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Pear Scab in Oregon

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Introduction

The pear scab fungus (*Venturia pyrina* Aderh.) has been in Oregon for many years. It has become a serious economic problem in the main pear-growing districts since 1932. Of all diseases, scab causes the most consistent depreciation of Oregon's 6-million-box pear crop, although pear blight may be more spectacular during occasional seasons of epidemics. During seasons favorable for scab infestations, losses of 20 to 30 per cent of the fruit have not been uncommon, and where control practices have been neglected the losses often reach 80 to 90 per cent in individual orchards. Pear scab is common in western Oregon, occasionally severe in the Hood River and Rogue River valleys, but is rare in the drier districts of eastern Oregon.

Studies were started in 1932 to develop satisfactory control measures for pear scab, particularly for the tender-skinned varieties which were subject to injury by the fungicides in general use at that time.

Symptoms of Pear Scab

On the fruit

Pear scab is similar in appearance to the better-known apple scab. Each disease is caused by a distinct species of fungus which is not capable of infecting the other plant.

About the time the petals fall in the spring, dark velvety or sooty spots may appear on young fruits. Infections may occur on fruit stems, the calyx lobes, the fruit surface, or even the flower petals. When the fruit stems are attacked, the young fruits usually fail to set. If growth continues, a badly misshapen pear results (Figure 1). The scab spots usually continue to enlarge as the fruit grows until they are arrested by hot, dry weather or by fungicidal sprays. Early infections may eventually involve the whole side of a fruit, and later infections may result in numerous smaller spots (Figure 2). The central, or older part of a scab spot may die, leaving a corky or russeted skin area (Figure 2). An olive-brown rim of

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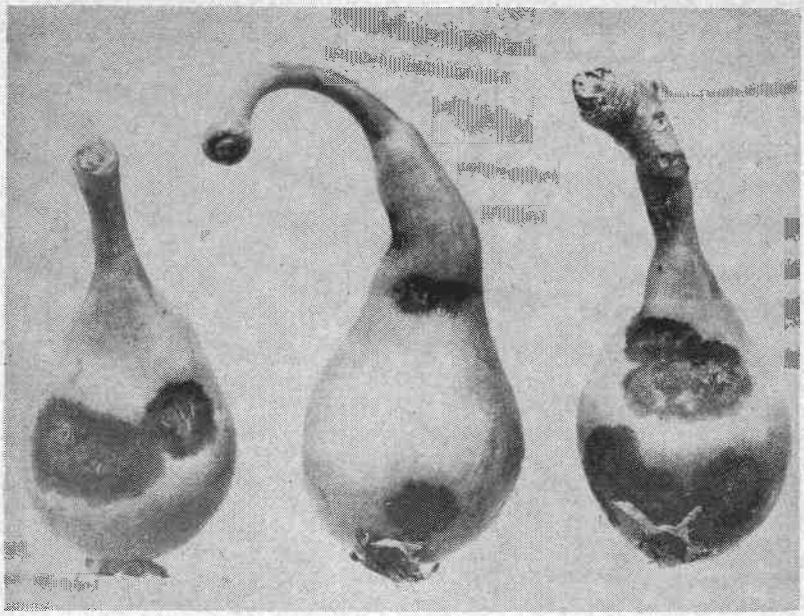

Figure 1. Scab infections on young pear fruits. Middle pear Bartlett; others Anjou.

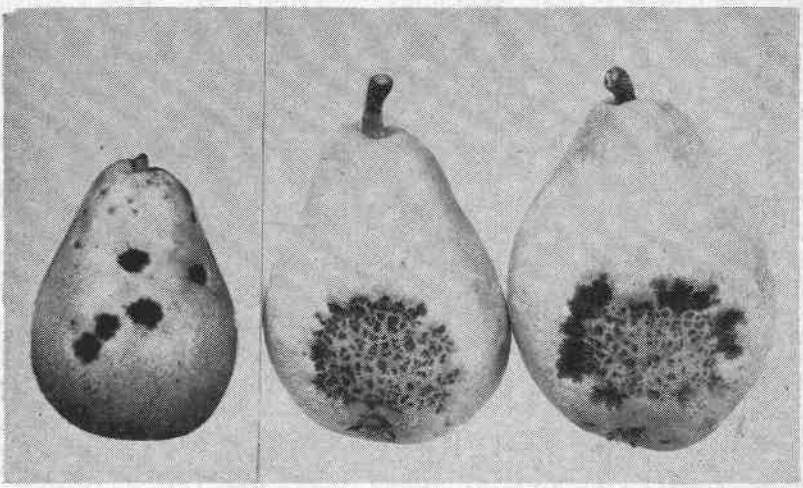

Figure 2. Scab infections on Anjou pears. Fruit at left with late-season or secondary infections only. Middle pear with an early primary infection that has become inactive. Fruit at right shows a primary infection with the fungus alive only at the edge.

active fungus tissue often remains alive at the edge of a primary infection (Figure 2), which may produce spores and numerous secondary infections during wet weather. If fruit infections occur 10 to 14 days before harvest, the scab spots may not become visible on the fruit surface for a month or more after it is placed in cold storage. Such late infections are responsible for the "pin-point" scab spots (Figure 2, spots near the stem end of fruit at left) frequently observed near the harvest period or during the storage season.

On the leaves

Leaf infections (Figure 3) resemble fruit infections, but frequently appear slightly later. They are more common on the lower

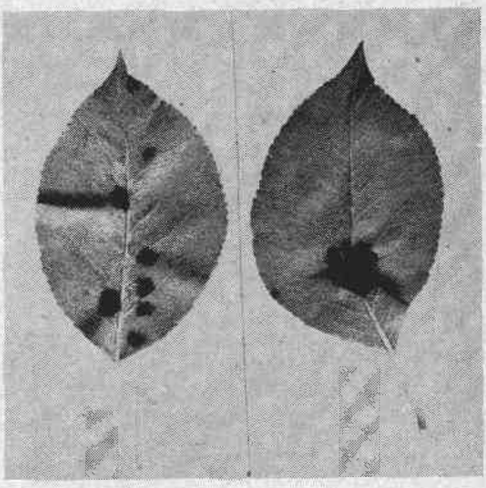

Figure 3. Scab infections on Bartlett pear leaves.

surface of the leaves than on the upper. Individual spots rarely become more than ¾ inch in diameter and look black, because of the compact growth of the olive-brown fungus. Sometimes the fungus threads radiate in less compact masses to produce a fernlike, irregular scab patch. Single scab spots are common on the leaves. They frequently envelop the midrib or leaf veins, causing considerable puckering or twisting of the leaf. As the scab spots age and dry out they may crack or tear, leaving a jagged, black-rimmed hole in the leaf. Scab infections decrease the capacity of the leaves to manufacture food for the tree. Numerous infections may cause the leaves to dry up, and drop prematurely, and continued attacks seriously devitalize the trees.

