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Citrus Canker Diseases – A Review

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Abstract

Of all the agricultural pests and diseases that intimidate citrus crops, citrus canker is one of the most devastating. The disease is caused by a bacterium called Xanthomonas axonopodis pv.Citri. occurs in large areas of the world's citrus growing countries including India. At least 3 distinct forms or types of citrus canker are recognized in the world. 1) Canker A, 2) Cancrosis Band3) Cancrosis C, among these, Asiatic form (Canker A) is the most destructive and affects most of the major citrus cultivars. Severe contagion of the disease produces a variety of effects including defoliation, dieback, severely blemished fruit, reduced fruit quality, and premature fruit drop. There are certain environmental atmospheres like Warm, humid, cloudy climate, along with heavy rainfall and strong wind promotes the disease. Also, Phyto-sanitary measures involving analogous cultural practices and resistant hosts, Proper removal of inoculums sources. This review focuses primarily on developments of canker disease host-pathogen interactions, variability, and Challenges to the latest achievements in cancer management and its effects.

Keywords: Citrus canker, Xanthomonas axonopodis pv. Citri, pathogen, disease control management

Introduction

Citrus canker is a bacterial disease of the citrus plant Pseudomonas citri or Xanthomonas citri. Fawcett and Jenkins - 1933 first of all Report this disease in Dehradun, India around 1827, Java between 1842 and 1844. This indicates that the disease may have originated in India or Java and then spread to other countries. Now it is known to occur in every citrus growing area of the world (Fawcett and Jenkins, 1933). The use of copper-based bactericidal products by spray application has been a widely used practice for more than two decades for the control of bacterial citrus cancer. Prolonged exposure to bacterial strains in copper has increased the resistance in local areas.

There are two different approaches we can consider for biological control of bacterial citrus canker. This antagonism specifically focus in a quorum quenching of DSF(Diffusible signal factor) pathway and antibacterial activity by Pseudomonas bacteria against Xanthomonas citri subsp. citri ethological agent of citrus canker disease.

Citrus canker is mainly controlled by the use of various chemicals such as fungicides and disinfectants at different times of the year. Copper oxychloride (Khan *et al*. 2018), streptomycin sulfate (Graham *et al*. 2011), streptomycin + oxytetracycline (Graham *et al*. 2008), various chemicals in combination with streptomycin copper oxide),sodium arsenate and copper sulphate have been found effective in controlling citrus canker in different In order to avoid the deleterious effect of Synthetic pesticides on the environment, an alternative approach to the control of plant pathogens is important to deal with this problem (Khan *et al.* 2018). Mahajan and Das (2003) reported plants and microorganisms as potential sources of pesticides for future use.

To control the disease thus spread. Culture Control, steps for restricting Chemical Control and or biocontrol to prevent it. Cut off the affected part of the disease or cut from the root, limiting the affected area pesticides control used. Thus, Different controls are used.

Description of Citrus Canker

Classification (C H Hasse, 1915)	
Domain:	Bacteria
Phylum:	Proteobacteria
Class:	Gammaproteobacteria
Order:	Xanthomonadales
Family:	Xanthomonadaceae
Genus:	Xanthomonas
Species:	*X. axonopodis*
Binomial name:	*Xanthomonas axonopodis*

Table - 1 Description of Citrus Canker pathogen

Disease identification:

Brown spots on leaves

Origin and Distribution:

Year	Location	Year	Location(India)
1800(**Fawcett and Jenkins *et al.*** 1933)	India	(Luthra and Sattar 1940)	Punjab
1827(**Fawcett *et al.*** 1933)	India in herbarium specimens (Dehradun)	(Chowdhury 1951)	Assam
1910-12	Florida, USA (Fawcett and Jenkins*elal.*1933)	(Govinda Rao 1954)	Andhra Pradesh, Tamil Nadu
(Doidge1916)	South Africa	(Venkatakrishnaiah 1957; Aiyappa 1958)	Karnataka
1979	Australia (Garnsey *et al.* 1979)	(Parsai and Prasad 1959)	Madhya Pradesh Rajasthan
1980 **1981**	Australia, Mexico, and Florida	(Nirvan 1960)	Uttar Pradesh
1984	Mexico	Now the disease is known to occur in almost all citrus-growing areas of the country (Gupta and Sharma 2000) Thus, citrus canker was distributed in various places.	
1995	Florida		
1998 **(Goto 1992)**	Miami		

Table – 2 reporting of Citrus Canker in different places.

