Relation of Soil Physical and Fertility Properties to the Occurrence of Cytospora Canker in French Prune Orchards

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ABSTRACT

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Twenty-six separate plots, located in commercial plantings of French prunes, were surveyed for soil properties and the occurrence of Cytospora canker. Trees with a high incidence of Cytospora canker were found associated with soils that were high in clay content and/or unable to supply adequate potassium. A regression equation developed from soil data and disease counts from 13 plots in a 20-year-old orchard accounted for 88% of the variation in disease occurrence. A similar equation developed from data from plots in 13 separate orchards of various ages accounted for 74% of the variation in disease occurrence.

Additional key words: Prunus domestica, predisposition, epidemiology.

In the summer of 1973, a general survey was undertaken in three prune (*Prunus domestica* L. 'French')-growing areas around Yuba City-Marysville, Red Bluff, and Porterville in the Sacramento and San Joaquin valleys of California. Some very striking differences were observed. Most orchards in the Porterville and Red Bluff areas showed little or no evidence of Cytospora canker (caused by *Cytospora leucostoma* Sacc.), whereas many of the orchards in the Yuba City-Marysville area were heavily infected. The soils in the Porterville and Red Bluff areas generally tend to be light textured, deep, and potassium-rich. Many of the soils in the Yuba City-Marysville area are heavy textured, shallow, and/or low in potassium. The syndrome known as "prune die-back" tends to be common in the Yuba City-Marysville area, but rare or absent in the other areas. Prune die-back is a disorder associated with heavy crops and potassium deficiency (6). When French prune trees set heavy crops, there is a greater demand for potassium. The potassium-rich soils of the Porterville and Red Bluff areas generally are able to meet this demand. Low-potassium soils often cannot meet this demand, and when crop load is high the leaf potassium often drops below the 1.0 - 1.3% level which is considered critical. This potassium deficiency can become very severe, causing leaf scorch, defoliation, and die-back. Orchards that commonly suffer from prune die-back also commonly suffer from Cytospora canker.

In order to determine if there was any relation between soil properties and the occurrence of Cytospora canker, intensive sampling and canker evaluation were done in 26 plots of 35 to 50 trees located in commercial plantings of French prunes.

MATERIALS AND METHODS

The Eckels' ranch, 5 miles west of Yuba City, provided an excellent location to begin this study. This orchard is a 20-year-old, 40-acre planting on nonuniform soil. Management practices do not vary within the orchard. Differences in tree size reflecting differences in vigor and incidence of Cytospora canker in various areas of the orchard are easily seen in the aerial view shown in Fig. 1. The smaller appearing trees tend to be nonvigorous and severely damaged by Cytospora canker. Thirteen of the 26 study plots were laid out in different areas of this orchard.

This study also included single plots in 13 separate French prune orchards of various ages and management regimes. These 13 orchards were located throughout the Northern California prune-growing regions.

The following parameters were considered in relation to the incidence of Cytospora canker: (i) percent sand, silt, and clay in the root zone; (ii) soil depth; (iii) soil potassium in the root zone; and (iv) leaf potassium level. Root-zone soil samples were taken 30 to 76 cm below the soil surface, around six to ten trees in the center of each plot.

The percent clay in soil was determined by mixing 50 g of air-dry soil with 100 ml of dispersing solution. This mixture was shaken vigorously for 36 hours on a rotary shaker. The dispersing solution served to dissociate the soil aggregates into their smallest individual components. It was prepared by dissolving 40.9 g of sodium hexametaphosphate and 9.1 g of sodium carbonate in 1,000 ml of water. At the end of 36 hours, the soil suspension was rinsed completely into a large cylinder, brought to a total volume of 1,000 ml, and mixed thoroughly. A blank was prepared by mixing 100 ml of the dispersing solution in 900 ml of water in a second

cylinder. The cylinders were allowed to stand undisturbed for 6 hours at room temperature (20 C ± 3 C). At this time all particles larger than 2 μm in diameter had settled out leaving only the clay particles in suspension. Hydrometer readings were taken at this time on the soil suspensions and blanks. The clay content of the soil then was calculated according to Day (5). The percent sand was determined by dispersing 10 g of air-dry soil in 20 ml of solution for 36 hours on a rotary shaker. The sands then were separated by wet- and dry-sieving as described by Day (5). Corrections for moisture in the air-dry soil were made. Ten grams of air-dry soil were oven-dried at 105 C for 7 days and reweighed. The weight loss from 10 g was used to correct the values obtained for percent clay and sand in air-dry soil to an oven-dry soil basis. The percent silt in the soil was taken as the difference between 100% and the sum of the percent sand and clay.

