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THE PREVALENCE PER VARIETY AND CONTROL FOR CITRUS CANKER DISEASE IN SWEET ORANGE (*Citrus Sinensis L*), CASE STUDY OF GWERI SUB-COUNTY, SOROTI DISTRICT

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DECLARATION.

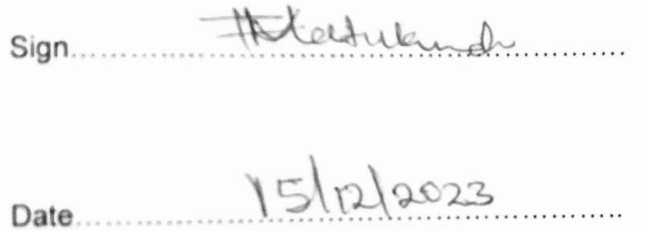
I **EWAGU GIDEON** certify that this research proposal is my original work and it has never been presented or submitted to any University or any other higher institution of learning for the award of a Bachelor's Degree

Signature.....

Date.....05th/12/2023.....

APPROVAL

This research report has been entirely prepared and produced under the supervision of **Madam Flavia Natukunda** from the department of Biology, faculty of science and Education Busitema University.



DEDICATION

I would like to dedicate this piece of work to all positive contributors in my life but most especially to my supervisor, **Madam Flavia Natukunda** for the hand extended in the writing of this piece of work

May God bless thee abundantly?

ACKNOWLEDGEMENT

I take this opportunity to express my sincere, heartfelt gratitude to ALMIGHTY GOD for giving

Me the health and potental to make this research a reality.

I appreciate my supervisor, Madam Flavia Natukunda for her guidance.

Exquisite thanks goes to my Uncle Dr. Ojulong Julius who sponsored this Bachelor's Degree Program.

May GOD bless you?

ABSTRACT

Citrus canker is a disease caused by the bacterium *Xanthomonas axonopodis PV. Citri*, which infects all forms of citrus fruits among them includes sweet oranges. The disease is believed to have its origin in Asia from where it spread to all other tropical and sub-tropical citrus growing regions, it does not infect arid citrus growing areas. The study was conducted in Gweri sub-county in late July where data was collected using questionnaires from farmers across the three parishes where sweet orange is grown in quite large amounts, the study involved face-to-face interaction and making observations to identify signs of the disease by conducting a random simple zig-zag format of sampling on the lines of orange plants, data obtained was analyzed to calculate the prevalence using the formula in the methodology section. It was found that canker disease was more prevalent in Valencia (26.2%) and least in Washington (7.3%), only 20% of the participants were using the effective control measures, this study, therefore, was aimed at finding out the prevalence per variety, and control of citrus canker disease by farmers of sweet oranges at Gweri sub-county.

LIST OF TABLES AND FIGURES.

ABBREVIATIONS AND ACRONYMS

Xac……. *Xanthomonas axonopodis PV. Citric*

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CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND

Sweet orange *(Citrus sinensis L.)* is one of the high value fruit crops in both tropical and sub-tropical countries(Ssebunya & Kilcher, 2011).

Citrus canker is one of the most threatening sweet oranges (generally citrus) diseases. It causes extensive damage to all forms of citrus and severity of damage varies with the species and variety of the crop and the prevailing climatic conditions. The disease is most prevalent in India, Japan, and other South-eastern countries in Asia from where it has spread to other continents except Europe, generally the disease does not occur in arid citrus growing areas.

The geographical origin of canker disease is not clear, Lee (1918) said that it might have arisen in southern China and reported *Fortunella hindisii* to be the wild host plant. Fawcett and Jenkins (1933)reported the origin of citrus canker as India Java because they detected canker lesions on the oldest citrus herbaria kept at the Herbaria of the Royal Botanic Gardens in Kew. These findings show the origin of citrus canker as the tropical areas of Asia, i.e., South China, Indonesia, and India where citrus species are presumed to have originated and spread to other citrus growing regions in form of bud wood.

The disease later was reported in the Gulf of States region of USA due to shipment of infected nursery stock, it also appeared in South America, South Africa and Australia. Citrus canker presently occurs in over thirty countries in Asia, USA, Africa, Indian ocean islands and South America, the disease was also reported in Florida and it was introduced to the northern part and the gulf states through trifoliate citrus rootstock material from Japan where it was unclearly described until 1915 where it was described as a bacterial disease(Das, 2003).

In Uganda, Citrus canker was detected in Northen Uganda in 2010 (anonymous, 2012), where it was first noticed in an orchard in Lira district from there it spread to all citrus (sweet orange) growing areas in the region, and reached to Teso sub region (where Gweri sub county is located) through seedling transportation for planting by farmers

Citrus (sweet orange) canker is a disease caused by bacterium *Xanthomonas axonopodis PV citri*, (Kumar, Jarial, Jarial, Banyal, & Jandaik, 2020; Sharif et al., 2021), a gram-negative obligate aerobe. It causes damage to oranges and severity depends on the species and variety and prevailing weather conditions. The disease is endemic in India, Japan, and South eastern Asia(Das, 2003); including now Uganda (gweri the area of study). The disease has no health effects to human consumption but makes the fruit to have an ugly look thus affecting marketing of the sweet orange *(citrus sinensis L.).* Conditions suitable for disease outbreak occur when growth flushes and fruit expansion coincide with warm temperatures and frequent rainfall associate with gusty wind, Lesions in the fruit are much economically important as they increase premature fruit fall and reduces marketability of fresh fruits.

