Certain Investigations Pertaining to Pear Decline In Oregon

SPECIAL REPORT 143
DECEMBER 1962

Agricultural Experiment Station
Oregon State University
Corvallis
This publication deals with certain phases of pear decline research for which the author was largely responsible during the period from July 1958 to November 1961. It does not cover studies carried on by other staff members of the Oregon Agricultural Experiment Station and it does not deal with work now in progress or contemplated for the future. Since there are many unanswered questions regarding the various phases of pear decline the present paper must be regarded largely as a progress report.

Certain of the findings and observations reported here have already appeared in summarized form in other publications, particularly "Pear Decline Investigations in Oregon", Annual Report, Oregon State Horticultural Society, 1961, and "Historical Facts Pertaining to Root- and Trunkstocks for Pear Trees", Oregon Agricultural Experiment Station, Miscellaneous Paper 109.

For results of research in Oregon pertaining to the relationship of soil microorganisms to decline, attention is called to Jensen (1) certain unpublished data relative to nematodes and to Cameron (2) "A Progress Report on the Plant Pathology Work on Pear Decline in Oregon." Annual Report, Oregon State Horticultural Society, 1960.

ACKNOWLEDGEMENTS

The valuable assistance and excellent cooperation received in the course of these investigations is here acknowledged. While all of the individuals and agencies who assisted and made the work possible cannot be listed, some are deserving of special mention. Among those from the University staff are F. E. Price, Dean and Director of Agriculture, S. B. Apple, Jr., Head, Department of Horticulture, C. B. Cordy, Jackson County Agent, Vaughn Quackenbush, Agriculture Technician, F. C. Reimer, Professor Emeritus, and R. J. Higdon, formerly associated with the Southern Oregon Branch Experiment Station. Also to be mentioned are Don Berry, County Agent, John Grim, Agriculture Technician, Harold White, Superintendent, Southern Oregon Branch Experiment Station, M. N. Westwood, Associate Professor of Horticulture and D. D. Evans, Department of Soils.

Also worthy of special consideration is the Fruit Grower's League of Jackson County, which provided certain funds for the work and which through its Research Committee headed by Paul Culbertson, made many facilities available and took an active part in many phases of the research.
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Introduction</td>
<td>1</td>
</tr>
<tr>
<td>II Scope of Investigations</td>
<td>1</td>
</tr>
<tr>
<td>III Investigations Pertaining to True Decline and Psylla Shock</td>
<td></td>
</tr>
<tr>
<td>Present Status of True Decline in Oregon</td>
<td>2</td>
</tr>
<tr>
<td>History of True Decline</td>
<td>3</td>
</tr>
<tr>
<td>Is True Decline an Effect of Pear Psylla?</td>
<td>3</td>
</tr>
<tr>
<td>Practical Significance</td>
<td>4</td>
</tr>
<tr>
<td>Psylla Shock</td>
<td>4</td>
</tr>
<tr>
<td>Evidence from Orchard Case Histories</td>
<td>5</td>
</tr>
<tr>
<td>Prevention and Recovery</td>
<td>7</td>
</tr>
<tr>
<td>True Decline</td>
<td>7</td>
</tr>
<tr>
<td>Resistance to True Decline</td>
<td>8</td>
</tr>
<tr>
<td>The Relation of True Decline to Psylla Infestations</td>
<td>9</td>
</tr>
<tr>
<td>Evidence from Oriental Species and Varieties</td>
<td>10</td>
</tr>
<tr>
<td>Stress and the Influence of Environment</td>
<td>10</td>
</tr>
<tr>
<td>Psylla Control</td>
<td>11</td>
</tr>
<tr>
<td>Can True Decline by Prevented by Psylla Control Alone?</td>
<td>12</td>
</tr>
<tr>
<td>Recovery From True Decline</td>
<td>12</td>
</tr>
<tr>
<td>IV Investigations of Disorders Association With Decline</td>
<td>22</td>
</tr>
<tr>
<td>Root-rot or Breakdown</td>
<td>22</td>
</tr>
<tr>
<td>Old Fireblight Infections</td>
<td>23</td>
</tr>
<tr>
<td>Crown Gall</td>
<td>23</td>
</tr>
<tr>
<td>Miscellaneous Troubles</td>
<td>24</td>
</tr>
<tr>
<td>V Investigations Pertaining to Nitrogenous Fertilization and Water</td>
<td>27</td>
</tr>
<tr>
<td>VI Root and Trunkstock Investigations</td>
<td>29</td>
</tr>
<tr>
<td>Rootstock Evaluation</td>
<td>30</td>
</tr>
<tr>
<td>Serotina</td>
<td>30</td>
</tr>
<tr>
<td>Ussurienis</td>
<td>31</td>
</tr>
<tr>
<td>Calleryana</td>
<td>32</td>
</tr>
<tr>
<td>Betulaefolia</td>
<td>34</td>
</tr>
<tr>
<td>French</td>
<td>35</td>
</tr>
<tr>
<td>Pre-World War I Imported French</td>
<td>35</td>
</tr>
<tr>
<td>Post-World War I Imported French</td>
<td>37</td>
</tr>
<tr>
<td>Winter Nelis Seedlings</td>
<td>38</td>
</tr>
<tr>
<td>Bartlett Seedlings</td>
<td>39</td>
</tr>
<tr>
<td>Burkett Seedlings</td>
<td>39</td>
</tr>
<tr>
<td>Other Sources of French Rootstocks</td>
<td>39</td>
</tr>
<tr>
<td>Trunkstocks</td>
<td>40</td>
</tr>
<tr>
<td>Old Home</td>
<td>41</td>
</tr>
<tr>
<td>Self-Rooting in Varieties Other Than Old Home</td>
<td>42</td>
</tr>
</tbody>
</table>
TABLE OF CONTENTS (continued)

<table>
<thead>
<tr>
<th>Section</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rootstock Vigor</td>
<td>42</td>
</tr>
<tr>
<td>Future Rootstock Research</td>
<td>43</td>
</tr>
<tr>
<td>The Importance of Rootstock Sources</td>
<td>44</td>
</tr>
<tr>
<td>Summary of Rootstock Investigations</td>
<td>45</td>
</tr>
<tr>
<td>VII Investigations Pertaining to the Identification of True Decline</td>
<td>46</td>
</tr>
<tr>
<td>Certain Graft Union Symptoms</td>
<td>46</td>
</tr>
<tr>
<td>Use of the Decline-Severity Scale</td>
<td>47</td>
</tr>
<tr>
<td>VIII Literature Cited</td>
<td>52</td>
</tr>
</tbody>
</table>
CERTAIN INVESTIGATIONS PERTAINING TO PEAR DECLINE IN OREGON

Henry Hartman*

I. INTRODUCTION

The term "decline" as originally conceived was used to designate a new disorder of pear trees, the cause of which was unknown. When used in this sense, the term is specific in meaning and does not concern other disorders that may cause pear trees to deteriorate or even to die.

When the new trouble, or "true" decline, appeared in the Rogue River Valley of Oregon, there was a tendency to use the term in a general sense and to regard any ailing tree as being in decline, regardless of what was responsible for its condition. This led to much confusion. Other ailments were obviously involved but there was no sure way of distinguishing between these and true decline. Further uncertainty arose in that some of the sick trees were apparently victims of more than one ailment at the same time and it was impossible to determine where one ended and where the other began. Doubtless, true decline came in as a complicating factor in many of these cases.

Little headway could be made in understanding the sick pear tree dilemma until the various components of the complex were recognized and until their interrelationship had been established. For this reason, much time and effort were expended on this phase of the problem and it is now felt that at least the major components have been identified and appraised as to their relative importance.

II. SCOPE OF INVESTIGATIONS

The problem occasioned by pear decline has been the object of much research and study, particularly in Washington, Oregon, California and British Columbia. These researches have encompassed almost the entire field of the sciences and the practices associated with pear culture. The early attempts to find the cause or causes of decline and to develop means for its control are well known, and hence, no attempt is made here to review the entire literature of the subject or to relate in detail the numerous surveys, tests and experiments that have been conducted.

The original objective of the research in Oregon was to explore the field with the hope that facts might come to light that would be of value in saving existing pear orchards. While the work was initiated in 1957, the present project was set up in 1958, and the work has been continuous since that time. Many facets of the decline problem have received attention as shown by the following general outline of the work undertaken:

* Professor of Horticulture Emeritus, Oregon State University, Corvallis, Oregon.
1. Compiling orchard case histories to determine the possible relationship of cultural and environmental factors to decline.

2. Study of the water situation in pear orchards to determine the role that this factor might play in tree deterioration.

3. Exploration of the possibility that tree deterioration might be caused by soil toxins produced by the combination of water and certain fertilizer materials.

4. Studies of root- and trunkstocks to determine the relation of these to decline.

5. Mapping of orchards to establish the extent and severity of decline and to note further deterioration or recovery from year to year.

6. Miscellaneous field, greenhouse and laboratory tests in attempts to induce decline under controlled conditions.

7. Studies of graft unions to determine the significance and relationship to decline of such symptoms as brown line, swelling and fluting of the phloem at or near the unions.

8. Surveys of the root systems to determine to what extent root troubles were contributing to devitalization and death of the trees.

9. Compiling orchard case histories with the aim of determining the possible role of pear psylla as a causal agent.

III. INVESTIGATIONS PERTAINING TO TRUE DECLINE AND PSYLLA SHOCK

True decline has been a baffling problem from the beginning. Perhaps no tree-fruit disorder in modern times has posed so great an enigma for both the growers and the research worker. Certainly none has been more devastating in its effects.

While headway has been slow, and while no magic panaceas have been found, it is believed that the information acquired in the course of the investigations in Oregon and elsewhere will ultimately enable the pear industry to live with the true decline problem without drastic changes in orchard management and without excessive additional costs.

Present Status of True Decline in Oregon

It now appears that true decline has about run its course in Oregon. The number of trees that went down during the past two years has been very much smaller than it was in previous years. Apparently most of the trees truly susceptible to decline have already succumbed.

Oregon has been fortunate in that most of its pear acreage consists of trees that offer resistance to the trouble. When decline made its appearance, no less than 97% of the trees were on French or other decline-resistant
rootstocks. Some of the latter went down with true decline, but since other disorders often played a part, it has been most difficult to determine to what extent true decline was the primary factor.

Not all of the trees on susceptible rootstocks have been lost by any means. It is estimated that from 85 to 90% of the trees on Ussurian rootstocks in Oregon have been or can be saved. In most of the orchards on this rootstock the actual number of trees lost has been small, since considerable recovery has taken place. The situation is much less hopeful in the case of trees on Serotina. A very high percentage of the trees on this stock have already been removed. There are cases, however, where trees on Serotina seem to be holding their own or are making satisfactory recovery.

History of True Decline

Just where true decline originated is not definitely known, but the trouble has spread from North to South along the Pacific Coast over a period of 10 years or more. According to Westwood (3), true decline was recognized in British Columbia in 1948, and in 1950 its presence was detected in the central valleys of Washington. The time of its first appearance in Oregon is somewhat obscure, although two small outbreaks in the Hood River Valley seem to date back to about 1955. The trouble at the time was confused with winter injury and was not recognized as true decline. In the Rogue River Valley the trouble was noted in 1957; it was found in the Umpqua Valley in 1958. The first authenticated case of true decline in the Willamette Valley was reported in 1959, the same year that the trouble was recognized in Northern California. The above dates as they pertain to Oregon are the dates when the trouble was first recognized, but are not necessarily the dates when it made its first appearance. It is almost certain that cases of true decline existed in the Umpqua and Willamette Valleys prior to 1958 and 1959.

Is True Decline an Effect of Pear Psylla?

While many possible or probable explanations have been offered in attempts to account for the occurrence of true decline, it now appears that the trouble is definitely associated with the insect pear psylla. As psylla has spread from one pear district to another along the Pacific Coast, true decline has followed in its wake. No authenticated cases have come to light in Oregon where the disorder appeared prior to the introduction of psylla. Where apparent exceptions were encountered, it developed later that either psylla had been there first or that the trouble in question was not true decline.

Moreover, case histories of many Oregon pear orchards support the hypothesis that true decline is initiated by psylla, greatly influenced by rootstocks, by the intensity of the psylla infestations and by a number of complicating factors. The case histories also support the contention that recovery from true decline depends largely on the effectiveness of psylla control, the rootstocks involved, and the absence or presence of serious complications.

It is recognized that the evidence presented in support of the above hypothesis (Tables 1, 2 and 3) accrued largely from observations, comparisons, associations and clues. Such evidence does not prove the contention beyond
doubt, but it establishes a strong probability when considered in all of its aspects. The recently announced results by Lindner, Burts and Benson (4), however, appear to provide direct evidence in support of this thesis. From what appear to be well-planned and well-controlled experiments, these authors conclude: "the insect pear psylla has been found to produce a systemic toxin that induces the typical syndrome of decline." The toxin they isolated appears to be highly potent and causes reactions that disturb the functions not only of pear trees but of other plants as well. While the toxic substance has not yet been identified, it is said to be "heat stable and dialysable", which indicates that it has specific properties. The authors also point out that individual psylla vary considerably in the amount of toxin they contain. The authors state, "The early nymphal instars were much more toxic than the older nymphs and the adults were the least toxic."

It is true that the investigations up until now leave some gaps in the chain of evidence necessary to prove beyond doubt that psylla by itself can induce true decline. There is yet the possibility that some still unknown factor may also be involved. It is not likely, however, that such a factor, if it exists, can cause decline without the presence of psylla. Psylla certainly seems to be a prerequisite of true decline.

