The Costs and Benefits Associated with Eradicating Citrus Canker in Florida

Authors

Thomas H. Spreen
Marisa L. Zansler
Ronald P. Muraro
Fritz Roka

Food and Resource Economics Department
University of Florida

Additional Contact Information:
T. Spreen: thspreen@mail.ifas.ufl.edu
M. Zansler: mzansler@ufl.edu
Phone: (352) 392-1826 x-209

Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Montreal, Canada, July 27-30, 2003

The Costs and Benefits Associated with Eradicating Citrus Canker in Florida

Citrus canker (*Xanthomonas campestris* pv. *citri*) is a bacterial disease causing lesions on the leaves, stems and fruit of citrus trees. Although fruit infected with citrus canker is not harmful for human consumption, the physical scars of the disease adversely affect the proportion of fruit that is suitable for the fresh market. Citrus canker can also diminish the productivity and vigor of the tree leading to a reduction in fruit yields. It is estimated that fruit from canker-affected trees will reduce packout rates by as much as one-third for the fresh market.[1] Experiences with this disease in other countries suggest that yield losses will range from five to 30 percent, depending upon the scion (variety). Some citrus varieties are more susceptible to canker than others. For example, grapefruit varieties are more vulnerable to canker lesions than some varieties of oranges, such as Valencia oranges.

The largest contributing factors in the spread of citrus canker include contact by grove workers, grove equipment, and wind driven rain. First, contact by grove workers or the equipment used by those workers can spread the disease to other groves. A human carrier will not be aware that the disease is on his/her clothing or on the equipment used in the grove because citrus canker does not affect human health. Equipment such as ladders, sprayers, and trucks can easily contract the disease and transmit it to other trees in neighboring groves. Second, canker can be transmitted by wind driven rain. Recent research has established that a radius of 1900 feet is a safe limit as the maximum distance that canker can spread via wind and rain (Gottwald, et al.). Florida's flat terrain

[1] Packout refers to the proportion of fruit sent to the packinghouse that is suitable for the fresh market.

facilitates the efficient transmission of the disease with such wind driven rain as hurricanes and tropical storms.

The most recent battle with citrus canker in Florida was first discovered in the residential neighborhoods of the Miami-Dade County area in 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.

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., the CCEP also stipulated that all trees within a radius of 1900 feet 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.).

As of August 2001, compliance agreements affecting all facets of the Florida citrus industry from production to processing 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 & distribution of fruit from the quarantine areas (Chung, et al.).

Efforts to eradicate both infected trees and trees within a 1900-foot 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.

In areas where canker has become prevalent, windbreaks have been planted and copper-based sprays have been applied to protect against the development of lesions on the fruit.

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 the Florida citrus industry. The industry would face an increase in the cost of production resulting from increased spraying to mitigate the effect of canker on tree productivity and fruit appearance, and the cost of 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 percent of citrus acreage in Florida.

Methodology

The three markets analyzed in this study have different structures and characteristics. Approximately 95 percent of Florida's orange crop is sent to the processing sector; therefore, one can focus on the world processed orange market (FASS). Sao Paulo, Brazil and Florida account for approximately 85 percent of world orange juice production (FAO). As such, events affecting Florida production impact its competitive position vis-à-vis Sao Paulo in the world orange juice market. Analysis of the impact of citrus canker on the world orange juice market is conducted using a model development at the University of Florida (McClain; Brewster and Spreen; Spreen et al). This model is a spatial equilibrium of the world orange juice market in with implicit supply. The demand side of the model includes consumption in the United States, European Union, Canada, and Japan (which serves as the proxy for the rest of the world). In the United States and Canada, demand is disaggregated into frozen concentrated orange juice (FCOJ) and not-from-concentrate (NFC) given that NFC consumption accounts for 40 percent and 33 percent, respectively, of total orange juice consumption in these two markets. In the EU and Japan, only FCOJ demand is considered. Tariffs imposed by the United States, EU, and Japan are also incorporated into the model.

