

MORPHOGENETIC CHARACTERIZATION OF XANTHOMONAS CITRI PV. CITRI AND ITS MANAGEMENT

by Muhammad Saqlain Zaheer

Submission date: 30-Jun-2024 02:15PM (UTC+0500)

Submission ID: 2265157425

File name: Research_Paper_Akhtar_student.docx (1.54M)

Word count: 3672

Character count: 20990

MORPHOGENETIC CHARACTERIZATION OF *XANTHOMONAS CITRI* PV. *CITRI* AND ITS MANAGEMENT

ABSTRACT

Background: Pakistan's economy largely depends on citrus cultivation, and citrus fruits generate significant foreign exchange. *Xanthomonas citri* pv. *citri* (Xcc) is the primary cause of citrus canker (CC), which poses a significant threat to the industry. The management of disease is made more difficult by the lack of resistant variants against different Xcc races. Understanding and addressing Xcc are critical for maintaining the industry given the economic reliance on citrus.

Methods: In order to isolate Xcc in a lab, a thorough survey was conducted in the districts of Bahawalpur, Multan, and Dera Ghazi Khan to collect samples showing canker symptoms. Gram-negative bacteria were identified in the isolates by biochemical analysis, and Koch's postulates confirmed Xcc as the CC causing agent. DNA extraction and sequencing were used in the molecular characterization, which confirmed the phylogenetic relationship with Xcc. Using the disc sensitivity method, nine antibiotics were tested at 300, 500, and 700 ppm concentrations to evaluate CC management. Amoxicillin was found to be highly effective in inhibiting the growth of Xcc colonies.

Results: The study provided morphogenetic insights and established Xcc as the causal agent of CC. All strains matched Xcc in molecular characterization, but antibiotic sensitivity testing revealed inconsistent efficacy. Amoxicillin proved to be very effective at stopping the growth of Xcc colonies at every tested dosage.

Conclusion: This study makes an important contribution to our understanding of XCC and helps the citrus industry develop better disease control plans. Future interventions against citrus canker can benefit greatly from the understanding provided by morphogenetic characterization and antibiotic sensitivity profiles. The discovery of amoxicillin's high efficacy highlights the drug's potential for treating diseases linked to Xcc. These results help to protect citrus growing, maintaining the viability of an important industry in Pakistan's agricultural landscape.

Key words: Antibiotics, Characterization, Citrus canker, Management, *Xanthomonas citri* pv. *citri*.

1. Introduction

Citrus belongs to a genus of flowering tree and shrubs in the group Aurantioideae of the rue family Rutaceae, which is a large group of shrubs and trees (Liu et al., 2012). The genus produces citrus fruits, including important crops such as oranges, lemons, grapefruits, pomelos and limes. Citrus fruits are grown in over 140 countries and are native to South Asia, East Asia, Southeast Asia, Melanesia and Australia. China, United States, Mexico, Brazil, India, Spain, and Argentina are known as prominent contributors to the global citrus production (Faostat, 2016). In 2021, citrus fruits accounted for 161.8 million tons, making them the world's second most produced fruit (Gonzatto and Santos, 2023). Citrus fruits are known for their refreshing flavour and high nutritional value. These possess a high content of essential nutrients, including vitamins, minerals, dietary fiber and various bioactive compounds such as carotenoids, flavonoids, and limonoids, which have been associated with various health benefits. Citrus fruits are considered functional foods that can contribute to the prevention of chronic diseases (Kumar et al., 2023; Meng et al., 2024).

Citrus production faces several challenges that can decrease both yield and fruit quality. These challenges include insect infestations, lack of proper nutrition, and sudden

changes in overall climate. Pathogens such as bacteria, fungi, viruses and nematodes can also attack citrus fruit, directly reducing plant production and lowering farmers' earnings associated with citrus production (Khan et al., 2023). Pakistan has reported several diseases affecting citrus crops, including citrus canker, citrus gummosis, citrus decline, CTV and HLB, caused by various microorganisms. Canker disease poses a significant challenge for citrus cultivation on a global scale and results in substantial annual losses. This disease is primarily responsible to various strains of the *Xcc* bacterium that can significantly reduce the market and nutritional value of citrus crops. The disease is found in all regions of the world where citrus is grown and can have negative impacts on both yield and fruit quality (Ali et al., 2023).

