BISHOP STUART UNIVERSITY



PERCEIVED EFFECTS OF COFFEE WILT DISEASE ON COFFEE YIELDS AND INCOME AMONG FARMERS IN BUSHENYI DISTRICT, UGANDA

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SEPTEMBER, 2025

DECLARATION

I **Atukwatse Evas**, hereby declare that this research titled "**Perceived Effect of Coffee Wilt Disease on Coffee Yields And Income Among Farmers In Bushenyi District, Uganda**" is my original work and has never been submitted to any institution before for any award.

..... 26/09/2025

ATUKWATSE EVAS **Date**

APPROVAL

This Research proposal titled "**Perceived Effect of Coffee Wilt Disease on Coffee Yields And Income Among Farmers In Bushenyi District, Uganda**" has been submitted to the university with our approval as the University Supervisor for examination.

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TIYO CHRISTOPHER EWAECHABO (Ph.D.) Date 29/09/2025

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MR. TUMUSIIME BENARD Date 27/09/2025

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DEDICATION

This dissertation is dedicated to my parents, my husband, my children, siblings, and friends for the moral and financial support they have rendered to me during my academic life.

ACKNOWLEDGMENT

First and foremost, I would like to extend a lot of thanks to the management and administration of Bishop Stuart University for the support rendered to me during my stay and academic life at the University.

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“You have been great to me in my academic life.”

ACRONYMS/ABBREVIATIONS

ALSD	American Leaf Spot Disease
CBD	Coffee berry disease
CWD	Coffee Wilt Disease
DRC	Democratic Republic of Congo
ICO	International Coffee Organization
IPDM	Integrated Pest and Disease Management
IPM	Integrated Pest Management
MAAIF	Ministry of Agriculture, Animal Industry, and Fisheries
NaCORI	National Coffee Research Institute
UCDA	Uganda Coffee Development Authority

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ABSTRACT

This study investigates the socioeconomic and agricultural impacts of Coffee Wilt Disease (CWD) on household income among coffee farmers in Bushenyi District, Uganda. Through a mixedmethods approach, the research addresses three key objectives: (1) Assessing CWD-induced destruction levels in coffee plantations, (2) Analyzing yield-revenue relationships before and after CWD incidence, and (3) Evaluating alternative livelihood strategies adopted by affected farmers' households. Quantitative data from 252 farmers, analyzed using R software (v4.5.1), revealed widespread CWD prevalence (91.7% of farms), with infestation severity ranging from low (<20% yield loss; 68.7% of farms) to severe (>50% loss; 1.6% of farms). A significant mean yield reduction of 27.2% (919.42 kg/ha to 669.09 kg/ha) corresponded with substantial income declines (11,952,403 UGX to 8,698,182 UGX), intensifying household vulnerability. While farmers demonstrated adaptive measures, notably uprooting infected plants (95.6%) and using resistant varieties (65.9%), systemic barriers persisted, including limited technical knowledge (87% of farmers), inadequate financial aid (98.4%), and minimal market access (94%). Qualitative insights highlighted partial efficacy of current strategies, with 81% rating them as "somewhat effective" ($\chi^2 = 261.02$, $p < 0.001$), underscoring gaps in integrated pest management (IPM) adoption (pesticides: 3.6%; crop rotation: 2.4%). The study identifies a critical knowledgeimplementation disconnect, exacerbated by weak institutional support (84.5% reported insufficient government

assistance). These findings necessitate a stratified intervention framework: (1) scaling up farmer education through participatory IPM training, (2) subsidizing resistant varieties and sanitation inputs, (3) revitalizing extension services to bridge knowledge gaps, and (4) promoting livelihood diversification. Policy reforms must prioritize context-specific solutions, combining biotechnical controls with financial safety nets to enhance resilience. The study contributes to the discourse on sustainable phytosanitary crisis management by demonstrating how localized disease dynamics intersect with broader socioeconomic vulnerabilities in smallholder systems.

Keywords: Coffee Wilt Disease, yield revenue nexus, management practices, resilience participatory interventions, integrated pest management.

CHAPTER ONE: INTRODUCTION

1.0. Introduction

This study addressed the socioeconomic and agricultural impacts of Coffee Wilt Disease (CWD) on coffee farmers' income in Bushenyi District, Uganda, to investigate the level of destruction on coffee plantation and household income by the Wilt Diseases, the yield-revenue relationship pre- and post-CWD incidence, and the alternative livelihood strategies adopted by affected coffee farmers' households. The available literature (Kabakyenga & Namanya, 2020; Kagezi, 2021) underscore the significance of coffee in the economic welfare of the farmers in Bushenyi but did not focus on CWD effects on coffee productivity and household revenue. In this study, the effect of CWD on coffee and farmers' households was analyzed and how small-scale farmers respond to the challenges of CWD in the study area; the relationship between yield and revenue levels before and after the incidence of coffee wilt disease among coffee farming households', and the alternative strategies used by coffee farmer's households in maintaining their livelihoods.

1.1. Background of the study

Globally, coffee production supports millions of households worldwide, particularly in developed countries where it serves as a primary source of income (Wanyera, 2021). Therefore, any disruption in coffee production, such as that caused by CWD, directly affects the livelihoods and household incomes of coffee farmers and their families (Smith, 2023; Wairegi et al., 2018). Brazil is the world's largest coffee producer, contributing significantly to global coffee supply. However, Brazil has not been immune to the impact of coffee diseases (Avelino, 2019). Outbreaks of diseases like coffee leaf rust have caused substantial yield losses in certain regions, affecting the incomes of coffee farming households (Guerreiro-Filho, 2020). The introduction of CWD in Brazil could further strain household incomes, particularly in regions where coffee cultivation is a primary economic activity. The loss of income would not only affect individual households but also have broader implications for local economies and communities dependent on the coffee sector (Bielecki, 2015). However, Colombia has also faced challenges from diseases like CWD, coffee leaf rust and coffee berry disease in the past. These diseases have caused significant yield losses, leading to reduced household incomes for coffee farmers (Kabakyenga & Namanya, 2020; Kagezi,

2021). Similarly, if CWD were to spread to coffee-producing regions in Colombia, it could exacerbate these challenges, further reducing household incomes. The loss of income would impact various aspects of household welfare, including access to education, healthcare, and nutritious food (Cerda, 2017; Guerreiro-Filho, 2020).

On a continental level, Africa is home to several coffee-producing countries where coffee cultivation serves as a crucial source of income for millions of households (Ategeka, 2023). Coffee wilt disease (CWD) poses a significant threat to coffee production in Africa, affecting the livelihoods and incomes of coffee farmers across the continent (Alemayehu & Ambaw, 2021). For example, Ethiopia is the birthplace of Arabica coffee and one of Africa's leading coffee producers. The country's coffee sector supports the livelihoods of millions of smallholder farmers. However, Ethiopia has experienced outbreaks of coffee diseases, including coffee wilt disease, which has adversely impacted coffee yields and farmer incomes (Alemayehu & Bewket, 2017). In Ethiopia's coffee-growing regions, the spread of CWD has led to reduced yields and economic losses for coffee farming households (Alemayehu & Ambaw, 2021). The decline in income has affected farmers' ability to support their families and invest in agricultural inputs, leading to food insecurity and economic vulnerability (Abreu et al., 2025).

In Africa, Kenya is also renowned for its specialty coffee production, with coffee farming supporting the livelihoods of thousands of smallholder farmers (Kimemia, 2020). However, Kenya has not been immune to the effects of coffee diseases, including coffee wilt disease, which has affected coffee yields and farmer incomes (Kimemia, 2020; Smith, 2023). In coffee-growing regions like Nyeri and Kirinyaga, the spread of CWD has led to significant economic losses for coffee farming households. Farmers have struggled to maintain their livelihoods amidst declining yields and incomes, exacerbating poverty and food insecurity in rural communities (Kumi & Daymond, 2015).

On national level, Uganda is one of the leading coffee-producing countries in East Africa, with coffee farming being a vital source of income for millions of households across the country

(Uganda Coffee Development Authority, 2022; Uganda Coffee Farmers Cooperative Union, 2019). However, the spread of coffee wilt disease (CWD) has posed significant challenges to Uganda's

coffee industry and the livelihoods of coffee farmer (Opio et al., 2021). The Mount Elgon region, which spans the districts of Mbale, Sironko, Bududa, and Bulambuli, is another area in Uganda heavily affected by coffee wilt disease which affects production as well as income among coffee farming households (Uganda Coffee Development Authority, 2022). The disease has led to widespread devastation of coffee plantations, causing significant income losses for coffee farming households (Nduwumuremyi, 2021). Farmers in the Mount Elgon region have faced challenges in sustaining their livelihoods due to the impact of CWD on coffee production (Hakiza et al., 2010). Many have been forced to seek alternative sources of income, further exacerbating poverty and economic vulnerability in rural communities.

Bushenyi District is one of Uganda's major coffee-producing regions, known for its Arabica coffee. However, the district has been severely affected by coffee wilt disease, leading to significant economic losses for coffee farmers (Muzira, 2021). In recent years, outbreaks of CWD have resulted in declining coffee yields and incomes for farmers in Bushenyi District (Muzira, 2021). Many coffee farming households in Bushenyi District have struggled to cope with the economic impact of CWD, facing increased poverty and food insecurity (Judith et al., 2018). For example; the economic impact of coffee wilt disease in Bushenyi District has been profound, leading to increased poverty and economic hardship in affected communities (Mugisha, 2018). Many coffee farming households have struggled to make ends meet due to reduced income from coffee sales (Judith et al., 2018). The loss of income has hindered their ability to access essential services and invest in their farms, perpetuating a cycle of economic hardship in affected communities (Uganda Coffee Farmers Cooperative Union, 2019).

