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Florida Citrus Growers' First Impressions on Genetically Modified Trees

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Citrus greening is jeopardizing the Florida citrus industry. A line of research some expect to be the ultimate solution to the disease is developing trees that are resistant to it by using genetic modification. Little, though, is known regarding the willingness of US citrus growers to adopt GM technology, their concerns surrounding its adoption, or even the degree to which the disease has impacted them. Thus, we present growers' survey-based estimates of the significant impact of citrus greening on citrus operations in Florida as well as growers' self-assessed level of information, potential concerns, and impressions regarding potential adoption of GM technology as a way to deal with the disease. We also examine growers' preferences on desirable attributes of a Huanglongbing-resistant tree. The most significant heterogeneity in producers' concerns and trait preferences lies in the areas of environment, safety, and gene origin.

Key words: adoption, citrus greening, genetically modified trees.

Introduction

Citrus greening, also known as Huanglongbing (HLB) for its Chinese origin, is a bacterial disease rapidly spreading worldwide. It is also currently considered to be the most devastating citrus disease in all major producing regions (Food and Agriculture Organization of the United Nations [FAO], 2015). To date, there is neither a cure nor an economically viable option for managing HLB infected trees. To slow down the disease's progress and its infection rate, growers have had to modify their groves' management. In Brazil, for example, large growers eradicate symptomatic trees. In US affected regions, growers have increased overall chemical use, which has in turn increased not only costs but also associated health and environmental concerns.

Researchers are working on developing short- and long-term treatments for growers to manage HLB more effectively. Many of these efforts have focused on best management practices such as early detection, pest control efforts, strengthening of root systems of the trees to help tolerate the infection, and combining integrated management approaches for sustaining production in infected trees (US Department of Agriculture [USDA], National Agricultural Statistics Service [NASS], 2015a). Research related to longer-term solutions includes how to hinder the reproductive cycle of the vector of the disease—or its ability to transmit the disease—and the development of resistant trees. A line of research some expect to be the ultimate solution to HLB is developing trees that are resistant to it by using genetic modification. Little, though, is known regarding the willingness of US citrus growers to adopt genetically modified (GM) technology, their concerns surrounding its adoption, or even the degree to which the disease has impacted them.

The purpose of the present study is three-fold. First, we present growers' survey-based estimates of the impact of HLB on citrus operations in Florida, which is the largest orange-producing state in the United States. To the best of our knowledge, these estimates represent the first of their kind. Second, we present and analyze Florida citrus growers' self-assessed level of information, potential concerns, and impressions regarding GM technology adoption as a way to deal with HLB. Finally, we also examine growers' preferences on desirable attributes of an HLB-resistant tree. The *ex-ante* character of our study—that is, while different governmental and private funding agencies and private companies are currently evaluating and supporting a multitude of approaches to deal with HLB[1]—should provide useful input and guidance to industry stakeholders and research funding agencies.

Citrus Greening in Florida

In Florida, approximately 95% of all oranges are processed for juice (USDA NASS, 2015b). However, HLB is jeopardizing the state's citrus industry. HLB causes citrus trees' overall health to decline within a few years.

1. *The 2014 Farm Bill alone established a provision of $125 million spread over five years to specifically fund research to tackle HLB.*

The disease negatively affects yield, fruit size and quality, tree mortality, and cost of production. Moreover, tree mortality rates are generally higher in young trees (Gottwald, 2010). HLB has the potential to destroy the production, appearance, and economic value of citrus trees of all cultivars (Batool et al., 2007).

First found in Florida in 2005, HLB has spread rapidly across the state from south to north and has had a major impact on the profitability of orange production. Since HLB was found,[2] orange acreage and yield in Florida decreased by 26% and 42%, respectively. Thus, orange production dropped from 242 to 104.6 million boxes in 2014. Despite that, on-tree prices for oranges have increased from $2.89 to $7.12 a box (USDA NASS, 2015b), the cost of production per box has increased three-fold (University of Florida, Citrus Research and Education Center [CREC], 2015a).

The increment in chemical use in response to HLB—particularly in terms of enhanced nutritional programs and insecticides for the vector of the disease, the Asian citrus psyllid (ACP)—accounts for the bulk of the increase in costs.[3] Despite the high percentage infestation, insecticide sprays are applied for two reasons. First, to limit re-inoculation to prevent the load of the bacteria to increase. This is a controversial issue since it is not clear whether re-inoculation is in fact worth preventing or not. However, the second reason why sprays are applied is to try to prevent (new) young trees from becoming infected—or, at least, to delay the infection as much as possible. Prior to HLB, processed orange growers in Central Florida spent $183.55 (expressed in 2015 dollars) per acre in foliar sprays whereas in 2015 they spent $649 per acre. Thus, despite the 170,457-acre reduction in orange acreage in Florida from 2004 to 2015, we estimate growers have increased their spending in foliar sprays alone by $179 million.

Undoubtedly, the use of chemicals has contributed chiefly to increase agricultural productivity in the last few decades. Fertilizers are an essential input for crop production; they contribute to productivity by increasing output, while pesticides do so by reducing crop damage. However, there is typically a difference between the social and private optimum use. Such difference arises because producers do not internalize all the costs of their application and, therefore, create an externality on the environment when chemicals are lost through volatilization, leaching, and runoff. An externality can also occur on human health when either field workers' or consumers' are exposed on the field or through residue on food. Therefore, governmental agencies regulate the use of chemicals to limit the extent of the divergence in social and private optima (Sexton, Lei, & Zilberman, 2007).

Since the mid-1990s, genetic modification of crops has become an alternative tool to pesticide use. Qaim and Zilberman (2003) found that the gains from adopting genetically modified crops were larger either in regions where the pesticides were not effective or pest pressure was high. The authors also found that despite the lower pesticide use, the benefits of GM for the case of Bt cotton in India were not in terms of reduced costs—due to the higher cost of seeds in that case—but in terms of increased yields. The gains from GM adoption in the face of a widespread and devastating disease can also be significant, as was the case for the papaya ringspot virus. Sankula and Blumenthal (2004) report that the adoption of a GM virus-resistant papaya in Hawaii caused yields to increase by 44% from 1998 to 2003.

It is precisely the development of a biotechnology-derived citrus tree resistant to HLB that some Florida industry stakeholders expect, eventually, to become the solution to the disease. Currently, the most advanced process consists of introducing HLB-resistant genes from spinach into orange trees (Voosen, 2014). However, despite its potential to cope with HLB and the benefits it would bring from reduced chemical use, there is general resistance to this technology. The aversion GM technology generates in segments of the general public regarding its safety and environmental effects—the same areas of concern as chemicals—may slow down its potential for adoption by growers.

In the following sections we explore the degree to which HLB has impacted US citrus growers and how this may be associated to their willingness to adopt GM technology and, in particular, whether the devastating damage they have faced has lead growers to overcome

2. *Even though HLB was first found in Florida in 2005, the initial figures we use next to illustrate its impact on the industry correspond to 2004 because they provide a better estimate of the scale of the industry prior to HLB. Florida was hit by four hurricanes between August and September of 2004. A little over a year later, in October 2005, another hurricane hit the state. Those hurricanes had a significant negative impact on yield and, therefore, production of oranges statewide in 2005, 2006, and 2007.*

3. *Growers started to implement foliar nutritional programs more intensively as a way to try to improve the trees' overall health. The effect of such programs on yield is still a matter of debate. See Gottwald, Graham, Irey, McCollum, and Wood (2012).*

Table 1. Comparison of the number (and percentage) of citrus operations in Florida versus surveyed by acreage.

	Acres						
	<49	50 to 99	100 to 499	500 to 999	1,000 to 2,999	>3,000	Total
Florida growers	2,412	307	479	85	65	30	3,378
	71%	9%	14%	3%	2%	1%	100%
Survey respondents	14	7	19	3	11	15	69
	20%	10%	28%	4%	16%	22%	100%
Survey respondents as % of Florida growers	1%	2%	4%	4%	17%	50%	

Source: USDA NASS (2012)

environmental and safety concerns of this technological option.

Surveying the Citrus Industry

We conducted a paper-based survey with individuals involved in citrus production in Florida. The survey participants operated 156,614 acres, which account for approximately 30% of the total acreage devoted to citrus in Florida. The survey was conducted at a biannual event organized at the Citrus Research and Education Center of the University of Florida in Lake Alfred, Florida. The purpose of the meeting was to summarize in lay terms the scientific presentations given at the International Research Conference on HLB (IRCHLB) that had taken place a month earlier. The topics of the talks included care for (young) non-bearing trees in the context of current management practices, mature tree-care in the context of current management practices, new scientific discoveries that will lead to progress in delivering solutions, and research (on HLB) from outside Florida. The summary of scientific progress discussed genetic modification of rootstocks and/or scions as a way to prevent or mitigate HLB. Given that the discussions were strictly scientific, it is unlikely that growers attitudes or concerns regarding GM were influenced by them.

