Short Note 3.3

Survey Errors and the Impact on the Eradication Program

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1. Introduction

This short note further extends the discussion of survey errors in my book. Survey errors can impact the eradication program and assessments of the epidemic. Generally, the intent of a survey is to identify all citrus trees with symptoms of citrus canker. Inspections can also result in collection of samples for further laboratory testing. In general, visual examination alone is not recommended due to the similarity of canker symptoms to other conditions and diseases. [2] There are many laboratory tests available. Serological and molecular methods can be used together with pathogenicity tests. [3] A review of these tests is beyond the scope of this short note.

Two types of errors can occur – false positives and false negatives, or Type I and II errors, respectively, as follows:

> Misidentification: A tree is considered to be infected with citrus canker, when in fact it is not. This is a misidentification problem. This is the false positive error.
>
> Failure to Detect: A tree is considered healthy or free of canker symptoms, when in fact it has citrus canker infections. This is a false positive error.

Note if a canker infected tree is misdiagnosed as scab or citrus bacterial spot (CBS), this is a failure to detect error, not a misidentification error. The frequency of each of these errors during the CCEP is unknown, as the Department has never released data in errors made during surveys.

There are two other sources of error. The first is misidentification of trees as citrus trees, which obviously can only occur with residential inspections. This was reported by the Miami Herald on November 5, 2000 based on a review of 22,000 complaints from the Citrus Canker Hotline. These misidentified trees include mango, Surinam cherry and avocado. Many species can be identified by the double leaflet (petiole wings) and the distinct scent of crushed leaves.

The second source of errors is the misdiagnosis of Asian strain citrus canker when in fact the Wellington strain exists. This is discussed in my book in Section 9: Canker Hosts and the Two Strains Problem. Under the rules of the CCEP, the infected tree and all healthy citrus trees within the eradication circle were destroyed, when, in fact only Key lime trees were host trees for this strain.

Visual Inspection Survey Errors

Survey error, including failure to detect and misidentification, are possible in residential and commercial settings. Access and complete inspections are more problematic in residential area. Within the CCEP, inspectors did not have ladders to go over fences, but in some instances, it was reported they climbed over fences. Dogs in the back of lots posed another danger. The citrus trees have varying levels of care, and other pests and diseases may be present, making identification of canker more difficult. Many residents are generally not home during daylight hours.

In Schubert et al's 2001 article [2], the authors states that approximately 50% of homeowners do not have any citrus trees. [1] It is not known how many lots could be entered and citrus trees could be inspected every day during the CCEP. Access problems became far more difficult once the courts required search warrants or permission by homeowners. Residents were sent waivers, so inspectors could survey yards. It is likely residents without citrus trees would respond more positively to waivers.

A backyard inspection is further complicated by the fact that residents plant their trees in the back or corners of their yard, so the branches extend over to the next neighbors in back of the yard. Citrus may extend over lakes and canals. Both Miami-Dade and Broward counties have numerous canals as part of the Lake Okeechobee system of drainage canals. Artificial lakes are very common in residential developments.

Attorneys for the Department argued in court that residential surveys are similar to routine entry into backyards for reading electric or water usage meters. However, in each case, the reader knows precisely where the meter is located, and is gone as soon as the meter is read. Water meters are commonly located in front of the house. If access to meters is a problem, then an approximation of monthly usage is made until the access problem can be remedied.

Misidentification problems in residential areas were not limited to faulty diagnosis of canker. The Miami Herald reported on November 5, 2000 that there were 51 cases where inspectors with FDACS had incorrectly identified mango, Surinam cherry and avocado trees as citrus trees.

2. Misidentification Error (False Positives)

The typical appearance of citrus canker is described in my book and other references. The idtools.org website is an excellent source of images of citrus canker.