On the twigs

New twig growth on pear trees may be infected at any time during the growing season, but infections occur most commonly during spring months when rainfall is likely to be most frequent. During spring and summer new twig infections may remain invisible or appear merely as small, blisterlike cushions, often no larger than a pinhead. Occasionally a shallow, spore-producing stroma is formed. A corky layer sometimes forms beneath these twig infections and many are sloughed off during the growing season, leaving a small craterlike depression on the twig (Figure 4, middle twig). If the

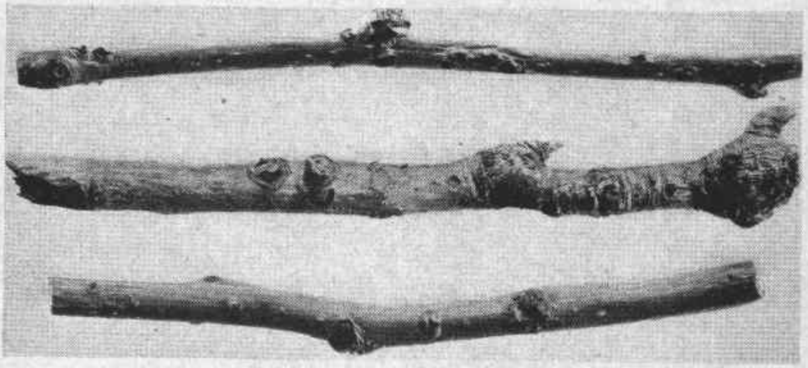

Figure 4. Scab pustules on Anjou pear twigs. Middle twig showing depressions remaining after pustules have been sloughed off.

twig infections are not sloughed off, the fungus remains dormant in the twigs until the following spring. With renewal of tree growth the fungus breaks through the twig covering forming a scab pustule (Figure 5), in which numerous scab spores mature usually before the blossom clusters separate. These twig lesions are generally sloughed off during the summer season, but occasionally a few remain and may form spores the second season. Evidence of previous twig infections is often seen on 2- to 5-year-old branches in the form of circular depressions.

Life History of the Fungus

The pear scab fungus has two distinct stages in its life cycle.

Fusicladium stage

During its summer, or Fusicladium stage, the fungus lives as a true parasite growing within the host tissue. When summer spores (conidia) are formed they break or push through the surface of

Figure 5. Twig scab pustules enlarged 15 X. Note that spores protected by overlapping cuticle may be difficult to contact with fungicides.

infected twigs, fruit or leaves. These spores are formed in great numbers on the tips of special branches (conidiophores) under favorable weather conditions, and are readily dispersed by rain and wind to cause new infections (Figure 6, *A*). Each spore, under favorable moisture and temperature conditions, is able to develop a tiny germ tube which may enter the host tissue and cause a new infection. Spore production and germination may occur many times during the season and numerous secondary infections may result.

This summer stage may also overwinter on the twigs, and because the spores are generally formed before the current-season susceptible host tissue is exposed to infection, it acts as the most important source for primary infections the following spring.

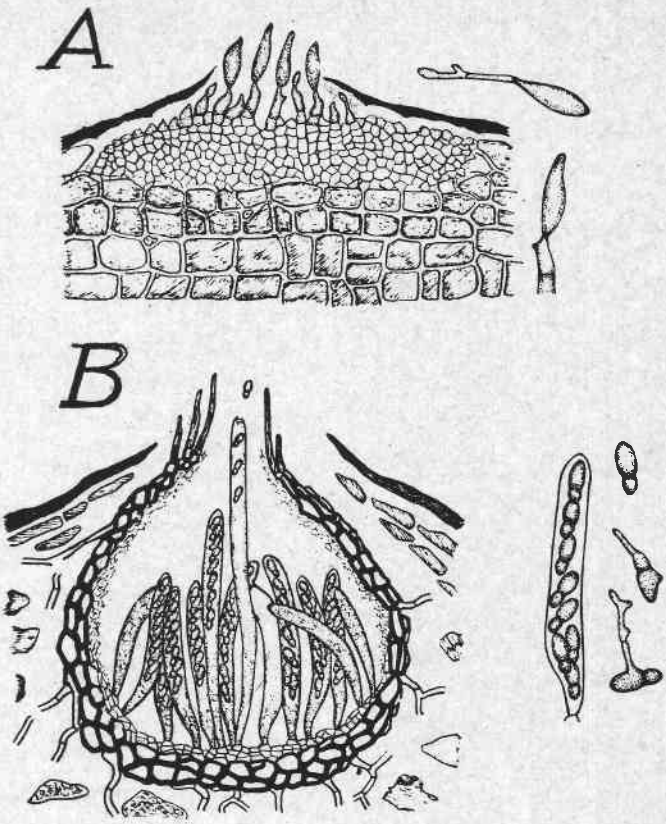

Figure 6. The vegetative and sexual stages of the pear scab fungus. *A:* cross-section through a twig pustule showing the one-celled conidia produced on conidiophores after the fungus has broken through the twig epidermis. Enlarged conidiophore and germinating conidium at right. *B:* cross-section of overwintered leaf with a perithecium containing asci, each with 8 two-celled ascospores (enlarged ascus and germinating ascospores at right).

Venturia stage

In addition to overwintering as a parasite on the twigs, the fungus may overwinter as a saprophyte on the infected leaves that drop to the ground. This is the saprophytic, or Venturia, stage of the fungus (Figure 6, *B*). During the winter thick-walled, flask-shaped beaked structures known as perithecia are formed within the old leaf tissue. Numerous tiny saclike structures, called asci, containing 8 small two-celled spores (ascospores) are produced within the perithecia. The ascospores usually mature about the time pear buds are unfolding, and when moisture and temperature conditions are favorable they are discharged through the beaks into the air. Air currents carry the ascospores to the trees, where they may germinate and cause primary spring infections. These infections soon produce conidia. Secondary infections occur when conditions are favorable for the fungus. Scab spores are disseminated only during moist periods. Continual moisture for 5 to 48 hours is necessary for the spores to germinate and infect susceptible pear tissue. If the temperature during the rainy period is about 75° F., a spore may germinate and infect the plant within approximately 5 hours. At lower temperatures moisture must persist for a correspondingly longer time, so that at 40° F. a wet period of approximately 48 hours is required before infection occurs. After infection has taken place, an incubation period of 12 to 25 days is required for the fungus to become visible to the naked eye. That is why scab lesions often appear during periods that seem unfavorable for scab infections.

Varietal Susceptibility

All of the pear varieties commonly grown in Oregon are susceptible to the scab fungus, but in different degrees. Fruits of Anjou, Bartlett, Comice, Winter Nelis, Easter Beurre, Forelle, Seckel, and Flemish Beauty are frequently severely affected. Bosc fruits are very susceptible in the young stage, or until they shed their pubescence; afterwards they become highly resistant. Oftentimes a variety only lightly affected in one district may be the most seriously affected of all varieties in another. The Easter Beurre, frequently planted as a pollinator variety for Anjou, is likely to develop more scab infections than Anjou, because its bud tissues unfold earlier. The delayed dormant spray is generally timed for the bud development of the more profitable Anjou variety, thus leaving Easter Beurre buds exposed to infection for a time before the first spray application is made.

Climatic conditions, fertilizers, pruning practices, soils, cover crops, and other factors all play a part in determining resistance to scab infections. Twig infections have never been observed on Bartlett in the Hood River Valley; yet, 20 miles to the west, where rainfall is twice that at Hood River, twig scab is common on this variety. Twig infections develop more often on the succulent water sprouts than on terminals from bearing wood.

