# Fungi and Shell Bark of Lemon

## complex disorder of bearing lemon trees studied to establish role of fungi and control of the disease

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**The best and cheapest** shell-bark control—the only real control—is the use of resistant lemon selections on good root-stocks.

Control or prevention of small shell-bark lesions by fungicidal treatment is probably impossible because of the fact that many such lesions develop in the absence of fungi.

A detailed examination of many trees revealed that shell-bark lesions followed the appearance of small spots of dead tissue in the middle bark. Microscopic examination and approximately 1,000 attempts to culture fungi from these internal lesions showed no fungi present in them.

In direct contrast, large external lesions were full of fungi. Advancing margins of shell-bark lesions in ten orchards were sampled and placed in culture dishes or tubes to determine the fungi most commonly present. The results of fungus isolations from three orchards in three climatic situations—Riverside, Corona, Ventura—are shown in the table on this page.

**Percentages* of Shell Bark Margins Yielding Listed Organisms.**

| Organism | Present in margins at River-side % | Corona % | Ventura % |
|---|---|---|---|
| No growth | 4 | 10 | 8 |
| Alternaria | 20 | 11 | 5 |
| Bacteria | 58 | 34 | 47 |
| Botrytis | 0 | 0 | 1 |
| Cephalosporium | 6 | 7 | 6 |
| Cladosporium | 1 | 3 | 0 |
| Colletotrichum | 3 | 8 | 0 |
| Diplodia | 4 | 1 | 0 |
| Dothiorella | 1 | 4 | 4 |
| Fusarium | 5 | 13 | 0 |
| Penicillium | 0 | 1 | 1 |
| Phoma | 4 | 0 | 0 |
| Phomopsis | 3 | 6 | 71 |
| Other fungi | 30 | 29 | 5 |

* Total number of lesion margins sampled: Riverside, 158; Corona, 100; Ventura, 200. Some margins contained two or more organisms.

### Inoculation Tests

Many observations and data suggested that several fungi might be important in the enlargement of shell-bark lesions when the environment and bark condition favor fungus development. Consequently, in April 1952, inoculations in bark wounds on the trunks of 17-year-old Eureka lemon trees were made with four of the strongest decay fungi taken from shell-bark lesions. This experiment was located about four miles from the coast, near Oxnard. All except one of the inoculated trees had some shell bark at the time of inoculation. This one exception developed natural lesions at uninoculated spots within two months after treatment.

Forty-one trees were inoculated with each of the four fungi, *Botrytis cinerea, Diplodia natalensis, Dothiorella gregaria,* and *Phomopsis citri.* The fungi were inserted into chisel cuts about half-way through the bark. Lesions enlarged rapidly through July, then more slowly. Many lesions ceased growing by late summer. This deceleration of growth was especially apparent in the largest lesions.

Largest lesions were produced by *Botrytis.* Next largest were certain ones with *Phomopsis,* although the average size of *Dothiorella* lesions was slightly in excess of *Phomopsis* lesions. Fungi used in the inoculations were easily recovered in July. Considerable gummosis occurred near some of the lesions, especially some of those containing *Botrytis* or *Dothiorella.* A portion of the gum remained in the young wood and inner bark and hardened. Check wounds, except a few accidentally infected, soon healed or produced only small spots of dead bark.

One year after inoculation the depth of bark killing 1″ from each remaining inoculation wound was determined. The average bark thickness was 0.15″, but in

*Left, Botrytis gummosis and shell bark on 17-year-old Eureka lemon tree 6½ months after inoculation with Botrytis at white patch. Right, Shell bark lesions on 17-year-old Eureka lemon trunk were outlined with chalk 3½ months after inoculation with Phomopsis at "X." Small lesions developed without Phomopsis.*

**Frequency of Separation Layer Occurrence between Inner and Outer Bark One Year after Inoculation.**

| Inoculum | Lesions examined No. | Lesions with layer % |
|---|---|---|
| Botrytis | 35 | 66 |
| Diplodia | 29 | 83 |
| Dothiorella | 6 | 50 |
| Phomopsis | 31 | 100 |

many lesions less than one-fourth of this amount remained alive and even this portion was often gum filled. *Botrytis* killed to the greatest average depth.

The bark of each lesion was examined for the presence of a separation layer or cork cambium in the bark beneath the lesions at distances of 1″, 2″, and 4″ from the inoculation wounds. Separation layers had formed beneath all *Phomopsis* lesions but had also developed in a high percentage of lesions from other fungi. The formation of this separation layer is essential in the development of typical shell bark.

Many natural shell-bark lesions developed on the same trees simultaneously with lesions resulting from wound inoculations. In some cases these occurred in the vertical elliptical pattern common in shell bark. *Pyrenochaeta* and *Alternaria* were the fungi most commonly found, but 38% of the lesions apparently contained neither fungi nor bacteria.