Disease Symptoms

The symptoms of the disease are observed on all the aerial parts including leaves, old branches, and fruits. Although phylogenetically different strains of Xanthomonas cause citrus canker, the symptoms, and signs elicited on susceptible hosts are the same (Gottwald, 2000).

Cancer causes premature leaf and fruit fall, twigs dieback, general shrinkage, and spotted fruit. The blister-like lesions on the leaves and fruits start small and expand with the progression of the disease. These lesions may darken to tan or black and develop a water-soaked Margin with a Canker infected fruit, foliage yellow halo, and stems. (T.R. Gottwald *et al.* 2000) (Kevin Ong *et al.* 2016)

Disease name	Micro-organisms	Pathogen name	Effects (symptoms)
Citrus canker	bacterium	Xanthomonas axonopodis	brown spots on leaves, often with an oily or water-soaked appearance
Apple canker	fungus	Neonectria galligena	On small branches and fruiting spurs
Butternut canker	fungus	Sirococcus clavigignenti-juglandacearum	Which commonly originate from leaf scars, buds, or wounds. In spring, an inky-black fluid exudes from cracks in the canker; in summer, the cankers appear as sooty black patches, often with a whitish margin.
Southwest canker	environmental condition	cold and sun	include round-to-irregular sunken, swollen, flattened, cracked, discolored, or dead areas on the stems (canes), twigs, limbs, or trunk
Ash bacterial canker	bacterium	Pseudomonas savastanoipv. fraxini	sunken patches of dead bark and small holes in leaves called shot hole

Bleeding canker of horse chestnut,	bacterium	Pseudomonas syringae pv. aesculi	Cracks in the barks which ooze dark or reddish-brown sticky liquid.
Rose cankers	fungus	Leptosphaeriaconiothyrium and Cryptosporella umbrina	spots ranging in color from yellow to purple
Cypress canker	fungus	Seiridium cardinale	Which causes characteristic sunken, lens-shaped cankers and ring barking.
Rapeseed stem canker,	fungus	Leptosphaeria maculans	Spots develop on the upper side of the leaf, with the underside clear of fungal growth
Foamy bark canker		Geosmithia putterillii	Wet discoloration seeps from the beetle entry holes, Foamy liquid, and Reddish sap oozing from entry holes.
Poplar canker,	bacterium	Xanthomonas populi	Young twigs develop brownish, sunken, roughly circular areas in the bark
Grape canker	fungus	Eutypa lata	Foliar symptoms may be observed as mild chlorosis or wilting due to inhibition of water transport

Pine pitch canker	fungus	Fusarium circinatum	Wilting and yellow-green discoloration of needles
Honey locust canker	fungus	Thyronectria austro-Americana	sunken, dead areas of bark; dieback; reduced foliage; yellow foliage; premature fall coloration; and early leaf drop
Oak canker	fungus	Diplodia quercina	Yellow, brown leaves, Small leaves and reduced twig growth, Dead limbs, and branches, Epicormic shoots (water sprouts) growing on trunks and large limbs, White and stringy sapwood in the cankered area
Larch canker	fungus	Lachnellula willkommii	white and hairy and resemble small cups with a yellow-orange center
Mulberry canker	fungus	Gibberella baccata	Small leaves, Brown leaves, Early cankers will be continually moist, brown areas, Bark cracks or falls away from the tree, which normally

			reveals the later black cankers.	

Table – 3 Different canker' sin formation (Gardan, 1999) *(International Journal of Systematic Bacteriology*)

Leaf harm:

Citrus canker effects start appearing after 15-20 days. Bud bursts pinpoint oily-looking spots and attain a maximum size of 2 to 10 mm circular spots usually on the abaxial surface (Zhong *et al*, 2002). Leaf miner wound leaves when they begin feeding. The feeding channel is just below the epidermis. When galleries are contaminated with citrus cancer bacteria, numerous infections can occur, resulting in tremendous inoculums (Nirvan, 1961; Sohi and Sandhu, 1968; Sinha, 1972; Cook, 1988). Tree with wounds caused by leaf miners remain susceptible for 7-14 days compared to only 24 hours for wounds caused by wind, thorns, or pruning (Filho and Hughes., 2000) Later, both epidermal surfaces may become ruptured by tissue hyperplasia induced by the pathogen, resulting in the formation of the diagnostic symptom. Signs of the pathogen are generally evident in older harm as masses of rod-shaped bacteria stream from the edges of thinly cut harm sections under the microscope (James h. Graham, 2000).

