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A REFEREED PAPER

THE COSTS AND VALUE LOSS ASSOCIATED WITH FLORIDA CITRUS GROVES EXPOSED TO CITRUS CANKER

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Abstract. **The transmission of citrus canker (*Xanthomonas axonopodis* pv. *citri*) from private residences to the commercial groves of southwest Florida in the mid-1990s lead to an intense citrus canker regulatory program of eradication. Citrus canker is a bacterial disease causing lesions on the leaves, stems, and fruit of all varieties of citrus trees. The citrus canker eradication program in Florida stipulates that any tree determined to be infected with the disease, as well as all trees within a 1900-foot radius, be removed. The economic costs to citrus growers in Florida associated with citrus canker discovery is estimated in two scenarios: production costs associated with the eradication of citrus groves due to a canker find and production costs associated with living with citrus canker. A hypothetical canker-free grove is modeled for comparison. Results indicate that the estimated economic loss to citrus growers in an endemic citrus canker situation, assuming an optimistic price scenario, exceeds the estimated economic loss to citrus growers under eradication for all varieties examined.**

Citrus canker (*Xanthomonas axonopodis* pv. *citri*) was first discovered in the Miami-Dade County area of Florida during the mid-1990s. The spread of the disease from private residences to the commercial groves of southwest Florida lead to an intense citrus canker regulatory program of eradication. Even with the initiation of eradication, canker soon proliferated to the lime production area located in Dade County and nearly destroyed the entire industry. Since that time, canker has been found in several counties located throughout the citrus production area.

Citrus canker is a bacterial disease that adversely affects all varieties of citrus. The main horticultural consequence of canker is the appearance of lesions on both leaves and fruit, which adversely affects the proportion of fruit that is suitable for the fresh market. These lesions also diminish the productivity of the tree leading to a reduction in fruit production. In terms of tree vigor, canker serves to weaken the tree. In other countries, yields have been known to decrease by 5-30% percent depending upon the scion (variety) and effectiveness of the citrus canker control programs employed. Although grapefruit is most vulnerable to canker, early maturing varieties such as 'Navel' and 'Hamlin' are also highly susceptible. 'Valencia' oranges and tangerines are thought to be the least affected of the major citrus varieties grown in Florida.

Citrus canker has two primary vehicles of transmission. First, contact by grove workers or the equipment used by those workers can spread the disease to other groves. Grove workers may not be aware that their clothing or equipment have been contaminated the bacterium that causes citrus canker, and unwittingly transport it to other groves. Similarly, equipment such as ladders, sprayers, and trucks can also become contaminated with the canker pathogen, and spread it to other trees. Second, canker can be transmitted by wind driven rain. Recent research has established that the majority of new canker infections occurred within a 1900 foot radius of citrus trees known to be infected with citrus canker (Gottwald et al., 2001). Florida's flat terrain facilitates the efficient transmission of the pathogen with such wind driven rain as hurricanes and tropical storms.

Given the possible economic consequences of citrus canker, the State of Florida has pursued a policy of immediate eradication of any tree found to be infected with canker. In addition, all trees within a radius of 1900 feet of any infected trees are also eradicated based upon the finding that weather conditions are known to spread canker to nearby trees. Eradication is mandatory in such situations even if the trees within this radius do not yet show signs of infection.

The primary objective of this paper is to focus on the economic loss incurred by a grower whose trees are eradicated due to a canker find. This will be accomplished using the income approach to grove valuation. Three of the most important citrus varieties produced in Florida are considered: 'Hamlin' oranges, 'Valencia' oranges, and red seedless grapefruit.

Overview of Florida's Citrus Canker Eradication Program

Florida's Citrus Canker Eradication Program (CCEP) was implemented in the mid-1990s in an attempt to establish the guidelines for averting the spread of the disease. The CCEP instituted a policy of immediate eradication of any tree infected with citrus canker. Based upon the research by Gottwald et al. (2001), the CCEP also stipulated that all trees within a radius of 1900 ft of any infected trees be eradicated. Eradication is mandatory in such situations even if the trees within this radius do not yet show signs of infection. In addition to eradication, the CCEP defined additional regulations such as the decontamination of grove workers, field equipment, and packinghouses with approved chemicals (Chung et al., 2002).