The supply side of the model includes endogenous sub-models for Florida and Sao Paulo and fixed supply from California and Mexico. The supply sub-models are based upon the inventory bearing and non-bearing orange trees in Sao Paulo and Florida. In a given year, it is assumed that the number of trees by age is known. Multiplying this vector by a vector of yields gives orange production in a given season. Multiplication of orange production by processed utilization and juice yield gives the gallons of orange juice produced in each region. This production is allocated across the four markets so as to achieve the spatial price equilibrium under the assumption that no inventory adjustment exists. Once prices are determined in the consumption markets, a marketing margin is deducted (including any applicable tariffs) yielding processor prices in Florida and Sao Paulo, respectively. An additional marketing margin is deducted given on-tree or growth price. This price is used with past grower prices to predict new tree plantings. The existing tree inventory is aged and adjusted to account for death loss, and the model is solved again in a forward recursive fashion. For a mathematical description, see Spreen et al. With linear demand functions, it becomes a quadratic programming model that can be solved using GAMS.

The grapefruit market differs from the world orange juice market in three fundamental ways. First, Florida is the dominant supplier of grapefruit in the world accounting for nearly 50 percent of world production (FAO). Accounting for only 10 percent of the world's production of grapefruit, Israel is the second largest supplier. Therefore, analysis of grapefruit prices can be conducted while considering only Florida supply. Second, there is a greater degree of uncertainty as to whether grapefruit are intended for the fresh or processed markets. In other words, nearly all grapefruit

produced in Florida are seedless varieties that are used for both the fresh and processed markets. In recent years, fresh utilization in Florida has fluctuated between 34 and 50 percent (FASS). Third, white seedless and red seedless grapefruit varieties are treated separately in the fresh market. In recent years, red seedless grapefruit has been the preferred variety in the United States, Canada, and the EU while white seedless grapefruit has been favored in Japan.

In this analysis, a mathematical programming model of the world market for Florida grapefruit is used. It was first developed by Pana and later modified by Busby and Spreen and Ali, et al. In this model, nine markets are considered: eight fresh fruit markets and one processed market. The eight fresh fruit markets are the red seedless and white seedless grapefruit markets in the United States, Canada, the EU, and Japan. A single market for grapefruit juice is also considered. Simple linear own price-own demand equations were estimated for each market (Pana).

The supply side of the model is similar to the world orange juice model in the same way red seedless and white seedless grapefruit production is generated. The main difference is that the grapefruit model includes an endogenous allocation of fruit between fresh and processed utilization. The model also incorporates different quality standards across fresh markets. For example, the quality standard in Japan is much higher when compared to that of the United States. This is reflected through lower packout rates for the Japanese market.

Similar to the world orange juice model, grapefruit production is predetermined in the current season. Once the crop is allocated across fresh and processed utilization and across spatial fresh markets, packinghouse and processor prices can be established.

Deduction of marketing costs confers grower prices (on-tree), and the prices are used to predict new plantings. In this manner, the model is solved in a forward recursively fashion over time.

Empirical Analysis

The two models used for the market analysis are validated for the 1999-00 marketing year. In addition to the market analysis, partial budgeting is used to document the impact of canker on cost of production.

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. (2001), if canker were to become endemic in Florida, citrus production practices would be affected in two ways. Muraro et al. (2001) estimate that two additional sprays would be required for fresh fruit at a cost of $59.08 per acre. For processed fruit, one additional spray would be needed at a cost of $32.36 per 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 canker 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. Muraro et al. (2001) estimate the annual cost of establishing and maintaining a windbreak at $44.89 per acre.

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 projected that yields of late maturing (Valencia) oranges would be reduced by five percent. Grapefruit and all specialty fruit varieties would see a 10 percent decline and early oranges (specifically Hamlin) would experience the largest yield effect at 15 percent. Early oranges tend to be higher yielding compared to late oranges and are thought to more adversely affected by canker infection (Muraro, et al, 2001).