The fungus also varies in its capacity to infect different varieties. One strain is known to attack Bartlett, but not the Anjou variety, while another infects Anjou but not Bartlett. Inoculations of young pear trees in the greenhouse (14)[1] with the fungus obtained from each variety proved that two strains existed. Each was specific in its host selection. The complete range of varieties that each strain will attack, and the total number of strains present in Oregon, is unknown.

Orchard Practices in Relation to Control

Special effort must be put forth to control pear scab. If trees are too crowded to allow proper movement of spray machinery through the orchards, trees should be thinned systematically. This is especially necessary where speed sprayers or dusters are being used. Trees should be pruned to give an open type of growth to facilitate proper aeration within the trees and to allow a thorough spray coverage to be made. It is often profitable to eliminate excessive water sprout growth during the summer, as this decreases the chance for some twig infections.

Portions of orchards that are unfavorably located and continue to be persistent sources of scab carry-over should be eliminated and the land used for other purposes.

When twig lesions are absent in the orchard, the primary spring infections originate from ascospores discharged from old fallen leaves, or from ascospores and conidia blown in from adjacent infected orchards. Early spring cultivation, to bury the old leaves or to keep them stirred up and thus prevent the orderly maturation of the fungus, will reduce the amount of inoculum for spring infections. Since many leaves remain undisturbed close to tree trunks, along fence rows, or on the ground adjacent to the orchard, this method of control is only supplemental to that of control by fungicides.

A method has been developed in the eastern United States to spray overwintered apple leaves on the ground in early spring to prevent the normal development of the apple scab fungus (6) (9) (10) (16). A dilution of dinitro-o-cresol (Elgetol or Krenite) at 0.5 per cent strength, used in amounts ranging from 400 to 600 gallons per acre, was found to prevent the discharge of about 95 per cent of the available ascospores from overwintering leaves. Later control of apple scab was then accomplished more easily with a regular spray program. Without the ground treatment, satisfactory control was difficult to obtain with cover sprays alone. Ground treatment for pear scab control in Oregon has little merit, because twig infec-

[1]Numbers in parenthesis refer to literature cited at the end of the bulletin.

tions are usually so prevalent during bad scab years that killing the spores on overwintering leaves would be of only secondary importance. The method could be tried if twig infections were absent.

Russet Injury on the Fruit

Some pear varieties must be free from surface blemishes to command the highest prices on the fresh fruit market. This is particularly true for Anjou and Comice, two of the choice tender-skinned winter varieties grown in Oregon.

Conditions that are known to cause russeting of fruits on tender-skinned pears are: (1) injuries due to insects, including blister mite, thrips (Figure 7), European red mite, and rust mites; (2) mildew

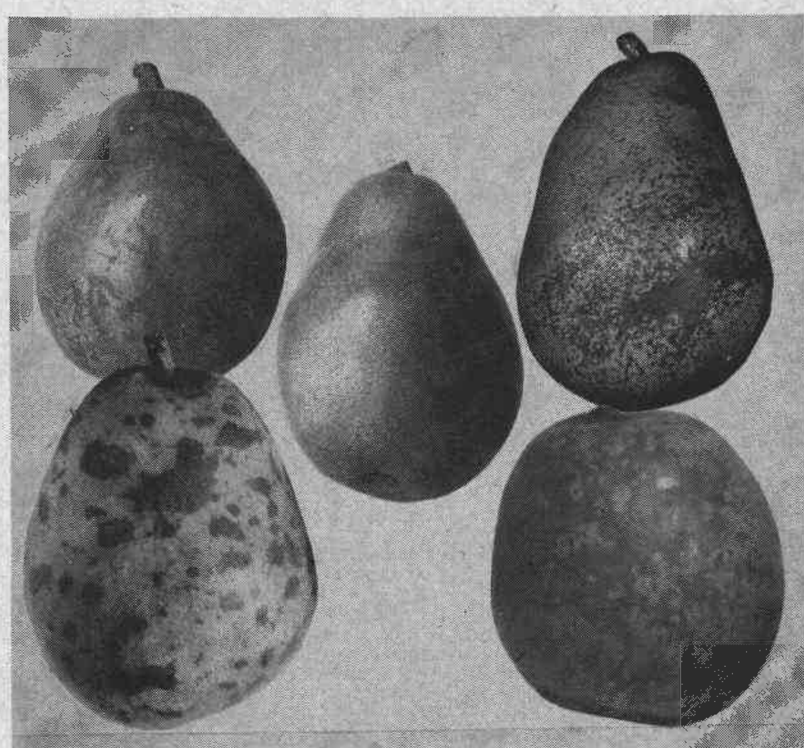

Figure 7. Some types of russet injury on Anjou pears. Middle pear russet-free. Top left, russet caused by bordeaux mixture; top right, frost russet; bottom left, lime-sulphur injury; bottom right, russet and deformity caused by thrips.

infection; (3) environmental factors including excessive moisture and frost injury (Figure 7); (4) inherent factors including mutations and phases of the black-end trouble of fruit grown on Oriental rootstocks; (5) mechanical injuries; (6) spray injuries (Figure 7). Frost damage occasionally occurs on very young fruit ovaries before the buds open, causing the epidermis to slip easily when rolled between the thumb and finger. The epidermis on unfrosted buds remains tight. Many of the frosted buds set and mature fruits, but the pear surface will generally be russeted, presumably because of a failure of certain epidermal cells to unite with active cells below after they have separated because of the frost damage.

Most fungicides tested so far cause definite russet on Anjou and Comice pears (12). The period of greatest susceptibility begins early in the season and lasts until the young fruits have shed their pubescence. This process is generally complete by the middle of June. By that time it is too late for effective control of scab even though sprays that would cause injury earlier can be used safely. Unfortunately the weather conditions that favor scab infection aggravate russet caused by fungicides. For this reason the spray schedule is generally planned for the spray-sensitive varieties, especially if the orchard contains mixed varieties.

The orchard environment and weather conditions exert an influence on the fruit finish at maturity. Excessive moisture for considerable periods in the form of rain, dews, fog, or high humidity may cause russeting of pears. Fungicides that do not cause russet in an orchard with proper air drainage may cause excessive russet in an orchard where excessive moisture persists. Even unsprayed fruit from the latter type of orchard tends to be russeted or inferior in quality. These relationships are illustrated in Table 1, which com-

Table 1. EFFECT OF WET AND DRY LOCATIONS IN THE PRODUCTION OF FRUIT RUSSET ON ANJOU PEARS

Spray treatment	Cover sprays	Year tested	Total fruit russet: Wet orchard	Total fruit russet: Dry orchard
	Number		*Per cent*	*Per cent*
Unsprayed trees	0	1939	50.0	7.2
Copper phosphate	2	1939	26.0	0
Wettable sulphur	2	1939	51.2	0.4
Unsprayed trees	0	1940	63.0	8.4
Copper phosphate	3	1940	79.1	12.4
Wettable sulphur	3	1940	68.9	14.2

pares the amount of fruit russet on unsprayed fruit with that sprayed with copper phosphate or wettable sulphur over a period of 2 years in orchards of these types.

Control by Fungicides

Dormant sprays

It is desirable to use lime-sulphur or lime-sulphur-oil (3) consistently as a delayed dormant spray on pear trees in Oregon. When this application is omitted, the fruit is generally russeted to some degree, either from mildew, blister mites, or other russet-producing organisms.