As of August 2001, compliance agreements affecting all facets of the Florida citrus industry from production to processing

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were implemented by the CCEP. The compliance agreements provide the general provisions for preventing the spread of citrus canker as they apply to grove operations, packinghouses, harvesters, and processors. These provisions include decontamination procedures, the maintenance of groves located in quarantine areas, and the shipment and distribution of fruit from the quarantine areas (Chung et al., 2002).

Efforts to eradicate both infected trees and trees within a 1900-ft radius of infected trees in the residential areas of the Dade and Broward counties were hindered by outraged homeowners who filed lawsuits to protect their property. The lawsuits resulted in restraining orders being issued which halted eradication efforts in late 2001. Since that period, homeowners and the Florida Department of Agriculture and Consumer Services have been in and out of court and eradication efforts have been sporadic.

The purpose of this study is to examine the economic impact if citrus canker were to become endemic in Florida. Citrus canker would have multiple effects on producers in the Florida citrus industry. By adopting management practices commonly used in countries where citrus canker is endemic, the citrus industry would face an increase in the cost of production resulting from; 1) the increased use of copper based sprays to mitigate the effects of citrus canker on productivity and fruit appearance, and 2) from establishing windbreaks to slow the spread of the disease.

In addition, per acre yields are expected to decline due to increased fruit drop. The effect of canker on external fruit appearance would substantially reduce the proportion of fruit suitable for the fresh market. It is also likely that Florida fresh fruit shippers would lose market access to other citrus growing regions including Texas, California, and Western Europe. Therefore, to quantify the economic impact of citrus canker requires a multi-faceted approach including analysis of both fresh and processed citrus markets.

Because of space limitations, the analysis presented in this paper is limited to processed oranges and fresh and processed grapefruit. These outlets account for nearly 95% of citrus acreage in Florida.

Muraro et al. (2000) annually publish cost of production for oranges and grapefruit produced in three regions of Florida. These studies are based on a survey of citrus grove caretakers located in each of the three regions. Based upon figures published by Muraro et al. (2001a), if canker were to become endemic in Florida, citrus production practices would be affected in two ways. Muraro et al. (2001b) estimate that two additional sprays would be required for fresh fruit at a cost of $59.08/acre. For processed fruit, one additional spray would be needed at a cost of $32.36/acre. First, growers would make additional sprays of copper in an attempt to mitigate the adverse effect that canker has on both fruit appearance and yield. Second, a major problem facing Florida in the presence of citrus canker is its flat terrain. Since the primary vector for transmission of the canker pathogen is wind and rain, it would be difficult for the Florida citrus industry to keep canker isolated to a confined area. Construction of windbreaks is one means to limit the spread of canker from one grove to another; especially for fresh market grapefruit. Muraro et al. (2001b) estimate the annual cost of establishing and maintaining a windbreak at $7.33/acre. Establishment of windbreaks would likely require citrus trees be removed around the perimeter of a block representing about 5% of the total trees in the block. For grapefruit varieties, yields of the "two tree rows" adjacent to the windbreaks would decrease by one-third due to the shading affect from the windbreaks. This would equate to an average 3% box yield loss per tree over the entire grapefruit block. Endemic citrus canker is expected to reduce per acre yields as well as packout, the proportion of fruit that is suitable for the fresh market. Based upon estimates provided by Graham, it is projected that yields of late maturing ('Valencia') oranges would be reduced by five percent. Early oranges (specifically 'Hamlin') and grapefruit (without windbreaks) would experience the largest yield effect at 10%. Early oranges and grapefruit varieties tend to be more vigorous compared to late oranges and, therefore, are thought to be more adversely affected by canker infection (Muraro et al, 2001b).