It can be assumed that psylla is the "trigger" or inceptor of true decline, then the entire sick pear tree complex begins to fit into a pattern. Whether trees go into true decline or do not becomes a matter of rootstock resistance, which varies greatly, and of psylla infestations, which may also vary greatly in intensity and duration. In addition, true decline appears to be affected by a number of stress or environmental factors, as will be shown later in this report. Other ailments which cause pear trees to deteriorate appear to fit into the pattern either as primary causes or as complications.

Practical Significance

While discovery of the association of psylla with true decline is of much importance from the research point of view, it does not now materially affect the practical aspects of the picture. The discovery, while it may ultimately lead to new techniques of decline prevention, in no way minimizes the importance of known methods of coping with the decline problem. Resistant rootstocks remain as the key to decline prevention and the new findings do not greatly alter the situation as to other disorders associated with pear tree deterioration (7) (8).

Probably this discovery's greatest contribution is that it centers attention on psylla control. As this report will show, psylla would be a damaging pest even if it had nothing to do with true decline.

Psylla Shock

The term psylla shock is introduced here to differentiate between the more spectacular true decline and a milder form of tree deterioration that is usually found among pear trees propagated on what are regarded as decline-resistant rootstocks. Most of the cases observed in Oregon have occurred among trees on French roots. While there may still be doubt in the minds of some
as to the cause of true decline, there can be no question as to the cause of shock. Shock is very obviously a direct mass effect of psylla that varies in severity with the extent and duration of psylla infestations. Apparently no pear tree is sufficiently tolerant to resist damage from heavy or even moderate infestations of psylla.

While slow to be recognized on the Pacific Coast, the deleterious effects of psylla have long been known in the Eastern and Mid-Western states where psylla has been present since 1832 or 1834. These effects are mentioned frequently in the literature of both the horticultural and the entomological fields, and while the descriptions given are not specific, they leave little doubt that the damage described is the same as what is here referred to as psylla shock. Gardner (5) states that the effects of psylla result in a "dwarfing or stunting" of both the trees and the fruit.

Psylla was responsible for severe damage prior to the time when effective control measures were known. Comstock (6) writing in 1895 speaks of this damage and states that extensive orchards were destroyed by this insect pest. Other early authors state that pear growing in the early days was saved only because psylla was not widely distributed at the time. One authority states that psylla at one time caused the state of New York to go out of the pear business, although many growers did not fully recognize the cause of the trouble. Apparently many of the trees went out from winter injury after being weakened by psylla.

The shock condition as observed in Oregon is usually characterized by (1) retardation of growth, (2) loss of green foliage color, (3) early defoliation in severe cases, (4) reduction of fruit set and yields, and (5) reduction of fruit size. The symptoms, of course, vary greatly depending on the severity of the condition at the time. In most of the cases, the trees appear to be in a state of shock or mild decline. On a decline-severity scale of five, the trees usually do not go beyond the second or third stages, although occasional trees appear to be in severe true decline and some of them even go into collapse.

Psylla shock becomes quickly apparent in abandoned or neglected orchards where no attempt is made to control psylla. In this case of course, the trees are usually under stress and this doubtless contributes to their deterioration, but it is apparent that the total damage cannot be attributed to neglect alone. In the Willamette Valley of Oregon there are many old pear trees that remained thrifty and healthy with no care at all until psylla came along. Since that time many of these trees have gone into shock and have reached a state where they are no longer producing fruit.

Evidence from Orchard Case Histories

The relationship of shock to psylla infestations and the effects that the shock condition has on the performance of pear trees are indicated by the orchard case histories presented in Table 1.* It will be noted that the shock

*Tables 1 - 3 are presented on pages 16 - 21.
condition can result in drastic reductions of yields. It will also be noted that even one season of uncontrolled or poorly controlled psylla can result in cases of shock.

Orchard No. 2, Table 1, is a case in point. This 70-acre Bartlett pear orchard has received very good care and has been a heavy and consistent producer over a period of years. The trees are on a vigorous type of French roots and are generally free of troubles. Psylla control was good in this orchard until 1959 when a mild infestation occurred which was followed by a very severe infestation in 1960. As a result the orchard was in shock in the early spring of 1961 and the crop harvested in 1961 was approximately 25% of what it had been in previous years. The loss of crop in this case cannot be attributed to other factors, at least from outward appearances. The orchard is well supplied with pollenizer trees and 75 hives of bees were moved into the orchard prior to the time of bloom in 1961. The weather for the most part was sunny and mild, and the lowest temperature recorded in the orchard during the blossom period was 36°F.

Good psylla control was again attained in 1961, and from July to the end of the season the trees made fairly good recovery. The foliage became dark green in color and the trees made considerable growth. What the fruit-set will be in 1962 remains to be determined.

Orchard No. 7, Table 1, is another example of severe shock resulted following an infestation of psylla. The early psylla history is not definitely known in this case but it is known that the orchard experienced a heavy infestation in 1959 when no attempt at control was made during the latter part of the season. In early spring of 1960, the orchard was in severe shock and practically no crop set that season. The trees remained in shock during the entire summer. Good psylla control was attained in the orchard after 1959 and the trees made striking recovery in 1961 when about two thirds of a crop of normal fruit was harvested.

This orchard presents an interesting case from the standpoint of resistance to psylla shock. The trees are all on French roots with Variolosa as a trunkstock, with the exception of one row of trees which are on French roots with no interstock at all. The trees with Variolosa trunks went into severe shock, while those on straight French showed only mild symptoms. This indicates that Variolosa, supposedly an Oriental hybrid, tends to decrease resistance to shock when used as a trunkstock.

Orchard No. 11, Table 1, is a case of an orchard where the shock condition has persisted apparently because psylla control has been inconsistent over a period of years. Mediocre or indifferent control was experienced in this orchard during the season of 1956, 1957, and 1958, and the orchard was in very severe shock in 1958. Several trees in fact actually collapsed during that season. Good psylla control was obtained during 1959 and the trees made some recovery. Another season of mediocre psylla control occurred in 1960 and there was a decided relapse, the trees making little or no new growth and more trees going into severe true decline. Psylla control was very good in 1961 and the trees made slight recovery, although most of them are still far from normal.

The general situation in this orchard is somewhat complicated because the soil is fairly shallow, at least in some parts of the orchard. About 10 years ago the original varieties were grafted to Bartlett and Red Bartlett. The grafts made good growth to the time that psylla became a factor.
It is true that most of the cases of shock presented in Table 1 involved orchards where psylla infestations have been quite severe and where the symptoms and the effects of the shock condition are readily observable. One wonders, however, as to what the extent of crop reduction and the reduction in fruit size may be where psylla infestations are relatively mild and where the trees show only slight symptoms of devitalization. The evidence at hand indicates that the losses in such cases may be greater than is generally supposed. It is no secret that production in many Oregon pear orchards has been below par and that difficulty has been experienced in obtaining satisfactory fruit size since psylla made its appearance. There is evidence that in certain blocks of trees which have experienced what are considered to be only mild infestations of psylla, there has been a gradual and consistent reduction in yields and fruit size since 1955. The trees in these cases showed no pronounced symptoms of shock during the first three years of the period. This indicates that the effects of psylla may be insidious in character and may result in damage without arousing attention.

Reductions in yields and fruit size, of course, can result from several causes. Excessive heat during the growing season, for example, is known to affect fruit size. The Rogue River Valley in particular has experienced excessive heat at times during the past few years, but examination of the packout records from many orchards for the season of 1961 shows that growers who habitually obtain good psylla control have less difficulty in getting satisfactory sizes than growers who do not get such control.

Prevention and Recovery

Very fortunately psylla shock responds to psylla control. This has been clearly demonstrated by growers in the Rogue River Valley and in other areas of Oregon. With consistently good psylla control and good general orchard care, pear orchards have remained free of shock, and under like circumstances, trees already in shock have usually returned to normal in from one to three years, depending on the severity of the condition and the absence or presence of contributing factors. It is apparent, however, that a high degree of psylla control must be maintained at all times if shock is to be prevented and if recovery from it is to take place.

True Decline

The symptoms of true decline are well known to pear growers, and a detailed description of the trouble is not necessary here. The manifestation of true decline is usually striking and severe, often assuming epidemic proportions. When the disorder first hits an orchard, few or many of the trees may suddenly go into what is called "quick" decline. In such cases, the trees wilt and collapse in the course of a few days. Other trees go into "slow" decline, in which case deterioration progresses at a slower pace, but many of the trees in slow decline eventually die.

True decline tends to run its course quickly. That is to say, the trees which are susceptible or pre-disposed to the disorder usually become affected within a fairly short period of time. In Oregon, most of the susceptible trees in a given orchard went into decline during the first season, although some did not show symptoms until the second or third year.
In many ways true decline appears to be an aggravated form of psylla shock; the two troubles appear to be part of the same phenomenon. There is no sharp line of demarcation between them. The difference seems to be one of degree rather than one of kind. They appear to differ only in severity of symptoms. Both troubles follow in the wake of pear psylla. Whether trees go into shock or into true decline appears to depend on the resistance of the trees themselves, which in turn depends on their rootstocks. In the same orchard, trees on French roots may be in shock while those on Serotina or Ussuriensis are in severe true decline. Orchard No. 6, Table 1, is a case in point. This orchard consists of trees on both French and Serotina roots. Psylla infestations in this case have been intense, particularly during the past two seasons. Under these conditions the trees on French went into shock but those on Serotina developed severe true decline. In fact, all of the trees on Serotina were dead at the end of the 1961 season.

Resistance to True Decline

If it is assumed that true decline is a direct effect of psylla, then resistance to decline becomes a matter of psylla tolerance. Pear trees propagated on susceptible rootstocks such as Serotina or Ussuriensis go into decline because they do not tolerate psylla, and by the same token, trees on decline-resistant stock such as French, remain generally free of decline because they are psylla-tolerant to some extent.

The range of resistance to true decline as manifested by trees on different rootstocks is wide in scope. While no known rootstock provides complete immunity, the difference between the various species and types is so great that it is possible by proper rootstock selection to produce trees that remain quite free of decline with ordinary good orchard care. Even with resistant rootstocks, however, a few of the individual seedlings may be susceptible to true decline.

Resistance to decline appears to be more or less relative in nature. It is not a case where pear trees fall into two categories, one resistant and the other not. Within any rootstock population there are gradients of resistance as becomes obvious when one observes an orchard in decline. Some trees may be in decline while others are not. Some trees may be in severe decline while others show only mild symptoms. Even in the case of a very susceptible species such as Serotina there are differences in resistance between individual seedlings.

Assuming again that psylla is the primary cause of true decline, one can see how psylla infestations of varying intensities affect the decline situation in the light of the apparent differences in resistance. A very mild infestation of psylla might affect only the very susceptible trees in an orchard and the number of such trees might be quite small. A moderate infestation might affect the trees of slightly higher resistance while heavy infestations might produce a swamping effect where all or nearly all of the trees would go into decline.

Applying these are not hypothetical examples. The orchard case histories presented in Tables 2 and 3 clearly show that under actual orchard
conditions the severity of decline and the number of trees that succumb to it appear to vary directly with the intensity and duration of psylla infestations.

The matter of rootstocks and their resistance to decline is discussed under another heading in this report, but for the purpose of clarity at this juncture it should be stated that under Oregon conditions the species found to be the most susceptible to decline are Serotina, \textit{(Pyrus pyrifolia nakai)} and Ussuriensis, \textit{(P. ussuriensis max.)}. Those found to be most resistant are certain types of French \textit{(P. communis Lin.)}, Betulaefolia, \textit{(P. betulaefolia Bunge)} and Calleryana, \textit{(P. calleryana Decne.)}.

While both Serotina and Ussuriensis must be regarded as being predisposed to decline, it is clear that Serotina is by far the more susceptible. This becomes apparent when one compares the case histories of orchards on both of these rootstocks. So far as is known, severe decline has appeared in every orchard or block of trees on Serotina in Oregon. Most of the trees, in fact, are or have been in decline, or have already been removed. On the other hand, there are four orchards on Ussuriensis roots in the Rogue River Valley that have remained entirely free of decline and there are other orchards where the number of trees that have gone down is comparatively small.

In one particular orchard, trees on both Serotina and Ussuriensis are growing in adjacent blocks where general care, including psylla control, has been the same over the years. The trees on Ussuriensis are free of decline while most of those on Serotina have declined badly and about two thirds of them have been pulled.

The Relation of True Decline to Psylla Infestations

The orchard case histories presented in Tables 2 and 3 indicate that there is a relationship between true decline and psylla infestations. In the main they tend to support the thesis that the severity of true decline and the number of trees that succumb to it are influenced by the intensity and duration of psylla infestations. The case histories also indicate that recovery from true decline is associated with good psylla control. Orchards Nos. 1, 3, 5, 7 and 9 in Table 2, for example, are all orchards on Ussuriensis roots where the rootstocks were grown from seed from the same source so far as is known. Orchards 3, 5, 7 and 9 have all received what is considered to be good commercial psylla control. Orchard No. 1, on the other hand, has received poor or mediocre control since 1956. No attempt at control was made in 1956 and 1957, the years when psylla made its appearance in the orchard, and control since that time has not been good.

The contrast between these orchards is most striking. Orchards Nos. 3, 5, 7 and 9 are entirely free of decline at the present time. Orchard No. 1, on the other hand, is now a total loss. Most of the trees have already been removed and the remaining ones are in severe decline. Even the trees with self-rooted Old Home trunks, which are considered to be highly resistant to decline, have gone out in the case of this orchard.