There were 326 attendees at the event including growers, researchers, extension agents, media, and state officials. The number of growers was estimated at 200. The forms were distributed throughout the room before the meeting started so that every chair in the room had one. The moderator reminded growers several times during the meeting to complete the survey. Thus, growers filled out the forms on their own before, in between, and after the talks. They handed back the survey once the meeting was over. The number of completed surveys was 76, giving a response rate of 38%.

As shown in Table 1, 69 respondents disclosed their operations' acreage. While the sample is not representative of the entire citrus grower's population, we captured a high percentage of very large growers (e.g., 50% of the growers had more than 3,000 acres). Therefore, despite the small size, the sample may be informative about large growers' grove management practices, as well as their thoughts and concerns. Such growers can be very influential when trying to obtain impressions on potential technology adoption such as GM because they can be industry trendsetters.

The survey questions were divided into four sections according to the nature of the information they intended to gather. The first part of the survey included questions regarding the profile of the participants, such as responsibilities in the grove, location, and size of the operation. The second part collected data on the impact of HLB on citrus operations in Florida. The third part elicited information on growers' preferences for traits of HLB-resistant trees, and the fourth inquired about their concerns regarding obtaining that resistance through GM trees.

The proportion of grove owners and production managers that participated in the survey were 65% and 22%, respectively, while 13% of the respondents classified themselves as other. Those in the latter category defined their responsibilities as caretaker, nursery manager, manufacturer, processor, research farm manager, or researcher.

Regarding farm location, 49% of the respondents had operations in Central Florida (Ridge), 25% in Southwest Florida (SW), 4% in the East Central region (Indian River, IR), and 2% in other regions. However, another 20% of the respondents indicated that they had operations in two of the regions simultaneously; 14% stated that their operations were in both Central/SW; 3% indicated Central/East, and other 3% were located in SW/East (Figure 1).

Even though the majority of the respondents were from Central Florida, the majority of the acreage was from Southwest Florida, which resembles the actual citrus acreage distribution reflected in the 2014 Florida

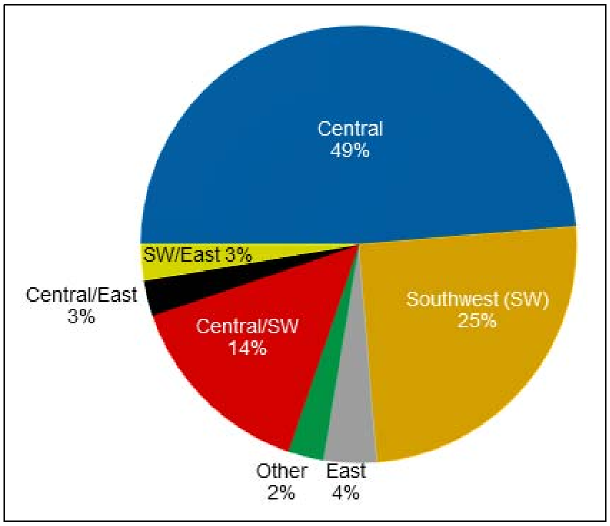

Figure 1. Location of operations reported by survey respondents.

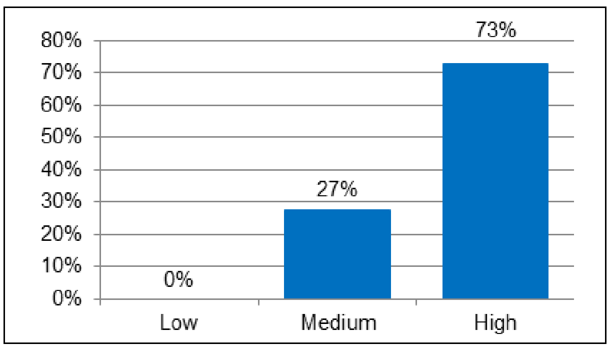

Figure 2. Distribution of overall level of impact of HLB reported by respondents.

Citrus Statistics (USDA NASS, 2015b). In our sample, 71% of the total acreage is in SW, 18% in the Ridge, and 11% is distributed across both regions. USDA reports that 54% of the total citrus acreage was in SW in 2014 while 29% was in the Ridge. This distribution also closely follows the regional contributions in terms of production (boxes), with the SW contributing 52% of total production and the Ridge region contributing 30%.

Survey-based Estimates on HLB Impact

Both the rate of HLB infection across the state as well as its effect at the farm level are key for understanding, among others, citrus growers' demand for traits from a potential biotech cure to HLB. Figure 2 shows how respondents assessed the overall impact of HLB on their operations. None indicated low impact. Twenty-seven percent indicated the impact to be medium, while 73% indicated a high impact.

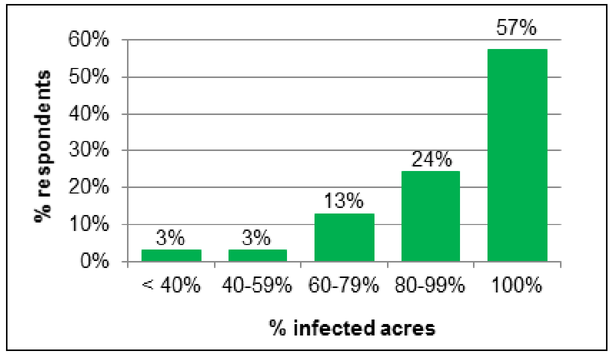

Figure 3. Distribution of percentage of acres infected with HLB reported by respondents.

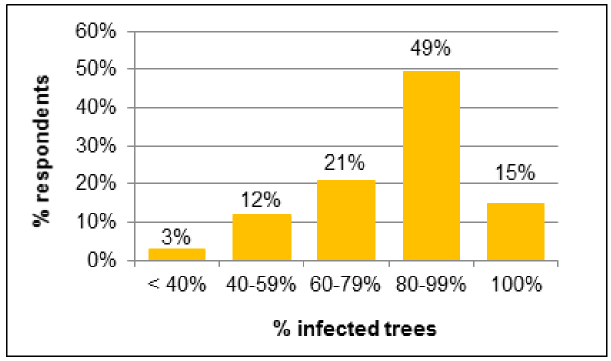

Figure 4. Distribution of percentage of trees infected with HLB reported by respondents.

The questions in the survey aimed at quantifying the impact of HLB with greater detail reveal that high impact translates into higher percentages of infected acres, higher rates of infected trees per acre, as well as higher rates of yield losses. First, growers were asked to estimate the percentage of acres in their operation infected with HLB. The average percentage of infected acres across respondents to this question was 90%. The responses, by range of infection, are shown in Figure 3. The percentage of growers that indicated that all of their acres are infected with HLB was 57%, while 24% stated that between 80% and 99% of their acres are infected. Thus, 81% of the respondents have their acreage infected with HLB anywhere from 80% to 100%.

At 80%, the average percentage of trees infected with HLB across operations was reported to be somewhat lower than that of acres. The responses by range are depicted in Figure 4. It can be seen from that figure that 49% of the individuals stated their operations have a percentage of infected trees that is greater than or equal to 80% but less than 100%, while 15% indicated that 100% of their trees are infected. Thus, these two groups account for 64% of the respondents.

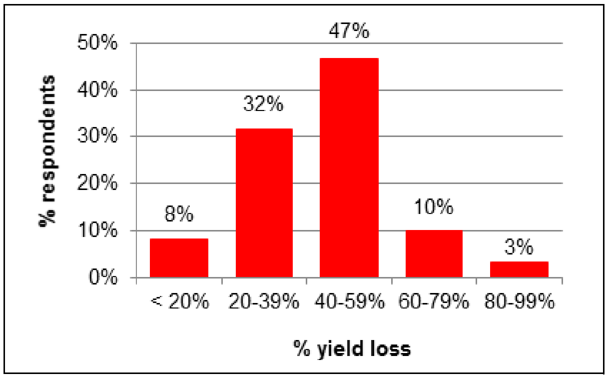

Figure 5. Distribution of percentage of yield loss attributed to HLB reported by respondents.

The last of the three questions aimed at collecting data on the impact of the disease asked growers to estimate the average yield loss per acre they attribute to HLB. Some of the responses were given in the form of ranges; in such cases, we used the midpoint of the range provided. The average yield loss reported was 41%. The results by range are shown in Figure 5. Overall, 60% of the respondents reported a yield loss greater than 40%.

In sum, these results confirm the devastating impact of HLB on citrus operations in Florida. Of the 156,614 operated acres in our sample (which represent roughly 30% of citrus acres in the state), 130,204 acres are infected. On average, a citrus operation in Florida has 80% of its trees infected and experiences a yield loss of 41%.

