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Phytopathogenomics and Disease Control*., *2025, 4(1)45-49
ISSN (Online):2957-5842; ISSN (Print):2957-5834
DOI: https://doi.org/10.22194/Pdc/4.1056
https://societyfia.org/journal/PDC

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Variation in Incidence of Citrus Canker in Relation to Epidemiological Factors in District Toba Tek Singh, Pakistan

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Citrus canker is the major threat to citrus production. Survey of different localities was conducted in the areas of Toba Tek Singh, Gojra, Kamalia and Pir Mahal for citrus canker disease incidence recording on five citrus varieties (Grapefruit, Sweet lemon, Lemon, Musambi and Kinnow). Maximum disease incidence (65%) was recorded in Kamalia during August and September and minimum disease incidence (18%) was recorded at Pir Mahal during May, 2019. Out of fifteen localities surveyed, maximum disease incidence (65%) was recorded in Chak 712GB from august to October and minimum disease incidence was recorded at Chak 330GB during May. Grapefruit being the most affected (65% in October) and Kinnow the least (7.5% in May). Environmental factors like maximum temperature, minimum temperature, rainfall, relative humidity and wind speed were correlated with citrus canker incidence on Grapefruit, Lemon, Sweet lemon, Musambi and Kinnow. Environmental factors...were positively correlated with disease incidence An increase in any of these parameters corresponded with an increase in citrus canker incidence. With every one-unit increase in maximum temperature, minimum temperature, rainfall, relative humidity and wind speed, disease incidence also increased. Characterization of environmental factors conducive for citrus canker disease development was determined on Grapefruit, Sweet lemon and Kinnow. Maximum disease development was recorded at 32-38ºC maximum temperature, 18-29ºC minimum temperature, 2-7.5mm rainfall, 2.5-6.5 km/h wind speed and 40-80% relative humidity. Special care of citrus orchards during August and September against citrus canker disease is suggested for citrus growers of Toba Tek Singh District.
Keywords: *Xanthomonas axonopodis* pv. *citri*, environmental factors, disease incidence, grapefruit, correlation.

INTRODUCTION

Citrus, originally from China, is an economically important fruit crop for Pakistan and is widely cultivated in tropical and subtropical regions across more than 140 countries (Ismail & Zhang, 2004; Aslam et al., 2024). Citrus is extensively cultivated in Pakistan on 183.8 million hectares area with production of 2.35 million tons, among which Punjab shares 174.2 thousand hectares area and 2.28 million tons production (GOP, 2017-18). The production and quality of citrus is greatly disturbed by a number of diseases including citrus canker, citrus gummosis, citrus greening and citrus tristeza virus induced by various microbes, among which citrus canker induced by bacterium *Xanthomonas axonopodis* pv. *citri* is the major threat to citrus growers (Sahi et al., 2007; Atiq et al., 2018; Gilani et al., 2025). In the form of water soaked and corky lesions, symptoms of citrus canker appeared prominently after few days of infection on the surface of leaves and fruits. Severe infection of citrus canker resulted in defoliation, premature fruit drop and no production of fruits (Gottwald et al., 2002; Hassan et al., 2025). Surveys of citrus orchards are crucial for evaluating disease spread, informing regulatory agencies and commercial growers on eradication feasibility (Gottwald & Irey, 2007), and providing current disease status to policymakers (Arora et al., 2013). Survey and characterization of environmental factors is helpful for farmers for timely management of citrus canker disease, as it provide knowledge about environmental conditions

Zafar, H., Akram, A., Atiq, M., Jahangir, M.M., Shafi, J., Jabar, A., Matloob, M.J., Ijaz, A., Ullah, A. & Usman, M. (2025). Variation in Incidence of Citrus Canker in Relation to Epidemiological Factors in District Toba Tek Singh. *Phytopathogenomics and Disease Control*, 4, 45-49.
[Received 11Dec 2024; Accepted 2 Mar 2025; 23 Jun 2025]
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conducive for citrus canker development (Khan et al., 2020). All the epidemiological factors play a significant role in development of citrus canker disease. Environmental factors like temperature (maximum and minimum), rainfall, relative humidity and wind speed significantly influenced the spread of citrus canker by the end of September (Khan et al., 2002). Citrus canker incidence increases with every one unit increase in maximum temperature, minimum temperature, rainfall and wind speed (Khan & Atiq, 2020). Temperature (maximum and minimum), relative humidity and wind speed are significantly correlated with citrus canker incidence (Imran et al., 2015). Temperature is the main environmental factor which influenced the disease spread; there was 1 to 2 fold increase in density and 10 fold increases in the area of necrotic spots reported along with 100% incidence of citrus canker at 25-35ºC temperature (Christiano et al., 2009).

