# Peach Yellow Leaf Roll Epidemic in Northern California: Effects of Peach Cultivar, Tree Age, and Proximity to Pear Orchards

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**ABSTRACT**

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An unprecedented epidemic of peach yellow leaf roll (PYLR) occurred in 1978 in commercial cling peach orchards in the "peach bowl" area of northern California. Disease incidence did not differ significantly among peach cultivars but was significantly lower in trees 4 yr old or younger than in older trees. PYLR incidence was highest in peach orchards adjacent to commercial pear orchards, and the incidence generally decreased with increasing distance from pears. There was no evidence of peach-to-peach spread of PYLR.

Additional key words: disease gradients, epidemiology, mycoplasmalike organisms, MLO, resistance, spiroplasma, X-disease

An epidemic of peach yellow leaf roll (PYLR) unprecedented in intensity is occurring in northern California's "peach bowl" of Sutter, Yuba and Butte counties. PYLR is caused by a strain of the peach X-disease agent, based on similarities in symptoms in peach (1,10), vector range (4,5), and partial cross protection (Nyland, *unpublished*).

PYLR originally was described in 1951 (10) from orchards a few kilometers northeast of Marysville, CA. Incidence of PYLR from 1951 to 1969 in the three-county peach bowl is shown in Fig. 1, which is based on data accumulated by the California Department of Food and Agriculture (CDFA) from annual surveys from 1950 until 1969 (Dan Rosenberg, CDFA, *personal communication*). This program attempted to identify and remove all peach trees with PYLR (11).

After its initial detection in Yuba County in 1950, the incidence of PYLR dropped precipitiously until 1954 and increased during this period in adjacent Sutter County. Aside from a slight increase of PYLR in Sutter County in 1955 and 1956, the incidence in subsequent years changed more or less synchronously in the three counties. Two other California counties with large acreages of cling peaches—San Joaquin and Stanislaus—were surveyed for PYLR during 1951-1969. San Joaquin County was not surveyed from 1954 until 1964, but the incidence of PYLR during this period was probably not more than a few trees per year. PYLR was first detected in both counties in 1965. The trend of annual changes in PYLR incidence in San Joaquin and Stanislaus counties followed that in Butte, Sutter, and Yuba counties except for 1967, when PYLR incidence dropped slightly in the three peach bowl counties but continued to rise steeply in San Joaquin and Stanislaus counties.

In 1978, several growers in Sutter, Yuba, and Butte counties noticed a sharp increase in the number of trees with PYLR symptoms. In midsummer of 1979, the number of trees with symptoms prompted the California Cling Peach Advisory Board to map all commercial cling peach orchards in the peach bowl and a representative sample of orchards in central California counties. We examined the information obtained by this comprehensive survey in order to assess spatial patterns of PYLR spread and the influence of peach cultivar on PYLR incidence.

## MATERIALS AND METHODS

From late July through August 1979, all commercial plantings of cling peaches in Butte, Sutter, and Yuba counties (15,026 acres) were surveyed for PYLR. Trees with PYLR symptoms (1,10) were tagged with red plastic tape and their locations recorded on a map of each orchard block. We defined a block as a contiguous planting of trees of the same age and cultivar. We recorded the following data on a computer card for each block: orchard and block identification number, cultivar, date of planting, number of trees with PYLR symptoms, and total number of trees. A computer-aided multivariate regression analysis of tree age, cultivar, and percent PYLR considered cultivar as a nominal variable (7).