Potential Solutions

Tree Resetting

Replacing individual trees that are dead or no longer commercially viable in a standing grove is known as resetting—as opposed to solid-set planting, which refers to planting an entire new grove. Eradication of symptomatic citrus trees was the proposed scientific response to other severe diseases such as canker (Gottwald, Hughes, Graham, Sun, & Riley, 2001). However, recent research has suggested that tree eradication is not an economically efficient control for citrus greening, especially in small groves (Moss & Schmitz, 2014).

In our study, the percentage of growers and production managers who are resetting trees is 88%, while those not resetting total 12%. The size of the operations in the non-resetting group ranged widely, from 10 to 20,000 acres, with a median size of 115 acres. Resetting operations ranged from 6 to 16,000 acres, with a median size of 300. Thus, the majority of farms that are not resetting are smaller than the ones resetting. Many operations that are not resetting had previous resetting experiences where they had problems keeping those new trees healthy or consider the cost of resetting too high. Some of the comments included as part of growers' answers hint to these facts. For example, the respondent with the largest operation included a comment mentioning it was too risky to reset new trees. Another respondent commented that he planted resets three years ago and they are now all infected, further adding that he will wait until a cure to HLB is found before resetting again. A third grower commented that his operation is located in an area with poor area-wide psyllid control, which results in infected resets and, therefore, diminishes the chances of such resets from reaching bearing age, hence his response. Another grower indicated he will wait for payments from the recently implemented USDA cost-sharing program, known as Tree Assistance Program, to start resetting.

More than half of the growers who are not resetting stated that the overall impact of HLB on their operation is high. But despite being infected, if mature enough, trees still produce marketable fruit for a number of years. One major problem with eradication, besides its cost, is that early removal of infected trees is very difficult due to the long incubation period of the disease, which prevents infected trees from being detected prior to the symptomatic stage. Even when just resetting, differing strategies among neighboring growers in terms of caretaking may lead to infection of young trees that are adjacent to groves that harbor the disease.

How Informed are Growers about GM Organisms, and How Willing are They to Plant Them?

Growers were asked to state how informed they consider themselves regarding GM organisms (the scale included the options not informed, not much informed, somewhat informed, quite a bit informed, and very much informed). The majority of the growers, 60%, considered themselves either not much informed (12%) or only somewhat informed (48%) about GM organisms (Figure 6). About 30% considered they are quite a bit informed about GM organisms, while only 9% responded they are very much informed. These results highlight the potential importance of educational workshops as a way to increase the working knowledge of citrus growers on the subject and potentially help them make more informed decisions. This is particularly rele-

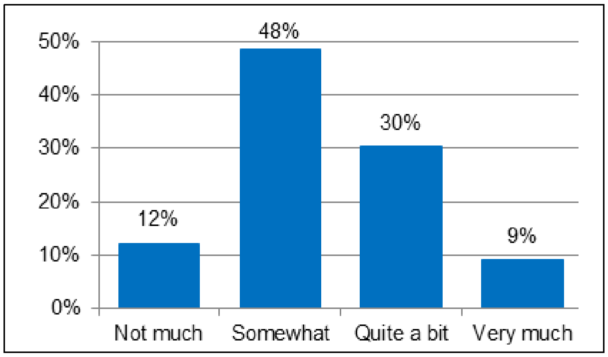

Figure 6. Distribution of respondents' self-assessed knowledge regarding GM.

vant in the face of rapidly advancing developments in research on GM orange trees.

Growers were also asked whether they would be willing to plant a genetically modified tree that is HLB resistant. The majority of respondents (74%) answered they would be willing to plant a GM HLB-resistant tree. This result is not surprising given the widespread level of infection and the significant negative impact of HLB on yields. The yield loss, together with increased costs, contributes to the margins of citrus production becoming increasingly narrow for the average grower. It is worth noting that 12% of the growers who are willing to adopt a GM HLB-resistant tree explicitly commented in this question that consumer/processor acceptance would be a concern for planting GM trees.

Only 3% of the respondents stated they would not be willing to plant a GM HLB-resistant tree; they were production managers of operations located in the Central Florida (Ridge) region. Moreover, these operations can be characterized as small since each manages less than 140 acres. Interestingly, these respondents stated the overall negative impact of HLB on their operations to be medium, and also estimated the infection of acres and trees to be lower than the survey's sample average. In fact, one of the managers rated acreage, tree infection, and yield loss at only 10% each, which was the lowest value across the entire sample in each of the corresponding questions. That production manager also stated processor and consumer acceptance of GM trees to be only somewhat concerning when deciding whether to plant GM trees, but rated environmental and safety issues, as well as the origin of gene, as very concerning. On average, respondents in this category claimed to be more informed about GM organisms than respondents in other categories.

Finally, grove and production managers who responded they were not sure about whether to plant a GM HLB-resistant tree accounted for 23% of the sample. The majority of the respondents in this category, 60%, stated they were either not much informed or somewhat informed on GM organisms. It is also noteworthy that some of the growers who were "not sure" commented that the cost of the tree would be a consideration, sound and long-term horticultural data would be needed, or mentioned consumer acceptance would be a concern. The size of the operations of these unsure respondents ranged from 30 to 20,000 acres.

Growers' Desired Traits for HLB-resistant Trees

Based on the pioneering work of Useche, Barham, and Foltz (2009), here we provide a first examination at the valuation of traits of HLB-resistant trees by Florida citrus growers. Thus, respondents were asked to indicate on a Likert scale from 1 to 5 the relative importance of different potential traits of an HLB-resistant tree (not necessarily GM). The hypothesized attributes participants had to rank were environmental benefits, no residue in fruit, reduction in number of sprays, cost of materials savings, labor/management savings, and increase in yields. This section may provide input to industry stakeholders and research funding agencies regarding growers' preferences for tree's traits. In other words, it helps answer the question: What will it take for growers to adopt the technology?

Figure 7 shows the distribution of the participants' responses. This figure illustrates that environmental benefits were considered the least important attribute, with only 37% of the respondents ranking it with a 5 (very important). The ranking for the rest of the attributes, in increasing order of importance (measured by the percentage of respondents choosing the "very important" category) was: 1) labor/management savings, 2) no residue in fruit, 3) reduction in number of sprays, 4) cost of materials savings, and 5) increase in yields. In the case of the latter, 84% of the respondents considered yield increase to be a very important attribute of an HLB-resistant tree; this is not surprising given the 41% average yield reduction growers stated they are experiencing due to HLB.

Of the desired traits for HLB-resistant trees, the cost-related traits show high correlation (Table 2). In particular, the trait 'cost-savings materials' and 'reduction in sprays,' 'cost-savings materials' and 'labor cost savings,' and 'reduction in sprays' and 'labor cost savings' all have correlation coefficients of 0.63 or higher. This is not surprising given the close relationship between them (say, labor and spraying), as well as steep

Table 2. Correlation matrix of survey variables.

