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CITRUS LIMON DISEASES –A REVIEW

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ABSTRACT
Citrus is considered as one of the most important tropical fruit crop in India. It plays a vital role in the fruit economy of the country next to mango. Citrus cultivation in India is facing plethora of production constraints viz., non availability of disease free planting material, bud wood transmissible diseases, general neglect, scarcity of water and poor management practices, cultivation in unsuitable soils. Beside this, Citrus spp. are prone to attack by more than 150 diseases and disorders caused by fungal, viral and few bacterial pathogens right from nursery level to bearing stage resulting in considerable yield losses. Citrus canker is a serious bacterial disease of commercial varieties of citrus, and relatives, caused by the bacterium *Xanthomonas citri* subsp. citri. It is a serious menace to our most valued citrus orchards causing objectionable blemishes on the fruit. The disease causes serious damage in India, China, Japan and Java. At least 3 distinct forms or types of citrus canker are recognized. Among these, Asiatic form (Canker A) is the most destructive and affects most of the major citrus cultivars. Severe infection of the disease produces a variety of effects including defoliation, dieback, severely blemished fruit, reduced fruit quality and premature fruit drop. Warm, humid, cloudy climate, along with heavy rainfall and strong wind promotes the disease. Citrus canker has resulted in heavy economic losses to citrus industries across the globe, due to damage to trees, reduced fruit production and access to export markets and increased cost of management.

KEYWORDS: Citrus canker, *Xanthomonas citri*, symptoms, pathogenicity.

INTRODUCTION
The genus Citrus, one of the most important group of fruit crops worldwide, belongs to the family Rutaceae comprising 140 genera and 1300 species distributed throughout the world. It is a long-lived perennial crop and is grown in more than 100 countries across the world.[1] Citrus is the third most important fruit crop in the world after apple and banana and accounts for the production of about 100 million tons with massive area of cultivation spread over 7.2 million hectares. Favourable hotspots for citrus cultivation are tropical and sub-tropical areas, falling approximately within 4000 latitude on each side of the equator, where temperatures are predominantly warm. The major citrus producing countries include Brazil, US, Spain, Italy, Egypt, Mexico and China. India ranks sixth amongst the various citrus producing countries in the world. Citrus is an evergreen crop requiring a rich and fast draining sandy loam soil with a pH range of 6-7. Citrus trees are very sensitive to temperature fluctuations and require warm temperature 20ºC at night and 35ºC during the day for proper growth and maturation of fruit. Abundant sunshine of 6 to 7 h is an absolute must for their best performance. Citrus trees do not need high humidity, especially during blooming season and excess water is bad for their growth, as it encourages fungal and root pathogens.

In the last two to three decades there has been a growing awareness of the role of diet in the etiology of the chronic diseases that are major contributors to morbidity and mortality in industrialized countries. Natural sources have provided us with an excellent hunting ground for discovering newer therapeutically active moieties and plant kingdom is one of these sources for giving us natural drugs. A wide range of bioactive substances have already been identified in foods and drinks and it is likely that many more exist. Many diseases, such as cancer, atherosclerosis and inflammation are caused by free radicals and lipid peroxidation inside human bodies. This kind of risk can be reduced by an appropriate dietary pattern including a great portion of fruit and vegetables[2,3], because of the great amount of natural antioxidants in these plantfoods.[3] There are many biologically active substances in fruits including both nutrients and non-nutrients for which protective health effects have been postulated. Citrus fruits, including oranges, lemons, limes and grapefruits, are a principal source of such important nutrients, which are suggested to be responsible for the prevention of degenerative