## RESULTS AND DISCUSSION

**Overall incidence.** As of August 1979, PYLR was found in 32,593 trees, which

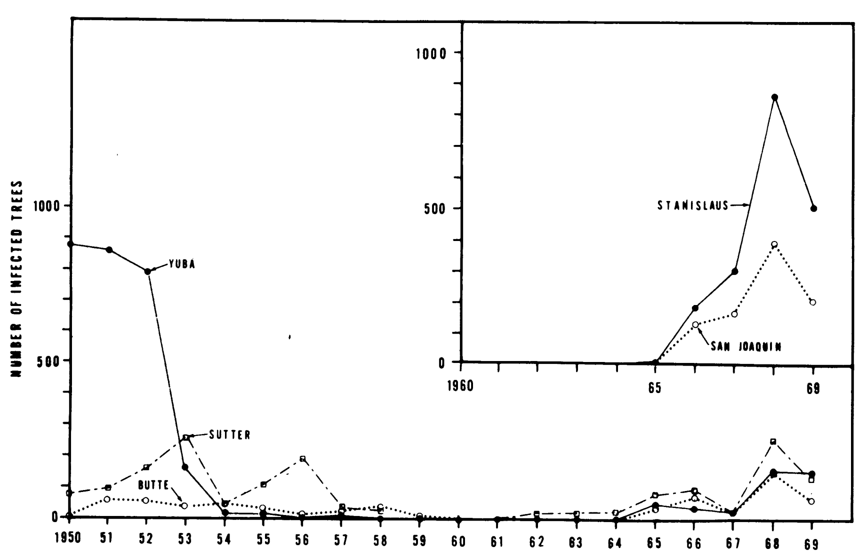


**Fig. 1.** Numbers of peach trees with peach yellow leaf roll (PYLR) in five California counties, 1950-1969. No PYLR noted in San Joaquin or Stanislaus counties 1950-1964, but no data available for San Joaquin County for 1954-1964. Source: California Department of Food and Agriculture.

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constituted an overall incidence of about 2.87% on 11,582 acres of bearing (≥4-yr-old) trees in the three counties. Mapping of selected orchards in October revealed approximately 10% more trees affected by PYLR than noted 2 mo previously. The overall incidence of PYLR in individual orchards ranged from 0 to 66%. The Green Valley strain (12) of the peach X-disease agent produced symptoms on 51 trees in 37 orchards.

**Effects of cultivar and tree age.** PYLR incidence did not differ significantly among cling peach cultivars, but few trees younger than 5 yr were diseased. Multivariate regression of tree age, cultivar and percent PYLR by orchard block revealed no significant differences due to cultivar or fruit maturity group (extra early—Carson, Dixon, Fortuna, Loadel, Shasta, Sweeny, Tufts, and Vivian; early—Andora, Andross, Bowen, Cortez, Johnson, Jungerman, Klampt, Palora, Peak, and 5A-3; late—Carolyn, Everts, Herrington, McKune, Monaco, Sims, Stanford, and Sullivan 2, 16-4, and 18A-2; extra late—Corona, Rand, Starn, Stuart, Sullivan 5, and Wiser). A higher degree of PYLR incidence that approached statistical significance ($P>0.05$) was noted for the cultivars Jungerman and Klampt.

A linear regression of PYLR incidence with tree age showed a small but highly significant age effect. The percent infection by block increased with age in all cultivar maturity groups. Although age effects were highly significant ($t$-test, $P<0.01$), they explained only 1.1% of the variation in the incidence of PYLR for

**Table 1.** Incidence of peach yellow leaf roll (PYLR) in cling peach trees in Butte, Sutter, and Yuba counties, August 1979

| Age (yr) | No. of trees (× 1,000) | No. of diseased trees/1,000 | | Fraction of blocks diseased[b] |
|---|---|---|---|---|
| | | All blocks[a] | Diseased blocks only | |
| 6 | 72.7 | 12.48 | 14.45 | 76/89 (86%) |
| 5 | 83.5 | 22.25 | 28.51 | 112/171 (65%) |
| 4 | 197.9 | 1.57 | 4.29 | 74/256 (29%) |
| 3 | 117.7 | 0.07 | 2.09 | 5/190 (3%) |
| 1,2 | 226.7 | 0.00 | 3.21 | 1/221 (0.5%) |

[a] A block is an even-age contiguous planting of one cultivar.

[b] Numerator is number of blocks with one or more trees with PYLR; denominator is total number of blocks of same age.

