Short Note 6.4

1990 Highlands Observational Study

Selected observational studies are very briefly summarized in Chapter 6 of my book. This short note provides additional details on the observational study in the Smoak grove located in Highlands County as documented by Gottwald et al. in Plant Disease journal in April 1992. [1] The name of the grove is not specified within the article, but is consistent with media stories at the time. [4] This study was done during Canker War II, as described in my book. It was a case of true citrus canker, and unrelated to the false canker eradication.

The Highlands study was used as supporting evidence of the range of windblown rain in the published 2002 article by Gottwald et al, can transport bacteria and cause infections in the range of 230 m (755-ft) to 810 m (2657-ft).

An objective of the article is to "reconstruct conditions that most probably gave rise to the spatial arrangement of disease that existed" and provides a number of spatial analyses. It is a process of working backwards from what has been discovered to suggest short and long distance mechanisms of dissemination of the disease. The study would be classified as retrospective and observational.

Findings in observational studies should be confirmed, as well as possible, with experimental studies, particularly when causal relationships are suggested. Two near discoveries of canker occurring at the similar times may be related to contaminated stock in nurseries located miles away from the incidences. This is a confounding effect. The problems of inspections and observation time lag are discussed in Chapter 3 of my book.

The spatial analyses as provided in the article are not reviewed within this note. Instead, this note summarizes the more descriptive aspects of the article and the conclusions relative to the introduction of disease into the grove. The full article is posted to the website and available on the APS website.

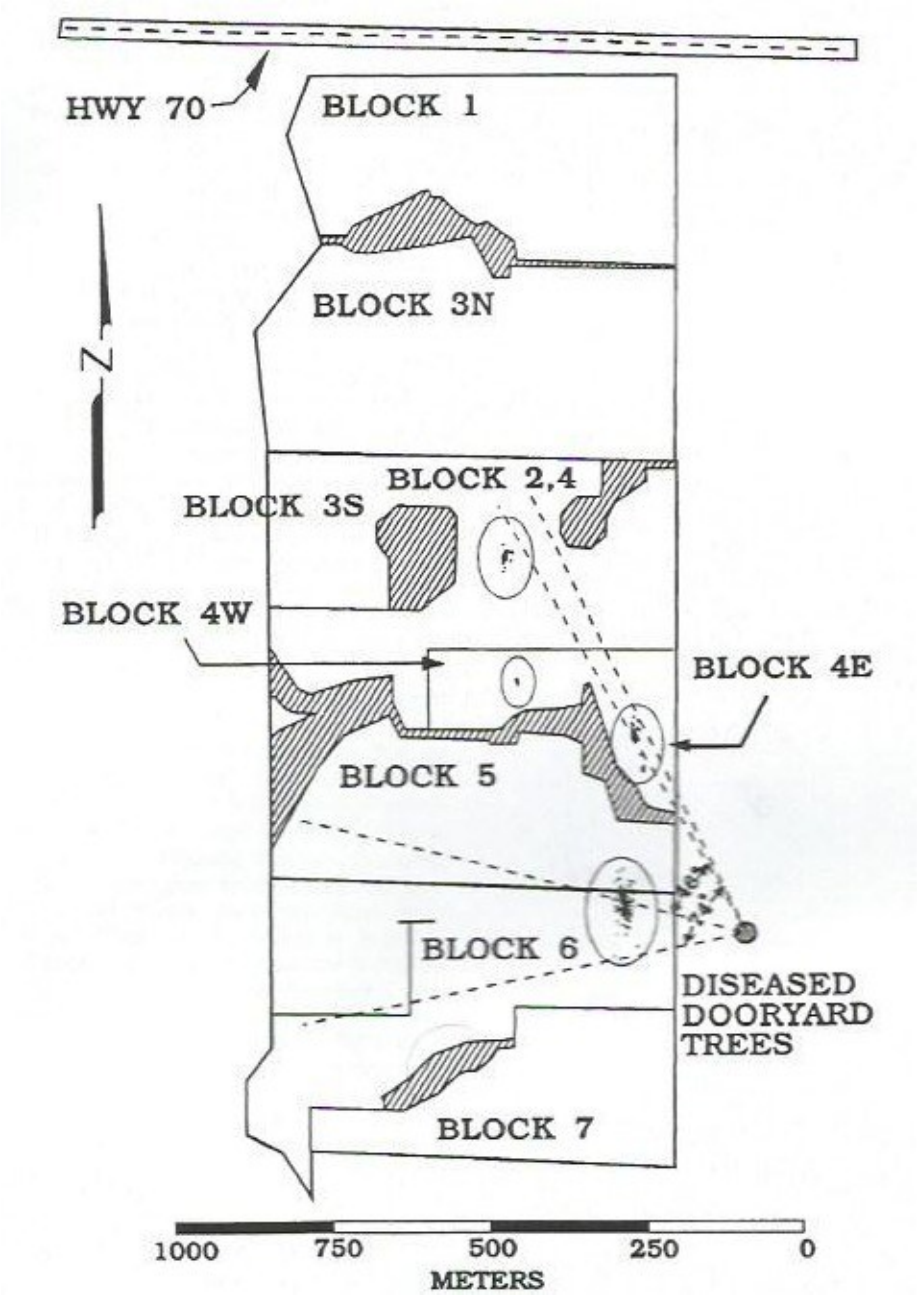
The Department reported a discovery of Asian citrus canker in October 1990 in a grove near Lake Placid, Florida. This was a 400 acre grove contained 69,401 Hamlin and Valencia orange trees (173 citrus/acre). Citrus canker had been found on 250 trees representing a 0.36% of the infection ratio. The trees were had been planted to two years ago. The low ratio (0.36%) ratio is surprising given these were young trees and supposedly more susceptible to citrus canker, because they produce new flushes more often than mature trees. [3]

