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The Potential Economic Cost and Response to Greening in Florida Citrus

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Huanglongbing (HLB), also known as citrus greening, has emerged as an increasing threat to the economic viability of citrus production in Florida. Citrus greening was first observed in non-commercial, backyard citrus in South Florida in August 2005. By February 2009, citrus greening had spread throughout the traditional citrus areas of the state. Thus far, quarantine, tree removal, insecticide applications, heat treatments, and foliar nutritional techniques designed to mask the disease symptoms are the only available, but not completely effective, techniques for managing citrus greening. The disease directly affects the citrus tree resulting in reduced yield and fruit quality following an initial incubation period, eventually making the tree unproductive and contributing to greater mortality.

The Disease-Causing Bacterium and its Vector

Like many plant diseases, the infection of citrus with HLB is a multifaceted process. The disease is caused by the bacterium *Candidatus* Liberibacter asiaticus which infects the phloem of the tree. Phloem is living tissue in the inner part of the branches and stem that carries sucrose to the roots, young leaves, and fruits. This has two effects: First, the plant accumulates toxic levels of starch in the plant cells. Second, blockage of phloem cells may starve the roots of the citrus tree.

The vector of the disease is the Asian citrus psyllid, *Diaphorina citri*, which transports the disease-causing bacterium between trees. The Asian citrus psyllid was first observed in Florida in 1998, prior to the arrival of HLB (Burrow et al., 2014). One plausible source of the psyllid and the disease in Florida was orange jasmine, an ornamental shrub. The disease spreads from the point of infection, a young shoot, throughout the tree (Chiyaka et al., 2012), but additional psyllids can accelerate the disease development within a tree and transmit the disease from tree to tree.

Economic Effects of Citrus Greening

HLB economically affects commercial citrus groves in three ways. First, the disease increases the mortality rate of citrus trees. Second, the disease reduces the marketable yield per tree. Third, greening increases production costs. Hodges and Spreen (2012) estimate that HLB reduced the value of Florida citrus output by $4.51 billion between the 2006-07 and 2010-11 crop production years.

Tree Mortality

Historically, the two primary determinants of citrus tree mortality in Florida have been weather events, such as freezes and hurricanes, and the conversion of citrus groves to urban uses. Florida Citrus Mutual (2012) provides a timeline of major Florida freeze events including most recently the 1981 and 1982 freezes that resulted in major citrus losses in the northern ridge around the Orlando area, and the 1985 and 1989 freezes. Hurricanes caused significant citrus tree loss in 2004. Florida experienced four hurricanes that year, and the paths of three of those hurricanes—namely Charley, Frances, and Jeanne—crossed though a major citrus county, Polk County. In addition to killing trees, these storms provided a mechanism to spread several diseases. Most of the loss of groves to urban uses in the 1980s through the 1990s followed the freeze patterns; citrus groves converted to urban uses in the

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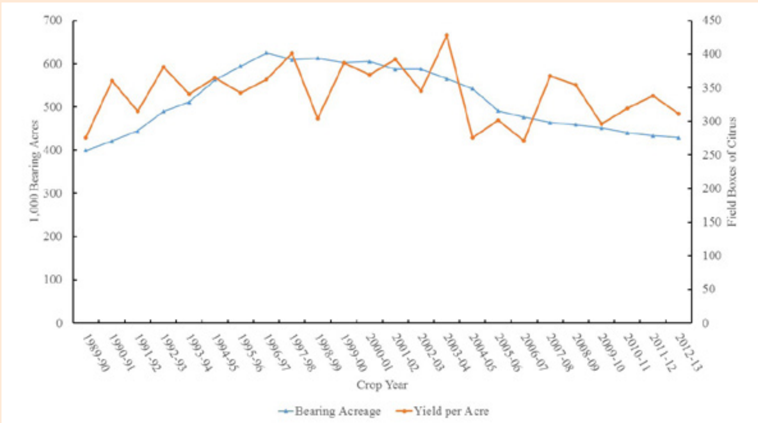
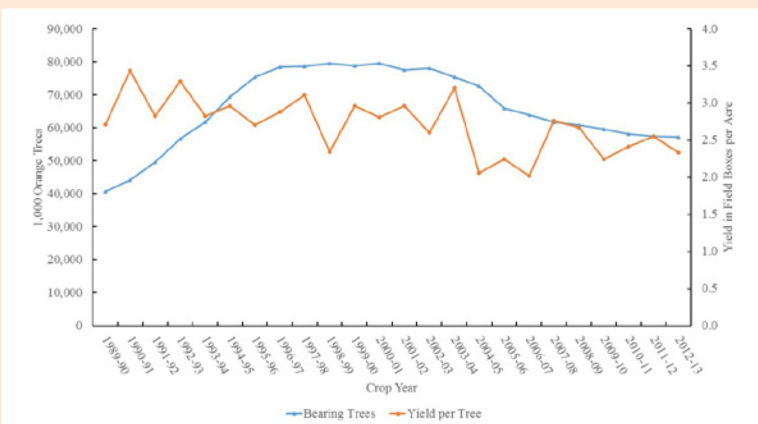
Figure 1: Orange Acreage and Yield per Acre, Crop Years 1989-90 through 2011-12