Scab infections on pear twigs, when they are present, are more important sources of primary spring infections than the stage of the fungus produced that overwinters on fallen leaves (11). Spores are generally shed from some twig lesions before the pear buds open and expose the susceptible tissues. Furthermore, although spores are shed

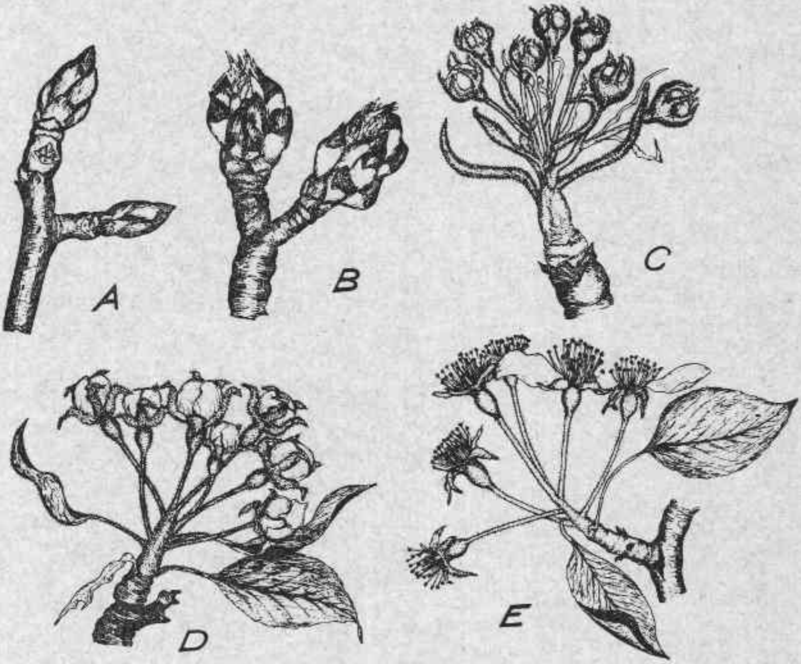

Figure 8. Anjou pear bud development in relation to spray dates: *A:* Dormant buds. *B:* Delayed dormant stage (green tip). *C:* Pre "pink" stage (green bud). *D:* "Pink" stage (preblossom). *E:* Calyx stage (petal fall).

from 90 per cent or more of the twig lesions by the time of the delayed dormant period (Figure 8) of bud development, a small percentage may begin to sporulate after this time. For this reason, the lime-sulphur application is delayed as long as possible in order to "burn out" as many twig lesions as possible without causing damage to exposed pear buds. Lime-sulphur will usually cause severe russet on tender-skinned varieties, when applied in the more humid districts, after the outer bud scales drop; but it is frequently used somewhat later without injury on some varieties in the less humid Rogue River Valley.

Lime-sulphur was found to be the most effective material for destroying the spore masses within twig lesions. The fungicide exerts a caustic action that kills the spore-bearing surface even under the protective covering of the pustule, so that new spores are not

Table 2. EFFECT OF FUNGICIDES ON GERMINATION OF CONIDIA FROM SCAB PUSTULES ON TWIGS

Treatment	Average spore germination from pustules		Years tested
	At center*	At edge†	
	Per cent	*Per cent*	*Number*
Unsprayed	76.9	81.4	4
Lime-sulphur 4-100	0	27.5	1
Lime-sulphur 6-100	0	3.3	3
Lime-sulphur 8-100	0.4	2.7	3
Lime-sulphur 10-100	0	1.6	4
Lime-sulphur 6-100 plus dormant oil 3 gallons	2.4	7.5	2
Lime-sulphur 6-100 plus dormant oil 1 gallon	0	0.8	1
Lime-sulphur 3-100 plus dormant oil 3 gallons	0	24.7	3
Dry lime-sulphur 12-100	0	27.3	1
Dry lime-sulphur 24-100	0	12.2	2
Wettable sulphur 6-100 plus dormant oil 3 gallons	0	20.0	1
Dormant oil 3 gallons to 100	77.3	77.0	2
Bordeaux 8-100 plus dormant oil 3 gallons	9.7	38.0	1
Basic copper sulphate 3-100 plus dormant oil 3 gallons	63.3	59.6	2
Copper oxychloride 4-100 plus dormant oil 3 gallons	77.8	45.8	1
Copper phosphate 4-100	31.5	65.0	1
Copper phosphate 4-100 plus dormant oil 2 gallons	40.0	45.0	1
Dinitro-o-cresol 0.5 per cent	35.7	35.3	2
Dinitro-o-cresol 2 per cent	38.5	29.6	2
Malachite green 1-10,000 dilution	31.3	60.6	1

* Spores completely exposed.
† Spores protected in the lesion by the epidermis of the twig. (Figure 5.)

formed under moist conditions. Other fungicides, like wettable sulphur and bordeaux mixture, kill only a small percentage of the spores, and do not penetrate under the epidermal covering of the pustule. Lime-sulphur at 6 gallons to 100 gallons of water was found to be about the minimum concentration that gave effective results against twig spores. Thorough coverage of the twigs is essential, since the fungicide kills the spores only by contact. The effect on spore germination of various fungicides sprayed on open twig pustules is shown in Table 2.

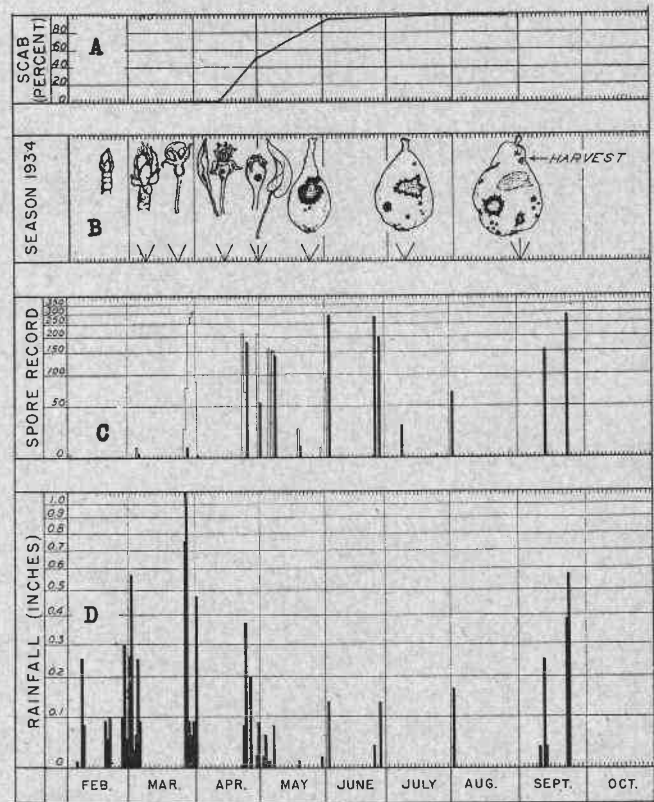

Figure 9. Rainfall and spore records in relation to pear scab, 1934. *A:* Scab infection on fruit of unsprayed trees. *B:* Stages of development and infection of buds, blossoms, and fruit. *C:* Record of spores caught; open columns represent number of ascospores per square millimeter from captive leaves (only 3 ascospores were caught during the season on slides hanging in the trees), black bars represent number of conidia per square inch (6.5 square centimeters) caught in orchard. *D:* Record of rainfall.