Xanthomonas citri pv. *citri* (*Xcc*) is the primary inducer of CC, causing significant economic losses for citrus-producing countries worldwide by reducing export market value and fruit production (Ali et al., 2023). The epidemiology of citrus disease affected by *Xcc* appears at 29-29.5°C with 80-90% humidity and rainfall of 8.9-9.97mm (Thind, 2012). The *Xcc* bacteria are classified into five different pathovars: citri (Pathotype A), aurantifolii (Pathotype B, C, D), and citrumelo (also known as type E). These pathovars contain a variety of bacterial strains as well (Ali et al., 2023; Yao et al., 2023).

The primary symptom of CC is the emergence of lesions of varying sizes on the surface of leaves, initially appearing as pinpoint spots that are typically found on the abaxial side (Du et al., 2023; Hu et al., 2022). After a few days, the lesions become corky and the lesions on the leaves or fruits typically take on a sunken appearance at the center with an elevated margin that is encircled by a yellow halo. The size of lesions on infected fruits can also vary and fruits are more susceptible to infection compared to leaves because they can undergo multiple infection cycles on their surface (Derso et al., 2007). In severe cases of infection, the disease can cause premature fruit drop, twigs to dieback, defoliation of the tree, and result in blemished fruit. Of these, premature and non-marketable fruits are the most economically significant damages caused by the disease. Bacteria may endure in infected leaves for up to 6 months and infected twigs for up to 76 months (Dunger et al., 2005).

The rise in international travel and trade has considerably heightened the chances of introducing invasive plant pests and diseases to crops, including citrus canker (Gottwald et al., 2002). Different strategies are being implemented to prevent the introduction of invasive plant pests and diseases like citrus canker, limit their spread, and eliminate them. Significant amounts of money are allocated each year towards the implementation of quarantines, prevention measures, eradication initiatives and management programs on a global scale. In areas where canker is prevalent, effective management strategies necessitate the integration of many cultural practices, such as the implementation of windbreaks, sanitation measures, the use of pesticides to suppress the leaf miner and the use of antibiotics (Gottwald and Graham, 2014). The timing of antibiotic treatment and the duration between successive sprays are crucial factors to consider. The initial three-month period following the shedding of petals is of utmost importance, as it is at this time that the fruit is particularly vulnerable to the development of canker. Therefore, it is advisable to spray antibiotics onto the surface of the fruit during this particular time period (Ibrahim et al., 2017). Therefore, conducting an assessment of the effectiveness of several commercially available antibiotics would greatly contribute to the efficient treatment of the condition (Almalki and Varghese, 2020).

The present study was aimed to analyse the morphogenetic characterization of the *Xcc* causal organism of CC in the regions of District Bahawalpur, Multan and Dera Ghazi Khan of Punjab Province of Pakistan. Moreover, the present investigation was conducted

with the aim of assessing the comparative effectiveness of commercially accessible antibiotics in combating the pathogen in in-vitro conditions.

2. Material and Methods

2.1. Survey plan for the collection of samples

A systematic survey was conducted for collection of leaves samples showing citrus canker disease symptoms in areas of District Bahawalpur, Multan and Dera Ghazi Khan of Punjab Province. A total of 72 leaves samples affected with citrus canker disease were collected from the 12 sampling sites and put in brown paper bags (Figure 1). These samples were brought to the Diagnostic laboratory of MNSUAM for the purpose of bacterial isolation and stored in the refrigerator at 4°C until further processing.



Figure 1. Location of survey areas for sampling of citrus canker infected leaves

2.2. Isolation and purification and multiplication of the pathogen

A nutrient agar media was prepared to isolate, multiply and purify the pathogen. A sterilized beaker with capacity of 1L was taken and 14 g of nutrient agar and 500 mL of distilled water were added to it. Autoclaved the media at 121°C and 15 psi for sterilization (Riaz et al., 2008). After that infected leaves were carefully cut from infected portion around with small healthy portion. Surface sterilization was done by using distilled water follow by 0.1% HgCl₂ and distilled water. After surface sterilization moisture was removed by putting the samples on blotter paper. These samples were put on poured plates containing NA media and wrapped with wrapping tape to protect them and the experiment's integrity. After proper tagging, the plates were kept in the incubator

at 28 °C for 24 hours. After 24 hours, a light yellowish ooze was appeared beneath the infected samples and streaked in to new plates containing NA media by using streaking method for purification and preserved (50% glycerin solution) 4 °C at for further study.