Due to unawareness regarding environmental factors favorable for citrus canker disease development, this disease is still prevailing in citrus orchards of Pakistan. Survey of citrus orchard in Sargodha district revealed 73% incidence of citrus canker disease in the areas of Kot Momin and Bhalwal (Khan et al., 2020). To create awareness among citrus growers regarding environmental conditions favorable for development of citrus canker disease, a survey of citrus orchards was conducted in District Toba Tek Singh. As Toba Tek Singh is the second most important citrus growing region of Pakistan, so the study of environmental factors responsible for citrus canker spread was highly needed for making policies regarding management of citrus canker.

MATERIALS AND METHODS

***Survey of different localities of District Toba Tek Singh*:** In each of the fifteen citrus orchards surveyed, ten symptomatic plants were randomly selected, totaling 150 plants from Gojra (Chak 303JB Kathore, Chak 161JB Mungi Bangla and Chak 162GB Nowshera), Kamaliya (Chak 708GB Shamu Wala, Chak 712GB and Chak 714GB), Pir Mahal (Chak 330GB Kotli, Chak 334GB Rajowal and Chak 665GB Krishen Nagar) and Toba Tek Singh (Chak 257GB Kot Badal Khan, Chak 358GB Mughli, Chak 252GB Lasoori, Chak 183GB Pakhowal, Chak 302GB Bhatti Chak and Chak 343GB Jurahan). Incidence of citrus canker disease was recorded on five different varieties i.e. Grapefruit, Lemon, Kinnow, Sweet lemon and Musambi. Not all varieties were present in every orchard; variety presence was recorded based on farmer cultivation, and data were collected only for those available in each location. The survey was repeated fortnightly from May to October during 2019. Disease incidence was recorded by following formula.

$$\text{Disease Incidence \%} = \frac{\text{No. of infected plants}}{\text{Total No. of Observed plants}} \times 100$$

***Correlation and Characterization of Toba Tek Singh environmental conditions suitable for citrus canker*:** Data of environmental factors like maximum temperature, minimum temperature, rainfall, relative humidity and wind speed for six months of survey (May to October) was collected from the website of Punjab Government. Effect of these environmental factors on citrus canker disease incidence on Grapefruit, Sweet lemon, Lemon, Musambi and Kinnow were studied by correlation analysis. All the data were plotted and most favorable environmental conditions for disease development on Grapefruit, Sweet lemon and kinnow were determined by regression analysis.

RESULTS

***Incidence of citrus canker disease in District Toba Tek Singh*:** Maximum disease incidence (60%) was recorded in Kamalia in October and minimum disease incidence (18%) was recorded in Pir Mahal in May (Figure 1). From sites maximum disease incidence (65%) was recorded at Chak 712GB located in Kamalia from August to October and minimum disease incidence (0%) was recorded at Chak 330GB located in Pir Mahal in May (Figure 2). In case of varieties maximum disease incidence (65%) was recorded on Grapefruit during October and minimum disease incidence (7.5%) was recorded on Kinnow during May (Figure 3).

***Correlation and characterization of environmental factors conducive for the development of citrus canker in District Toba Tek Singh*:** All the environmental factors (maximum temperature, minimum temperature, rainfall, wind speed and relative humidity) expressed significant positive correlation with incidence of citrus canker on all varieties (Grapefruit, Sweet lemon, Lemon, Musambi and Kinnow) (Table 1). In relationship of environmental factors and disease incidence maximum disease was recorded at 32-38ºC maximum temperature (Figure 4), 18-29ºC minimum temperature (Figure 5), 2-7.5mm rainfall (Figure 6), 2.5-6.5km/h wind speed (Figure 7) and 40-80% relative humidity (Figure 8) as expressed by r-value.

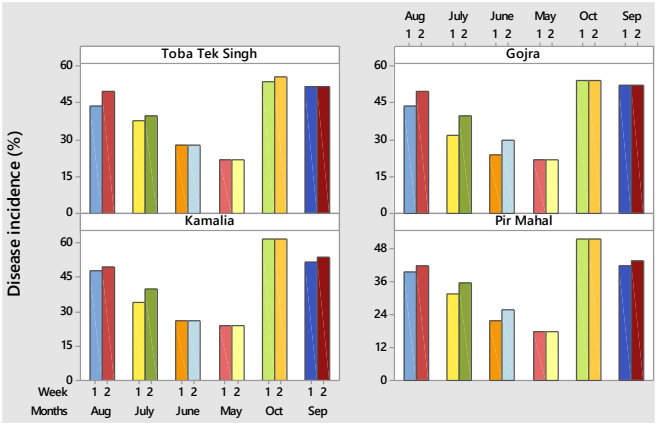

Figure 1. Citrus canker disease incidence recorded at four tehsils of Toba Tek Singh.