By hanging glass slides with vaselined surfaces in the trees, some idea of the number of spores being disseminated within the trees is obtained. Microscopic examination of these slides during several seasons established the importance of overwintering twig lesions as a source of primary infections. A graphic illustration (Figure 9) for the 1934 season is typical of these findings.

Dispersal of ascospores from overwintered leaves, or conidia from twig lesions, or later fruit and leaf infections, occurred only during periods of rainfall. The ascospore records illustrated in Figure 9 are from slides placed directly over overwintered leaves on the ground. Only three ascospores were caught during the entire 1934 season on the glass slides hanging in the orchard trees. On the other hand, the small numbers of conidia dispersed from overwintering twig lesions during March initiated primary infections. Numerous secondary conidia were caught during the next rainy period late in April. Since only a few primary infections are necessary to produce many spores for secondary infections, the initial infections from conidia or ascospores must be largely prevented to realize satisfactory

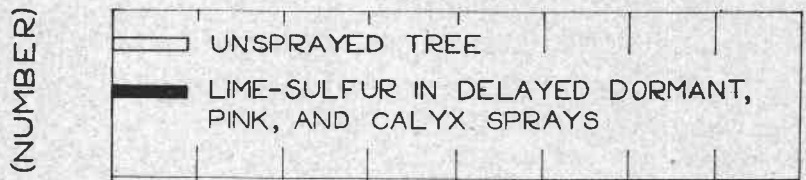

Figure 10. Effect of spray on dispersal of conidia, 1934.

scab control. Spores from twig lesions, when they are present, are able to establish primary infections more easily than ascospores because of their favorable location within the trees.

Glass slides hung in one unsprayed tree, and in one receiving three rather poorly timed lime-sulphur applications in 1934, were examined for number of spores caught throughout the season. The effect of spraying upon the number of spores disseminated in a tree is shown in Figure 10.

More spores were caught in the trees from 2 to 8 feet above ground level than at 16 feet, but the latter have a better chance to be scattered about by rain to contact susceptible tissues.

Cover sprays

Since some twig infections may produce spores later than the delayed dormant period, and since ascospores produced on fallen leaves usually mature after this period, it is necessary to apply cover sprays to protect new growth from scab infections.

Fungicides tested as cover sprays for scab control may be conveniently classified into three groups: (1) those causing definite injury on fruit or foliage, but otherwise might give efficient scab control; (2) materials that commonly caused no injury but failed to control scab; (3) a group giving fair to good scab control without causing commercial injury most seasons. The fungicides falling in each group are listed below:

GROUP 1—fungicides causing russet or foliage injury on Anjou pears: basic copper sulphate, bordeaux mixture, Copper-Bordo, copper oxides (red or yellow forms), copper oxalate, copper silicate, copper hydro "40," copper oxychloride, copper acetonate, liquid lime-sulphur, dry lime-sulphur, ammonium polysulphide, flotation sulphurs, colloidal sulphurs, gas-house sulphurs, micronized wettable sulphurs, polyethylene polysulphide, Dithane D-14, Isothan Q15, Puratized Agricultural Spray, and Phygon.

GROUP 2—fungicides giving inadequate scab control: copper oxide (black), phenothiazine, zinc-Bordo, zinc sulphate, 66A, fused bentonite sulphur, wettable sulphurs exceeding 325-mesh, morpholine thiuram disulphide, fungicide 341C, and Preventol GD.

GROUP 3—fungicides giving fair to good scab control without causing commercial injury most years: wettable sulphurs of approximately 325-mesh, copper phosphate mixture, and the iron and zinc salts of dimethyl dithiocarbamate (ferbam and ziram).

Of all fungicides tested on Anjou pears prior to 1941, only copper phosphate mixture compared favorably with the wettable sulphurs, which were standard for scab control on the variety up to

Table 3. PERCENTAGE OF FRUIT SCAB AND RUSSET INJURY ON SPRAYED AND UNSPRAYED ANJOU PEAR TREES IN THE SAME ORCHARD

Year	Number of cover sprays	Unsprayed trees		Copper phosphate		Wettable sulphur†	
		Scab	Russet*	Scab	Russet*	Scab	Russet*
1935	4	30.4	1.2	2.4	2.0	4.1	2.5
1936	3	9.0	6.9	0.8	3.3	0.8	20.1
1938	4	32.5	18.9	1.3	13.8	1.9	86.0
1939	2	0.3	50.0	0.0	26.0	0.2	51.2
1942	4	56.4	5.3	8.6	8.4	9.9	86.8
1943	3	79.2	9.0	21.3	4.0	47.2	37.9
1944	3	79.3	11.1	19.7	8.6	10.3	68.1
Average	....	41.0	14.6	7.7	9.5	10.6	50.4

* Injury sufficient to lower fruit grade from extra-fancy to fancy or lower by western grading rules.

† Wettable sulphur of 325-mesh except in 1942 when micronized wettable sulphur was used.

that time. Its favorable showing in scab control and russet injury as compared with wettable sulphur is evident in Table 3. Because of the bulky nature of the copper phosphate mixture (5), to which orchardists objected, and since it is no longer commercially available, it has been discarded. Bordeaux mixture, and some of the prepared copper fungicides have been found to be safe and effective fungicides for the Comice variety in the Rogue River Valley, but sulphur in any form in the cover sprays is extremely injurious.

An increasing number of new organic fungicides have been introduced since 1940 (4). Many of these have been tested for pear scab control, and several have been found promising for use on pear trees. Most encouraging results have been given by the iron- (ferbam) and zinc- (ziram) dimethyl dithiocarbamates. The comparative merits of ferbam, copper phosphate mixture, and wettable sulphur in scab control and fruit injury are shown in Table 4.

Those varieties intended for cannery purposes (Bartlett), or on which a russet skin does not cause a lowering of the grade (Bosc), may be sprayed with more caustic fungicides. In the case of Bartlett pears for cannery use, lime-sulphur was the most effective spray in controlling scab in heavily infected orchards (Table 5). It has an advantage over the purely protective fungicides in being both an eradicant and a protective fungicide. It may cause serious injury if used when temperatures are around 90° F., or if followed by an oil spray within 45 days. All of the copper fungicides tested, if not causing an actual russet injury on the fruit, intensified any russet already present from other causes.

Table 4. COMPARATIVE CONTROL OF FRUIT SCAB AND RUSSET ON ANJOU PEARS

Spray treatment*	1942		1943		1944	
	Scabby fruit	Fruit russet	Scabby fruit	Fruit russet	Scabby fruit	Fruit russet
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Unsprayed check trees	56.4	5.3	79.2	9.0	79.3	11.1
Copper phosphate 4-4-4-100	8.6	8.4	21.3	4.0	19.7	8.6
Wettable sulphur, 325-mesh, 8-100	.....	.....	47.2	37.9	10.3	68.1
Wettable sulphur, micronized, 8-100	9.9	86.8	36.0	50.2	10.3	71.0
Ferbam 1½-100	3.8	2.0	8.0	0.6	5.0	3.6

* Four cover sprays in 1942; 3 each in 1943 and 1944.