2.3. Biochemical and physiological tests

All the isolates that grew on the NA media culture plate was identified morphologically by observing its colour, type of colony and conducting biochemical tests viz., Gram staining and 3% KOH test (Mubeen et al., 2015).

2.4. Pathogenicity test

Confirmation of the bacterial isolates was done by fulfilling Koch's postulates (Juhasz et al., 2013). For pathogenicity, the bacterial culture was grown overnight in 45 ml nutrient broth at 28°C following Hoque and Mansfield's (2005) protocol and placed on a shaking incubator (NB-205LF) at 250 rpm. The resulting bacterial suspension was centrifuged at 10⁴ rpm at 4°C for ten minutes. The pellet of bacteria was resuspended in sterile 10 mM MgCl₂ solution and centrifuged again. The washed pellet was suspended in 10 mM MgCl₂ solution more than once and adjusted to 620 nm, which was equal to 10⁸ colony-forming units/mL and 0.1 OD with the help of a spectrophotometer (Hoque and Mansfield, 2005). For pathogenicity, one and half year-old citrus plants were obtained from a nursery. Prior to inoculation, all plants were watered properly and covered with polythene bags for 2 hours and placed in sunlight to create high humidity conditions and maximum opening of stomata. Inoculation was done in the morning using the syringe method, with approximately 2 µl of bacterial suspension injected into the plant leaves (Francis et al., 2010). Plants that were treated as control were injected with distilled water.

2.5. DNA isolation and PCR

The process of isolating cellular DNA from a freshly grown aqueous bacterial culture was conducted using the modified CTAB method (Iqbal et al., 2021). The quantification of the extracted DNA was conducted, followed by its utilization in polymerase chain reaction (PCR) for the purpose of molecular identification of the pathogen. For the optimization of the PCR-based identification process, *Xcc* specific primers were used (Golmohammadi et al., 2007). The PCR protocol included a total of 40 amplification cycles. Each cycle consisted of denaturation at 94°C for 1 minute, annealing at 56°C for 1 minute, and extension at 72°C for 1 minute. The PCR reaction completed with a final extension step at 72°C for 10 minutes. After staining with ethidium bromide, the amplified product was separated on a 1.5% agarose gel and subsequently observed using a UV gel documenting system (Photonyx Ultra, NYXTechhnik).

2.6. In-vitro evaluation of different antibiotics

Relative efficacy of nine antibiotics (Amoxicillin, Kanamycin, Erythromycin, Azithromycin, Vibramycin, Ampicillin, Clindamycin, Streptomycin and Clarithromycin) against colony growth of *Xcc* was evaluated at 300, 500 and 700 ppm by disc sensitivity method (Fairbrother and Martyn, 1951). Sterilized distilled water was put to use as the control treatment. The Petri plates were enveloped with parafilm and subjected to incubation at 28°C. Inhibition zones data were recorded by measuring after 24, 48 and 72 hours of incubation with the help of digital Vernier caliper (500-196, Mitutoyo). The experimental design employed in this study was a Completely Randomized Design (CRD) with three replications.

2.7. Statistical analysis

The analysis of variance was performed on the recorded data with a significance level of 5%. In order to compare the effectiveness of various treatments of antibiotics, the Fisher's Least Significant Difference (LSD) test was employed (Steel et al., 1997). The "Microsoft Office-2016" was used for analysing and presenting data.

3. Results

3.1. Biochemical and physiological tests

Twelve isolates of bacteria isolated from infected citrus plants formed yellow pigmented, less convex, round and smooth colonies on NA media. The bacterium was determined to be Gram-negative based on the positive result obtained from the KOH test. After Gram's staining, microscopic examination revealed the presence of bacterial cells exhibiting a slight-pink coloration.

3.2. Pathogenicity test

The typical symptoms of CC disease, such as corky water-soaked spots, necrotic lesions with a yellow halo and defoliation were observed on the citrus leaves two weeks after they were inoculated. These symptoms closely resembled those observed in the citrus orchards during our surveys. The bacterial pathogen's ability to cause disease of CC were confirmed by re-isolating and re-purification from the inoculation citrus plants and confirmed the Koch's postulates.

3.3. Molecular characterization

DNA was extracted and PCR was carried out using 16s rDNA, resulting in a 581 base pairs DNA product. This product was purified and visualized using gel electrophoresis under fluorescent light. The identified DNA was commercially sequenced (Figure 2, 3).



Figure 2. Molecular identification of *X. citri* using PCR technology.