Branches harm

The cankers are irregular spots of this disease that arise above. Rough becoming white or yellow pustules and more prominent on twigs and branches. On stems, harm can remain viable for several seasons. Thus, stem harm can support the long-term survival of the bacteria. These pustules may coalesce to split the epidermis along the stem length, and occasionally girdling of young stems may occur the disease causes the stems to dry out and break easily (Dasel, 2003).

Fruits harm

On the fruits, the harm is almost similar to those on leaves and have a crater-like depression in the center and extend to 1 mm in depth. The rind is susceptible for a longer time than for leaves and more than one infection cycle can occur (Gottwald, 2000).

Further, the presence of a large number of lesions on the fruit surface may result in small and misshapen fruits especially when the infection is early. Crop yields are low and economic yields are low due to diseased lemons (Stall and Seymour, 1983).

Pathogen name:
*Xanthomonas axonopodis pv***.** *Citri*

Hosts:

Affects some plant species, particularly citrus varieties (such as grapefruit, lime, lemon, mandarin, orange, cumquat, and their hybrids)

Civerolo (1984) lists numerous plants in the Rutasi family other than citrus and ponsirus that may serve as hosts of Xac in experimental conditions or under severe disease pressure in nature. Among commercial citrus varieties and rootstocks, Asiatic citrus cancers are most severe on grapefruit (C. paradisus), limes (C. orantifolia, C. limetioids), and their hybrids because of their high susceptibility.

Characteristics	Citrus Canker			Citrus bacterial spot (CBS)
Canker form	A	B	C	
Pathogen	*X. axonopodis* pv. *citri*	*X. axonopodis* pv. *aurantifolii*	*X. axonopodis* pv.*aurantifolii*	*X. axonopodis* pv. *citrumelo*
Distribution	Asia, Africa,South AmericaOceania	Argentina, Paraguay, Uruguay	Brazil, Mexico	America (Florida)
Host range	Wide	Limited	Limited	Wide
Major host plant	Citrus spp.	Lemon	Mexican lime	Citrus spp. (nursery)
Symptoms	Spongy erupted at first; corky rough lesions with a raised, greasy margin later; water-soaked appearance			Flat or sunken lesion; extreme water soaking

Table–4 Comparison of three different forms of citrus canker and citrus Bacterial spot (CBS) of citrus (Civerolo *et al*. 1984) (Goto, 1992)

The disease is endemic throughout India, Pakistan, and the islands of the Indian Ocean, Southeast Asia, China, and Japan. Cancrosis is caused by B (cancer bore false cancer), X. axonopodis pv. aurantifolii (Hasse) Gabriel Water is a serious problem with lemons in Argentina, Paraguay, and Uruguay. Mexican lime, sour orange, and pummelo are also susceptible. Cancrosis causes cancer-type lesions on fruits, leaves, and twigs that are similar to but smaller than those produced by a form (Civerolo *et al*. 1984).

In culture, Cancr osis B bacteria grow more slowly on nutrient agar than canker bacteria, and a specific medium containing sucrose, peptone, salts and refined agar has been developed for this form. Isolates of Cancrosis B can be serologically isolated from Cancer A bacteria but not from Cancrosis C isolates. Cancrosis is also caused by C, X. axonopodis pv. aurantifolii, separated from the Mexican lime in Brazil. The symptoms are similar to those of cancer A. In 1984, a new Xanthomonad disease of citrus was finedin Florida nurseries. The causative bacterium has nothing to do with the two existing pathogens of Xanthomonas axonopodis (causes cancers A, B, and C) and is named Xanthomonas axonopodis pv.Citrumelo (Hussey) Gabriel Water in (formerly known as Group Cancer or Cancer E) (Goto *et al*., 1992).

The disease is commonly referred to as Citrus bacterial spot (CBS). CBS is currently only known from Florida, where it appears to be limited to nurseries (Gotwald & Graham, 2000).