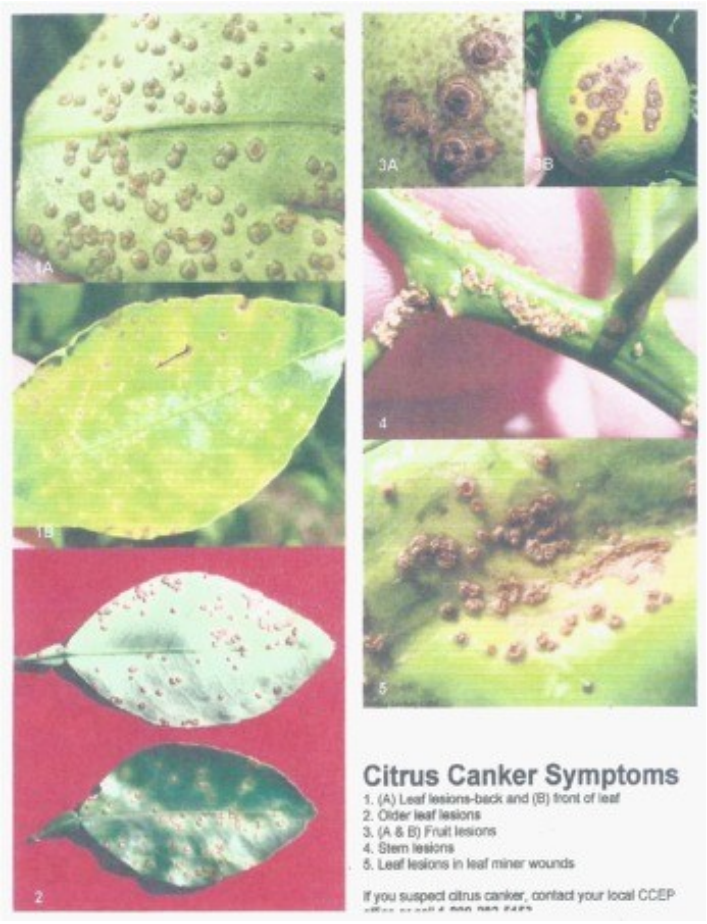
- "Picture Perfect" Citrus Canker Images

An image of citrus canker on an orange is shown below. This image is also shown on the cover of my book. It shows numerous well raised lesions, with yellow and brown halos on the fruit of an orange, giving impression that canker lesions can be readily identified in all cases. This is simply not true.

Figure 1: Citrus Canker Symptoms on an Orange (courtesy of the image library at www.padil.gov.au)

The “picture perfect” canker lesions were used on the cover, to quickly let readers know what citrus cankers look like. The Department also provided images showing very identifiable lesions.

Figure 2: Citrus Canker Lesions (Ref 1: FDACS, Publication 377)



Most identifications were likely done on leaves as opposed to stem and fruit lesions. Inspection of stems of a large citrus tree can be difficult.

There are many reasons for misidentification. Misidentification can occur because in the early stages of disease development, prior to the corky brown raised area, the symptoms of citrus canker on leaves can resemble other diseases, such as citrus bacterial spot (CBS).

As shown in Figure 3, the orange fruit to the right of the image has only flat lesions. If only flat lesions occur on the foliage of the citrus tree, it can be CBS disease.

Figure 3: Changes in canker lesion appearance with time (Image source: FDACS website)

- Similar looking blemishes

Healthy citrus plants may show brown and yellow blemishes on the surface of citrus fruits and leaves. Sunburn and application of horticultural oil can result in similar looking blemishes.

