage: Injury to grapevines from late spring freezes or frosts may range from only slight damage to some leaves to severe killing of shoots and under severe conditions cracking of the bark and killing of canes. Irregular, angular, chlorotic, often translucent chlorophyll-free areas in the leaves that persist through their lives are symptoms of low temperature damage.

Lightening damage: The high potentials from electricity from lightening when it strikes the ground or grapevines will often cause severe damage to them. Direct contact may destroy the grapevine. Degrees of cane and leaf blighting often develop within a few days following a strike of lightening. Shoots or green canes may develop internal browning and necrosis and irregular patterns particularly along the cambium. Shoots or canes damaged by lightening will bleed or ooze sap through cracks in the bark as if leaking from the cambium areas. This symptom seems to be quite characteristic of damage caused by lightening.

Smog: Not much is known about "smog" effects on grapevines. However, one of the "smog" components has been evaluated.

Ozone damage (oxident stipple): (78) The disease is generally recognized as early bronzing, yellowing, senescence and fall of leaves of

grapevines. The primary or early symptoms are small, discrete brown to black groups of pigmented cells just below the layer of upper leaf surface epidermal cells. The discolored areas become necrotic and appear as stippled over the leaf. They are typically small in leaves of most grape varieties. Stipple may appear most any time of the growing season following exposure.

Diseases caused by agricultural chemicals:

Arsenic spray injury, bud kill: (68) Arsenic applied as sodium arsenite will kill green foliage of grapevines. Leaf scar, vascular traces and buds may be killed after spraying canes of Thompson Seedless grapes. Leaf vascular traces in the leaf scar serve as entry courts for the arsenic solution. Necrotic leaf vascular traces may extend for several millimeters below the scar. When excessive, the injury may also kill the bud. Tissue below the bud becomes brown and necrotic and fail to grow.

Bordeaux mixture toxicity: Bordeaux mixture applied to grapes will burn young tender leaves and shoots and cause older leaves to thicken and turn to a dark green. Grapevines sprayed with Bordeaux mixture will generally have smaller and fewer clusters than normal grapevines.

Diseases caused by tissue growth regulators: (85, 86, 87, 90, 92) Grapes are highly sensitive to 2,4-D (2,4-dichlorophenoxyacetic acid). Practically all green portions of the grapevine are highly susceptible to this chemical. Leaves, shoots, canes, flower clusters display varying degrees of damage that may show as slight chlorosis and malformation of growth to severe necrosis and deformity, and die back of shoot tips. Spongy, calloused type growth, often occurs in damaged cane tissue. It is accompanied by cracking of the bark in many places and the development of root primodia. Leaves with spots that have translucent veins associated with deformed marginal teeth characterize 2,4-D damage most commonly found on grapevines in vineyards of California. Affected portions of leaves may vary in size from rather small areas of 1/2 inch to as large as 2 or 3 inches in diameter. Some forms of 2,4-D damage may be found in most any vineyard in California. The damage may also be found in vineyards most anywhere in the world.

Some other auxin compounds that may induce damage to grapes are 4-CPA (4-chlorophenoxyacetic acid), 2,4-DB (2,4-dichlorophenoxybutyric acid), auxin BOA (benzothiazole-2-oxyacetic acid).

Gibberellins: (85, 88, 92) The gibberellins in low concentrations are used for various reasons on grapevines, some to expand growth and development of clusters and more generally, however, to increase size of fruit. Applied in excess they may induce variousforms of damage to the grapevine. Shoots may elongate excessively rapidly and become larger in diameter. Leaves of vines sprayed with excessive gibberellin are often variously deformed with wide open basal sinuses. They may show slight mottling. Clusters often develop seedless shot berries. If concentrations are too high the bud development may be inhibited and bud break retarded.

Sulphur burn: Sulphur dust applied during the hot period or just before the hot period may result in excessive burn of the young leaves. Young leaves are most susceptible to sulphur burn. Black or "gas house" sulphur

finely divided may cause excessive burn of leaves and canes if applied just before or during a spell when the weather exceeds 100°F.

Lime sulphur damage: Grapevines sprayed with lime sulphur may show varying degrees of leaf burn. Concentrations of lime sulphur, an excess of 1 gallon commercial grade lime sulphur per 100 gallon of water may induce burn of leaves.

Weed control chemicals: (61, 83, 85, 86, 92) Chemicals used in the control of weeds when taken up by grapevines will cause different and varied symptoms to develop. Leaves may show varying degrees of chlorosis, sometimes interveinal and sometimes vein chlorosis. Some symptoms of excess weed killing compounds often resemble those of iron deficiency. They may be from mild to severe. In severe burning leaves dry from the margins to the petiole, shoots die back from the tips. In other cases the symptoms resemble those induced by viruses, such as yellow vein and vein banding.

Diseases - cause not known or associated:

Cluster stem knot: The cause of this disease is not known. Excessive enlargement of irregular areas of the grape cluster stem often accompanied by cracking characterizes the disease. Swelling most frequently occurs in the cluster stem above the shoulder branches and often near attachment to the cane. The disease has been observed most frequently on the varieties Calmeria and Emperor.

Spindle shoot: (41, 90) The disease is known only in the variety Colombard. It is recognized only in the spring. The shoots have small variously deformed and cupped leaves and thus appear to be spindly. Leaves often have chlorotic areas in the blade and large irregular chlorotic areas that extend from the margins of the leaf into the leaf blade. They may be puckered and cut. The disease is known to be carried in propagation wood to new progeny. The symptoms of the disease will vary with the season and range from slight in some seasons to quite severe in others.

Spring fever: In the spring marginal somewhat yellowish chlorotic mottle develops in the basal leaves on shoots of some vines in certain varieties. The chlorotic mottle is usually limited to the basal leaves and seldom occurs on more than the first 8 leaves on a shoot. In the spring, grapevines with these symptoms are sometimes slightly smaller than are other vines; however, they grow out of the disease with the advancing season. It has been noted, however, that spring fever will recur in the same grapevines in certain seasons.

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