Soil depth, the distance between the soil surface and the first impenetrable layer below the surface, was measured with a stainless steel probe 138.8 cm long. The measurements were taken in the winter of 1973-74, when the soil was wet, by pushing the probe into the ground until an impenetrable layer or "hard-pan" was struck. Soil depth was then calculated by subtracting from 138.8 cm the length of the probe that still protruded. Twelve to 50 readings per plot were taken depending upon variation. In taking these measurements, two assumptions were made: (i) any soil deeper than 138.8 cm would exert no shallow-soil effects; (ii) a layer impenetrable to the probe within this depth would act as a hard-pan to limit root growth and inhibit soil drainage. In soil high in clay content, it was sometimes difficult to tell if a hard-pan had been encountered or if the dense, wet clay was preventing the probe from entering the soil any further.

Composite leaf samples were taken from 10 trees in the same area of each plot from which soil samples were taken. Each leaf sample consisted of 100 fully developed spur leaves (10 per tree) taken at shoulder height around the periphery of the tree. Leaf samples from the 13 plots in the Eckels' orchard were prepared for analysis by a method developed by R. M. Carlson (*unpublished*) involving rapid liquid digestion in concentrated nitric acid. Leaf samples from the other plots were prepared for analysis by a dry ash method (Department of Pomology, University of California, Davis; *unpublished*). Soil potassium was extracted with boiling nitric acid (7). All potassium analyses were done by flame photometry.

The severity of Cytospora canker in an orchard was estimated by counting the number of separate fruiting cankers on a tree and giving each a weighted value based on its location within the tree. Cankers on small branches had a value of 1, those on large branches a value of 3, and

Fig. 1. An aerial view taken in June 1973 of a portion of the 20-year-old French prune orchard on the Eckels' ranch near Yuba City, California, showing the great variation in incidence of Cytospora canker, as reflected by tree size, in different areas of the orchard.

cankers on the major scaffolds a value of 9. The sum of the weighted canker values for all trees evaluated divided by the number of trees gives the average amount of canker per tree. The amount of Cytospora canker in a susceptible orchard tends to increase year after year because of canker enlargement and new infection. Dividing the canker counts by an age factor minimizes the effect of age on the disease index. Six years was subtracted from the age of the orchard, because Cytospora canker generally is not a problem in California until the trees begin to bear crops, which is generally after about 6 years' growth. Dividing by this age factor only results in an approximation, since it assumes an equal yearly increase in the amount of disease, which is probably not the case. Disease counts were made on dormant trees so that cankers could be seen more easily. The disease index (D.I.) was calculated by the following formula:

$$\text{D.I.} = \frac{\text{Average amount of canker per tree}}{\text{Orchard age} - 6} \times 100$$

RESULTS AND DISCUSSION

The soil-plant data and disease indices for the 13 plots in the Eckels' orchard are presented in Table 1. A regression analysis was performed on the data. The coefficient of determination ($R^2 = 0.8824$) indicated that a regression equation ($P = 0.01$) derived from the data accounted for 88% of the variation in D.I. Only soil clay content and leaf potassium levels made a significant contribution to the model.

TABLE 1. Soil-plant data and disease indices for French prune plots in the Eckels' orchard near Yuba City, California

Plot	Soil depth[a] (cm)	Clay in root zone[b] (%)	Leaf K (%)	Observed disease index	Predicted disease index[c]
A	118.2	53.4	1.08	80	80.4
B	88.8	42.4	1.30	30	44.0
C	110.2	51.5	1.01	90	77.8
D	113.8	47.4	0.55	96	82.3
E	111.2	37.4	1.74	21	16.0
F	90.0	28.0	1.60	8	−4.1
G	97.5	50.0	0.81	80	80.5
H	81.0	36.0	1.33	17	26.1
I	91.2	40.0	1.34	17	36.3
J	80.0	28.0	1.40	13	2.6
K	66.8	36.0	0.79	39	44.1
L	54.2	33.0	0.76	26	37.2
M	97.8	32.0	1.14	28	21.8

[a]Soil depth is the distance down from the soil surface to the first impenetrable layer encountered with a steel probe.
[b]The root zone is taken as that zone 30 to 76 cm below the soil surface.
[c]Prediction of disease index based on a regression equation developed from percent soil clay and leaf potassium content:

$$\text{D.I.} = -24.66 - 33.45\ (\text{leaf K}) + 2.64\ (\%\ \text{clay})$$

TABLE 2. Soil-plant data and disease indices for 13 French prune orchards in northern California

