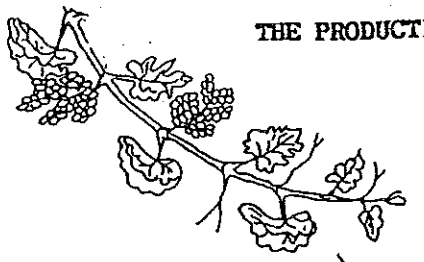
THE PRODUCTION OF CERTIFIED GRAPE STOCK

11/2/90
Colina



Any grower may propagate their own vines. State nursery license is required if vines are grown to sell. For material to be sold, California Certified Grape Stock must be produced following these procedures. (See Below)

Imported material, breeding material, valuable cultivars known to be virus infected, rootstocks, etc.

Obtain from the cleanest possible source

NEW SELECTION

FOUNDATION PLANT MATERIALS SERVICE (FPMS)

Diseases of Concern: leafroll, corky bark, fanleaf, tomato ringspot, Asteroid Mosaic, Fleck, Pierce's Disease and Yellow Speckle

TESTING

- Biological indexing
- Laboratory testing which may include:
  - Culturing
  - ELISA
  - Labeled Nucleic Acid Probes

If clean

If infected

Heat Therapy

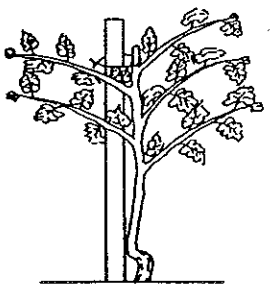
Discard - Find new sources if available

FOUNDATION STOCK

Mother Blocks
- At FPMS
- Inspected 2x/year
- White Tags

REGISTERED STOCK

- At Nurseries
- Increase Blocks
- California Department of Food and Agriculture (CDFA) Inspected
- Purple Tags



CERTIFIED STOCK

- Available to Growers
- CDFA Inspected
- Blue Tags

COMMERCIAL VINEYARDS

Table 1. Symptom expression of leafroll, corky bark and Rupestris stem pitting on grapevine virus indicator plants.

Indicator plants	Diseases		
	Leafroll	Corky bark	Rupestris stem pitting
St. George (*Vitis rupestris*)	-[1)]	+(corky bark, wood grooving, rough bark)	+(wood pitting below inoculation bud)
Cabernet Franc (*Vitis vinifera*)	+(red leaves)	+(red leaves)	-
Mission (*Vitis vinifera*)	+(red leaves)	+(red leaves)	-
LN-33 (Couderc 1613 X Thompson Seedless)	+(red leaves)	+(red leaves, vine dwarfing & wood grooving)	-

1). No disease symptom (-); Disease symptoms expressed (+).

LIST OF ABBREVIATIONS

AMV	Alfalfa Mosaic Virus
BD	Bois Noir
FD	Flavescence Dorée
GBLV	Grapevine Bulgarian Latent Virus
GCBD	Grapevine Corky Bark Disease
GCMV	Grapevine Chrome Mosaic Virus
GDD	Grapevine Degeneration Disease
GED	Grapevine Enation Disease
GFD	Grapevine Fleck Disease
GFLD	Grapevine Fanleaf Disease
GFLV	Grapevine Fanleaf Virus
GJSV	Grapevine Joannes-Seyve Virus
GLRD	Grapevine Leafroll Disease
GLegRD	Grapevine Legno Riccio Disease
GSND	Grapevine Shoot Necrosis Disease
GVMD	Grapevine Vein Mosaic Disease
GVND	Grapevine Vein Necrosis Disease
GYD	Grapevine Yellows Disease
GYSD	Grapevine Yellow Speckle Disease
GYVD	Grapevine Yellow Vein Disease
LDBS	Leaf Curl and Berry Shrivel
PD	Pierce's Disease
PRMV	Peach Rosette Mosaic Virus
TRSV	Tobacco Ringspot Virus
TmRSV	Tomato Ringspot Virus
UBLD	Union Brown Line and Decline
V	Vergilbungskrankheit
VIGD	Virus-Induced Grapevine Decline
GY	GRAPEVINE VIROID

Identifying Latent Disease in Grapevines by Graft or Serological Testing at Davis, CA

Disease	Causal Agent	Test Method	Indicator Plant	Time Required for Test Evaluation
Leafroll	Unknown	Indexing	Cabernet franc Mission LN-33	6-18 months 6-18 months 6-18 months
Corky bark	Unknown	Indexing	LN-33	6-18 months
Stem pitting	Unknown	Indexing	Rupestris St. George	6-18 months
Infectious degeneration	Grapevine fanleaf virus	Indexing	Rupestris St. George *Chenopodium* spp.	15 days-15 months 8-14 days
(fanleaf, yellow mosaic, vein banding)		ELISA	----	2 days
Yellow vein	Tomato ringspot virus	Indexing	*Chenopodium quinoa* *C. amaranticolor*	5-15 days
Asteroid mosaic	Unknown	Indexing	Rupestris St. George	15 days-15 months
Fleck	Unknown	Indexing	Rupestris St. George	15 days-15 months
Pierce's disease (PD)	PD bacterium	ELISA	----	2 days
Yellow speckle	Unknown	Unknown	----	----

Grape viruses

GRAPEVINE VIRUS AND VIRUS-LIKE DISEASES IN CALIFORNIA

Diseases caused by NEPOviruses and their vectors:

Infectious degeneration	Fanleaf virus	*Xiphinema index*
Yellow vein	Tomato ringspot	*X. americanum*, *X. californicum*

Disease with insect-transmitted pathogen and vector:

Pierce's disease	a bacterium	sharpshooter insects

Diseases with natural vector unknown:

Leafroll	closterovirus association	
Corky bark	"	"
Rupestris stem pitting	"	"

PIERCE'S DISEASE VECTORS*

name	alternate hosts	occurrence
Draeculacephala minerva Ball the Green Sharpshooter	alfalfa, grasses, pastures, etc.	Central Valley
Carneocephala fulgida Nottingham the Red-headed sharpshooter	same	same
Graphalacephala atropunctata (Signoret) the Blue-green sharpshooter	riparian habitat, woody perennials	Coastal area

*Other economic hosts: alfalfa (dwarf), almond (leaf scorch)

Woody indicator hosts	Disease detected
Cabernet franc	leafroll
LN33	corky bark
Rupestris du lot (St. George)	fanleaf, Rupestris stem pitting

UNIVERSITY OF CALIFORNIA, DAVIS

FOUNDATION PLANT MATERIALS SERVICE

COLLEGE OF AGRICULTURAL & ENVIRONMENTAL SCIENCES
201 SEED CERTIFICATION CENTER
UNIVERSITY OF CALIFORNIA
DAVIS, CALIFORNIA 95616 U.S.A.
TELEPHONE: (916) 752-3590
TELEX: TWX 910531 0785 UC DAVS

PROGRAM DESCRIPTION

Foundation Plant Materials Service (FPMS) is a service unit created to provide virus-indexed plant materials for research and commercial use. New releases developed at the University, as well as several unique collections are maintained by FPMS.

Most of the material maintained and distributed by FPMS is propagated vegetatively. Although vegetative propagation has the advantage of creating daughter plants that are genetically identical to the mother, it has the disadvantage of transmitting and increasing virus disease. It is important to avoid propagation of virus-infected material because it has been shown to be less vigorous, less uniform, shorter lived and to produce less crop with poorer quality fruit.

The University's policy is to release plant material as "virus-tested stock" whenever possible. Testing procedures are used, as available, to check for harmful virus diseases before release of plant material. If disease is found, selections are treated to eliminate pathogens and then reindexed on known virus indicator hosts. Although foundation materials supplied by FPMS are apparently free of known virus, insofar as can be ascertained by the virus detection methods used, it is not possible to guarantee that materials are healthy.

The value of virus-tested stock is widely recognized, as evidenced by the establishment of Certification programs in many states and countries. The California State Department of Food & Agriculture (CDFA) has designated FPMS as the source of propagation materials for its grapevine, deci-

duous fruit & nut tree, and strawberry certification programs. Initial plant material from FPMS is called **Foundation stock**, which is used to produce **Registered stock** and then Certified stock. Each generation of stock is identified with a different color tag issued by CDFA--white for Foundation stock, purple for Registered stock and blue for Certified stock. Color coding allows nurserymen and growers to identify the respective stocks. Regulations available from CDFA describe growing conditions, inspection and testing procedures required to produce Foundation, Registered and Certified stock.

Summarized below are the official certification programs, as well as programs for the various non-certified crops handled by FPMS. Each is unique in the indicator hosts used for virus disease detection.