disease. These include vitamins C, folic acid, carotenoids, dietary fibres, potassium, selenium and a wide range of phytochemicals.[5] A great number of epidemiological studies have shown that Citrus fruit consumption is protective in a variety of human cancers. It is presumed that most, if not all, of this protective effect is due to vitamin C. The frequency of Citrus fruit consumption is more closely related to risk reduction than vitamin C intake. This suggests that Citrus fruits contain not one but multiple cancer chemopreventive agents. Citrus genus belongs to the large family Rutaceae, containing 130 genera in the seven subfamilies with many important fruit and essential oil producers.[7] A genus of evergreen aromatic shrubs and small trees distributed in the Indo-Malaysian region, South-East Asia and China but cultivated throughout the topical and temperate region of the world. About 22 species occur in India, besides about 15 exotic species have been introduced for experimental trials. Citrus occupies a place of considerable importance in the fruit economy of the country. Citriculture as a garden industry existed for centuries in India. It comprises the third largest fruit industry after mango and banana and occupies about 7.5% of land under fruits. Among the Citrus fruits of commerce oranges (sweet, mandarin and sour) are the most important as fresh fruit and they contribute to roughly 80 percent of the world's Citrus fruit production. The species cultivated in India includes: *Citrus aurantifolia, C. aurantium, C. deliciosa, C. grandis, C. jambhiri, C. karna, C. latifolia, C. limetta, C. limettioides, C. limon, C. limonia, C. lycopersicaeformis, C. macroptera, C. maderaspatana, C. madurensis, C. medica, C. megaloxycarpa, C. nobilis, C. paradisi, C.paratangerina, C. pennivesiculata, C. pseudolimon, C. reshni, C. reticulata, C. rugulosa, C. sinensis, C. unshiu.*[9] Citrus is one of the most important fruits, which is consumed mostly fresh and has been used as an herbal medicine or additive or food supplement. Citrus fruit and juices have long been considered a valuable part of a healthy and nutritious diet and it is well established that some of the nutrients in Citrus promote health and provide protection against chronic disease. Citrus is believed to possess bioactivities such as antioxidant, anti-inflammatory, antimicrobial, and is suggested to be responsible for the prevention of cancer and degenerative diseases. Those bioactivities of Citrus are due to the presence of bioactive compound such as phenolics, flavonoids, essential oil and vitamins.[10] The composition of the fruits is affected by climate, growing conditions, various treatments, maturity, rootstock and variety. Citrus species show broad spectrum of pharmacological properties these properties are related to the presence of specific phytochemical groups. Vitamin C Citrus species are best known for being rich source of vitamin C. Vitamin C is an antiscorbutic factor and possess antioxidant properties. Flavonoids -Citrusspecies are rich in flavonoids. Citrus flavonoids have antioxidant properties. They possesses excellent hydroxyl radical scavenging activity superoxide scavenging activity and antilipoperoxidant activity.[13,14]

Citrus canker is a contagious disease of citrus (and some other plant species of the Rutaceae family) caused by the bacteria *Xanthomonas axonopodis* pathovar *citri*. Infected trees display unsightly lesions, which can form on leaves, fruit and stems. Trees infected with the disease may suffer from low vigour and a reduction in fruit quality and quantity. Citrus canker is a serious disease impacting on citrus production and is the subject of a number of control and eradication programs around the world. While not harmful to humans, canker significantly affects the vitality of citrus trees, causing leaves and fruit to drop prematurely; a fruit infected with canker is safe to eat, but too unsightly to be sold. The disease, which is believed to have originated in Southeast Asia, is extremely persistent when it becomes established in an area. Citrus groves have been destroyed in attempts to eradicate the disease. There is no cure for citrus canker. Prevention is the best option to protect against citrus canker. Canker causes the citrus tree to continually decline in health and fruit production until the tree produces no fruit at all. Citrus canker is highly contagious and can be spread rapidly by Wind-driven rain, lawnmowers and other landscaping or farm equipment, people carrying the infection on their hands, clothing or equipment, moving infected or exposed plants or plant parts (fruit, leaves or stems).

Citrus Canker

Citrus canker is one of the major citrus disease which affects all types of important citrus crops. The disease is endemic in India, Japan and other South-East Asian countries, where it has spread to all other citrus producing continents except Europe. However, widespread occurrence of the disease in many areas is a continuous threat to citriculture especially in canker free areas.

HISTORY AND DISTRIBUTION

The geographical origin of citrus canker is a matter of controversy. Lee (1918) reported that, it may have arisen in Southern China, and he assumed Fortunella hindsii to be the wild host plant. However, Fawcett and Jenkins (1933) reported that citrus canker originated in India and Java, rather than in other regions of the Orient, because they detected canker lesions on the oldest citrus herbaria kept at the Herbaria of the Royal Botanic Gardens in Kew, England (i.e., Citrus medica collected from India in 1827-1831 and C. aurantifolia from Indonesia in 1842-1844). These findings suggest the origin of disease in the tropical areas of Asia, such as South China, Indonesia, and India, where Citrus species are presumed to have originated and to have been distributed to other citrus-growing areas in the form of bud wood. In India, citrus occupies third position among fruits after mango and banana and canker is one of the major constraints of its cultivation. Citrus canker was first reported from Punjab. Its occurrence was further recorded in Tamil Nadu . Several others have reported the incidence of canker on the acid lime and other varieties of citrus. Further, the disease appear as a serious problem where ever acid lime

(C. aurantifolia) is grown on a large and commercial scale (e.g., Akola region in central India, Nellore and Periyakulum regions in southern India and Khera region of western India) and has become a permanent major problem to the citrus growers of this country. Recently canker has been detected in kinnow mandarin nursery in the state of Punjab.