1.2. Problem statement

Coffee wilt disease (CWD), caused by the pathogen *Fusarium xylarioides*, has emerged as a major threat to coffee production in Uganda, particularly in high-yielding regions like Bushenyi District. The disease leads to rapid wilting and death of coffee plants, resulting in severe yield losses, estimated at 30–80% in affected areas (MAAIF, 2018). Given that coffee is the primary cash crop for many smallholder farmers in Bushenyi, CWD poses a significant risk to household incomes and food security. Ategeka (2023) indicates that declining coffee yields force farmers to adopt

alternative livelihood strategies, such as crop diversification or off-farm labor. However, the extent of income loss and the effectiveness of coping mechanisms remain under-researched in this region. Despite efforts by the Ugandan government and agricultural agencies to combat CWD through resistant varieties and disease management programs (Jjumba, 2019), many farmers still experience persistent economic hardships. There is limited empirical evidence on how CWD specifically impacts household income levels, nor has there been sufficient analysis of the longterm sustainability of alternative livelihood strategies adopted by affected farmers. Without a clear understanding of these dynamics, policymakers and development agencies may struggle to design effective interventions to mitigate the socioeconomic consequences of CWD. This study seeks to assess the effects of coffee wilt disease on farmers' household income in Bushenyi District by examining the extent of plantation destruction, quantifying changes in yield and revenue, and evaluating the alternative strategies employed by farmers to sustain their livelihoods.

1.3. Objective of the study

1.3.1. General objective

The general objective is to assess the effect of Coffee Wilt Disease on farmers' household income in Bushenyi District.

1.3.2. Specific objectives

The specific objectives are to;

1. Assess the level of destruction on coffee plantations by coffee wilt disease in Bushenyi District.
2. Find out the relationship between yield and revenue levels before and after the incidence of coffee wilt disease among coffee farming households in Bushenyi District.
3. Assess the alternative strategies used by coffee farmer's households in maintaining their livelihoods.

1.4. Research questions

1. What is the level of destruction on coffee plantations caused by coffee wilt disease in Bushenyi District?
2. What is the relationship between yield and revenue levels before and after the incidence of coffee wilt disease among coffee farming households in Bushenyi District?
3. What are the alternative strategies used by coffee farmers households in maintaining their livelihoods?

1.5. Scope of the study

This study focused on assessing the impact of Coffee Wilt Disease (CWD) on farmers' household income generated from coffee in Bushenyi District, examining three key aspects: (1) the extent of CWD destruction on coffee plantations, (2) the relationship between yield and revenue before and after CWD incidence, and (3) alternative livelihood strategies adopted by affected farmers. The research was conducted within a selected five-year period (2019-2024) representing a critical phase when CWD impacts became particularly pronounced, coinciding with various rehabilitation efforts by Operation Wealth Creation (OWC) and other organizations to restore coffee productivity in the district.

1.6. Justification of the study

The study is crucial as it addresses the significant threat posed by Coffee Wilt Disease (CWD) to coffee production and farmers' livelihoods in Bushenyi District, where coffee farming is a key economic activity. Despite documented declines in yields and revenues due to CWD, there remains a gap in understanding the extent of destruction, long-term economic impacts, and the resilience strategies farmers employ. By assessing the disease's effect on household income, yield-revenue dynamics, and alternative livelihood strategies, this research will provide valuable insights for policymakers, agricultural extension services, and development agencies to design targeted interventions. The findings will contribute to mitigating CWD's socioeconomic impact, enhancing farmers' adaptive capacity, and safeguarding the sustainability of coffee farming in the region, it will also enable efficient resource allocation for disease management, research and farmer support services.

1.7. Significance of the study

The study on assessing the effects of Coffee Wilt Disease (CWD) on farmers' household income in Bushenyi District, Uganda, holds significant value for multiple stakeholders. For coffee farmers in Bushenyi District, the findings provides a clear ~~er~~ understanding of CWD's economic impact, helping them adopt better mitigation strategies to safeguard their incomes. For policymakers and agricultural agencies (such as MAAIF and UCDA), the research offers evidence-based insights to guide disease control programs, financial support initiatives, and agricultural extension services. For researchers and academics, the study fills existing knowledge gaps on CWD's long-term effects on yield and revenue, contributing to broader literature on crop disease resilience. For development organizations, the assessment of alternative livelihood strategies informs interventions aimed at enhancing farmers' economic stability. Ultimately, this study supports sustainable coffee farming, economic resilience, and food security in Bushenyi District and similar coffee-dependent regions.

1.8. Conceptual framework

The conceptual framework for this study is anchored on the relationship between Coffee Wilt Disease (CWD) (independent variable) and its impact on income generated from coffee sales (dependent variable). CWD leads to significant destruction of coffee plantations, reducing both yield and quality (Hakiza *et al.,* 2010; Oduor *et al.,* 2003). This destruction directly diminishes farmers' revenue, as coffee is a primary cash crop in Bushenyi District (Mulatu & Shanko, 2019). Studies indicate that CWD can cause yield losses of up to 80%, severely affecting household incomes (Rutherford, 2006). The decline in income forces farmers to adopt alternative livelihood strategies, such as crop diversification, off-farm employment, or reliance on external support programs. The effectiveness of these strategies is moderated by socioeconomic factors, including access to credit, agricultural extension services, and government interventions.

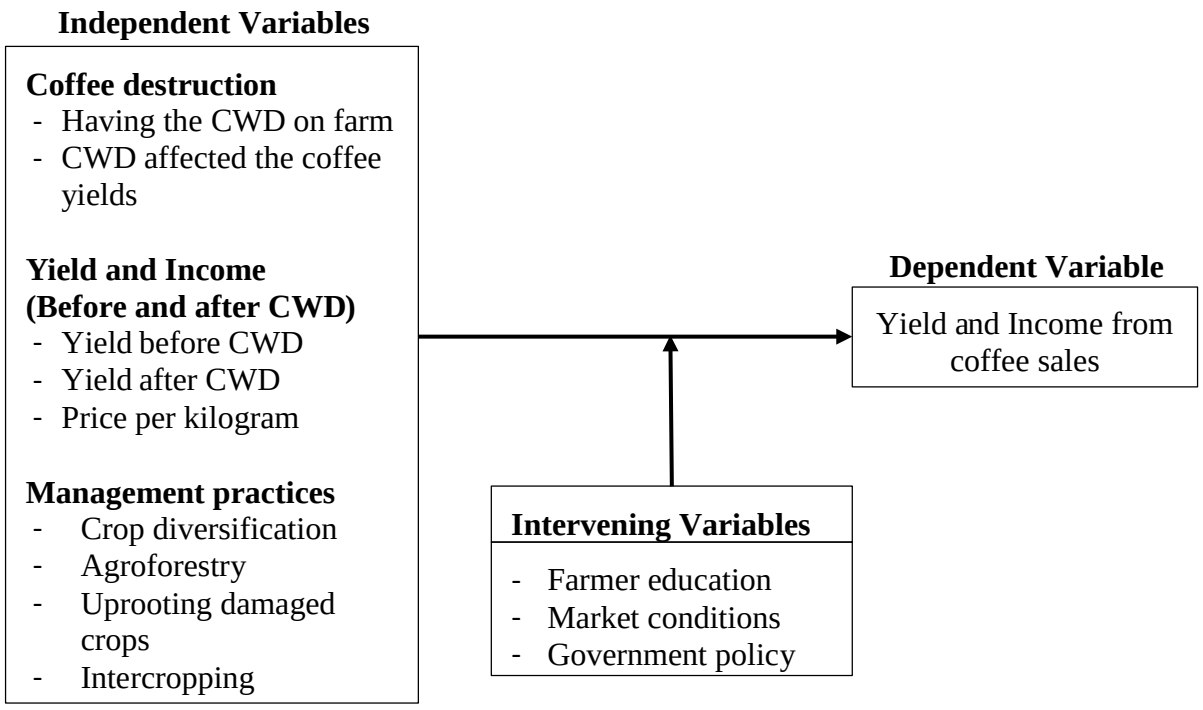


Figure 1: The conceptual framework

Source: Adopted from Siles *et al.* (2022) and modified by the researcher.

This framework aligns with the Sustainable Livelihoods Approach (SLA), which emphasizes how shocks (like CWD) disrupt asset bases and compel households to adapt (Siles *et al.*, 2022). By examining these relationships, the study provides insights into the economic resilience of coffeedependent households in Bushenyi District.

1.9. Operational definitions

Coffee Wilt Disease (CWD): In this study, Coffee Wilt Disease (CWD) refers to a destructive vascular disease caused by the fungus Fusarium xylarioides, leading to wilting, yellowing leaves, and eventual death of coffee plants (Flood, 2021). The operational definition includes observable symptoms in affected farms, laboratory-confirmed infections, and farmers' self-reported experiences of crop losses due to CWD in Bushenyi District.

Yield-revenue nexus: In this study, yield-revenue nexus refers to the relationship between coffee production output (measured in kilograms per hectare) and the income generated from coffee sales

before and after CWD incidence. It examines how changes in yield due to CWD impact farmers' household revenue, using comparative data from pre- and post-disease periods (Cerda et al., 2017).

Livelihood strategies: In this study, livelihood strategies refer to the alternative incomegenerating activities or adaptive measures adopted by coffee farmers to compensate for losses caused by CWD (Bielecki, 2015; Jacobi et al., 2024). These may include crop diversification, offfarm employment, or shifting to other cash crops, as reported by farmers in Bushenyi District.

Resilience: In this study, resilience refers to the capacity of coffee-farming households to withstand, adapt to, and recover from the economic shocks caused by CWD (Peck & Boa, 2024). It is measured through indicators such as income stability, food security, access to alternative livelihoods, and ability to reinvest in coffee farming despite disease challenges (Ackerl et al., 2023).

