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مقاله مروری

بیماری سوختگی برگ و گل (بلاست) و گوده سیاه میوه مرکبات: یافته‌های جدید

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چکیده

***Pseudomonas syringae* pv. *syringae* (Pss) به مدت چندین دهه به عنوان تنها عامل ایجاد کننده بیماری سوختگی برگ و گل (بلاست) و فرورفته‌گی سیاه یا گوده سیاه میوه مرکبات شناخته شده است. در سال‌های اخیر تعداد باکتری‌های عامل این بیماری به بیش از ۱۰ گونه افزایش یافته است. در حال حاضر گونه‌های *P. viridiflava*، *P. lurida*، *P. moraviensi*، *P. simiae*، *P. cerasi*، *P. caspiana*، *P. kairouanensis* و *P. nabeulensis* نیز به عنوان عامل بیماری معرفی شده‌اند، که سه گونه آخر گونه‌های جدیدی از جنس *Pseudomonas* هستند. تعداد مناطق و کشورهای تولید کننده مرکبات که تحت تاثیر این بیماری قرار گرفته‌اند نیز، از سال‌های اخیر، رو به افزایش بوده است. میزان حساسیت گونه‌ها و ارقام مرکبات به بیماری مزبور متفاوت بوده و برخی مانند کوم‌کوآت، تعدادی از ارقام پرتقال نافدار (ناول) و پاره‌ای از گونه‌ها و ارقام نارنگی به سوختگی برگ و شاخه و گل بسیار حساس بوده ولی میوه‌های آنها متحمل تا مقاوم هستند. این ویژگی در مورد ارقام لیموترش (لیمو خاگی یا لمون) برعکس بوده و میوه‌های آنها به آلودگی بسیار حساس هستند. این درجات حساسیت و مقاومت عمدتاً محدود به واکنش‌ها در برابر Pss و *P. viridiflava* بوده و آگاهی چندانی در زمینه واکنش ارقام به گونه‌های جدیدتر بیمارگرها هنوز در دست نمی‌باشد. روش‌های توصیه شده برای مدیریت بیماری در حال حاضر محلول‌پاشی با ترکیبات مسی، هرس شاخه‌های آلوده و خشکیده، مبارزه با علف‌های هرز در باغ‌ها و حاشیه آنها و ایجاد زهکشی مناسب است.**

کلید واژه‌ها: ارقام مرکبات، باکتری‌ها، بیماریزایی، حساسیت، سودوموناس، مبارزه بیولوژیک، مدیریت بیماری، مقاومت

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Review Article

Citrus Blast and Black Pit: Some Recent Advances

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Abstract

Blast and black pit disease of citrus has been known to be caused by *Pseudomonas syringae* pv. *syringae* for several decades. The bacterial incitant of the disease has been rising to over 10 species in recent years. The inciting bacterial species, at the present, consists of *P. viridiflava*, *P. lurida*, *P. moraviensis*, *P. simiae*, *P. cerasi*, *P. caspiana*, *P. kairouanensis* and *P. nabeulensis*, the last three being novel species of *Pseudomonas*. The number of citrus-producing countries affected by the disease appears to be increasing as well. The relative susceptibility of citrus species and cultivars to the disease varies, and some, like kumquat, a few navel oranges, and some mandarins, are very susceptible, while most lemons are resistant to the blast state but sensitive to black pit. The disease control measures presently recommended and practiced are spraying with copper fungicides, pruning out dying shoots and control of weeds in and around groves.

Keywords: Bacteria, *Pseudomonas*, biocontrol, pathogenicity, disease control.

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Introduction

Citrus is the most widely grown subtropical and among the major tropical fruit crops throughout most of the world. It has a great share in several aspects of human nutrition and health, such as fresh produce, fruit juice, conserved products, food flavoring, and jelling agents, as well as the cosmetics industry (Anonymous). The crop suffers from a considerably large number of pests and diseases in most, if not almost all, of its production areas (Klotz 1978, Timmer *et al*. 2000).