The grove was subdivided into a seven major blocks, as shown in Figure 1. The striped areas represent drainage canals and ponds. The figure shows the infected trees were grouped into four areas, as shown with ellipses. The shortest distance between these areas is 820-ft.

The article states the grove was isolated by pasture, with the exception for a few homes located on the eastern edge. Citrus canker had been found in three of the backyard trees on the eastern side of the grove.

In 1991, most of the 400 acre Smoak grove was burned down by the owner to prevent canker from spreading. [4, also see media report] Thus, no disease progression analysis was possible.

Figure 1: Smoak grove and four area of canker discoveries presented in 1992 article by Gottwald et al. Shaded area are drainage canals and ponds.

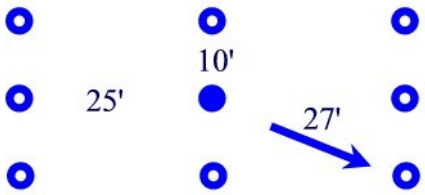


Introduction of Citrus Canker to the Smoak Grove

Citrus canker is frequently introduced into new areas by contaminated nursery plants. This possibility was prematurely excluded in the 1992 article, as follows, "Nursery sources of trees used to establish the orchard were also checked. No other infestation of Asiatic citrus canker was found." However, it can not be determined if contaminated stock was bought when the trees were first planted.

The article states that 250 infected trees were discovered in the grove and the spacing in the grove was 10 ft x 25 ft as shown below.

Figure 2: Smoak Grove Spacing (center tree is assumed to be infected)



In Table 3 of the article, the aggregation of disease within rows is significantly higher than across rows, suggesting secondary spread occurs more often over short distances. It is suggested that very few trees were introduced into the grove, and over the following two years, there was short distance dispersal of citrus canker. The average number of rainstorms in South Florida is about 120.

It takes very few introduced trees in a grove to cause additional disease incidences. If the dispersal distance for windblown rain is limited to 10 ft, then one infected can infect two other trees within a row. Thus if 83 infected trees came from the nursery, secondary spread would result in 166 infected trees. If the dispersal distance is limited to 27 ft, then secondary spread within the row is 4 trees, plus 6 trees across rows, resulting in 10 newly infected trees. In this case, it takes only 22 infected trees from the nursery to infect 228 trees. Based on the data within the article, it is seems possible that 22 of the 69,401 recently planted trees or 0.032% of the planted trees could have had subclinical infections and avoided early detection.

The article ignores this possibility and instead focuses on the three diseased backyard trees as the source of the canker in the grove. The article supports this conclusion with the statement, "... the foci with the greatest number of disease trees were closest to the dooryard source." The distance between the three diseased trees and the edge of the grove was 200 m (656-ft). The distance between the dooryard trees and center of the nearest area of disease was 230 m (755-ft).

The DNA analysis does not seem to add any support to the "dooryard tree theory." Instead, the DNA analysis shows a commonality between prior outbreak in Manatee County with incidences of disease in this grove and homeowner's property. Weather records were also reviewed. The authors contend that a major rainstorm in mid-August 1989 supports the dooryard theory based on lesion ages found on the infected trees (see page 393, second and end of third columns). There is no data presented to support this contention. It is not known how often the grove was inspected and when the discoveries were made.

The authors also contend that the directional gradient could be established within the four areas, and were consistent with a source being the dooryard trees. However, the data are confounded by secondary spread of disease.