Methodology

The income approach to asset valuation is to first project future net returns derived from the asset. These future returns are discounted and summed providing an estimate of the net present value (NPV) of the future revenue stream. The formula for calculating NPV is

$$\text{NPV} = \sum_{t=1}^{T} \frac{R_t}{(1+r)^t} \qquad (1)$$

where R_t is the net return realized in period t and r is the rate of interest. Therefore, the economic loss associated with eradication of citrus trees is estimated using the expected NPV of the eradicated trees compared with the NPV of the replacement trees. That is, the economic loss is given by

$$\text{EL} = \text{NPV}_1 - \text{NPV}_2 \qquad (2)$$

where NPV_1 is the net present value estimated for the eradicated grove and NPV_2 is the net present value associated with the replacement grove.

In order to estimate the economic loss, yields associated with both the canker-free grove as well as yields associated with the replacement grove after eradication are estimated. Costs associated with both canker-free and replacement groves are also established. Grove maintenance costs, which vary by age of tree, are also estimated. Finally, the expected price of each of the citrus products in this study is estimated.

Data and Discussion

Scenario one: Eradication program prevails in Florida. A comparison of the net returns associated with a canker-free grove and the net returns associated with the replacement grove for Valencia oranges is depicted in Fig. 1. The top line is associated net returns generated by a 10-year-old, canker-free grove using average Florida yields. The bottom line depicts the net returns that are realized when a grove is eradicated due to canker and replaced with an identical grove.[2]

Under Florida regulations, a grove eradicated due to canker must remain fallow for 2 years. Therefore, the first 2 years after eradication no return can be realized, and the only costs

[2]Identical in that the variety, tree density, and management practices of the replacement grove are the same that were used on the previous grove before eradication.

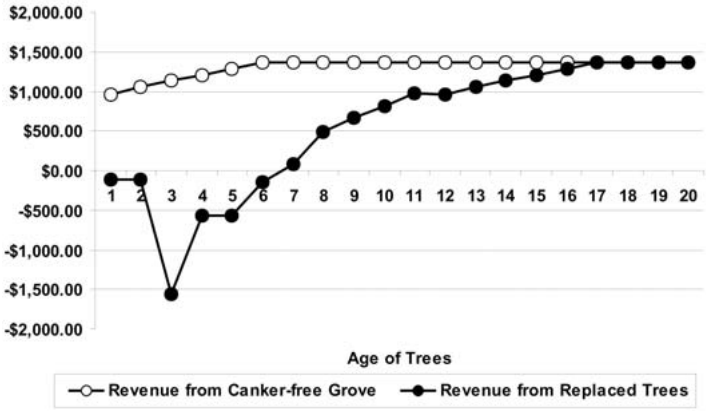

Fig. 1. Expected undiscounted net returns from a productive 10-year-old Valencia orange canker-free grove versus the net returns from a replanted grove after eradication due to canker.

are those associated with maintaining the property such as mowing or other expenses. In the third year after eradication, a major outflow of cash is incurred as the grove is replanted. The annual grove care costs under eradication in Florida are outlined in Table 1. Estimated replacement costs in the first year after the fallow years are $10.37 per tree for both 'Hamlin' and 'Valencia' oranges, and $12.38 for red seedless grapefruit. These charges include the cost of site preparation, the nursery tree, and planting. In this analysis, it is assumed that tree density is 150 trees per acre for both 'Valencia' and 'Hamlin' oranges and 115 trees per acre for red seedless grapefruit. Therefore, the fallow and replacement costs for 'Valencia' and 'Hamlin' oranges are $1,784/acre. Fallow and replacement costs for grapefruit are $1,651/acre. After planting, citrus trees do not generally produce fruit in the first 3 years of life. Although, revenue is not realized for these 3 years, young trees still require care in the form of fertilization, pest control, and irrigation. Using estimates from Muraro et al. (2001a), a charge of $3.86/tree per year for oranges and $5.37 for grapefruit is assumed for years 2 through 4 on non-bearing groves. These figures translate to per acre maintenance costs of $561 and $618 for oranges and grapefruit, respectively.

After the new trees begin to bear fruit, net returns gradually increase. In the example illustrated in Fig. 1, positive net returns are realized at the beginning of year 5, which is 7 years after eradication. Afterwards, fruit yields continue to climb until they plateau in this study at age 15 for oranges and age 14 for grapefruit. Projected per acre fruit yields by age and variety after eradication are shown in Table 2.