## Injury and Shell Bark

In May 1953, numerous small scratches were made on Allen Eureka and Rosenberger Lisbon lemon trees of various ages. The wounds on 4-year-old Rosenberger Lisbon trees healed rapidly. Satisfactory healing occurred on 4-year-old Allen Eureka and 13-year-old Rosenberger Lisbon trees. Extremely variable rates of healing—with considerable death of bark next to some scratches—were observed on 13-year-old and 18-year-old Allen Eureka trees. The poorest healing and the largest areas of dead bark were found on the 18-year-old Allen Eureka trees which had shell-bark lesions on other portions of their trunks at the time the scratches were made.

Studies of small shell-bark lesions indicated that no fungi were present at first but that the dead bark was soon invaded by one or more fungus species. The bark reacts to these fungi by gum formation, tissue death, and wound tissue formation. Unless the outer bark completely walls off a wound or fungus invasion, a barrier develops in the bark beneath the dead tissue and extends almost parallel to the surface of the bark as the dead area increases in size. Cracking and sloughing of the dead outer bark then produce typical shell bark, often called dry bark in severe cases.

The control of fungus activities within shell-bark lesions is theoretically possible although it has never been achieved on a commercial basis. Various experimental fungicidal treatments during the past forty years have failed to give practical control, although *Avenarius Carbolineum* has, in some experiments, apparently delayed or retarded lesion spread.

A large-scale experiment aimed at developing fungicidal treatments for delaying and reducing the severity of shell bark was started recently in Ventura County.

## Resistance

Damage from shell bark can be virtually eliminated by planting lemon selections with an inherently high degree of resistance, which seems to involve the maintenance of a good wound-healing potential by the outer bark.

**Comparison* of Cultures Obtained from Small Shell Bark Lesions with Those Grown from Dead Areas Adjacent to Small Scratches on Trees with Shell Bark.**

| Organism | New S.B. lesions % | Dead spots by scratches % |
|---|---|---|
| No growth | 38 | 12 |
| Bacteria | 26 | 0 |
| Pyrenochaeta | 25 | 12 |
| Alternaria | 9 | 29 |
| Diplodiella | 7 | 0 |
| Cladosporium | 5 | 47 |
| Colletotrichum | 5 | 0 |
| Dothiorella | 3 | 0 |
| Phomopsis | 1 | 0 |
| Other fungi | 3 | 6 |

* Total samplings: 76 shell bark lesions, 34 dead spots near scratches.

All old-line true Eureka selections are moderately to extremely susceptible to shell bark. Most open-type Lisbons are no better. Carefully chosen seedling-line—nucellar—selections from Eureka lemons are somewhat more resistant to shell bark than old-line Eurekas and should be used when Eureka lemons are propagated. Certain vigorous Lisbon or Lisbon-type trees—especially Monroe and Prior—have very high resistance to shell bark. Propagation stock should be carefully chosen from virus-free sources.

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## BIURET

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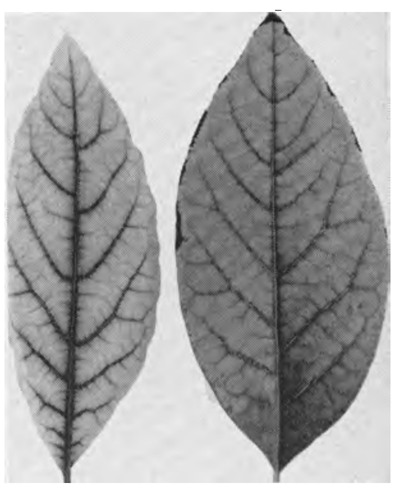
leaves, and at higher concentrations the chlorosis increased.

The toxicity of biuret was also tested on the growth of rooted leafy-twig Zutano — Mexican — avocado cuttings grown in two-gallon-capacity soil cultures. These cultures received Hoagland's complete nutrient solution from time to time and on March 9, 1954, each culture received two liters of the nutrient containing: 0, 50, 100, 150, or 200 ppm of biuret. Within a few days, wherever immature leaves occurred, the symptoms of biuret toxicity were present, mature leaves requiring a somewhat longer period in which to show the symptoms.

On April 9, 1954, the effects were severe, and a few of the cultures were photographed. Many of the immature affected leaves, even at the 50 ppm concentration, were shed. The initial effects were practically all confined to the immature leaves of the culture with biuret.



**Chlorosis of immature leaves of large and previously healthy avocado seedlings brought about within a few days by the addition of 50 ppm of biuret in a single application of two liters of nutrient to the soil cultures.**

The toxic effect of biuret on the leaves of avocado seedlings was also very pronounced. Hass—Guatemalan—avocado seedlings were grown in soil cultures with Hoagland's complete nutrient solution until they were several feet high and possessed cycles of immature leaf growth.

A few days after a single application of the nutrient solution containing 50 ppm of biuret, the partially mature leaves became markedly chlorotic.

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