(USDA, 2014)

Figure 2: Number of Orange Trees and Yield per Tree, Crop Years 1989-90 through 2011-12



(USDA, 2014)

Figure 3: Fruit Exhibiting Citrus Greening Symptoms

(Spann et al., 2010b)

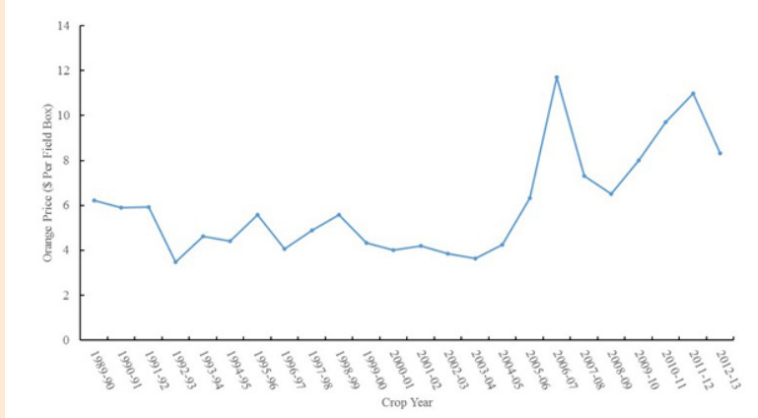
northern ridge between Orlando and Tampa. In addition, urban pressure reduced citrus acreage in the Indian River area. However, the conversion of groves to housing slowed significantly with the collapse of the housing market beginning in 2008. Since 2005, citrus greening has introduced a third major source of tree loss.

The story of changes in the citrus industry is complicated by the perennial nature of tree crops and by changes in technology. Figure 1 presents the overall bearing acreage of all oranges in Florida for each crop production year from 1989-90 to 2012-13 together with the yield per acre. The bearing acreage reached 624,900 acres in the 1996-97 crop year. The acreage declined at an average rate of 1.8% from the 1996-97 crop year through the 2003-04 crop year. The rate of decline almost doubled to an average annual rate of 3.1% for the 2004-05 crop year through the 2012-13 crop year. Due to the presence of other market factors it would be premature to attribute the post-2005 decline in acreage solely to citrus greening, but it is clear that greening has contributed significantly.

The trends in tree numbers are similar to those in total orange acreage (Figure 2). Between the 1994-95 and the 2002-03 crop years the number of trees increased at an average annual rate of 1.6%. However, between the 2005-06 and 2012-13 crop years the number of trees declined at an average annual rate of 3.1%.

Tree density has also recently fallen, further compounding yield losses. In the 1989-90 crop year, the average density was 101.79 orange trees per acre. This increased to 132.21 trees per acre in the 2001-02 crop year. Tree density then remained relatively steady until the introduction of citrus greening in 2005. The recent decline is likely due to the removal of diseased trees. Growers do not always immediately replant removed

Figure 4: Orange Prices in Dollars per Field Box, Crop Years 1989-90 through 2011-12



(USDA, 2014)

trees and the replants may not reach fruit-bearing age before succumbing to citrus greening. Taken together, the data support the conjecture that HLB has resulted in a higher rate of tree mortality.

Marketability

In addition to higher rates of tree mortality, citrus greening reduces the marketable yield of the average citrus tree by affecting the quantity, size, visual attributes, and flavor of the fruit. Symptomatic trees produce misshapen, lopsided fruit (Figure 3). These fruit may never ripen or only partially ripen. Other visual symptoms include a discolored peel and aborted seeds within the fruit (Spann et al., 2010b). HLB-positive citrus trees also tend to experience more severe fruit drop than trees without the disease and are more susceptible to other diseases as well (Hodges and Spreen, 2012).