The impact of canker on packout has not been documented in published research. Experience in other countries, however, suggests that endemic canker would have a strong negative effect on the external appearance of fruit and thereby result in substantially lower packout. In this paper, a figure of 1/3 is used to reduce packout rates. For example, historical packout rates for fresh grapefruit sent to the domestic market have been approximately 60 percent (Brown and Spreen). Under this assumption, endemic canker would result in a 1/3 decrease in that packout rate to 40 percent.

In the market models, prices and quantities reported by FASS and the Citrus Administrative Committee (CAC) are used a reference points for the mathematical programming models. These models are calibrated so as to replicate the 1999-00 marketing year. For most endogenous variables, the models do a good job of replicating observed data for that year.

Empirical Results

The empirical results are presented in four sections. These are the impact of endemic citrus canker on the annual per acre returns for Florida fresh and processed grapefruit, estimated FOB cost of producing grapefruit for the fresh market, market impacts on the world market for Florida red and white grapefruit, and market impacts on Florida's processed orange market.

The Fresh and Processed Market for Florida Grapefruit

The impact of citrus canker on the annual per acre returns for fresh and processed Florida grapefruit is reported in Table 1. The results indicate that fresh fruit utilization will decline, while fresh fruit on tree revenue will increase if canker becomes endemic for both red and white grapefruit. This is offset by the significant increase in the fresh on-tree price per box. Fresh utilization of red grapefruit will decline from 13.9 to 8.4 million boxes, and fresh utilization of white grapefruit will decline from approximately 4.3 to 2.7 million boxes with the occurrence of canker. The fresh on-tree price is expected to increase significantly from $5.52 per box to $9.92 per box for red grapefruit, and from $9.78 per box to $15.35 per box for white grapefruit. As a result, fresh on tree revenue increases from approximately $77 million to $83.8 million. Processed fruit, on the other hand, experiences a decline in on-tree revenue from $30.3 million to $21.6 million.

The overall total production is expected to decline by 10 percent if canker becomes endemic from 31.9 to 28.7 million boxes for red grapefruit and from 20.9 to 18.8 million boxes for white grape fruit. The average on-tree price for red grapefruit increases from $3.36 per box to $3.93 per box, and the average on-tree price for white grapefruit increases from $3.87 per box to $4.60 per box. As a result, total combined on-tree revenue for the fresh and processed markets declines for both red and white grapefruit. Total on-tree revenue for red grapefruit declines by nearly 2 percent from approximately $107.2 million to $105.4 million, while on-tree revenue for white grapefruit declines 14 percent from $80.9 million to $69.5 million. The larger percentage decline in on-tree revenue for white grapefruit compared to red grapefruit is due to the higher proportion of white grapefruit utilized in processed form.

FOB Cost of Production for Fresh Grapefruit

The impact of citrus canker on the FOB packinghouse costs for red grapefruit is reported in Table 2. In Table 2, the estimated cost of production including growing, harvest, hauling, and packing grapefruit is shown based upon the figures provided by Muraro, et al. (2000). In those production budgets, Muraro et al analyze a typical southwest Florida red grapefruit grove under the assumption that per acre yield is 555 boxes per acre and marketable yield for the fresh market (packout) is 60 percent. This means that 666 cartons of fresh fruit can be marketed from one acre (two cartons per box). Assuming that canker reduces fruit yield by 10 percent, per acre yield declines from 555 to 500 boxes per acre. Further assuming the packout declines by 1/3 with canker, fresh market utilization with endemic citrus canker is reduced from 666 to 400 cartons per acre. Using the Florida market grapefruit model, with canker, the delivered-in price of eliminations decreases from $0.65 to $0.60 per pound solid because additional fruit will be processed. Growing costs per acre increase through the additional costs associated with the placement of windbreaks and additional copper applications from $867.06 to $971.03. When adjusted to per carton, growing costs increase by approximately 47 percent from $1.30 to $2.43 per carton. Other costs - which include interest on operating costs, management costs, taxes, and interest on capital investment – increase from $0.83 to $1.38 per carton. Harvesting costs – which include pick and haul – increase from $1.94 to $2.91 per carton. Overall, total delivered in costs are projected to increase by approximately 40 percent from $4.07 per carton to $6.72 per carton. Packing and selling costs increase from $3.79 per carton to $3.91 per carton. Net cost of fresh eliminations is the average yield of pound solids per box times price per pound

solids minus the packinghouse elimination charge of $1.00 per box. After factoring in the credit associated with net costs of eliminations, total FOB costs at the packinghouse level increase by roughly 20 percent with endemic canker from $7.25 to $9.08 per carton.