At least three different forms of forms of citrus canker are recognized, among this Asiatic form (Canker A) is the most destructive, severe disease infection produces a variety of effects (Das, 2003), it's also believed to have originated from south-east Asia or India and then widely spread around the world, In India, the citrus canker was first reported from Punjab(Kumar et al., 2020).

The affected plants have the following symptoms; conspicuous raised necrotic lesions(J. O. Honger, E. Essuman, & E. W. Cornelius, 2016) on leaves twigs and fruits, which become rough, corky, brownish pustules bordered by a yellow halo/ring. Also appears on the pedicel causing premature leaf and fruit drop. It doesn't affect the flesh; consumption of cankered fruit is safe for humans but the market value is drastically reduced because of their poor appearance. The bacterium penetrates into the host plant via the stomata, Hydathodes and wounds, and the symptoms vary depending on the age of the lesions, the plant part affected. Shoot lesions produce few bacteria compared to leaf and fruit lesions. (Sharif et al., 2021)

In countries where citrus canker is present, integrated systems of management or cultural practices and phytosanitary measures consisting of resistant hots, removal of inoculum source, properly designed wind brake systems, timely application of antibiotic sprays are the most effective ways of disease management

1.2 PROBLEM STATEMENT

Citrus (sweet orange) is one of the most important fruit crops worldwide because of its delightful flavor and scent(Huang, Wang, & Wang, 2022), as well as its health properties. Sweet orange (*Citrus sinensis*) is the most economically important species for the citrus industry. Worldwide much of the research has been conducted on citrus canker generally considering all the citrus trees.

Citrus (sweet orange) growing has been so much adopted by farmers in Gweri Sub-County, the cultivars whether in small or large scale have been affected by diseases and among them includes the citrus canker. Even though a lot of research has been conducted on citrus canker, little has been documented on sweet orange in Gweri sub county and worldwide especially as per the level of infestation per sweet orange variety. The disease is wide spread and has much affected the market value of the oranges in the sub county and other orange growing regions in general. This disease is caused by bacterium *Xanthomonas axonopodis* which has short life span in the soil or fallen leaves(Aglave, 2018; Das, 2003; Gottwald, Graham, & Schubert, 2002; J. Honger, E. Essuman, & E. W. Cornelius, 2016; Lanza, Marti, Silva, & Jr., 2018; McBride, French, Schuster, & Ong; Pérez-Sierra, Durán, Jung, Balci, & Scanu6, 2018).

This research therefore aimed at finding out the prevalence per variety of sweet orange and control measures for citrus canker disease among the farmers at Gweri subcounty through conducting a survey study to collect data.

1.3 GENERAL OBJECTIVE

To determine the prevalence per variety and control measures for the citrus canker disease by farmers in Gweri Sub-County, Soroti district.

1.3.2 SPECIFIC OBJECTIES

- To quantify the level of infestation of sweet orange per variety by the citrus canker disease.
- To identify the control measures used by farmers on citrus canker.

1.4 RESEARCH QUESTION

What proportion of the orange plants are affected by citrus canker per visited field?

Which control measures are used by farmers to control citrus canker disease?

1.5 HYPOTHESIS

H_O:

- There is no significant difference between the levels of infestation of sweet oranges per variety.
- Farmers do not use effective control measures in the control of citrus canker on sweet oranges.

H_A:

- There is a significant difference in the level of infestation by canker on sweet orange per variety.
- Farmers use effective control measures against citrus canker.

1.6 SCOPE OF HE STUDY

This study, aimed at finding the prevalence per variety and control measures by farmer against the canker disease was not conducted on the entire sub-county due to the slightly larger geographical nature of Gweri Sub County, therefore only few farmers were selected from three parishes where sweet orange growing is more practiced.

The study did not have any formulation for trial or field test but only was interested in already existing or used practices among farmers. Findings from selected farmers were recorded and used to make generalization of the prevalence of the disease and also arrive at a conclusion of the effective control measure for the disease at the time.

1.7 JUSTIFICATION OF THE STUDY

Due to the dependence of a majority of people in Gweri sub-county on output from orange planting, it would require favorable conditions and a healthy environment to ensure maximum output support for farmers, which in the context of the research was not the case because of disease with citrus canker being one of the serious one. Therefore, this study was aiming at finding out the prevalence per variety of the disease and the control measures used by selected farmers, later on other farmers were also be made aware of the quite effective control so that their output is not much compromised.

CHAPTER TWO: LITERATURE REVIEW

The study was focused on finding the prevalence per variety and control measures for the citrus canker disease which is affecting, though they are small scale orange farmers in Gweri sub county, The disease is caused by bacterium *Xanthomonas axonopodis pv. Citri,* with its severity resulting into losses to farmers.