Compounding these yield losses, orange juice from symptomatic fruit often has greater concentrations of limonin and nomilin. These compounds contribute to a bitter or sour taste in the juice (Baldwin et al., 2009). As a result, orange juice quality is highly variable depending on the harvest date, citrus variety, and extent of HLB symptoms. However, scientists theorize it is possible for producers to blend juice from fruit that does not exhibit HLB symptoms with limited amounts of symptomatic fruit juice and maintain an acceptable commercial product (Plotto et al., 2010). Research programs are currently underway to determine a method of blending that ensures juice quality. Fruit with severe HLB symptoms are otherwise unmarketable and must be rejected.

These negative fruit characteristics and marketable yield losses can be partially mitigated by providing infected trees with an enhanced nutritional program via multiple foliar applications. A modified nutritional program does not inhibit the HLB-causing bacterium considerably, but has been shown to be effective in reducing HLB symptoms (Shen et al., 2013a). Multiple nutritional formulations are available depending on the specific HLB symptoms exhibited by the infected trees. Currently, the use of these supplemental nutritional programs is widespread among Florida citrus growers (Hodges and Spreen, 2012; Shen et al., 2013a; and Spann et al., 2010a).

Tree Yield

The effect of greening on the marketable yield per orange tree can be estimated with statistical techniques; that is, with a simple linear regression. Results from using this approach support the conclusion that greening had a statistically significant negative effect on orange yield per tree (Moss et al., 2014). However, this simple statistical analysis ignores two complications. First, overall orange yield per tree is complicated by the age structure of orange-bearing trees. In general, orange trees start bearing a commercially viable crop in year 4 or year 5. The yield per tree increases with age, reaching a maximum at about 15 years of age. In periods of increased planting, the state average yield per tree declines because of the influx of new, young trees. Anecdotal evidence suggests that younger trees are more susceptible to greening. Specifically, the psyllid is drawn to new growth in the tree, also known as a "flush." Hence, since young trees flush more often, they are more susceptible to the disease. Secondly, price changes will affect growers' incentives to utilize inputs, remove trees, and replant trees, all of which affect average yield per tree. Prices did, indeed, vary over the period of the study. As depicted in Figure 4, the orange price spiked in the 2006-07 crop year, and then declined in the 2007-08 and 2008-09 crop years. Further, while the price increased in the 2009-10 and 2011-12 crop years, it declined in the 2012-13 crop year even as the quantity of orange produced declined.

Response to Greening

Most of the early response to greening followed Florida's protocols established for citrus canker. Citrus canker, which is caused by the bacterium *Xanthomonas citri* pv. *citri,* is a disease that reduced the marketability of fresh fruit from Florida because it was considered a quarantine disease. The canker protocol called for the removal of trees within 1,900 feet of an infected tree. Besides production of clean nursery stock, symptomatic tree removal was also the primary recommended method of control for HLB in the main citrus-producing areas, Brazil and Florida, although the canker protocol of removing surrounding trees was not followed (Gottwald, 2010). Initially, some Florida growers implemented this strategy. However, recent research indicates that removal was not an economically efficient control for citrus greening in relatively small groves in South Florida for three primary reasons (Moss and Schmitz, 2014). First, in mature trees, a tree may show symptoms of the disease, but still produce marketable fruit for several years. Immediately removing such a tree and replacing it with a new tree that will not produce fruit for several years imposes a large opportunity cost on the grower in the form of lost yields. Second, HLB has a long incubation period during which the tree can serve as a source of the disease without showing any symptoms of the disease (Shen et al., 2013b). This prevents complete removal of all diseased trees, impeding complete eradication of the disease in a given grove. Third, without a coordinated effort across growers within a region, a grower not following an eradication program could impede the efforts of a neighboring grower attempting to eradicate the disease. For all of these reasons, most Florida growers have abandoned tree removal. However, a few larger, isolated citrus groves are still implementing eradication programs despite these setbacks.

Most growers implement two primary control and management practices. The first is an insecticide program that involves 8 to 12 insecticide applications per year to control psyllids (unpublished grower records). This insecticide program costs $1,000 or more per acre each year (Muraro, 2009). For reference, prior to the introduction of HLB in Florida, total annual production costs, including all insecticides and fertilizers, totaled only $800 per acre. Due to the limited number of effective insecticides available, pesticide resistance is an increasing problem (Tiwari et al., 2011). Over time, the efficacy of each insecticide application is expected to decrease, consequently requiring more frequent applications to maintain the same level of control.