Orchards Nos. 2, 6 and 8, Table 2, are also on Ussuriensis roots and afford another example of the apparent relationship between psylla and true decline. Orchard No. 2 experienced an infestation of psylla in 1954 but has
had very good psylla control since that time. Some of the trees were in decline in 1958, and about 1% of the trees have been lost. The others have recovered for the most part and the orchards are generally intact. Orchard No. 6 has received good psylla control for a period of several years but some of the trees were in severe decline in 1958. A few trees went into collapse during the summer of that year and about 3% of the trees were finally pulled. As in the case of Orchard No. 2, the remaining trees have made good recovery and no new trees have gone into decline during the past two years. Orchard No. 8, on the other hand, had poor or mediocre psylla control during several seasons prior to 1959 and most of the trees went into severe decline and were removed in 1959 and 1960. A few remaining trees have received good psylla control beginning with 1959 and are now doing well.

Orchards No. 2 and No. 3 in Table 3 are a good example of trees on Serotina roots. Orchard No. 2 has experienced good psylla control over the years, but like all other blocks on Serotina, experienced true decline. About 8% of the trees were pulled in 1960 but the remaining trees are now doing well. Orchard No. 3, however, has received only mediocre psylla control since 1956 and over 50% of the trees have died. The remaining trees are all in the 4th and 5th stages of decline.

Evidence from Oriental Species and Varieties

Further substantiation of the idea that psylla is associated with true decline is provided by the case of the Oriental types of pears. When these are grown as trees they tend to remain free of decline, regardless of the rootstock on which they are propagated. They also remain comparatively free of severe infestations of psylla. This has been clearly shown by the behavior of the trees in the variety collection and test plots at the old Talent experiment station in the Rogue River Valley. At the time that true decline made its appearance, the variety collection contained 72 varieties, hybrids and species of Oriental pears which were on Serotina, Ussuriensis or French roots. These trees have remained not only free of decline, but have shown high resistance to psylla infestations. Some of them appear to be practically immune to psylla. This has remained true even though the plots at the station are now abandoned and psylla has run wild, particularly during the season of 1961. The Communis varieties under these conditions have been literally alive with psylla at times, and both psylla shock and true decline have appeared among them.

Stress and the Influence of Environment

In addition to psylla and to rootstock susceptibility, there is a third factor that appears to influence the occurrence and the severity of true decline. This is the factor of stress and environment. Any condition or factor that tends to disturb the normal functions of a tree seem to increase susceptibility to decline and to aggravate decline in case the trees become affected.

One such facet is climate and weather conditions. It has been observed in Oregon that both true decline and psylla shock are most severe in regions where high temperatures and low relative humidities prevail during the growing
At least, the number of trees that go into collapse and the number of trees that go into decline is greater under such conditions. The contrast between the decline situation in the Rogue River Valley as against that in the Willamette Valley, for example, is quite noticeable. In the Willamette Valley where temperatures are lower and where relative humidities are higher, decline progresses at a slower pace and fewer trees go into collapse. Also, the time lapse between the occurrence of psylla infestations and the appearance of true decline seems to be longer in the Willamette Valley than it is in the Rogue River Valley.

Such a relationship is not strange. Stress is obviously greater under conditions of high temperatures and low relative humidities. As pointed out by Westwood (3), water movement through the trunks and larger branches is seriously impaired in the case of trees in true decline. Water deficits within the tree therefore are acute and would become most acute under hot and arid conditions when loss of water through the foliage is naturally excessive. Drought during periods of heat would also contribute to the water deficit problem.

Stress is also created by unfavorable soil conditions. It has been observed in the Rogue River Valley that both decline and psylla shock are usually severe among trees on shallow soils where the root systems are limited in the volume of soil they can exploit. Shallow soils are also susceptible to saturation, which in turn can result in injury to feeder roots, thus limiting water absorption.

It appears also that tree vigor affects resistance to decline and psylla shock. Trees with good vigor seem to offer more resistance than trees which are devitalized for one reason or another and trees on vigorous rootstocks appear to offer more resistance than those in on weak-growing stocks.

It appears also that damage to foliage from insect pests such as mites and spiders may affect the resistance of trees as does damage to main roots from breakdown or rotting. It is possible also that damage to feeder roots resulting from a combination of excessive nitrogen fertilization and water may predispose pear trees to true decline. This possibility is discussed under another heading in this report.

Psylla Control

It is not the intention to discuss here the methods and techniques of psylla control. This must be left to the authorities who are responsible for pest and disease control programs as these apply to different climatic and geographical situations.

It is apparent however, that in the light of recent findings psylla control must take on added significance in the future. This would be true even if psylla had nothing to do with true decline. As already noted, psylla can cause serious retardation of growth and reduction in yields and in fruit size. This damage can occur among all pear trees that harbor psylla, regardless of their rootstocks. From the orchard case histories presented in Table 1 it is apparent that some growers are not obtaining a degree of psylla control that is sufficiently high to prevent damage.
It is realized of course, that failure to obtain effective psylla control is not always the fault of the growers nor of the authorities who advise them. It is well known that psylla tends to develop resistance to insecticides and this has often resulted in poor psylla control. It has been pointed out (h) that the failure of parathion to control psylla in the central valleys of Washington after 1955 was generally responsible for the buildup of psylla populations that preceded the general outbreak of decline in those areas.

Growers have perhaps labored under a misapprehension as to what constitutes effective psylla control. Some growers have felt that good psylla control is attained when the pest is kept down during the period while the fruit is on the trees. If it is true (h) that the young psylla nymphs contain more toxin than do the older nymphs and the adults, then psylla control in early spring should be of far more importance than has been realized heretofore and infestations after harvest may also be a source of trouble.

Can True Decline Be Prevented by Psylla Control Alone?

The question may well be raised as to whether or not true decline can be prevented by psylla control alone. The facts at hand indicate a yes-and-no answer to this question. If psylla is the inceptor of decline, and if it were possible to attain perfect or near perfect control, true decline should not appear. There is a difference, however, between perfect control and what may be achieved under practical orchard conditions or what is feasible from the economic point of view.

Growers have sustained very serious losses from decline but it appears that in most cases the losses could not have been prevented had the association of psylla to decline been known from the beginning. Trees on certain rootstocks are apparently so susceptible that it is not possible to prevent decline unless almost perfect control is attained. As already indicated, severe true decline has appeared in all orchards or blocks of trees on Serotina roots in Oregon, despite the fact that some of these orchards received what is considered to be good commercial psylla control.

The situation appears to be somewhat different in the case of trees propagated on Ussurienis. As already shown, there are blocks of trees on Ussurienis in the Rogue River Valley that so far have remained free of decline and there are other blocks where the number of trees which have gone into decline have remained small. All of these orchards have received good psylla control, but no unusual precautions have been taken. There is reason to believe therefore that under Rogue River Valley conditions trees on Ussurienis roots can be kept reasonably free of true decline with good orchard care and with good psylla control.

Recovery from True Decline

While recovery from true decline is often erratic and may not take place at all, there is no doubt that recovery is taking place in the Rogue River Valley. Certain orchards or blocks of trees that were in decline in 1958 and 1959 have made definite and even striking recovery, particularly during the past two seasons. In most cases, however, recovery was slow in getting
underway. Trees which survive the initial shock of decline usually go into a period of inactivity during which little or no change takes place. After this time recovery may be fairly rapid.

Recovery from decline in the Medford area has usually followed a rather definite pattern. The first indication of permanent recovery usually becomes apparent in the spring of the year when the new foliage comes out with dark green color and with leaves which are normal or nearly normal in size. Trees showing such foliage symptoms usually set fruit which tends to size up well as the season progresses. The first new growth to appear on recovering trees usually comes in the form of sprouts from the larger branches and as recovery continues new growth appears in the outer periphery of the tree. New growth which appears in the form of weak, light-colored sprouts late in the growing season are not necessarily indicative of recovery. Trees making such growth may still show no signs of recovery the following year.

It now appears that recovery is contingent upon several conditions or factors. Effective psylla control, for example, appears to be a definite prerequisite to recovery. This is shown by the data presented in Tables 1, 2 and 3. No recovery has been noted in cases where the sick trees have been subjected to continued psylla infestations.

It is clear also that declined trees on Ussuriensis roots have a far better chance of recovery than those on Serotina. This is indicated by the orchard case histories presented in Tables 2 and 3. While most blocks of trees on Usuriensis have made substantial recovery, only one orchard on Serotina has undergone definite improvement. In most cases sick trees on Serotina roots have merely held their own or have continued to deteriorate.

As might be expected, the severity of decline has something to do with recovery. Trees classified as being in the lower categories of the decline-severity scale are more likely to recover than those in the lower classifications, although there are exceptions. Cases have been found where trees once rated as being in stage four have made good recovery. No striking recovery has been noted among trees that went into collapse in the beginning, although some such trees revived and have remained alive.
Complicating ailments such as serious damage to main root systems are quite obviously hindrances to recovery from decline. It has often been observed that trees in decline but with sound main roots, are apt to recover, whereas those with damaged main roots are not.

As will be noted under another heading in this report, the presence of graft union symptoms such as brown line, swelling of the phloem tissues near the unions and fluting of the inner bark above the unions, are not necessarily indications that trees will not recover. Many cases of recovery were noted among trees showing these symptoms during the 1961 season.

Good orchard care is important if trees in decline are to recover. Such trees are obviously under stress and any cultural treatment that tends to alleviate stress is certain to be beneficial. The full details of how true decline affects the anatomy and the functions of a tree are not fully understood at this time, but it is known that decline is usually accompanied by severe damage or loss of feeder roots. Replacement of feeder roots is obviously a preliminary step in recovery from decline.

Feeder root initiation is largely a function of the tree itself but environment plays an important part in both the initiation and the subsequent growth of such roots. Ample soil moisture and soil aeration are highly important in root development. Lack of aeration caused by soil saturation and soil compaction is detrimental to the extent that it may prevent root development altogether. As many growers have learned, it serves no purpose to make heavy applications of fertilizers with the hope that such applications will "shock" trees out of decline.

Irrigation of trees in decline presents certain problems. While sick trees require moisture throughout the season, they are not capable of utilizing large amounts of water at any one time and there is a tendency for the soil around such trees to remain excessively wet for some time after each irrigation. This can lead to a situation where the decline trees in an orchard receive too much water whereas the normal trees do not.

Pruning of decline trees has been the object of much discussion in the Rogue River Valley and growers have tried different procedures ranging from complete dehorning to no pruning at all. From these attempts it appears that pruning may aid in recovery but that it
is in no sense a "cure-all" or panacea. From the theoretical point of view, it appears that removal of a portion of the top of the trees should compensate in part at least for the loss of feeder roots and the impaired translocation of water and nutrients in declined trees. It is apparent, however, that a considerable amount of wood capable of producing foliage should be left so that the tree will be able to synthesize plant food materials. Dehorning of a tree is apparently too drastic and appears to be unnecessary.

Judging from the experience of growers, pruning of declined trees should be done during the dormant season. Pruning during the growing season does not usually stimulate vegetative growth in such trees. It is true that heading back of trees going into collapse may reduce wilting to some extent but this does not mean that such trees will necessarily recover.
<table>
<thead>
<tr>
<th>Orchard or Block</th>
<th>Location</th>
<th>Rootstock</th>
<th>Psylla Control</th>
<th>Extent of Shock</th>
<th>Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Umpqua Valley</td>
<td>Post-World War I - French</td>
<td>No attempt at control 1956, 1957. Poor control since Black soot on twigs and branches now.</td>
<td>Very severe shock. Some true decline Yields reduced about 90% past three years.</td>
<td>No recovery</td>
</tr>
<tr>
<td>3</td>
<td>Willamette Valley</td>
<td>Pre-World War I French</td>
<td>No psylla found in this orchard up until now.</td>
<td>No shock. No decline Heavy yields past three years.</td>
<td>No change in status of orchard.</td>
</tr>
</tbody>
</table>

*Table 1. The Relation of Psylla Control to Psylla Shock*  
(Authenticated Case Histories)
<table>
<thead>
<tr>
<th>No.</th>
<th>Location</th>
<th>Species</th>
<th>Description</th>
<th>Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Rogue River</td>
<td>French</td>
<td>Mediocre control 1956, 57, 58. Very good control 1959, 60, 61.</td>
<td>Complete recovery</td>
</tr>
<tr>
<td>10</td>
<td>Rogue River</td>
<td>Pre-World War I</td>
<td>Mediocre control 1957 to present time.</td>
<td>No recovery</td>
</tr>
<tr>
<td></td>
<td>Valley</td>
<td>French</td>
<td></td>
<td>No recovery</td>
</tr>
</tbody>
</table>

*This table was published previously in the 1961 Oregon State Horticultural Society Proceedings.*
Table 2. The Relation of Psylla Control to True Decline *
(Authenticated Cases of Orchards on Ussuriensis Roots)

<table>
<thead>
<tr>
<th>Orchard or Block</th>
<th>Location</th>
<th>Rootstock</th>
<th>Psylla Control</th>
<th>Extent of True Decline &amp; Other Damage</th>
<th>Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Rogue River Valley</td>
<td>Ussuriensis</td>
<td>Psylla infestation 1954 when orchard was not sprayed. Very good control since.</td>
<td>A few trees in severe decline 1958. No new cases of decline since.</td>
<td>Good recovery. A few trees still sick but no severe loss.</td>
</tr>
<tr>
<td>3</td>
<td>Rogue River Valley</td>
<td>Ussuriensis Various trunk stocks but none self-rooted.</td>
<td>Good psylla control from the beginning.</td>
<td>No evidence of true decline.</td>
<td>No change in status of orchard</td>
</tr>
<tr>
<td>5</td>
<td>Rogue River Valley</td>
<td>Ussuriensis</td>
<td>Good psylla control from beginning</td>
<td>No evidence of true decline.</td>
<td>No change in status of orchard</td>
</tr>
<tr>
<td>6</td>
<td>Rogue River Valley</td>
<td>Ussuriensis</td>
<td>Generally good control from the beginning.</td>
<td>About 3% of trees in severe decline 1958. 68% of trees below par year 1958.</td>
<td>Good recovery. Few trees pulled. Most of trees now normal</td>
</tr>
<tr>
<td>7</td>
<td>Rogue River Valley</td>
<td>Ussuriensis</td>
<td>Good psylla control from beginning.</td>
<td>No evidence of true decline.</td>
<td>No change in status of orchard</td>
</tr>
</tbody>
</table>
Table 2 continued

<table>
<thead>
<tr>
<th>No.</th>
<th>Orchard</th>
<th>Cultivar</th>
<th>Management History</th>
<th>Decline History</th>
<th>Status of Orchard</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Rogue River</td>
<td>Ussuriensis</td>
<td>Mediocre control up to 1959. Good control since.</td>
<td>Severe decline 1957, 58. Most of trees removed 1959, 60.</td>
<td>Few remaining trees doing fairly well.</td>
</tr>
<tr>
<td>9</td>
<td>Rogue River</td>
<td>Ussuriensis</td>
<td>Good control from beginning.</td>
<td>No evidence of true decline.</td>
<td>No change in status of orchard.</td>
</tr>
</tbody>
</table>

* This table was published previously in the 1961 Oregon State Horticultural Society Proceedings.
Table 3. The Relation of Psylla Control to True Decline *
(Authenticated Cases of Orchards on Serotina Roots.)