GRAPEVINE REGISTRATION & CERTIFICATION PROGRAM

In 1952 it became apparent that severe virus disease problems existed in California vineyards. In response to this situation, USDA scientist Dr. Austin Goheen developed field indexing methods for disease detection and discovered that disease elimination could be accomplished with thermotherapy. Today, the following indicator varieties are used to detect the common virus diseases:

Indicator Plant/Disease

St. George--Fan leaf degeneration, fleck, asteroid mosaic, stem pitting & corky bark

Cabernet franc, LN33, or Mission--Leafroll

LN33--Corky bark and leafroll

Chenopodium sp.--Grape decline (yellow vein) and fanleaf degeneration

All grape selections registered today in the California Registration & Certification Program have been field indexed on the above indicator varieties. In addition, registered vines are inspected twice a year, as prescribed by state regulations, to ensure no new disease problems have occurred. If a virus disease is detected, thermotherapy at 100 degrees F. for 60 or more days is used to eliminate it.

FPMS maintains 186 registered table, wine and rootstock varieties that qualify for Foundation stock status (complete list available upon request). Small quantities of unrooted dormant cuttings from these vines are sold to the public during the winter months. Priority is given to California growers when planting registered increase blocks and producing certified stock. In this way, the Foundation stock supplied by FPMS is increased sufficiently to satisfy the commercial need for certified grape stock. In the event that dormant Foundation wood supplies are insufficient, FPMS will produce grape plants on a contract basis using greenhouse mist propagation techniques. These plants qualify for Foundation stock status and may be used to plant registered increase blocks.

FPMS also maintains records as to the source, treatment, and index test used for each grape selection. This information has been compiled in a computer file and is available to the public for a fee of $5.00. Information about growers who produce California Certified grape stock is also available and sold for $5.00.

Private individuals or companies can contract with FPMS on a fee-for-service basis to have special grape varietal selections heat treated and virus tested as necessary to qualify them for Foundation stock status. Contracts and fee schedules are available from FPMS upon request.

FRUIT & NUT TREE REGISTRATION & CERTIFICATION PROGRAM

Over 144 California registered varieties of almond, apricot, cherry, nectarine, peach, pear, plum, prune, flowering cherry, flowering peach, flowering plum and apple are maintained by FPMS in the Foundatin Orchard (list available upon request). Foundation budwood, as well as Certified Lovell & Nemaguard peach, Myrobalan plum, Mazzard & Mahaleb cherry seed, is allocated between all who request material before order deadline and afterwards on a first come first served basis (check with FPMS office for deadline dates). In the event of limited supply, priority is given to those using the material to establish California registered increase blocks.

All Prunus stock with Foundation status has been field indexed using the following indicator varieties to detect the diseases noted below:

Indicator Plant/Disease

Elberta Peach--Peach yellows, little peach, peach rosette, rosette mosaic, phony peach mosaic, x-disease complex, yellow bud mosaic, wart, peach mottle, prunus stem pitting and asteroid spot

Bing Cherry--Western-x, rusty mottle, mottle leaf, rasp leaf, twisted leaf, tatter leaf, small bitter cherry, and peach mottle

Kwanzan Cherry--Green ring mottle

Shirofugan Cherry--Prunus ringspot complex and prune dwarf virus

Tilton Apricot--Ring pox

Shiro Plum--Line pattern

In addition, every tree in the Foundation Orchard is indexed each year for pollen-transmitted Prunus Ring Spot and Prune Dwarf viruses on Shirofugan cherry. Also, as prescribed by State regulations, the orchard is inspected annually for disease. If found, steps are immediately taken to eliminate diseased tree(s) and replace them with healthy ones.

Patent holders, breeders or propagators of tree material may submit special private selections to FPMS for custom indexing (and heat treatment as necessary) to qualify materials for the California certification programs on a fee-for-service basis. Contracts and fee schedules are available upon request from FPMS.

STRAWBERRY CERTIFICATION PROGRAM

In 1986 FPMS facilities were expanded to include a plant tissue culture laboratory and thermotherapy room. This enables FPMS to produce Foundation strawberry stock of UC patented and breeder lines (some still being tested by University researchers).

Because strawberry virus diseases are readily transmitted by certain types of aphids, yearly tests using greenhouse indicator plants are performed to monitor

the health of Foundation stock plants and to detect virus disease:

Indicator Variety/Disease

Fragaria virginiana selection and/or Fragaria (alpine) vesca selection--Mottle, veinbanding, crinkle, pallados is, necrotic shock, tomato ringspot, leafroll, witches-broom, latent "C", feather leaf, mild yellow edge, pseudo mild yellow edge

Thermotherapy and shoot tip culture are used to eliminate harmful virus diseases and create virus-tested strawberry stock. This process has also been shown to improve the vigor of plants that test healthy on virus indicator plants--perhaps due to removal of bacterial, fungal or undetected virus contaminants. Virus-tested stock is therefore reprocessed through thermotherapy and shoot tip culture each year to produce Foundation stock plants for sale.

Foundation plants are produced on a contract basis and supplied in April and May. Orders are placed with FPMS in late spring or early summer preceeding the year plants are needed. More information as to varieties available and price is available from FPMS upon request.

PLANT MATERIALS AVAILABLE FROM FPMS BUT NOT COVERED BY A CALIFORNIA STATE CERTIFICATION PROGRAM

Virus-tested Rose Collection

FPMS maintains a collection of approximately 312 rose scion varieties and 6 rose rootstock varieties. These selections have been tested for virus disease using the following indicators:

Indicator plant/Disease

Rosa multiflora--Rose rosette, rose ring pattern, rose spring dwarf

'Shirofugan' cherry--Rose mosaic

Rose rootstock cuttings are sold in the fall. Orders should be placed with FPMS before the end of September. Mature canes are cut and shipped approximately November 1. Rose scion varieties can be supplied mid-summer through approximately December. Lists of varieties and costs are available upon request from FPMS.

Hybrid Pistachio Seed

Hybrid pistachio seed (*P. lentiscus* x *P. integerrima*) developed by Dr. Lee Ashworth is available. Preliminary tests indicate a high degree of verticillium wilt resistance. Testing is now underway to check for cold tolerance and ability to survive bareroot transplanting. Parent trees have not been treated or tested for virus disease. No clean stock program has been developed for pistachios to date.

Persimmon Seed

Diospyros virginiana and *Diospyros kaki* seed from the UCD Pomology Collection is available. These seed trees have not been treated or tested for virus disease. No clean stock program has been developed for persimmons to date.

FOUNDATION SEED & PLANT MATERIALS SERVICE
University of California
Davis, California 95616

Registered Grape Varieties

This material is collected from vines in the Foundation Vineyard. It has been indexed and meets the requirements of the California Department of Food and Agriculture's Registration and Certification Program for Grapevines.

When supplies of registered material are limited, priority will be given to participants in the Grapevine Registration and Certification Program.

All orders must be received by November 15th each year for consideration in the allocation process. After November 15th, orders will be filled on a "first come, first served" basis.

TABLE/RAISIN

Alden
Almeria
Anab-E-Shahi
Autumn Black
Beauty Seedless
Black Corinth
Black Damascus
Black Malvoisie
Black Prince
Blackrose
Bronx Seedless
Burgrave
Calmeria
Campbell Early
Canner
Cardinal
Catawba
Christmas
Concord
Dattier
Delight
Diamond
Dizmar
Duchess
Early Muscat
Emerald Seedless
Emperor
Exotic
Ferdinand de Lesseps
Fiesta
Flame Seedless
Flame Tokay
Gasconade
Gold
Himrod
Hunisa
Hussiene
Isabella
Italia
July Muscat
Khandahar
Katta Kourgane
Kishmishi
Loose Perlette
Malaga
Monukka
Muscat of Alexandria
Muscat Flame
Muscat Hamburg
New York Muscat
Niabell
Niagara
Olivette blanche
Ontario
Pierce
Queen
Red Malaga
Ribier
Rish Baba
Romulus
Ruby Seedless
Schuyler
Seneca
Suavis (IP 365)
Thompson Seedless
Thomuscat

ROOTSTOCK

Couderc 1202
Couderc 1613
Couderc 1616
Couderc 3309
Dog Ridge
Foex 33 EM
Freedom
Ganzin 1 (AXR #1)
Harmony
Kober 5BB
LN 33
Millardet & de Grasset 41B
Millardet & de Grasset 420A
Millardet & de Grasset 101-14
Oppenheim 4 (SO4)
Richter 99
Richter 110
Riparia Gloire
Saint-George
Salt Creek
Teleki 5A
Vitis rupestris Constantia
Paulsen 775
Paulsen 1045
Paulsen 1103
Ruggeri 225