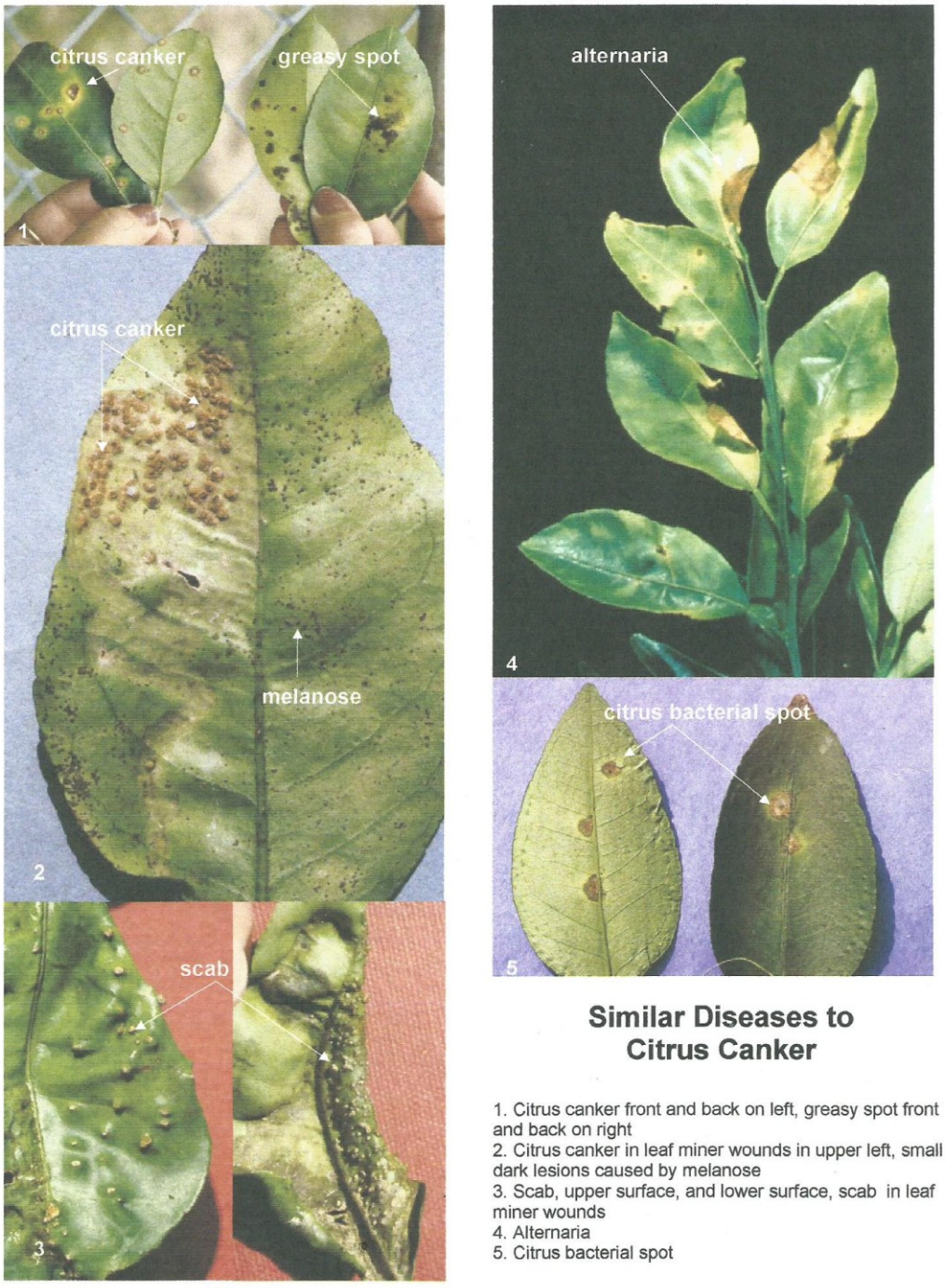
Figure 4: Damage caused by horticultural oil and sunburn (Source: idtools.org)

Damage by horticultural oil

Sunburn blemishes

There are other similar looking foliar diseases in Florida. On leaves, citrus canker may be confused with citrus bacterial spot (CBS), greasy spot and citrus scab. On fruit, citrus canker may be confused with alternaria, citrus scab and damage to the fruit. (Ref: idtools.org).

Figure 5: Foliar diseases with similar appearance [1]



- Wellington Strain Complications

The Department's eradication program was specifically directed to finding and eliminating Asian citrus canker. Another strain was discovered in May 2000, and designated as the Wellington strain or A_W strain. This strain only infected Key lime citrus and could only be detected through DNA testing. [3] The Department continued its policy of eradicating all citrus trees within the 1900-ft circle, even when the discovered citrus tree was a Key lime tree.

- Citrus Bacterial Spot

Citrus bacterial spot (CBS) disease was discovered in 1984 on the west coast of Florida and mistaken for citrus canker. This was the start of Citrus Canker War II as described in my book in Chapters 1 and 2. The symptoms of CBS are very similar to citrus canker except the lesions are flat.

The early reports of CBS indicated that the disease was mainly in the nurseries, and would not survive well in commercial groves. It is typically found on the leaves of citrus plants, so it would not cause a loss in fresh fruit sales. In 1990, Drs. Graham and Gottwald published a study on CBS, indicating that there was variations in the aggressiveness of strains as found in 25 infested nurseries. The authors express concern on the potential for spread if more aggressive strains if the nursery stock is outplanted in a newly established grove. Due to latency, symptoms may not be detected when planted.