	Responsibility	Region	Acres	Overall	Informed GM	% Infect acres	% Infect trees	% yield loss	Resetting	Environ. benefits	No residue	Reduction sprays	Cost-savings materials	Labor cost saving	Increase yields	Production issues	Processor acceptance	Consumer reactions	Cost trees	Environ. issues	Safety issues	Gene (plant vs. non-plant)
Responsibility	1	0.07	0.20	-0.16	-0.03	-0.13	-0.21	-0.06	-0.13	0.00	-0.33	-0.36	-0.52	-0.30	-0.43	-0.39	-0.30	-0.26	-0.07	-0.08	-0.05	-0.07
Region	0.07	1	0.38	-0.11	0.17	0.16	-0.10	-0.37	0.21	0.08	0.14	0.02	0.08	0.24	0.01	-0.15	0.06	0.00	0.24	-0.13	-0.14	-0.02
Acres	0.20	0.38	1	-0.14	0.09	0.10	-0.23	-0.34	0.11	-0.05	0.07	-0.09	-0.18	0.03	0.00	-0.27	-0.27	-0.04	-0.09	-0.22	-0.23	0.03
Overall	-0.16	-0.11	-0.14	1	0.07	0.41	0.49	0.14	0.00	-0.02	0.00	0.14	0.23	0.08	-0.03	0.05	0.14	0.17	-0.17	-0.14	0.12	-0.09
Informed GM	-0.03	0.17	0.09	0.07	1	0.26	-0.04	-0.19	0.19	0.32	0.28	0.07	0.24	0.28	0.24	0.16	0.27	0.03	0.13	0.13	-0.03	0.13
% infect acres	-0.13	0.16	0.10	0.41	0.26	1	0.51	0.11	0.05	-0.23	0.10	0.12	0.20	0.14	0.08	-0.08	0.19	0.19	-0.02	-0.27	-0.13	-0.25
% infect trees	-0.21	-0.10	-0.23	0.49	-0.04	0.51	1	0.34	-0.06	0.03	-0.10	0.13	0.11	0.05	-0.10	0.21	0.31	0.21	0.06	-0.07	0.19	0.03
% yield loss	-0.06	-0.37	-0.34	0.14	-0.19	0.11	0.34	1	-0.35	-0.05	-0.10	0.02	0.00	0.02	-0.22	0.05	0.01	0.22	0.11	0.19	0.29	0.18
Resetting	-0.13	0.21	0.11	0.00	0.19	0.05	-0.06	-0.35	1	0.24	0.39	0.37	0.32	0.26	0.41	0.23	0.18	0.14	0.32	0.28	0.18	0.08
Environ. benefits	0.00	0.08	-0.05	-0.02	0.32	-0.23	0.03	-0.05	0.24	1	0.20	0.12	0.10	0.16	0.19	0.27	0.27	0.22	0.38	0.67	0.32	0.35
No residue	-0.33	0.14	0.07	0.00	0.28	0.10	-0.10	-0.10	0.39	0.20	1	0.35	0.35	0.33	0.18	0.21	0.37	0.40	0.24	0.34	0.32	0.28
Reduction sprays	-0.36	0.02	-0.09	0.14	0.07	0.12	0.13	0.02	0.37	0.12	0.35	1	0.78	0.63	0.43	0.20	0.25	0.22	0.29	0.13	0.15	0.31
Cost-savings materials	-0.52	0.08	-0.18	0.23	0.24	0.20	0.11	0.00	0.32	0.10	0.35	0.78	1	0.73	0.50	0.27	0.44	0.25	0.35	0.16	0.20	0.27
Labor cost saving	-0.30	0.24	0.03	0.08	0.28	0.14	0.05	0.02	0.26	0.16	0.33	0.63	0.73	1	0.43	0.24	0.19	0.19	0.33	0.20	0.09	0.30
Increase yields	-0.43	0.01	0.00	-0.03	0.24	0.08	-0.10	-0.22	0.41	0.19	0.18	0.43	0.50	0.43	1	0.38	0.28	0.17	0.31	0.23	-0.06	0.04
Production issues	-0.39	-0.15	-0.27	0.05	0.16	-0.08	0.21	0.05	0.23	0.27	0.21	0.20	0.27	0.24	0.38	1	0.36	0.15	0.23	0.52	0.39	0.28
Processor acceptance	-0.30	0.06	-0.27	0.14	0.27	0.19	0.31	0.01	0.18	0.27	0.37	0.25	0.44	0.19	0.28	0.36	1	0.35	0.45	0.26	0.28	0.27
Consumer reactions	-0.26	0.00	-0.04	0.17	0.03	0.19	0.21	0.22	0.14	0.22	0.40	0.22	0.25	0.19	0.17	0.15	0.35	1	0.24	0.25	0.27	0.30
Cost trees	-0.07	0.24	-0.09	-0.17	0.13	-0.02	0.06	0.11	0.32	0.38	0.24	0.29	0.35	0.33	0.31	0.23	0.45	0.24	1	0.42	0.30	0.35
Environ. issues	-0.08	-0.13	-0.22	-0.14	0.13	-0.27	-0.07	0.19	0.28	0.67	0.34	0.13	0.16	0.20	0.23	0.52	0.26	0.25	0.42	1	0.67	0.39
Safety issues	-0.05	-0.14	-0.23	0.12	-0.03	-0.13	0.19	0.29	0.18	0.32	0.32	0.15	0.20	0.09	-0.06	0.39	0.28	0.27	0.30	0.67	1	0.51
Gene (plant vs. non-plant)	-0.07	-0.02	0.03	-0.09	0.13	-0.25	0.03	0.18	0.08	0.35	0.28	0.31	0.27	0.30	0.04	0.28	0.27	0.30	0.35	0.39	0.51	1

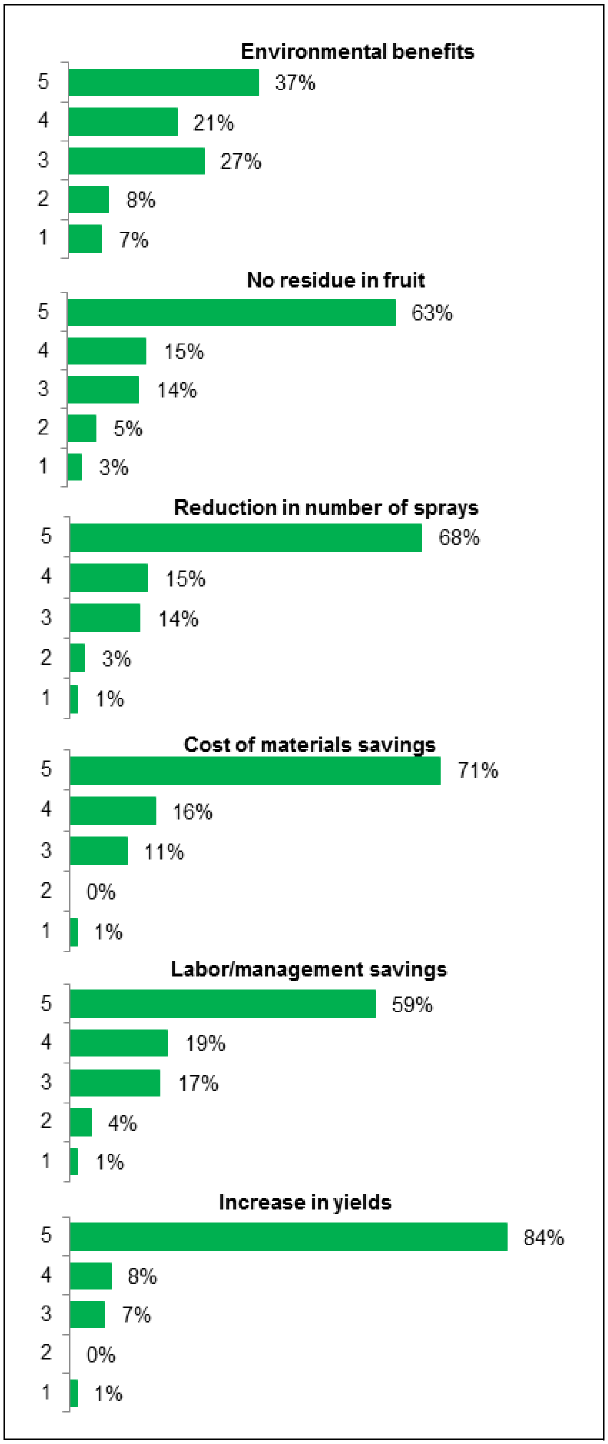

Figure 7. Likert scale responses distributions regarding the importance of attributes of an HLB-resistant tree.
Reference: Not important (1), somewhat important (3), very important (5)

increase in cost of production of citrus in Florida in the last few years.

Growers' Concerns Regarding GM Trees

Participants were also asked to indicate how concerning different issues would be when deciding whether to plant a GM tree (in a Likert scale from 1 to 5). The hypothesized concerns participants had to rank were production issues, processor/packinghouse acceptance, consumer reactions, cost of new trees, environmental issues, safety issues, and origin of gene (plant vs. non-plant). The least concerning issue to growers was the environmental one, with only 27% of the participants indicating it to be very concerning. The ranking for the rest of the issues, in increasing concern (measured by the percentage of respondents assigning very concerning to it) was: 1) safety issues tied with origin of gene, 2) cost of new trees, 3) production issues, 4) processor/packinghouse acceptance, and 5) consumer reactions (Figure 8).

The correlation matrix depicted in Table 2 shows that some of the concerns regarding GM trees are highly correlated. Safety issues and origin of the gene (plant vs. non-plant) have a correlation of 0.51; environmental issues and production issues have a correlation of 0.52 and environmental issues and safety issues have a correlation of 0.67. It is interesting to note, however, that despite the similar distribution of responses observed for processor/packinghouse acceptance and consumer reactions in Figure 8, they have a correlation coefficient of 0.35.

However, growers' rankings show they are aware of the reactions to GM by the general public. Thus, despite the potential advantages that a GM tree would advance against HLB, growers are mostly concerned about whether they would be able to sell GM fruit to processors and packinghouses and, eventually, to consumers. All other concerns could be classified as being part of a second tier. It is precisely for this reason that, in addition to genetic modification, there are currently a number of solutions under trial for HLB-infected trees. Those include the use of anti-bacterials, nanotechnology compounds, or even genetic modification of the ACP just to name a few; these are not without controversies but consumer reactions, for example for nanotechnology, were found to be not as adverse as for biotechnology (Priest, Lane, Greenhalgh, Hand, & Kramer, 2011).