Table 5. SCAB CONTROL AND RUSSET INJURY IN HEAVILY INFECTED BARTLETT PEAR ORCHARD DURING 1944

Spray treatment*	Per cent fruit scab	Per cent leaf scab	Per cent fruit russet injury
Unsprayed check trees	94.9	83.0	0.0
Ferbam 1½-100	25.5	41.9	0.0
Bordeaux 4-4-100	12.2	11.5	37.2
Lime-sulphur 3-100 in "pink"; 2-100 later	8.9	7.2	0.0

* In three cover applications.

Table 6. RELATION OF THE POSITION OF FRUIT ON THE TREE TO SCAB CONTROL AND RUSSET INJURY ON ANJOU PEARS FOLLOWING SPRAYING WITH WETTABLE SULPHUR

Fruit location on tree*	Per cent scab	Per cent russet
Bottom third	10.0	62.0
Middle third	14.5	27.3
Top third	23.2	16.9

* Trees averaged approximately 25 feet in height.

A well distributed and properly timed coverage is essential to obtain satisfactory scab control regardless of the fungicide used. The average operator applies too much spray to the lower and too little to the top half of a tree (2). If a greater amount of the fungicide could be deposited in the tops of the trees, considerable redistribution of the fungicide to unprotected new growth would occur during rain periods (7). Failure to adjust the spray nozzle to a fog type mist when spraying the lower portions of a tree often drives fine spray or dirt particles (if dirty spray water is used) into the fruit surface. Such minor injuries on tender-skinned pears develop into a russeted fruit surface. The effect these practices have in influencing scab control and fruit russet when using wettable sulphur fungicides is shown in Table 6.

Effect of Fungicides on Anjou Pear Yields

Wettable sulphur fungicides were used almost exclusively to control pear scab in Oregon prior to 1943. Field observations during this time indicated that sulphur sprays often seemed to reduce the fruit set of Anjou pears when compared with unsprayed trees, and to produce a poor foliage color as well. A preliminary test in 1942 gave further confirmation of this effect of sulphur on Anjou pear yields. Special plots were selected during the next 3 years to test the effect of fungicides in their relation to fruit yields. Each plot received a delayed dormant application of either lime-sulphur or lime-sulphur plus oil emulsion to control insect pests and the over-wintering scab lesions on twigs. Three cover spray applications ("pink," calyx, and first cover) of the selected fungicides were applied after the delayed dormant period during each test year (13).

To determine the fruit set on the trees, all the blossoms on the trees were counted during 1943 and 1944, and blossoms on one large leader branch were counted in 1945. Fruits maturing after the "June drop" were counted to determine yields. Three replicated plots were used in 1943, 6 in 1944, and 12 in 1945. The effect of three fungicides on the set of fruit of Anjou pears is given in Table 7.

Table 7. EFFECTS OF 3 FUNGICIDES UPON THE SET OF FRUIT OF ANJOU PEARS

Treatments	Per cent of blossoms setting and fruits maturing		
	1943*	1944	1945
Unsprayed check trees	0.27	3.4	2.84
Wettable sulphur 8-100	0.11	1.9†	1.8†
Ferbam 1½-100	0.17	2.5	3.04
Copper phosphate mixture 4-4-4-100	0.25	3.5	3.71†

* Frost damage and poor pollination.
† Results differ significantly from those of corresponding check at the 5 per cent level.

Previous evidence had indicated that the delayed dormant sprays had no adverse effect upon fruit set. Additional tests showed that a single calyx application of sulphur caused the greatest reduction in fruit yields, but that each additional application was cumulative in effect, so that a full spray program of sulphur caused the greatest loss in fruit yields.

Ferbam was first used commercially in the Hood River Valley to replace sulphur in pear scab control during 1944. By 1945 sulphur sprays were almost entirely replaced by ferbam for this purpose. It is interesting to follow the commercial production of Anjou pears since that time. In Figure 11 it will be noted that up to 1944 Anjou pear trees tended to bear fruit in alternate years. In fact, an old saying among orchardists was that if an Anjou tree bore two

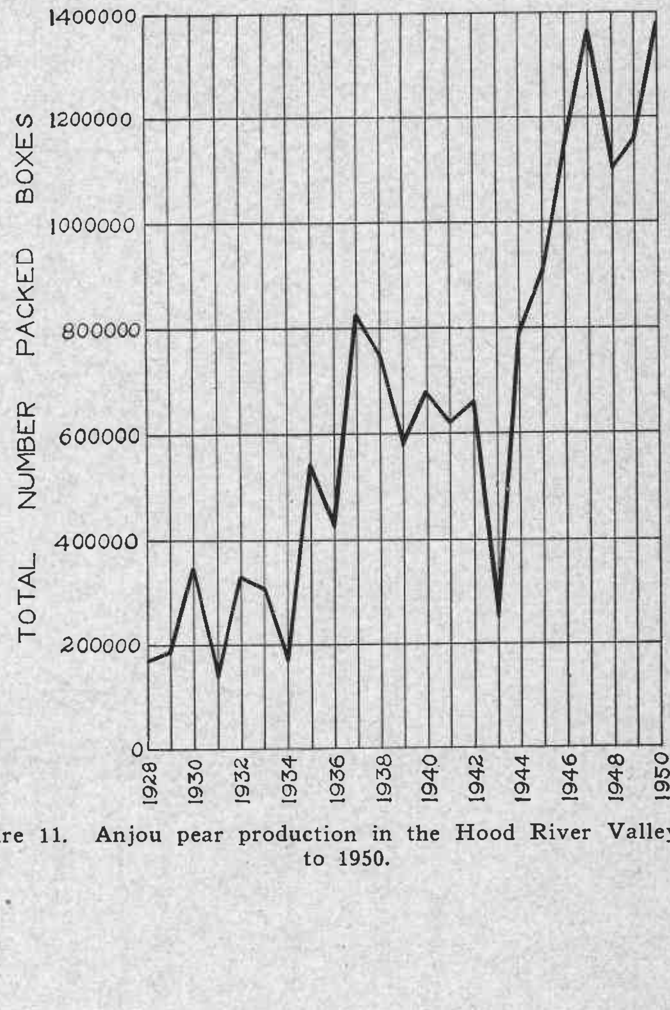

Figure 11. Anjou pear production in the Hood River Valley, 1928 to 1950.

crops successively, it was sure to "lay off" the third year. Since the adoption of ferbam or ziram in place of wettable sulphur, beginning in 1944, Anjou pear production steadily increased for 6 years, almost doubling the previous high yield. Unfavorable pollination weather during 1948 decreased yields somewhat, but the yield for 1948 was greater than the highest yield previous to 1944. Advancing tree age, weather conditions, and other factors may have partly contributed to this increased yield, but much of it can be attributed to the substitution of ferbam and ziram for wettable sulphur. Based on an approximate 30 per cent increase in fruit set determined from actual blossom counts, it is estimated Anjou pear tonnage was increased in the Hood River Valley on an average of about 300,000 boxes per year for the period 1944 to 1950. Savings in handling costs, storage space, improved fruit quality, and better tree vigor are other benefits derived from using ferbam in place of sulphur.

The Spray Schedule

For scab control

The spray schedule for pear scab control will vary somewhat according to weather conditions, seasonal development, the amount of scab previously present in the orchard, varieties involved, and other pests.