Highly susceptible	*Citrus paradisi* Macf., grapefruit *C. aurantifolia* (Christ.) Swingle, acid lime *C. limettioides* Tan., Palestine sweet lime *Poncirus trifoliata* (L.) Raf., trifoliate orange
Moderately susceptible	*C. sinensis* (L.) Osbeck, sweet orange *C. aurantium* L., sour orange *C. limon* (L.) Burm., lemon *C. tangelo* J. Ingram & H.E. Moore, tangelo
Highly resistant	*C.reticulata* Blanco, mandarin, tangerine *C. maxima* (Burm.) Merr., pummelo *C. aurantifolia* (Christ.) Swingle, Person or Tahiti lime
Moderately Resistant	*C. medica* L., citron *Citrofortunella microcarpa* (Bunge) Wijnands, calamondin *Fortunella spp.*, kumquat

Table – 5 Susceptibility of several citrus varieties and Rootstocks to Xanthomonas *axonopodispv.Citri*

Recently, it was reported that goat weed (Ageratum conyzoides L.) could serve as a host of Xac. This plant is common in citrus orchards in the state of Assam in India (Kalita *et al*., 1997). This represents the only report of a non-Rutaceous host of Xac.

Pathogen

Causal organism

The genus Xanthomonas is a diverse and economically important group of bacterial phytopathogens, belonging to the gamma subdivision of the Proteobacteria. X. axonopodis pv. citri causes citrus canker, which affects most commercial citrus cultivars, resulting in significant losses worldwide (da Silva *et al*,. 2002). The bacterium is rod-shaped measuring 1.5-2.0 × 0.5-0.75 µm, Gram-negative, and has a polar flagellum. Colonies on laboratory media are yellow due to 'xanthomonadin' pigment production. When glucose or other sugars are added to the culture medium, colonies become very mucoid due to the production of exopolysaccharide slime. The optimum temperature range for growth is 28 to 30°C and the maximum temperature range for growth is 28 to 39°C (Goto, 1992). They can live up to six months in a year.

Disease Cycle:

The spores of the fungus are thick-walled, multicellular, and pigmented and therefore tolerate adverse conditions well. Spores are mainly produced on old lesions that live on mature leaves that live on trees as well as those that have fallen to the ground, but they do not produce fruit.

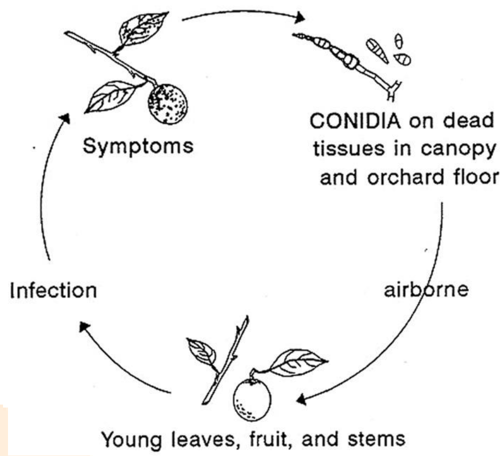

Figure: 1 Disease Cycle

The spores are carried in the air and carried by the wind. Rainfall events or sudden changes in relative humidity cause the spores to release. The length of the wetting period required for infection is about eight to ten hours when the temperature is favorable (20°C–29°C)(Brlansky, R. H. , 2002). At temperatures of less than l7°C, extended periods of leaf wetness (greater than 24 hours) are needed before much infection occurs. Most infections may follow rain, but dew is often sufficient for infection.

How it is spread

- The canker lesions ooze bacteria when wet, which can infect new growth, and are Scattered over short distances by wind, rain showers, and overhead irrigation.
- Long-distance spread can occur through flooding and cyclones, and human-assisted movement of clothes, equipment, and infected plant material (including bud wood, rootstock seedling, budded trees).
- Plants become infected when bacteria or bacterial spores enter the wound and enter the natural pores on the leaves, growing branches, and fruits. The disease is spread by birds, insects, and humans, especially when the trees are wet.
- The bacteria can survive in diseased plant tissue as well as in soil. It may winter more in angular shoots and become active again in the following season *(Department of Primary Industries and Regional Development's Agriculture and Food).*

Disease control management:

Steps for restrict

Once positively identified, diseased trees in uprooted, placed in a pile, and burned. Surrounding, disease-free trees are destroyed as well, as an added precaution. In residential areas, diseased trees, and surrounding, open trees are cut down or removed. Areas, where trees have been destroyed, should be kept free from citrus sprouts and seedlings. Movement of infected fruit bud wood and other plant parts is prohibited to adjacent sites, where infected plants are located. All clothing, tools, and equipment used in infested areas must be properly disinfected (Gupta and Sharma, 2008).