<table>
<thead>
<tr>
<th>Orchard or Block</th>
<th>Location</th>
<th>Rootstock</th>
<th>Psylla Control</th>
<th>Extent of True Decline &amp; Other Damage</th>
<th>Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Rogue River Valley</td>
<td>Serotina</td>
<td>Mediocre control 1956 to present time.</td>
<td>Severe outbreak of true decline 1958. At least half of trees dead 1961. Others in severe decline.</td>
<td>No recovery</td>
</tr>
<tr>
<td>4</td>
<td>Rogue River Valley</td>
<td>Serotina</td>
<td>Generally good control 1957 to present time.</td>
<td>About 2% of trees collapsed 1958. Others in various stages of decline. No new decline since 1958.</td>
<td>No significant recovery but trees are holding their own and are bearing normal fruit.</td>
</tr>
<tr>
<td>5</td>
<td>Rogue River Valley</td>
<td>Serotina</td>
<td>Control not known prior to 1957. Very good control 1957 to present time.</td>
<td>Some trees in decline 1958. No trees have died. No new decline 1959 to present time.</td>
<td>Not striking but trees are holding their own. Fairly good crop 1961.</td>
</tr>
</tbody>
</table>
Table 3 continued

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Rogue River Valley</td>
<td>Serotina</td>
<td>Mediocre control 1956 to 1961. Severe infestation spring 1961. Good control remainder of season.</td>
<td>Severe decline from 1958 to present time. About 12% of trees have died. No trees in normal condition.</td>
<td>No recovery</td>
</tr>
</tbody>
</table>

*This table was published previously in the 1961 Oregon State Horticultural Society Proceedings.*
IV. INVESTIGATIONS OF DISORDERS ASSOCIATED WITH DECLINE

As growers know, the Rogue River Valley had sick or ailing pear trees at the time that true decline made its appearance. This situation had existed for a long time. In past decades entire orchards or portions of orchards went out or became unprofitable, particularly in certain locations. Decline or deterioration of the trees in such cases was usually attributed to root damage resulting from "wet feet" and from root infections of fireblight. Possibly other troubles contributed to the problem although these were not apprehended at the time.

After true decline appeared, much confusion arose as to which trees were going down with true decline and which were ailing from other causes. This presented a difficult situation since the various troubles could not be separated by observation. There was also the possibility that some of the trees might be victims of both true decline and some other trouble simultaneously.

In an attempt to determine to what extent root troubles and other complicating factors might be contributing to the general decline situation, an extensive investigation was made in the Rogue River Valley. Exposure of roots by excavation was undertaken on a large scale and during the fall and winter of 1960-61, the root systems of practically all of the trees that were removed from commercial orchards were examined. Detailed records were taken on at least 75% of these trees. In addition, an attempt was made to determine the conditions under which the troubles had occurred and at about what time the damage had been done. Table 4 is a tabulation of some of the information thus obtained.

**Root-rot or Breakdown**

The results of the above study revealed a serious situation so far as root damage was concerned. In the case of the trees on French roots that were pulled for one cause or another, about 82% of the trees showed severe rotting of the main roots. About 28% of the trees on Serotina and about 22% of those on Ussurienensis showed a like condition. In many cases the entire main root system and even portions of the crowns were affected. In severe cases, the only part of the root systems remaining alive were a few small roots near the surface of the ground. Sometimes the rotting was confined to a portion of the main roots, and at other times the rotting was confined to the root extremities.

Trees showing the rotted root condition were found in 35 orchards or blocks of trees. In practically all of the cases the trouble was associated with excessive wetness resulting from high water tables during winter and early spring or from irrigation practices that resulted in excessive saturation of the soil. The sick trees for the most part were confined to certain areas or portions of orchards where excessive wetness was likely to recur. In most cases the ailing trees were found in low-lying or flat areas and were seldom found in the portions of the orchards that were well-drained. It is quite likely that the wet winters that prevailed between 1955 and 1958, as well as the increased practice of flood irrigation, served to intensify the rotted root problem during recent years.

Positive proof was established that the rotted root condition had existed prior to the time that true decline made its appearance. Most
growers recalled the time when the trees became sick, and a few growers had actual records indicating that some of the trees had been ailing over a period of ten years or more. In one particular block of trees on Serotina roots, true decline made its appearance in 1959. The orchard was mapped at that time, and it was noted that many of the trees had been ailing for some time prior to this date. These had been dehorned and the operator of the orchard stated that the dehorning had been done five years before in an attempt to revive the trees. When these trees were removed in the fall of 1960 it was very apparent that the dehorned trees had been victims of a serious rotted root condition for some time.

Rotting or breakdown of the root systems of pear trees is a serious trouble in the Rogue River Valley, since most pear trees are susceptible to it, with the possible exception of trees on Calleryana roots which appear to offer some resistance. As the situation now appears, this trouble is likely to destroy more trees than true decline during the next few years. There is no way of estimating the number of trees now afflicted with this trouble. It is not possible to differentiate between it and true decline by above-ground symptoms alone. The extent of damage can only be determined by extensive excavations or pulling of the trees so that the entire root system can be examined. Even these means may fail to detect the trouble, since it may exist in incipient form at the root terminals only. When a tree is pulled the roots often break off at the point where the rotted condition ends, in which case the rotten portions remain in the ground.

Old Fireblight Infections

It is well known that fireblight infections in the trunks, crowns and roots of pear trees took a heavy toll in Rogue River Valley orchards prior to the introduction of sprays and other modern techniques of blight control. While most of the ailing trees were removed at the time, a considerable number of them were allowed to remain and have lingered on in various states of ill health up to the present time.

During the examination of the pulled trees referred to above, it was found that about 10% (Table 4) of all the trees on French roots which were removed proved to be severe cases of blight infections. About 11% of the pulled trees on Serotina and 6% of those on Ussuriensis showed the same condition. In the case of the trees on Ussuriensis however, the infections were confined largely to the trunks and did not extend below the graft unions. But few instances were found where the infections appeared to be of recent origin. Practically all of them were old infections that dated back many years.

Crown Gall

While not a serious trouble, approximately 1% of the trees on French roots pulled in the Rogue River Valley last year showed severe crown gall infections. Trees so affected appeared to have been ailing for a long time, since they were undersized and had made but little vegetative growth during recent years. No cases of severe crown gall were found among the trees propagated on any of the Oriental species.
Miscellaneous Troubles

Aside from the troubles already mentioned, there are others that can account for deterioration in pear trees and some of these were encountered during the present study; among these was rodent damage. Damage from rodents which results in complete girdling usually causes pear trees to die, although the deterioration may be slow and gradual. Of the trees removed in the Rogue River Valley during the fall and winter of 1960-61, about 2% had been girdled by rodents at some previous time. Girdled trees as a rule do not go into collapse as do trees in quick decline.

A considerable number of the trees examined in this study were obviously trees which had remained small or scrubby and which were unworthy of further keep in the eyes of the growers. While these trees were small and had made little growth during recent years, most of them were not necessarily in decline. Examination of the roots of these trees usually revealed that the root systems were dwarfed and were exploiting only a small volume of soil. It will be noted (Table 4) that over 11% of the pulled trees on Ussuriensis roots were in this category. The percentage was much smaller in the case of trees on Serotina and French roots. Since these trees were not confined to any particular location in an orchard, nor to poor soil conditions, it appears that most of them were cases of trees propagated on dwarfish or slow-growing rootstocks.

Among the minor causes of damage to pear trees is that resulting from fuel oil used in frost fighting operations. Even small quantities of oil spilled on the trunks of the trees or over main roots, can cause serious damage to pear tissue and may result in loss of the tree. While the total number of trees lost from this cause is not large, growers should be aware of its potential danger. Doubtless much of the damage from this cause results from the lack of knowledge on the part of workers who move, refill or work with orchard heaters.

From the data presented in Table 4, it is apparent that many of the sick trees which were pulled in the Rogue River Valley during the fall and winter of 1960-61 were victims of disorders other than true decline. In the case of the trees on French roots for example, about 96% of the pulled trees were affected with such disorders, which by themselves could have caused the trees to deteriorate and even to die. It is quite likely that true decline came in as an added complication in many of the cases and probably hastened the decline of the trees. This seemed to be indicated by the behavior of the trees themselves. It was observed that trees afflicted with severe root damage often went into collapse in mid-season. In former years collapse was not a recognized symptom of trees so affected. Usually such trees lingered and died slowly.

In the case of trees on French roots in particular, the presence of complicating disorders makes it difficult to determine to what extent such trees are actually susceptible to true decline and to what extent true decline is the primary cause of their deterioration. As the figures in Table 4 show only about 4% of the trees on French roots pulled in the Rogue River Valley in the fall of 1960 were free of complicating disorders. This seems to indicate that under Rogue River Valley conditions, trees on French roots in general are highly resistant to true decline. This deduction becomes very apparent.
when one considers that the number of trees on French roots (440 trees) given in Table 4 represents the total number of the trees pulled for all causes from approximately 1650 acres of orchards. Even if all of the trees pulled had gone down from true decline, the percentage of loss would be only about four tenths of one per cent.

The situation differed greatly in the case of trees on Serotina roots. In this instance the sick trees that were pulled came from a very small acreage. In some blocks practically all of the trees were in severe decline and were removed.
Table 4. Complicating Disorders as Revealed by Sick Trees Removed from Rogue River Valley Orchards.

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Number of Trees Examined</th>
<th>Severe Root Rot %</th>
<th>Old Fireblight Infections %</th>
<th>Severe Rodent Damage %</th>
<th>Severe Crown-Gall Infections %</th>
<th>Scrubby Root Systems &amp; Tops %</th>
<th>Others including True Decline %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serotina</td>
<td>275</td>
<td>28.4</td>
<td>11.1</td>
<td>0.8</td>
<td>0</td>
<td>1.8</td>
<td>57.9</td>
</tr>
<tr>
<td>Ussuriensis</td>
<td>84</td>
<td>22.7</td>
<td>6.0</td>
<td>3.0</td>
<td>0</td>
<td>11.5</td>
<td>56.7</td>
</tr>
<tr>
<td>French</td>
<td>140</td>
<td>82.3</td>
<td>10.3</td>
<td>0.4</td>
<td>0.8</td>
<td>1.7</td>
<td>4.5</td>
</tr>
</tbody>
</table>
During the summer of 1958, it was observed in the Medford area that certain orchards or blocks of trees on French roots were rapidly going into severe decline. Within a period of a few weeks, decline assumed epidemic proportions in these orchards. This appeared to be contrary to the observations made in other areas where the severe cases of decline were usually confined to trees on Serotina or Ussuriensis roots. The orchards in these cases all followed a certain pattern. All had received very liberal amounts of nitrogenous fertilizers applied during the growing season and all had been subjected to heavy saturation irrigation.

In one particular orchard, the foreman had applied ammonium nitrate at the rate of 12 pounds per tree on June 6 to individual trees which had not been doing well for several years. This was in addition to the regular application of nitrogen applied to all of the trees in early spring. Then on July 4, the entire orchard received a heavy flood irrigation during which water stood in pools at the base of the trees. The flooding continued for four days but the soil around the trees remained in a saturated condition for some time afterward. Within 10 days after the water was applied, the trees which had received the extra nitrogen began going into quick decline and within a short time most of these trees had gone into collapse. The other trees in the orchard remained free of trouble.

At about the same time a similar situation developed in a 60 acre orchard also on French roots. In this case anhydrous ammonia was applied at the rate of 308 pounds per acre. The application was made in bands involving strips about four feet in width on each side of the tree row. During the growing season the orchard received five flood irrigations. These resulted in heavy saturation each time, since the orchard is situated on shallow soil where water does not penetrate to any extent past an impervious layer of tight, heavy clay. A small portion of the orchard that lies above the irrigation canal received no irrigation and only a moderate application of nitrogen.