But the real problem with the dooryard tree theory is disease transport. There is a total lack of experimental data which shows citrus canker is capable of being transported more than 59-ft by windblown rain as discussed in Chapter 6 of my book. Further, it appears there are several rows of disease free trees before this area of infected trees. Did the August 1989 rainstorm manage to carry citrus canker from to the two northern areas in the grove, at distances of approximately 500 m (1640-ft) and 816 m (2657-ft) respectively? Did this rainstorm manage not to cause any infections between these two areas?

Dissemination by Birds

The authors state that the wind direction of the mid-August 1989 storm was to the north, while the infected trees were to the northwest. Then, they provide the second possibility of dissemination by birds as follows:

> The presence of the abandoned bird's nest in the most heavily infected dooryard lemon tree on the adjacent property suggests the possibility of bird dissemination of the initial inoculum. Single-tree infection foci are consistent with bird dissemination. However, this mode of dissemination seems less likely than windblown-rain dissemination of the bacteria to have initiated three contemporaneous disease foci. Nevertheless, the distance of approximately 230 m from the dooryard trees to the nearest focus of disease is much greater than has been previously recorded for windblown rain dissemination of citrus canker bacteria.

The dissemination of canker by birds or insects is unsupported by any valid experimental research as discussed in Chapter 3 of my book. I have not found any other research study, which suggested introduction of canker by birds.

Other means of disease transport

Mechanical transport of bacteria is suggested as a means to disseminate canker within the infected areas. It is suggested that bacteria transport was possible on the pads of a herbicide applicator. However, this appears to transport the bacteria only along the ground.

Transport of bacteria by an air sprayer is also suggested. It is stated that the incidence data are confounded by dissemination by windblown rain making observations difficult. This would also compromise the directional gradient analyses used to support the dooryard tree theory.

Data lacking

The authors do not provide detailed information on the date the grove were planted, and approximately the size and age of the seedlings when planted. Nor is there any information on how often this grove was inspected during the eradication program. Further, the all important mid-August 1998 storm details are lacking, namely the date of the storm, wind speed and inches of precipitation. There is a weather station at Lake Placid, FL but the accessible NOAA records only go back as far as 1998. The weather station appears to be close to the grove, so the wind direction is likely accurate. The authors claim to be able to

backdate lesions to support the dooryard theory, but provide no information on the approximate age of lesions.

Relationship to 1900-ft Research

The Department claims the 1900-ft policy was supported by evidence of long distance transmission of citrus canker, based on a field study done in 1998. The field study is documented in an April 2002 article by Gottwald et al. The following is an excerpt from this article [6, page 275-376]:

> **Consistency of findings.** The findings of the current study for the spread of ACC in urban Dade and Broward counties are consistent with those previously described for spread of the disease first discovered in October 1990 in commercial citrus in South Central Florida (8). In the case of an epidemic in a commercial citrus orchard, inoculum originating from lemon trees in an adjacent residential property was disseminated to the neighboring commercial planting. Meteorological data from the National Weather Service were examined to reconstruct the relationship of inoculum spread with weather. The age of the oldest lesions in the commercial planting coincided with a mid-August 1989 storm that passed through the area. No other storms of significance occurred at the location of the commercial planting around this time period. Source to secondary-foci distances for the commercial outbreak were 230 m (754 ft), 410 m (1,345 ft), and 810 m (2,657 ft) for the three secondary foci. The urban environment is considerably different from that of a commercial orchard. Citrus plant age, cultivar, horticultural health, etc., vary widely among residential properties and affects susceptibility both quantitatively and temporally. In addition, plant density is much less than in commercial orchards and exposure of citrus trees to wind-blown rain can be affected by physical windbreaks such as buildings, enclosures, and trees of other species. Wind can also be irregularly channeled between such obstacles and numerous complex eddies likely also affect inoculum dispersal. Even so, the range of distances of spread measured in the present study corresponded with those distances of spread determined in the 1990 commercial citrus study. Thus, even though the urban and commercial citrus environments are vastly different, the underlying spatial dynamics appear to have a commonality of spatial process. That is, inoculum dissemination via wind-blown rain occurred over similar distances in both situations regardless of variability of citrus plant species/cultivar, density, susceptibility, horticultural health, etc.

The authors are suggesting the dispersal range of bacteria in a grove with 173 citrus trees/ acre would be similar to residential areas with approximately 3 citrus trees/acre. Chapter 3 of my book reviews planting densities. Chapter 5 of my book discusses effects of physical barriers.