Citrus canker is one of the most feared diseases of citrus including oranges, the disease causes extensive damage and severity of the infection varies with the species and/ or the variety of the orange and the prevailing weather conditions. The disease is endemic in India, Japan, and some South Eastern Asian Countries and it has spread to all other citrus growing continents except Europe. It is important to note that canker does not occur in arid citrus producing countries and it has been eradicated in some areas, even in areas where it's still prevalent .(Das, 2003)

2.1 AETIOLOGY

Citrus canker has created havoc in many citrus producing countries in the world. It is caused by the bacterium *Xanthomonas axonopodis PV. Citri,* which isa gram negative, obligate aerobe, straight rod shaped and 0.4-1.0µm wide by 1.2-3.0µm long. It also contains a single polar flagellum, forms yellow pigmentation and secrets extracellular polysaccharides in the culture medium. The favorable temperature for colonization ranges from 4-37ºC with optimal growth at 25-30ºC.(Pattanayak, Das, Mayanglambam, & Behera, 2023)

2.2 PATHOGEN BIOLOGY

Pathogens and strains; based on the available sources of information, there are three stains(pathovars) of Xanthomonas axonopodis that have been recognized, which are distinguished from one another by geographical distribution and by different pathogenicity to members of the genus citrus. The pathogen for canker A (Asiatic form/cancrosis A or true canker) was first identified and described as *pseudomonas citr*i by Hasse in 1915, bacterial nomenclature has undergone many changes and currently it's called *Xanthomonas axonopodis PV. Citri*. The pathogen for canker an s the most common, widespread and severe form of the disease. Cancrosis B (canker B or false canker) caused by *X. axonopodis PV. Aurantifolii* is a serious problem on lemons, sour orange and pumelo, it causes canker type lesions on fruits, leaves and twigs that are similar to but smaller than those of A form. In culture Cancrosis B

bacterium grows more slowly than canker a bacterium on nutrient Agar and a specific medium containing sucrose, peptone, salts, and purified agar. Cancrosis C is also cause by *X. axonopodis PV. Aurantifolii,* its symptoms are the same as for canker A.

Xanthomonas axonopodis PV. Citri (Xac) and *Xanthomonas axonopodis PV. Aurantifolii* (Xaa) are bacterial pathogens responsible for citrus canker, a disease that seriously affects commercial citrus varieties worldwide. Xac causes the most damaging 'Asiatic' or type a canker on a wide range of citrus species, including sweet oranges (Citrus sinensis), grapefruits (Citrus paradisi) and lemons (Citrus Limon). Xaa, by contrast, has a narrower range of citrus hosts and is responsible for the B and C types of canker, which are restricted to some citrus-producing areas in South America(CERNADAS, CAMILLO, & BENEDETTI, 2008).

Other forms of citrus canker have also been reported, for example canker D sometimes called citrus bacteriosis, reported in Colima area of Mexico I 1980s but later was named *Alternaria limicola.* Another typical form of canker A bacterium which has high resistance levels to penicillin antibiotics has been described from Reunion and surrounding islands in Indian Ocean(Das, 2003).

Table 2.2. 1 Comparison of the three different forms of citrus canker.

Characteristic	**Citrus canker form.**		
	A	B	C
Pathogen	*X. axonopodis pv. Citri*	*X. axonopodis pv. Aurantifolii*	*X. axonopodis pv. aurantifolii*
Distribution	Asia, Africa, South America, Oceania	Argentina, Paraguay, Uruguay	Brazil, Mexico
Host range	Wide	Limited	Limited
Major host plant	All Citrus species	Lemon	Mexican lime
Symptoms	Spongy erupted at first; corky rough lesions with raised, greasy margin later; water-soaked appearance		

2.3 LIFE CYCLE AND TRANSMISSION

The citrus canker bacterium (*Xanthomonas axonopodis PV. Citri*) by wind-blown rain drops to healthy plants especially during the onset of the rain season.(Pattanayak et al., 2023)The bacterium survives primarily in occurring lesions with cankerous leaves, twigs and branches being the main source of inoculum, the pathogen can survive in diseased twigs up to 76 months; in infected leaves for more than six months; sterilized soils for 52 days and unsterilized soils for 9 days only(Das, 2003)**.** The bacterium enters the plant through any mechanical injuries in the mesophyll tissues or through the stomatal openings. The bacterial cells ooze out from the lesions and disseminate to other citrus plants spore splash due to rain or wind. Wind driven rain is the main natural dispersal agent and the speed of wind speeds the penetration of the bacterium through the stomata or wounds made by thorns insects such as Asian leaf minor(Aglave, 2018). Several man-made activities assist the bacterium inoculum to spread to other plant tissues.

After successful invasion, the disease spreads rapidly in the orchard. The longevity of the bacterium is shorter in fallen leaves/ twigs and soil due to its antagonistic microbial association particularly the predatory reaction of protozoa but in the presence of an active host the bacterium can survive for a longer period of time in the soil.