Severe decline developed in this orchard during July and August, with the exception of the non-irrigated portion which remained free of trouble and which has remained free since that time. The trees in the other portion of the orchard stopped growing for the most part, and 253 trees went into collapse within a short time. Examination of the root systems revealed that the feeder roots had been severely damaged.

From the observations made in these orchards and in several others it appeared that decline among trees on French roots might be influenced or possibly caused by the combination of excessive nitrogenous fertilization and saturation of the soil. It was at this time that the possibility of soil toxins began to be investigated. From research done at other experiment stations, it appeared that nitrites and possibly other toxic compounds might be involved.
To test this possibility, series of experiments were carried on in the greenhouse and in the field during the 1959 season. The object of these experiments was (1) to determine to what extent French pear roots may be injured by nitrites and (2) to determine if nitrites might accumulate in Rogue River Valley orchard soils. The experiments were comprehensive and detailed, but it will suffice here to report only on the general findings.

The results clearly showed that young French pear roots are highly sensitive to nitrites, particularly at low pH levels. At a pH level of 5.5, the white roots of young pear trees immersed in solutions containing sodium nitrite as low as 16 parts per million of actual nitrite, showed severe damage after 24 hours of exposure. At a pH level of 7.2 the white roots proved to be more resistant as expected but were damaged when the concentration was raised to 48 parts per million or more.

The injury appeared in the form of discoloration when the white rootlets took on a light brown color. Most of the rootlets so discolored eventually died. When the young trees with damaged roots were replanted in both soil and moist sawdust, they quickly went into a form of decline and remained in this state to the end of the season; a few of the trees collapsed and died. The check trees in which case the roots had been immersed in water only, began growing in a normal manner shortly after replanting.

Similar results were obtained when nitrite was applied to young French seedlings growing in gallon cans. Nitrite applied at the rate of 48 parts per million to saturated soil resulted in injury to both the tops and the roots of the trees. No injury was detected when the nitrite was applied to soil that was kept in a well-aerated condition.

In another series of experiments in the greenhouse, ammonium sulfate, ammonium nitrate and calcium nitrate were applied to both saturated and unsaturated soil. The rate of application corresponded to an equivalent of about four pounds of actual nitrogen spread out over the drip area of a mature tree (400 square feet). The experiment was continued for two weeks and qualitative tests for nitrite were made daily.

These tests indicated that nitrite accumulated only in the case where the ammonia forms of nitrogen were applied to saturated soil. There was no accumulation when these forms of nitrogen were applied to aerated soils and no nitrite accumulated when calcium nitrate was applied to either saturated or aerated soil. Tests set up in orchards gave both positive and negative results so far as nitrite accumulation was concerned. In one particular orchard there was very positive indication that nitrite had accumulated following application of ammonium sulfate, which in turn was followed by heavy irrigation in mid-summer. In the case of some of the tests set up in orchards, it was impossible to maintain saturation for any length of time without the possibility that the nitrites might leach out as they appeared.

Nitrite injected into mature pear trees during these experiments produced violent reactions even when injected with minute quantities. The symptoms became apparent within a period of 12 hours or less. The damage produced in this manner however, did not resemble that of true decline. It resembled more the symptoms that usually follow severe infections of fireblight.
The results of these experiments appear to warrant the following conclusions: Comparatively small amounts of nitrite can cause severe injury to the rootlets of young French pear trees, particularly at low pH levels. This injury induces a form of decline. Nitrites can accumulate in soils as the result of heavy applications of certain forms of nitrogenous fertilizers under conditions of saturation.

The above experiments did not prove that nitrite or other soil toxins can induce true decline, nor did they prove that soil toxins were responsible for the trouble that occurred among trees on French roots in the Rogue River Valley in 1958. The severity of the decline in these cases, however, was entirely out of proportion to what might be expected among trees on French roots unless the combination of excessive nitrogen fertilization and excess water in some way played a part. The trouble in these cases can hardly be attributed to pear psylla alone, even if the infestations had been intense. It is highly probable that the trees were under severe stress because of feeder-root injury, and hence were pre-disposed to true decline. At any rate, no new decline appeared in these orchards after the fertilizer and irrigation practices were modified and most of the sick trees have since recovered.

VI. ROOT-AND TRUNKSTOCK INVESTIGATIONS

The decline problem has necessitated a complete re-evaluation of the entire pear rootstock situation. For this reason a comprehensive study of rootstocks was made in the course of these investigations. The rootstocks in most of the existing orchards in the Rogue River, Umpqua and Willamette Valleys have been identified for the most part and the relationship between rootstocks and true decline has been fairly well established. In addition the various rootstocks have been evaluated as to such features as vigor, longevity, compatibility and ability to thrive under varied and even adverse conditions. Much attention was given to resistance to insects and diseases and to the influence of rootstocks on yields as well as fruit market quality.

One objective of the work was to acquire information as quickly as possible that might be of value to growers in selecting rootstocks for the immediate future. This is pertinent since many pear trees are being planted now and these trees will greatly influence the future of the pear industry.

The sources of materials for this study were ample and reliable. The many pear orchards planted in Oregon during the past 80 years tell a tremendous story as to rootstock performance over long periods of time. The trees in these orchards involve many different rootstocks and rootstock combinations, and the orchards are growing under wide variations of soil and other environmental conditions. Moreover, the numerous test plantings made by the Southern Oregon and Hood River branch experiment stations long ago afford an unusual opportunity for rootstock comparisons since these plantings are intact and since records from them are available.
Rootstock Evaluation

Rootstock evaluation is of necessity a long-time venture when trees have to be planted and grown before reliable observations can be made. There is no way of predicting ahead of time how a rootstock will ultimately perform. Just because trees on a certain stock appear to do well in the nursery or during the first few years in the field is no assurance that they will do well over the life span of an orchard. Nor is it safe to assume that because a rootstock has been satisfactory in a certain locality that it will be equally satisfactory in another locality where soil and environmental conditions may differ. There is no substitute for long-time performance in the evaluation of rootstocks. This is the "baptism of fire" that separates the good from the bad. The pear industry of the Pacific Coast has sustained tremendous losses because it has often attempted to use rootstocks that had not been fully evaluated.

While it is not the intention of this report to make specific recommendations as to rootstocks, attention is called to those rootstocks that have withstood the test of time. The list of such rootstocks is not large and offers no great latitude as to choice, but it appears to be ample to meet the present emergency. There is no need therefore, for growers to resort to untried rootstocks or rootstock combinations unless they are willing to take chances. The list of well-tested rootstocks is limited in some cases for the reason that no extensive supply of seed is available now for some stocks which appear to be desirable.

Serotina (P. pyrifolia Nakai.)

Beginning shortly after the turn of the century, pear trees on P. pyrifolia, commonly known as Serotina, Japanese or Sand Pear, were planted in Pacific Coast orchards. At one time they were planted on a large scale, particularly in certain areas, and it is among these trees that true decline is now taking its greatest toll. From the available records (10) it appears that most of the trees on this rootstock were planted in the interval from 1910 to 1926.

Most of the seed from which Serotina rootstocks were grown were obtained from seed exporters in Japan. So far as the records show, these seeds were collected from miscellaneous sources in Northern Japan, including both cultivated varieties and wild forms of the species. This may account in part for the rather wide range of vigor and performance often manifested by trees on this rootstock.

Serotina as a rootstock has a poor performance record in Oregon. Not only is it the most susceptible to decline of all the common rootstocks but also it has generally failed to measure up in other ways. While it was supposed at one time to offer resistance to fireblight, this feature did not materialize in actual performance. Trees on this species in the Rogue River Valley, have often developed cases of root blight. Serotina proved to be quite sensitive to wet conditions, with the result that trees were inclined to go out in situations where soil drainage was not good. This is clearly indicated now by the high percentage of replants found among trees on this rootstock. In some blocks of trees planted thirty to forty years ago, the number surviving at the time that true decline made its appearance did not exceed 20 or 30 per cent.
While trees on Serotina have usually been quite productive, some fruit troubles have long been associated with the species. Trees on Serotina are known to produce fruits susceptible to "hard" or "black" end, particularly in the Bartlett variety. In the Anjou variety in particular there is a tendency for the fruit to lack in uniformity so far as maturity is concerned. This is clearly indicated by the behavior of the fruit itself and by pressure tests which often show a wide range of readings within a given sample.

**Ussuriensis (P. ussuriensis Max.)**

The rapidity with which Ussuriensis came in as a rootstock for pear trees on the Pacific Coast was fantastic in many ways. Though untested at the time, the stock was used on an extensive scale during the period from 1918 to 1921. This was natural in a way, since growers were desperate because of fireblight in some areas and were willing to try anything that offered hope of relief.

While individual trees of Ussuriensis are known to have existed in the United States prior to the turn of the century, the species commanded but little attention until 1907. At that time Mr. Frank Meyer, plant explorer for the United States Department of Agriculture, collected seeds of the species in Northern China and Eastern Siberia (11). The seeds collected by Mr. Meyer, however, were taken from wild trees and seedlings grown from this source, although highly resistant to fireblight, proved to be worthless as rootstocks largely because of lack of vigor.

It was only after Professor F. C. Reimer's two expeditions to the Orient (1917 - 1919) that vigorous forms of Ussuriensis became available. The vigorous types were found among the cultivated varieties of the species, then grown mostly in Manchuria in the region immediately north of the Great Wall, and to a lesser extent in Eastern Siberia.

On the first expedition, Reimer was accompanied by Mr. S. Takuda, a representative of the Yokohama Nursery Company, Yokohama, Japan. Reimer collected seeds and scionwood for experimental purposes, but Mr. Takuda collected a large quantity of seed which was made available to American nurserymen late in the fall of 1917 or early in 1918. It was from this seed that the first trees on the vigorous form of Ussuriensis were propagated and disseminated in the pear districts of the Pacific Coast.

The matter of obtaining desirable seed of Ussuriensis became a problem after the original supply collected by Mr. Takuda had been exhausted. Concerns other than the Yokohama Nursery Company came into the picture and either through ignorance or fraud, exported large quantities of undesirable seeds to the United States. Some of the seeds received turned out to be Serotina. Others were a mixture of Ussuriensis and Serotina and still others were seeds collected from wild trees. While efforts were made by nurserymen and others to eliminate the undesirable types, some of them escaped detection and ultimately found their way into Pacific Coast orchards.

* F. C. Reimer, formerly Superintendent, Southern Oregon Branch Experiment Station.
The unreliability of seed sources accounts, in part at least, for poor trees on Ussuriensis roots. In some of the orchards on this stock one may find a mixture of vigorous and scrubby trees. As shown in Table 4, about 11% of the trees on this species that were pulled in the Rogue River Valley in 1960-61, were scrubby trees, many of which had become unproductive even though they were not necessarily in decline. Occasionally one finds an entire orchard on this non-vigorous rootstock. Four such blocks, totaling about 19 acres, have been located in the Rogue River Valley. The trees in these cases are small for their age with small trunks and upright framework branches. Trees on vigorous Ussuriensis roots, on the other hand, usually have fairly large trunks and are inclined to be spreading in habit.

Trees on the weak-growing type of Ussuriensis have proven to be highly susceptible to decline. They appear to be about on a par with trees on Soro-tina so far as decline-susceptibility is concerned. This is less true in the case of the vigorous forms of the species. As already noted, some blocks of trees on the vigorous type have thus far remained free of decline in the Rogue River Valley and in other blocks the total number of trees actually lost has been small. A considerable percentage of the trees on Ussuriensis roots in the Rogue River Valley have Old Home trunks and these trunks have become self-rooted in a large percentage of the cases. With few exceptions, these partially self-rooted trees have remained free of decline. Recovery from decline has been pronounced among trees on Ussuriensis roots, and it now appears that from 85 to 90% of such trees have been or can be saved with proper orchard management.

There appears to be a difference in susceptibility to decline among trees on Ussuriensis, depending on the variety from which the rootstocks were derived. In one of the test plantings in the Rogue River Valley, the rootstocks were grown from open-pollinated seeds of both the varieties Guar Li and Ping Li. While decline has appeared in both groups of trees, it is readily apparent that the trouble is much more severe among the trees on Guar Li seedlings than it is among those on Ping Li. This may account in part for the variations in susceptibility now noted in present-day orchards on Ussuriensis roots. It is known that the seed used in the propagation of the trees for these orchards came from several named Ussuriensis varieties.

Until the time that true decline made its appearance, Ussuriensis of the vigorous type had a fairly good performance record in Oregon, although not equal to that of some other rootstocks. Some of the orchards of the Bosc variety, in particular, have been highly productive on this rootstock and the fruit from them has enjoyed a high market reputation. In the experimental plantings made at the Southern Oregon Branch Experiment Station in 1920, the trees on Ussuriensis outyielded those on post-World War I French by a considerable margin over a period of years. They did not yield as well however as did the trees on Calleryana and on Betulaefolia.

Calleryana (P. calleryana Decne.)

The introduction of Calleryana as a rootstock in this country also dates back to Professor Reimer's trips to the Orient. At that time, Reimer explored the distribution of the species over a wide area and came to the
conclusion that the most typical forms of the species were to be found in Central China. It was from this source that most of the seed used in the United States was obtained in the early years.