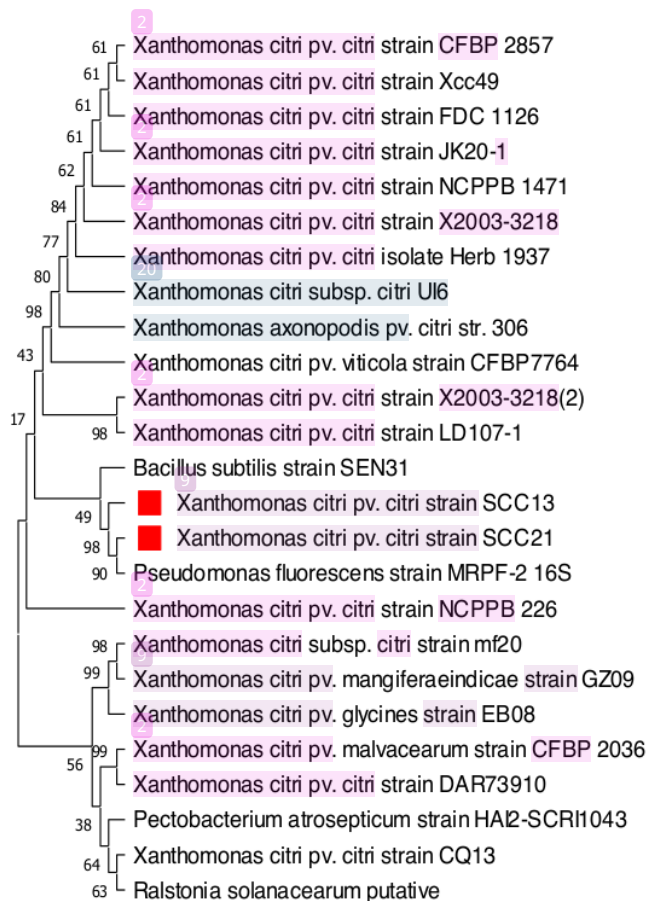


Figure 3. Dendrogram representing genetic relationships between isolated Scc13 and Scc21 with the strains of *X. citri* pv. *Citri*

3.4. In-vitro evaluation of different antibiotics

Different amounts of antibiotics showed substantial differences in *Xcc* colony growth efficacy (Table 1). No inhibitory zone was seen where sterilized distilled water was utilized as the control. There were the maximum inhibition zones (mm) produced by Amoxicillin (16.14) followed by Ampicillin (15.50), Kanamycin (11.31), Vibramycin (11.11), Streptomycin (10.78), Azithromycin (10.44) Clarithromycin (10.39), Clindamycin (10.33), Erythromycin (9.33) mm respectively as compared to control by different antibiotics (Figure 4, Figure 5).

Table 1. Detail list of antibiotics, their active ingredients, mode of action, molecular formula and molecular weight used in this study

Sr No.	Antibiotics	Active ingredients	Mode of action	Molecular formula	Molecular Weight
1	Amoxicillin	Amoxicillin Trihydrate	inhibition of cell wall synthesis	C ₁₆ H ₁₉ N ₃ O ₅ S	365.4 g/mol
2	Kanamycin	Kanamycin sulfate	misreading of mRNA	C ₁₈ H ₃₆ N ₄ O ₁	484.499 g/mol
3	Erythromycin	Erythromycin BP	inhibit protein synthesis	C ₃₇ H ₆₇ NO ₁₃	733.9 g/mol
4	Azithromycin	Zithromax	inhibit protein synthesis and proinflammatory cytokine production	C ₃₈ H ₇₂ N ₂ O ₁₂	749 g/mol
5	Vibramycin	Doxycycline Hyclate	inhibit growth of bacteria	C ₂₂ H ₂₄ N ₂ O ₈ ·H ₂ O	462.46 g/mol
6	Ampicillin	Ampicillin Trihydrate	inhibit cell wall synthesis	C ₁₆ H ₁₉ N ₃ O ₄ S	349.4 g/mol
7	Clindamycin	Clindamycin Hydrochloride	inhibit protein synthesis	C ₁₈ H ₃₃ Cl ₁ N ₂ O ₅ S	424.98 g/mol
8	Streptomycin	Streptomycin Sulfate	blocking the ability of 30S ribosomal subunits to make proteins	C ₂₁ H ₃₉ N ₇ O ₁₂	581.6 g/mol
9	Clarithromycin	Clarithromycin	inhibit protein synthesis	C ₃₈ H ₆₉ NO ₁₃	747.953 g/mol
10	Water	Control	-	H ₂ O	18.01528 g/mol