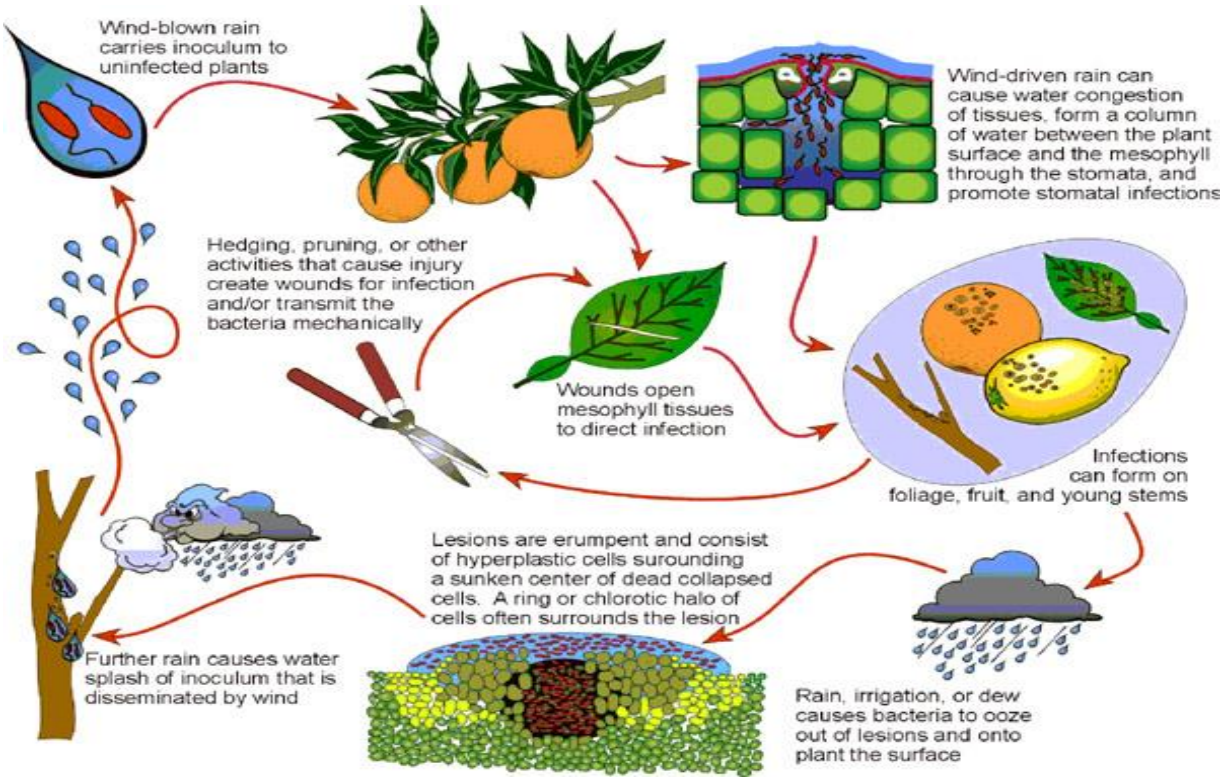

Figure 2.3.1 illustration of the canker life cycle (Gottwald et al., 2002)

2.4 PATHOGENESIS

The bacterium has the inherent ability to extensively produce extracellulary polysaccharides (Xanthan) which help it to attach to the host tissue by forming a biofilm. The virulence and epiphytic survival of the bacterium is assured by the biofilm, then later the canker develops. Also, the transcriptional-like (TAL) effectors delivered by the type-III secretion of *Xanthomonas* which interacts with the host machinery to direct the initiation of transcription of genes that regulate plant hormones such as gibberellins and auxin(Pattanayak et al., 2023; Pereira et al., 2014; Rigano & Siciliano, 2007).

Identical symptoms induced by two strains (canker A and B) are indicative of a common pathogenicity factor, gene *pthA* is essential for *Xac* to elicit cankers on citrus. The gene have the ability to cause hyperplasia on all citrus species in the normal host range of the recipient strain(Das, 2003).

2.5 EPIDEMIOLOGY

The majority of the epidemiological studies on citrus canker have concentrated on local disease increase and spread of *Xac* within citrus nurseries and commercial plantations. In nurseries spread of infection is due to splash by rain, resulting in the development of numerous secondary foci that increase the incidence of the disease, making the description and quantification of the disease difficult. The disease gradient of the citrus canker in nurseries varies due to disease - induced defoliation on severely diseased nurseries and subsequent infection of newly emerging foliage. High aggregation of the citrus canker infected trees is associated with splash dispersal.(Gottwald et al., 2002)

Xac survives primarily in lesions, it survives up to 6months in the infected leaves and being carried from season to season on twigs and branches where it can survive for up to 76 months. The bacterium also survives epiphytically at lower populations on citrus hosts without symptoms, in association with non-citrus weed and grass hosts and also in soil.

Bacterial cells ooze from the lesions during wet weather to provide inoculum for further disease spread, resistance of leaves, stems and fruits increases as they mature but the period of susceptibility to wound infection is longer than for stomatal infection. *Xanthomonads* have a mucilaginous coat and easily suspend in water thus water dispersed, spread of canker by wind and rain is mostly for shorter distances that's within trees or neighboring trees. There is no record of seed transmission, commercial shipments of diseased fruits are potentially a means of long-distance spread. Temperatures between 20-30ºC and evenly distributed rainfall elevate disease spread(Das, 2003)

2.5.2 HOST RANGE

Of the citrus cultivars and rootstocks, citrus is most severe on grapes, sweet orange varieties like Hamlin, pineapple and Navel; Mexican limes and lemons including trifoliate orange and their hybrids that are used for rootstocks. These cultivars are now challenging to profitably produce in the presence of citrus canker in moist tropical and subtropical climates; all other cultivars of citrus though differing in susceptibility are susceptible enough that they must be in an eradication effort when the symptoms manifest, a number of plants in the family Rutaceae other citrus and Poncirus can serve as hosts for Xac under experimental conditions or heavy disease pressure in nature, this plants are expected not to play any significant role in the citrus canker epidemiology

where the disease is endemic but serve as problematic inoculum reservoirs during eradication or suppression program.

