Plant Biotechnology: Current and Potential Impact For Improving Pest Management In U.S. Agriculture An Analysis of 40 Case Studies

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Bacterial Resistant Citrus

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Bacterial Resistant

Production
Florida is the number one citrus producing state in the country, accounting for more than 75% of United States production [1]. Of Florida’s approximately 762,000 bearing acres of citrus, 79% is planted to oranges and 15% to grapefruit. The 3,000 acres of limes grown in Florida are the only commercially grown limes in the U.S. Florida produces approximately 65% of domestic fresh grapefruit. The on-tree value of the 1999-00 Florida citrus crop was $1.2 billion. The annual economic impact of the Florida citrus industry is estimated to be more than $8.5 billion [2].

Approximately 80% of the value of Florida citrus is from the processing market. Florida oranges are sold primarily for orange juice. The biggest value from grapefruit, tangerines and limes comes from fresh market sales. For example, grapefruit sales in the fresh market totaled $120 million in 1999-2000 [1]. Fresh fruit exports from Florida totaled 22 million four-fifths bushel cartons in 1999-2000 and consisted primarily (92%) of grapefruit. The total value of fresh citrus shipments from Florida is approximately $171 million per year.

Production of Florida citrus in the 1999-00 marketing year totaled approximately 13 million tons (26 billion pounds) [14]. In 2000, Florida orchards contained 78 million orange trees, 12 million grapefruit trees and 6 million other citrus trees, including tangerines and limes. [1]

Citrus Canker
Citrus canker is one of the most devastating diseases to affect citrus crops. Citrus canker is caused by the bacterium Xanthomonas axonopodis pathovar citri, and is highly contagious. There are three known strains of the bacterium. The A strain, or Asian strain, is most common, most damaging, and is the only form to have been found in the U.S. [3][4].

Citrus canker affects many types of citrus, with strain severity varying with citrus variety. Asian canker affects most citrus, especially grapefruit, lime, and trifoliate orange [4]. The timing of infection also dictates the severity of symptoms. Leaves, stems and fruit are most vulnerable as they are first emerging and developing, and become more resistant to infection as they mature. If
infection occurs later than three months after petal fall, the lesions on fruit remain small and inconspicuous [3].

Citrus canker causes spotting, or lesions, on the fruit, leaves and stems of infected plants [3]. The lesions are darkened, raised regions where the bacterium reproduces.

When conditions are moist, the bacteria ooze out of the lesions and are dispersed to other parts of the plant or to new plants. When conditions are dry, the pustules become corky and crater-like. The bacterium enters plant tissue through natural openings in the leaves or through wounds. Damage by the Asian citrus leafminer has been associated with higher infection and spread rates. Severe canker infections can cause defoliation, dieback and premature fruit drop. Yields can fall 20% to 50% as a result of citrus canker induced premature fruit drop [10].

Canker is commonly spread to other trees over short distances by wind and rain. It is spread over long distances by stormy weather. Another major method of infection spread is through human activity. The bacteria can be carried to new areas on the shoes, clothes and hands of workers, and on equipment. The main method of infection spread, however, is through transport of infected plant material, including budwood and young plants as well as picked leaves and fruit [4].

Canker does not alter the taste or internal quality of citrus fruit. An orange from an infected tree can be made into juice like any other orange [10].

Thought to have originated in southeast Asia/India, the A strain of citrus canker was first reported in the U.S. in 1910 in the Gulf Coast States, from Texas to South Carolina [3]. In Florida, a quarantine was imposed, 258,000 trees were removed from orchards and more than 3 million nursery plants destroyed. After spending $6 million, eradication was declared in 1933 in Florida, and in 1947 in the rest of the U.S. [5]. In 1986, canker was found again in Florida, in residential and later commercial trees. The second eradication program removed and destroyed 88,000 commercial and 600 residential trees at a total cost of $27 million. Eradication was declared again in 1994.
Citrus canker was detected once again in Florida in 1995, in residential trees near Miami International Airport [6]. With additional outbreaks occurring and subsequent spread of each outbreak [7], Florida is now fighting citrus canker in seven counties where its presence has been confirmed [8]. From 1996 through late 1999, the eradication program up-front costs escalated from about $10 million to about $50 million per year. In 2000, the program was broadened and expanded to $145 million in an all-out effort to gain the upper hand against further disease spread [3]. Eradication efforts include removal of infected trees and all trees within 1,900 feet of infected trees, including commercial and residential plantings. As of February, 2001, the Florida Department of Agriculture and Consumer Services reports 597,497 residential trees and 1,239,918 grove trees destroyed.

The ongoing citrus canker eradication program in Florida is the largest single regulatory agricultural program to eradicate a plant disease ever undertaken in the history of the world [3].

There is considerable opposition to the eradication program in Florida with litigation and budget cuts as possible barriers to the successful completion of the program. In addition there are some who suggest that the program cannot and will not be successful and that the bacteria will reappear.

An analysis has been made of the reasonably anticipated cost to the Florida citrus industry if the canker eradication program were abandoned or were unsuccessful [9].