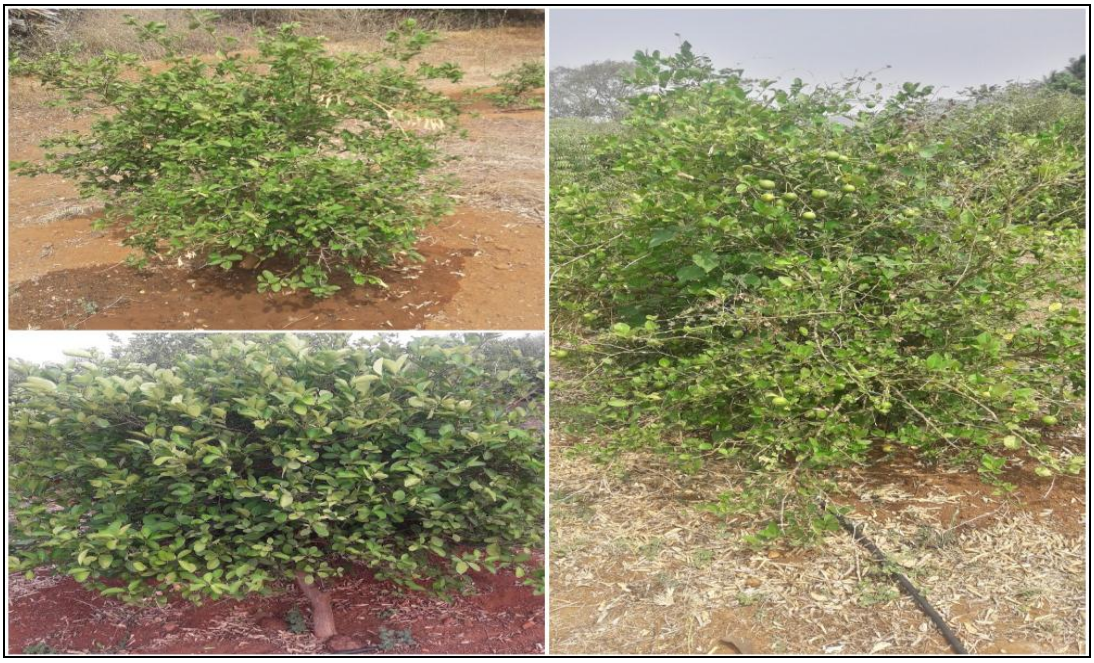

Fig 1: A citrus tree.

Types of Diseases on Lemon Leaf

Citrus canker is a exotic disease infecting the leaves. Its causal organism is a bacteria named Xanthomonas axonopodis.It easily spreads from one plant to other and the infection causes lesions on the leaves, stems, and fruit of citrus trees, including lime, oranges and grapefruit and the leaves starts falling off at an earlier stage at a faster rate [15]. Copper fungicides can help in mitigating the disease.

Anthracnose is a fungal disease caused by Colletotrichum. It causes the twigs to dieback, premature leaf drops and dark fungal spores and staining on the leaf and lemon fruits. Usage of fungicides with potassium bicarbonate can control the disease.

Fig 2: *Pseudocercospora* fruit and leaf spot caused by the fungus.

Citrus greening disease also known as HLB is a disease caused by motile bacteria Candidatus Liberibacter. It is difficult to maintain the infected plant and to regenerate it. It can be treated with antibiotics like biocide 2,2-dibromo-3-nitrilopropionamide and penicillin G sodium and to manage the effects of the disease.

Fig 3: Citrus Canker Lesions in leaf and fruit.

Citrus leafminer is a very small, lightcolored moth, less than 1/4 inch long. It consists silvery white iridescent forewings with brownish white markings and a distinct black spot on each wing tip. Citrus leafminers can be eradicated by using various parasites and predators, including tiny nonstinging, naturally occurring wasps such as Pnigalio and Cirrospilus species[16]. Imidacloprid sprayed to the base of citrus trees provides the longest duration of control, 1 to 3 months. Imidacloprid should only be applied only once in a year. Imidacloprid applications should be properly timed to protect periods of leaf flushing, such as in the spring and fall.