Table 1. Correlation between environmental factors and incidence of citrus canker disease on different varieties of citrus in District Toba Tek Singh.

Varieties	Max. Temp. (ºC)	Min. Temp. (ºC)	Rainfall (mm)	Windspeed (km/h)	Relative humidity (%)
Grapefruit	0.953**	0.720**	0.888**	0.914**	0.978**
	0.000	0.008	0.000	0.000	0.000
Sweet Lemon	0.948**	0.692**	0.906**	0.903**	0.970**
	0.000	0.013	0.000	0.000	0.000
Lemon	0.932**	0.701**	0.895**	0.915**	0.970**
	0.000	0.011	0.000	0.000	0.000
Musambi	0.943**	0.694**	0.903**	0.914**	0.971**
	0.000	0.012	0.000	0.000	0.000
Kinnow	0.938*	0.713**	0.865**	0.914**	0.986**
	0.000	0.009	0.000	0.000	0.000

Upper value indicates Pearson's Correlation coefficient, Lower value indicates P-value

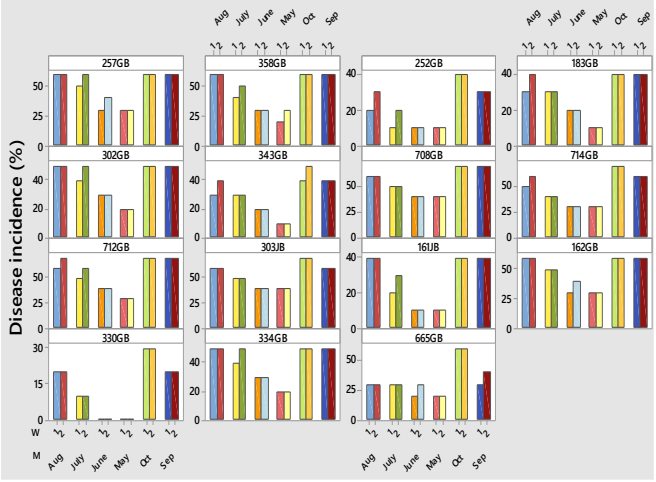

Figure 2. Disease incidence recorded at different sites surveyed in Toba Tek Singh.

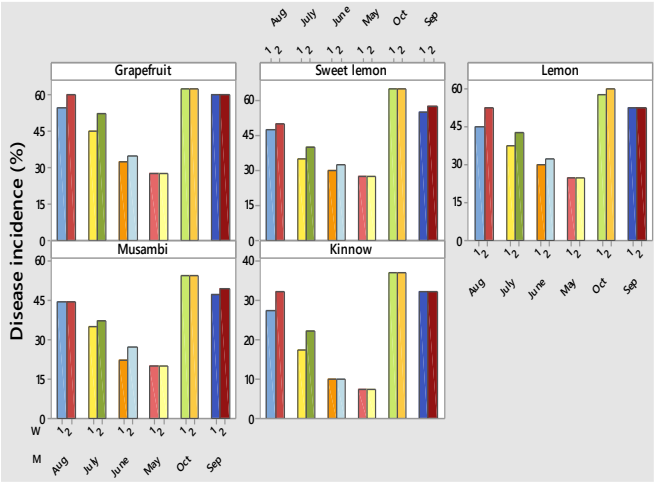

Figure 3. Disease incidence recorded on different varieties of citrus.

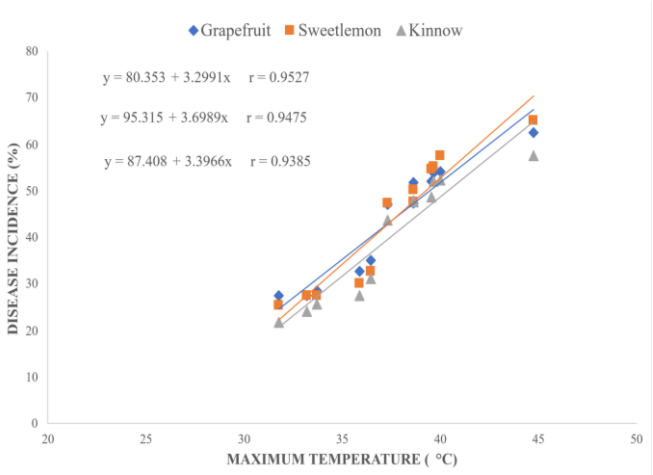

Figure 4. Relationship between maximum temperature (ºC) and citrus canker disease development.