*PATENTED**

Table

Blush Seedless
Centennial Seedless
Christmas Rose
Dawn Seedless
Redglobe

Wine

Carmine
Carnelian
Centurion
Symphony

Rootstock

039-16
043-43

*FSPMS can sell patented items only to those having signed license agreements with the University. For information concerning becoming a licensee, contact: *Mr. Robert Fissell, Patent, Trademark & Copyright Office, Office of the President, 2150 Shattuck Ave., Suite 1000A, University of CA, Berkeley, CA 94720, telephone (415) 642-5000.*

Revised 1 October 1987

(CONTINUED ON REVERSE)

Aleatico
Alicante Bouschet
Aligoté
Alvarelhao
Aramon
Baco blanc (22A)
Burger
Cabernet franc
Cabernet Sauvignon
Calzin
Carignane
Charbono
Chardonnay
Chasselas doré
Chenin blanc
Clairette blanche
Early Burgundy
Emerald Riesling
Feher Szagos
Fernao Pires
Flora
French Colombard
Fresia
Furmint
Gamay
Gewurztraminer
Grand noir
Gray Riesling
Green Hungarian
Green Veltliner
Grenache
Grillo
Helena
Inzolia
Lagrein
Lambrusco de Salamino
Malbec
Malvasia bianca
Mataro
Melon
Merlot
Meunier
Mission
Montua de Pilas
Muscadelle du Bordelais
Muscat blanc
Muscat Ottonel
Muscat Saint-Vallier
Nebbiolo
Nebbiolo fino
Nebbiolo Lampia
Orange Muscat
Palomino
Pedro Ximenes
Petit Bouschet
Petite Sirah
Peverella
Pinot noir*
Pinot Saint-George
Primitivo di Gioa
Red Veltliner
Refosco
Rkatsiteli
Royalty
Rubired
Ruby Cabernet
Saint-Emilion
Saint Macaire
Salvador
Sangiovese
Sauvignon blanc
Sauvignon gris
Sauvignon vert
Scarlet
Seibel 5279
Seibel 9110
Seibel 13053
Sémillon
Servant
Shiraz
Souzão
Sultana Crimson
Sylvaner
Tannat
Teroldico
Tinta Madeira
Tinto cão
Touriga
Traminer
Trebbiano Toscano
Trousseau
Valdepenas
Viognier
Walschriesling
White Riesling
Zinfandel

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*To order a Gamay Beaujolais selection of Pinot noir, please specify "Pinot noir GB" on the order form.

Two publications are available from FPMS for $5.00 each offering additional information on FPMS registered grape selections:

"FPMS Registered Grape Selections--Source, Heat Treatment and Disease Indexing Information" AND

"FPMS Registered Grape Selections in Calif. Registered Increase Blocks By Variety and By Nursery"

FOUNDATION PLANT MATERIALS SERVICE

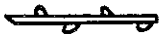
University of California, Davis, CA 95616 (916/752-3590)
TELEX: TWX 910531 0785 UC DAVS

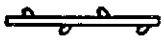
PRICELIST

Revised 10/01/87

GRAPE MATERIAL

Available in units of 12"-14" **unrooted:**

†CUTTING: 
For growing rooted plants, the proximal cut is flat and adjacent to the bottom bud, while the distal cut is slanted at an internode. The regular #1 size is larger than ¼", but not more than ¾" in diameter. If the supply is short, one may wish to indicate acceptance of #2 size (¼" in diameter) and/or #3 size (less than ¼" in diameter). These are sold at a reduced amount; however, they may be more difficult to grow. PLEASE NOTE THAT ONLY CUTTINGS ARE SOLD IN THE ABOVE-MENTIONED THREE SIZES.

†GRAFTSTICK: 
For grafting to a rootstock variety, both cuts are flat and at the internode. These are ⅜" and ½" in diameter (approximately 4 buds per stick).

†BUDSTICK: 
For budding to a rootstock variety, both cuts are flat and at the internode (approximately 4 buds per stick), with ¼" to ⅜" diameter.

†If an unspecified size is desired, please indicate the prefered diameter on the order form and FPMS will do its best to accommodate.

Registered and Non Registered Material*

5 to 49 units/variety	$ 1.50 each
50 to 99 units/variety	1.25 each
100 to 499 units/variety	1.00 each
500 to 4999 units/variety	.75 each
5000+ units/variety	.60 each

*#2 & #3 size cuttings can be supplied at slightly reduced rates

Pollen	$ 31.25/packet

Mist Propagated Grape Plants

5 to 99 plants/variety	$ 3.75 each
100+ plants/variety	2.50 each

TREE FRUIT MATERIAL

Individual Bud* (supplied in 12" - 14" cuttings)	5 to 99 units/variety	$ .40 each
	100+ units/variety	.20 each
Walnut Wood		1.00/foot

*Please specify diameter of wood desired. If you wish to cut your own budwood, please call FPMS to make arrangements.

SEED

Mahaleb Cherry	$ 23.75/pound
Mazzard Cherry	22.50/pound
Lovell Peach	.095/seed
Nemaguard Peach	.095/seed
Myrobalan Plum	15.00/pound
Betulaefolia Pear (uncleaned fruit)	8.00/pound
Betulaefolia Pear (cleaned seed)	50.00/ounce
Hybrid Pistachio (P. lentiscus x P. integerrima)	1.00/seed
Persimmon	.095/seed

ROSE MATERIAL

Rose Variety	5 to 99 units/variety	$ .30/bud
	100+ units/variety	.20/bud
** **Rose Rootstock**	5 to 99 units/variety	.30/8" cane
	100+ units/variety	.20/8" cane

** *DEFOLIATED CANES ARE PROVIDED. GROWER WILL DETHORN, DEEYE AND MAKE INTO CUTTINGS.*

CUSTOM HEAT TREATMENT & INDEXING SERVICES

Shirofugan indexing only	$ 5.00/item
Custom heat treatment & indexing to qualify material for inclusion in CA Registration & Certification Program	
Public Variety	200.00/item
Proprietary or patented variety	1,000.00/item
Maintenance of proprietary selection in Foundation Vineyard, Foundation Orchard or FPMS Rose Block	25.00/year/item

—More on Reverse—

PUBLICATIONS AVAILABLE

1. *FPMS Registered Grape Selections:* A list of all currently registered grape selections, their sources, recent disease indexing history, and number of days in heat treatment ..... $ 5.00 each
2. *FPMS Registered Grape Selections By Nursery:* A list of grape selections included in CA Registered Increase Blocks by participating nursery and by specific grape variety and selection number; names, addresses and phone numbers of participants are included ..... 5.00 each

A minimum amount of $25.00/order is required. The minimum order quantity is 5 units per variety.

California sales tax will be added where applicable, unless a tax exempt resale number is indicated on the order form (issued by State Board of Equalization). All wood is taxed; seed is not taxed.

All shipping costs will be added to the price of the material. In addition, packing and handling charges will be made as follows:

Orders shipped WITHIN CALIFORNIA, 10% of order cost.
Orders shipped OUTSIDE CALIFORNIA (WITHIN U.S.A.), 20% of cost.
Orders shipped OUTSIDE U.S.A., 25% of order cost.

At customer's request, material will be packed in a styrofoam ice chest for an additional charge of $5.00 per chest.

All foreign orders will be shipped by a forwarding company, with the customer paying all fees. Up to 20% of shipping and forwarding fees will be charged as a service charge.

Prepayment of 50% on all U.S. orders is required; 100% of cost of materials plus shipping, packing, handling and service charge for foreign orders. Prepayments on all foreign orders must be made via a bank draft from a U.S. bank (U.S. currency), payable to The Regents of the University of California. NO LETTERS OF CREDIT WILL BE ACCEPTED. PLEASE SEND ALL CORRESPONSENCE TO FPMS, UNIVERSITY OF CALIFORNIA, DAVIS, CA 95616. FPMS reserves the right to retain prepayments for cancelled orders.

ALL MATERIALS ARE SHIPPED F.O.B. DAVIS, CALIFORNIA. BUYER AGREES TO PAY ALL COSTS OF TRANSPORTATION AND ASSUMES ALL RISK OF LOSS DURING SHIPMENT.

Prices are subject to change without notice.