Bacterial canker caused by subspecies of *Xanthomonas citri* and their variants has been treated as the most devastating bacterial disease of citrus for decades. Strict control measures, including chemical, cultural, quarantine, and inspection approaches have been sought and implemented by plant protection agencies to restrict its expansion and entry into the unaffected areas (Klotz 1978, Timmer *et al*. 2000, Reuther *et al*. 1978). Despite the extensive effort made in mitigation of the citrus canker impact, the disease has not ceased to expand, and the introduction of its diverse variants into new areas and the emergence of new stains have not stopped (Gottwald *et al*. 2004, Gottwald *et al*. 2002, Kado 2002).

In more recent decades, a similarly, if not more, destructive bacterial disease of citrus, named Huanglongbing or greening disease, associated with *Candidatus* Liberibacter spp. (*Ca*. L. africanus, *Ca*. L. americanus, and *Ca*. L. asiaticus) has emerged and kept spreading in several countries. All three forms of the disease, Asiatic, African, and American types, are spread by psyllid species, and infection with any of them can lead to the decline and eventual death of the trees (Klotz 1978, Timmer *et al*. 2000, Zhang *et al*. 2018, Li *et al*. 2019).

Stubborn disease caused by *Spiroplasma citri* is also a major disease of citrus in many parts of the world (Klotz 1978, Timmer *et al*. 2000, Sagouti *et al*. 2022). whereas a somewhat related wall-less but un-culturable organism, *Candidatus* “Phytoplasma aurantifolia” is associated with a devastating disease of acid lime (Mexican lime) named witches’ broom disease of lime (WBDL) but is of limited geographic distribution (Al-Sobhi *et al*. 2021, Donkersley *et al*. 2018).

Citrus variegated chlorosis caused by certain strains of *Xylella fastidiosa*, is likewise destructive although confined in distribution to a few American countries including Brazil (Coletto-Filha *et al*. 2020, Lopez 2020).

Crown gall caused by *Agrobacterium tumefaciens*, in spite of being of major concern in the production of many fruits and other agricultural crops, has not thus far been of any threat to citriculture worldwide. Some citrus species, including oranges, grapefruit, and lemons, are listed as hosts of the bacterium (Kado 2002) but reports on its occurrence in the past several years or decades are nil and has, just recently, been recorded as affecting Navalina sweet orange, Okitsu mandarin and their rootstock, Carrizo citrange in a production nursery in Iran (Bradbury 1986, Nesyer *et al*. 2005, Ganeh *et al*. 2020).

Blast and black pit of citrus, first identified in California in 1916 and shown to be incited by *Pseudomonas syringae*, constitutes the second known bacterial disease of citrus, next to citrus canker, in historical terms (Klotz 1978, Timmer *et al*. 2000). Much of the works done on the symptomology, ecology, management and other attributes of the disease have been concentrated in the first few decades since its initial report (Donkersley *et al*. 2018, Mougou *et al*. 2022). The disease has regained importance in some citrus-growing areas, including Iran, Tunisia, and Turkey, in recent years, concurring with the emergence of a number of new causative agents (Timmer *et al*. 2000, Mougou *et al*. 2022, Shams Bakhsh and Rahimian 1997, Beiki *et al*. 2016, Busquets *et al*. 2017, Abdellatif *et al*. 2017, Mirik *et al*. 2005, Ivanovic *et al*. 2017).

Symptoms

Foliar symptoms predominantly appear on the petiole (wing) as water-soaked spots which expand and extend to the base of the leaf lamina and towards the site of attachment on the stem. Some lesions start from the tip or edges of the leaves and anywhere on the leaf lamina where wounds occur, especially on thorny species and cultivars. Cankers are commonly formed at the juncture of petioles on the twigs as elliptical somewhat sunken lesions. The spots and cankers expand and turn dark brown to black in color. Affected leaves tend to roll, dry, and remain attached to the branch for some time but fall off eventually. In severe infections twigs and branches distal to the cankered sites wilt and die. Some stem cankers split open, and many exude gum (Figures 1 and 2). Buds become necrotic and fail to grow. Extensive defoliation of very susceptible cultivars may occur in severe cases when conditions favoring dissemination and repeated infections prevail (Klotz 1978, Reuther *et al*. 1978, Mougou *et al*. 2022, Beiki *et al*. 2016).