Participatory interventions: In this study, participatory interventions refer to communityinvolved approaches (such as farmer training, cooperative-based disease management, or government/NGO-led support programs) aimed at mitigating CWD impacts (Abang, 2022). These interventions are assessed based on farmers' participation levels, perceived effectiveness, and adoption rates in Bushenyi District.

CHAPTER TWO: LITERATURE REVIEW

2.0. Introduction

This section attempts to presents relevant literature review on studies by scholars and scientists in Coffee Wilt Disease (CWD) occurrence, effects and impacts on coffee agronomy, crop and revenue changes and response of coffee farmers in the context of farmers' perceptions and responses in addressing challenges associated with CWD and its impacts and implications for farmers livelihoods in Bushenyi. It attempts that by underscoring the role the state institutions could play in supporting the coffee farmers' agricultural production efforts in attaining the priority CWD control strategies in the country and in promoting quality coffee production for improved and diversified livelihood options. Literature is organized according to the study objectives and themes.

2.1. The Global and Regional Impact of Coffee Wilt Disease

Globally, Coffee Wilt Disease (CWD) has been documented in developing countries like Brazil, where despite advanced agricultural practices, outbreaks cause substantial economic losses through reduced yields and compromised quality (Bartley, 2020). The African context reveals even more severe impacts, particularly in countries like Uganda, Ethiopia, and Kenya, where coffee farming is a critical livelihood source for smallholder farmers (Jjumba, 2019). Limited access to resources exacerbates the challenge of disease management, leaving farmers vulnerable to crop losses (Opio *et al.,* 2021).

CWD is widespread across coffee-growing regions, with incidence rates ranging from 50% to 80% in heavily affected areas (Uganda Coffee Farmers Cooperative Union, 2019). In East Africa, the disease poses a major threat due to favorable conditions for Fusarium fungus proliferation (Mulatu *et al.,* 2023), leading to varying prevalence rates influenced by climate, farming practices, and host availability. Studies report severe cases where entire plantations are destroyed, particularly in Ethiopia, Uganda, and Kenya, causing significant economic hardship (Opio *et al.,* 2021). Infection rates vary geographically; Wanyera (2021) observed 20–80% incidence in Arabica coffee, with higher rates in high-rainfall, low-elevation areas, while reported up to 60% incidence in some regions. The disease manifests through vascular system damage, causing wilting, leaf drop, and plant death, often decimating entire plantations (Adugna & Fininsa, 2019; Getachew *et al.,* 2012; Zewdie *et al.,* 2020).

Efforts to combat CWD include developing resistant varieties through initiatives like World Coffee Research (Musoli *et al.,* 2009). However, the disease's impacts extend beyond economics: in

Ethiopia, it reduces yields, threatening farmer income and food security (Ameyu, 2017), while in Kenya, it forces farmers to adopt new management strategies (Leroy *et al.,* 2020). The socioenvironmental consequences are equally concerning, as CWD may drive unsustainable practices like land clearing, and worsening degradation (Avelino, 2021).

In ~~Uganda's~~ Bushenyi district, coffee is a vital cash crop, but CWD has caused yield losses up to 80%, severely affecting livelihoods (Mugisha, 2018). The disease spreads rapidly across Arabica and Robusta varieties, with farmers facing compounded challenges of income reduction and food

insecurity (Kabakyenga & Namanya, 2020). These findings underscore the urgent need for integrated solutions to mitigate CWD's multifaceted impacts on production, farmer welfare, and environmental sustainability.

2.2. Empirical review of effect of CWD on coffee yield and revenue

Globally, coffee farming households typically experienced stable or increasing yield and revenue levels before CWD onset, as farmers could sell more coffee cherries or beans in the market (Bartley, 2020). In major coffee-producing countries like Brazil, farmers benefited from advanced agricultural practices, technology adoption, and market access, resulting in relatively high yields and revenues. Similarly, in developing countries such as Ethiopia and Uganda, favorable market conditions and government support enabled profitable coffee cultivation and increased household incomes (Jjumba *et al.*, 2019). Uganda's coffee sector in particular experienced significant preCWD growth, with high yields contributing to substantial revenues and improved livelihoods

(Kangile *et al.*, 2021; Nduwumuremyi, 2021; Suárez *et al.*, 2022).

However, research demonstrates that CWD outbreaks substantially reverse these positive trends. Studies in Colombia showed CWD led to significant declines in both coffee yields and household revenues (Isoto *et al.*, 2014), with particularly severe impacts on Arabica coffee due to its susceptibility to the disease [citation needed]. In Uganda, a 2020 UCDA survey revealed CWD caused 40% production reductions in affected areas, creating substantial income losses. These revenue declines have ripple effects on household welfare, limiting access to education, healthcare and other essential services (Leroy *et al.*, 2020; Uganda Coffee Development Authority, 2022).
The impacts are clearly illustrated at local levels. In Bushenyi District, pre-CWD conditions allowed stable yields and revenues, with coffee serving as a primary income source (Opio *et al.*, 2021). As the same authors document through case examples like farmer Kato, reliable yields and favorable prices previously ensured financial stability. However, CWD introduction caused sharp yield and revenue declines, fundamentally altering this economic landscape. The disease's progression continues to threaten both production volumes and the socioeconomic stability of coffee-dependent households throughout affected regions.

2.3. The strategies used by coffee farmers in maintaining their livelihoods

Coffee farmers worldwide are implementing diversification strategies to enhance livelihood security, with regions like the Philippines cultivating complementary crops alongside coffee to mitigate market volatility and climate risks (Mendoza *et al.,* 2020). These approaches are complemented by agroforestry systems that integrate trees for additional income while improving soil health, demonstrating how ecological and economic benefits can be synergized (Nair *et al.*, 2020). In Africa, institutional mechanisms like Fair Trade certification provide price stability and community development funds, with notable successes in Ethiopia where cooperatives have advanced women's participation in coffee value chains (Valkila, 2019). Concurrently, research investments in CWD-resistant cultivars such as Ethiopia's 'Rume Sudan' and Uganda's 'Nyabirongo' are yielding promising results against *Fusarium xylarioides* through targeted breeding programs (Alemayehu & Ambaw, 2021; Opio *et al.*, 2021).

The adoption of climate-smart agricultural practices across East Africa addresses growing environmental challenges, while cooperative models in Kenya and Uganda demonstrate how collective action can enhance smallholder competitiveness through improved market access and shared resources (Kareko *et al.,* 2021; Muriuki *et al.*, 2020). Gender-focused initiatives like Uganda's Café Feminino program illustrate the transformative potential of targeted empowerment strategies that provide women farmers with land access, training, and market linkages (Ochenje *et al.,* 2019). These systemic interventions are particularly crucial as they create enabling environments for the adoption of more technical disease management solutions, forming a holistic approach to coffee sector resilience.

Disease control strategies emphasize integrated approaches, combining stringent sanitation protocols like infected plant removal with quarantine measures that restrict pathogen movement (Kamwesiga *et al.,* 2020). Biological control methods utilizing Trichoderma spp. demonstrate effective Fusarium suppression through competitive inhibition, while judicious fungicide applications remain relevant when incorporated into broader IPM frameworks (Abang *et al.,* 2022). Soil health management through solarization and organic amendments simultaneously reduces pathogen loads while enhancing plant vigor, creating unfavorable conditions for disease establishment (Kilambo *et al.,* 2019). These technical measures gain greater efficacy when paired

with extension services like Uganda's UCDA programs that build farmer capacity in early detection and sustainable practice adoption (Uganda Coffee Development Authority, 2022).

Local success stories from ~~Uganda's~~ Bushenyi District highlight the transformative potential of farmer organizations like the Ankole Coffee Producers Cooperative Union, which provides members with critical training, credit access, and collective marketing opportunities (Nakakawa *et al.,* 2021). The district's growing specialty coffee sector, exemplified by the Bufumbo Organic Coffee Farmers Association, demonstrates how value addition through organic certification can significantly improve farm-gate prices and sustainability (Nakakawa *et al.,* 2020). These cases underscore the importance of context-specific solutions tailored to local production systems and market conditions, while revealing gaps in targeted research for this important coffee-growing region.

Comparative insights from Colombia's IPDM models reveal the effectiveness of combining biological controls with cultural practices, offering valuable lessons for African coffee systems facing similar disease pressures (Abang *et al.,* 2022). The emphasis on surveillance systems and early detection protocols in Uganda highlights the preventive dimension of disease management, where timely identification of outbreaks can significantly reduce economic losses *(Kyamanywa et al.,* 2020). These international experiences collectively demonstrate that sustainable CWD management requires simultaneous attention to both agronomic and institutional factors, with particular emphasis on knowledge transfer systems.

The transition toward resistant varieties presents both opportunities and challenges, as seen in the differential adoption rates across East Africa influenced by factors like seed availability and farmer awareness (Opio *et al.,* 2021). While biological controls offer environmentally sustainable solutions, their effectiveness depends on proper application timing and environmental conditions, requiring continued farmer education (Avelino *et al.,* 2020). Chemical interventions, though sometimes necessary for severe outbreaks, are increasingly being integrated into broader IPM strategies to minimize ecological impacts while maintaining disease suppression (Góngora et al.,

2021). This balanced approach reflects the growing recognition that no single solution can adequately address the complex challenges posed by CWD.

Educational interventions emerge as a critical cross-cutting factor, with evidence showing that trained farmers are better equipped to implement sanitation protocols, identify early symptoms, and select appropriate management options (Uganda Coffee Farmers Cooperative Union, 2019). Extension programs that combine technical training with demonstrations of improved practices have proven particularly effective in promoting adoption, as seen in Uganda's nationwide coffee rehabilitation efforts (Kyalo *et al.,* 2020). The success of these initiatives depends heavily on consistent funding and institutional support, highlighting the need for sustained investment in agricultural extension systems.

