Effects of different rootstocks, and degree of psylla infestation on

LEAF CURL IN YOUNG PEAR TREES

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Differences in pear varieties, source of scion wood, and kind of rootstock had little effect on the incidence of leaf curl in these tests. Psylla are evidently the vectors of curl and there appears to be little hope of controlling the disease through selection of propagating material, unless psylla are excluded. If not infected in the nursery row, many pear trees may quickly become infected in the young orchard even under the best commercial spray program.

THE DISEASE NAMED CURL, or leaf curl, has become apparent throughout California's pear districts in a high percentage of young trees of the common varieties, although older trees also may show symptoms. Late in the season varying portions of the leaves of affected trees become undulated and curl downward with the leaf tip sometimes touching the ventral side of the midrib (see photo). The curled leaves may become thickened, and some change from green to reddish-purple. Affected leaves may drop two to three weeks earlier than normal leaves. Reduced yields have been noted on some trees with curl. Preliminary studies suggest that the disease can be transmitted through seed, bud, and scion wood used in propagation, and by pear psylla, *Psylla pyricola* Foerster. Curl seems to be associated with pear decline: some workers believe that it is caused by pear-decline virus or a related strain, while others have tentatively concluded that it is caused by a separate virus.

In these experiments most of the leaves showing curl symptoms were located on vigorous current-season shoot growth.

The trees used in this study were originally grown to determine their relative resistance to pear decline under different levels of psylla infestation. During 1961 and 1962 a randomized planting of Bartlett, Winter Nelis, and Hardy pear trees with different types of rootstocks was developed in old pear orchard soil at Davis. The rootstocks were Bartlett and Winter Nelis (*Pyrus communis* L.) seedlings, *P. calleryana* Decne. seedlings, own rooted Old Home (*P. communis*), and *P. serotina* Rehd. (*P. pyrifolia* Burm), and *P. ussuriensis* Maxim. seedlings. Seeds were collected from fruit resulting from open-pollination in the University orchards. The own-rooted Old Home trees were developed from hardwood cuttings taken from a number of trees. All of the Bartlett and Hardy bud and scion wood was taken from one vigorous, mature tree of each variety, while the Winter Nelis propagating wood came from a number of trees. Approximately one-fourth of the rootstock trees were allowed to develop without being topgrafted.

Most of the combinations were subjected to three treatments: (A) exposed control, (B) psylla-infestation, and (C) caged control. The trees under exposed control, treatment A, received good culture and the standard sprays for normal insect and mite control. They were subject to occasional visitation by adult psylla, but the sprays prevented any increase by breeding. The trees of treatment B were subjected to psylla infestation by confining adult psylla on from one to four scaffold branches by means of organdy sleeve cages. Most of the psylla were obtained from commercial orchards, where at least some of the trees were affected by pear decline. It was assumed, therefore, that the psylla were carrying pear-decline virus inoculum. From 50 to 100 psylla were placed in each sleeve and allowed to feed and multiply for varying periods. Most trees were subjected to three or four months of infestation during either the 1962 or 1963 growing season.

The psylla thrived within the cages and apparently multiplied until the foliage became limiting. The caged control trees of treatment C were completely protected from insect visitation with 4 × 8 ft Saran cloth cages from June or July 1962 until May 1964. Varying numbers of trees of each type were used for the different treatments. A total of 582 trees were included under exposed control, 162 under psylla infestation, and 52 under caged control. Tree survival, trunk and shoot growth were studied each year in relation to pear decline. During October 1965 all surviving trees were examined for symptoms of leaf curl. The trees were pulled early in 1966 to make way for campus expansion.

The data were statistically analyzed, but the tables are omitted in this report.

Survival

All three varieties with either Bartlett, Winter Nelis or *P. calleryana* seedling or own-rooted Old Home rootstocks showed high percentages of survival under all treatments and confirmed the decline-tolerance of trees with these stocks. For any one variety, there were no significant differences in the survival of trees with these rootstocks and the differences in survival between varieties were small. On the other hand, the pear decline loss of trees with either *P. serotina* or *P. ussuriensis* rootstocks, under the exposed-control (A) and psylla-infested (B) treatments, confirmed the susceptibility of *P. communis* varieties with these rootstocks. Enclosing trees with these decline-susceptible stocks with the psylla-tight cages (treatment C) protected them from decline—corroborating previous reports that the pear psylla is the pear-decline vector. Trees with *P. ussuriensis* stocks were more tolerant to psylla feeding and pear decline than those with *P. serotina* stocks, but neither of these species should be used as rootstocks for varieties of *P. communis* in commercial plantings.