Boligala C. Raju
Yoder Brothers, Inc., Alva, FL

John M. Wells
Rutgers University, New Brunswick, NJ

Diseases Caused by Fastidious Xylem-Limited

The term "xylem-limited bacteria" (XLB) is now being used to describe prokaryotic plant pathogens difficult to isolate by standard bacteriologic procedures. These fastidious organisms require complex media for growth, occur in the xylem of infected plants, are transmitted by xylem-feeding leafhoppers, and cause difficult-to-control diseases of economically important crops. When first associated with plant diseases (5,10,14), these agents were referred to as "rickettsialike bacteria" because of ultrastructural similarities to animal rickettsiae. Recently, many XLB have been cultured in vitro, and pathogenicity has been demonstrated (3,19,22). Pure cultures of the bacteria have been used to study the guanine + cytosine (G + C) ratios and serologic relationships with other plant-pathogenic bacteria and rickettsiae, and XLB have been found to be unrelated to ricksettsiae and other plant pathogens.

Diseases Caused by XLB

Pierce's disease of grapevines (*Vitis vinifera* L.), reported in California in 1892, brought the professional plant pathologist N. B. Pierce to the state. The disease was originally observed near Anaheim and was called California vine disease. Pierce studied the symptomatology and distribution of the disease extensively, but because bacteria isolation techniques were limited, he could only hypothesize that the disease was caused by a "minute microorganism."

When Pierce's disease was found to be graft-transmissible, the cause was attributed to a virus (7). This conclusion was strengthened by detection of insect vectors (8). While studying insect transmission, Hewitt et al (8) observed a high incidence of Pierce's disease in vineyards near alfalfa (*Medicago sativa* L.) fields with a high incidence of alfalfa dwarf disease. Later, Pierce's disease and alfalfa dwarf disease were shown to be caused by a similar pathogen (5).

First author's present address: Weyerhaeuser Tissue Culture Center, Apopka, FL.

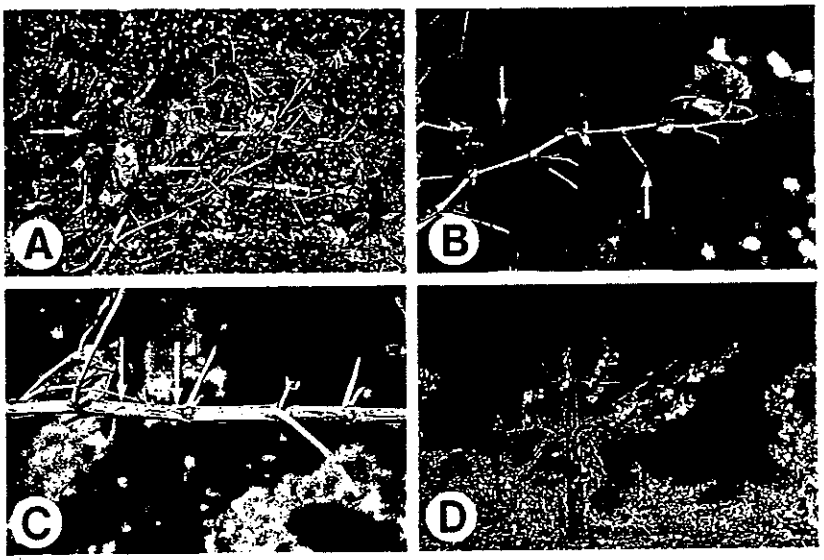


Fig. 1. Symptoms of Pierce's disease of grapevines: (A) Leaf scorching and bronzing, with chlorotic areas next to necrotic areas (arrows); (B) loss of leaf blades, with only petioles remaining (arrows); (C) irregular maturation of diseased stem, with patches of brown (arrows) and green tissues; (D) decline and death of the plant.

Even though no virus or viruslike agents were observed in diseased grape and alfalfa tissues and Koch's postulates were not fulfilled, the two diseases were considered to be caused by a virus until 1973, when pathologists in California and Florida independently found "rickettsialike" bacteria in the xylem of affected plants but not in that of healthy plants (5,10). Heat therapy studies supported the association of bacteria with Pierce's disease (5). After Davis et al (3) succeeded in formulating bacteriologic culture media and in vitro isolation techniques, the bacterium could be cultured, Koch's postulates were fulfilled, and new avenues were opened for the study of XLB biology. The Pierce's disease bacterium was also shown to cause almond leaf scorch disease in almond (*Prunus amygdalus* Batsch), responsible for severe losses in some almond cultivars in California, and the same insects were found to be the vectors of both diseases (13).

The most characteristic symptom of Pierce's disease of grapevines is leaf scalding or scorching. Another early sign is sudden drying of part of a green leaf. Affected areas of a leaf usually turn brown, and adjacent tissue turns yellow or red. Usually, scorching begins at the leaf margin and progresses inward (Fig. 1A). Sometimes only the tip of a leaf appears scorched; other times an entire leaf is affected and the blade drops off, leaving the petiole (Fig. 1B). Diseased stems often mature irregularly, with patches of brown and green tissues (Fig. 1C). During the second year, growth is delayed, dwarfing occurs, fruit yields are reduced, the root system declines, and the plant dies (Fig. 1D). Hopkins (9) suggested that scorching results from restricted flow of water and nutrients owing to partial or complete plugging of xylem vessels by bacteria. We have suggested that bacterial toxins induce the symptom.

Symptoms of almond leaf scorch are

Bacteria and Strategies for Management

similar to those of Pierce's disease (Fig. 2). Alfalfa under field conditions, however, does not show scorching; instead, affected plants show decline and stunting (Fig. 3).

Phony peach disease was known to pathologists even before Pierce's disease was observed in California, having caused serious losses in peach (*P. persica* (L.) Batsch) orchards in the southeastern United States as early as 1890 (11). Because of graft- and insect-transmissibility, the disease was attributed to a virus, until 1973, when "rickettsialike" bacteria were detected by electron microscopy in the xylem tissues of affected peach (14). Wild *Prunus* spp. were found to be hosts. In 1977, a leaf scald disease of Japanese plum (*P. saliciana* Lindl.) was reported from Georgia and Alabama. Plum leaf scald also occurs in Argentina, Brazil, and Paraguay. Recently, bacteria morphologically and ultrastructurally similar to the Pierce's disease bacterium were isolated in pure culture (2,23) from plant material affected with phony peach disease and plum leaf scald, and Koch's postulates were fulfilled (19,22). Pathogenicity tests showed the diseases to be caused by the same pathogen.

Peach trees with phony peach disease do not show scorching or scalding but are severely stunted and have a compact growth habit (Fig. 4). The trees do not die but produce small, distorted fruit with no market value. Diseased plum trees, however, show leaf scorching or scalding similar to that of grapevines with Pierce's disease.

In recent years, XLB have been shown to be the causal agents of, or associated with, several plant diseases for which no etiologic agents or abiotic causes were previously known (6,20). These include ragweed (*Ambrosia artemisiifolia* L.) stunt, periwinkle (*Vinca minor* L.) wilt, and leaf scorch of elm (*Ulmus americana* L.) (Fig. 5A), oak (*Quercus rubra* L.) (Fig. 5B), mulberry (*Morus rubra* L.), and sycamore (*Platanus occidentalis* L.). Diseased ragweed has been reported only in Florida; no symptoms were apparent in nature, but reduced growth and stunting were observed under greenhouse conditions. Similarly, periwinkle wilt has been found in a greenhouse in Florida but not observed in nature; symptoms included chlorosis and yellowing of foliage, stunting, and wilt. Leaf scorch symptoms on elm, oak, mulberry, and sycamore have been observed in the northeastern and southern United States and are similar to those of Pierce's disease of grapevines.

Insect Vectors

XLB are transmitted by leafhoppers known as sharpshooters and spittlebugs, including *Draeculacephala minerva* Ball, *Carneocephala fulgida* Nottingham, *Helochara communis* Fitch, *Homalodisca coagulata* (Say), and *Oncometopia nigricans* (Walker) (15). The observation that Pierce's disease of grapevines was severe near alfalfa fields and decreased with distance led to the discovery of insect vectors (8). Some sharpshooters, e.g., *H. coagulata* and *O. nigricans*, transmit not only the Pierce's disease bacterium but also phony peach disease, plum leaf scald, and periwinkle wilt bacteria.

In insect transmission tests on 100 plant species, Freitag (4) identified 75 symptomless hosts of the Pierce's disease bacterium. The leafhoppers usually overwinter and breed on the symptomless wild hosts, then spread the pathogen to and within cultivated crops. A recent study (18) showed the importance of wild plants as sources of the Pierce's disease

Fig. 2. Almond leaves with scorching symptom typical of almond leaf scorch disease.

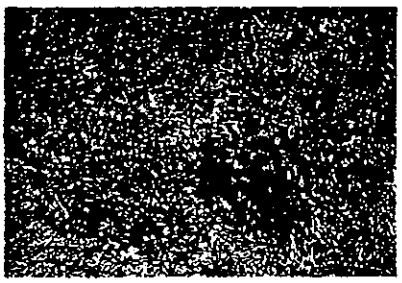


Fig. 3. (Left) Stunting and compact growth of alfalfa plant with alfalfa dwarf disease; (right) healthy plant. (Courtesy D. Hall)

Fig. 4. (Left and center) Stunting, short internodes, and compact growth of peach trees with phony peach disease; (right) healthy tree.