FOB Revenue Associated with Grapefruit

The impact of citrus canker on world FOB revenue for red seedless and white seedless grapefruit is reported in Table 3. According to the results of the model, the average FOB price for both red and white grapefruit in the United States, Canada and Japan increases significantly when citrus canker becomes endemic. The adjusted FOB price for red grapefruit increases to $9.93, $10.19, and $14.16 in the United States, Canada, and Japan, respectively. The adjusted FOB price for white grapefruit increases to $10.34, $10.30, and $14.14 in the United States, Canada, and Japan, respectively. Adjusted FOB revenue in the United States increases to $12.1 million for red grapefruit and to $13.4 million for white grapefruit. Adjusted FOB revenue in Canada increases to $18.3 million for red grapefruit and to $1.5 million for white grapefruit. Adjusted FOB revenue in Japan, however, decreases to $39.4 million for red grapefruit and to $57.0 million for white grapefruit. Under the assumption that market access to the EU is denied with endemic canker, the FOB revenue from that market is eliminated. Total FOB revenue decreases from $322.2 million to $$250.7 million when citrus canker becomes endemic to Florida.

The Processed Orange Market in Florida

The projected impact of citrus canker on the processed orange market in Florida is reported in Table 4. Results from the world processed orange model indicate that

processed utilization would decline 127.5 million boxes to 109.8 million boxes for Hamlin oranges if canker becomes endemic. In addition, processed utilization of Valencia (late maturing) oranges would decline from 96.1 to 92.1 million boxes. The expected on-tree price is expected to increase from $3.07 per box to $3.56 per box for Hamlin oranges, and is expected to decrease from $4.31 per box to $4.26 per box for Valencia oranges. The on-tree price increases as s consequence of reduced processed utilization in Florida and increased imports from Brazil are not sufficient to offset the decline of Florida orange juice production. While demand for orange juice at the consumer level is near unitary elastic, derived demand at the grower level is clearly inelastic. Total grower revenue is projected to decline from $391.4 million to $359.3 million for Hamlin oranges, but increase for Valencia oranges from $414.2 million to $422.7 million for Valencia oranges. Aggregate grower revenue shows a small decline from $805.6 million in 1999-00 to $782 million under an endemic canker scenario.

Summary of the Benefits Associated with Canker Eradication

In the analysis presented in this paper, the likely impact of endemic citrus canker in Florida was evaluated from several perspectives. Both grower level and FOB level revenue impacts are estimated as well as projections of the increased cost associated with fresh grapefruit. At the grower level, a negative impact on grower revenue is projected for both processed oranges and fresh and processed grapefruit. In aggregate, observed grower revenue was $993.7 million in the 1999-00 season and is projected to be $956.9 million assuming canker is endemic, a decline of $36.8 million. There were 716,200 acres of orange and grapefruit production in Florida in the 1999-00 season. Per acre cost of production is projected to increase from $74 to $104 depending on whether the fruit is

targeted for the fresh or processed market. Since the acreage allocated to each market outlet is not known precisely, using the lower figure suggests an aggregate increase in production cost of approximately $53 million. The combination of decreased revenues and increased costs suggests that grower net revenues would decline by $89.8 million on an annual basis. A loss of revenue of this magnitude would significantly reduce the profitability of citrus production in Florida and ultimately place downward pressure on the value of Florida citrus groves. If accurate, reduced profitability would serve to contract the industry over time resulting in fewer acres of citrus production in Florida.