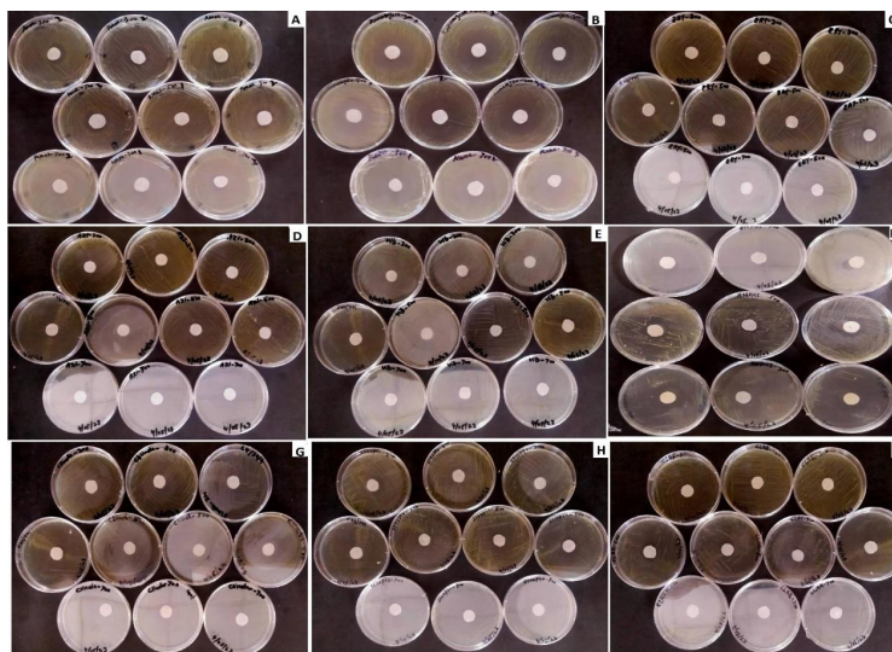
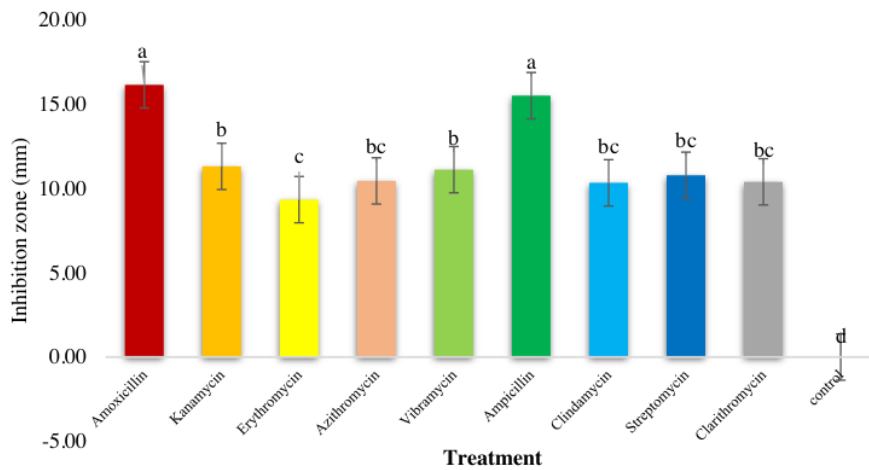
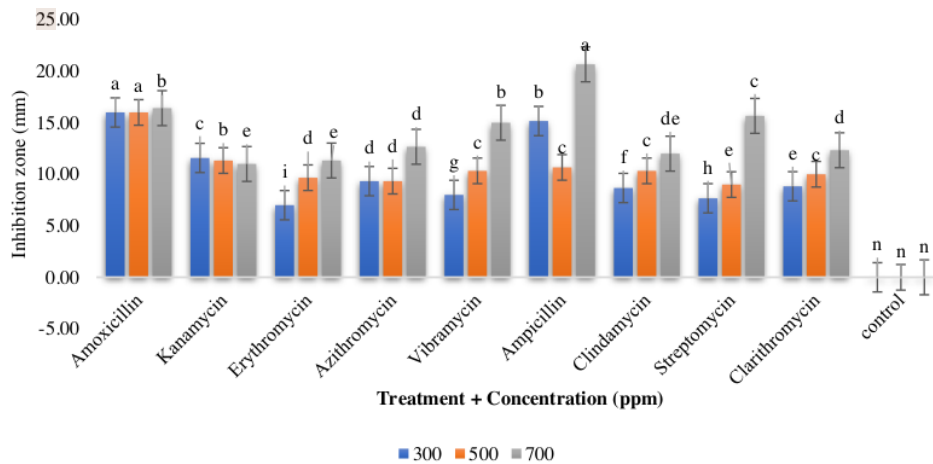