Fig. 5. Leaf burning and necrosis of (A) elm and (B) red oak with leaf scorch disease. (Courtesy S. Kostka)

bacterium for leafhoppers. Differences in vector efficiency may be related to the vectors' host preferences. For example, *D. minerva* feeds primarily on grass and only occasionally on grapevines and almond trees, whereas *Graphocephala atropunctata* (Signoret) is found primarily on woody perennials, including wild and cultivated grape.

Nymph and adult sharpshooters are equally efficient in transmitting XLB. The minimum latent period is 2 hours or less; in some instances, the vectors transmit the bacterium almost immediately after acquisition. The insect remains infective until molting. XLB do not circulate via the hemolymph to the salivary glands, as do mycoplasmalike organisms and spiroplasmas, but do propagate in the foregut, which is shed during molting.

On the basis of scanning electron microscopy studies, Purcell et al (16) proposed the following mechanism of transmission for the Pierce's disease bacterium: Bacterial cells taken up by xylem-feeding insects from diseased plants attach to the floor of the cibarium and the apodemal groove of the diaphragm and multiply, forming a bacterial plaque (Fig. 6); during subsequent feeding, the bacteria are flushed from the foregut by egestion of the sucking pump and enter the host's xylem tissues. Similar observations were made with other XLB and their insect vectors (1).

Unlike the Mollicute plant pathogens (i.e., those with no cell walls), XLB cannot be transmitted by leafhoppers through Parafilm, even though the bacteria can be readily injected mechanically into the plant. Fimbriaelike structures are easily observed by electron microscopy in XLB in plant and insect hosts but are rarely seen in XLB from pure cultures. Possibly, these structures are necessary for vector transmission.

The Bacteria

XLB are rod-shaped with distinctive rippled cell walls (Fig. 7). The bacteria are nonflagellate, do not form spores, measure 0.3–0.5 μm in diameter and 1–5 μm in length, and occur only in xylem tissues of affected plants. The fastidious bacteria cannot be cultured on conventional bacteriologic media. The recently developed BCZE medium (19), as well as some others, can be used to isolate and grow several XLB. The bacteria grow well at 20–25 C and pH 6.7–7.0. The tolerances for salt and carbon dioxide are 1 and 2.5%, respectively. Some type of hemin chloride seems to be essential for growth. Primary colonies are generally white or greenish white, are mostly circular with smooth or rough margins, and can be seen 1–2 weeks after the primary isolation.

Phony peach disease and plum leaf scald bacteria are gram-negative and are positive for catalase, gelatinase, and hippurate and negative for acid fastness, oxidase, coagulase, β-galactosidase, H_2S production, urease, phosphatase, indole production, and acid formation from glucose (21). Studies with various XLB show the G + C ratio to be about 50.5 mol%, with genome molecular weights of $1.4 \times 10^9 + 0.2 \times 10^9$ (12). No genetic relatedness has been shown between XLB and other plant-pathogenic bacteria.

Fig. 6. Scanning electron micrograph of inoculative leafhopper cibarium with dense growth of Pierce's disease bacterium. (Courtesy A. Purcell)

Serologic studies have indicated, and pathogenicity tests have confirmed, two distinct XLB groups: the Pierce's disease group and the phony peach disease group. Morphological, ultrastructural, genetic, serologic, and pathological studies have identified XLB as a distinct group of plant pathogens not related to other organisms. Hence, a new name, *Xylemella fastidiosum*, has been proposed for the Pierce's disease bacterium (21), with this bacterium as the type strain for the genus *Xylemella*.

Detection Methods

A method was devised as early as 1920 for detecting the phony peach disease agent. When stem sections were treated with acidified methanol, diseased xylem stained red (Fig. 8). This test worked well only with mature wood, however. Other XLB-detection methods that have been used, some with only limited success, are vacuum extraction of bacteria with potassium hydroxide, phase-contrast microscopy, direct and indirect immunofluorescence, and in situ immunofluorescence. More recently, enzyme-linked immunosorbent assay (ELISA) has been used extensively to detect XLB in diseased plants, symptomless hosts, and insects. With the help of in vitro isolation techniques and ELISA, several laboratories now routinely detect XLB in plants.

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Fig. 7. Transmission electron micrographs of ultrathin sections of (A) phony peach and (B) plum leaf scald bacteria from culture; arrows indicate rippled cell walls. (C) Unusually long bacterial cell. Scale bar = 0.5 μm. (Courtesy S. Lowe)

Epidemiology

Pierce's disease of grapevines is endemic in symptomless wild plants throughout the southern United States and is the major limiting factor there in production of European-type and bunch grapes. In California, the disease occurs in "hot spots" adjacent to permanent water sources and several weed hosts. A recent study showed the importance of symptomless wild plants in the epidemiology of Pierce's disease in California (18). These plants not only support vast vector populations but also are excellent sources of the bacterium, which explains why removing affected grapevines has been of limited value in preventing disease spread in California vineyards. Similar observations have been made in Florida. Pierce's disease of grapevines has been reported from Costa Rica and Mexico but not from Europe.

Alfalfa dwarf disease has been observed only in the southern United States and in California, even though the insect vectors have also been found in midwestern and northern states. Almond leaf scorch has been reported only in California. Under greenhouse conditions, the same bacterium causes Pierce's disease of grapevines, alfalfa dwarf disease, and almond leaf scorch. When two different crop hosts are located near each other, however, only one is affected. For example, almond trees growing next to heavily diseased grapevines in California show no symptoms of almond leaf scorch, and vice versa. When mechanically inoculated with the bacterium in the field, however, almond trees show typical almond leaf scorch symptoms. Vector preference may be an important factor in this phenomenon.

Phony peach disease, plum leaf scald, ragweed stunt, and periwinkle wilt occur in the southern United States but not in California. Plum leaf scald, but not phony peach disease, has been reported from South America. In Argentina, peach trees adajacent to areas affected with plum leaf scald showed no symptoms of phony peach disease, even though the same bacterium causes both diseases under greenhouse conditions (19). In peach trees, populations of the phony peach disease bacterium are high in root tissues but low or absent in leaf and stem tissues (22), whereas in plum trees, populations are high in all three tissues. Peach, therefore, may be a dead-end host for the bacterium, since insect transmission from peach to peach is poor. Because plum leaves support good growth of the bacterium and stem tissue is excellent for graft and in vitro isolation studies, native and wild plums are considered important hosts for spread of phony peach disease.

Management Strategies

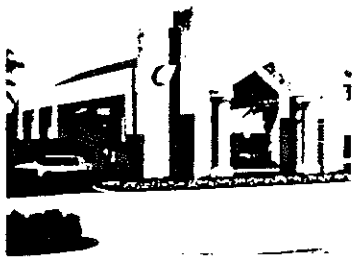
Because XLB infections are usually lethal and kill cultivated host plants within 2–3 years, the diseases are often self-eliminating. Some diseased plants serve as sources of inoculum for further spread, however. Diseased plants take up valuable space in an orchard but do not produce marketable fruit, even during the early stages of infection. Roguing infected plants and replanting with disease-tolerant cultivars is therefore important.

Removal of alternate hosts has been recommended for Pierce's disease of grapevines and phony peach disease. The practice of removing diseased wild plums in Georgia dates back to 1930, and our studies in California indicate selective removal of symptomless hosts of Pierce's disease reduces availability of both bacterium and vector. Whether maintaining orchards free from weeds and wild plants helps control XLB-caused diseases is not known, but weeds and wild plants do support XLB vectors, so clean ground maintenance practices should be considered.

Practical control of all XLB vectors is difficult. Several studies have shown that insecticide sprays are not an economical means of controlling vectors of Pierce's disease of grapevines in California. During certain times of the year, however, insect populations increase drastically, and application of effective insecticides may be necessary.

Injections of antibiotics, particularly tetracycline hydrochloride, into diseased tree trunks adequately control some XLB-caused diseases. Plants with advanced disease have severely plugged xylem, however, and are difficult to treat in this manner. We tested the efficacy of several chemicals and antibiotics other

1986 Annual Meeting to be held at newly remodeled Hyatt Orlando Hotel



Plans are under way for the 1986 APS Annual Meeting in Kissimmee, FL, August 10—14, 1986. The Hyatt Orlando Hotel has recently undertaken a complete face-lift and provides excellent meeting accommodations.