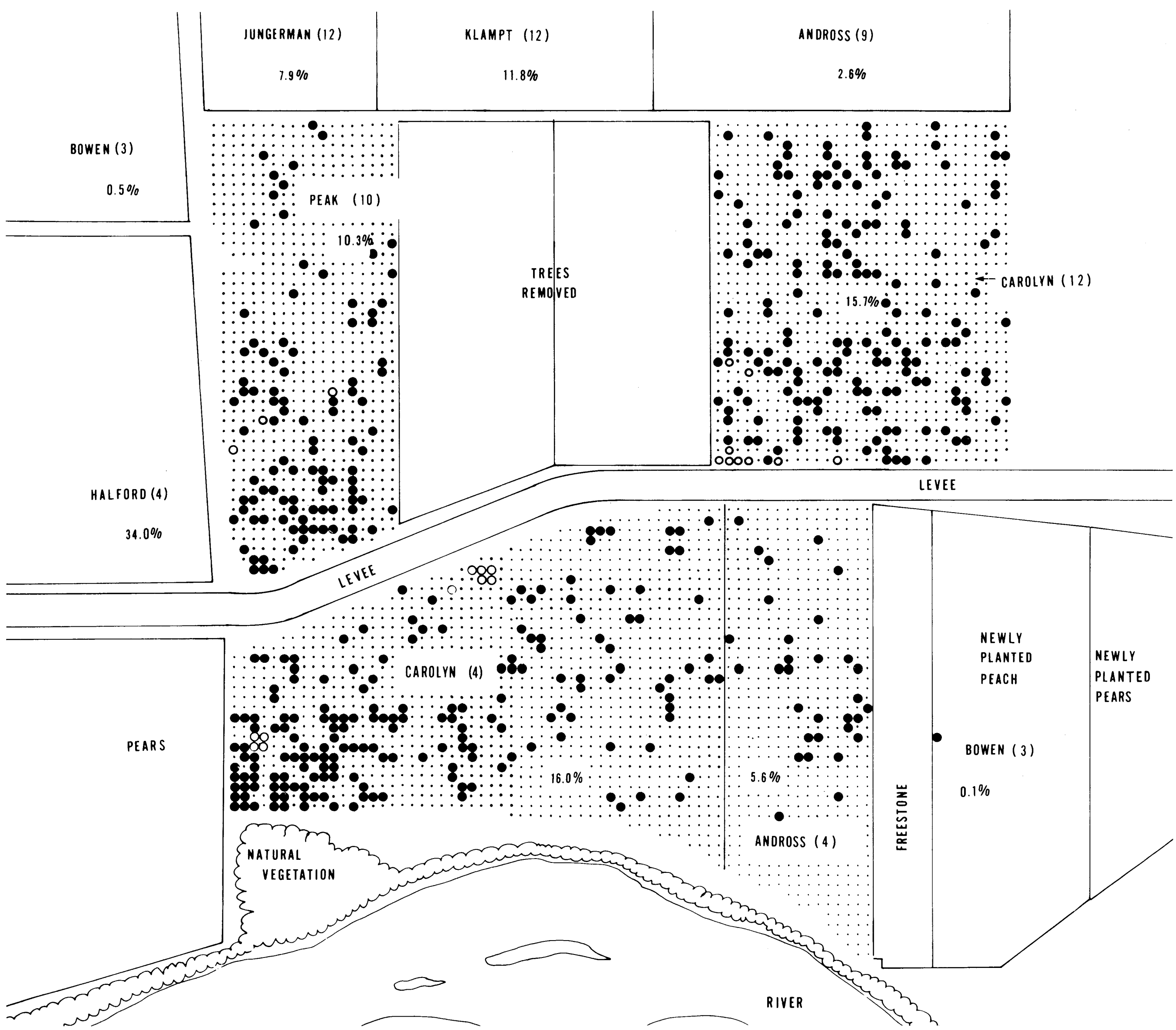


**Fig. 2.** Peach yellow leaf roll (PYLR) in peach orchards near a pear orchard in Yuba County, 1979. The cultivar, number of years since planting, and percent of trees with symptoms are labeled in each block. · = peach trees without PYLR symptoms, ● = trees with PYLR, o = recently removed trees.

late cultivars and 6.5% of that in extra late cultivars. For the early and extra early cultivar groups, $r^2$ was 4.7 and 3.4%, respectively. The maximum age effect for any cultivar group amounted to an average increase of only 0.16% per year.

More striking was the much lower incidence of PYLR in trees less than 5 yr old. As shown in Table 1, 3- and 4-yr-old trees had a much lower incidence than did 5- and 6-yr-old trees ($X^2 = 3208$, df = 1). If trees less than 5 yr old were excluded from the regression analysis, the age effect was not significant. PYLR was not detected in 1- or 2-yr-old trees as of August 1979. Possible explanations for the lower incidence of PYLR in young trees are that most spread occurred in 1976 or earlier or that the likelihood of infection is proportional to tree age or size. The incubation period reported for X-disease (2,3,9,15), including PYLR (4,5), does not exceed 2 yr.

**Relationship of PYLR to pear orchards.** Our analyses of survey maps of peach orchards indicated a consistent spatial relationship between PYLR spread and nearby pear orchards. All cling peach orchards with an incidence of PYLR greater than 5% were surveyed by light aircraft in September 1979. In all but one case where the location of the mapped orchard could be determined with certainty from aerial survey, commercial pear orchards were next to an affected peach orchard. Because many heavily diseased peach orchards were in river bottom areas near the Feather or Yuba rivers, we examined the hypothesis that the association of PYLR with pear was due to the colocation of Bartlett pears and PYLR-affected peach orchards in river bottom areas. However, close examination of the spatial distribution of PYLR in individual orchards showed that the association was with pear orchards per se rather than with riverbank or river bottom vegetation.