Black pit infections occur mainly on lemon, grapefruit, and some sweet orange cultivars. Small brownish depressed lesions form on the ripening fruits, which may expand to over one centimeter in diameter. The flavedo and albedo layers of the peel are affected and necrotized, leading to the appearance of dark brown to black pits on the fruits. The disease is more prevalent in fruits kept on the tree, and their picking is postponed in the humid subtropics (Figure 3). The black pits may continue to expand during storage. The flesh of the fruits is not affected, but the disease reduces marketability (Klotz 1978, Mougou *et al*. 2022).

Varietal Susceptibility

Sweet orange and grapefruit leaves and twigs and the fruit of lemons were initially reported to be very susceptible to infection, the former to the blast and the latter to the black pit disorder, respectively (Klotz 1978, Cetinkaya Yildiz *et al*. 2022, Mougou *et al*. 2022). Subsequent research works have disclosed the susceptibility of oranges and grapefruit to both blast and black pit and the sensitivity of mandarins to blast as well (Ivanovic *et al*. 2017).

Recently, an extensive study on the susceptibility of citrus and stone fruit cultivars to *P. syringae* pv. *syringae* has been done in Turkey. About 25% of the 16 cultivars of sweet orange, mandarin, grapefruit, and lemon evaluated were susceptible, including the favored commercial cultivars Cara Cara sweet orange, Midnight orange, Nova tangerine, Okitsu Satsuma mandarin, Meyer lemon, and Rio Red grapefruit. Ortanique tangor was highly susceptible. The majority of cultivars assessed, including Fukuoto navel, Lane Late sweet orange, Navelina navel orange, Murcott mandarin, and Robinson tangelo. Clausellina mandarin and Eureka lemon were rated as moderately susceptible. Lisbon lemon has also been slightly susceptible to *P.s.* pv. *syringae (*Cetinkaya Yildiz *et al*. 2022). Washington navel orange, Page tangelo, Owari Satsuma mandarin, Eureka lemon, Clementine tangerine, Nagami kumquat, and alemow (*Citrus excelsa*) have been found to be highly susceptible cultivars and species to the blast incited by *P. viridiflava*, in Iran (Beiki *et al*. 2013, Rahimian unpublished).

Casual Agents

P.s. pv. *syringae*, since its first records as the incitant of citrus blast and black pit in 1910s had remained for decades as the sole causative agent of the disease. Most of the information, although not extensive, available on the disease deals with this host-pathogen association (Klotz 1978, Timmer *et al*. 2000, Mougou *et al*. 2022, Beiki *et al*. 2016, Beiki *et al*., 2013, Busquet *et al*., 2017, Abdellatif *et al*. 2017, Mirik *et al*. 2005, Ivanovic *et al*. 2017, Cetinkaya Yildiz *et al*. 2022).

P.s. pv. *syringae* strains are among the ubiquitous bacterial pathogens having a wide host range among the woody and herbaceous cultivated and wild plants (Bradbury 1986, Beiki *et al*. 2013, Lamichhane *et al*. 2015, Ruinelli *et al*. 2022). Their features in the LOPAT (L, levan formation; O, oxidase production; P, potato rot; A, arginine dihydrolase; T, tobacco hypersensitivity) set of tests, routinely used for differentiation from some other commonly encountered or similar *Pseudomonas* species is + - - - +, respectively (Lelliott *et al*. 1966). Their identity has conventionally been further verified by positive ice nucleation activity (INA) and syringomycin production, formerly through bioassay and more recently by PCR amplification of the *syrD* gene involved in the production of the toxin and the presence of *ice* gene, respectively. These two activities, however, are not solely restricted to of *P.s.* pv. *syringae* and some other pathovars of *P. syringae* display one or both as well (Gonzalez *et al*. 1981, Ruinelli *et al*. 2022). Syringotoxin is the name given to the type or isomer of syringomycin produced by the strains of *P.s.* pv. *syringae* causing citrus blast and black pit (Gonzalez *et al*. 1981). Syringomycins contribute to the virulence of the pathogenic isolates (Baltrus *et al*. 2017).