Figure 4. Pictorial view of inhibition zones formed by the antibiotics (a) Amoxicillin, (b) Kanamycin, (c) Erythromycin, (d) Azithromycin, (e) Vibramycin, (f) Ampicillin, (g) Clindamycin, (h) Streptomycin and (i) Clarithromycin with control *in-vitro* application for the management of *X. citri pv citri*



1
2 **Figure 5.** In-vitro evaluation of various antibiotics on the development of Xcc.

3
4
5 The interaction between treatments and concentrations (T×C) showed that maximum
6 inhibition zones (20.66) mm were produced by Ampicillin at 700 ppm, (10.66) at 500 ppm
7 and (15.16) mm at 300 ppm respectively while Erythromycin exhibited minimum inhibition
8 zones of (7.00) mm while Amoxicillin expressed 16.00, 16.00, 16.41, Kanamycin 11.58,
9 11.33, 11.00, Vibramycin 8.00, 10.33, 15.00, Streptomycin 7.66, 9.00, 15.66, Azithromycin
10 9.33, 9.33, 12.66, Clarithromycin 8.83, 10.00, 12.33, Clindamycin 8.66, 10.33, 12.00 mm
11 inhibition zone at 300, 500 and 700 ppm concentration respectively as compared to control
12 (Figure 6).



13 **Figure 6.** Impact of interaction b/w treatments and concentrations (TxC) on the development
14 of citrus canker

15 4. Discussion

16 Citrus canker disease poses a significant threat to citrus production worldwide and
17 results in substantial economic losses by affecting the physical appearance of the fruit,
18 rendering it unsuitable for the market (Ali et al., 2023). This disease is primarily responsible
19 to various strains of the *X. citri* pv. *citri* bacterium. The bacterium primarily affects the leaves
20 of trees and leads to defoliation and reduced fruit production in affected plants. In severe
21 cases, it can even prevent fruit formation altogether. Through stomatal openings, injuries and
22 wounds, the bacteria can penetrate the plant tissues where they multiply and colonize the
23 apoplast pathway by breaking through the epidermis of leaves through hyperplasia in the cell
24 (Thind, 2012). Bacteria may endure in infected leaves for up to 6 months and infected twigs
25 for up to 76 months (Dunger et al., 2005). Some citrus resistance varieties have shown
26 tolerance to the CC disease. The major strategy for controlling citrus canker disease on a
27 commercial scale is thought by most to be chemical control (Gottwald et al., 2002). Chemical
28 management strategies, such as preventing or disrupting metabolic processes, have been
29 shown to be successful in inhibiting the growth and spread of diseases (Ali et al., 2024), but
30 they also have serious limitations (Mahmud and Chong, 2021). Environmental and health
31 dangers from these practices are considerable. On the other hand, using antibiotics has shown
32 to be useful in both controlling plant disease and increasing the plants' resistance to
33 prospective diseases (Islam et al., 2014).

34 *X. citri* pv. *citri* was isolated from citrus with canker symptoms in areas of District
35 Bahawalpur, Multan and Dera Ghazi Khan of Punjab Province of Pakistan. The pathogen
36 displayed some heterogeneity in physiological and biochemical tests. Similar results were
37 observed during the KOH and Gram staining test performed by the Iqbal et al. (2021) that
38 confirmed the *Xcc* bacterium were Gram-negative and exhibit pinkish color of under the
39 microscope respectively. This study used the pin-prick method to inoculate the bacterial
40 suspension on healthy citrus plant leaves for a pathogenicity test. After 13-15 days, small,
41 moist patches first developed on the bottom surface of the leaves, and then they spread to the
42 top surface. The lesions developed corky, crust-like symptoms as they became older, along
43 with a depressed yellow symptom. The pathogenicity findings were in line with the results
44 from previous research conducted by Mustafa et al. (2015), who also observed same way
45 symptoms after the pathogenicity of *Xcc* by spray inoculating 10 citrus seedlings that were
46 two years old.