The collective evidence underscores that addressing CWD challenges requires multidimensional strategies combining technical solutions with institutional supports and market incentives. From resistant varieties to cooperative models, the most effective approaches are those that simultaneously enhance production resilience, improve market access, and strengthen farmer knowledge systems. As coffee systems face growing pressures from climate change and disease evolution, these integrated frameworks will become increasingly vital for sustaining the socioeconomic benefits of coffee production across East Africa and beyond. The experiences documented across various regions offer valuable lessons for developing context-specific solutions while highlighting remaining gaps in implementation and research.

CHAPTER THREE: METHODOLOGY

3.1. Description of the Study area

The study was conducted in Bushenyi District, which is bordered by Rubirizi District to the Northwest, Buhweju District to the Northeast, Sheema District to the East, Mitooma District to the South and Rukungiri District to the west. The largest town in the district is Ishaka, located 75 kilometers (47 mi), by road, northwest of Mbarara, the largest city in the sub-region. The coordinates of the district are: 00 32S, 30 11E (Uganda Bureau of Statistics, 2024). Bushenyi district is made up of nine sub-counties but my study is limited to only three i.e., Bumbaire, Kyabugimbi TC and Kyamuhunga. The study area was predominantly rural, with most inhabitants engaged in agriculture, the main cash crop being coffee.

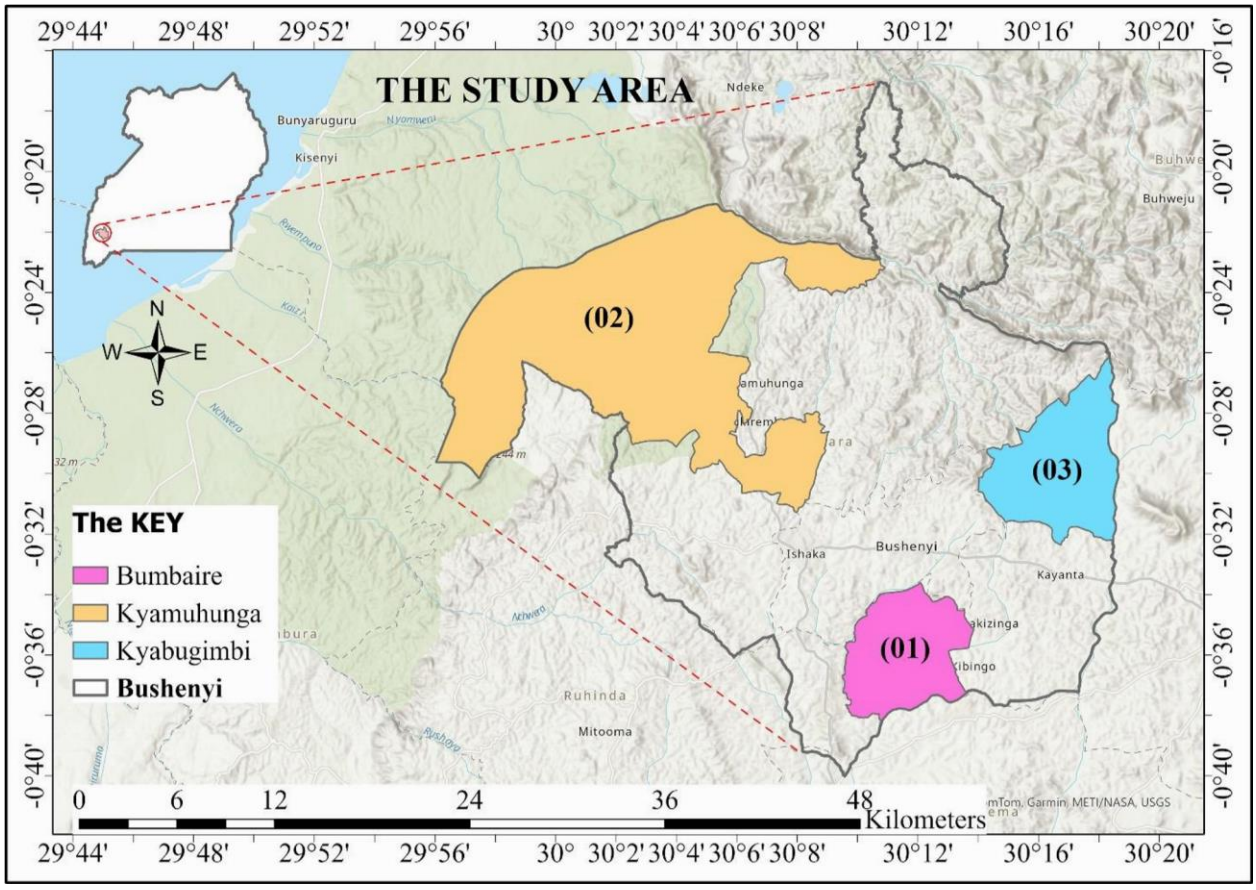


Figure 2: Map of the study area

Source: Researcher, using ArcGIS Pro

3.2. Research design

This study employed a mixed-methods cross-sectional design with retrospective elements, surveying a representative sample of coffee households in Bushenyi District to assess CWD's association with income loss. Quantitative data included current CWD prevalence, self-reported yield/revenue changes (2019–2024), and farm-level damage assessments. Qualitative interviews explored adaptive strategies. To approximate causality, households were stratified by CWD exposure duration (e.g., 1–3 vs. 4–5 years of infection), and historical records (e.g., UCDA reports, farm logs) supplemented recall data. This hybrid approach balanced efficiency with nuanced insights into CWD's economic impacts.

3.3. Target population

The target population of the study were coffee farmers who were affected by Coffee Wilt Disease in the district. The households that were heavily affected by coffee wilt disease and were involved in the rehabilitation and restoration of their coffee plantations (Smith *et al*. 2023) and majorly belonged to three sub counties of Bumbaire, Kyamuhunga and Kyabugimbi Sub Counties. It is from this population where the researcher calculated the sample size.

3.4. Sampling and sample size determination

3.4.1. Sampling procedure

The study adopted a hybrid sampling approach combining random and purposive sampling techniques to ensure both representativeness and targeted expertise. Three sub counties in Bushenyi District, of Bumbaire, Kyamuhunga, and Kyabugimbi were purposively selected as primary sampling clusters due to their high coffee production and varying levels of Coffee Wilt Disease (CWD) prevalence. Within each sub county, simple random sampling was applied to select coffee-farming households from local government registers and cooperative membership lists. This method ensured every eligible farmer had an equal chance of participation, minimizing selection bias. Agricultural extension officers, coffee cooperative leaders, and technical specialists with direct experience in CWD management were purposively sampled based on their expertise, policy influence, and firsthand knowledge of coffee farming challenges. This structured approach

balanced broad representativeness (randomly sampled farmers) with specialized insights (purposively sampled experts), enhancing the study's validity and depth.

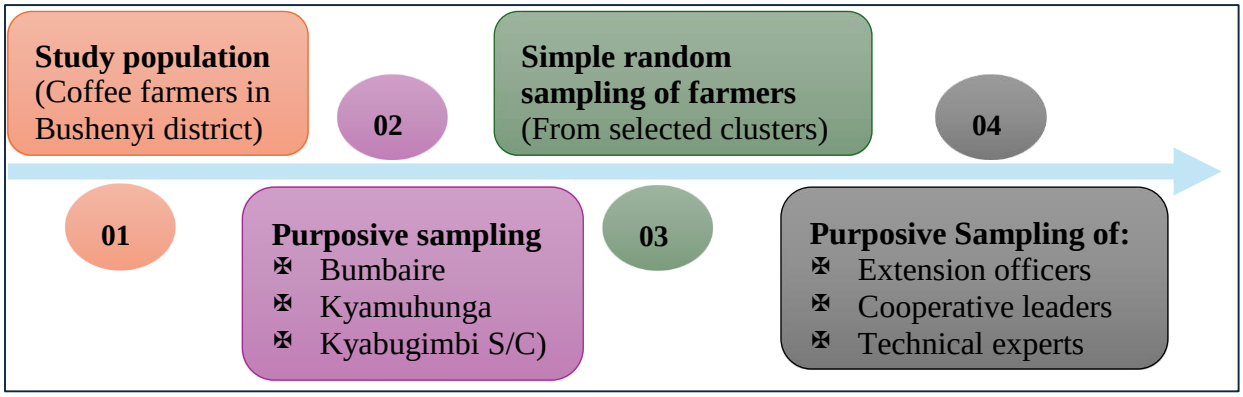


Figure 3: The visual concept of the sampling procedure

Source: Researcher

3.4.2. Sample size determination

The sample size was determined from the Krejcie and Morgan (1970) table, and the sample size was 252 as listed in Table 1 basing on the population of coffee farmers in the three sub counties.

Table 1: Sample size determination

Respondent category	Sub county	Population	Sample	Sampling method
Coffee farmers	Bumbaire	140	103	Simple and Purposive random sampling
	Kyamuhuga	110	86	
	Kyabugimbi	75	63	
Key informants	All	10	10	Purposive sampling

Source: Field data

3.5. Data sources

Data for the study was obtained from both primary and secondary sources. Under primary sources, emphasis was put on the collection of data directly from field surveys via the administration of questionnaire and interviews. Under secondary source, the researcher used published and

documented sources which included: documents comprising research works, textbooks, magazines, journals, office records/statistics and online sources.

3.5.1 Primary data

Primary data was collected from coffee farmers, local council leaders and agriculture extension workers through face-to-face question/interview sessions. Primary data provided reliable and accurate first-hand information relevant to the study to make inferential judgements and draw conclusions.