Figure 1. General view of a blast-affected Washington navel sweet orange tree showing dead and dying leaves and branches of the canopy (top); a closer view of symptoms (bottom).

Figure 2. Canker-like lesions incited by *Pseudomonas viridiflava* on twigs of Washington navel sweet orange (top); leaf spot on Washington navel (bottom left) and alemow (*Citrus macrophylla* Wester) (bottom right).

Figure 3. Field symptoms of black pit disease on a Eureka lemon fruit in Mazandaran.

P.s. pv. *syringae* and other pathovars of the species possess pathogenicity island (PAI), which consist of genes encoding the type three secretion system (TTSS) and specific effectors which are secreted or translocated by the system to the plant cells and act as the main determinants of pathogenicity (Baltrus *et al*. 2017, Ruinelli *et al*. 2022).

P. viridiflava was noted to be the causative agent of citrus blast and black pit in Mazandaran province, northern Iran, in 1997 (Shams Bakhsh and Rahimian 1997, Beiki *et al*. 2016). The strains isolated from the affected tissues of leaves, twigs, and fruits seemed atypical, as they were very mucoid and the majority pale yellow in color. In the LOPAT test set they were + - + - +, a pattern uncommon then for strains diagnosed as *P. viridiflava* (Lelliott *et al*. 1966, Lipps and Samac 2022). The strains did not produce the green-colored colonies on yeast dextrose calcium carbonate (YDC) medium, a feature serving as the characteristic for naming the species as such (viridiflava meaning green-yellow in Latin).

At present, phylogroups of *P. viridiflava* with both mucoid and non-mucoid colony types have become known as disease-causing agents on an increasing number of crop plants (Bradbury 1986, Cariddi *et al*. 2024, Bartoli *et al*. 2014, Lipps and Sumac 2022). Strains harbor a PAI of noncanonical tripartite (T-PAI) or single partite (S-PAI) with some TTSS effectors and *avrs*. They also possess other pathogenicity and virulence factors, including INA and lipopeptide, which affect their aggressiveness, toxin (ecomycin), and secretory pectolytic (pectate lyase) enzymes. *P. viridiflava* has shown phenotypic plasticity, manifested by different colony morphologies and altered attributes (Bartoli *et al*. 2014, Lipps and Sumac 2022, Araki *et al*. 2006, Liao *et al*. 1988).

Recently, the number of *Pseudomonas* species capable of inciting blast and black pit has kept increasing. The new species *P. caspiana* and some previously known species, including *P. lurida*, *P. moraviensis, P. orientalis* and *P. simiae,* in addition to *P. syringae* and *P. viridiflava*, were isolated from the blast-affected citrus plants in Mazandaran and Gilan provinces and their pathogenicity on citrus species confirmed (Beiki *et al*. 2016, Busquets *et al*. 2017). Recent reports on the occurrence of blast and black pit in Tunisia have demonstrated the involvement of two species, *Pseudomonas kairouanensis* and *P. nabeulensis* and implicated role of *P. cerasi* on the disease as well (Mougou 2022, Abdellatif *et al*. 2017).

In spite of the emergence of several new *Pseudomonas* spp. as the causative agents of citrus blast and black pit in some citrus growing areas, *P.s.* pv. *syringae* remains the most widespread and damaging among all (Mougou 2022, Abdellatif *et al*. 2017, Mirik *et al*. 2005, Dillon *et al*. 2021).