Botanical control

Studies on biological control of canker are still in a preliminary stage. Some species of bacteria, such as Pseudomonas syringe, Ervina herbicola, Bacillus subtilis, and Pseudomonas fluorescence were isolated from citrus phylloplane, which was reported to be in vitro antagonists for cancer pathogens (Ota, 1983; Goto, 1979; Unnimalai and Gnanamanickam, 1984).

An experiment was set up in a farmer's field (acid lime orchard) using an inhibitory strain of Bacillus subtilis (S-12) showed that a single spray of aqueous suspension (2.7 x 109cells/ml) of bacterial cells was spread on 5 batches (6 numbers of plants/batch) of plants keeping 4 batches unsprayed. (Das *et al*., 2004)

Extracts of Lucas indica were the most effective in suppressing the disease and demonstrated 78.46 and 77.78% disease control compared with the control (Bora *et al*., 2001). Similarly, spraying with leaf extracts of Tamarindus indica resulted in the lowest citrus canker incidence (48%) under greenhouse conditions. Under field conditions, the number of diseased leaves and disease incidence was greatly reduced compared to the control after spraying of T. indica aqueous extracts (Leksomboon *et al*.,2001).

Chemical control :

The spread of the disease, chemical control measures is not completely effective. However, copper-containing materials (Bordeaux mixture, copper hydroxide, basic copper chloride, copper oxychloride, and triabic copper sulphate) are the most effective bacterial sprays to protect leaves and fruits. (kishumand Chand *et al*,. 1987)

In addition to pruning along with four sprays of copper oxychloride (0.5%) or Bordeaux mixture (1%) have been reported to be effective against the disease by Kishun and Chand (1987). under Indian environmental conditions. Control of citrus canker with 4 sprays of copper oxychloride at 30-day intervals during the growing season was satisfactory.

Spraying 500X dilution of solution of 77% Kocide [copper hydroxide] wettable powder at 20-30 days after bud burst and spraying summer-autumn shoots at 10-15 days after bud burst could get 100% of the shoot leaves without canker infection (Zhong and Ling 2002; Pan 2004). Spraying with 500-fold and 400-fold solution of 77% copper hydroxide and 60% chlorothalonil solution, respectively, resulted in the efficient control of the disease (Fu and Xu., 2001).

CaCl2 was applied to Kagzi Kalan lemon at 3 stages of fruit development (pea, marble, and half-grown) at 4 concentrations (0.25, 0.50, 0.75, and 1.0%). CaCl2 at 0.5% was the most significant at the half-grown stage of fruit development in reducing fruit cracking (15.6%) with an insignificant reduction in fruit weight and juice content and increased yield tremendously (Sharma *et al*,. 2002).

Control was also achieved by spraying 600 × 10-6 Agrostreptomycin or 0.5% lime-sulfur (calcium polysulfide) on young fruits and shoots (Ye *et al.*, 2001). While Zhang *et al.*, (1996) observed the best control of canker after foliar sprays of copper hydroxide (800 ppm). Gottawald and Timmer (1995) suggested the use of windbreaks along with the application of copper bactericides as effective control measures of citrus canker.

Integrated application of Bordeaux mixture or copper oxychloride, streptocycline, and neem cake in combination with pruning during winter, budding stage, and after petal fall was quite effective for controlling canker (Khodakaramian and Ghasemi 2002; Das and Singh 2003). In addition, foliar application of streptomycin sulphate + copper oxychloride is given three times a year i.e., before monsoon, in August and December.

Conclusion:

This review article describes citrus canker disease. Citrus canker is a bacterial disease caused by Xanthomonas axonopodis. Citrus canker spreads easily and can spread over large distances on equipment (vehicles, tools, mechanical hedges, sprayers, gardening equipment) and people (hands, shoes, and clothing). They damage citrus plants, destroy crops and stop trade, and affect aboveground parts of the plant such as leaves, older branches, and fruits. all traits are connected to each other. Limit the affected parts of the damaged plant. Method of biological control, the use of biological control of certain bacteria, such as Pseudomonas syringae, Erwinia herb, etc. and chemical control, they use copper (Bordeaux mixture, copper hydroxide, basic copper chloride, etc.) which are the most effective bacterial sprays for leaf and fruit protection. Throughout this article, we've covered how citrus canker is spread, controlled, and how certain strains and chemicals are used.

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