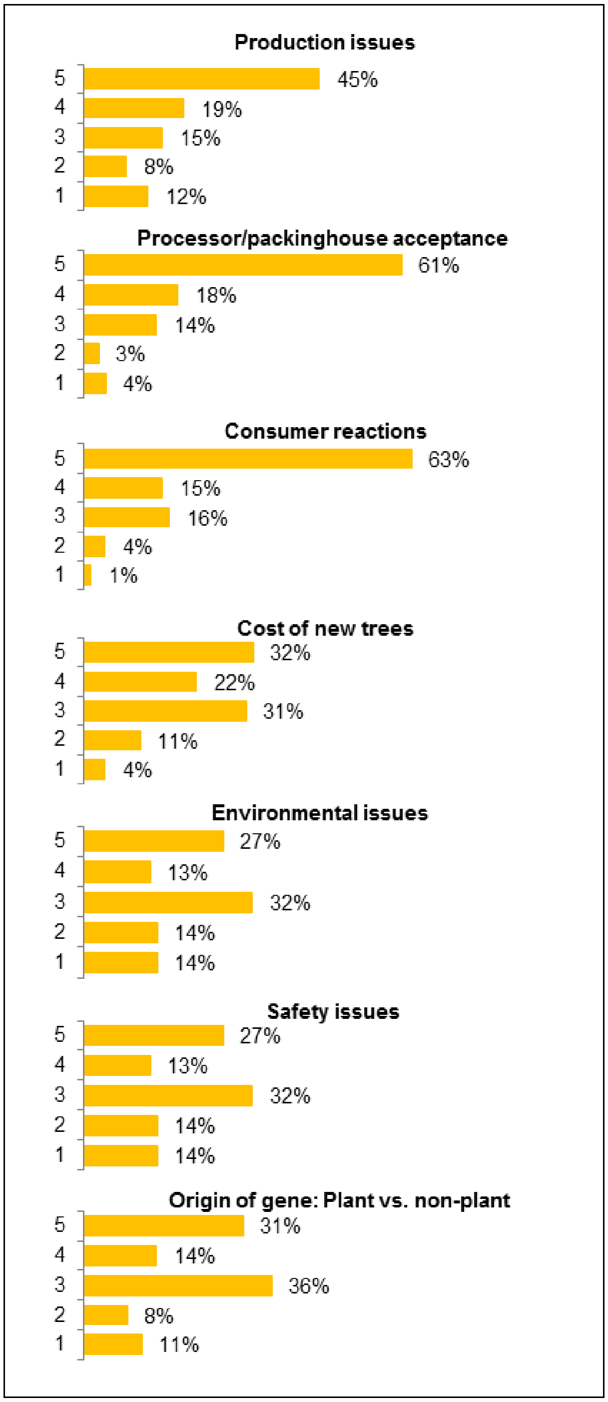

Figure 8. Likert scale responses distributions regarding the concerns for deciding whether to plant a GM tree.
Reference: Not important (1), somewhat important (3), very important (5)

Regional Analysis

Despite the relatively small size of our sample, a regional analysis of the results is relevant because there are significant differences in citrus production across the state. The first difference is agronomic; soil and water management are different. While the Central region soil is sandy and, therefore, well-drained, the SW region soil—commonly known as the flatwoods—is poorly drained because a clay sub-surface layer restricts water flow (Obreza & Collins, 2002). Drainage of water is important for citrus trees because it can otherwise cause root damage. Thus, while drainage is not required in the Central region, the water table must be controlled in the SW (Bowman & Tucker, 2002). In addition, while growers in the Central region use ground water for irrigation, most growers in the SW use surface water, making their management practices different in this regard. The second difference is size. After the devastating effect freezes had on the Florida citrus industry in the 1980s, much of the citrus acreage was replanted in the SW region in larger continuous extensions of land (Bouffard, 2009). Taking into account the counties that have more than 1,000 acres of citrus production, bearing citrus acreage in the SW is 244,082 and is distributed across 996 operations. Thus, the average-sized operation in that region is 245 acres. In the Central region there are 142,091 bearing acres across 1,523 operations, making for an average size of 93 acres (USDA NASS, 2012).

After re-categorizing our observations into three main regions—Central, Central/SW, and SW—we analyze the regional impact of HLB as well as use of the different responses to the disease mentioned earlier.[4] Table 3 summarizes these aspects, as well as the sample distribution of operations and acreage by region. After the re-categorization, 44 participants represent Central Florida, 11 have operations in both Central Florida and the Southwest, and 21 in the Southwest. Column 2 in Table 3 shows the average size of the operation in each region; these include 693, 1,962, and 5,818 acres for

4. *Only two participants were included in the categories SW/East and Central/East. Given the likely similarity of the practices in the East part of their operations relative to SW and Central, we included such respondents in SW and Central, respectively. Three participants were from East Central and, given the small size of their operations, we re-categorized them as Central. Two participants that stated they were from another region, were also re-categorized as Central, though neither of those two answered the questions regarding acres of their operations nor the impact of HLB.*

Table 3. Survey responses by region.

Region	(1) Surveys count	(2) Average # acres	(3) Total acres	(4) Average % infected acres	(5) Average % infected trees	(6) Average % yield loss	(7) Resetting: Percentage*	(8) Informed GM: Mode*	(9) Willing to plant GM: Percentage*
Central	44	693	28,414	88	83	45	87	2	69
Central/SW	11	1,962	17,655	90	74	37	89	2	89
SW	21	5,818	110,545	92	77	33	88	3	78

** These estimates were calculated using the sample of growers and production managers only*

Central, Central/SW, and SW, respectively. Thus, the average operation size is significantly larger in Southwest Florida. After three severe freezes that killed a large proportion of the state's citrus trees in the 1980s, the industry responded by planting new larger groves further south of what used to be the state's primary citrus-growing region.

Column 3 in Table 3 shows the total acreage in our sample by region. Columns 4, 5, and 6 show the average percentage of HLB-infected acres, infected trees, and HLB related yield loss per acre, respectively. Interestingly, the percentage of HLB-infected acres in the SW is 4% larger relative to Central Florida, but the percentage of infected trees is 6% lower. Furthermore, the average yield loss per acre in the SW is 12% lower than in Central Florida. Both the percentage of infected acres and average yield loss for operations with acreage in Central/SW are at the mid-point of the other regions, but the percentage of infected trees is the lowest of the three.

It can be argued that a likely explanation for the lower percentage of infected trees and for the lower percentage yield loss in SW relative to the Ridge is the size of the operations. While we cannot attribute causality in our study in terms of the relationship between farm size and HLB impact, it adds to the evidence available on the subject (Ayres, 2013; Lopes, Massari, Barbosa, & Ayres, 2009) and on the more effective control of the disease in larger farms (Belasque, Jr. et al., 2010). In addition, Citrus Health Management Areas (CHMAs) are a voluntary area-wide pest-management approach to control the Asian citrus psyllid. Thus, each CHMA constitutes a grouping of growers who work cooperatively to coordinate insecticide application timing and mode of action to control the spread of ACP across neighboring commercial citrus groves. The idea behind this cooperative effort is that it provides a larger and more lasting effect relative to individual (uncoordinated) farm sprays because it minimizes movement of psyllids between groves (University of Florida, CREC, 2015b). However, due to the decrease in profitability, many growers have reduced inputs for caretaking of trees, including insecticide applications. Thus, they either do not participate in CHMAs or do so in a limited fashion. However, by doing so, those growers impose an externality on their neighbors. Larger operations are less dependent upon the willingness of neighboring growers to participate in CHMAs and are, therefore, better able to control for ACP and manage the impact of HLB.

Column 7 in Table 3 shows that the percentage of growers resetting in each region is very similar. Column 8 shows the mode for the question asking how informed participants were regarding GM organisms was 2 (somewhat informed) for both Central Florida and Central/SW, whereas for SW it was 3 (quite a bit informed). Finally, Column 9 shows the percentage of growers in each region willing to plant GM trees is lowest (highest) for Central Florida (Central/SW) at 69% (89%). At 78%, the SW is close to the mid-point between the two other regions.

Growers who have operations in the SW are significantly more willing to plant GM trees. This may be related to the fact that HLB has been in the SW region for a longer period of time (as mentioned above), and operations located in such areas have a higher percentage of their acreage infected. It may also be related to the larger size of their operations. Due to their larger financial resources, larger operations may be more willing to plant GM trees because they could adopt the technology only to a limited extent at first and limit the risk of switching the entire operation to GM at once. In addition, such operations are likely in a better position to deal with the eventual implementation of buffer zones and segregation costs associated with GM crop production.