Costs associated with Eradicating Citrus Canker in Florida

The income approach to asset valuation was utilized in Spreen, et al (2003b) to first project future net returns derived from the grove. Future returns were discounted and summed providing an estimate of the net present value (NPV) of the future revenue stream. The formula for calculating NPV is

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

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 was estimated using the expected NPV of the eradicated trees compared with the NPV of the replacement trees. That is, the economic loss was given by

$$\text{EL} = \text{NPV}_1 - \text{NPV}_2 \tag{2}$$

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 eradicated grove (under the assumption the grove had not been eradicated and was assumed to be canker-free) as well as yields associated with the replacement grove are estimated. Costs associated with both eradication and replanting 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

A comparison of the net returns associated with the existing grove and the net returns associated with the replacement grove for Valencia oranges is depicted in Figure 1. The top line is associated net returns generated by a ten-year old grove using average Florida yields, and assuming that canker is not endemic to Florida. The bottom line depicts the net returns that would be realized if that grove had been eradicated due to canker and replaced with an identical grove[2].

Under Florida regulations, a grove eradicated due to canker must remain in fallow for two years. Therefore, the first two years after eradication no return can be realized, and the only costs 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. Annual grove care costs in Florida are outlined in Table 5. 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

[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.

115 trees per acre for red seedless grapefruit. Therefore, total fallow and replacement costs for Valencia and Hamlin oranges are $1784. Fallow and replacement costs for grapefruit are $1651. After planting, citrus trees do not generally produce fruit in the first three years of life. Although, revenue is not realized for these three years, young trees still require care in the form of fertilization, pest control, and irrigation. Using estimates from Muraro, et al., a charge of $3.79 per 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 $569 and $618 for oranges and grapefruit, respectively.

After the new trees begin to bear fruit, net returns gradually increase. In the example illustrated in Figure 1, positive net returns are realized at the beginning of year five, which is seven 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.

Depending upon the price assumption used, it was estimated that the per acre value of Hamlin groves eradicated due to canker ranges from $6342 to $8850 and for Valencia groves the range was $7155 to $9238 per acre. The estimate for red grapefruit was $4005 to $6766 per acre. These figures provide estimates of the cost associated with eradicating citrus canker in Florida. It does not include the cost associated with non-commercial citrus production such as that found in the residential neighborhoods of Dade and Broward counties.

Concluding Remarks

Citrus canker is a bacterial disease that attacks the leaves, stems and fruit of citrus trees. Citrus trees are adversely affected through reduced yields and a lower proportion

of fruit suitable for the fresh market because of the visual external blemishes on the fruit.

There is no known protocol to eradicate citrus canker through chemical or biological controls. The current policy is to eradicate all citrus trees within a 1900-foot radius of a positive canker find. Current policy dictates that commercial growers receive compensation for eradicated trees. The overall purpose of this paper is estimate the costs and benefits associated with the canker eradication policy.

Because citrus production in Florida is primarily utilized in the processed market, there is some belief that endemic citrus canker would have minor effects on the Florida citrus industry. Any disease that reduces per acre yields, however, ultimately increases the cost per unit of production. Furthermore, fresh fruit producers face possible loss of market access in other citrus producing regions. Given its past actions, it likely that the European Union would place an embargo on fresh citrus shipments from Florida.

In this paper, a partial analysis of the costs and benefits associated with the canker eradication program in Florida is presented. The analysis included the study of the impact of endemic citrus canker in Florida on processed oranges, as well as fresh and processed grapefruit. Avoidance of this impact is deemed to be the benefits associated with the canker eradication program. The analysis did not encompass fresh oranges and specialty varieties such as tangerines and tangelos. The figures presented here suggest a decline of nearly $37 million annually in grower revenue if canker were endemic in Florida. Combined with an increased cost of production, producer net revenue is projected to decrease by nearly $90 million annually. A decrease of this magnitude would significantly impact the profitability of citrus production in Florida. The analysis also suggested that the FOB cost of fresh grapefruit would increase substantially placing

additional pressure on packinghouse returns if canker were to become established in Florida.