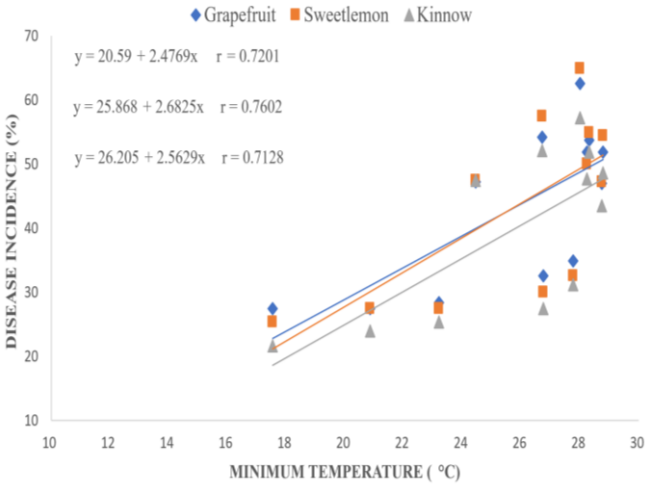

Figure 5. Relationship between minimum temperature (ºC) and citrus canker disease development.

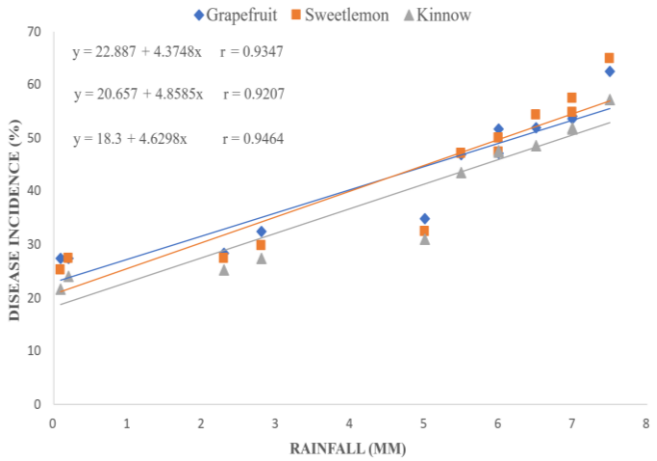

Figure 6. Relationship between rainfall (mm) and citrus canker disease development.

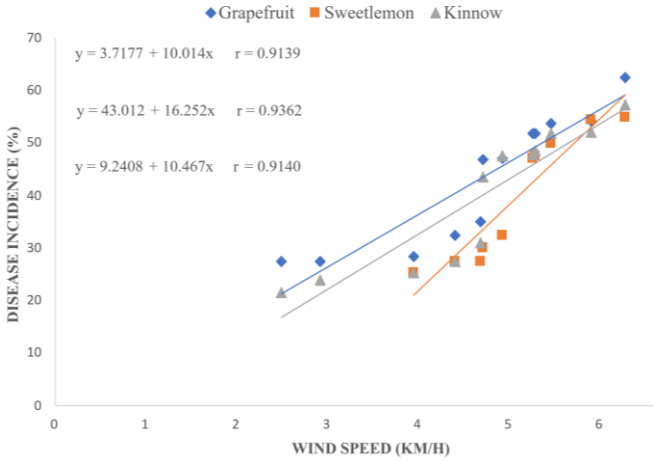

Figure 7. Relationship between wind speed (km/h) and citrus canker disease development.

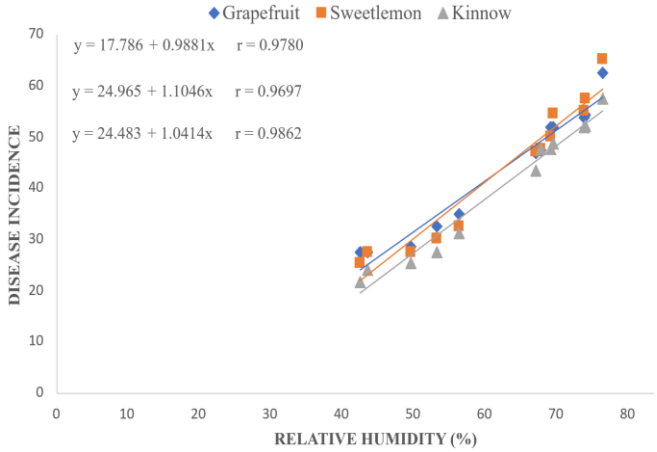

Figure 8. Relationship between relative humidity (%) and citrus canker disease development.