The non-topgrafted Bartlett, Winter Nelis, and *P. calleryana* seedlings and the own-rooted Old Home trees showed high percentages of survival regardless of psylla infestation. Survival was not as high for the unworked *P. serotina* and *P. ussuriensis* seedlings. A few of the *P.*

serotina seedlings under exposed control apparently died of decline and their susceptibility was verified by increased mortality following psylla infestation—adding to evidence that trees without graft unions may succumb to decline.

Growth

Under exposed control (A), all three varieties on *P. calleryana* seedling rootstocks made significantly more trunk and shoot growth during the first two years than comparable trees with the other five rootstocks. For the remaining three years there were no significant differences between the trunk circumferences of these trees and those with either Winter Nelis or own-rooted Old Home stocks. Trees with Bartlett seedling stocks were consistently smaller in trunk circumference than those with Winter Nelis or Old Home stocks, but their annual increments of trunk growth compared favorably with them. Differences in shoot growth between trees with these stocks were small or inconsistent. Trees with *P. serotina* and *P. ussuriensis* rootstocks were smaller in trunk circumference and generally made less shoot growth than did trees with the decline-tolerant stocks.

The greater initial vigor of trees with *P. calleryana* rootstocks is suggested as an advantage for replants in old orchards. Under psylla infestation (B), shoot growth was reduced, but the year following the removal of the psylla, trees with any of the rootstocks except *P. serotina* seedlings made about as much or more growth than did comparable exposed-control trees. Trunk growth was definitely reduced in surviving trees with *P. serotina* stocks, but only slightly or not at all in those with the other types of rootstocks.

Caged-control (C) trees with the decline-tolerant rootstocks made about the same amount of growth while those with *P. serotina* or *P. ussuriensis* stocks made more trunk and shoot growth than comparable exposed controls. Part of the advantage in keeping the trees completely free of psylla visitation was offset by the heavy pruning required to keep them within the cages.

The rootstock trees allowed to grow without being topgrafted to commercial varieties grew more rapidly and attained greater size than did their topgrafted counterparts. The *P. calleryana* trees showed remarkable vigor. The own-rooted Old Home trees were significantly smaller in trunk circumference than were the *P. calleryana* trees, but significantly larger than the other types. Winter Nelis, Bartlett, *P. ussuriensis,* and *P. serotina* seedlings followed in order of mean size of trunk.

Bartlett

High percentages of all the Bartlett trees under exposed control showed leaf-curl symptoms in October 1965 (graph 1). Most of the individual trees with curl symptoms made relatively good growth in 1965 while most of those with no curl made poor growth. All Bartletts on Old Home under exposed control were vigorous, and all showed curl.

The Bartlett trees exposed to psylla infestation during 1962 and 1963 made poor shoot growth during 1963. However, after the psylla were removed, trees with any of the rootstocks except *P. serotina* seedlings made as much growth as the exposed controls. Trunk growth was definitely reduced in the surviving trees with *P. serotina* stocks, but only slightly or not at all in those with the other types of rootstocks. High percentages of all of these trees, except those with *P. serotina* stocks, showed curl symptoms, emphasizing relationship between vigor and curl.

For the Bartlett trees protected by the psylla-tight cages during 1962 and 1963, those with Bartlett seedling rootstocks were vigorous and showed curl symptoms in October, 1965 (graph 1). Sixty-seven per cent of the Bartletts with Old Home stocks were free of curl, however, and had made vigorous growth. This suggested that the cages gave some protection against curl, possibly by preventing or delaying its transmission by psylla feeding. On the other hand, the Bartletts with *P. serotina* or *P. ussuriensis* rootstocks that showed no curl (33% and 50%, respectively) made poor growth and may have simply lacked the vigorous growth necessary for symptoms to develop.