Unlike a high-rise hotel, the Hyatt Orlando's 947 guest rooms are arranged in four convenient two-story clusters or "mini-hotels." Each cluster has its own adult swimming pool, children's pool, playground, self-service laundry, and recreational facilities. A scenic fitness trail with a series of exercise stations will be a nice diversion for both new and experienced health enthusiasts.

The Hyatt Orlando is ideal for family vacations. The cost for a single, double, triple, or quad accommodation is only $60.00 per night. Nearby Walt Disney World, Epcot Center, Sea World, and Circus World will make it a memorable trip for children.

Annual meeting registration materials and hotel reservation forms will be sent to U.S. and Canadian APS members in May 1986. Members from outside the United States may write to APS headquarters to request registration materials. Abstracts for oral and poster presentations are due to APS headquarters by March 31, 1986. Abstract forms can be found in the November 1985 issue of *Phytopathology News* or requested from APS headquarters.

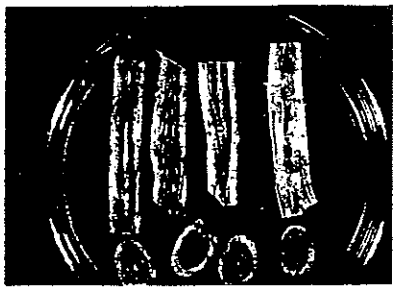


Fig. 8. When treated with acidified methanol, tissue of almond stems infected with Pierce's disease bacterium stains red, whereas healthy tissue (right) remains clear. (Courtesy S. Mircetich)

than tetracycline against some XLB and found that most are either phytotoxic to the host or cost-prohibitive. We also found that symptoms remitted only after injections, and not after foliar applications, and that treatment had to be given at least annually to maintain the remission. Therefore, unless highly effective new ones are developed, chemicals seem to offer little hope for controlling XLB-caused diseases.

Planting tolerant cultivars is one of the best strategies for long-range management of XLB-caused diseases, especially in areas where diseases occur in "hot spots." Several popular wine grape cultivars in California have been screened against the Pierce's disease bacterium under greenhouse and field conditions, and some tolerant ones have been identified (17). Grape cultivars tolerant to Pierce's disease have also been identified in Florida. Our recent studies indicate that almond is immune to phony peach disease and that peach is immune to Pierce's disease. Because survival of bacteria in roots is an important factor in chronic infection, these two hosts could be used as rootstocks. Almond rootstocks may be especially useful in controlling phony peach disease, since that bacterium survives mainly in the roots.

Future Directions

Innovative research in breeding and genetics is needed to achieve long-range control of diseases caused by XLB. A tissue culture system offers the greatest potential for developing XLB-tolerant plant material. For example, clones of grape resistant to Pierce's disease may be generated by using protoplast or callus cell cultures employing the bacterium or its products produced in culture. This approach may permit development of a "resistant clone" of a popular cultivar that is susceptible in the field.

Most of the XLB that cause plant diseases in the United States have been isolated and maintained in pure culture, yet their taxonomic status has not been defined. Taxonomic studies of XLB would improve communication among researchers.

The mechanism of pathogenesis is not fully understood. Research in this area would aid disease control and possibly open avenues for the use of nonharmful XLB or other agents in biocontrol programs.

For a better understanding of vector-pathogen-host relationships, we need to determine why vectors can easily transmit XLB from infected plants and mechanically injected culture-grown bacteria can cause disease in healthy plants but vectors feeding on cultures cannot transmit the bacteria. We also need to determine why plum leaf scald, but not phony peach disease, is a serious problem in several South American countries, and why phony peach disease and plum leaf scald are not seen in California despite the presence of both host and vectors. Why has Pierce's disease of grapevines been restricted to North and Central America, while other grape pathogens are distributed worldwide? The role of environmental factors in these phenomena and in the epidemiology of diseases caused by XLB needs to be elucidated.

Such serologic tests as ELISA with polyclonal antibodies have been of great help in detecting, characterizing, and identifying symptomless host plants and vectors of XLB. Development of monoclonal antibodies may enable researchers to define the exact serologic relationships of XLB, and use of DNA probes and dot-blot hybridization tests may further enhance the sensitivity of XLB detection.

In recent years, great progress has been made in developing media and techniques for isolating XLB from plants and insects and for demonstrating pathogenicity. Currently, the nutritional requirements of XLB need to be understood. Studies in this area may aid the development of media for other bacteria residing in the phloem and causing such diseases as citrus greening and clover club leaf.

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Strategies Against Grapevine Fanleaf Virus and Its Nematode Vector

Soil fumigation for nematode control was first developed to protect high-value annual and biennial crops, such as beans, carrots, cotton, and pineapple. Fumigants were placed at a depth of 15–30 cm by chisels set 30 cm apart. The treatments worked well for short-lived crops, but the shallow placement did not give adequate control for disease of long-term perennials, such as grapes.

A new strategy, in which fumigants were placed at a depth of 75–90 cm at 90-cm intervals, was developed against the degeneration of grapes caused by grapevine fanleaf virus (GFV) and *Xiphinema index*. This disease complex is devastating to new vines planted in soils from which affected vines have been removed. Deep placement and high dosage rates have given economically successful control of this complex (8) and have also been used extensively against root-knot nematode and other associated nematode species.

Grapevine Fanleaf Virus and *Xiphinema Index* Complex

Infectious degeneration. The disease caused by GFV is of paramount importance as a threat to the production of grapes, and infectious degeneration was the first generally recognized name applied to it. The causal agent is a nepovirus (*ne*matode-transmitted, *p*olyhedral-shaped) related to arabis mosaic virus. In Europe, it has been recognized as a soilborne disease for approximately 100 years, the first report being that of Rathay in 1883 (14). Various names have been applied to the disease, including court noué, arriciamento, urticado, and Reisigkrankheit. In California it is known as fanleaf, yellow mosaic, and veinbanding, names derived from symptom patterns in the leaves of affected vines.

Infectious degeneration was first reported in California in 1950 by Hewitt, who also determined it was soilborne (5). The vector was discovered to be the dagger nematode, *Xiphinema index* (6), and GFV was isolated and purified shortly after that (4). The virus along with its vector undoubtedly was introduced to this country through infected cuttings or rootings. There is no evidence to indicate the virus is native to California or the United States, but both virus and vector are found in old vineyards in the eastern Mediterranean area.

Symptoms and pathology. Infectious degeneration produces a variety of symptoms expressed in the foliage. The name *fanleaf* is derived from the sharply toothed leaf margin, mottling, closeness of primary veins (as in a partly closed fan), and open petiolar sinus (Fig. 1). Other symptom types include *yellow mosaic*, with leaves partially or completely a deep chrome-yellow (Fig. 2), and *veinbanding*, with light-green to chrome-yellow chlorotic bands along the veins (Fig. 3). Often, the only leaf symptoms are obscure speckles or small yellow spots (Fig. 3). The malformations on canes include short internodes, double nodes, fasciations, and zigzag growth between nodes (Fig. 4). Perhaps the most striking symptoms are in fruit—poor set, loose clusters, and excessive "shot berries" (small seedless berries that may not mature) (Fig. 5). The effect on fruiting lowers yields and can result in total loss of production.

The Nematode Vector

X. index was first collected and described in California in 1950 from fig trees showing leaf drop and poor growth in Madera County. First reported as a pathogen of grapevines in 1954, it was

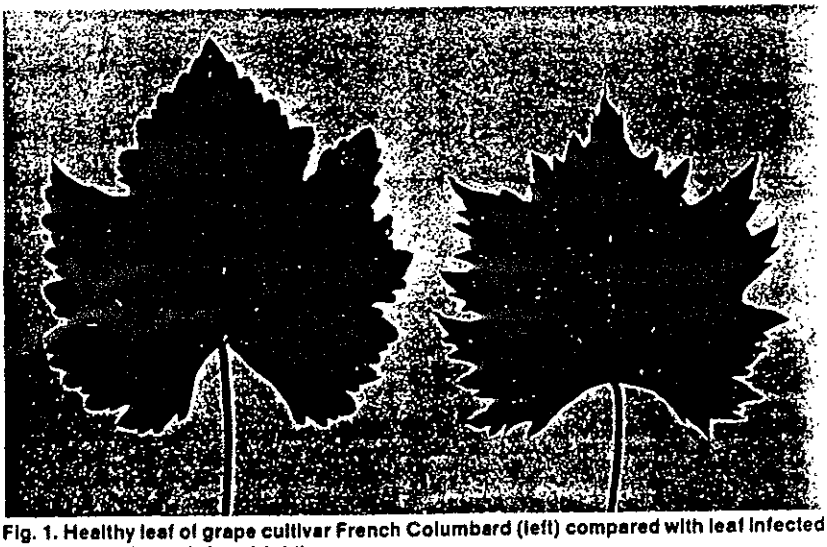

Fig. 1. Healthy leaf of grape cultivar French Columbard (left) compared with leaf infected by grapevine fanleaf virus (right).