DISCUSSION

Toba Tek Singh is a major citrus growing district of Pakistan (Siddique & Garnevska, 2018). In this study effect.comt of environmental conditions on incidence of citrus canker disease in Toba Tek Singh was studied on Grapefruit, Sweet lemon, Lemon, Musambi and Kinnow. Maximum disease incidence was recorded on grapefruit and sweet lemon as Imran et al. (2015) demonstrated that these varieties are highly susceptible to citrus canker infection. Over all disease incidence was recorded maximum in Kamalia Tehsil during August, September and October 50%, 54% and 62% respectively and these findings are supported by work of Arora et al. (2013) who found maximum incidence of disease during August, September and October in Indian Punjab. Significant positive correlation among all environmental factors and disease incidence on all varieties was recorded. Results of correlation of disease incidence with maximum temperature, minimum temperature, rainfall and wind speed is supported by (Khan et al., 2020). Also, Gottwald & Irey (2007) positively correlated the minimum temperature, rainfall and relative humidity with citrus canker incidence on Kinnow, Musambi and Grapefruit. Similarly Dalla Pria et al. (2006) found significant positive correlation of minimum temperature, rainfall and relative humidity with citrus canker incidence. Also Imran *et al*., (2015) found significant positive correlation of maximum temperature, minimum temperature, rainfall and wind speed with disease incidence on Kinnow, Musambi and China lemon.

During this study maximum disease was recorded at 32-38ºC maximum temperature and these results are supported by outcomes of (Christiano et al., 2009) who found that maximum disease development occurs at 30-35ºC temperature. Also Dalla Pria et al. (2006) concluded that temperature above 40ºC reduced the disease incidence. At 18-29ºC minimum temperature the disease incidence was maximum and these results are supported by Dalla Pria et al. (2006) who demonstrated that maximum incidence of citrus canker occurs above 20ºC temperature and temperature below 20ºC reduces the incidence of disease. Rainfall 2.5-7.5mm resulted in maximum disease development in this study as Khan & Atiq (2020) demonstrated that 2-4mm rainfall induces maximum citrus canker disease development. At 40-80% relative humidity maximum disease incidence was recorded as Khan & Atiq (2020) concluded that disease incidence increases from 28% to 59% when relative humidity increased from 47 from 59%. Similarly, Srivastava et al. (1997) demonstrated that maximum incidence of disease occurs when relative humidity reaches up to 80%. In relationship between citrus canker incidence and wind speed maximum disease was recorded at 2.5-6.5km/h as Khan & Atiq (2020) concluded that maximum disease occurs at 1.8-6.8km/h wind speed.

***Conclusion*:** It was concluded that maximum citrus canker disease incidence was recorded in Kamaliya mainly in Chak 712 GB on Grapefruit during August, September and October, 2019. All the environmental factors exhibit significant positive correlation with citrus canker disease incidence. Great care of citrus orchards is required specially in August, September and October.

***Acknowledgement*:** This article is extracted from the M. Sc (Hons.) dissertation of Hafiz Muhammad Hasnat Zafar. We are very grateful to Dr. Muhammad Aslam Khan and Dr. Muhammad Atiq for their kind supervision and to the researchers of citrus pathology who provide opportunity to complete my M. Sc (Hons.) research under the HEC-NRPU # 6373 and also provided me technical assistance in writing this manuscript.

***CRediT author statement*:** H. Zafar, A. Akram, M. Atiq, M.M. Jahangir designed, completed the experiments; J. Shafi, A. Jabbar. M.J. Matloob prepared the draft, A. Ijaz, A. Ullah, M. Usman reviewed and finalized the draft.

***Conflict of interest*:** The authors declare no conflict of interes

***Ethical statement*:** This article does not contain any studies which require ethics committee approval.

***Availability of data*:** The data is available with the corresponding author which can be made available on request.

***Consent to participate*:** All participants consented for this research study.

***Informed consent*:** The participants signed informed consent regarding publishing their data and photographs.

***Consent for publication*:** All authors submitted consent to publish this research article in JGIAS.

***SDGs addressed*:** No poverty; Zero hunger; good health and well-being.

***Policy referred*:** Seasonal Disease Surveillance and Control Program; Weather-Based Early Warning System.

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