Given the assumptions regarding the shape of the yield curve for citrus in Florida, the value of T in equation (1) needed to calculate economic loss is 17 years. This is the number years after eradication occurs that the net return of the replacement grove attains the level that would have been realized from the previous grove if it had survived. This scenario is depicted in Fig. 1. The two curves representing the value of the canker-free grove and the revenue from the replaced trees merge together over time.

Future grower prices for citrus are also needed for this analysis. To establish a base, a 5-year average of on-tree prices for early and midseason (predominantly 'Hamlin') as reported by the Florida Agricultural Statistics Service (FASS) over the period 1996-1997 through 2000-2001 was computed. A similar computation for 'Valencia' oranges was also made. The results were an average price of $3.12/90-lb box for 'Hamlin' and $4.52/90-lb box for 'Valencia'.[3] Over the past several seasons, overproduction of grapefruit has depressed the price. In order to generate positive grove valuations, an 8-year average was computed for red seedless grapefruit. This computation gave a historical on-tree price of $2.27/85-lb box.

To complete the calculations needed for equations (1) and (2), the estimated net returns are discounted. Choice of a discount rate is governed by several factors. For a crop such as citrus, the discount rate should probably include a risk premium given both the weather and disease risks faced by citrus growers. In this study, a discount rate of 10% is applied. The magnitude of the discount rate is expected to affect the economic loss estimate; however, a sensitivity analysis is conducted to determine the level impact a change in the discount rate will have on economic loss.

Scenario Two: Citrus Canker is Endemic to Florida. Often, there is the case where the eradication program fails to be implemented or is ineffective. In such a case where citrus canker has become endemic to Florida, many of the assumptions of scenario one must be modified, including production costs, yield curves, and tree density. In this section, the assumptions of scenario one will hold with the following exceptions. Additional copper sprays increase spraying costs by $32.36/acre for 'Hamlin' and 'Valencia' oranges and $59.08/acre for red seedless grapefruit. It is assumed that per acre yields will decline by 10%, 5%, and 10% for 'Hamlin', 'Valencia', and red grapefruit varieties, respectively. In addition, if citrus canker were to become endemic to Florida, the tree density for red seedless grapefruit would decline by 5% to 109.25 trees per acre due to the planting of windbreaks designed to protect citrus intended for the fresh market. The per acre cost associated with windbreaks is $7.33/acre. Annual "canker-free" certification costs for fresh grapefruit are included at a value of $57.96/acre. Finally, due to expected additional fruit loss

[3]In recent years, 'Valencia' oranges have commanded a substantial premium over early and midseason varieties due primarily to the increase consumption of not-from-concentrate orange juice in which a higher proportion of 'Valencia' oranges is used.

Table 1. Annual post eradication per acre grove care costs in Florida.

		Age of trees			
Variety	Replacement costs	Years 2-4	Years 5-9	Years 10-12	Years > 12
Hamlin	$1,784	$561	$743	$860	$877
Valencia	1,784	561	743	860	877
Red Grapefruit	1,651	618	837	982	1002

Source: Muraro et al. (2001a).

Table 2. Projected per acre yields by variety in Florida.

Year	Hamlin Oranges (boxes)		Valencia Oranges (boxes)		Red Grapefruit (boxes)	
	Post eradication	With endemic canker	Post eradication	With endemic canker	Post eradication	With endemic canker
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	96	86	75	71	184	166
5	171	154	149	141	242	217
6	246	221	222	211	299	269
7	300	270	255	242	345	311
8	350	315	282	268	391	352
9	399	359	309	294	437	393
10	420	378	323	306	460	414
11	441	397	333	316	483	435
12	462	416	345	328	518	466
13	483	435	357	339	552	497
14	504	454	369	351	575	518
15	525	473	375	356	575	518
16	525	473	375	356	575	518
17	525	473	375	356	575	518
18	525	473	375	356	575	518
19	525	473	575	356	575	518
20	525	473	375	356	575	518