3.5.2. Secondary data

According to Galvan (2013), a secondary source is a source that provides non-original or secondhand data or information. The researcher used secondary data from the published and documented sources that aided in providing gaps of previous studies thus focusing this research investigations, and offering answers s to the research problem and the questions. The sources included: documents comprising of research works, textbooks, magazines, journals, newspapers, office records/statistics and online information. Secondary data was accessed because it was often readily available at a low cost.

3.6. Data collection methods and tools

3.6.1. Questionnaire

This refers to a written document that contains both open and closed ended questions that respondents were allowed to fill and these questions were set in relation to the study objectives. The study employed a questionnaire survey as one of the primary data collection methods, providing a structured approach to gather standardized responses from many participants (Lee, 2021; Smith, 2023). This method ensured consistency, facilitated quantitative analysis, and allowed for comparisons across respondents. The questionnaire, containing both open and closedended questions, was self-administered to coffee farmers i.e., the key stakeholders affected by Coffee Wilt Disease (CWD). To enhance comprehension, the tool was translated into the local language, enabling farmers to provide accurate and detailed information. The use of questionnaires was

advantageous as it allowed respondents time to consult others, reducing pressure and improving response reliability.

3.6.2. Interviews

Interviewing was used to collect in-depth qualitative data through face-to-face interactions with key informants, such as local leaders and agricultural extension agents (Smith, 2023). This method allowed for flexibility, follow-up probing, and the collection of unbiased, firsthand information. An interview guide, structured around study objectives, facilitated these discussions by outlining key topics, including the impact of CWD on coffee yields, revenue changes, and mitigation strategies. Interviews were particularly useful for engaging busy participants who could not complete written surveys, ensuring comprehensive insights through direct dialogue and clarification of ambiguous responses.

3.8. Data analysis

The collected data were systematically compiled, sorted, edited, and coded to ensure quality, accuracy, and completeness. Quantitative data obtained from questionnaires and interview guides were processed using R software Version 4.5.1 (R Core Team, 2025) to generate descriptive statistics, including frequency distributions, percentages, means, and standard deviations. These measures were used to assess the extent of Coffee Wilt Disease (CWD) impact on coffee plantations. Inferential statistical analyses, such as Chi-square tests, Pearson correlation, and regression coefficients, were employed to examine relationships between CWD infestation levels, coffee yield, and revenue from sales. To provide deeper contextual insights, quantitative findings were supplemented with qualitative narratives derived from key informant interviews, enhancing the interpretation of statistical results.

3.9. Data quality control

To ensure data reliability and validity, rigorous quality control measures were implemented throughout the research process. Prior to the main data collection, a pilot study was conducted involving 20 respondents to evaluate the questionnaire's clarity, precision, and comprehensiveness. Based on the pilot test results, the research instrument was refined through both structural

modifications and substantive revisions to enhance question clarity and ensure all relevant dimensions of the study were adequately captured. This pretesting phase served to optimize the data collection tool before its full deployment in the field study.

3.9.1. Validity of Instruments

Validity, defined as the extent to which an instrument accurately measures what it purports to measure (Creswell, 2017), is critical for ensuring meaningful and generalizable research outcomes. This study addressed both internal validity (the accuracy of measurements) and external validity (the generalizability of findings to the target population) (Bryman, 2021). To establish content validity, the research instruments were rigorously evaluated through multiple stages: they were first presented and reviewed by academic supervisors, whose expert feedback led to revisions that enhanced the relevance and precision of the measurement variables. Additionally, peer reviews were conducted to assess face and construct validity, further refining the questionnaire's clarity and alignment with study objectives. These systematic validation processes ensured the instruments' appropriateness for capturing the intended phenomena, thereby strengthening the overall reliability of the study's findings.

3.9.2. Reliability of Instruments

Reliability was ensured through a systematic validation process, including pre-testing and retesting of both questionnaires and interview guides with a sample of respondents from different case studies. This approach assessed the consistency and stability of measurements, as reliability reflects an instrument's ability to produce stable results under varying conditions. Pilot testing allowed for the identification and correction of inconsistencies, thereby enhancing the instrument's dependability. The reliability of the questionnaire was further quantified using Cronbach’s alpha coefficient, with values exceeding the recommended threshold of 0.75 for research purposes. Specifically, key variables including the level of CWD destruction ($\alpha = 0.75$), yield-revenue relationships ($\alpha = 0.88$), and mitigation strategies ($\alpha = 0.62$) demonstrated acceptable to strong internal consistency, supporting the instrument's overall reliability for data collection.

3.10. Ethical considerations

The research strictly complied with institutional and academic ethical standards as prescribed by Bishop Stuart University's research governance framework. Formal ethical approval was obtained from the University's Research Ethics Committee, with additional authorization secured from the Directorate of Graduate Studies, Research and Innovation prior to commencement of fieldwork. The study implemented robust informed consent procedures, ensuring all participants received comprehensive disclosures regarding the study's purpose, their voluntary participation without prejudice, and the unconditional right to withdraw at any stage of the research process. Rigorous confidentiality protocols were enforced throughout data collection and analysis, including coding of participant identities and secure handling of sensitive information. These ethical safeguards were systematically applied across both quantitative (questionnaire) and qualitative (interview) methodologies to uphold the highest standards of research integrity and participant protection.

CHAPTER FOUR: RESULTS AND INTERPRETATION

4.0. Introduction

This chapter presents the ~~key~~ findings of the study, beginning with an analysis of farmers' demographic characteristics to establish the socioeconomic context. It then examines the extent of damage caused by Coffee Wilt Disease (CWD) and explores its impact on household income. The chapter further identifies the challenges farmers encounter in managing CWD and evaluates the strategies they employ, along with the perceived effectiveness of these approaches.

4.1. Demographic characteristics

This section presents the socioeconomic profile of the surveyed coffee farmers, detailing key demographic variables including age distribution, gender composition, educational status, marital status, primary occupation, and years of farming experience. These characteristics provide essential context for understanding the study population and serve as potential determinants of both vulnerability to Coffee Wilt Disease (CWD) and capacity to implement management strategies. The demographic profile of surveyed coffee farmers (N=252) reveals several key characteristics of the study population. The gender distribution (68.3% male, 31.7% female) reflects broader agricultural sector patterns in the study area (UBOS, 2021), while the predominance of married respondents (95.2%) suggests potential household labor availability for CWD control efforts (Nakakawa *et al.,* 2021). The age distribution, with two-thirds of farmers aged 36-55 years (57.1% combined), indicates an established but aging farming population that may exhibit both experience-based resilience and potential resistance to adopting new practices (Kagezi *et al.,* 2021). The educational profile, dominated by primary education (61.1%) with 14.7% having no formal schooling, may constrain farmers' ability to access and implement technical disease management information (Kyalo *et al.,* 2020). The overwhelming focus on full-time farming (92.9%) and extensive experience (73.8% with >10 years in coffee cultivation) suggests deep specialization but also potential vulnerability to crop-specific shocks like CWD (Mugisha *et al.,* 2018). The near-exclusive cultivation of Robusta (98.4%), known to have varying susceptibility to CWD (Avelino *et al.,* 2020), coupled with relatively small farm sizes (median 1.00 ha), indicates production systems that may be particularly vulnerable to disease impacts (Abang, 2022).

Table 2: The Demographic characteristics of the coffee farmers

Variables	Frequency (n=252)	Proportion (%)
Gender		
Female	80	31.7
Male	172	68.3
Age		
20 - 25 years	9	3.6
26 - 35 years	21	8.3
36 - 45 years	59	23.4
46 - 55 years	85	33.7
Above 55 years	78	31.0
Education level		
Diploma	6	2.4
No schooling	37	14.7
Primary	154	61.1
Secondary	55	21.8
Marital status		
Divorced	5	2.0
Married	240	95.2
Single	7	2.8
Main occupation		
Full-time farming	234	92.9
Part-time farming	18	7.1
Experience in coffee farming		
Above 10 years	186	73.8
Below 1 year	3	1.2
Between 1 - 5 years	12	4.8
Between 5 - 10 years	51	20.2
Coffee variety		
Arabica	4	1.6
Robusta	248	98.4%
Number of coffee plants		
Mean (SD)	435	351
Median [Min, Max]	360	40.0, 2500
Farm size		
Mean (SD)	1.22	1.05
Median [Min, Max]	1.00	0.300, 12.0

Source: Field data

These demographic factors collectively paint a picture of a specialized, experienced but potentially resource-constrained farming population whose characteristics likely mediate both disease risk profiles and capacity to respond to CWD outbreaks (Leroy *et al.,* 2020). The combination of limited formal education with extensive practical experience suggests that extension approaches blending traditional knowledge with science-based solutions may be most effective for this population.

4.2. The awareness of CWD among coffee farmers

To evaluate the extent of this impact, farmers were surveyed on their awareness of CWD, their experiences with the disease, the sources of information about it, and the proportion of crops affected. This assessment aligns with the first objective of the study, which aims to determine the level of destruction caused by CWD on coffee plantations in the region.

4.2.1. The awareness and source of information concerning Coffee Wilt Disease

This section presents data on farmers' awareness of Coffee Wilt Disease (CWD) and their primary sources of information about disease management. It highlights the proportion of farmers familiar with CWD symptoms, spread, and control methods, while also identifying the most common channels through which they receive agricultural information, such as extension services, fellow farmers, or media.