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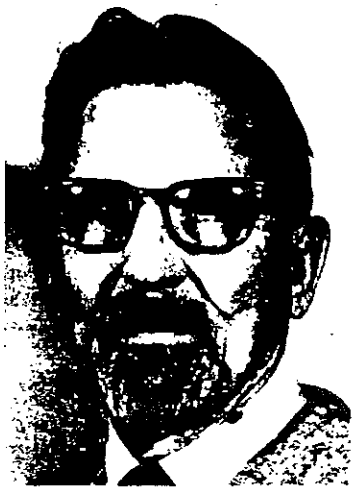

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Dr. Raski received his Ph.D. degree from the University of California at Berkeley in 1948 in entomology, majoring in nematology. He joined the faculty there the same year, then transferred to the University of California Davis campus in 1953. His major research interests ever since have been concerned with nematode problems in vineyards. At present he is cooperating with the coauthors in a multidisciplinary project evaluating germ plasm sources for tolerance to the nematode-virus-phylloxera complex.

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C. P. Meredith

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soon after (6) proved the vector of fanleaf. Just as with GFV, *X. index* almost certainly was introduced into California, because no evidence exists to suggest it is native there.

Life history. *X. index* has four larval stages. Males are rare, and females reproduce parthenogenetically. The first stage develops to an elongate form, then emerges from the egg and almost immediately sheds its cuticle, a molting process leading to the second stage. This happens three more times, resulting in the third and fourth stages, then the adult female. At every molt the entire cuticular covering is cast off, including the lining of the esophagus. This is important because infectivity is also lost at molting. The virus particles are located in the lumen of the esophagus and are shed along with the cuticular lining. To become infective again, the nematode must feed on roots of infected grape.

Life cycle from egg to egg is quite short, as little as 15 days, so the reproductive rate is high. Although susceptible to drying or excessive heat, the nematodes are protected in the soil and survive for months as infective vectors in the absence of host roots. They are obligate plant parasites, however, and have few or no suitable hosts other than grape in vineyard plantings.

Symptoms and pathology. *X. index* feeds entirely externally on the tips of grape roots, causing curvature or bending with swelling (slightly reminiscent of phylloxera damage) and often accompanied by necrosis appearing as irregular dark-brown to black patches (Fig. 6). Root tips may be totally blighted and produce no further growth. Excess production of lateral feeders, which in turn are killed, may result in a matted effect. General dearth of feeder roots leads ultimately to poor vine vigor and productivity.

Epidemiology. Infectious degeneration may be spread through the use of infected planting stock, whether bench-grafted rootstocks, field-budded rootstocks, or own-rooted cuttings. If such plantings are free of the nematode vector, no further spread will occur and disease can be controlled simply by replanting with healthy plant materials.

Contaminated soil on rooted plants is by far the most efficient means of spreading the nematode vector. Nematode infection alone is serious because *X. index* is a dangerous pathogen capable of reducing vines to weakened, unproductive plants. Infection with both GFV and the vector is particularly distressing because of the inexorable, slow spread from infection foci in every direction. Absolute control is at present unattainable because total eradication of either the vector or the virus-infected root fragments is not possible. Reinfestations by both pathogens occur regardless of measures taken. Simple rotation is not effective either,

because infective nematodes and roots are known to survive in the soil for 5 years or longer after removal of infected vines.

Control Measures

Side-dressing treatment. Vineyards infested with *X. index* alone responded remarkably in the past to treatments with 1,2-dibromo-3-chloropropane (DBCP) (13), an especially effective chemical against ectoparasitic nematodes such as *Xiphinema* species. DBCP was also widely used in vineyards against root-knot nematode and other species. DBCP was withdrawn in 1976 and no alternative was available until 1981, when two chemicals became available on a limited basis (12). Fenamiphos (Nemacur) and carbofuran (Furadan) are nonfumigant, systemic-type treatments that show promise as side-dressing treatments of dagger and other nematodes in vineyards. Both are sold and applied in California under Emergency Exemption Permits issued under Environmental Protection Agency Section 18.

Vineyards with infectious degeneration, with or without the nematode vector, will not respond to chemical treatments. The only control measure to consider is replanting.

Replanting. If GFV is present alone, replanting with healthy stocks is a totally effective means of permanently eradicating the disease. Presence of both vector and GFV requires replanting after preplant soil fumigation. High-dosage, deep-placement fumigation is recommended after at least 1 year of fallow rotation, preferably more. Soil preparation also must include deep-ripping in at least two directions perpendicular to each other. This is normal soil preparation for all new plantings but is even more essential for fumigation because the equipment cannot deliver precision applications in unbroken soil. Removal of old root systems as completely as possible also is important, especially where root-knot nematode is the principal problem.

Two chemicals are currently in use for preplant soil treatments: methyl bromide (MBr) and 1,3-dichloropropene (1,3-D). Deep-placement testing started about 1968–1969 and was a significant departure from the conventional fumigation practices in general use. Deep-placement necessitated wider spacing and higher dosages to achieve control through a greater total soil profile in order to protect perennial plants longer.

The 1,3-D dosage is 2,336 L/ha for D-D and 1,400 L/ha for Telone II; both should be applied 75–90 cm deep with 90-cm spacing (Fig. 7A). Roller-packing with a ring roller should follow as soon as possible, and planting should be delayed 5–6 months after treatment.

MBr is a highly volatile fumigant for which a continuous cover of 1-mil polyethylene sheeting is required (Fig. 7B). The dosage is 448 kg/ha applied by chisels 50–75 cm deep with 1.65-m spacing. For control of root-knot nematodes, 560 kg/ha without a cover is now possible, and experimental tests are under way to determine the feasibility and efficacy of the same treatment for *X. index*/GFV control. Fumigation without a cover should be followed immediately with roller-packing with a ring roller to seal the chisel marks.

It has been established that 2.5–2.7 ppm of 1,3-D for 3 days (1) or 500–650 µl of MBr per liter air for 3 days (2) is required for 100% kill of *X. index* and *Meloidogyne incognita* (root-knot). The distribution of MBr from the point of field injection was followed by gas chromatographic analyses. The material first surged upward through the broken soil to the surface, then stabilized; by the third day after treatment, the gas followed gravity to depths of 2.5 m or more, even into the unbroken lower soil layers. Dosages well in excess of the requirements were found at all levels for MBr, but dosages of 1,3-D were less than 2.5–2.7 ppm at levels below 61 cm. Nevertheless, the excellent control attained by 1,3-D suggests that longer exposures (up to 21 days) at lesser concentrations are sufficient to kill the nematodes.

Cost of treatment varies according to

acreage treated, ie, the greater the acreage, the lower the cost. Estimates for treating 40 acres, including tax and cost of application, are: 1) D-D at 2,336 L/ha or Telone II at 1,400 L/ha = $3,519/ha ($1,425/acre); 2) MBr at 448 kg/ha with plastic cover = $2,150/ha ($870/acre), plus $50–62/ha ($20–25/acre) for removing the cover; and 3) MBr at 560 kg/ha without plastic cover = $1,395/ha ($565/acre).

When conditions are optimum, control assessment by normal soil sampling procedures shows no recurrence of nematodes for 4–5 years. Then, isolated foci of nematodes and scattered symptoms of infectious degeneration begin to appear. Surveys of vineyards in the Napa Valley–Gilroy areas replanted in *X. index*/GFV-infested soils after commercial treatments with 1,3-D or MBr have shown a gradual buildup of nematodes and affected vines (8). Because only 3–5% of the vines show disease symptoms after 10 years' growth, however, the treatment is considered economically successful. A replacement or alternative to DBCP is urgently needed to deter buildup of nematodes after preplant fumigation and to mitigate damage resulting from nematode feeding.

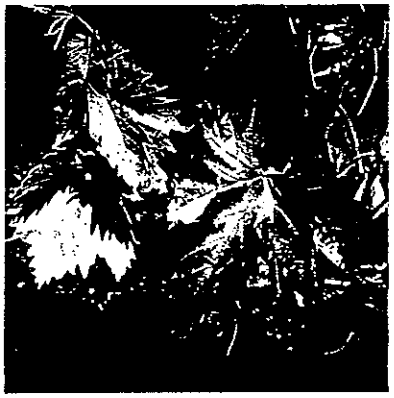

Fig. 2. Yellow mosaic symptoms of infectious degeneration on leaves of grape cultivar Thompson Seedless.

