Canker resistance: lesson from kumquat

By Naveen Kumar, Bob Ebel and P.D. Roberts

Xanthomonas citri pv. citri (Xcc) is the causal agent of one of the most serious citrus diseases worldwide, Asiatic citrus canker. In the United States, Florida experienced three major outbreaks of Asiatic citrus canker in 1910, 1984 and 1995, and it is a constant threat to the $9 billion citrus industry.

Citrus genotypes can be classified into four broad classes based on susceptibility to canker. First, the highly-susceptible commercial genotypes are Key lime, grapefruit and sweet lime. Second, moderately-susceptible genotypes include sweet oranges. Third, the least susceptible class includes mandarin, citron and Persian lime. The fourth class is highly resistant and includes close citrus relatives such as calamondin, Ichang papeda and kumquat.

Kumquats belong to the genus *Fortunella*. A kumquat tree is small, evergreen and bears small edible fruits. Although kumquats are in a different genus than commercial citrus, plant breeders have used kumquats because of their canker resistance and sexual compatibility with citrus.

The citrus physiology laboratory at the Southwest Florida Research and Education Center is exploring the biochemical basis of kumquat resistance to citrus canker, which may be used to develop canker-resistant citrus genotypes. Following artificial inoculation of *Xcc* in kumquat and grapefruit leaves, 75 percent decline in bacterial population was observed in kumquat leaves four days after inoculation (DAI) (Fig. 1). However, a 1,000-fold increase in *Xcc* populations was observed in canker-susceptible grapefruit. Similar observations were also observed in kumquat by others.

Canker development in citrus is governed by a characteristic sequence of events. The first visual symptom after artificial inoculation with the bacterium is water soaking followed by raised and ruptured epidermis at later stages of canker development. Epidermal rupturing is of ecological significance since *Xcc* infection induces cell division in plant cells causing a rupture of epidermis. This provides a means of dispersal of *Xcc* via action of wind and rain.

The development of Asiatic citrus canker in kumquat leaves produced localized yellowing (5 DAI) or necrosis (9-12 DAI) that was restricted to the actual site of inoculation 7-12 DAI (Fig. 2).

In contrast, grapefruit epidermis became raised (5 DAI), spongy (5 DAI) and ruptured from 7 to 8 DAI. On 12 DAI, the epidermis of grapefruit was thickened, corky, and turned brown on the upper side of the leaves.

Disease development and population dynamics studies have shown that kumquat demonstrated both disease resistance and disease avoidance mechanisms. Disease resistance can be explained on the basis of a decline in *Xcc* populations at 4 DAI. Disease avoidance is characterized by the abscission of *Xcc*-infected leaves from 7 to 12 DAI. Abscission of infected leaves not only reduces bacterial load on the plant, but may also protect adjoining leaves and plants from further disease dissemination by wind and rain.

Throughout their evolution, plants have developed many defense mechanisms against pathogens. One of the most characteristic features associated with disease resistance against entry of a pathogen is the production of hydrogen peroxide (H_2O_2). Hydrogen peroxide is toxic to both plant and pathogen and thus restricts the spread by directly killing the pathogen and the infected plant tissue. Hydrogen peroxide concentrations in *Xcc*-infected kumquat and grapefruit leaves were different. Kumquat produces more than three times the amount of H_2O_2 that grapefruit produces. Higher concentrations of H_2O_2 seem to be associated with a decline in *Xcc* populations in kumquat.

Our goal is to artificially enhance the concentrations of H_2O_2 in *Xcc*-compromised grapefruit through an understanding of the mechanisms of canker resistance in kumquat. We are using eco-friendly chemical compounds to augment the concentration of H_2O_2 in susceptible varieties of citrus.

We also believe kumquat is an indispensable source of canker resistance and needs to be evaluated carefully at morphological, physiological, biochemical and genetic levels to design suitable strategies for canker control in susceptible citrus crops.

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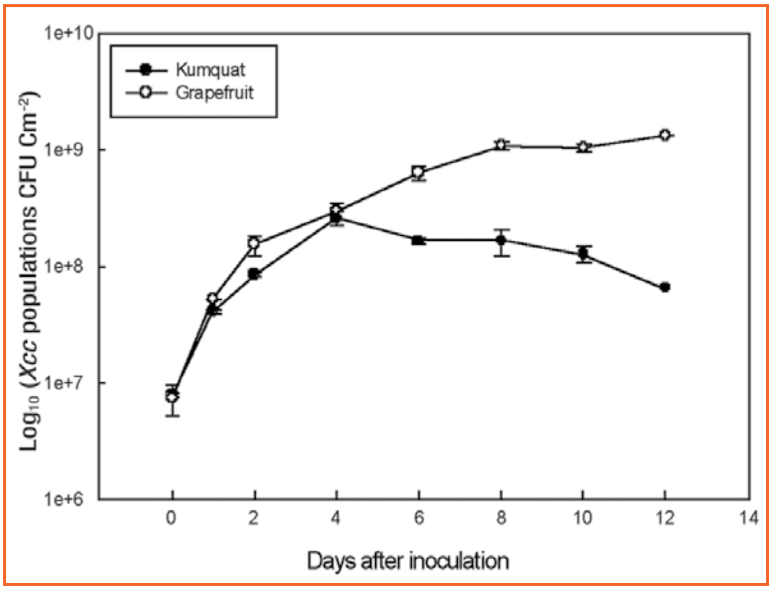

Fig. 1 (above). *Bacterial population (colony forming units cm^{-2}) in kumquat and grapefruit leaves*

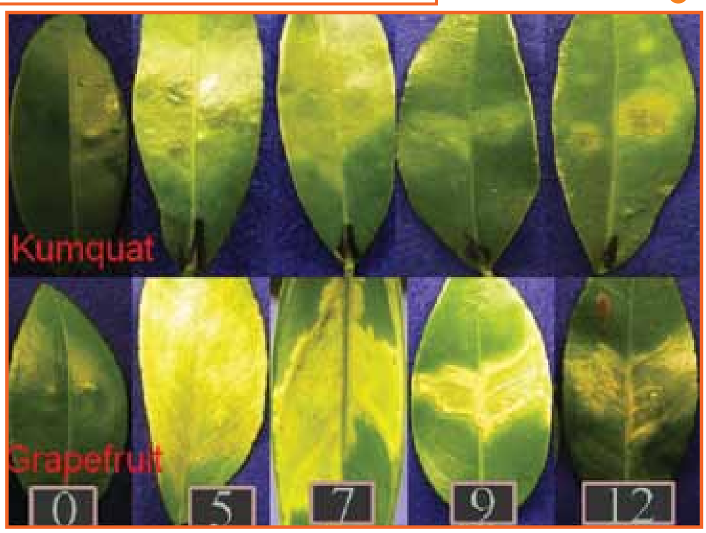

Fig. 2 (right). *Visual symptoms of canker development in kumquat and grapefruit leaves. The numbers at the bottom represent the number of days after inoculation (DAI).*