Other Presentations

In 2001, a comprehensive online publication, “Citrus Canker: The Pathogen and Its Impact” by Drs. Gottwald and Graham summarized their 1992 analysis stating that typically studies of disease development are infrequent, given the lack of time between discovery and eradication. [2] The Highlands study therefore considered an exception. A map showing the four areas, as provided in Figure 1 in this note, along with the following discussion:

> The focus of infection was determined to be three, 8- to 10-year-old lemon trees in a rural home site that predated the planting of a large commercial orange orchard immediately to the west. An August 1989 rainstorm with associated high winds resulted in dissemination of inoculum and the establishment of four foci of infection in the orange orchard that ranged from 230 to 810 m (755 to 2657 ft) from the infected home site source trees (Fig. 36). This was the first documented spread of citrus canker over longer distances associated with rainstorms (24).

Concluding Remarks

The article quickly rejected the possibility that the citrus canker was introduced from contaminated nursery stock. If the authors had suggested that the infected trees came from a particular nursery, this might have been hard to prove. The records of nursery stock sales in the same time period (1987-1988), to other groves might gave been revealing. However, this might have resulted in destruction of a nursery or severe loss of business. Quarantines of nurseries unlike quarantines of groves result in the nurseries going out of business.

However, the authors chose to focus on three backyard trees, as the Citrus Canker Task Force, had shown particular interest in the source of canker in these three dooryard trees (Task Force Meeting held on Oct 26, 1990 [1]). It may have been easier to investigate the ongoing theory of dooryard trees as the foci rather than pursuing alternatives, such as contaminated stock.

An observational study can calculate distances between any two infected trees, perhaps miles apart. One tree is likely more infected than the other hence a gradient is possible. Or perhaps one location has two infected trees and the second has one. Again, a disease gradient can be determined. While the distance between two trees may be accurate, the interpretation of this distance can be meaningless if attributed to windblown rain. This idea is stated more formally in Schubert et al. 2001 article in Plant Disease [3], where "outposts of infection" could be two infected trees or collection of infected trees separated by a long distance:

> However, the fact that intervening uninfected citrus exists between these outposts of infection makes the case seem stronger for human involvement [than weather events] in most long distance inoculum dispersal. This assumes that a disease gradient of some form should exist between source and destination of inoculum distributed by weather events, but this may not be a safe assumption. It is frankly impossible at this time to be absolutely certain how long-distance movement of inoculum occurs.

This is why, experimental studies are critical to a realistic determination of the maximum distance of dissemination.

Dr. Whiteside was an early pioneer in suggesting windbreaks around groves. [5, also see short note 1.2] It is a recommended practice today for grove owners to use windbreaks to protect the spread of canker.

References

1. Gottwald, T.R., Graham, J.H., Egel, D.S., 1992. Analysis of Foci of Asiatic Citrus Canker in a Florida Citrus Orchard, Plant Dus. 76:389-396.
2. Gottwald, T.R., Graham,J.H., and Schubert, T.S., 2002. Citrus canker: The pathogen and its impact. Online. Plant Health Progress. Website: http://www.apsnet.org/publications/apsnetfeatures/Pages/citruscanker.aspx
3. Schubert, T.S. , Gottwald, T.R., Rizvi, S.A., Graham, J.H., Sun, X., Dixon, W.N., 2001, Meeting the Challenge of Eradicating Citrus Canker in Florida- Again, Plant Disease, Vol. 85-4.
4. Nielsen, K., 2000, Anatomy of a Quarantine, Miami New Times. July 6, 2000. Available online.
5. Whitesde, J.O., 1985, Canker Threat, How Serious a Threat is Canker to Florida Citrus Production, The Citrus Industry, November 1985.
6. Gottwald, T.R., X. Sun, Riley, T. Graham, J. H., Ferrandino, F. and Taylor, E., 2002, Geo-Referenced Spatiotemporal Analysis of the Urban Citrus Canker Epidemic in Florida, Phytopathology, Vol 92, No. 4.

.

Media story January 30, 1991:

CANKER-STRICKEN GROVE

STARTS BURNING TREES

LAKE PLACID, Fla. - A central Florida citrus grove is burning about 29,000 young trees in hopes of stopping the spread of Asian citrus canker.

"The quicker we get it out, the quicker we can get on with the program by planting new trees," said Ed Smoak, owner of Smoak Grove Inc. He said burning the trees over 166 acres will take several weeks.

State agriculture officials confirmed last week that a Asian citrus canker had reappeared in a non-producing group of 2-year-old citrus trees owned by Smoak Grove near Lake Placid.

Mr. Smoak said he has already destroyed about 15,000 trees to get rid of the incurable and highly contagious bacterial disease.