Table 2.2. 2 Relative susceptibility/ resistance to citrus canker of citrus species

Rating	Citrus cultivars
Highly resistant	Calamondin, kumquats
Resistant	Mandarines—Ponkan, Satsuma, Tankan, Cleopatra, Sunki, Sun Chu Sha
Less susceptible	Tangerines, Tangors, Tangelos, Cravo, Dancy, Kara, Emperor, Fallglo Fairchild, Fremont, Clementina, King lee, Murcott, Nova, Minneolla, Page, Midwest, Ruby blood, sour orange, Valencia, Shamouti.
susceptible	**Sweet orange** (Hamlin, Marrs, Navels), Parson Brown, Pineapple, Piralima, Ruby, Seleta Vermelho (Early gold), Tarocco, Westin, Tangerines, Tangelos, Trifoliate orange, Pummelo, Orlando, Citranges/Citrumelos
Highly susceptible	Grapefruit, Mexican/key lime. Lemons and pointed leaf Hystrix

(Gottwald et al., 2002)

2.6 SIGNS AND YMPTOMS

- ✓ Initially, disease appears as minute water soaked round, yellow spots which enlarge slightly and turn brown, eruptive and corky.
- ✓ These pustules are surrounded by a characteristic yellow halo.
- ✓ Canker lesions on the fruit do not possess the yellow halo as on leaves (Lesions on leaves will range from 2 to 10 mm in size and will have raised concentric circles on the underside of the leaf, The yellow halo eventually changes to dark brown or black and the water-soaked margin surrounding the lesion may diminish).
- ✓ Several lesions on fruit may coalesce to form larger canker (range from 1 to 10 mm in size. Larger lesions usually penetrate a few mms into the rind, on some varieties these circles are raised with a rough texture; on other varieties the concentric circles are relatively flat like the surface of a record.
- ✓ Due to severe infections the leaves may be defoliation, and twig and stem may show die-back symptoms(Korlapati, 2014).

- ✓ Twig lesions on angular young shoots perpetuate Xac inoculum in areas where citrus canker is endemic. Twig dieback, fruit blemishes, and early fruit drop are major economic impacts of the disease in advanced stages. If twigs are not killed back by girdling infections, the lesions can persist for many years, causing raised corky patches in the otherwise smooth bark(Aglave, 2018; Das, 2003; Gottwald et al., 2002; Javed, Ahmed, Anwar, Javed, & Zia, 2007; McBride et al.).

Figure 2.6.1 symptoms of the citrus canker disease.

2.7 TREATMENT AND CONTROL.

Cultural practices

Cultural practices including windbreaks (most effective), and pruning in dry season or defoliation of diseased summer and autumn shoots, are recognized throughout the world as important measures for the management of citrus canker.

Chemical control.

Worldwide, citrus canker is managed with preventive sprays of copper-based bactericides. Such bactericides are used to reduce inoculum build up on new leaf flushes and to protect expanding fruit surfaces from infection. Effective suppression of the disease by copper sprays depends on several factors, such as the susceptibility of the citrus cultivar, environmental conditions, and adoption of other control measures. The timing and number of copper sprays for effective control of citrus canker are not only highly dependent on the susceptibility of the citrus cultivar, but on the age of the citrus trees, environmental conditions, and the adoption of other control measures. In general, three to five copper sprays are necessary for effective control of citrus canker on citrus cultivars with intermediate levels of resistance, whereas, with time as the weather will

highly be conducive for epidemic development of citrus canker, up to six sprays may be recommended

Integrated management.

In regions where citrus canker is endemic, integrated control measures rely most effectively on the planting of resistant varieties of citrus. The strategies of the integrated program for citrus canker control are based on research carried out in the 1960s and early 1970s in Japan, and later in the 1970s in Argentina and 1980s in Brazil with the aim to shift from planting susceptible to resistant varieties, nurseries can only be located in areas free of citrus canker. In orchard production areas designated as citrus canker-free, regulations are designed to prevent or reduce the risk of citrus canker epidemics through the establishment of windbreaks, construction of fences to restrict the access to the orchard, and the use of preventive copper sprays (Aglave, 2018; Gottwald et al., 2002; Javed et al., 2007; Pattanayak et al., 2023).

CHAPTER THREE: METHODOLOGY

3.1 Study area

The study was conducted in Gweri Sub-County, Soroti district, eastern region of Uganda. Gweri Sub- County is situated in the Eastern part of Uganda, I's geographical coordinates are 1º40º50º'' North, 33º45º34º'' East with a population of **58,800** by [2020] – *Projection*, **311.1 km²** Area, **189.0/km²** Population Density [2020], **3.6%** Annual Population Change [2015 → 2020]. The main economic activity of the people is Agriculture.

Gweri sub-county was chosen for the study because it's one of the major oranges producing area in the district and therefore even the diseases for oranges have always been registered which tend to hinder this economic activity.

3.2 Study design

A cross-sectional research design was used to determine the prevalence and control measures for citrus canker disease where quantitative methods were used to obtain numeric data using questionnaires and interviews whereas qualitative methods were used to obtain descriptive data.