Examining the regional distribution of concerns that individuals reported having regarding the use of GM trees provides more explanations regarding the regional differences in stated adoption rates and overall heterogeneity of GM concerns (Figure 9). There are two groups of concerns that follow similar regional distribution patterns. The first group consists of consumer reactions, processor acceptance, and production issues. These dis-

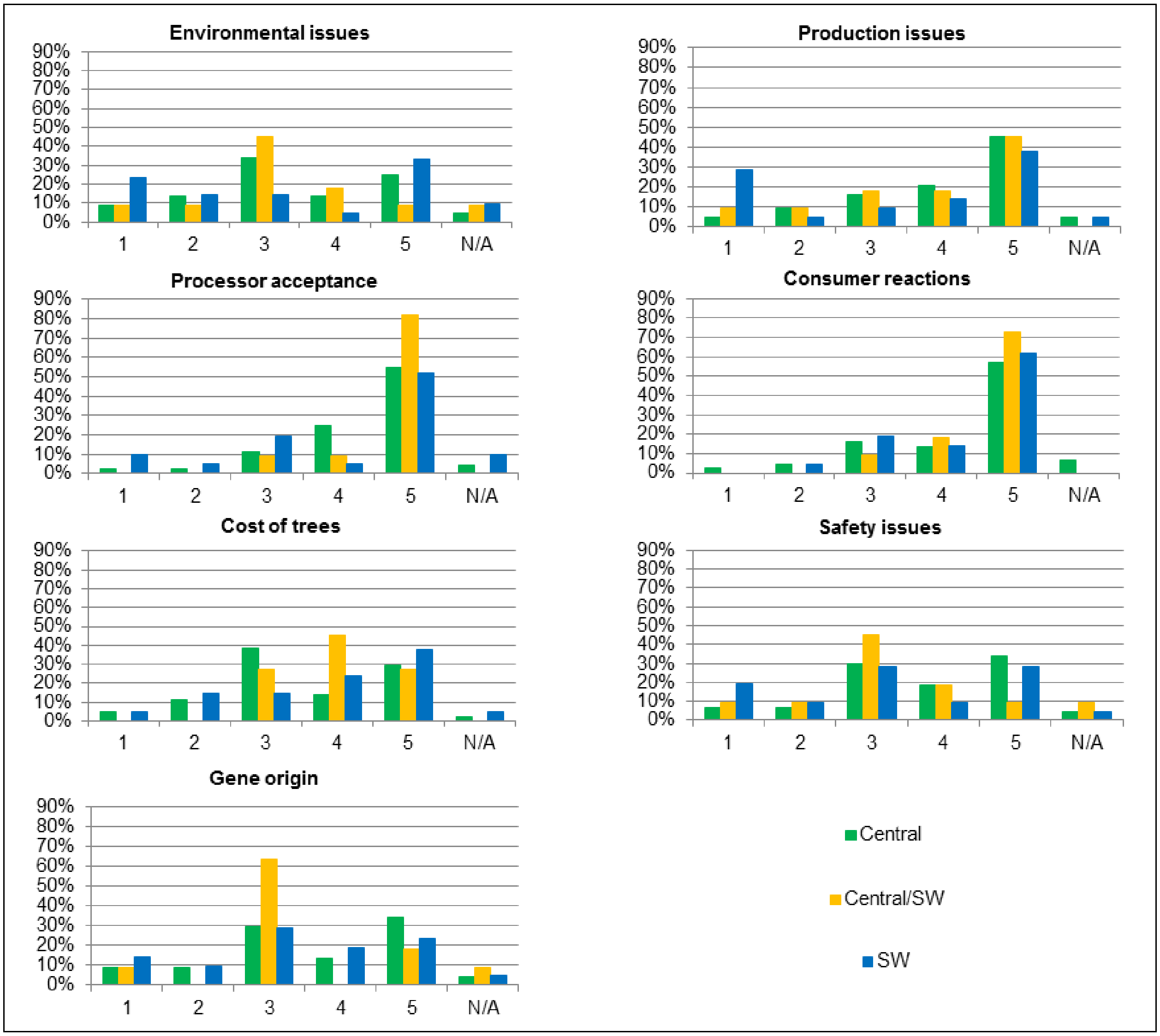

Figure 9. Regional distributions of concerns regarding the use of GM trees.

tributions are characterized by having a solid majority of growers who think of these issues as "very concerning" in all three regions. The main divergence occurs in the case of production issues in the SW, where a significant but smaller percentage of growers clearly diverges considering production issues related to GM not concerning. A similar divergence occurs in our next group of issues. To the contrary, a larger percentage of growers who have operations in both Central and SW regions are very concerned with processor acceptance and consumer reactions (which does not deter them from wanting to adopt GM technologies). Thus, other than production issues in the SW, these concerns do not seem to explain the different rates of willingness to adopt GM technologies in the different regions.

The second distinguishable group of concerns encompasses environmental concerns, safety issues, and gene origin; the distribution of responses of the latter two concerns are very similar, indicating that respondents' safety concerns are likely highly linked to gene origin. This group is characterized by having a wide distribution of responses, with a majority of individuals' concerns between somewhat concerning and very concerning, and a significant minority between not concerning and a little concerning. The great regional divergences are associated with the fact that there is a larger minority of growers with operation in the SW and in SW/Central who are not concerned or less concerned with this group of issues. The regional differences in attitudes among growers can be explained by the fact that operations and growers are heterogeneous across regions; operations in the SW are larger and more prone to be run by corporations, whereas those in the Central region are typically smaller and family run. Differences in size have been evidenced using USDA census data in a previous section. As a consequence of their size, larger operations might find it easier to implement safety measures such as buffer zones between GM and non-GM and deal with issues related to pollen drift (GM contamination) because they can be less reliant on their neighbors. Thus, this result does shed some light on the different issues that may deter more operators in Central Florida from adopting GM tree technologies.

Finally, the distribution of concerns regarding the cost of the GM trees is also wide and looks very similar across regions. However, growers in the SW are slightly more concerned about this cost, whereas growers in Central Florida are less concerned about it.

Examining Growers' Preferences and Concerns: Discrete Choice Model

We used a discrete choice model to examine growers' preferences on desirable attributes of an HLB-resistant tree as well as growers' concerns regarding the possibility of planting GM trees. Given the Likert-scale structure of the questions, the responses were ordered and we used ordered probit models to examine the factors associated with heterogeneity in these preferences.

First, we examined the determinants of preferences for each of the potential attributes of an HLB-resistant tree, namely environmental benefits, no residue in fruit, reduction in number of sprays, increase in yields, labor/management savings, and cost of materials savings. It is important to emphasize that in this question we did not refer in any way to genetic modification; the question asked how important each of the attributes of an HLB-resistant tree would be. Second, we examined growers' hypothesized concerns for deciding whether to plant GM trees. Those concerns include environmental issues, safety issues, the origin of the gene (plant vs. non-plant), consumer reactions, processor/packinghouse acceptance, production issues, and the cost of GM trees.

Explanatory variables in the models included characteristics of the operation, such as the region where the farmer's operation is located (a set of dummy variables using SW as base category) and the size of the operation in acres; the different types of impact HLB has had on the operation (percentage of acres infected and proportion of yield loss);[5] and whether farmers are resetting trees and how informed they are about GM. The latter control is a measure of how informed an individual assessed his/herself to be on the subject. Growers' preferences and, therefore, responses might be affected by their level of knowledge of GM maximum potential traits, such as yield potential or labor cost savings.

Results

Tables 4 and 5 show the results of the ordered probit regressions, which were run independently of each other. Therefore, there is no multicollinearity in our model between, for example, the variable "reduction in sprays" and "cost-savings materials" (which have a correlation of 0.78). Column 1 in Table 4 shows that growers who have a larger percentage of infected acres care less about the potential environmental benefits of an HLB-resistant tree, while growers who are resetting trees and those that are more informed about genetic modification care more about this type of trait. These latter groups of individuals, who are resetting and informed, similarly, care significantly more about finding HLB resistance through a method that does not leave residue in the fruit. As denoted in Columns 3 and 6, operators who have farms in the Central/SW regions care significantly less about the potential reduction in the number of sprays or in materials' cost savings of an HLB-resistant tree. Overall these findings may denote the longer-term commitment of growers who are resetting and more informed about GM as reflected by their preference for environmental benefits, in contrast to shorter decision horizons of farmers more worried about the level of HLB incidence in their groves.

Columns 4 and 5 in Table 4 denote being informed about genetic modification is also significantly related to more highly desiring increased yields and labor cost saving in a resistant variety. This may be related to the awareness of the greater potential that can often be reached through GM varieties in many crops. The results in Table 4 also indicate that owners generally care mostly about yield increases and cost savings, including reducing the number of sprays, and they care significantly more than managers. The only exception—where managers care about the same or more for an attribute of the resistant trees—is reduction of sprays.

5. *We did not include percentage of infected trees to prevent multicollinearity issues due to the high correlation such variable has with percentage of infected acres.*

Table 4. Ordered probit regression results for HLB-resistant tree attributes.