Fig 4: Citrus leafminer in lemon tree.

Bacterial blast also known as citrus blast is a bacterial disease caused by pseudomonas syringe. It starts its infection by curling of leaf and rapidly spreading dark brown blothes that develop on the back of the leaf. Predominantly visible lesions is another major symptom for the disease. Sooty mold is a fungal disease caused by Scorias, Capnodium and Fumago. Sooty mold in itself doesn't cause harm to the plants but they get deposited on places where honeydew drops get collected. Coated leaves are deprived of sunlight and the leaves may fall prematurely.

Fig 5: Bacterial blast in lemon tree.

SYMPTOMATOLOGY

In India, citrus canker is reported to be relatively more on acid lime and less commonly on mandarin and sweet orange.[17] The diseased plants are characterized by the occurrence of conspicuous raised necrotic lesions that develop on leaves, twigs and fruits. Lesions can be detected by drawing the fingers over the surface of infected tissues. On leaves, first appearance is as oily looking, 2-10 mm circular spots, usually on the abaxial surface (reflecting stomatal entry following rain dispersal). Lesions are often similarly sized. Later, both epidermal surfaces may become ruptured by tissue hyperplasia induced by the pathogen. On leaves, stems, thorns and fruit, circular lesions become raised and blister-like, growing into white or yellow spongy pustules. These pustules then darken and thicken into a light tan to brown corky canker, which is rough to the touch. Often a water- soaked margin develops around the necrotic tissue and is easily viewed with transmitted light. On stems, pustules may coalesce to split the epidermis along the stem length, and occasionally girdling of young stems may occur. Older lesions on leaves and fruit tend to have more elevated margins and are at times surrounded by a yellow chlorotic halo (that may disappear as canker lesions age) and a sunken center. Sunken centers are especially noticeable on fruits, but the lesions do not penetrate far into the rind thereby not affecting internal quality.

Severe infection results in defoliation, dieback, deformation of fruit and premature fruit drop [18]. Canker causes fruit losses ranging from premature fruit drop due to abscission to non-marketable quality due to lesions. Disease of the fruit is probably the most economically important damage since fruits with canker lesion are not acceptable for fresh market and fetch very little price. An essential diagnostic symptom of the disease is citrus tissue hyperplasia (excessive mitotic cell divisions), resulting in cankers.[19]

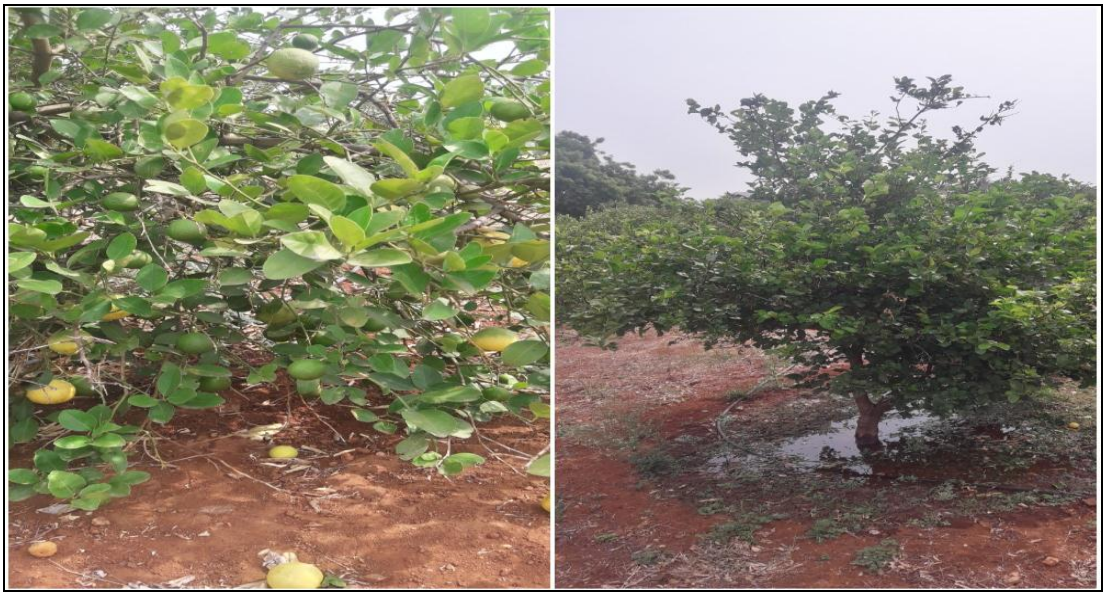

Fig 6: Citrus leprosis leaf and fruit drop.