3.3 Sample size

A survey was conducted in the sub-county by selecting at least ten farmers from the three major sweet orange growing parishes of the six parishes which make up Gweri sub-county. An estimate of an acre of the orange farm which having different varieties of sweet orange, namely, Valencia, Washington, and Hamlin were taken as a standard measure. In each acre, a systematic random sample in a zig zag pattern was conducted to identify and study 30 trees, irrespective of variety, for the determination of the disease prevalence. Each selected tree was observed and the presence or absence of the disease signs on either the leaves or fruits were noted. The number of trees showing the disease symptoms were then be recorded. The disease prevalence (DP) per plot (in terms of severity) was calculated using the formula given by (J. Honger et al., 2016; Kumar et al., 2020; Sharif et al., 2021).

3.4 Data collection

The research involved physical observation of the orange trees to determine the prevalence of the disease (looking for the signs and symptoms of citrus canker disease or the most affected part, fruit or leaves) and interaction with the farmers to determine the total number of orange plants each has, the control measures being used to curb the effect of the disease, and the effectiveness of those control measures when used. The total number of orange trees was be determined from the farmers record books if present. The diseased plants were recorded after observation.

The disease control measures were recorded as given by farmers, time of application, and the outcome after application. This data was later summarized in the data sheet.

The process of data collection ran for a period of one week where by five farmers were visited per day.

3.5 Data collection tools

Data collection sheets were designed and used to capture information on date of data collection, age and sex of farmer, variety of the orange, number of oranges observed among others and a questionnaire was designed to collect information about the control used.

Material required for data collection included gumboots, pen, data collection sheets and questionnaires.

3.6 Data types

Data collection was both quantitative like total number of orange trees, number of orange trees having disease signs and symptoms, number observed per day and overall, age of orange plants from time of planting, spacing between plants; and qualitative like frequency of disease occurrence (endemic/ epidemic), type of control used (chemical, cultural or both). Quantitative methods were used to collect numerical data using a checklist and interviews whereas qualitative methods were used to obtain descriptive data through observation, checklist and interviews with the farmers as to obtain primary data.

3.7 Data Analysis

The prevalence of citrus canker was calculated as the number of orange trees having disease signs and symptoms expressed as a percentage (%) of the total number of orange trees that was examined during the study.

Disease prevalence (DP) =) where n = number of trees with disease symptoms, N= total number of trees inspected**(J. Honger et al., 2016; Kumar et al., 2020; Sharif et al., 2021).**

CHAPTER FOUR: RESULTS

4.1 DATA PRESENTATION

A survey was conducted in three different parishes (where sweet orange is grown in large quantities) to collect data on the prevalence per variety and the control measures used by farmers to control citrus canker disease in their orange farms, data was collected in mid-July for five days on three commonly grown varieties of sweet orange. The education levels of the participants are shown in the pie chart below.

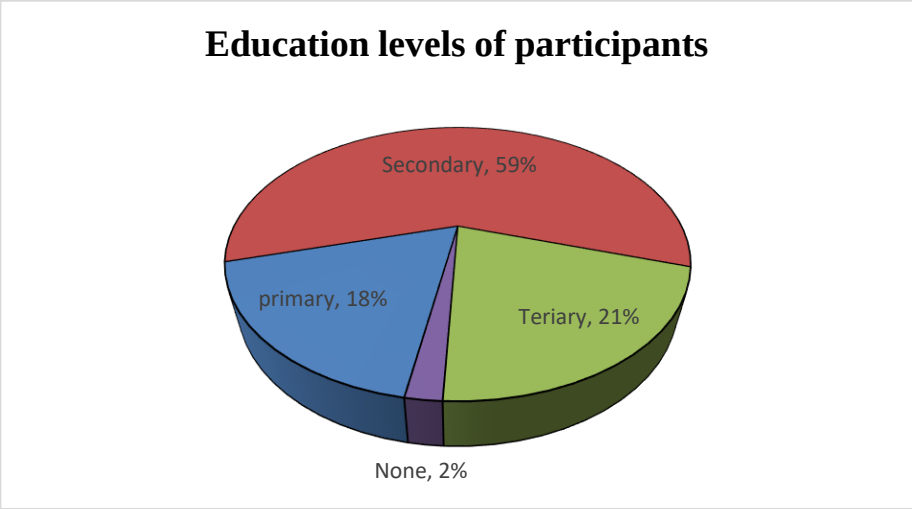

Figure 3. Pie chart showing the education levels of the participants.

Gender.

Most of the participants that were involved in this study were males with of 80% and the other 20% were females (only 6 participants)

Size of Land.

As the study had taken an acre of land as a standard for making observations, a majority of farmers had at least an acre of land purposely being utilized for orange production, but also other seasonal crops are being integrated or cultivated in between the rows and columns which are managed together with oranges.

Other crops on the farm.

The study found that 93.3% (28 farmers) do not use their farmlands purely for orange production but also integrate other crops to support the day-to-day living in their homes, crops such as cassava, peas species, millet, and groundnuts are commonly grown together in between columns and rows.

Spacing of oranges.

A majority of the farmers have spaced their oranges at 7×5 Meters which is almost the recommended spacing, however some few had their oranges under spaced.

Disease prevalence.

Generally, the disease prevalence was 48.9% of the total sample size with the maximum prevalence of canker found in Valencia (26.2%) and the least registered on Washington (7.3%). The following table shows the data collected regarding disease prevalence per variety.