The eradication program entails destruction of all trees within a 1900-foot radius of a positive canker find. Two issues complicate the process of estimating total cost of the eradication program. First, the acreage that must be eradicated associated with a positive canker find depends upon the configuration of land use surrounding the infected tree. If an infected tree is surrounded by other citrus production, a radius of 1900 feet translates to approximately 260 acres. Given the range of estimates presented in this paper for the economic loss associated with eradicated trees, each positive find could result in an economic loss ranging up to $1.8 million for oranges and $1.2 million for grapefruit. Second, it is unknown how many trees will eventually be eradicated before the current effort proves to be successful. This analysis is left for additional study.

References

Brewster, Charlene, and Thomas H. Spreen. "Price Equilibrium in Spatially Separated Multi-Product Markets: An Application to the World Processed Orange Juice Market." Selected paper presented at the American Agricultural Economics Association meetings, Salt Lake City, UT, August 1998. (Abstract: *Amer. J. Agr. Econ.* 80(1998): 1175).

Brown, Mark G., Thomas H. Spreen, and Ronald P. Muraro. "Fresh Vesus Processed Utilization of Florida Grapefruit." *Journal of Food Distribution Research*, 30:3(1999):22-32.

Busby, Jean C., and Thomas H. Spreen. "The Impact on the U.S. Grapefruit Industry on Banning the Pesticide Sodium Ortho-phenylphenate." *Journal of Food Distribution Research* 26:2(1995):39-46.

Gottwald, T. R., G. Hughes, J.H Graham, X. Sun, and T. Riley. "The Citrus Canker Epidemic in Florida - the Scientific Basis of Regulatory/Eradication Policy for an Invasive Plant Pathogen." *Phytopathology* 91(2001):30-34.

McClain, E. A. "A Monte Carlo Simulation Model of the World Orange Juice Market." Unpublished Ph.D. dissertation, University of Florida, Gainesville, 1989.

Muraro, Ronald P., Fritz Roka, and Thomas H. Spreen. "Grower Costs of Having Citrus Canker in Florida." Extension fact sheet No. FE 286, Florida Cooperative Extension Service, University of Florida, September, 2001. Available at http://edis.ifas.ufl.edu/FE286

Muraro, Ronald P., Fritz M. Roka, and Robert E. Rouse. "Budgeting Costs and Returns for Southwest Florida Citrus Production, 1999-00," Economic Information Report EI 00-6. Institute of Food and Agricultural Sciences, University of Florida, December 2000.

Pana, Regina. "A Model of the World Market for Fresh and Processed Grapefruit." Unpublished M.S. thesis, Food and Resource Economics, University of Florida, Gainesville, FL, 1991.

Spreen, Thomas H., Charlene Brewster, and Mark G. Brown. "The Free Trade Area of the Americas and the World Processed Orange Market." *Journal of Agricultural and Applied Economics* 35(2003a):107-26.

Spreen, Thomas H., Ronald P. Muraro, and Marisa L. "Estimating the Economic Value Associated with Citrus Trees Lost to Citrus Canker," Selected paper presented at the Southern Agricultural Economics Association meetings, Mobile, AL., February 2003b.

Table 1. Impact of Citrus Canker on annual per acre returns of fresh and processed Florida grapefruit, 1999-0.

	Fresh Fruit			Processed Fruit			Total Production	Average on-tree price	Total on-tree revenue
	Fresh Utilization	Fresh on-tree price	Fresh on-tree revenue	Processed Utilization	Processed on-tree price	Processed on-tree revenue			
w/o Canker									
Red Grapefruit	13,946	5.52	76,982	17,954	1.69	30,342	31,900	3.36	107,184
White Grapefruit	4,271	9.78	39,078	16,629	2.35	39,078	20,900	3.87	80,883
w/Canker									
Red Grapefruit	8,449	9.92	83,813	17,979	1.20	21,582	28,710	3.93	105,395
White Grapefruit	2,651	15.35	40,699	15,686	1.84	28,799	18,810	4.60	69,497

Table 2. Impact of Citrus Canker on packinghouse costs of red grapefruit, 1999-0.