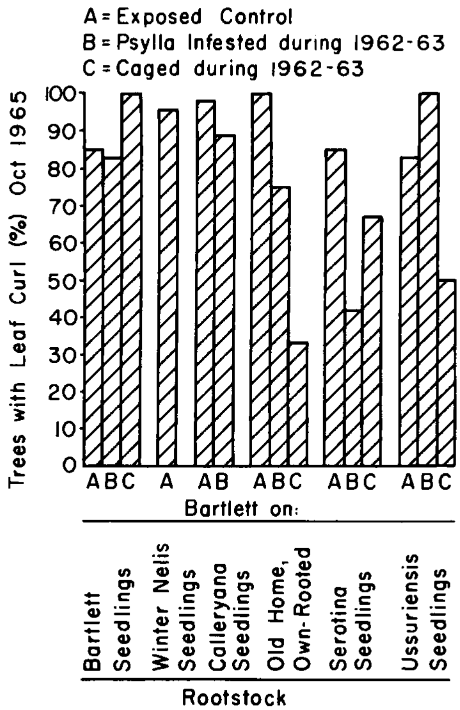
Winter Nelis

Under exposed control, Winter Nelis trees with any of the rootstocks except *P. serotina* and *P. ussuriensis* showed high percentages of curl (graph 2). The fact that the surviving trees with *P. serotina* and *P. ussuriensis* stocks were considerably smaller in trunk circumference and made less shoot growth during 1965 than the others again indicated a relationship between vigor and curl. A study of the individual trees, however, revealed that although most of the trees with curl were vigorous, a good portion of those showing no curl symptoms also made good growth.

Of the trees previously subjected to the psylla sleeves, all with either Bartlett seedling, *P. ussuriensis* seedling, or own-rooted Old Home stocks showed curl symptoms (graph 2). These trees had recovered from any stunting caused by the psylla feeding and had made good growth during 1965. The trees with *P. calleryana* stocks that were free of curl also made good growth, but most of those with *P. serotina* made poor growth.

Protecting the Winter Nelis trees from psylla visitation with cages during 1962 and 1963 did not prevent most of them from contracting curl, presumably after the cages were removed. It appears, however, that the cages gave some protection since 50% of the trees with Old Home or *P. ussuriensis* stocks and 25% of those with *P. serotina* stocks did not show curl (graph 2). Since these trees generally made good growth, their freedom from curl symptoms could not be explained on the basis of lack of shoot growth.

Old Home pear tree with severe symptoms of leaf curl after one growing season (photographed November 2, 1961).



Graph 1. Effect of rootstock and psylla infestation on the incidence of leaf curl in five-year-old Bartlett pear trees.

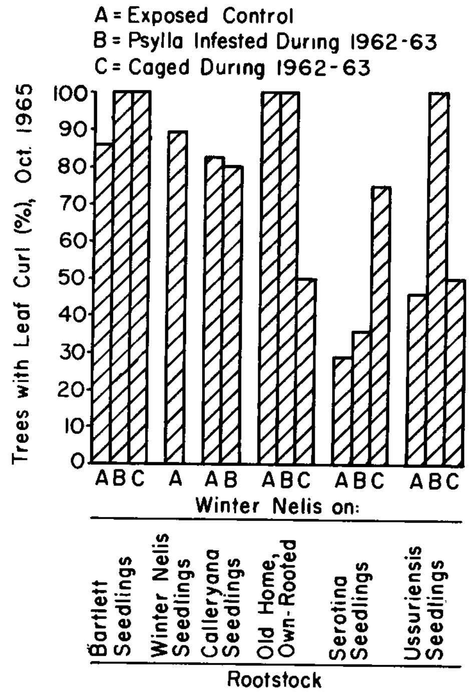
Although the majority of the vigorous Winter Nelis trees under the different treatments showed curl symptoms, the relationship between vigor and curl was less consistent than it was for the Bartlett trees.

Hardy

Under exposed control, most of the Hardy trees with Bartlett, Winter Nelis, or *P. calleryana* seedling rootstocks (100%, 91%, and 100%, respectively) showed curl symptoms, while those with *P. serotina* stocks showed significantly less (65%) curl (graph 3). Since the surviving trees with *P. serotina* stocks had significantly smaller trunk circumferences and made significantly less shoot growth in 1965 than those with the other stocks, the relationship between vigor and curl again was indicated. Only two vigorous trees were free of curl. These had Winter Nelis seedling stocks.

For trees previously exposed to psylla infestation, all of the Hardy trees with *P. calleryana* stocks showed curl and all were vigorous (graph 3). Trees with *P. serotina* that showed no curl symptoms made approximately one-third as much shoot growth as those showing curl.

The Hardy trees with *P. serotina* stocks that were caged during 1962 and 1963 showed curl symptoms and made good to fair growth in comparison with the exposed controls.



Graph 2. Effect of rootstock and psylla infestation on the incidence of leaf curl in five-year-old Winter Nelis pear trees.

Trees not topgrafted

Higher proportions of the unworked Bartlett seedlings, Winter Nelis seedlings, and own-rooted Old Home trees showed curl than of the unworked *P. calleryana*, *P. serotina*, and *P. ussuriensis* seedlings (graph 4). A comparison of the trunk circumference measurements made in 1965 showed that, with the exception of the *P. calleryana* seedlings, the trees with the largest trunk circumferences had the greatest percentages of curl.