under a citrus canker endemic situation, total fruit production of oranges and grapefruit would decrease (Spreen et al., 2003). This would result in a moderate increase above historic on-tree price (less than 10%) for oranges and grapefruit would have a greater increase. The average on-tree prices used in the citrus canker endemic analysis were $3.32/90-lb box and $4.81/90-lb box for early and late variety oranges, respectively. For red grapefruit, the on-tree price used in the citrus canker endemic analysis was $2.65/85-lb box. The annual grove care costs per acre in Florida when citrus canker becomes endemic are outlined in Table 3. As trees mature, grove care costs increase from $579 in years 2 through 4 to $913 per acre for both 'Hamlin' and 'Valencia' oranges trees older than 12 years. The grove care costs increase from $699/acre in years 2 through 4 to $1,116/acre for red grapefruit trees older than 12 years. Projected per acre fruit yields by age and variety under endemic citrus canker are shown in Table 2.

Results

The estimated economic loss associated with eradicating a citrus grove infected with canker using historical prices for 'Hamlin' oranges, 'Valencia' oranges, and red seedless grapefruit is shown in Table 4. Assuming historical prices (5-year average for oranges and 8-year average for grapefruit), the estimated economic loss was $6,401/acre for 'Hamlin' oranges, $6,510/acre for 'Valencia' oranges, and $4,006/acre for red seedless grapefruit. These figures represent the fair compensation owed to the grower to cover the loss of income resulting from eradication of a citrus grove. Currently, the federal government has been providing compensation to growers. If the decision is made to privatize the compensation process via insurance, this value gives an indication of the amount of insurance a grower should carry to be fully compensated for a loss due to eradication.

One could argue that historical prices are not an accurate reflection of future prices for Florida citrus. In particular, grapefruit in Florida has endured a long period of low prices. As a result, acreage has been contracting. In addition, a disease known as citrus tristeza virus (CTV) has become active in Florida. CTV is lethal to citrus trees planted in sour orange rootstock, which accounts for a large proportion of the grapefruit acreage in Florida (Brown and Spreen, 2000). The presence of CTV will speed the acreage contraction process for grapefruit in Florida, therefore, it is likely that grapefruit prices will increase over the next few years. CTV also affects orange trees in Florida, although a much smaller proportion of orange trees are planted on sour orange rootstock compared to grapefruit. Florida's main competitor in the world orange juice market is Brazil. Brazilian growers are currently dealing with another xylem-limited bacterial disease known as citrus variegated chlorosis (CVC). CVC has killed millions of trees

Table 3. Projectal annual per acre grove care costs associated with endemic citrus canker in Florida.

Variety	Age of trees			
	Years 2-4	Years 5-9	Years 10-12	Years > 12
Hamlin	$579	$772	$896	$913
Valencia	579	772	896	913
Red Grapefruit	699	938	1,096	1,116

Source: Muraro, et al. (2001a, b)

Table 4. Projected per acre economic loss due to eradication from citrus canker.

Variety	Historical price		Optimistic price	
	On-tree price ($)	Value of destroyed trees	On-tree price ($)	Value of destroyed trees
Hamlin	$3.12	$6,401	$4.09	$8,909
Valencia	4.52	6,510	5.58	8,428
Red Grapefruit	2.27	4,006	3.27	6,768

in Brazil. The outlook for future citrus production in Brazil is more pessimistic until this disease subsides (Fernandes and Spreen, 2002).

Consistent with these observations, a second analysis was conducted assuming higher prices for both oranges and grapefruit. Red seedless grapefruit prices were assumed to increase by $1.00/85-lb box to $3.27. Delivered-in prices (prices paid by the processor) for both 'Hamlin' and 'Valencia' oranges were increased by approximately 15% that resulted in on-tree prices of $4.09 and $5.58 per 90-lb box for 'Hamlin' and 'Valencia', respectively. The estimated economic loss associated with eradication for the three citrus varieties are shown in Table 4 under the "Optimistic Price" scenario. In this case, the estimated per acre economic loss is $8,909 for 'Hamlin' oranges, $8,428 for 'Valencia', and $6,768 for red seedless grapefruit. Given the price outlook likely to be faced by Florida citrus growers over the next few years, these values likely represent a more accurate estimate of the economic loss resulting from grove eradication after a positive canker find.