Variables	(1) Environmental benefits	(2) No residue	(3) Reduction sprays	(4) Increase yields	(5) Labor cost saving	(6) Materials cost savings
Central region	-0.06	0.06	-0.39	0.38	-0.63	-0.69
	(0.425)	(0.484)	(0.514)	(0.559)	(0.496)	(0.608)
Central and SW region	-0.43	0.04	-1.04*	5.56	-0.81	-1.19*
	(0.506)	(0.573)	(0.567)	(327.497)	(0.553)	(0.631)
Acres (1,000)	-0.00	0.02	-0.06	0.02	0.04	-0.08
	(0.058)	(0.074)	(0.059)	(0.082)	(0.066)	(0.069)
% infected acres	-0.04***	0.00	0.00	-0.00	-0.01	0.00
	(0.012)	(0.011)	(0.010)	(0.012)	(0.010)	(0.011)
Yield loss	0.01	0.02	0.01	-0.00	0.02	0.02
	(0.011)	(0.012)	(0.012)	(0.016)	(0.012)	(0.015)
Resetting	1.39**	1.46**	0.74	0.47	0.62	0.25
	(0.543)	(0.615)	(0.553)	(0.715)	(0.527)	(0.637)
Informed GM	0.68***	0.48*	0.08	0.93**	0.44*	0.47
	(0.238)	(0.262)	(0.243)	(0.451)	(0.251)	(0.290)
Owner	-0.14	7.17	2.15**	1.58*	1.76**	2.60***
	(0.808)	(465.395)	(0.872)	(0.942)	(0.854)	(0.903)
Manager	-0.36	7.21	2.23**	0.83	1.09	1.95*
	(0.906)	(465.395)	(0.984)	(1.110)	(0.966)	(1.011)
Constant cut1	-2.51	2.84	0.77	1.19	0.08	0.97
	(1.675)	(1.824)	(1.648)	(2.006)	(1.610)	(1.741)
Constant cut2	-1.84	8.60	1.51	2.43	0.91	2.42
	(1.659)	(465.397)	(1.626)	(2.009)	(1.602)	(1.768)
Constant cut3	-0.68	9.56	2.40	3.02	1.86	3.29*
	(1.652)	(465.397)	(1.613)	(2.011)	(1.596)	(1.787)
Constant cut4	0.27	10.18	3.09*		2.58	
	(1.648)	(465.398)	(1.629)		(1.605)	
Observations	55	54	55	55	55	54
Pseudo R^2	0.147	0.181	0.117	0.212	0.102	0.196

Standard errors in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

This may be the case because spraying might have a direct effect on the use of their time or even on their health.

Table 5 shows the results of the ordered probit regressions for growers' hypothesized concerns for deciding whether to plant GM trees. The most significant characteristic related to lack of concern for the use of genetic modification is the percentage of acres in the operation that is infected with HLB. Growers that have high levels of infected acres are particularly less concerned about gene type as well as environmental and safety issues. However, facing larger yield losses per acre are positively related with those same concerns, and to the cost of new trees. The apparent contradiction of these contrasting findings can be explained by realizing that percentage of infected acres includes acres that might have only a few infected trees. Therefore, the percentage of infected acres does not necessarily reflect a higher impact of the disease throughout the operation. (As it was shown in Table 3, the SW region has the highest percentage of infected acres but the lowest yield loss.) Thus, growers experiencing larger actual losses are likely to be more wary and concerned about the consequences of adopting GM.

Table 5 also shows that resetting trees is positively related with higher concerns for environmental and safety issues, the cost of the GM trees, and to a lower extent to the type of gene used and production issues. This can be explained by realizing that when growers invest in new trees—that will take three years to start bearing fruit—they commit to stay in business for the long run. More informed individuals tend to care more about gene type, environmental, and production

Table 5. Ordered probit regression results for GM concerns.

Variables	(1) Environmental issues	(2) Safety issues	(3) Gene origin	(4) Consumer reactions	(5) Processor acceptance	(6) Production issues	(7) Cost trees
Central region	0.05 (0.432)	0.01 (0.427)	-0.22 (0.424)	0.12 (0.483)	-0.00 (0.496)	0.11 (0.451)	-0.74* (0.423)
Central and SW region	0.00 (0.540)	-0.11 (0.539)	-0.98* (0.561)	0.45 (0.599)	0.71 (0.621)	0.36 (0.551)	0.31 (0.514)
Acres (1,000)	-0.05 (0.062)	-0.03 (0.058)	0.09 (0.063)	0.01 (0.065)	-0.08 (0.065)	-0.07 (0.064)	-0.01 (0.057)
% infected acres	-0.03*** (0.010)	-0.02* (0.010)	-0.04*** (0.011)	0.01 (0.010)	0.01 (0.010)	-0.02 (0.010)	-0.01 (0.009)
Yield loss	0.03** (0.011)	0.03*** (0.012)	0.02** (0.011)	0.02* (0.012)	0.01 (0.012)	0.01 (0.012)	0.02** (0.011)
Resetting	2.02*** (0.607)	1.85*** (0.606)	1.23** (0.572)	0.20 (0.592)	0.74 (0.564)	1.01* (0.533)	1.69*** (0.539)
Informed GM	0.37* (0.216)	0.09 (0.215)	0.40* (0.220)	0.08 (0.243)	0.37 (0.245)	0.44* (0.244)	0.13 (0.207)
Owner	0.12 (0.826)	-0.12 (0.814)	0.07 (0.793)	2.02** (0.856)	1.27 (0.810)	1.08 (0.800)	-0.46 (0.862)
Manager	-0.10 (0.952)	-0.31 (0.933)	-0.59 (0.919)	2.21** (0.976)	1.10 (0.931)	0.13 (0.899)	-1.01 (0.954)
Constant cut1	-0.03 (1.535)	-0.18 (1.542)	-2.07 (1.568)	2.50 (1.656)	1.42 (1.570)	-0.13 (1.562)	-1.44 (1.518)
Constant cut2	0.79 (1.522)	0.27 (1.539)	-1.53 (1.563)	3.64** (1.684)	1.68 (1.557)	0.65 (1.555)	-0.41 (1.504)
Constant cut3	2.09 (1.544)	1.67 (1.543)	-0.07 (1.551)	4.03** (1.692)	2.58 (1.584)	1.27 (1.564)	0.80 (1.521)
Constant cut4	2.72* (1.565)	2.26 (1.548)	0.54 (1.551)		3.39** (1.610)	1.91 (1.573)	1.63 (1.519)
Observations	53	54	54	55	54	55	55
Pseudo R^2	0.146	0.117	0.138	0.0830	0.102	0.129	0.117

Standard errors in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

issues. Overall, owners' and managers' concerns related to genetic modification do not differ significantly; for both, the major concern is the reaction of consumers.

Given our findings above, we examine the impact of the different concerns on the growers' willingness to adopt GM trees using a probit model. Concerns' responses were transformed by making the "very concerning" category equal to 1 and 0 otherwise. Some of the variables are conceptually related; so, for example, the variable concerns regarding the gene origin (plant vs. non-plant) is more specific than the variable safety issues concerns, which is intended to capture broader aspects related to safety. The same is true for the variable concerns regarding environmental issues and safety issues concerns. Those two pairs of variables have correlation coefficients of 0.56 and 0.50, respectively (Table 6). To examine the impact of collinearity of concerns, we run the model grouping two highly correlated concerns at the time. The results in Table 7 show that while the coefficients of concerns for environmental, processor acceptance, and consumer reactions are significant in some specifications and not in others, the coefficient for the concerns regarding the origin of the gene is stable (i.e., significant) throughout, thus, making Model 4 the preferred model.

Conclusions

The Florida citrus industry currently faces the challenges imposed by HLB—decreasing yields and production, lower quality fruit, and higher tree mortality rates. We surveyed Florida citrus growers and found that HLB is endemic across the state; on average, the current percentage of HLB-infected acres and trees in a citrus

Table 6. Correlation matrix of GM concerns for responses "very concerning."

	Very conc. env.	Very conc. safety	Very conc. gene	Very conc. cons.	Very conc. proc.	Very conc. produc.	Very conc. cost tree
Very conc. env.	1.00	0.56	0.37	0.20	0.24	0.36	0.46
Very conc. safety	0.56	1.00	0.50	0.14	0.24	0.33	0.38
Very conc. gene	0.37	0.50	1.00	0.18	0.28	0.17	0.21
Very conc. cons.	0.20	0.14	0.18	1.00	0.40	0.09	0.16
Very conc. proc.	0.24	0.24	0.28	0.40	1.00	0.32	0.38
Very conc. produc.	0.36	0.33	0.17	0.09	0.32	1.00	0.42
Very conc. cost tree	0.46	0.38	0.21	0.16	0.38	0.42	1.00

Table 7. Probit regression results for willingness to plant GM trees.