Table 4. 1: showing the number of infected orange plants per variety.

Parish	Total number of oranges	Number of oranges observed	Number of affected oranges per variety		
			Hamlin	Washington	Valencia
A(Gweri)		300	20	10	40
B(Dokolo)		300	26	9	36
C(Opucet)		300	23	14	42
TOTAL		**900**	**138**	**66**	**236**

The pie chart below shows the proportions of the affected orange plants per variety and the ones unaffected in terms of percentages.

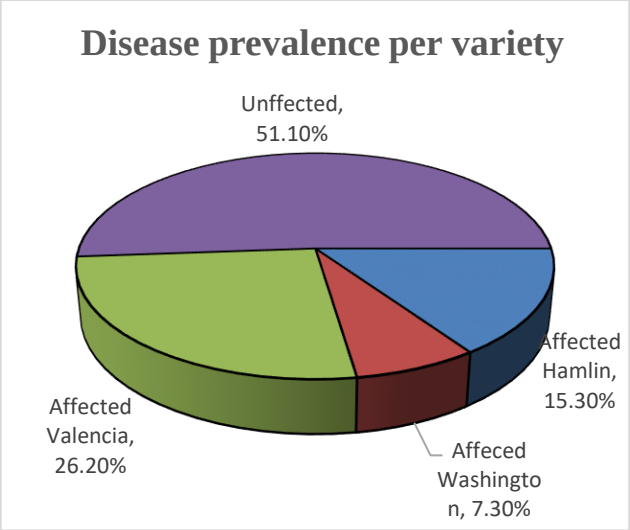

Figure 4. Pie chart showing the canker prevalence per variety

Harvest.

The harvest from sweet orange has greatly been affected by citrus canker among other factors like weather changes which also impacts significantly, farmers report that the harvest they get is always variable generally due to such factors and it's quantified in terms of sacks/bags and on average from farmers interviewed they get between 12-25 bags.

Disease control.

The survey found out that a variety of control measures are being used to control citrus canker on varying frequencies of application as seen below.

Table 4. 2: Shows control measures used against citrus canker.

Control used	Frequency of application of control	Number of farmers using	Number of farmers (%)
Spraying (Cyper, Rocket (most used), Agri-Mycin, Nordox (used by only 6 participants)	**E**very two weeks **W**hen spraying other mixed crops/when money to buy is present	30	100

	When help is available		
Pruning or cutting severely diseased plants	Whenever severe signs are noticed After harvesting	16	53
Removing fallen fruits under	Whenever they are noticed	9	30
Continuous tillage or vegetation clearing	Durin the planting of other crops When vegetation is grown	26	87
Continuous monitoring	Evenings or morning hours. When working on other integrated crops	7	23
Proper spacing	During transplanting time	5	17
Cutting off severely diseased plants	When the severity of the infection is noticed	6	20

Discussion of rresults.

Introdauction.

In this study, the researcher attempted to find out the prevalence per variety and the control measures for citrus canker disease in sweet orange (*citrus sinensis L*) disease affecting orange farmers in the Gweri sub-county, as other factors like crops grown on the farm other than oranges, land size, the quantity of harvest among others were recorded. The study found out the prevalence of citrus canker, a disease influenced by several factors that may have been identified in the study.

Size of the Land.

Most farmers that were approached are doing orange farming on a small scale primarily because they do not have enough land to invest in orange planting but because of the gains seen in this enterprise they get themselves in it with the little land they have, Some few farmers have large pieces of land but continue to cultivate oranges on a small scale because they also want to produce other crops like groundnuts, cassava, sweet potatoes among others which may not yield well if mixed on the orange farm, therefore they always leave separate land for such enterprises.

Other crops on the farm.

Due to the shortage of land and also the need to produce oranges because of their returns, farmers are not only using their farms for orange production but also cultivating other crops like Groundnuts, peas species, and Cassava among others as supplements to their production from oranges and to support their families through food. These crops also drive farmers to ensure that the farms are in good condition by weeding, spraying, and monitoring thus ensuring that even the oranges are in good condition, however, some of these crops may be harboring the causative agent for citrus canker thus increasing the chances of infection.

Spacing of oranges.

The recommended spacing for oranges depends on various factors such as the type of orange tree, the climate, and the desired yield. Proper spacing is crucial for optimal growth, fruit production, and overall health of the orange trees. In general, for standard-sized orange trees, a spacing of 20 to 25 feet (6 to 7.5 meters) between trees is recommended. This allows enough room for the trees to grow and spread their branches without overcrowding(Condon, 2012). It also ensures adequate sunlight penetration and air circulation, which are essential for healthy fruit development and disease prevention. This results in high infection since the distance between two successive plants is small and spores from the bacterium can easily be blown to the next plants, thus high prevalence of canker disease.

Disease prevalence.

From the study, it was found that the total canker prevalence was 48.9% of the total observed orange plants which is a very significant number of infections to cause serious economic losses

to orange farmers, the disease was more prevalent in Valencia (26.2%), followed by Hamlin (15.3%) and least on Washington (7.3%). This is possibly due to the high susceptibility of Valencia in combination with environmental factors which are prevailing disease spread. (Sharif et al., 2021)

The general registered high disease prevalence was due to factors such as improperly spaced plants which eases the spread of disease through spores blown by wind, integration of other crops may make it hard to supervise the farm hence poor control, and some crops may harbor the bacterium thus acting as a vehicle for infection of oranges by canker. Also, irregularities in the application of chemicals for spraying, late spraying, and identification due to poor monitoring, some farmers report that the effective chemicals are not readily available and even when accessed they are expensive, some farmers are just reluctant to do effective control of the disease because of the poor market available for the oranges and under some cases, poor climate also hinders production or growth of oranges.