47 The DNA of the two most aggressive isolate culture was extracted and analyzed using
48 PCR targeting the 16s rDNA gene. Gel electrophoresis with fluorescent light was used to
49 observe a DNA fragment of 1500 base pairs. After identification, the DNA was commercially
50 sequenced. To perform a phylogenetic analysis of the *Xcc* genome sequence, the BLAST tool
51 on NCBI was employed. The BLAST results confirmed the correspondence between the
52 genome sequence and *Xcc*, confirming that this pathogen is the causal agent of CC. Iqbal
53 et al. (2021) analyzed rep-PCR fingerprinting on two isolates and sequencing revealed 100%
54 similarity with 40 nucleotide sequences of *Xcc* indicating the presence of pathogen in
55 Sargodha districts of the Punjab, Pakistan. Izadiyan et al. (2018) also confirmed similar
56 results after sequence that all their six irani isolated *Xcc* strains were closely related to the
57 other *Xcc* strains found in the gene sequence data of NCBI. Arshadi et al. (2013) conducted
58 rep-PCR fingerprinting analysis on a total of 25 isolates of *Xcc*. A significant amount of
59 genetic variation was identified among the isolates, suggesting the potential existence of
60 multiple pathotypes of the bacterium within the Malaysia.

61 The efficacy of nine antibiotics in managing the canker disease was examined in *in-*
62 *vitro* condition. The most effective in preventing the development of *Xcc* among them was
63 ampicillin at a concentration of 700 (ppm). The present study was in line with research done
64 in by Naqvi et al. (2014) who studied at the manner in which various antibiotics affected

65 bacterial blight of rice. They came to the conclusion that Ampicillin Trihydrate had the
66 second best results in reducing *X. oryzae* pv. *oryzae*. By attaching to the bacteria act as
67 inhibition of cell wall peptidoglycan synthesis and inactivation of inhibitors to autolytic
68 enzymes. Ampicillin trihydrate has been proven to have antibacterial ability against
69 *Xanthomonas* spp. with inhibitory zones in *in-vitro* conditions (Islam et al., 2014). Hameed et
70 al. (2022) also studied at the manner in which various antibiotics against *Xcc* were evaluated.
71 They came to the conclusion that oxytetracycline had the best results in reducing *Xcc*. By
72 attaching to the bacterial chromosomes, oxytetracycline inhibits bacterial reproduction and
73 functions as a bacteriostatic drug. Islam et al. (2014) conducted an evaluation of various
74 antibiotics, including cefotaxime, chloramphenicol, bacitracin, gentamycin and
75 streptomycin, in order to assess their effectiveness against *Xcc*. The efficacy of
76 chloramphenicol was determined to be the highest.

77 The results of this study highlight how important it is to manage citrus canker brought
78 on by *Xanthomonas citri* pv. *citri* (*Xcc*) by using morphogenetic characterization and
79 antibiotic sensitivity profiling. Because of its high effectiveness in preventing *Xcc* growth,
80 amoxicillin is a good option for managing diseases in citrus crops. In comparison to
81 conventional antifungals and antibacterials, amoxicillin is more effective against *Xcc*.
82 Conventional therapies, like compounds based on copper, have drawbacks because of the
83 possibility of resistance growing and environmental issues. Nanoscaled oxides like zinc oxide
84 and titanium dioxide have antimicrobial properties but can be cost-prohibitive and require
85 further research for long-term impacts (Madubuonu et al., 2020). Natural extracts offer an
86 eco-friendly alternative but often need higher concentrations for comparable results (Maaza
87 et al., 2014). The use of amoxicillin provides a robust, cost-effective, and highly effective
88 means of controlling *Xcc*, making it a practical solution for the citrus industry
89 (Mboniyirivuze et al., 2015). By comparing amoxicillin with other treatments, this study
90 emphasizes the potential for tailored antibiotic use in agricultural disease management and
91 advocates for further research to optimize its application in the field.

92

93 **Conclusions and Recommendations**

94 This study was focused on morphogenetic characterization of *Xcc*, that evaluated the
95 aggressiveness of bacteria that isolated from Districts Multan, Bahawalpur and Dera Ghazi
96 khan and to explore effective management strategies using various antibiotics. The findings
97 will contribute to the development of appropriate management strategies against this
98 pathogen in citrus. Furthermore, antibiotics (Amoxicillin) show significant results against
99 citrus canker alone and in various combinations under lab conditions. These less toxic and
100 eco-friendly strategies should be including in the management programs against citrus
101 canker.