In addition to controlling the psyllid, growers can mitigate some of the symptoms of the disease via foliar applications of essential micro- and macronutrients, often supplemented with resistance-enhancing products (Shen et al., 2013a; and Spann et al., 2010a). These applications increase costs by $200 to $600 per acre, depending on the nutrient mix applied (Roka and Muraro, 2010).

Table 1

Estimated Producer and Consumer Losses from Greening (Millions of Dollars per Year)		
	Change in Tree Stock	Change in Tree Stock and Increased Cost of Production
Producer Losses	-18.089	-141.976
Consumer Losses	-154.927	-900.941
Net Economic Cost	-173.015	-1,042.92
Source: Moss et al., 2014		

Economic Impact

Moss et al. (2014) estimate supply and demand for Florida orange production using data from the 1989-90 crop year through the 2012-13 crop year. Given the number of orange trees in the sample (65.86 million trees), they predict that the equilibrium quantity of oranges is 170.5 million field boxes with an equilibrium price of $7.67 per field box. If tree numbers decline from 65.86 million trees to 57.14 million trees—which is equivalent to the tree number observed in the 2012-13 crop year—the quantity of oranges supplied would fall to 158.9 million field boxes at a price of $8.59 per box. As a result of this change, consumers would be expected to lose $154.9 million due to higher prices and less consumption. Despite higher prices, producers would be expected to lose $18.09 million because the decrease in sales would outweigh the increase in price received. Hence, the total economic cost of greening is estimated to be $173.0 million. However, these estimates may understate the economic cost of citrus greening since, in addition to tree mortality, growers experience higher production costs. To approximate these increased costs, we increase the estimated marginal cost of producing oranges by 1% in addition to the effect of tree loss. The 1% increase is arbitrary, but it provides a baseline measure of the potential economic loss, and increases the estimate of economic loss from greening to slightly over $1 billion per year (Table 1).

Providing context for these estimated losses, Hodges, Rahmani, and Mulkey (2009) estimated that Florida citrus produced 292 million boxes of fruit in the 2003-04 season. This production represented $3.69 billion in total sales. Given that 82.9% of this output was orange production, we approximate total orange sales in the 2003-04 season of $3.06 billion in 2003-04 dollars, or $3.77 billion in 2014 dollars. Hence, the economic loss from greening (using the tree numbers for 2012) represents about 4.6% of the size of the orange industry based on changes in the tree numbers, or 27.6% of the industry if we consider the potential increased cost of production. In addition to these impacts on production and sales, Hodges, Rahmani, and Mulkey (2009) found that the Florida citrus industry accounted for 76,336 jobs. Of these jobs, 61,307 jobs were in the processing sector while 15,029 jobs were in the fresh marketing sector. In general, oranges are processed into juice, including frozen orange juice concentrate and not-from-concentrate fresh and frozen juice. The latter has increased in importance in recent years. Hence, most of the job losses from citrus greening are likely to occur in the processing sector. Furthermore, if we assume that job loss would be proportional to the drop in production, we expect that HLB in orange groves will result in the loss of approximately 5,000 jobs per year in the state's processing sector. These job loss estimates are consistent with the estimates in Hodges and Spreen (2012) who estimate that citrus greening has cost the State of Florida an average of 8,257 jobs per year.

Looking Forward

Given this analysis, it is apparent that the effects of HLB are potentially large and far-reaching. Consumers who drink orange juice daily may be forced to pay significantly higher prices or switch to another beverage. Growers face higher costs, reduced yields, and reduced profits, while those in related industries face job losses.

To solve these problems, researchers are putting tremendous time and effort into finding solutions to HLB. The U.S. Department of Agriculture has allocated $24 million for fiscal year 2014 specifically for citrus disease research. The money is allocated to researchers through a competitive grant process under the Specialty Crop Research Initiative/ Citrus Disease Research and Extension program. Proposed projects from researchers at many institutions include developing and testing compounds to cure the disease itself, developing and testing improved insecticide programs to increase efficacy and reduce resistance development, and developing and testing alternative psyllid controls such as the use of biological options. Other possible solutions include genetically modifying citrus trees to be resistant to the disease or genetically modifying psyllids to be incapable of vectoring the disease. Thus, substantial time and effort have been allocated to finding solutions to the problem, but most possible solutions will take time to develop and test before growers will be able to benefit from them.

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