Disease control.

Generally, the disease is managed by field hygiene and spraying with chemicals, the disease is best controlled by using copper-based fungicides and bactericides at regular intervals(Gottwald et al., 2002). The bactericides reduce inoculum buildup on younger leaves and protect expanding fruits from further infection whereas b the effectiveness of disease control by copper spray depends on the susceptibility of the oranges, environmental conditions, and incorporation of other control measures however, the study found that a majority of the farmers though they spray their oranges just use commonly available chemicals without consultation from the experts, such chemical as Cyper-lacer and Rocket were found to be most used. The recommended and effective chemicals were Agri-Mycin, and Nordox which are not easily accessed by farmers besides being expensive and this has made most farmers call the disease uncontrollable simply because they can not access the effective chemicals.

Other control measures have also been highlighted in Table 4 above and of all the control measures at least all farmers control the disease by spraying with chemicals irrespective of their effectiveness and field hygiene was also seen being used by all the farmers.

5.0 CHAPTER FIVE: CONCLUSIONS & RECOMMENDATIONS

CONCLUSION

From the study and in general, the prevalence of canker on sweet oranges at Gweri sub-county was highest in Valencia (26.2%) and least in Washington (7.3%), this therefore disagrees with the first null hypothesis which states that there is no significant difference between the level of infection of sweet oranges per variety, therefore the alternative is accepted. Also, the results agree at 47.1% with the second null hypothesis which stated that farmers do not use effective control measures in the control of citrus canker.

RECOMMENDATIONS

Due to the high rate of infection of the canker disease in Valencia and the less effective control measures used, farmers;

- Should not mix all three varieties on the same piece of land
- Ensure proper spacing to avoid disease spread by wind due to improper spacing
- They should plant more of Hamlin and Washington which were less affected (resistant varieties)
- Form groups with the aim of joint control of the orange disease and marketing.
- Always seek help or guidance from the extension workers on the best ways to control the canker disease.

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APPENDIX.

1. **QUESTIONNAIRE:**

Dear Respondent;

I am **EWAGU GIDEON**, a third-year student of Busitema University pursuing a Bachelor of Science in Education with a registration number ***BU/UP/2020/2040***. I am conducting academic research on the "prevalence and control of citrus canker disease affecting orange farmers in Gweri Sub- County, this checklist/questionnaire is designed to gather data and you have been identified as a key participant in this study, therefore request you sincerely and voluntarily provide as much information as possible. The information provided will be treated with due confidentiality and will be for **ONLY** academic purposes.

SECTION A: BIO DATA.

Please tick appropriate, fill in the blank spaces provided.

1) **Gender:**
   i) Male ☐ ii) Female ☐
2) **Age group in years:**
(i) 11-20 ☐ ii) 21-30 ☐ 31-40 ☐ iv)41-50 ☐
   iii) 50 and above ☐
3) Level of education……..
   Are Are you an orange grower? Yes/No.
4) Land tenure: Owner. ☐ Rent. ☐
5) **For how long have you been growing oranges?**
   i) 1-5 years ☐ 6-10 years ☐ 10-15 years ☐ above 15 ☐

SECTION B: FARM DETAILS:

1. What is the size of your farm?

2. Crops grown on the farm…….

3. Varieties present.

Hamlin ☐ Washington ☐ Valencia ☐

3. How have you spaced the oranges between rows and lines/ columns

4. Number of orange trees on the farm.

350-450 ☐ 450-550 ☐ 550-650 ☐ 650 above ☐

5. What quantity of harvest do you always get…….

SECTION C: DISEASE INFORMATION.

1) Has your farm been affected by a disease(s)

   Yes ☐ No ☐

2) If yes, which variety is/ was most affected?

   Hamlin ☐ Washington ☐ Valencia. ☐

3) What are/ were the symptoms of the disease? (Tick appropriate)

Sign/symptom	Yes	No
Yellow-spotted leaves/ fruits		
Fruits fall prematurely		
Twigs and leaves dieback		
Water-soaked and corky lesions on fruits.		
Defoliation (leaf fall).		
others		

4) Which control (specify the commonly used)

   Chemical (which chemicals do you use for spraying and in which interval).

   ……

   Cultural practices used

   ……

   ……

   According to you, were/was the control measure used effectively?

……..

END

THANKS FOR YOUR PARTICIPATION AND INFORMATION PROVIDED

Table 5. 1: **Daily data collection sheet to determine the prevalence and control of citrus canker in the Gweri sub-county, Soroti district.**

S/N		**Date**	**Size of the farm**	**Number of**	Number of oranges with disease symptoms.			Control and its frequency of application.			
					Hamlin	Washington	Valencia				
1	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
2	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										

	9										
	10										
3	1										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										

2. PICTURES OF DISEASE SIGNS

YELLOW LESSONS ON FRUITS

DIE BACK OF STEMS

YELLOW SPOTTED LESSONS ON LEAVES