Neither 1,3-D nor MBr will disperse through highly organic soils or through clay layers in soil. Moisture also limits penetration of the fumigants when it reaches the saturation point or becomes standing water.

Another precaution concerns use of MBr in soils low in zinc or phosphorus. Fumigation has resulted in severe stunting of new plants in such soils. Experimental results (J. A. Menge, D. J. Raski, L. A. Lider et al, *unpublished*) suggest that elimination of mycorrhizal fungi may be an important factor in this deleterious effect. Growers planning soil fumigation should check target soils for mineral analyses and avoid MBr in areas of low zinc or phosphorus until exact causes are determined and means of avoiding this stunting are definitely established. Commercially available mycorrhizal fungi for inoculating nursery rootings intended for such soils may be a valuable help, but knowledge in this area needs development.

Tolerant rootstocks. Rootstocks selected from American *Vitis* species were introduced in France over 100 years ago to combat ravages of phylloxera, a root aphid. These were successful, and *V. vinifera* vineyards of France and the rest of the world were saved. Early rootstock testing was carried out empirically over long evaluation periods with little regard for soil problems other than phylloxera. The pure American rootstocks, such as Rupestris St. George, are very sensitive to GFV. Recent work shows that some rootstocks may be useful for controlling nematodes (9), specifically *X. index* (7).

The value of rootstocks for use against the *X. index*/GFV complex is beginning to receive attention. Certain rootstocks and selections appear tolerant to GFV (F. Jimenez, *unpublished*) and to feeding by the nematode vector (3). Tolerance to GFV appears to come from *V. vinifera* selections of western and central Asia where the disease probably originated. Tolerance to a disease resembling infectious degeneration was reported from *V. vinifera* grapes (Malvasia bianca, Somarello, and Pagadebito) in Italy over 40 years ago (11). Tolerance to GFV transmission by *X. index* appears to be present in muscadine grapes and actually may be tolerance to the nematode vector itself (3).

The prospect for combining germ plasm of different grape species to achieve a genetic solution to the *X. index*/GFV problem is promising. A rootstock with tolerance to *X. index* alone will not protect the vine from GFV because only a very brief feeding period is sufficient to transmit the virus. Tolerance to GFV alone is insufficient because the nematode can greatly weaken the vine even in the absence of the virus. Because most *X. index*/GFV sites are also plagued with phylloxera, the virus and nematode tolerance ideally should be supplemented with a high level of tolerance to the insect. By combining, in a carefully conceived breeding program, it should be possible to produce a superior rootstock with horizontal, multigenic resistance for use in affected areas. It is on the basis of such a premise that a breeding program is currently under way at Davis.

Cultural practices. Special care is needed for new vines growing in fumigated soils. Usually the plants grow

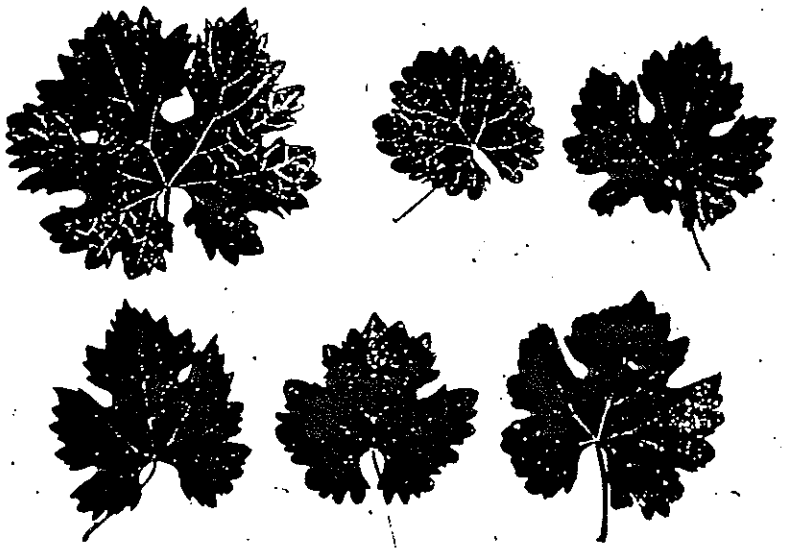

Fig. 3. Symptoms of infectious degeneration on leaves of grape cultivar Cabernet Sauvignon include veinbanding (top row) and obscure speckles or small yellow spots (bottom row).

Fig. 4. Healthy cane of grape cultivar Cabernet Sauvignon (left) compared with canes with infectious degeneration symptoms (center and right).

with remarkable vigor compared to untreated checks (Fig. 8). These vigorous plants must be managed to avoid overcropping, especially when the vines are young. Excessive fruit production is a common stress factor on young vines. Adequate water is critical, especially in the Central Valley and on light, sandy soils. Timely insect and fungus disease control is important on young plants to help establish the strongest vine structure possible before reinfestation with nematodes occurs.

Summary

Grapevine fanleaf virus and its nematode vector can be expected to pose an increasing threat to the grape industry. The known distribution of infectious degeneration is increasing, with new records of infection being added every year. Replanted vines in untreated infested soils cannot grow to maturity or sustain productivity. Soil fumigation is the only effective control measure now available. Many vineyards have succeeded after being replanted in soils infested with *X. index* and fanleaf virus that have been treated with nematicidal fumigants, but this method is very costly and not without risk.

A few reports have been made of new plantings that show infectious degeneration symptoms after only 2–3 years' growth and accompanied by high populations of nematodes. Soil preparation, moisture content, and details of the actual conditions of application are not always known. But it is quite clear that the requirements for fumigation must be followed as carefully and exactly as possible to achieve maximum control.

With careful management, strong, thrifty vines can be produced during the nematode-free years with a structure and productivity that can be sustained even after the nematodes begin to build up again. The replanting process can be scheduled every 15–20 years and still be successful economically.

The development of a hybrid rootstock with horizontal, multigenic resistance to GFV, *X. index*, and phylloxera is an exciting possibility and one that is being explored in the rootstock breeding program at Davis (10). Such a rootstock would be of inestimable value for controlling infectious degeneration and its nematode vector, a condition inadequately controlled by soil fumigation at the present time.

Fig. 5. Healthy fruit of grape cultivar Cabernet Sauvignon (left) compared with fruit with infectious degeneration symptoms (right).

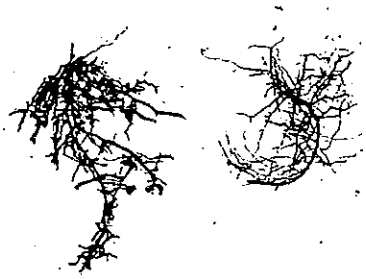

Fig. 6. Grape root damaged by *Xiphinema index* (left) compared with healthy root (right).

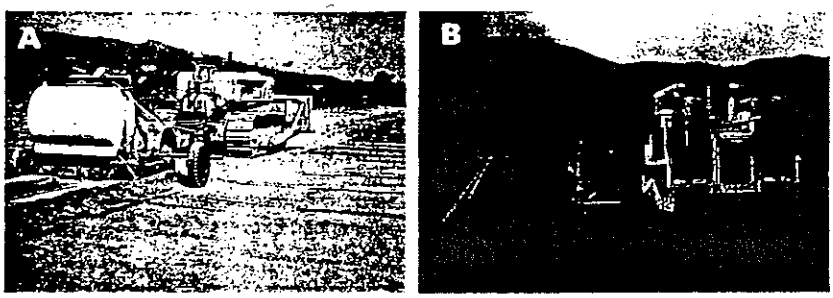

Fig. 7. Deep placement of (A) 1,3-D and (B) methyl bromide under polyethylene cover.

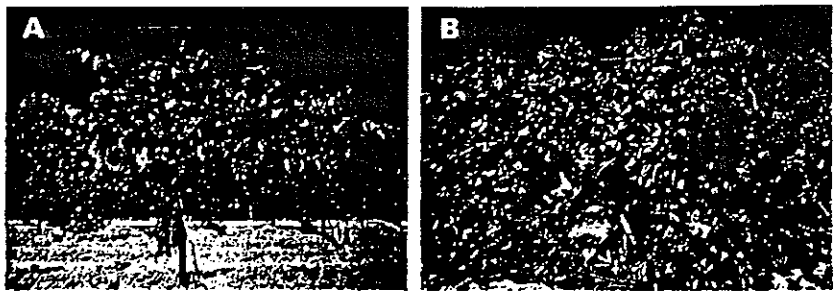

Fig. 8. Growth of grape cultivar Thompson Seedless replanted in (A) untreated soil infested with root-knot nematode and (B) nematode-infested soil treated with 1,3-D.

Acknowledgments

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