102

MORPHOGENETIC CHARACTERIZATION OF XANTHOMONAS CITRI PV. CITRI AND ITS MANAGEMENT

ORIGINALITY REPORT

13%

SIMILARITY INDEX

7%

INTERNET SOURCES

5%

PUBLICATIONS

4%

STUDENT PAPERS

PRIMARY SOURCES

1	www.notulaebotanicae.ro Internet Source	4%
2	Jarred Yasuhara-Bell, Gem Santillana, Isabelle Robène, Olivier Pruvost, Mark K. Nakhla, Vessela Mavrodieva. "Genome-informed multiplex conventional PCR for identification and differentiation of Xanthomonas citri pv. citri sub-pathotypes, the causal agents of Asiatic citrus canker", <i>PhytoFrontiers™</i> , 2022 Publication	1%
3	Submitted to Higher Education Commission Pakistan Student Paper	1%
4	eol.org Internet Source	1%
5	www.e-mjm.org Internet Source	1%
6	Submitted to University of New England Student Paper	1%

7

Muhammad Atiq, Maryam Ashraf, Nasir Ahmed Rajput, Shahbaz Talib Sahi et al.
"Determination of Bactericidal Potential of Green Based Silver and Zinc Nanoparticles against Bacterial Canker of Tomato", Plant Protection, 2022

Publication

<1 %

8

www.wvj.science-line.com

Internet Source

<1 %

9

Wenting Li, Zhenxi Li, Jiaquan Huang, Meirong Xu, Zheng Zheng, Xiaoling Deng.

"Characterization of Xanthomonas citri pv. citri from China based on spoligotyping", Horticultural Plant Journal, 2022

Publication

<1 %

10

Submitted to University of Melbourne

Student Paper

<1 %

11

Olivier Pruvost, Yasser Eid Ibrahim, Anwar Hamoud Sharafaddin, Karine Boyer, Arya Widyawan, Mohammed Ali Al-Saleh. "

Molecular epidemiology of the citrus bacterial pathogen pv. from the Arabian Peninsula reveals a complex structure of specialist and generalist strains ", Evolutionary Applications, 2022

Publication

<1 %

12

www.ilovemycarbondioxide.com

Internet Source

<1 %

13

www.pjbs.org

Internet Source

<1 %

14

Y. Guo, U. S. Sagaram, J.-s. Kim, N. Wang.
"Requirement of the galU Gene for
Polysaccharide Production by and
Pathogenicity and Growth In Planta of
Xanthomonas citri subsp. citri", Applied and
Environmental Microbiology, 2010

Publication

<1 %

15

Faezeh Habibollahi, Akbar Hosseinipour,
Azadeh Lohrasbi-Nejad. " Antibacterial activity
of the peptide against subsp , the causative
agent of citrus canker, as evaluated by and
studies ", Annals of Applied Biology, 2022

Publication

<1 %

16

Muhammad Junaid Rao, Hao Zuo, Qiang Xu.
"Genomic insights into citrus domestication
and its important agronomic traits", Plant
Communications, 2021

Publication

<1 %

17

Submitted to Fiji National University

Student Paper

<1 %

18

Muhammad Atiq, Ayesha Batool, Nasir
Ahmed Rajput, Nasir Ahmad Khan et al.
"Evaluation of Antifungal Potential of

<1 %

Phytoextracts and Chemicals against Root Rot of Soybean caused by *Rhizoctonia solani*", Plant Protection, 2023

Publication

19

Olivier Pruvost, Karine Boyer, Virginie Ravigné, Damien Richard, Christian Vernière.
" Deciphering how plant pathogenic bacteria disperse and meet: Molecular epidemiology of pv. at microgeographic scales in a tropical area of Asiatic citrus canker endemicity ",
Evolutionary Applications, 2019

Publication

<1 %

20

www.genome.jp

Internet Source

<1 %

21

"Scientific Opinion on the risk to plant health of *Xanthomonas citri* pv. *citri* and *Xanthomonas citri* pv. *aurantifolii* for the EU territory", EFSA Journal, 2014

Publication

<1 %

Exclude quotes Off

Exclude matches Off

Exclude bibliography Off