Disease cycle: Xanthomonas axonopodis pv. Citri overseason in infected area, which is canker lesion on leaf or stem. The bacteria ooze out of the lesions when there is free moisture. During the rainy weather, windblown rain carries the inoculum to the new susceptible hosts. The bacteria infect new plants through stomata and wounds. The wound can be caused by pruning or hedging that could cut open mesophyll tissues for direct infection. The rain can also cause water congestion on leaf surface, form column of water through stomata and promote infection through the natural opening. The infection can form on fruit, foliage and young stem. The varied size of lesions on citrus fruit is because of the multiple cycles of infections.

Pathogenicity: Xanthomonas axonopodis has the capability to form a biofilm for attachment on the host. The biofilm is the result of the production of extracellular polysaccharides (xanthan). The biofilm ensures the virulence and epiphytic survival of X. axonopodis pv. citri prior to the development of citrus canker. In addition, the bacteria secrete transcriptional activator-like (TAL) effectors through type III secretion system. The effector interacts with host machinery to induce transcription for genes that regulate plant hormones such as gibberellin and auxin. Host range: Among citrus cultivars and rootstocks, citrus canker is most severe on grapefruit some sweet oranges such as Hamlin, Pineapple, and Navel and lemons and trifoliate orange [Poncirus trifoliata (L.)] and their hybrids that are used for rootstocks. Disease management Exclusion: The first line of defense against citrus canker is exclusion. Citrus canker still does not exist in some countries or regions of countries where climatic conditions are favorable for pathogen establishment, which is probably because of rigid restrictions on the importation of propagating material and fruit from areas with canker. Unfortunately, with increased international travel and trade, the likelihood of X. axonopodis pv. citri introduction is on the rise as it is with many exotic pests and pathogens. Documentations of 6 separate introductions of citrus canker into India have occurred since 1985, demonstrating that even with eradication, reintroduction is a continual process and problem.

Sanitation: Numerous cases of new infections of citrus canker are linked to human and mechanical transmission. Humans can carry bacteria on their skin, clothing, gloves, hand tools, picking sacks, ladders, etc. Vehicles can become contaminated by brushing wet foliage or coming in contact with plant material. Machinery such as tractors, implements, sprayers, hedgers, etc. can similarly become contaminated and even inadvertently transport plant parts. In areas, where citrus canker is resident, it is necessary to construct decontamination stations for personnel, vehicles and machinery, which are sprayed with bactericidal compounds. Eradication : Once introduced into an area, elimination of inoculum by removal and destruction of infected and exposed trees is the most accepted form of eradication. To accomplish this, trees may be uprooted and burned or in urban areas, cut down and chipped and the refuse disposed of in a landfill. In India, state law requires that all citrus trees within 579 m (1900 ft) of infected trees must be removed in both residential and commercial situations.

Disease management: In countries, where the disease is well established and severe, only the more resistant types of citrus, such as Valencia oranges and mandarins may be profitable. In regions where canker is endemic, certain cultural practices are used to reduce the severity of the disease. It is imperative to avoid working in infected orchards when the trees are wet from dew or rain. The reduction of wind is another primary concern. Wind speeds are reduced by deployment of windbreaks on the perimeter of the orchard or between the rows. Reduction of wind speed lowers the probability of direct penetration of stomates by bacteria as well as entry of wind-induced

injuries on foliage and fruit. Where canker is a major problem, control requires integration of appropriate cultural practices including sanitation, windbreaks and leafminer control with frequent applications of copper sprays. Copper sprays have been shown to reduce infection somewhat. Because the fruit is susceptible to canker during the first 90 days after petal fall, it is important to maintain a protective coating of a copper material on the fruit surface during this period. Two or three treatments may be needed for this purpose, depending on rainfall and cultivar susceptibility. Windbreaks can greatly reduce spread and severity of disease and increase the efficacy of copper sprays. Leafminer control is particularly important on young trees and certain cultivars that have a high proportion and greater frequency of vegetative growth flushes.

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