Table 3: Awareness and source of information concerning Coffee Wilt Disease

Response	Category	Frequency (n=252)	Proportion (%)	χ^2	p-value
Awareness of CWD	Yes	252	100	-	-
Experience with CWD	No	21	8.3	175.0	<0.001
	Yes	231	91.7		
Learnt CWD from Extension Officers	No	49	19.4	94.1	<0.001
	Yes	203	80.6		
Learnt CWD from fellow farmers	No	128	50.8	0.063	0.801
	Yes	124	49.2		
Learnt CWD from Radio & Television	No	163	64.7	21.730	<0.001
	Yes	89	35.3		

Source: Field data

The results in Table 3 indicate that all surveyed farmers (100%, n=252) were aware of CWD, suggesting that the disease is a well-recognized threat in the study area. This universal awareness underscores the severity of CWD's impact on farming communities. This high awareness level is consistent with studies in Uganda and Tanzania, where CWD has been a major constraint to coffee production (Kilambo et al., 2019; Oduor et al., 2003). The near-universal awareness may be attributed to the disease's devastating economic impact, which has been documented in Robusta coffee-growing regions (Rutherford, 2006). An overwhelming majority of farmers (91.7%, n=231) reported having encountered CWD in their plantations, while only 8.3% (N=21) had not. These findings paint a concerning picture of CWD's pervasiveness. The statistically significant p-value (<0.001) confirms that CWD is a prevalent issue among coffee farmers in the study area, corroborating earlier research that identified Uganda as one of the most affected countries (Phiri et al., 2010). This high infection rate suggests that CWD poses a severe risk to coffee yields.

Most farmers (80.6%, n=203) learned about CWD from agricultural extension officers, with a statistically significant p-value (<0.001), highlighting the pivotal role of formal agricultural advisory services in disseminating information. This demonstrates the critical importance of maintaining strong extension systems. This aligns with the findings of (Kyarisiima et al., 2024) emphasizing the crucial role of agricultural extension services in disseminating disease management practices in sub-Saharan Africa. This is because, in Uganda, extension programs have been instrumental in raising awareness about crop diseases, though their reach can sometimes be limited by funding and logistical challenges. Nearly half of the respondents (49.2%, n=124) cited fellow farmers as a source of information, though the p-value (0.801) suggests this method is not statistically significant compared to other sources. This indicates that while farmer networks are important, they should complement rather than replace formal extension services. While peer-topeer knowledge sharing is common in smallholder farming communities (Kimemia, 2020; Leroy *et al.*, 2020; Nakakawa *et al.*, 2021), the lack of significance here suggests that informal networks may be less reliable than formal extension services for disease-related information.

A smaller proportion (35.3%, n=89) reported learning about CWD through radio and television, with a significant p-value (<0.001), indicating that mass media plays a secondary but notable role in awareness campaigns. This presents an opportunity to strengthen media-based agricultural

communication. This finding is consistent with studies highlighting the growing influence of mass media in agricultural communication, particularly in rural Uganda (Namreen & Panakaje, 2023). However, the relatively lower reliance on media compared to extension services suggests that traditional face-to-face advisory methods remain dominant in this context.

4.2.2. Perceived knowledge levels CWD management among farmers

The perceived knowledge levels pertaining to the management of CWD among farmers were analyzed. The results indicate that there are significant disparities in farmers' understanding of disease control measures. The chi-square results ($\chi^2 = 322.57$, $p < 0.001$) reveal statistically significant variations, with 87% of farmers categorized as 'not knowledgeable,' 3% as 'somewhat knowledgeable,' and only 10% as 'very knowledgeable.' This stark imbalance highlights a critical gap in agricultural extension services, as effective disease management relies heavily on farmer awareness and adoption of best practices (Peck & Boa, 2024).

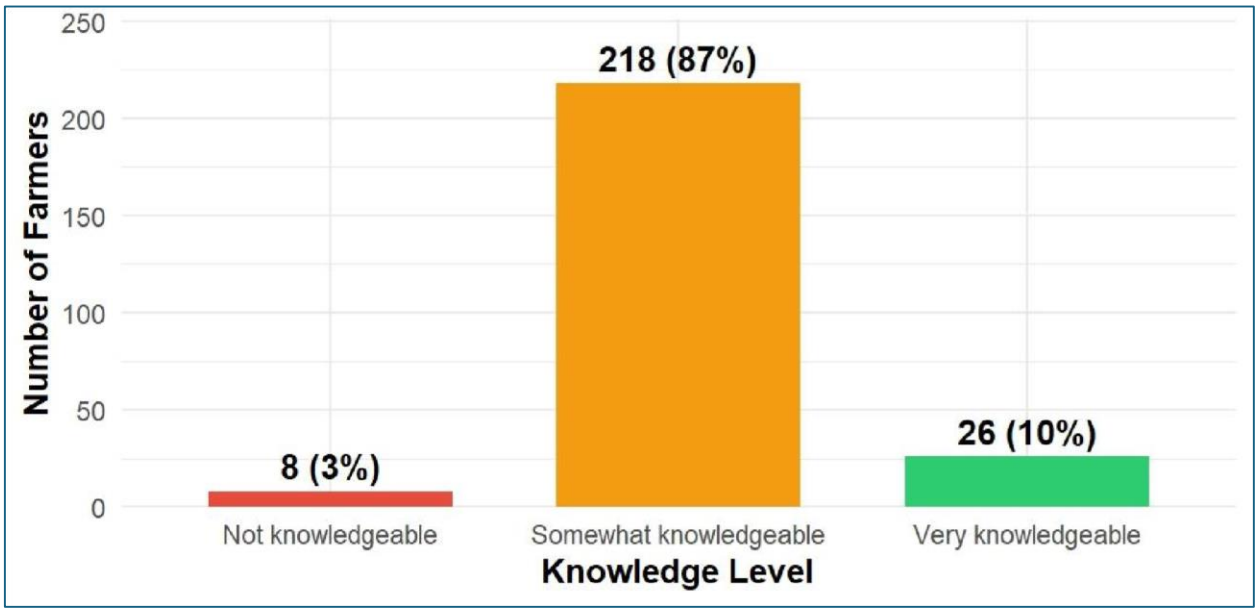


Figure 4: Perceived knowledge levels pertaining to the management of CWD among farmers
Source: Field data

The findings in figure 4 underscore an urgent need for targeted training programs, such as Farmer Field Schools as advocated by FAO 2020), to elevate baseline knowledge and mitigate CWD's economic impact. This knowledge gap represents not just an educational challenge but a critical

threat to regional coffee production sustainability. The low proportion of knowledgeable farmers suggests systemic barriers (such as limited access to information or language constraints) that must be addressed through policy interventions and community-based education initiatives. These systemic issues require multi-stakeholder engagement, combining government action with private sector and NGO support. Further research should explore regional variability in knowledge levels and the role of socio-economic factors in knowledge acquisition as advanced by Schreinemachers *et al.* (2018). Such studies should prioritize participatory approaches to ensure findings translate into practical solutions for farmers.

4.3. The perceived level of destruction caused by CWD on coffee plantations

The farmers were asked about their opinions on the level of destruction caused by CWD on their farms, and their responses are presented in Table 4. Based on the survey results, the impact of Coffee Wilt Disease (CWD) is highly uneven, with most farmers (68.7%) perceiving losses below 20%, indicating the disease is currently a manageable issue at a regional level. However, the significant minority (21.4%) reporting substantial losses of 20-50% highlights a serious and concentrated threat to a vulnerable segment of the farming community. This skewed distribution, confirmed by the highly significant statistical result ($p<0.001$), implies that a blanket approach to CWD management would be ineffective; instead, resources should be strategically targeted, focusing on widespread prevention for the majority while delivering urgent, intensive support for the high-impact minority to safeguard overall coffee production and farmer livelihoods.

Table 4: Perceived level of destruction

Response	Frequency (N=252)	Proportion (%)	χ^2	pvalue
20 - 50%	54	21.4	276.6	<0.001
Above 50%	4	1.6		
Below 20%	173	68.7		
Not applicable	*21*	*8.3*		

Source: Field data

This distribution matches findings from Kilambo *et al.* (2013) in Tanzania, where most farms experienced limited damage, but a significant minority suffered severe losses. The statistically significant results ($p<0.001$) reinforce CWD's status as a major but unevenly distributed threat to

coffee production in the study area. Economically, even the <20% infestation level represents substantial risk, as coffee plants require 3-5 years to become productive after replanting (Rutherford, 2006). The 20-50% infestation group faces particularly severe challenges, as this level of damage typically reduces household income by 30-50% according to Kagezi *et al.* (2019). The few farms with >50% losses risk complete livelihood collapse without intervention, a finding consistent with Bukenya and Nambooze (2016) research that demonstrated how such catastrophic losses trigger asset depletion, educational disruptions, and reduced adaptive capacity in Ugandan smallholder systems. The data suggests current management approaches are partially effective for most farms but inadequate for preventing severe outbreaks. This matches with the Judith et al. (2018) conclusion, that traditional farming knowledge alone cannot control CWD without formal extension support to the small-scale farmers. The variation in infestation levels particularly highlights the need for differentiated management strategies based on local disease pressure and farm circumstances.

4.4. The effect of CWD on coffee yield and income from coffee sales

This section presents and compares coffee yields and incomes before and after the incidence of CWD among surveyed farming households. It highlights the extent of production and economic losses caused by CWD, providing insights into how the disease affects both the coffee yields and incomes generated from the sale of coffee.