Figures 2 and 3 illustrate the relationship of PYLR spread to pear. The incidence of PYLR decreased in all directions from the pear orchard depicted in the lower left hand corner of Fig. 2. As previously noted, 3-yr-old peach trees were little affected. In fact, few of the PYLR-diseased 3-yr-old trees noted in Fig. 2 appeared until a second mapping of these orchards in September and October 1979, which suggests current season infection. In most older trees, symptoms of PYLR were clearly evident as early as July, indicating previous season or earlier infection.

In orchards several miles from a major river or river floodplain, the concentration of PYLR was greater near pear orchards and generally diminished with increasing distance from pear. Figure 3 depicts a typical example; the heaviest concentra-


**Fig. 3.** Peach yellow leaf roll (PYLR) in peach orchards near a Bartlett pear orchard in Yuba County, 1979. Note that the heaviest incidence of PYLR closely follows the irregular border of the pear orchard. Cultivar and tree age, eg, Starn (8), and percent of trees with PYLR are shown in each block of peaches. · = peach trees without PYLR, ● = trees with PYLR symptoms, o = recently removed trees.

tion of PYLR closely followed the irregular border of the adjacent pear orchard. The most heavily diseased orchard in the 1979 survey had an overall incidence of PYLR of 66%, and the heaviest concentration of PYLR was west of an adjacent pear orchard. The incidence of PYLR decreased toward the west with increasing distance from pear, even though a major river was less than 1 km to the west.

The decreasing incidence of PYLR with increasing distance from pear orchards is probably not due to random variation. Linear regressions of PYLR incidence (in five-row increments) against distance from adjacent pear orchards consistently yielded highly significant ($P < 0.001$) correlation coefficients for five orchard blocks. However, an identical analysis of PYLR incidence along a transect parallel to pear orchards in the same five blocks failed to reveal any significant ($P > 0.05$) correlation. Such disease gradients were not pronounced at distances greater than 50 tree spaces (307 m) from pear orchards.

Although the great majority of the orchards with more than 10% diseased trees were near pear orchards, a few peach orchards adjacent to mature pear orchards had very little PYLR. We listed all blocks in order of percentage incidence of PYLR and randomly selected 20 blocks with 6% or more trees with PYLR and an equal number of blocks with 1% or less PYLR. The average distance from the nearest pear orchard for heavily infected blocks was 250 m (range, 8–800 m), and for the blocks with 1% or less PYLR the average distance was 4,090 m (range, 800–9,650 m; *t*-test of independent means, $P < 1.1 \times 10^{-6}$, df = 38). The 51 peach trees with symptoms of the Green Valley strain of X-disease were widely scattered among 37 blocks, usually at the margins of peach orchards and with no apparent relationship to pear orchards.

The spatial pattern of PYLR incidence near pear orchards (Figs. 2 and 3) suggests primary spread by aerial vectors that are inoculative when they arrive in peach orchards, which is consistent with the relationship of X-disease spread in Connecticut (8,15,16), New York (1–3), Utah (14), and Michigan (6) from nearby chokecherries. There was no evidence of substantial peach-to-peach spread of the PYLR agent. At various intervals during the past 15 yr, isolated peach trees with PYLR have been noted with no subsequent spread of PYLR in the vicinity; this also has been the case for the Green Valley strain of peach X-disease (Nyland, *unpublished*). These observations are also consistent with observations and roguing experiments on X-disease in the eastern United States (2,13,15,16) but are contrary to previous theories (1,13) of PYLR spread in the western United States. Peach is reported to be a poor source plant for acquisition of the peach X-disease agent by leafhoppers (5,9,17).

The basis for the association of PYLR with pear orchards is not known. The most obvious possibilities are that pear trees or other pear orchard flora are major sources of inoculum, potential vectors, or both. Many, if not most, of the peach orchards with a high incidence of PYLR have been adjacent to pear orchards for at least 8 yr (in some cases much longer) but had little PYLR before 1978. The simultaneous rise and fall in PYLR incidence over separate areas in California (Fig. 1) suggests that a pervasive factor with year-to-year changes such as climate may trigger regional outbreaks of PYLR.

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