Epidemiology

Contrary to over a century of history behind the identification of citrus blast and black pit and its major incitant, information on its epidemiology is far less than adequate to devise and implement efficient control measures. *P.s.* pv. *syringae* has served as a model among the plant pathogenic bacteria in several aspects of genetics, ecology, virulence, and other pathogenicity attributes but less so in comprehensive studies of host specificity or preference, resilience, temporal and spatial consistency or fluctuation in population structure and adaptability to diverse biotic and abiotic, especially stressful, conditions, features that are of utmost importance in epidemiology and control (Lamichhane *et al*. 2015, Ruinelli *et al*. 2022, Baltrus *et al*. 2017, Bartoli *et al*. 2014).

Almost all strains of *P.s.* pv. *syringae,* as typical generalists, live as epiphytes, endophytes, and saprophytes in plant environments, including plant debris, weeds, soil, and water (various sources and reservoirs like irrigation systems, rivers, lakes and alike) in addition to their pathogenic behavior (Lamichhane *et al*. 2015, Baltrus *et al*. 2017, Bartoli *et al*. 2014, Dillon *et al*. 2021). Much of the studies and information thereof have been centered on *P.s.* pv. *syringae* strains associated with some herbaceous crops and deciduous fruit trees (mainly stone fruit trees) and considerably less with citrus (Ruinelli *et al*. 2022, Baltrus *et al*. 2017, Bartoli *et al*. 2014, Agrios 2005, Dillon *et al*. 2021). Strains of *P.s.* pv. *syringae* inciting citrus blast have been found to be genotypically heterogeneous, appearing as scattered populations in the phylogenetic trees so several to be strains can infect any single citrus species, and host-species or cultivar specificity or preference do not exist (Dillon *et al*. 2021, Baltrus *et al*. 2017).

Strains causing citrus blast, like most other strains, are prevalent in the subtropical areas and in the wet cool periods of the year, which prevail during late autumn to mid-spring. During the hot, dry periods, strains migrate to and thrive on herbaceous crops, weeds and probable cover crops in the grove or the borders and adjacent fields. Upon the onset of the cool period, the strains would jump or shift to the citrus trees. If a freezing event of enough duration occurs, the strains contributed to the formation of ice can get ingress through the cracks of freezing wounds to the damaged leaf and stem tissues and infect the plant. The strains may extend colonization and produce some cankers or leaf lesions if conditions become favorable or remain quiescent intercellularly until late winter or early spring (Mougou 2022, Eskalen and Adaskaveg, 2019, Dillon *et al*. 2021, Klotz 1978, Zaheer *et al*. 2024). Shifting from the ground covers is driven by rain splashes and, in the event of the existence of tall weeds directly through contact. Expansion of the leaf spots and cankers, dissemination of the bacterium and further infections with the accompanying leaf drop and die-back of the girdled branches keep happening until the start of the hot and dry months (Agrios 2005, Mougou 2022, Timmer *et al*. 2000).

Transfer of the populations from citrus to ground covers happens during spring and early summer. Some transfers to citrus start to happen in the late summer and during autumn which contributes to infection of the ripening fruits and appearance of black pit. Keeping the fruits for extended periods, following their ripening, on the trees, would lead to increased incidence of the fruit infections and severity of the black pit symptoms (Klots 1978, Mougou 2022, Dillon *et al*. 2021).

Information on the epidemiology of *P. viridiflava* as another causative agent of citrus blast and black pit is nil. Almost similar episodes of infection and progression of the disease can occur with the strains of *P. viridiflava* as the incitant of the citrus blast (Shams Bakhsh and Rahimian 1997, Bartoli *et al*. 2014, Lipps and Samac 2022). *P. viridiflava* can exist as a saprophyte, epiphyte, endophyte, and a generalist pathogen on a relatively large number of annual, perennial, herbaceous, and woody plants and weeds (Cariddi 2024, Lipps and Samac 2022). Most strains have ice nucleation activity, produce toxins (named ecomycin), and possess pectolytic activity. Several strains, including the ones, reported initially as the sole incitant (Shams Bakhsh and Rahimian 1997) and later as one of the major incitants of citrus blast and black pit in Iran (Beiki *et al*. 2016, Busquets *et al*. 2017) have the mucoid phenotype. These mucoid strains were also the incitant of leafspot and blight on *Calendula officinalis*, *Spinacia oleracea*, and *Gerbera* sp. but not on *Ocimum basilicum,* which was susceptible to and infected naturally with the non-mucoid strains of the bacterium (Beiki *et al*. 2016, Rahimian 1994, Unpublished data). These plants can serve as the alternative and epiphytic hosts of *P. viridiflava* strains infecting citrus.