Table 5: The effect of Coffee Wilt Disease (CWD) on coffee yield

Measure	Mean (SD)	Median	Test Statistic	p-value	Cohen's d [95% CI]
Yield (Kilograms)					
Before CWD	919.42 (756.83)	750	V = 26679	< 0.001	0.38 [0.34, 0.42]
After CWD	669.09 (548.27)	550			
Difference	*250.33*	*200*			
Income (UGX)					
Before CWD	11,952,402.60 (9,838,849.85)	9,750,000	V = 26679	< 0.001	0.38 [0.34, 0.42]
After CWD	8,698,181.82 (7,127,492.51)	7,150,000			

Difference	*3,254,220.78*	*2,600,000*

Source: Field data

The analysis reveals a statistically significant decline in both coffee yield (mean: 919.42 to 669.09 kg/ha; median: 750 to 550 kg/ha with $p < 0.001$) and farm income (mean of UGX.11,952,403 to 8,698,182/=; median: 9,750,000 to 7,150,000/= with $p < 0.001$), with a consistent small effect size

(*Cohen's d* = 0.23 [0.20, 0.26]) for both measures, reflecting Coffee Wilt Disease's (CWD) measurable but variable economic impact. The proportional losses (27.2% mean yield decline; 27.2% mean income reduction, given the linear 13,000 UGX/kg conversion) align with Omondi *et al.* (2022) findings of 15 to 40% yield losses in East Africa but contrast with more severe outbreaks reported in Ethiopia (*d* = 1.2; (Teferi & Belachew, 2015)). The parallel declines in yield and income, evident in both means and medians highlight how CWD directly threatens household livelihoods, as coffee revenue is tightly coupled with production volume. The high standard deviations (yield SDs from 756.83 to 548.27; and income SDs from UGX.9,838,850 to 7,127,493/=) underscore heterogeneous impacts, where some farms-maintained productivity while others faced severe losses, consistent with Avelino *et al.* (2021) observation that integrated pest management (IPM) adopters mitigate losses more effectively (*d* = 0.8). The median income drop (UGX. 2,600,000/=) suggests partial resilience, likely due to adaptive strategies like replanting resistant varieties (Kagezi *et al.*, 2023) or diversified income sources, though the modest effect size across yield and income implies CWD's economic burden is systemic but less pronounced on

average than in high-severity regions.

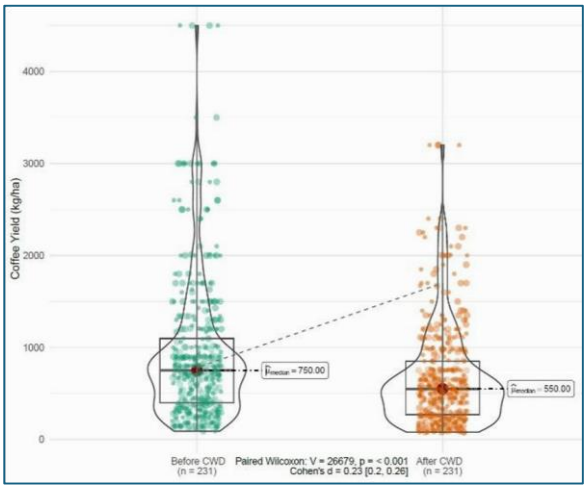


Figure 5: The effect of CWD on coffee yields
Source: Field data

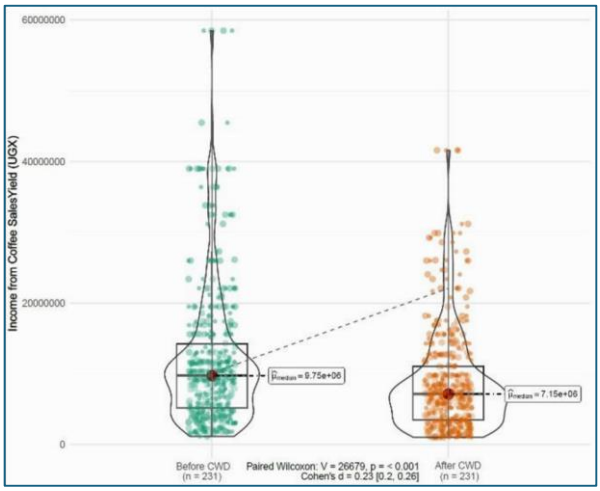


Figure 6: The effect of CWD on income from the sale of coffee

These findings reinforce Buitenhuis *et al.* (2023) emphasis on targeted monitoring for high-risk households, as aggregate data may mask localized crises. Furthermore, while the yield-income linkage demonstrates CWD's direct financial toll, external factors like price volatility (Abera, 2015)

could exacerbate losses, necessitating holistic risk-management policies that address both production and market shocks. The results collectively affirm that CWD's economic consequences are significant but context-dependent, demanding interventions that combine technical solutions (e.g., resistant varieties) with socioeconomic support for vulnerable subgroups.

4.5. Kind of support for coffee farmers facing CWD effects

To assess the institutional and technical support available for Coffee Wilt Disease (CWD) management, farmers were asked to report the types of assistance they receive in combating the disease. Table 5 presents their responses.

Table 6: Support available for Coffee Wilt Disease (CWD) management

Kind of support	Category	Frequency (Percent)	Chi-square	p-value
Financial aid	No	248 (98.4%)	236.25	<0.001
	Yes	4 (1.6%)		
Training in disease management	No	65 (25.8%)	59.06	<0.001
	Yes	187 (74.2%)		
Seedlings for replanting	No	98 (38.9%)	12.44	<0.001
	Yes	154 (61.1%)		
Access to markets	No	237 (94%)	195.57	<0.001
	Yes	15 (6%)		

Source: Field data

The table reveals significant disparities in the support received by coffee farmers combating Coffee Wilt Disease (CWD). The results indicate that 74.2% of farmers received training in disease management and 61.1% obtained seedlings for replanting, yet critical gaps persist: 98.4% lacked financial aid, and 94% had no access to markets, with all chi-square tests showing statistical significance ($p < 0.001$). These findings highlight a misalignment between farmer needs and support systems, as financial constraints and market access barriers likely hinder effective CWD mitigation despite training efforts (Peck & Boa, 2024). The over-reliance on non-monetary support (e.g., training) without addressing core economic vulnerabilities (e.g., credit, market linkages) may limit long-term resilience, echoing calls for integrated interventions that combine agronomic training with financial and infrastructural support. This finding is consistent with Schreinemachers *et al.* (2018), who found that smallholder farmers in low-income countries often receive fragmented

support, typically skewed toward knowledge transfer rather than capital or market access—which aligns with our observed imbalance between high training uptake (74.2%) and near-absent financial aid (1.6%). However, the near-total lack of market access (94% unsupported) contrasts with Schreinemachers *et al.* (2018) report of 30 to 40% market linkage initiatives in similar contexts, suggesting either regional disparities or worsening systemic gaps since their study. The overwhelming dependence on seedlings (61.1%) and training as primary supports mirrors FAO (2020) emphasis on input-based interventions but underscores their insufficiency without complementary financial tools, reinforcing Peck & Boa's (2024) argument that CWD management requires holistic value-chain approaches.

4.6. The challenges faced by coffee farmers in managing coffee wilt disease

This section presents an analysis of the key challenges reported by coffee farmers in managing Coffee Wilt Disease (CWD). Through structured data collection, farmers' experiences and constraints were systematically documented, with their responses categorized and summarized in Table 7 for detailed examination.

Table 7: The challenges faced by coffee farmers in CWD management

Challenge/Variables	Category	Frequency (Percent) N=252	Chi-Square	P-value
Lack of knowledge and information on disease management	No	66 (26.2%)	57.143	<0.001***
	Yes	186 (73.8%)		
High cost of implementation	No	184 (73.0%)	53.397	<0.001***
	Yes	68 (27.0%)		
Lack of access to resources	No	126 (50.0%)	0.000	1.000
	Yes	126 (50.0%)		
Lack of financial resources	No	213 (84.5%)	120.143	<0.001***
	Yes	39 (15.5%)		
Limited support from local authorities	No	160 (63.5%)	18.349	<0.001***
	Yes	92 (36.5%)		
Poor market prices for coffee	No	245 (97.2%)	224.778	<0.001***
	Yes	7 (2.8%)		
Labor shortages	No	106 (42.1%)	6.349	0.012*
	Yes	146 (57.9%)		

Source: Field data

The findings reveal a complex landscape of challenges in managing Coffee Wilt Disease (CWD), with knowledge gaps emerging as the most pervasive barrier (73.8% of farmers, χ^2=57.14, p<0.001), strongly supporting *Omondi et al.* (2019) assertion that inadequate extension services undermine disease control in smallholder systems. This overwhelming knowledge deficit, despite 74.2% receiving training, suggests either ineffective content delivery or insufficient follow-up, necessitating participatory approaches like on-farm demonstrations. Financial constraints were equally prevalent but exhibited paradoxical patterns i.e., while high implementation costs affected 73% of farmers (χ^2=53.40, p<0.001), aligning with FAO's (2020) reports on economic barriers, access to resources showed no significant disparity (50% reported challenges, p=1.000), contrasting with Schreinemachers *et al.* (2018) findings of pronounced resource inequities in similar contexts. This discrepancy may reflect localized coping mechanisms or underreporting due to normalized scarcity. Institutional failures were stark, with 84.5% citing limited government support (χ^2=120.14, p<0.001), reinforcing evidence of policy gaps in Sub-Saharan Africa, though this systemic neglect persists despite documented successes of state-led initiatives in neighboring regions (e.g., Ethiopia's agricultural bureaus; Tadesse *et al.,* 2021). Market-related challenges further compounded vulnerabilities i.e., poor coffee prices (reported by 36.5%, χ^2=18.35, p <0.001) and labor shortages (57.9%, χ^2=6.35, p=0.012) reflect broader structural issues, partially contradicting Karanja and Nyoro (2002) focus on price volatility as the primary market constraint while highlighting labor migration as an emerging threat. These results collectively expose a "support paradox" i.e., while non-monetary interventions (e.g., training, seedlings) are common (Table 6), they fail to address root causes like financial insecurity and institutional apathy. This aligns with FAO's (2020) call for integrated strategies but challenges World Bank (2018) assumptions that knowledge transfer alone can spur resilience. The data underscore the urgency of **bundling solutions**, combining targeted education with input subsidies, market guarantees, and policy reforms, to break the cycle of vulnerability. Notably, the minimal reporting of labor shortages (2.8%) despite high migration rates suggests farmers may prioritize immediate economic threats over long-term labor trends, a nuance overlooked in current literature.