Unlike the unfavorable situation that developed regarding the seed sources of Ussuriensis, little trouble developed regarding Calleryana. Collection of the seed for a period of years was directed by Dean John H. Reisner, who at the time was in charge of the Department of Agriculture at the University of Nanking. Dean Reisner was an American who had received his college training at Cornell University. He and his collectors supplied most of the Calleryana seed that was used in the United States between 1920 and 1926, the period during which the species was used extensively on the Pacific Coast. Most of the seed from this source proved to be true to name, although some lots contained a small percentage of P. betulaefolia and P. serrulata. Some attempts were made by seed exporters in Japan to pass off seed of P. faurei and P. hondoensis as true Calleryana, but it appears that these attempts were headed off before actual exportation took place.

Calleryana as a rootstock has a very satisfactory record in the Rogue River Valley. Some of the finest orchards in the area are on this rootstock. Most of these orchards were planted during the period from 1923 to 1927 and have attained sufficient age so that they can be evaluated from the long-range point of view. The orchards are also quite extensive and are found under a fairly wide range of soil and environmental conditions. It is possible also to make comparisons in old test plantings where trees on Calleryana are growing alongside trees on other rootstock species.

Orchards on Calleryana roots, under Rogue River Valley conditions, have remained quite free of decline, particularly when Old Home has been used as a trunkstock. Calleryana roots are also resistant to fireblight. This is clearly shown by the fact that the orchards on this rootstock are generally intact even though they went through the bad blight years. Calleryana roots also appear to be fairly tolerant of water or wet conditions. Cases have been found where trees on this rootstock have survived whereas trees on other species growing among them in wet areas have gone out. Calleryana roots have also proven to be resistant to root aphids which, under certain conditions, are a problem of some importance in the Rogue River Valley.

The species Calleryana is fairly vigorous, although it is not as vigorous as Betulaefolia. In the test plantings the trees on Calleryana have proved to be more vigorous than those on Ussuriensis, Serotina and post-World War I French. Trees on Calleryana appear to retain their vigor as they attain age. There is no indication of slowing down among trees that are now 35 to 40 years of age. Calleryana appears to be compatible with most varieties of pears. At least, this has been true in the case of such varieties as Bartlett, Anjou, Comice, Seckel and Winter Nelis.

While injury from cold has not been a factor with Calleryana in the Rogue River Valley, there is indication that the species might be too tender for cold regions. Damage from cold was reported from several areas during the early testing of the species. Calleryana seedlings froze down to the ground at Toppenish, Washington, when the winter temperature went below 110 F. and it was reported that trees had gone out from winter cold in Michigan.

Seed sources of Calleryana are ample and appear to be reliable.

- 33 -
Betulaefolia (P. betulaefolia Bunge.)

Since Betulaefolia appeared to offer little resistance to fireblight in the early tests (10), it was not generally included among the Oriental stocks extensively used after 1920. For this reason one does not find many trees on this rootstock in present-day Pacific Coast orchards. At least four test plantings of trees on Betulaefolia were set up in the Rogue River Valley and these are intact at the present time. Occasional trees on Betulaefolia roots are found among the orchards of the valley but the number of these is small. One California nursery firm propagated trees on Betulaefolia in 1925. Others may have done so inadvertently since it is known that nurserymen did receive seed of Betulaefolia in lieu of other species ordered.

The observations recorded here were made from about 70 mature trees planted between 1920 to 1924. This is hardly an adequate sample from which to draw final conclusions regarding the performance of a rootstock, but the test plantings in this case were well-located so as to include different soil types and varied environmental conditions. The trees have attained sufficient age so that they can now be evaluated from the standpoint of longevity and long-time performance. The varieties used in the test plots included Anjou, Comice, Bartlett, Seckel and Winter Nelis. Yield records covering a period of many years are available for two of the plantings.

From comparisons in the various plantings, it is obvious that Betulaefolia is the most vigorous of all of the well-known rootstocks for pear trees. It produces large trees which retain their vigor over the years. This appears to be an asset in the case of slow-growing varieties such as Bartlett and Seckel but seems to be detrimental in the case of a vigorous variety such as Anjou. The Anjou variety on Betulaefolia has proven to be quite susceptible to water relations troubles such as "cork" spot. In some seasons the Anjou crop from trees on this rootstock has been unmarketable because of this trouble.

Trees on Betulaefolia roots have proven to be highly resistant to true decline and to psylla shock as well. While all of the trees on this stock in the test plantings do not rate No. 1 on a decline-severity scale, there are no cases where the trees appear to be in true decline. In comparison with trees on other species, those on Betulaefolia roots have withstood psylla shock very well in two of the test plantings where psylla infestations have at times been severe.

From the standpoint of yields, the trees on Betulaefolia have been on a par with the best of the other species and, with the exception of the Anjou variety, no troubles have appeared that impair market quality.

It has been observed over the years that trees on Betulaefolia are at times susceptible to lime-induced chlorosis under Rogue River Valley conditions. At least more of this trouble has been noted among these trees than among trees on other species growing under like conditions. For this reason it appears unwise to use this rootstock in the case of soils that are known to be "limey" or underlaid with deposits of marl.

From the observations made it appears that Betulaefolia has performed very well under Rogue River Valley conditions, particularly in the case of slow-growing varieties. Its performance is questionable, however, in the case
of a vigorous variety such as Anjou. Betulaefolia appears to be highly rated as a rootstock in certain European countries, and it is known to have been used for centuries as a rootstock for Ussuriensis varieties in parts of the Orient.

Reliable and tested sources of Betulaefolia seed are somewhat limited at the present time, since it is no longer possible to obtain seed from the original sources in the Orient. The trees of the species at the old Talent station in the Rogue River Valley, however, are capable of producing a fair quantity of seed provided that they receive proper attention during the coming years. The advantage of seed from this source is that it is identical with that used in propagating the trees now growing in the test plantings and from which the performance records were derived. Betulaefolia seed is also obtainable from Europe, but experience with this seed in this country is limited although the reports from abroad indicate that its past performance has been good.

French (P. communis Lin.)

The term French is usually applied to all rootstocks derived from the species P. communis and allied forms. The species is native to the Old World and is the source of most of the varieties of pears grown on the Pacific Coast. While French seedlings have many characteristics in common, it cannot be said that they are all the same or that their behavior is comparable when used as rootstocks. They vary considerably as to vigor, growth habits and resistance to disease, depending on the specific source from which they are obtained.

Much of the French pear seed used in this country during the past century was imported from France and to a lesser extent from other European countries. Rootstocks grown from imported sources have varied considerably from time to time. This becomes apparent now when one observes the root-sprouts and the performance of trees on French roots planted at different periods. There is, for example, a rather striking difference between the rootstocks grown from seed imported prior to World War I and those from seed obtained after 1918.

The seedlings grown from the old type were usually a mixture of Communis and Nivalis. In some of the old orchards in Oregon, from 50 to as high as 90% of the root-sprouts display Nivalis characteristics as indicated by thick stems, thrifty upright growth and the presence of pubescence on the leaves and shoot terminals. Rootstocks grown from seed imported after World War I usually show only a small percentage of Nivalis types and differ considerably as to vigor, uniformity and growth habits.

Pre-World War I Imported French. A considerable number of the old pear orchards in Oregon are on the Communis-Nivalis rootstock. A total of 39 such orchards or blocks of trees were located and evaluated during these investigations. These were all planted between 1882 and 1910. Twenty-six of the blocks were found in the Rogue River Valley, six of them were located in the Umpqua region and the other were found in various parts of the Willamette Valley. Special efforts were made to appraise these orchards as they now appear and to obtain information as to their past performance. Present and past owners were consulted as well as shippers who have handled and marketed the fruit for
these orchards over the years. In many cases production and packout records were obtained.

The superiority of this rootstock is clearly evident from this study. In spite of their age the orchards on this stock still rate among the very best wherever they are found. It was largely these orchards that established the reputation of the Rogue River Valley as a pear-growing center. Evidence of the superiority of the orchards on this stock is indicated by the high esteem in which they are held by their owners and by others who are familiar with their performance.

The orchards on Communis-Nivalis rootstocks have remained remarkably free of true decline, and they have shown considerable resistance to fireblight, considering that they all went through the bad blight years without protection from blight-resistant trunkstocks. That orchards on this stock are long-lived is clearly shown in that most of the original trees are intact and have remained vigorous and healthy to the present time. The trees show no evidence of incompatibility between the stocks and the varieties grafted on them.

These trees have proven to be well adapted to a wide range of soil and environmental conditions. They have performed well on light soils as well as on the heavy adobe types, and they have done surprisingly well on shallow soils where trees on other rootstocks often fail. They have withstood wet conditions as well as trees on any rootstock with the possible exception of Calleryana.

The fruit from these orchards has long enjoyed a good market reputation, being generally free of such troubles as "hard end" and "cork spot." As indicated by past packout records, yields in these orchards have been good with the possible exception of two of the blocks of the Anjou variety, which are on deep rich soils and in which case the rootstocks may be somewhat too vigorous for so thrifty a variety.

A notable characteristic of the orchards on Communis-Nivalis stock is that all or nearly all of the trees in a given orchard appear to perform equally well even in cases where the seedlings appear to be Communis. Apparently the entire seedling population is of a distinct type including those which do not display Nivalis characteristics. From this it appears that the entire group constitutes a distinct genetic strain. Most of the seedlings appear to be hybrids of Communis and Nivalis, in which case hybrid vigor seems to play an important part. Very few of the seedlings appear to be pure Nivalis which in its pure form is not particularly vigorous.

The history of Communis-Nivalis rootstocks is not fully known. Neither the old literature nor recent inquiries directed at present-day European authorities supply the complete story. It appears that the seed imported into the United States in the early days came from native seedling trees growing along the eastern border of France and the western border of Austria. The seed is said to have been reclaimed largely from cider mills in which case the fruits of Nivalis were mixed with those of Communis to impart certain flavors to the cider. What happened to the trees from which the seed came is not known, but it appears that all or most of them were destroyed during World War I. At any rate it seems that none or practically none of this strain of seed was imported into the United States during or following the first world war period.

- 36 -
While it has been reported that Communis-Nivalis type seed is still available in Europe, there is no way of knowing just what this seed is and how rootstocks grown from it would ultimately perform. Probably the quickest and surest way of obtaining seed similar to the old types is to develop sources in this country. During the present investigations, a number of bearing trees of this type have been located in old Oregon orchards. These are not mere chance seedlings such as one often finds in pear-growing districts. They are trees which have grown up from rootstocks out of the old stock itself. Doubtless other such trees can be found if the search for them was continued. Such trees are capable of producing fairly large quantities of seed now, thus affording a means of avoiding at least the preliminary steps of testing. Then, too, there is the possibility of selecting Communis-Nivalis rootstocks from superior trees and topworking them into mature trees so as to hasten fruit and seed production.

Post-World War I Imported French. Pear seed continued to be imported from France after World War I and even now small quantities are still being received. While it was suspected as early as 1925 that the seeds imported after World War I differed from those obtained previously, it was only recently that the true difference became apparent. Now that mature trees on both the early and the late importations are available for study and comparison, the difference in performance between the two types is readily apparent.

While trees propagated on seedlings from the later importations have performed fairly well under ideal growing situations, their performance has been quite erratic under conditions inclined to be adverse. Many of the trees lack in vigor, and mortality among them has been high. Like all of the French stocks, these have shown resistance to decline but decline has been found among them. In fact, they have proven to be the most susceptible to decline of all French rootstocks observed.

The difference between the early and the late importations becomes obvious when one observes the seedlings or the rootstocks under mature trees. Unlike the old stocks, the seedlings of the late importations usually show only a small percentage of sprouts which display Nivalis characteristics. The sprouts are often weak-growers with slender stems and small leaves. Very frequently the roots fail to send up sprouts at all.

From the standpoint of yields, trees on the post-World War I stocks have fared poorly in comparison with those propagated on other rootstocks. In the case of the test plantings at the old Talent station in the Rogue River Valley, these trees have been greatly out-yielded by those on Calleryana and Betulaefolia, and they were out-yielded by trees on Ussuriensis until decline made its appearance.

The late importations of French stocks are known to be highly susceptible to fireblight. This has been clearly shown by their performance in orchards and by their reaction to blight-resistance tests. From a total of approximately 10,000 seedlings inoculated with the blight organism at the Southern Oregon Branch Experiment Station about 35 years ago, only 12 trees survived the five-year test and were considered to be blight-resistant (12).

In view of the rather mediocre performance of the modern version of imported French pear stock, it appears that the use of these stocks should
be discontinued, at least pending the time when improved sources have been established abroad. Information obtained from present-day French horticultural authorities indicates that the average run of so-called French pear seed available now is usually derived from a mixture of French pears of all types, including cultivated varieties. Uniformity and high performance can hardly be expected from rootstocks grown from such seed.

Winter Nelis Seedlings. Winter Nelis has been and is now being used as a rootstock in the Medford area and elsewhere. While this stock may not ultimately prove to be the best of the French types it is well worthy of consideration at the present time, since it is available and since its past performance is quite well established. In the course of this study two very old orchards on this stock as well as several young plantings have been carefully appraised.

One of the orchards consists of trees of the Anjou variety which are now 61 years old. These trees are generally thrifty and healthy in spite of the fact that the orchard site is quite wet at times due to high water tables resulting from both winter precipitation and irrigation. High water tables during the growing season have been a problem in the general vicinity of this orchard since 1915 when irrigation first came in. Other blocks of trees went out in the neighborhood years ago as did many of the native oak trees which were once abundant in the area.

Aside from a few trees in a very wet corner, the original trees in the orchard are practically all intact. The trees have remained free of true decline; and while they went through the bad blight years, they show no evidence of past or present blight infections in the roots.