	w/o Canker			w/ Canker (assume 10% yield reduction)		
Total Yield (boxes/acre)	555			500		
Percent Packout	60%			40%		
Fresh Mkt Utilization (cartons/acre)	666			400		
Eliminations for Processed Juice (boxes/acre)	222			300		
Pound Solids Yield of Eliminations (p.s./box)	4.70			4.70		
Processed Price of Eliminations (p.s.)	$0.60			$0.65		
Packinghouse Eliminations Charge (per box)	$1.00			$1.00		
Harvesting/Pick and Haul Costs (per box)	$2.325			$2.325		
Growing Costs (per acre)	$867.06			$867.06		
Additional Costs (per acre):						
Windbreaks	-----			$44.89		
Copper Application (2 sprays)	-----			$59.08		
	Acre	Box	Carton	Acre	Box	Carton
Total Growing/ Cultural Costs	$867.06	$2.604	$1.3019	$971.03	$4.860	$2.4300
Other Costs	552.70	1.660	0.8299	552.70	2.766	1.3831
Harvesting (Pick/Spot Pick, Haul, DOC Tax, Etc.)	1,290.38	3.875	1.9375	1,161.34	5.813	2.9063
Total Delivered-In Cost	$2,710.14	$8.139	$4.0693	$2,685.07	$13.439	$6.7194
Packing & Selling	2,520.81	7.570	3.7850	1,560.44	7.810	3.9050
Net Cost of Eliminations a/	-404.04	-1.213	-0.6067	-615.88	-3.083	-1.5413
Total F.O.B. Costs	$4,826.91	$14.495	$7.2476	$3,629.62	$18.166	$9.0831

a/ "Net Eliminations Cost" equals the average yield of pound solids per box times price per pound solids less packinghouse elimination charge and cannery hauling charge of per box.

Table 3. Impact of citrus canker on World FOB revenue, 1999-0.

	Red Grapefruit				White Grapefruit				World FOB Revenue
	US	Canada	EU	Japan	US	Canada	EU	Japan	
Marketings	14,225	2,086	6,587	4,999	1,488	168	248	6,888	--------
Average FOB Price	7.60	7.80	8.00	10.80	8.03	8.00	8.20	11.00	--------
FOB Revenue	$108,110	$16,271	$52,696	$53,989	$11,949	$1,344	$2,034	$75,768	$322,160
W/ Canker									
Baseline Marketings	14,530	2,156	6,350	4,656	1,641	185	257	6,340	--------
Canker Endemic Marketings	12,450	1,859	0	2,589	1,429	161	0	3,711	--------
Adjusted Marketings	12,189	1,799	0	2,780	1,296	146	0	4,032	--------
Baseline FOB Price	7.27	7.27	8.41	11.39	6.65	6.65	7.77	11.69	--------
Canker Endemic FOB Price	9.50	9.50	----	14.93	8.56	8.56	----	15.03	--------
Adjusted FOB Price	9.93	10.19	0.00	14.16	10.34	10.30	0.00	14.14	--------
Adjusted FOB Revenue	$121,048	$18,333	$0	$39,352	$13,394	$1,506	$0	$57,021	$250,652

Table 4. Impact of citrus canker on annual per acre Returns of processed Florida oranges, 1999-0.

	Total Production	Processed Utilization	On-Tree price	Actual Processed Net Revenue
w/o canker				
Hamlin	134,000	127,495	3.07	391,410
Valencia	99,000	96,112	4.31	414,243
w/canker				
Hamlin	113,900	109,795	3.27	359,303
Valencia	94,050	92,089	4.59	422,689

Table 5. Annual per acre grove care costs in Florida

Fruit Type	Replacement Costs	Age of Trees			
		Years 2-4	Years 5-9	Years 10-12	Years > 12
Hamlin	$1,784	$569	$755	$875	$893
Valencia	1,784	569	755	875	893
Red Grapefruit	1,651	618	837	982	1002

Source: Muraro, et al.

Figure 1. Expected undiscounted net returns from a productive 10-year old orange grove versus the net returns from a replanted after canker.