Information on the lifestyle, biology, virulence and epidemiology and relative importance of the strains of the newly emerged causative agents of citrus blast and black pit, namely *P. caspiana*, *P. lurida*, *P. mortellii*, *P. voraniensis*, *P. orientalis*, *P. simiae* in Iran (Shams Bakhsh and Rahimian 1997, Beiki *et al*. 2016). and *P. kairouanensis*, *P. nabeulonsis* and *P. cerasi* in Tunisia (Queslati *et al*. 2019, 2020). is nil warranting future research.

Disease Control

Citrus groves should be established in proper sites, not prone to water logging, and having adequate drainage.

Establishment of sustainable windbreaks of proper orientation is an absolute necessity and helpful in reducing wind damage, especially with thorny cultivars and their subsequent infection. Use of less thorny and more compact cultivars is recommended in areas and conditions conducive to blast.

Some information has become available on the susceptibility and tolerance of several citrus species and cultivars to *P.s.* pv. *syringae* as the incitant of blast and black pit, for example, susceptibility of oranges and grapefruit and resistance of some lemons, while fruits of the latter remain sensitive to black pit (Klotz *et al*. 1978, Mougou 2022).

In some recent assessments, the sweet orange cultivars New Hall and Thomson's navel have been found to be very susceptible followed by Ortanique tangor, and Star Ruby grapefruit. Baldi lemon and Valencia late sweet orange appeared moderately resistant (Eskalen and Adaskaveg 2019, Cetinkaya Yildiz *et al*. 2022). In a recent evaluation trial in Turkey, among 16 cultivars of grapefruit, mandarin, lemon, and sweet orange, Lisbon lemon was recorded as the least susceptible, while Cara Cara, the favored sweet orange cultivar, Okitsu Satsuma and Nova mandarin, Meyer lemon, and Rio Red grapefruit were rated as susceptible; orange cultivars Fukumoto, Lane Late and Navelina, Murcott and Clausellina mandarins, Eureka lemon and Robinson tangelo were moderately susceptible (Cetinkaya Yildiz *et al*. 2022).

In northern Iran, the widely grown Washington navel orange, kumquat, an old line of Clementine mandarin, and alemow are more seriously affected. However, Eureka lemon, Old Wase, Miyagawa, and Sugiyama Satsuma mandarins are less severely impacted by the blast incited by *P. viridiflava*, which has been the sole incitant for more than two decades since its initial report in 1997 (Shams Bakhsh and Rahimian 1997, Beiki *et al*. 2013, Beiki *et al*. 2016, Rahimian unpublished).

Control of weeds and voluntary plants is of considerable importance in reducing the over-summering populations of the pathogenic strains (Mougou 2022). It has been noted that in the groves where weeds were not properly controlled, blast infection foci were crowded in areas where weeds, especially the taller ones, were left uncontrolled (unpublished results). The ground should be kept free of plant debris and residues. The affected twigs and branches must be pruned a few centimeters below the lowest cankered sites. Pruning can preferably be done in the late spring to early summer (Eskalen and Adaskaveg 2019, Mougou 2022).

To reduce and hasten stimulation of new tender growth liable to infection in the autumn heavy use of fertilizers especially the ones rich in nitrogen in the late summer and early autumn months should be avoided (Mougou 2022).

In the biocontrol area, comprehensive works have been done the control of *Agrobacterium tumefaciens*, and led to the commercialization and widespread use of antagonist formulations under a number of registered names (Jones and Kerr 1989, Kado 2002, Kim *et al*. 2006). For the biocontrol of fire blight of apples and pears caused by *Erwinia amylovora*, several products and formulations have been worked out and are commercially available as well (Cabrefiga *et al*. 2011, Dagher *et al*. 2020, Fravel 2005).