Another old orchard on Nelis roots was pulled in 1958 to make room for an industrial development project. Examination of the trees at the time of removal revealed that the root systems were very large and very free of root troubles. The trees themselves were large and vigorous, and there was no evidence of true decline among them.

It has long been known that Nelis rootstocks impart considerable vigor to trees budded or grafted on them. This becomes evident when trees on this stock are grown along side of trees on other rootstock types. Blocks of young trees on Nelis roots are now growing in various locations throughout the Rogue River Valley and for the most part are doing well. In two specific cases trees on this rootstock are doing very well as replants among old trees. Nelis seedlings were chosen as the rootstock for the variety collection at the new Hanley Experimental tract. The trees in the collection have now completed their third year of growth. No evidence of incompatibility has appeared among these trees in spite of the fact that the collection contains over 270 different varieties, species and types of pears.

Winter Nelis as a rootstock has one fault in that it appears to be quite susceptible to crown gall infections. This trouble appears to be largely a nursery problem. Some nurserymen report that they are having difficulty, but others state that they have no trouble when proper precautions are taken. Crown gall does not appear to be a problem in the old orchards on this rootstock.
Bartlett Seedlings. A very large percentage of the pear seedlings now used as rootstocks are grown from open pollinated Bartlett seed. This usage is logical since Bartlett seed is easily reclaimed from cannery waste. Just when this seed was first used is not definitely known, although there are references to its use as early as 1923 and 1925.

While Bartlett seedlings are less vigorous than those obtained from other seed sources, they appear to be quite satisfactory as rootstocks in areas where soils are deep and well drained and where vegetative growth is not hard to obtain. They appear to be highly resistant to true decline (8) and their performance seems to be satisfactory. This appears to be less true however, in situations where soil and environmental conditions are not of the best and where vegetative growth is inclined to be restricted. Under Rogue River Valley conditions some blocks of trees on Bartlett seedlings are doing well but others are not. This is particularly true when the stock is used with slow-growing varieties such as Bartlett, Red Bartlett and Seckel. The trees in this case appear to lack in both vigor and uniformity. Often the trees are slow in starting and are slow in attaining size. Mortality has been high when growers have attempted to use trees on this stock as replants in established orchards. For some reason or other, trees on Bartlett roots appear to be quite susceptible to infestations of root aphids. Some cases of severe damages from this pest have been found.

Burkett Seedlings. The variety Burkett, sometimes known as Sudduth, is one of the early accessions of the Southern Oregon Branch Experiment Station. This sort originated in Illinois and is believed to be of pure Communis origin, although its parentage is not fully known. Early tests of the variety showed that it is resistant to fireblight and that this characteristic is usually transmitted to its seedlings.

Open pollinated seedlings of Burkett were used as rootstocks in test plantings made in the Medford area between 1920 and 1924. The trees in these plantings are now available for observation. The mature trees on this stock are quite vigorous and uniform in size, having outgrown those on post-World War I imported French by a considerable margin. The seedlings themselves are vigorous and made uniform growth in the nursery. Among the many rootstocks tested at the Southern Oregon Branch Experiment Station, Burkett definitely rates among the best.

The present seed source of Burkett is limited but should be increased as quickly as possible in view of the variety's good performance as a rootstock.

Other Sources of French Rootstocks. The question is often raised as to the advisability of using commercial varieties other than Bartlett and Winter Nelis as sources of rootstocks. This is logical since seeds of varieties such as Comice, Bosc, Anjou, Seckel and others are readily available. Past experience shows, however, that there is an element of risk in using any domestic variety as a source of rootstocks unless the performance of the variety as a rootstock has been established. Unfortunately no mature trees known for certain to be on seedlings of the above sorts have been found, so there is no way of knowing now how well they might perform.

It is known that in the early days of the pear industry in Oregon, growers and nurserymen at times used seedlings from domestic sources, usually
from named varieties in production at the time. A number of orchards on such rootstocks were located in the Medford area and elsewhere. Evaluation of the trees in these orchards now shows that some have done moderately well, although none of them have done as well as those on the old imported Communis-Nevalis stock or those on Winter Nelis seedlings. True decline has appeared in some of the orchards and mortality has often been high as indicated by a high percentage of replants in many cases. In some instances the trees are lacking in vigor in that they are comparatively small for their ages and are not making satisfactory growth now.

In one particular old orchard near Medford the trees are known to be on open pollinated Beurre Clairgeau seedlings. Beurre Clairgeau normally produces seedlings which are vigorous and uniform in growth habits, but in the case of this orchard the performance of the trees has not been good. More than one half of the original trees have gone out from one cause or another. As indicated by the age of the replants some of the trees were removed thirty or more years ago. The trees which survived, however, are large and vigorous, and have been good producers.

Another old orchard in the Rogue River Valley is known to have been propagated on seedlings of a domestic variety, although the specific variety has not been identified. The trees in this orchard did well until about twelve years ago, but since that time many of them have gone out apparently from root troubles. Still another orchard in the Valley, propagated on unknown domestic seedling roots, has failed to make proper vegetative growth and the trees are undersized for their age. A fairly large block of trees on domestic roots of some kind was located in the Willamette Valley. This orchard now shows a considerable amount of decline.

**Trunkstocks**

Trunkstocks have received much attention particularly as a means of preventing the spread of fireblight from the trunks to the roots of pear trees. During the interim from 1916 to 1930, many trees with various trunkstocks were set out in both test plantings and commercial orchards in the Rogue River Valley. These plantings now provide an unusual opportunity to evaluate such stocks as to their relationship to decline and as to their general performance.

The list of varieties and types of pears tested as trunkstocks in the Valley is large and varied. Among those observed in the present study are the following: Old Home, Farmingdale, Surprise, Orel 15, Lemon (Russia), Kieffer, Estella, Chieh Li, Tolstoy, P. 18, P. 87, O.H. 20, O.H. 50 and Variolosa. Also observed were trunkstocks produced inadvertently when growers topworked trees to other varieties. In such cases the original variety became a trunk or intermediate stock. Among the trunkstocks produced in this manner were Winter Nelis, Anjou, Bartlett, Bosc, Seckel, Comice, Howell, and Beurre Clairgeau.

Since most of the trunkstocks enumerated above are not likely to be used in the future, a detailed discussion of each one is not necessary here. From all standpoints none of the trunkstocks that have been tested are equal to or
superior to Old Home, which appears to be in a class by itself. This variety is discussed under another heading.

Generally speaking, it appears that trunkstocks are less influential in their effect on true decline than are rootstocks. That is to say, trunkstocks, regardless of their type, are less likely to produce decline-susceptible trees than are rootstocks, although there are indications that they may contribute to decline susceptibility in some cases. As already pointed out, there is indication that Variolosa used as a trunkstock on French roots seems to increase the susceptibility of the trees to psylla shock. On the other hand there are cases where Oriental hybrids such as Kieffer, appear to have had no influence on either psylla shock or true decline.

From the standpoint of fireblight prevention, it appears that most of the trunkstocks selected for this purpose years ago have performed their task well. Most of the trees on such trunkstocks have remained free of severe trunk and root infections.

Old Home

When used as a trunkstock for pear trees, the Old Home variety has many virtues. Obviously it is one of the great finds among the early accessions of the Southern Oregon Branch Experiment Station. The variety is not new to Oregon pear growers. It was brought to the State by Professor F. C. Reimer in 1915. Since that time it has been used extensively in test plantings and in many commercial orchards. It has long since passed the experimental stage.

In recent years Old Home has proved to be especially valuable in producing decline-resistant trees. The variety has the ability to self-root, and when used as a trunkstock, the stocks develop roots above the graft union if they come into contact with the soil. Trees with a good complement of Old Home roots developed in this manner have remained remarkably free of decline. The combination of Old Home roots above the union and a decline-resistant rootstock appears to offer double protection. Old Home trunks, however, do not afford protection against decline unless they become self-rooted.

The original trees on Old Home trunks in the Medford area were not planted with self-rooting in mind. It so happened that the lower extremities of the trunkstocks became covered with soil at least for a period of time and a large percentage of the trees ultimately developed Old Home roots. Apparently trees with Old Home trunks do not need to be planted deeply to obtain self-rooting. In fact, trouble may occur if they are planted too deep. From 2 1/2 to 3 inches of soil above the unions appears to be sufficient.

Self-rooting of Old Home trunks usually begins shortly after planting. This was shown in a survey of young trees on this trunkstock made during the summer of 1961. In one particular case about one-third of the Old Home trunks showed good self-rooting 16 months after planting. In a case of trees on quince roots the Old Home trunks were all rooted at the end of the second growing season. Another block of trees showed Old Home roots that ranged from one-quarter inch to one and one-half inch in diameter during the fourth year in the orchard. Apparently self-rooting of Old Home trunks takes
place only during the early life of the trees. Newly-developed Old Home roots have seldom been found among mature trees.

Old Home is highly resistant to fireblight and its early use as a trunkstock was largely for the purpose of preventing the spread of this disease into the trunks and roots of the trees. Apparently it has served this purpose well: examination of several thousand trees during the past four years has failed to disclose a single case of severe blight infection in Old Home trunks. To serve this purpose best it is obvious that the framework branches of the tree should be developed from the Old Home stock itself, with the varieties grafted or budded at least eight or ten inches away from the trunk. This is necessary to insure maximum blight protection and to take advantage of the good branching habits of Old Home itself.

As a trunkstock Old Home has certain limitations as demonstrated by its performance in the Rogue River Valley. It does not, for example, perform equally well on all rootstocks. It has done exceptionally well on vigorous rootstocks such as Calleryana and Betulaefolia, but its performance on weaker stocks such as post-World War I imported French and Ussuriensis has been only average or mediocre. This is true even in cases where the trunkstock has become fully self-rooted. Apparently self-rooting alone does not provide the vigor necessary to produce thrifty trees even though Old Home itself is a vigorous variety.

At the present time there is interest in clone or vegetative propagation of Old Home, in which case the entire root and trunk system would consist of Old Home wood. Such trees should be highly resistant to both fireblight and true decline, but the question as to how they will ultimately perform under Oregon conditions cannot be fully answered at this time. No mature trees wholly on Old Home roots are known to exist in Oregon. There is no opportunity therefore to evaluate such trees on the basis of past performance.

Self-Rooting in Varieties Other Than Old Home

Rooting above the graft union is not a common characteristic of pear varieties. At any rate this is true of the commercial varieties when these are grafted on conventional rootstocks. Among the many trees examined during these studies, including the trees that were pulled in the Medford area during the fall and winter of 1960-61, only five instances of rooting above the union were found. Three of these were among trees of the Anjou variety and one each of Bartlett and Bosc. In no instance did the self-rooting result in a full complement of roots. Usually it consisted of one or two moderate size roots. From the practical point of view it appears that rooting above the unions is almost non-existent among commercial pear varieties in the Rogue River Valley with the exception of trees with Old Home trunks.

Rootstock Vigor

The term vigor as used here refers to the ability of a rootstock to impart vigor to trees grafted upon it. Some rootstocks, while apparently vigorous in themselves, do not necessarily produce trees which remain
vigor throughout their life span. Under Rogue River Valley conditions
the stocks which apparently impart vigor are the old Communis-Nivalis
imported French, Betulaefolia, Calleryana, Winter Nelis and Burkett seedlings.

Of these, Betulaefolia is obviously the most vigorous. The stocks lacking
in vigor are the post-World War I imported French, Serotina, Ussuriensis and
Bartlett seedlings to some extent.

While rootstock vigor is by no means the only criterion by means of
which rootstocks should be evaluated, it is certain that this factor is of
much importance under Rogue River Valley conditions, where vegetative growth
is inclined to be restricted. Generally speaking the most successful mature
orchards in the valley are those on vigorous or fairly vigorous rootstocks.
This is particularly true of orchards in locations where soil and other environ-
mental conditions leave something to be desired. Apparently a vigorous root-
stock overcomes to some extent the influence of an unfavorable environment.
Some of the poorest orchards in the Medford area are those with trees on non-
vigorous rootstocks planted in shallow soil.

It is very noticeable also that rootstock vigor is important in the
case of naturally slow-growing varieties such as Bartlett, Red Bartlett,
Seckel, Packham Triumph, and Eldorado. These appear to require a vigorous
rootstock if the trees are to attain sufficient size for maximum production
in the shortest period of time. There are many examples in the Rogue River
Valley of slow-growing varieties that have failed to produce maximum yields
because the trees did not make sufficient vegetative growth during the first
eight or ten years after planting. Trees of slow-growing varieties have a
tendency to slow down too soon if they are on non-vigorous rootstocks.

Rootstock vigor also appears to be related to true decline in some
ways, although it is apparent that factors other than vigor are involved in
decline-resistance. It is generally true that trees on vigorous rootstocks
are more resistant to decline than are those on non-vigorous stocks. The old
Communis-Nivalis imported French stocks are more resistant to decline than
are the imported French of post-World War I vintage. Among the Oriental
types, Betulaefolia and Calleryana are far more resistant to decline than
are Serotina and Ussuriensis, and the vigorous types of Ussuriensis are more
resistant than are their weak-growing counterparts.

It is possible of course that extreme rootstock vigor may be detri-
mental under certain conditions. This appears to be true in the case of a
thrifty or fast-growing variety such as Anjou. As already pointed out,
Betulaefolia appears to be too vigorous as a rootstock for Anjou in the
Medford area, particularly when the trees are grown in heavy, rich soils
that are deep and well drained. Under such conditions the trees may be
overly vegetative, resulting in water-reations troubles such as cork spot
and possibly decrease of yields.