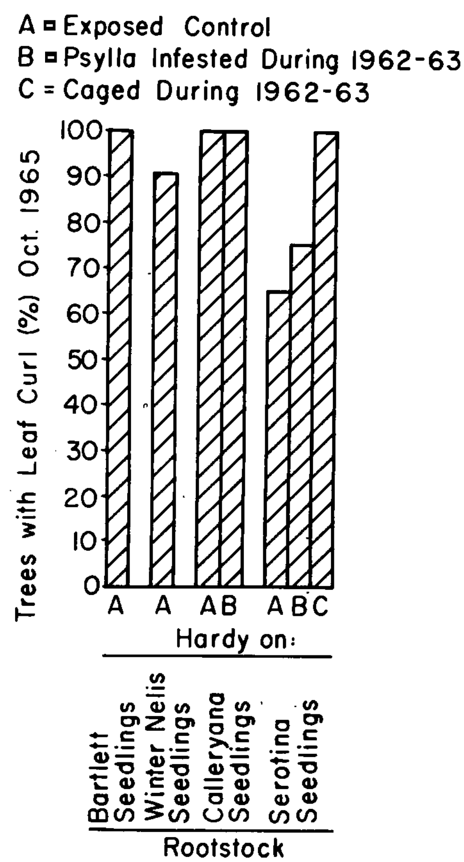
The proportion of these Bartlett seedlings under exposed control that showed curl symptoms (85%) was about the same as for trees consisting of Bartlett seedling rootstocks topgrafted with Bartlett (85%) or Winter Nelis (86%) (graphs 4, 1, and 2, respectively). This was surprising in view of the genetic variability of pear seedlings and the fact that the seed came from several trees. It seemed more likely that the high incidence of curl resulted from infection within the nursery or experimental plot rather than from a seed-borne virus. The few trees that were free of curl made vigorous growth during 1965 and, therefore, their lack of curl was not due to insufficient growth.

The percentage of unworked Winter Nelis seedlings with curl symptoms (75%) was somewhat lower than for trees consisting of Winter Nelis seedling rootstocks topgrafted with either Bartlett (96%), Winter Nelis (89%), or Hardy (91%). The Winter Nelis seedlings that were free of curl did not lack vigor.

None of the *P. calleryana* seedlings under exposed control showed curl symptoms and all showed great vigor (graph 4). It is interesting that this species, when topgrafted, evidently did not impart resistance to curl to the scion variety (graphs 1, 2, and 3). Since the leaves of these trees have wavy margins and other characteristics different from those of *P. communis*, it may be that curl expresses itself in *P. calleryana* in some undetected manner or that they are symptomless carriers of the disease.

All of the own-rooted Old Home trees under exposed control showed curl symptoms and all were vigorous. Since all of the Bartlett and Winter Nelis trees with own-rooted Old Home rootstocks also showed curl under exposed control, it would appear that the curl was transmitted from the Old Home stocks were it not for the high percentages of curl in these varieties with the seedling stocks.

The *P. serotina* and *P. ussuriensis* seedlings in this group showed lower percentages of curl than the Bartlett, Winter Nelis, and Hardy trees with these rootstocks. Their freedom from curl symp-

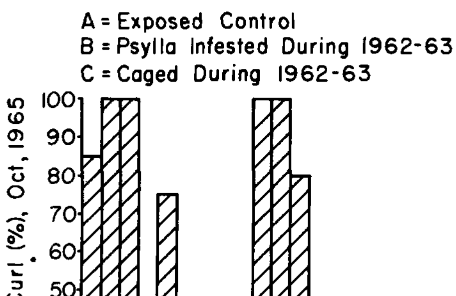


Graph 3. Effect of rootstock and psylla infestation on the incidence of leaf curl in five-year-old Hardy pear trees.

toms was not correlated with lack of vigor. The low incidence of curl for these seedlings could be due to more virus-free seed, greater resistance, or to psylla preference for *P. communis* leaves. The latter possibility seems unlikely since the psylla-infested *P. serotina* and *P. ussuriensis* seedlings did not develop curl even though they made vigorous growth. It seems most likely that curl simply does not manifest itself as readily in the oriental foliage.

All of the non-topgrafted trees subjected to psylla sleeves during 1962 and 1963 survived and most made good growth during 1964 and 1965. All of the Bartlett seedlings and the Old Home trees showed curl symptoms. This is not conclusive evdence that psylla were responsible for the curl, however, because the comparable trees under exposed control also showed high percentages of curl. None of the *P. calleryana*, *P. serotina* and *P. ussuriensis* seedlings showed curl following psylla infestation. This is interesting in view of the vigor of these trees and the high incidence of curl found in the commercial varieties with these types of rootstocks.