	Willingness to plant GM				
Variables	**1**	**2**	**3**	**4**	**5**
Very conc. env	-0.829* (0.447)				
Very conc. safety		-0.587 (0.400)			
Very conc. gene			-1.149*** (0.409)	-0.918** (0.368)	-1.104*** (0.392)
Very conc. cons.	-0.770* (0.444)	-0.855* (0.445)	-0.934* (0.484)	-0.488 (0.383)	
Very conc. process	0.641 (0.439)	0.674 (0.441)	0.978** (0.491)		0.512 (0.400)
Very conc. produc.	0.534 (0.419)	0.479 (0.410)	0.455 (0.421)	0.482 (0.393)	0.368 (0.398)
Very conc. cost tree	-0.230 (0.471)	-0.378 (0.451)	-0.447 (0.460)	-0.167 (0.411)	-0.320 (0.434)
Constant	0.929*** (0.340)	0.985*** (0.348)	1.100*** (0.368)	1.164*** (0.347)	0.692** (0.282)
Observations	70	70	70	71	70
Pseudo R^2	0.117	0.0996	0.179	0.129	0.126

Standard errors in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

operation in Florida is 90% and 80%, respectively. Furthermore, compared to pre-HLB levels, the average percentage yield loss is 41%. However, citrus operations in Central Florida experience a 12% higher yield loss relative to those in Southwest Florida. We also found that the majority of growers are resetting trees in their groves despite the widespread level of HLB infection.

As a consequence of the widespread impact of HLB, Florida citrus growers have significantly increased the use of chemicals as a means to deal with the disease. However, the usefulness of such practices is not yet clear despite their major contribution to the increase in cost of production. Therefore, a possible cure to HLB might be in the form of a GM tree. There currently are extensive public and private efforts and funding directed to find a cure to the bacterial disease through genetic modification, but there is no data or knowledge on citrus growers' views and preferences regarding the potential introduction of GM citrus varieties. This article presents the first estimates on growers' impressions on genetic modification for dealing with HLB.

Regarding Florida citrus growers' level of information with respect to genetic modification, we found that the majority consider themselves as not very knowledgeable in the topic. Nevertheless, growers in Southwest Florida have somewhat higher knowledge compared to those in other regions. Despite their low self-assessed level of knowledge, the vast majority of growers asserted they would be willing to plant GM trees, denoting how critical the situation currently is for many of them.

A priori, given the widespread impact of the disease across the state, it would be reasonable to expect that growers whose operations are impacted the most by HLB would show a preference for a solution with traits such as increased yield and cost savings while being less concerned about environmental and safety issues of a potential GM tree. In this respect our findings were surprising. Overall, farmers with a higher percentage of yield losses—and that are, therefore, in dire need of a solution—showed more concern not only for consumer reactions to GM orange juice and the eventual cost of GM trees, but also for environmental and safety issues involved in planting GM trees, as well as for the origin of the gene used.

We also found that individuals resetting trees are more concerned about both environmental and safety issues involved in planting GM trees; this is likely related to their long-term commitment to the industry. Owners and managers are very much aligned in their views of genetic modification, not so in their views of the traits that an HLB-resistant tree needs to have, but they agree on spray-reduction being one desirable trait. This is not surprising given the significant increase in number of sprays over the last decade.

Individuals that are more informed about GM organisms showed an understanding of the potential benefits that such type of crop has brought to the production of other crops; namely, higher yields, cost reductions derived from reduced spraying, along with the resulting environmental benefits of lower chemical use. At the same time, such individuals are also more concerned about potential environmental and production issues, and are also concerned about the origin of the gene that would be used in the genetic modification. The most significant heterogeneity in producers' concerns and trait preferences lies in the areas of environment, safety, and gene origin.

References

Ayres, A.J. (2013). *The experience of HLB management in Brazil*. Lake Alfred, FL: Citrus Research and Development Foundation, Inc. Available on the World Wide Web: http://citrusrdf.org/wp-content/uploads/2012/09/Juliano-Presentation-to-BOD-2-3-13.pdf.

Batool, A., Iftikhar, Y., Mughal, S.M., Khan, M.M., Jaskani, M.J., Abbas, M., & Khan, I.A. (2007). Citrus greening disease—A major cause of citrus decline in the world: A review. *Horticultural Science, 34*(4), 159-166.

Belasque Jr., J., Bassanezi, R.B., Yamamoto, P.T., Ayres, A.J., Tachibana, A., Violante, A.R., et al. (2010). Lessons from Huanlongbing management in Sao Paulo State, Brazil. *Journal of Plant Pathology, 92*(2), 285-302.

Bouffard, K. (2009, December 25). 1989 Christmas freeze: Florida's citrus industry was changed forever. *The Ledger*. Available on the World Wide Web: http://www.theledger.com/article/20091225/NEWS/912259950?p=3&tc=pg.

Bowman, B., & Tucker, D. (2002). *Drainage systems for flatwoods citrus in Florida* (Electronic Data Information Source [EDIS] Circular 1412). Gainesville: University of Florida, Institute of Food and Agricultural Sciences (IFAS). Available on the World Wide Web: http://edis.ifas.ufl.edu/ch165.

Food and Agriculture Organization of the United Nations (FAO). (2015). *Regional management of Huanglongbing (HLB) in Latin America and the Caribbean*. Author: Rome.

Gottwald, T.R., Graham, J.H., Irey, M.S., McCollum, T.G., & Wood, B.W. (2012). Inconsequential effect of nutritional treatments on Huanglongbing control, fruit quality, bacterial titer and disease progress. *Crop Protection, 36*(June), 73-82.

Gottwald, T.R., Hughes, G., Graham, J.H., Sun, X., & Riley, T. (2001). The citrus canker epidemic in Florida: The scientific basis of regulatory eradication policy for an invasive species. *Phytopathology, 91*(1), 30-34.

Gottwald, T.R. (2010). Current epidemiological understanding of citrus Huanglongbing. *Annual Review of Phytopathology, 48*, 119-139.

Lopes, S.A., Massari, C.A., Barbosa, J.C., & Ayres, A.J. (2009). *Huanglongbing in the state of Sao Paulo*. Sao Paulo, Brazil: Fundecitrus. Available on the World Wide Web: http://cal-citrusquality.org/wp-content/uploads/2009/05/huanglong-bing-in-the-state-of-sp-final.pdf.

Moss, C., & Schmitz, A. (2014). *A model of epidemiology of greening in Florida citrus groves and its economic implications*. Paper presented at the Pests, Germs and Seeds: The Economics of Policies, Programs and Technology for Managing Agricultural Pests and Diseases. Davis, CA.

Obreza, T.A., & Collins, M.E. (2002). *Common soils used for citrus production in Florida* (EDIS document SL 193). Gainesville: University of Florida, IFAS Extension. Available on the World Wide Web: http://ufdc.ufl.edu/IR00003134/00001.

Priest, S., Lane, T., Greenhalgh, T., Hand, L.J., & Kramer, V. (2011). Envisioning emerging nanotechnologies: A three-year panel study of South Carolina citizens. *Risk Analysis, 31*, 1718-1733.

Qaim, M., & Zilberman, D. (2003). Yield effects of genetically modified crops in developing countries. *Science, 299*, 900-902.

Sankula, S., & Blumenthal, E. (2004). *Impacts on US agriculture of biotechnology-derived crops planted in 2003: An update of eleven case studies* (Final report). Washington, DC: National Center for Food and Agriculture Policy (NCFAP).

Sexton, S.E., Lei, Z., & Zilberman, D. (2007). The economics of pesticides and pest control. *International Review of Environmental and Resource Economics, 1*, 271-326.

University of Florida, Citrus Research and Education Center (CREC). (2015a). Summary budget cost of production of citrus. Author: Gainesville, FL. Available on the World Wide Web: http://www.crec.ifas.ufl.edu/extension/economics/.

University of Florida, CREC. (2015b). Citrus health management areas (CHMAs). Author: Gainesville, FL. Available on the World Wide Web: http://www.crec.ifas.ufl.edu/extension/chmas/chma_overview.shtml.

US Department of Agriculture (USDA), National Agricultural Statistics Service (NASS). (2012). *Census of agriculture* (Quick Stats). Washington, DC: Author.

USDA NASS. (2015a). *Vilsack announces $30 million to fight citrus disease: USDA targets citrus greening with promising tools and long term solutions* (Press release No. 0032.15). Washington, DC: Author. Available on the World Wide Web: http://www.usda.gov/wps/portal/usda/usdamediafb?contentid=2015/02/0032.xml&printable=true&contentidonly=true.

USDA NASS. (2015b). *Florida citrus statistics 2013-2014*. Tallahassee: Florida Department of Agricultural Services.

Useche, P., Barham, B.L., & Foltz, J.D. (2009). Integrating technology traits and producer heterogeneity: A mixed-multinomial model of genetically modified corn adoption. *American Journal of Agricultural Economics*, *91*(2), 444-461.

Voosen, P. (2014). Can genetic engineering save the Florida orange? *National Geographic*. Available on the World Wide Web:http://news.nationalgeographic.com/news/2014/09/140914-florida-orange-citrus-greening-gmo-environment-science/.