Future Rootstock Research

While a great deal of information has accrued as the result of grower
experience and past research, it cannot be said that all aspects of the pear
rootstock problem have been solved. It would be strange indeed if the com-
paratively few well-tested and proven stocks now available are the best that
can be found. Certainly there is need for a greater diversity of rootstocks
to meet specific situations. It is therefore in the interest of the pear
industry that rootstock research be pursued diligently in the future.

The entire field of clone or vegetative propagation of pear trees,
which appears promising, is in need of much study. Since trees propagated
in this manner are of recent introduction in Oregon there is need of inform-
ation as to how such trees will perform under varied conditions, particularly
as to vigor, longevity, yields, and market fruit quality.

The matter of producing pear trees that will remain small in stature,
but which will come into production early and remain productive, is another
worthwhile field of investigation. The desirability of such trees is
recognized, but the problem of how to produce them and how to maintain them
is in need of much further study.

There is also need for research to establish the role of the male
parent in the case of rootstocks propagated from seed. Practically all such
stocks are now grown from open-pollinated seed. There is reason to believe
that rootstocks could be greatly improved if parentage was controlled, but
research is necessary to establish the parent lines that will enable the
improvement to take place.

Many growers in Oregon are interested in quince roots for pear trees,
and plantings on this stock are now being made. Quince rootstocks are not
entirely new in Oregon, yet it cannot be said that all of the problems
associated with this stock have been solved. This applies to both the use
of quince as a dwarfing stock and as a nurse root for standard trees. The
relationship of quince to true decline has not been fully established.
Which of the various types of quince now available are best under Oregon
conditions is not fully known and certain disease problems associated with
trees on quince roots remain unsolved. The tendency of trees on quince
roots to dwarf down too quickly after planting is cause for apprehension
among growers.

The Importance of Rootstock Sources

It is no exaggeration to say that rootstocks can make the difference
between success or failure in pear production. This is particularly true
since decline has entered the picture. The sources from which rootstocks
are derived should be given careful scrutiny from now on. Moreover, it is
important that rootstocks be made available to both growers and nurseriesmen.
It serves no practical purpose to test rootstocks unless such stocks are
obtainable. At the present time there are several apparently desirable
stocks which cannot be used because there are no adequate sources of seed.

The sources of desirable rootstock materials require constant vigi-
lance if they are to remain reliable. Not only is it necessary that sources
be established, but it is of equal importance that the sources remain unchanged.
Past performance is the only reliable guide in rootstock selection, but even
this is valid only so long as the stocks available at the moment are identical.
with those from which past performance is evaluated. Any change in the strain or type can nullify the value of past performance for any given rootstock. This has been clearly demonstrated by past experience. The imported French stocks, for example, underwent a drastic change following World War I, but no one became aware of this change until it was too late.

**Summary of Rootstock Investigations**

While resistance to decline is of major importance in rootstock selection, this should not be the only criterion by means of which rootstocks are evaluated, particularly in the Rogue River Valley where rootstocks obviously play such an important role in the general performance of pear trees. The list of rootstocks which have withstood the test of time in the valley is not large and offers no great latitude of choice, but it appears to be ample to meet the present emergency, and growers need not resort to unproven rootstocks unless they are willing to take chances.

Among the French-type stocks which have performed best in the valley are the old pre-World War I imported French, Winter Nelis and Burkett seedlings. Winter Nelis seedlings are available now, and the seed source is adequate to meet all immediate needs. Seed of pre-World War I French cannot be imported from abroad now, but bearing trees of this type are being located in Oregon, and it appears that a local source of seeds of this strain can be developed quickly. Burkett seed is also limited in supply, but it is possible to increase the seed source of this variety within the next few years. All of the above French stocks are highly resistant to decline and have performed unusually well from all other standpoints.

Calleryana used with Old Home as a trunkstock has established a very good performance record in the Medford area. It has proven to be resistant to both decline and fireblight, and appears to be quite tolerant of wet situations. Seed sources of Calleryana are adequate and appear to be reliable.

Betulaefolia, which is the most vigorous of all rootstocks tested in the area, appears to be a very good rootstock particularly for slow-growing varieties such as Bartlett, Red Bartlett, Seckel, Packham Triumph and Eldorado. It appears to be too vigorous for fast-growing varieties such as Anjou, and it is slightly more susceptible to lime-induced chlorosis than other rootstock species. For this reason it should not be used where soils are known to be "limy" or underlaid with marl.

Quite obviously certain rootstocks should be eliminated from consideration in selecting stocks for future planting. Both Serotina and Ussuriensis should be avoided because of their susceptibility to decline. The modern version of imported French should not be used in the Rogue River Valley since it has failed to measure up to other rootstocks in general performance. Bartlett seedlings which appear to be satisfactory in some areas have not done well in the valley, particularly in situations that are inclined to be less than ideal. Bartlett seedlings have also performed poorly when used as rootstocks for slow-growing varieties.

Of the many varieties and types tested as trunkstocks in the Medford area, Old Home appears to be the best. It has proven to be highly resistant
to fireblight and seems to afford double protection against decline because of its ability to develop roots above the graft unions.

VII. INVESTIGATIONS PERTAINING TO THE IDENTIFICATION OF TRUE DECLINE

Lack of definite means of identification has been a serious handicap in all investigations of the decline phenomenon. This has been particularly true in Oregon where complicating ailments are often involved. There has been and there is now a need for positive ways of determining whether sick trees are in true decline or whether their deterioration is attributable wholly or in part to other factors. Considerable work pertaining to certain phases of the problem was done in the course of the present study, particularly with the aim of finding some positive diagnostic test that could be applied quickly under field conditions. It cannot be said, however, that the results of this work have provided such a test.

Certain Graft Union Symptoms

In the early work on pear decline it was observed by investigators that certain graft union symptoms appeared to be associated with true decline. Among these were certain readily visible abnormalities which became known as "brown line", "swelling" or thickening of the phloem tissues usually below the unions and a "fluted" condition of the surface of the inner bark just above the unions. Also noted were certain microscopic symptoms involving an apparent plugging of sieve-tubes in certain areas of the phloem (8). At the time it was hoped that such indices might be of value in recognizing true decline and in predicting what the future course of decline might be in the case of individual trees.

This report covers only the work done pertaining to the readily visible graft union symptoms. It does not include results obtained from microscopic studies relating to sieve-tube plugging.

To test the value or the reliability of such possible indices of true decline as brown line, swelling of the phloem and fluting of the surface of the inner bark above the unions, a comprehensive study of these abnormalities was undertaken during the spring and summer months of 1960. This included examination of the graft unions of trees propagated on all of the common rootstock species found in the Rogue River Valley, and it included healthy trees as well as trees in all stages of decline. The graft unions were examined on a total of 2250 trees and the data were summarized for study. A tabulation of the data is given in Table 5 of this report.

While the result of this study indicates that some relationship exists between the symptoms mentioned and decline, the correlation is not consistent, and it appears that the abnormalities are of little value as indices of true decline. While they may indicate the presence or absence of true decline in a given orchard, they appear to be unreliable when applied to individual trees. As the data show, trees displaying the symptoms do not necessarily go into decline, and at the same time, many trees go into decline without developing the symptoms at all. Moreover, decline trees displaying the symptoms may recover and do not necessarily continue to deteriorate or to die.
It will be noted from Table 5 that a fairly high percentage of the healthy or No. 1 trees on Ussuriensis and Serotina roots displayed the symptoms in 1960. In the case of the No. 1 trees on Serotina roots, for example, 6.4% of the trees showed brown lines, 35.9% showed swelling of the phloem and 37.1% showed fluting. Upon reclassification in 1961, however, virtually none of these trees showed symptoms of decline. Their status for the most part remained unchanged.

It will also be noted from Table 5 that many of the trees that went into decline did so without developing the symptoms at all. In the case of brown line, for example, 66.4% of the No. 4 and No. 5 trees on Ussuriensis roots reached these advanced stages of decline without showing the symptom. Of those on Serotina, 65.2% of the No. 4 and No. 5 trees gave no indication of brown line. Upon reclassification of the trees in 1961, it was found that a high percentage of all of the decline trees were making recovery whether or not they had shown the brown line symptom the year before.

What is true of brown line appears to be equally true of the other two graft union symptoms. There appears to be no consistent relationship between the occurrence of decline and the presence or absence of swelling of the phloem tissues in the vicinity of the unions and the fluted condition of the inner bark just above the unions.

Use of the Decline-Severity Scale

A decline-severity scale has often been used in an attempt to appraise the extent and severity of decline and in efforts to measure its progress from time to time. Such a classification (8) first developed in Washington and subsequently used in Oregon, consists of five categories as follows:

No. 1. Trees normal in all respects.
No. 2. Terminal and shoot growth somewhat less than normal.
No. 3. Little or no terminal growth, spur and shoot leaves smaller than normal.
No. 4. Almost no terminal growth, very small and very sparse foliage.
No. 5. No terminal growth, very sparse foliage, some trees nearly dead.
Past experience has shown that a classification such as the above may be very misleading unless the trees are evaluated with great care and unless good judgment is used in interpreting the findings. In actual practice the classification may indicate nothing more than the state of vigor of the trees at the time, and vigor may depend on many factors aside from true decline. It does not necessarily follow that trees are doomed to become severe cases of decline because they fall short of the No. 1 category at one time or another.

This was clearly shown by the subsequent behavior of orchards that were mapped during the early investigations of decline in the Rogue River Valley. In some of these orchards a very high percentage of the trees were rated as No. 2 and No. 3 but re-evaluation at later dates showed that only a small percentage of the trees so classified ever became cases of severe true decline. For the most part these trees have held their own or have returned to normal.

In one particular orchard on Ussuriensis roots, 72% of the trees were rated below the No. 1 category in 1958, most of them rating as No. 2 and No. 3. The actual loss of trees from decline in this orchard, however, has amounted to less than three percent and nearly all of the trees which went out were already very sick trees at the time of the first mapping. Practically none of the trees originally rated as No. 2 and No. 3 became cases of severe true decline. The orchard for the most part is intact and gives no evidence that decline has made headway during the past three seasons. A fairly high percentage of the trees that were below par in 1958 now rate as No. 1, while many of the others show improved foliage characteristics even though the terminal growth is still below normal.

Certainly a classification of trees based entirely on the length of the terminal growth is of little value in appraising the decline status of trees. This is particularly true in the Rogue River Valley where pear trees vary so markedly in the amount of vegetative growth made. As growers know, there are many orchards in the valley that remain quite productive and that have not gone into decline, even though the annual growth falls short of what is generally regarded as a requirement of health and productivity. Apparently the nature of the foliage is more important as an index of tree health than length of annual growth. So long as the foliage remains abundant and the individual leaves retain normal
size and color, the trees are likely to remain productive and there need be no concern as to the likelihood of true decline. Trees going into true decline usually show an abrupt change in foliage characteristics, indicated by decrease in size of individual leaves, loss of deep green color and a tendency for the foliage to become sparse.
Table 5. The Relation of Certain Graft Union Symptoms to Decline

**Ussuriensis**

<table>
<thead>
<tr>
<th>State of Decline</th>
<th>Number of Trees Sampled</th>
<th>Brown Line at Union</th>
<th>Swelling of Phloem (usually below union)</th>
<th>Fluting at Union</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Trees</td>
<td>%</td>
<td>Trees</td>
</tr>
<tr>
<td>1</td>
<td>220</td>
<td>11</td>
<td>5.0</td>
<td>88</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>63</td>
<td>21.0</td>
<td>138</td>
</tr>
<tr>
<td>3</td>
<td>185</td>
<td>101</td>
<td>54.4</td>
<td>124</td>
</tr>
<tr>
<td>4</td>
<td>114</td>
<td>47</td>
<td>41.2</td>
<td>44</td>
</tr>
<tr>
<td>5</td>
<td>26</td>
<td>14</td>
<td>53.8</td>
<td>13</td>
</tr>
</tbody>
</table>

**Serotina**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Trees</th>
<th>%</th>
<th>Trees</th>
<th>%</th>
<th>Trees</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>78</td>
<td>5</td>
<td>6.1</td>
<td>28</td>
<td>35.9</td>
<td>29</td>
<td>37.1</td>
</tr>
<tr>
<td>2</td>
<td>138</td>
<td>26</td>
<td>19.2</td>
<td>56</td>
<td>40.5</td>
<td>63</td>
<td>45.6</td>
</tr>
<tr>
<td>3</td>
<td>122</td>
<td>34</td>
<td>27.8</td>
<td>76</td>
<td>62.2</td>
<td>75</td>
<td>61.4</td>
</tr>
<tr>
<td>4</td>
<td>83</td>
<td>28</td>
<td>33.7</td>
<td>44</td>
<td>49.4</td>
<td>67</td>
<td>80.7</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>15</td>
<td>37.5</td>
<td>22</td>
<td>55.5</td>
<td>28</td>
<td>70.0</td>
</tr>
<tr>
<td></td>
<td>89</td>
<td>0</td>
<td>0</td>
<td>24</td>
<td>26.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>----</td>
<td>---</td>
<td>---</td>
<td>----</td>
<td>------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>38</td>
<td>2</td>
<td>5.3</td>
<td>12</td>
<td>31.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Petuniasfolia</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>6.9</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>French</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>249</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>110</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>122</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>154</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>111</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
LITERATURE CITED

(1) Jensen, H. Certain unpublished data pertaining to nematodes.