The first application should consist of 6 to 8 gallons of liquid lime-sulphur or its equivalent (32° Baumé) to 100 gallons of water. If aphids, European red mites, or San Jose scale are also present, 3 per cent dormant oil should be added to 6 to 100 lime-sulphur spray solution after the spray tank is nearly full. The spray should be applied at the delayed dormant stage of bud development (green tip stage) (Figure 8). Maximum control of the twig scab pustules will be obtained if the application is delayed so that a few of the outer bud scales are shattered off during the spray operation.

The second spray application recommended for spray-sensitive varieties consists of commercial brands of ferbam or ziram at 1½ pounds to 100 gallons of water. (The commercial brands contain about 76 per cent of the pure chemical.) If spring weather is cool so that buds open slower than usual, the spray should be applied at the pre"pink," or green bud stage (Figure 8). When seasonal development is normal, this application is generally applied at the "pink" or preblossom period only (Figure 8). Both a pre"pink" and "pink" spray should be applied if the buds are slow in opening.

A third spray application of ferbam or ziram 1½ to 100 is generally necessary at the calyx period (Figure 8).

Additional applications of ferbam or ziram at 15 to 20 day intervals may be advisable if the season is excessively rainy.

Bordeaux mixture or prepared copper fungicides may be substituted for ferbam or ziram on Comice pears in the Rogue River Valley, but sulphur in any form should never be used on this variety after the delayed dormant period. On varieties not sensitive to the action of sulphur (Bartlett and Bosc), lime-sulphur 2½ gallons to 100 gallons of water is recommended through the calyx period, or until hot weather may be expected.

When some scabby fruits or leaves are present on the trees after midsummer, a late outbreak of scab may appear if heavy dews or fall rains occur. It may be advisable, under such conditions, to add ferbam or ziram at 1 to 1½ pounds to 100 gallons of water with the last codling moth spray to protect the fruit from late scab infections or storage scab. This practice is not recommended generally because of the difficulty in removing the spray residues after late applications. Careful planning of the early schedule will usually make late applications unnecessary.

Combination sprays

It may be necessary to consider the control of other pests in the pear scab control program. Ferbam or ziram do not give commercial control of powdery mildew. A fused bentonite sulphur (Kolofog) was found to cause no russet on Anjou pears, although it failed to control scab at Hood River. The use of a mixture of 1 to 1½ pounds of ferbam or ziram with 4 pounds Kolofog to 100 gallons of water gave good control of both scab and mildew.

Ferbam and ziram are compatible with most of the newer insecticides. Lime and calcium compounds (including casein type spreaders) decrease their effectiveness in scab control. While oil can be used safely with ferbam or ziram, it should not be used with them late in the season because of the difficulty in removing spray residues. Lead arsenate or DDT is safe in the combinations, and one or the other is usually added for codling moth control.

Since several of the newer insecticides are showing promise for the control of specific pests, and others are constantly being tested, growers should contact their County Extension Agent or Oregon State College for the latest recommendations on combination sprays.

Caution

Many of the new fungicides and insecticides are either inflammable or poisonous. All growers are cautioned to adhere strictly to the instructions for the use of these compounds given by manufacturers on the package labels.

Spray Equipment

The results reported in this publication were obtained with a portable spray machine and conventional hand spray gun. Since the completion of this work, many new types of spray applicators have appeared on the market. Results on scab control with these new machines have been carefully observed during the past three years.

Speed sprayers appear to give satisfactory scab control if the machines travel at approximately 1½ miles per hour. Sufficient time must be allowed to blow out the air surrounding a tree so that spray-laden air blown in may replace it. Liquid sprays are more effective in scab control than the same fungicides used as dusts. Dusting may give fairly good scab control when infections are not numerous, or when large acreages must be covered. Less is known about steam generating types of applicators for scab control, but weather conditions must be much more ideal for them to obtain proper spray coverages.

The new applicators may not leave as heavy a spray deposit as is obtained by hand spraying, but they do make it possible to cover an orchard rapidly in a shorter time. When weather reports indicate a major rainstorm may be due, it is usually possible to apply a protective fungicide over the whole orchard ahead of the rainy period, whereas with the slower portable equipment, time might be available to cover only a portion of the orchard. Regardless of the equipment used, it is still necessary to apply thoroughly, and time properly the fungicide applications to obtain satisfactory scab control.

Behavior of Pear Scab in Storage

Three questions often asked by fruit growers or cold storage operators about pear scab are: (1) Does the scab fungus spread from fruit to fruit in the storage house? (2) Do individual scab spots continue to increase in size during the storage period? (3) What effect other than causing unsightly appearance does scab exert during the storage life of the fruit?

Source of scabby pears in storage

It has been established for the related apple scab fungus that new infections in storage originate from late field infections, and that spread from fruit to fruit in storage does not occur. Bratley (1) briefly reviewed this work and has offered convincing proof of these statements.

A comparable behavior for pear scab was assumed by Wiant and Bratley (17), but specific tests with pears appear to be unreported in the literature.

Clean appearing pears picked from scabby unsprayed trees were placed in storage during five different seasons at Hood River. The amount of storage scab appearing on these fruits is shown in Table 8.

Table 8. EFFECT OF PREHARVEST RAINFALL ON THE DEVELOPMENT OF SCAB IN STORAGE ON CLEAN APPEARING FRUITS PICKED FROM SCABBY, UNSPRAYED TREES

Year	Pears developing new scab spots in storage	Scabby pears, unsprayed trees	Rainfall 30 days to harvest	Number of rainy days
	Per cent	*Per cent*	*Inches*	
1932-33	0.7	90.5	0.23	2
1933-34	75.0	99.4	0.53	6
1935-36	34.6	30.4	0.27	3
1941-42	29.0	96.9	0.99	7
1942-43	13.6	56.4	0.02*	1

* Infection resulted in the field entirely from heavy dews.

It appears that several factors determine the amount of infection that may occur in the field toward the harvest period. The length of time moisture remains on the fruit appears to be the most important factor if spores are present to cause infection. It is commonly believed that rain is necessary before infections will occur. In this connection it is of interest to note in Table 8 that during the 1942-43 season infection resulted without a rain of sufficient duration to form an infection period. Extremely heavy dews during late August and early September of 1942 caused an actual drip from fruit to fruit which caused wetting long enough for infection to occur. These data furnish proof that pears appearing free from scab at the harvest period developed visible scab spots during the cold storage season.

In a second test nonscabby pears from directly beneath scabby pears on unsprayed and sprayed trees, so located that they could hardly escape the inoculated drip water from above, were picked, individually labelled, wrapped in copper-treated paper, and placed in cold storage. The data on amount of storage scab developing from such fruit are presented in Table 9. They are similar to those reported for apple scab (1) in showing that new scab development in storage is inversely proportional to the amount of fungicidal protection afforded the fruit on the trees previous to the harvest period.

Pears from nonscabby orchards have been inoculated in moist chambers with spore suspensions, placed in contact with scabby pears, and run through washing machine water contaminated with scab spores. Scab spots have failed to appear on the fruit during its cold storage life when inoculated by these methods after the pears had been picked from the trees.