Although the Department made numerous laboratory tests for citrus canker during the nearly 10 year eradication program, it is unknown how often CBS was identified as canker. At the November 2001 hearings, a resident stated his citrus trees had been incorrectly misidentified as having citrus canker, when in fact it was citrus bacterial spot. This was later confirmed by an exchange of emails with the Department. The tree had recently been purchased at Lowes, one of the largest home supply outlets in Florida. Since CBS is not considered a minor foliar blemishing disease, it would not be against FDACS rules to sell trees with this disease. Most nurseries would likely either cull out infected trees or prune any branches with blemishes.

- Other Sources of Misidentification

Many trees have brown and yellow blemishes on their foliage. If a tree has a "canker-like" lesion, but the tree is not a citrus tree, this is a false positive error. This obviously would only occur within residential areas. The Department in their haste to identify new cases of citrus canker, had improperly trained inspectors, who marked other non-citrus trees as infected with citrus canker, within residential areas.

3. Failure to Detect Canker (False Negatives)

Detection errors can be the result of incomplete inspections or the misdiagnosis of canker as another similar disease. Both detection errors have been reported in the literature. It is generally impossible to visually identify the earliest symptoms of citrus canker, as there are pin size discolorations.

The false negatives do the most harm in nursery environments because they allow plants with canker to be disseminated throughout Florida. False negatives have been reported by researchers in Argentina and Brazil. These relate mostly to grove and nursery inspections.

Full inspections may not occur in all residential lots. Small citrus trees may be missed. Large trees may be only partially inspected because the limbs extend beyond the property. Lesions in large trees may not be visible to inspectors. Access to yards

As documented by Dr. Paul Chamoux of the USDA [6], the lesions tend to lose their yellow-brown halos, and can easily be missed or mistaken for citrus scab or other diseases.

Figure 6: Appearance Changes with Age

The most susceptible foliage to citrus canker are new flushes, and these may be high in the trees, out of sight to inspectors conducting residential inspections.

- Wounding and Citrus Leafminer Damage

Canker within wounds may be missed by inspectors looking for circular blemishes with yellow and brown halos. Wounds can be irregular, and the result of insects or mechanical damage. Plant pathologists have suggested that the broken off thorns from citrus trees during high winds may cause wounding and facilitate entry into the mesophyll layer of foliage.

The wounds caused by citrus leafminer (CLM) are easily identified. However, the early detection of citrus canker within these wounds may be more difficult as citrus canker would appear initially as a small brown speck within the mine. Over time, it is likely the citrus canker bacteria would spread to other foliage, and may be more easily identified.

4. Misidentification error impacts

The consequence of misidentification is the unnecessary removal of citrus trees. For mandatory removals under the CCEP, misidentification results in destruction of trees by FDACS which are beyond their legal authority. There were no funds allocated for wrongfully destroyed trees.

Misidentification also creates a false impression of "spread maps" showing areas where citrus canker is present. Epidemiology information, such as the distances between prior and newly discovered infected trees would also be completely erroneous, if the newly discovered tree was improperly diagnosed.

In a 1900-ft circle, all citrus with the 260 acres are destroyed. The impact of misdiagnosis of one citrus tree in a residential area can range from less than 100 trees being affected to hundreds of thousands trees. The lowest impact would be where planting densities are low, namely in residential areas, and there are many valid diagnoses of canker in the general area. In this case, the overlapping circles would mean that many of the destroyed healthy trees depended on more than one tree diagnosed with citrus canker.

Within residential areas, the residents are generally without recourse in the event of misdiagnosis. Grove owners have more resources to conduct independent evaluations. Prior to the Administration Court case in 2001, grove owners could have the Risk Assessment Group, individually evaluate the need for eradication and make downward revisions in the 1900-ft protocol or recommend additional tests to verify the existence of citrus canker. It was considered impractical by the Department for residents to have the same rights for reconsideration.

The impact to regulators is added cost to the program. Also, eradications within residential areas were commonly without owners permission, and relatively little warning, misidentification would generate a general distrust for the Department.

Ultimately, the lack of laboratory tests for residents was challenged in the courts. On July 18, 2003, Judge J. Leonard Fleet ruled that the Department had used unreliable tests in determining whether a citrus tree was infected with citrus canker. The ruling was reversed on appeal. The Appellate Court ruled that this was an administrative matter and the Administrative Court was the appropriate venue.

5. Failure to Detect Error Impacts

The failure to detect citrus canker is a concern to regulators as it may result in the continuation of an outbreak. Citrus canker may be considered absent or eradicated in a certain area, when in fact it is still very present. It is also noted that the early canker eradication programs burned down entire nurseries, so a failure to detect error was not possible.