Plot	Soil depth[a] (cm)	Clay in root zone[b] (%)	Leaf K (%)	Observed disease index	Predicted disease index[c]
Matthews West	135.2	29.8	3.83	0	8.8
Reynolds South	124.0	24.8	2.75	25	10.6
Masera	138.8	29.8	1.38	22	23.4
La Mantia	83.0	34.8	0.83	46	31.4
Barbaccia	104.2	45.4	0.47	38	43.5
Winfrey	79.0	33.4	0.70	28	30.8
Ruzich	138.8	16.2	1.99	8	7.0
Libby	138.8	12.4	1.24	6	8.0
Hall North	138.8	12.9	2.28	1	2.2
Hall East	138.8	16.8	2.44	2	4.9
Lindaur	138.8	17.4	2.87	9	2.9
Pacific	138.8	21.4	1.72	1	13.5
Butler	138.8	16.0	2.66	4	2.9

[a]Soil depth is the distance down from the soil surface to the first impenetrable layer encountered with a steel probe. Values of 138.8 cm indicate no impenetrable layers were encountered.
[b]The root zone is taken as that zone 30 to 76 cm below the soil surface.
[c]Prediction of disease index based on a regression equation developed from percent soil clay and leaf potassium content:

$$\text{D.I.} = 3.77 - 5.97\ (\text{leaf K}) + 0.94\ (\%\ \text{clay})$$

TABLE 3. Simple correlations[a] between disease index and various plant-soil properties in the 13 plots in the Eckels' orchard and the 13 other French prune orchards in northern California

	Eckels' orchard plots	Other orchard plots
Soil depth (cm)[b]	0.5775*	−0.8377**
Clay content in the root zone (%)[c]	0.8805**	0.7924**
Leaf potassium (%)	−0.6870**	−0.6753*

[a]Asterisks indicate significant correlation: **, $P = 0.01$; *, $P = 0.05$.

[b]Soil depth is the distance down from the soil surface to the first impenetrable layer encountered with a steel probe.

[c]The root zone is taken as that zone 30 to 76 cm below the soil surface.

The soil-plant data and disease indices for the plots in the 13 separate French prune orchards are presented in Table 2. Subjecting these data to regression analysis resulted in an equation ($P = 0.01$) which accounted for 74% ($R^2 = 0.7397$) of the variability in D.I. In this diverse group of orchards, the soil clay content and leaf potassium levels were used to construct the best regression model.

The sand, silt, and potassium content of the soils did not add significantly to either regression model. These two sets of data indicate that the incidence of Cytospora canker in French prunes is related to soil factors. Soil clay content, which has been believed linked with Cytospora canker (1), is of special importance. It is very difficult to estimate the long range effect of differences in management practices on the occurrence of Cytospora canker. In orchards growing on similar soils, differences in irrigation, tillage, pruning, and fertilization practices probably all have an effect. These differences could partially explain the lower R^2 value (0.7397) for the 13 separate orchards compared to a higher R^2 value (0.8824) for the 13 plots in the same orchard.

Simple correlations between D.I. and soil clay content, leaf potassium, and soil depth are presented in Table 3. The data on soil depth are inconclusive. In the Eckels' orchard, soil depth was positively correlated with D.I. ($R = 0.578$) indicating that disease severity tended to increase as the distance between soil surface and "hard-pan" increased. The data in Table 1 show the deep soils to be the higher clay soils. This correlation between soil depth and D.I. is misleading since generally it is believed that increasing soil depth should be correlated with increasing overall tree performance. The data from the 13 separate orchards (Table 2) show the more expected relation of soil depth and D.I. ($R = -0.838$). Shallow soils have been previously associated with Cytospora canker in peach (9). Owing to the inconsistent relation between soil depth and D.I. in this study, the models chosen for use are based only on soil clay content and leaf potassium levels.

High-clay soils are poorly drained, poorly aerated, and may have reduced availability of potassium (8). Poor drainage also occurs in shallow soils. Poor water drainage reduces the aeration of soil, and the resultant oxygen starvation impairs root growth and active uptake of nutrients. These effects may be most critical when winter ends and spring growth begins. Any interference with nutrient uptake or any clay soil fixation of potassium also could have an effect on the incidence as well as the severity of prune die-back. The rate and distance that water moves through a soil decreases with increasing clay content (4). For a given amount of irrigation, more water will be trapped in the soil layers above the root zone as clay content of the soil increases. High clay content, therefore, could also be related to the occurrence of water deficits which have been shown to affect the development of Cytospora canker (3). All of the above interactions could affect tree vigor and incidence of Cytospora canker.

Generally, most stone fruits are not grown on heavy, poorly drained soils because they are susceptible to crown rot and root drowning. Prunes on plum rootstocks, however, are generally believed to be better suited to such soils. The data presented do not refute this idea, but they do show the relationship of adverse soil conditions to the occurrence of Cytospora canker. It has been shown that the development of Cytospora cankers is greater in nonvigorous trees (2). Thus, the occurrence of this disease as measured by the D.I. is also a measure of relative tree vigor or success in a given soil situation. Data of the kind presented here could be of value in site selection for French prune orchards.

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