Protecting the trees from psylla visitation by caging during 1962 and 1963 did not protect the Bartlett seedlings from curl, but 20% of the Old Home trees were free of symptoms. Since all of the Old Home trees under exposed control and psylla infestation showed curl, it seems probable that the period of caging gave some protection against the disease.



Graph 4. Effect of psylla infestation on the incidence of leaf curl in five-year-old non-topgrafted pear rootstock trees.

Source of curl infection

High percentages of all of the Bartlett, Winter Nelis, and Hardy trees with any of the decline-tolerant rootstocks showed curl. Non-topgrafted Bartlett and Winter Nelis seedlings and own-rooted Old Home trees also showed high percentages of curl. Since all of the Bartlett and Hardy scion wood used in developing the experimental trees came from single trees of each variety, the parent trees would be logical suspects as sources of infection. However, the scion wood for the Winter Nelis trees and the cuttings used in developing the own-rooted Old Home trees, as well as the seed for the Bartlett and Winter Nelis seedlings, came from a number of trees. Unfortunately, none of the parent trees could be studied since they were pulled in 1964 to make way for campus expansion.

Rootstocks offered a second possible source of curl in commercial varieties. However, the uniformly high percentages of curl in vigorous trees with either seedling or clonally propagated rootstocks and the fact that caging gave some protection against curl tend to diminish the role of rootstocks as sources of curl.

Another possibility is that pear psylla infected the trees with curl while they were developing in the experimental plot. Data on curl symptoms were not recorded until 1965, but the photo of the young Old Home tree shows that curl was in the University orchard in 1961. Since the cages apparently gave some protection against curl, the psylla must have played an important role in transmitting the disease. More likely, a combination of all the factors was required for the high incidence of curl symptoms.

Additional evidence

Further evidence regarding curl transmission by pear psylla is shown in the two sets of photos of Bartlett trees. These trees were included in experiments conducted during 1963 to compare the effects in decline-susceptible pear trees of a possible psylla-transmitted decline virus (in virtual absence of psylla toxin) with the effects of prolonged psylla feeding in the absence of decline virus. Psylla, presumed to be free of pear-decline virus, were developed from adult psylla (imported from New York, where pear decline had not been reported)—by separating unhatched eggs from leaves of young greenhouse pear trees and hatching them in petri dishes. Populations were

Photos above show Bartlett pear trees with Pyrus serotina rootstocks photographed October 30, 1963 after having one and two branches exposed to high populations of psylla, apparently free of pear decline virus, for three months. Note leaf curl symptoms below the bags. Photos below of control trees show that they are free of curl symptoms (photographed October 30, 1963).

developed in the greenhouse on pear seedling foliage not previously fed on by psylla. A second group of psylla, presumably carrying pear-decline virus inoculum, were developed by caging psylla on the foliage of trees with pear decline and allowing them to reproduce.

During July, 1963, adult psylla from the different stocks were caged on young Bartlett pear trees with *P. serotina* rootstocks. One or two organdy cloth sleeve cages, each enclosing 75 to 100 adults, were placed on each tree. Seventy comparable trees were selected at this time to serve as psylla-free controls.

The psylla presumed to be carrying the pear-decline virus inoculum were caged on 42 trees and allowed to feed for periods of five to eight days, after which they and the eggs laid were killed. The short adult feeding periods left no discernible effects on any of the trees until September 11 when some started wilting and collapsing with pear decline. By October 30, 1963, 18 of the trees had collapsed, eight showed varying symptoms of decline, and 16 remained healthy.

The psylla presumed to be free of pear-decline virus were caged on 35 trees and allowed to feed and reproduce, some for three, and some for four months. Populations ranging from approximately 500 to several thousand developed on each tree. By October 30, only one of the trees had developed pear decline. The others remained vigorous except for varying amounts of defoliation and stunting of the branches enclosed by the sleeve cages. Photographs (included here) of some of these trees, taken October 30, show leaf-curl symptoms on leaves directly below the psylla cages. Since all of the control trees remained healthy throughout the season and comparable photographs of them show no curl, it appears that the curl was transmitted to the test trees by psylla that were free of pear-decline virus. This suggests that the curl and decline viruses are two separate entities. Evidently, the psylla obtained the curl-virus inoculum from the young pear seedlings in the greenhouse. Seedlings apparently contracted virus through seed transmission.

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