A comparison between the economic value loss under a citrus canker eradication program scenario and an endemic canker situation is shown in Table 5. With endemic citrus canker, market prices for both processed oranges and fresh and processed grapefruit increase because of a reduction in yields. Market equilibrium models for processed oranges and both fresh and processed grapefruit were used to estimate price changes (Spreen et al., 2003). These prices shown in Table 5 under scenario two. The comparative values (eradication and endemic, respectively) were $6,401/acre and $4,870/acre for 'Hamlin' oranges, $6,501/acre and $6,309/acre for 'Valencia' oranges and $4,006/acre and $4,012/acre for red grapefruit, respectively.

Additional sensitivity analysis was conducted with respect to the discount rate. The impact of alternative discount rates on projected per acre economic loss due to eradication is reported in Table 6. The two alternative discount rate scenarios considered were 8 and 12%. The estimated per acre economic losses for 'Hamlin' orange, 'Valencia' orange, and red seedless grapefruit assuming an 8% discount rate and using historical prices is $7,015, $7,076, and $4,398, respectively. This result is consistent with the notion that a lower discount rate serves to increase asset values. The per acre economic losses estimated under a discount rate of 12% are $5,866, $6,013, and $3,664 for 'Hamlin' orange, 'Valencia' orange, and red seedless grapefruit, respectively. Not surprisingly, a higher discount rate reduces the economic loss associated with eradication due to citrus canker. The impact of alternative discount rates on estimated economic losses is not as sensitive, however, as alternative assumptions regarding future prices for citrus.

Table 5. Comparison of projected per acre economic loss from citrus canker.

	Scenario One: Eradication		Scenario Two: Endemic Citrus Canker	
Variety	On-tree price ($)	Value of destroyed trees	On-tree price ($)	Value of destroyed trees
Hamlin	$3.12	$6,401	$3.32	$4,870
Valencia	4.52	6,510	4.81	6,309
Red Grapefruit	2.27	4,006	2.65	4,012

Table 6. Impact of alternative discount rates on projected per acre economic loss due to eradication from citrus canker.

		Discount rate		
Variety	On-tree price ($)	8.00%	10.00%	12.00%
Hamlin	$3.12	$7,015	$6,401	$5,866
Valencia	4.52	7,076	6,510	6,013
Red Grapefruit	2.27	4,398	4,006	3,664

Concluding Remarks

Citrus canker is a bacterial disease that adversely affects citrus trees. Under current policy, a positive find of canker results in eradication of all citrus trees found in a radius of 1900 ft. In commercial production areas, this could result in the loss of up to 260 acres of citrus.

In this paper, the economic loss associated with eradication of a citrus grove due to citrus canker was estimated. The analysis incorporated grove establishment and grove maintenance costs published by Muraro et al. (2001b), which are typical in Florida. Yield curves based upon state averages were derived. Two price scenarios were considered: one based upon historical prices and one that incorporated expected future supply-demand conditions in which prices are expected to be higher. The latter scenario considers a situation when eradication is ineffectual. The impact of alternative discount rates was also considered. The three most important citrus varieties produced in Florida, 'Hamlin' oranges, 'Valencia' oranges, and red seedless grapefruit, were analyzed.

The results under a historical price assumption gave economic loss estimates of $6,401/acre for 'Hamlin' oranges, $6,510/acre for 'Valencia' oranges, and $4,006/acre for red seedless grapefruit. The results are based upon the assumption that, consistent with current regulations, the land must be in fallow for 2 years and then replanted with the same variety and at the same tree density as the eradicated grove. When an endemic citrus canker situation was assumed, which included an expected decrease in total fruit supply and an increase in average on-tree prices, estimated economic loss was $4,870/acre for 'Hamlin' oranges, $6,300/acre for 'Valencia' oranges and $3,526/acre for red grapefruit. Under an optimistic price assumption, estimated per acre economic losses were $8,909 for 'Hamlin' oranges, $8,428 for 'Valencia', and $6,768 for red seedless grapefruit. The difference in the values obtained under different price assumptions clearly demonstrates the sensitivity of the results to changes in the assumptions about price. Alternative discount rate assumptions had the expected relative impacts on economic loss estimates, but the magnitude of the economic loss was secondary to the effect cause by changes in price.

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