If inspections are done on a regular basis, the detection of canker may occur. Human error in detection, pruning or topping off of trees, and natural leaf drop all contribute to this error. Human error is probably highest in residential areas, where citrus trees may extend over to other properties, or to inaccessible areas. A misdiagnosis of citrus scab for citrus canker is likely if only older lesions are present on a citrus trees. [2] The impact on false negatives in a nursery setting allows citrus canker to be disseminated throughout Florida.

The events leading up to the enactment of the 1900-ft policy are reviewed in my book. In particular, the discussion in my book in Chapter 9, pages 172 to 174 are relevant to the way survey errors influenced officials to enact the 1900-ft policy.

- Impact on eradication policy

Prior to the implementation of the 1900-ft rule, only the survey errors related to a failure to detect, seemed important to officials. This conclusion comes after a detail review of all Task Force meeting reports. The grove owners had the resources to check any misidentifications, so neither FDACS nor the USDA seemed concerned about this type of error.

The difficulty to access properties and make complete inspections of residential properties under the 125-ft policy in given as one reason to increase the eradication radius as discussed in the October 13, 1999 interim report by Gottwald et al. Limitations on the number of inspectors in response to new discoveries is also given as a reason to expand the radius. Dr. Gottwald wrote in this report:

> The ever-expanding canker quarantine area makes it less and less possible to resurvey all infested sections in a timely manner even with the increases in manpower. Survey crews never have 100% access to all properties.

The failure to detect is stated as follows:

> Surveys are less sensitive than we would like and numerous small infestations of the disease are not picked up until subsequent surveys.

In the transmittal letter of the report from Mr. Richard Gaskalla to Deputy Commissioner Craig Meyer, dated November 8, 1999, it is stated:

> Also, in the Conclusions, *Tim [Dr. Gottwald]* points out the problem with property access and finding all positive trees on a timely manner.

In the 2002 article by Gottwald et al. [7], the failure to detect results in a "false sense of security" of effective eradication using the 125-ft policy:

> Because visual surveys are less sensitive than desired, numerous small infestations of disease are not accounted for until subsequent surveys. Therefore, the conclusion that the 38.1-m radius *[125-ft]* could still be used if combined with more frequent survey cycles could lead to a false sense of security that the disease can be managed simply by increasing the frequency of resurvey. In our estimation, this is unlikely to hold true.

Dr. Gottwald explained in the first formal presentation of the field study in January 2001, that the 1900-ft radius would clear-cut large areas of urban Miami-Dade County. Thus, it would appear that the solution to the detection problem is to employ a large cutting radius to ensure a high level of areal coverage.

6. Concluding Remarks

During the CCEP, the misidentification errors were more likely to occur in residential environments due to training of inspectors, insufficient laboratory testing and other factors. Owners had no recourse if a misidentification occurred. If fact, the time to launch an appeal was so short (5 days, later extended to 10 days), that there trees would be doomed before any meaningful testing could be done.

The increase in cutting radius was clearly influenced by the inability to fully detect citrus canker within residential areas. In Brazil, the eradication program was limited only to their groves and nurseries, not residential areas, unless they were in close proximity to commercial areas. A recent article attributes success in part to intensive and repeated surveys of commercial areas. [8]

References

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4. Florida Fruit and Vegetable Association, 2000, Search and Destroy, Florida Steps Up War on Citrus Canker. May/June 2000. (Comments by DPI Director Richard Gaskalla)
5. Gottwald, T.R., 1999, Canker Spread Study in Urban Miami. This document was submitted by FDACS in November 2000, to the Broward Court.
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7. Gottwald, T. R., Sun, X., Riley, T., Graham, J. H., Ferrandino, F., and Taylor, E. L. 2002. Geo-referenced spatiotemporal analysis of the urban citrus canker epidemic in Florida. Phytopathology 92:361-377.
8. Behau, F., Barelli, N.L, and Belasque Jr., J., 2014.Lessons from a case of successful eradication of citrus canker in a citrus-producing farm in São Paulo State, Brazil, Journal of Plant Pathology, (2014), 96(3), 561-568.

Images of citrus canker are posted at idtools.org (University of Florida and USDA contributed to this site):

http://www.idtools.org/id/citrus/diseases/factsheet.php?name=Citrus%20canker