In order to prevent the spread of canker by humans and machinery, a mandatory program of cleaning and decontamination of workers and machinery has been implemented. In addition, mandatory tarping of trailer shipments of citrus has been implemented. These decontamination costs are estimated at $36.7 million per year [9]. Additional costs to manage the spread of citrus canker would include additional copper sprays ($8.8 million), the installation of windbreaks ($2.4 million), and additional harvested fresh fruit inspections ($8.8 million). The establishment of windbreaks would result in lost yield from having to remove some trees and from shading of adjacent trees. It is estimated that production losses associated with the windbreaks would
amount to $35.2 million per year. Despite additional copper spray applications, premature fruit drop is still likely to occur. A conservative estimated loss of 5% of Florida’s oranges amounts to an annual loss of $43 million. [9]

Because the citrus canker pathogen is disseminated in citrus fruit, countries and states that do not have the disease prohibit the importation of potentially infected fruit from areas that have citrus canker [5]. If canker is not eradicated from Florida, it is likely that shipments of Florida fresh citrus would be quarantined for sale in the U.S. and certain foreign countries. The domestic concern would be that shipments of citrus from Florida could lead to canker infections in other fresh citrus growing states. The estimated loss of domestic fresh sales would amount to $117 million per year.

Certain U.S. trading partners – particularly the European Union – would likely prohibit the import of fresh citrus from Florida. (Spain, Italy, Greece and Portugal are all citrus producing countries belonging to the EU and are canker free.) The estimated loss in fresh exports to the European Union would be approximately $54 million per year. Japan, Korea and China would not be justified in rejecting Florida fresh fruit because Asiatic canker is endemic in those countries [9].

Copper products are the only materials used for control of citrus canker. Depending on the amount of inoculum, the susceptibility of the species and the conditions in the area, frequent sprays are needed [12]. Because the fruit is particularly susceptible during the first 90 days after petal fall, it is important to maintain a protective coating of copper on the rind surface through this period [15]. Two or three treatments may be needed for this purpose depending on rainfall [15].

An average copper spray in Florida citrus consists of 2.15 pounds of active ingredient per acre [13]. If all 762,000 Florida citrus acres received a single copper spray for managing canker, an additional 1.638 million pounds of copper would be sprayed. (Currently, approximately 1.737 million pounds of copper are applied to Florida citrus during a production season.)
There is no cure for canker. In countries where citrus canker is an established ongoing problem, management practices include producing and planting more tolerant types of citrus, planting windbreaks to block infiltration of windborne bacteria, and application of copper. Use of copper may help protect leaves and fruit and reduce disease incidence, but it will not eliminate infections [4]. Infections remain to act as a source for continued spreading.

It takes four to five years for a citrus tree to mature into fruit production. The seeds produced in citrus fruit are not always fully representative of the tree’s hybrid genetic makeup, but rather may contain only the genes of its mother tree. In order to test the genetic makeup of a seed, it must be reared into a plant, its production and fruit qualities tested. These characteristics make traditional breeding of citrus a very long and laborious process. It is for this reason that new citrus varieties are few and far between. Therefore, the prospects of a canker-resistant variety developed through traditional breeding techniques is far off.

Transgenic Citrus

Biotechnology can greatly reduce generation time for new varieties because it allows exchange of genetic material without requiring plants to be sexually mature. And unlike traditional breeding techniques, where a new variety must be reared to maturity in order to test for successful integration and expression of new qualities, techniques in biotechnology allow such testing while the plant is a small seedling. Biotechnology can therefore reduce the time it takes to develop a new citrus variety, such as one resistant to citrus canker, by several years.

Researchers at Integrated Plant Genetics, Inc. are using biotechnology to develop citrus trees with canker resistance [10]. Once inside the plant, the bacterium that causes citrus canker produces certain pathogenic proteins that are injected into the plant cells. Genes coding for antibodies that specifically bind to and inactivate these pathogenic proteins have been engineered and inserted into citrus cells. The introduced genes are entirely synthetic, modeled after animal antibody genes but specially created to function in citrus cells. Transgenic, antibody-producing citrus plants have been produced that show moderate canker resistance, but with the belief that complete immunity is possible with this technique, research is continuing in pursuit of that goal.
The resistance genes have been inserted into two cultivated grapefruit varieties, four cultivated orange varieties and one lime variety [11].

In order to avoid regulatory action by other countries, the gene would have to provide immunity to canker, not just resistance [16]. The gene would have to be inserted into all major commercial varieties which would then need to be evaluated for yield and fruit quality which could easily require ten years [16]. At that point, susceptible varieties currently grown could begin to be replaced with resistant varieties. In order to avoid major drops in production, probably no more than 10% of the acreage could be replaced each year [16].

Estimated Impacts
It is assumed that transgenic canker resistant cultivars would be planted universally in Florida and result in the avoidance of the potential costs of treating and managing canker in the state ($56.7 million), including the cost of an increased use of 1.6 million pounds of copper. In addition, approximately $72 million in yield losses would be likely to occur in the absence of the transgenic (representing 6% of Florida citrus production or 1.56 billion pounds of citrus). In addition, the transgenic trees would prevent the diversion of fresh shipments of citrus from Florida ($171 million). It is assumed that these shipments otherwise would be diverted to the processed market, representing a loss in value of 15% or $25 million (the value of a processed box is approximately 85% of the value of a fresh box).
References