Research and evaluation of potential biocontrol agents for the control of citrus blast is in its early stages. Three strains of the undetermined species of *Bacillus* and the extracts of garlic have been found to be effective in reducing the severity of the blast caused by *P.s.* pv. *syringae* under greenhouse conditions in Tunisia (Mougou *et al*. 2018). In a similar set of experiments, one (BS5) among the three strains of *Bacillus* tested has been found to reduce the severity of stem necrosis caused by *P.s.*

pv. *syringae*, as did the use of ethanolic extracts of garlic, *Azadirachta indica* and *Moringa oleifera*, under greenhouse conditions (Islam *et al*. 2017, 2020). The yeast species *Cryptococcus albidus*, *C. magnus*, *Rhodotorula* sp., and *Sporobolomyces raberrimus* have been reported effective in reducing the incidence and severity of blast under greenhouse conditions (Beiki *et al*. 2015).

In a detailed *in vitro* study, Bacteriophage Φ6 has been found to be a potentially efficient bio-agent for the control of *P.s.* pv. *syringae*. The real potential of the phage in controlling infections is needed to be evaluated under the greenhouse and field conditions (Pinheiro *et al*. 2019).

Chemical control of citrus blast has been recommended and implemented from the early years of its diagnosis; a (10 – 10 – 100, 10 Lbs. copper sulfate – 10 Lbs. lime – 400 gallons water) Bordeaux mixture has been the most bactericide in California (Klotz 1978, DeWolfe *et al*. 1966). Several copper compounds are now available in the market, including copper oxychloride, copper oxide, copper hydroxide, and basic copper carbonate (Lamichhane *et al*. 2018). Application of copper fungicides is more commonly recommended once at the onset of cool conditions in the early autumn and again at the late winter. Excessive or unnecessary use of copper compounds must be avoided due to the possibility of the emergence of copper-resistant strains.

Isolates of *P.s.* pv. *syringae* causing citrus blast have been found to be very sensitive to carbenicillin and sensitive to penicillin and rifampicin while being fairly tolerant to oxytetracycline and streptomycin (not yet registered for wide-scale use in citrus) (Islam *et al*. 2017). The latter two antibiotics are registered for use in the management of fire blight, but neither is tested nor registered for use in citrus blast control.

Some plant growth stimulants or inducers of systemic acquired resistance (SAR), like Acibenzolar-S-methyl (Bion^{R}), have shown promise as disease control agents and are commercially available. Others like Prohexadione-calcium (Regalis of BASF Co.) has been found effective in mitigating the damage of fire blight of apples and pears. The efficacy of this group of chemicals in the control of citrus blast deserves evaluation.

The efficacy and other aspects of application of these compounds in different localities, climatic conditions and citrus types warrants further evaluations.

Conclusion

Whereas citrus blast and black pit disease has been known, almost exclusively, to be caused by strains of *P.s.* pv. *syringae* for decades, it is beginning to turn out that there has been a steady increase in its spectrum of incitants along with the extension of its geographical distribution to new citrus-producing countries.

Control of the disease can, to some extent, be achieved by the application of at least two copper sprays in conjunction with some cultural and sanitation practices consisting of pruning out infected and dead branches, control of weeds, and avoiding use of nitrogen fertilizers late in the growing season.

In spite of attaining some success in the area of biocontrol, none of the accomplishments has reached the commercialization stage. Taken together, the disease trend necessitates more comprehensive research on all aspects of etiology and biology and the evaluation of more effective and environmentally sustainable control measures.

Copper compounds can best be applied in the early spring, before the initiation of new growth, at full bloom on cultivars and species susceptible to blast of flowers, and in humid climates, repeated one to two weeks later if cool, humid conditions or rainy season prevails. Autumn sprays should precede the onset of the first cold breeze or cool rainy weather.

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