Table 9. PER CENT OF APPARENTLY SOUND ANJOU PEARS FROM SPRAYED AND UNSPRAYED TREES DEVELOPING SCAB IN STORAGE

Season and treatment*	Pears developing new scab spots in storage	Field infection on unsprayed trees	Rainfall 30 days to harvest	Number of rainy days
	Per cent	*Per cent*	*Inches*	
1941-42				
Unsprayed	29.0	96.9	0.99	7
Wettable sulphur 8-100	10.0	......	......	....
Copper phosphate 4-4-4-100	2.0	......	......	....
1942-43				
Unsprayed	13.6†	56.4	0.02	1
Wettable sulphur 8-100	2.0	......	......	....
Copper phosphate 4-4-4-100	0	......	......	....
Ferbam 1½-100	0	......	......	....

* Four cover sprays applied after delayed dormant lime-sulphur. Last cover spray applied during June.

† Infections occurred during heavy dews at night. Rain period too brief to allow spores to germinate.

Enlargement of scab spots in cold storage

The actual enlargement of 550 scab spots in storage has been recorded for two seasons. The majority of these continued to make some growth after the fruit was placed in either common or cold storage. In common storage the increase in size was more rapid than in cold storage. In the latter case the spots enlarged more rapidly as the fruit approached its maximum storage life. An area increase of nearly 300 per cent was recorded in a few cases, but in general the enlargement of the scab spots was less than half this amount. Fruit that had received certain spray treatments in the orchard or that had been subjected to commercial washing treatments generally showed a retarded scab spot development, but considerable variation on individual fruits occurred.

The pear scab fungus appears to follow closely the behavior of the apple scab fungus in storage (1). The actual diameter enlargement of any scab spot during the storage life of the fruit rarely exceeded 1 to 2 millimeters. Although the increase in size is definite, the actual commercial loss from such slight enlargement is comparatively insignificant. The enlargement of scab spots that are visible when the fruit is placed in storage should not be confused with the development of spots on fruit apparently free from scab when stored. These latter cases are in reality field infections that were not visible at the time of storage. When several or many of these appear per fruit, a serious reduction in quality and value may result even though the individual spots never enlarge much in size.

Comparison of weight loss by scabby and sound pears in cold storage

Hilitzer (8) reported that scabby pears transpired more rapidly than sound pears, and that those heavily attacked by scab always contained less water than healthy fruit. No correlation could be established, however, if the fruit was only slightly affected.

During two seasons sound and scabby Anjou pears picked from the same trees were wrapped and packed, and their storage weights recorded. The behavior of the fruit during the 1942-43 season after a period of 5 months in cold storage is typical. The weight differences in this test are given in Table 10.

It is of interest to note that a greater loss of weight occurred in the top and bottom layers of the box than in the three middle layers. This is in accord with other observations indicating that humidity is higher at the centers of packed boxes of fruit. A trend toward increased water loss with increase in scab spot size was indicated, but a correlation was not definitely established.

Table 10. LOSS IN WEIGHT OF SOUND AND SCABBY ANJOU PEARS AFTER 5 MONTHS IN COLD STORAGE, 1942-43

Layer in box	Sound pears: Average loss per fruit		Scabby pears: Average loss per fruit	
	Grams	*Per cent*	*Grams*	*Per cent*
Top	7.8	4.2	10.0	6.7
2	5.4	3.0	6.3	3.8
3	5.2	2.8	5.3	3.0
4	5.0	2.5	6.7	3.8
Bottom	8.1	4.0	10.4	5.8
Mean values*	6.3	3.3	7.7	4.6

* $s = Sx^2/(n-1) = 2.85657$; significant at 1 per cent level with 30 pairs.

It was noticed that fruit tissue surrounding active scab lesions usually ripened first in storage. Whether this is an indication that the scab fungus produces ethylene as has been reported for *Penicillium* by Miller, Winston, and Fisher (15), or that the gas emanates from the fruit tissue, was not determined.

Table 10 shows that a greater loss in weight occurs in scabby than in sound pears during the cold storage period. The data are highly significant. Many of the test pears bore scab lesions that would ordinarily not be packed in commercial grades. A smaller difference in weight loss could be expected between sound pears and scabby fruit which would pass grading regulations. Considering that only ½ pound difference in weight per box in the experimental lots occurred, the loss in weight of commercially packed scabby pears over that of comparable sound fruit should hardly cause great concern to the fruit industry. Scabby fruit naturally is undesirable. The present report merely indicates that field infections cause the greatest loss in value, and that after scab becomes visible on the fruit in storage, only slight additional loss may be expected.

Summary

Scab consistently reduces the income from Oregon's pear crop more than any other disease. It has been especially troublesome since 1932. The symptoms of pear scab are described and illustrated on the fruit, leaves, and twigs.

The life history of the scab fungus is discussed. The fungus may overwinter in two ways: (1) in infected leaves that drop in the fall, or (2) as twig infections on current season's shoot growth. The fungus in overwintering leaves produces perithecia in which sexual spores (ascospores) form in the spring. These spores, when mature, are "shot" into the air to be carried by air currents to the trees where they initiate primary spring infections. Twig infections remain dormant and invisible during the winter season. Even before susceptible bud tissue is exposed in the spring, twig pustules break open to expose a mass of summer spores (conidia), which cause primary spring infections as soon as host tissue is exposed and weather conditions are favorable for the fungus.

Scab infections occur only during wet weather, but scab spots require 12 to 25 days to become visible after the infection period. Dense trees or any practice causing slow evaporation will favor scab infections.

All pear varieties grown in Oregon are susceptible to scab infections, but some varieties appear to offer resistance in certain districts, or within orchards of the same district. Strains of the scab fungus exist which may attack only one pear variety or a small number of varieties.

Trees should be pruned and spaced to allow proper air movement within the trees, and to facilitate thorough spray coverages. Spring cultivation may assist in preventing primary infections by reducing chances for ascospore production in the overwintering leaves. Ground spraying for the same purpose is mentioned; but either practice would be effective only in the absence of twig infections.

Some causes of fruit russet are listed and the injuries are illustrated. Russet caused by fungicides under different environmental conditions is discussed.

A minimum of 6 gallons of lime-sulphur to 100 gallons of water is necessary in the delayed dormant spray to inactivate twig scab pustules. Three gallons of oil emulsion may be added for insect control if needed. The application should be delayed until a few of the outer bud scales are shattered off during spraying. *The secret of successful scab control is in the prevention of primary spring infections.* Cover applications at pre"pink", (if the season is cold),

"pink," and calyx are generally necessary for successful scab control. Later applications may be needed during excessively rainy seasons. Ferbam or ziram at 1½ pounds to 100 gallons of water is recommended for spray-sensitive varieties. Copper sprays may be substituted on the Comice variety in the Rogue River Valley, if desired. Lime-sulphur at 2½ gallons to 100 gallons of water is suggested on varieties not susceptible to spray injury. Certain principles of proper spraying are discussed.

Insecticide and fungicide combinations compatible with ferbam or ziram are discussed, and suggestions are given for a combined insect and disease spray program. The successful use of speed sprayers for this purpose has been observed. Spray timing according to stages of bud development is illustrated.

The effect fungicides may have on fruit set is indicated. The upward trend of commercial Anjou pear production in the Hood River Valley after the substitution of ferbam or ziram for the wettable sulphurs, is graphically shown.

Pear scab in storage is shown to originate as field infections previous to the harvest period. New infections do not occur on pear fruits after they are picked from the tree. Visible scab spots enlarge only slightly on stored fruit. Scabby pears transpire and lose weight more rapidly than sound pears in storage, but generally less than 1 pound per box difference can be measured after 5 months in cold storage.

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