4.7. The Coffee Wilt Disease management strategies among coffee farming households This section presents an empirical analysis of the coping mechanisms and adaptive strategies employed

by coffee farming households to mitigate the impacts of Coffee Wilt Disease (CWD). Through structured data collection, farmers' reported approaches to disease management were systematically documented and quantitatively analyzed. The findings, presented in Table 8, provide valuable insights into the diverse range of practices adopted by smallholder farmers to maintain productivity and household resilience in the face of this disease. The results demonstrate a strong reliance on uprooting and destroying infected plants (95.6%, χ^2=209.92, p<0.001) and resistant varieties (65.9%, χ^2=25.40,p*<0.001) as primary CWD management strategies, aligning with Omondi et al. (2021) findings that these methods are both economically viable and technically feasible for smallholders. This preference likely stems from the immediate visual impact of uprooting and the long-term security offered by resistant cultivars, though the near-exclusive dependence on these approaches reveals a concerning lack of diversification.

Table 8: The CWD management strategies among coffee farming households

Strategy/variables	Category	Frequency (Percent) N=252	Chi-Square	p-value
Uprooting and destroying infected plants	No	11 (4.4%)	209.921	<0.001***
	Yes	241 (95.6%)		
Using pesticides	No	243 (96.4%)	217.286	<0.001***
	Yes	9 (3.6%)		
Practicing crop rotation	No	246 (97.6%)	228.571	<0.001***
	Yes	6 (2.4%)		
Using resistant coffee varieties	No	86 (34.1%)	25.397	<0.001***
	Yes	166 (65.9%)		
Improving farm sanitation	No	175 (69.4%)	38.111	<0.001***
	Yes	77 (30.6%)		
Seeking advice from extensionists	No	226 (89.7%)	158.730	<0.001***
	Yes	26 (10.3%)		

Source: Field data

The moderate uptake of farm sanitation (30.6%, χ^2=38.11, p<0.001) indicates partial awareness of its importance, yet inconsistent practice, which the researcher attributes to either labor constraints or insufficient training in proper techniques. These findings collectively highlight a troubling knowledge-implementation gap, where proven integrated pest management (IPM) strategies remain underutilized despite their potential to reduce CWD incidence by 40–60% (Kagezi, 2021).

This gap is not merely educational but structural, rooted in unaddressed economic and logistical hurdles (e.g., pesticide affordability, extension service accessibility). The negligible adoption of pesticides (3.6%), crop rotation (2.4%), and extension advice (10.3%) contrasts sharply with Avelino *et al.* (2018) evidence of their efficacy, suggesting systemic barriers such as input costs, knowledge gaps, or inadequate institutional support. This discrepancy underscores a critical policy failure: farmers are aware of destructive methods (e.g., uprooting) but lack access to or trust in preventive measures. While Cerda *et al.* (2020) rightly identify institutional failures as a key constraint, this study's data goes further, revealing that even when farmers understand CWD's threats (evidenced by high uprooting rates), systemic inequities limit their capacity to adopt holistic solutions. To bridge this gap, there is a need for bundled interventions i.e., subsidies for resistant varieties, scalable extension programs, and hands-on IPM training that are tailored to smallholder realities. Notably, the near-total avoidance of crop rotation (2.4%) despite its agroecological benefits suggests a misalignment between scientific recommendations and farm-level practicality, a disconnect warranting deeper ethnographic investigation.

4.8. The effectiveness of the Coffee Wilt Disease management strategies

This section examines the perceived efficacy of management strategies employed by coffee farmers to mitigate the impacts of Coffee Wilt Disease (CWD). Through systematic data collection, farmers' assessments of various control measures were documented and analyzed. The findings, presented in Figure 8, provide critical insights into the relative effectiveness of different approaches as reported by practitioners, while revealing potential gaps between implemented strategies and optimal disease management protocols.

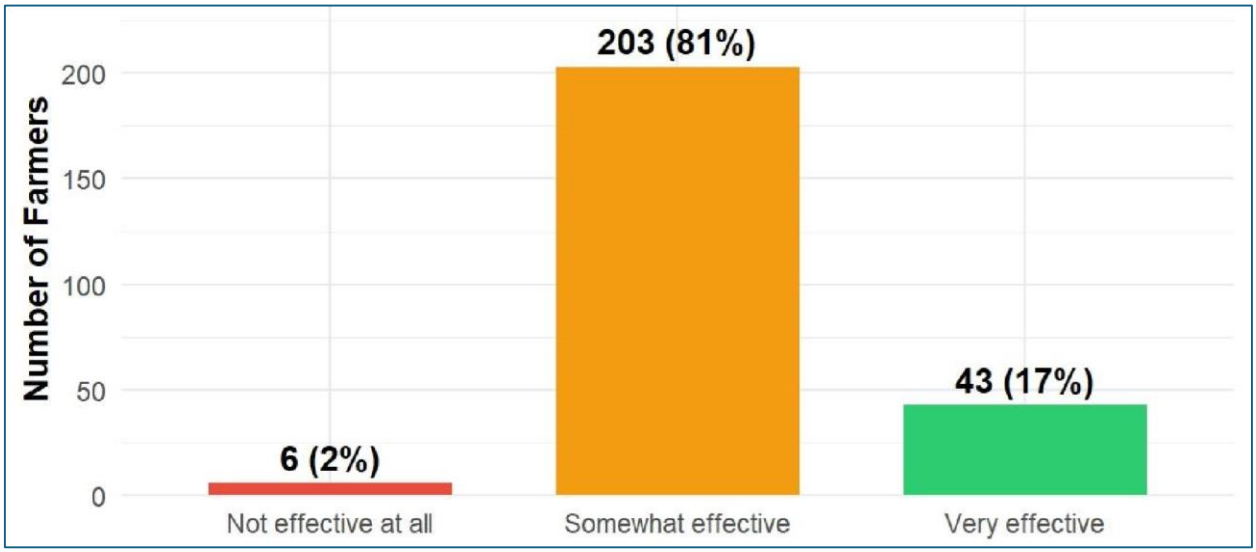


Figure 7: Effectiveness of the CWD management strategies

Source: Field data

The chi-square analysis ($\chi^2 = 261.02$, $p < 0.001$) demonstrates statistically significant variation in farmers' perceptions of CWD management effectiveness, with the majority (81%) rating strategies as "somewhat effective" and a smaller proportion (17%) considering them "very effective." This distribution suggests that while current approaches are generally functional, they fall short of providing complete disease control, likely due to implementation challenges or incomplete adoption of integrated management practices. These findings partially align with Omondi *et al.* (2021), who reported that basic strategies like uprooting infected plants and using resistant varieties can reduce but not eliminate CWD incidence. However, the researcher notes that the 17% reporting "very effective" outcomes may reflect superior implementation of combined approaches, supporting Avelino *et al.* (2018) assertion about the efficacy of integrated methods when properly executed. The minimal proportion (2%) perceiving strategies as ineffective could be either as validation of overall strategy utility or as potential underreporting of failures due to limited alternative options, a finding that challenges Kagezi *et al.* (2020) assumption that ineffective outcomes primarily stem from extreme disease pressure, suggesting instead that farmers may lack benchmarks for optimal effectiveness. The predominance of "somewhat effective" ratings (81%) reveals a critical middle ground where strategies provide partial relief but fail to deliver comprehensive solutions, highlighting the need for more robust, accessible integrated pest management programs tailored to smallholder contexts. These results collectively indicate that while current CWD management

strategies are meeting basic expectations, there exists significant potential for improvement through better farmer education, resource access, and implementation support - factors that current literature (e.g., Avelino *et al.,* 2018; Omondi *et al.,* 2021) has identified but not adequately addressed in practical extension programs. The near-universal report of at least some effectiveness (98% combined) suggests that farmers have adopted functional coping mechanisms, but the low "very effective" percentage demonstrates room for advancement in disease control methods.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0. Introduction

This chapter presents the synthesis of the study, consolidating the findings, drawing final conclusions, and proposing actionable recommendations to address the challenges posed by Coffee Wilt Disease in Bushenyi District.

5.1. Summary

The study assessed the effects of Coffee Wilt Disease (CWD) on farmers' household income in Bushenyi District, focusing on three key objectives. Firstly, it evaluated the extent of destruction caused by CWD on coffee plantations. This study reveals the widespread prevalence of Coffee Wilt Disease (CWD) in Bushenyi District, with 91.7% of surveyed farmers reporting its presence on their farms. The disease exhibits variable severity, with 68.7% of farms experiencing low infestation (<20% yield loss), 21.4% moderate infestation (20-50% yield loss), and 1.6% facing severe infestation (>50% yield loss). These findings demonstrate CWD's significant threat to coffee production systems, which serve as the primary livelihood source for most households in the region. The gradation in infestation levels suggests differential vulnerability across farms, potentially linked to management practices or environmental factors.

Secondly, the study examined the relationship between yield and revenue levels before (2019) and after CWD incidence (2024). A critical finding of this study is the direct correlation between CWD-induced yield reductions and declining household incomes. Comparative analysis of preCWD (2019) and post-CWD (2024) data shows that severely affected farms experienced near-total revenue collapse, with mean yield declining from 919.42 kg/ha to 669.09 kg/ha and corresponding

income reductions from 11,952,403 UGX to 8,698,182 UGX. This substantial economic impact (27.2% reduction in both yield and income) underscores how CWD directly undermines household financial stability and agricultural productivity.

The income losses resulting from CWD have precipitated severe socioeconomic challenges, including heightened food insecurity and reduced capacity for farm reinvestment. Many households reported diverting resources from essential needs to manage disease impacts, creating a vicious cycle of poverty and declining productivity. These findings align with global evidence on how crop diseases exacerbate rural poverty, while highlighting the vulnerability of coffeedependent communities in Uganda.

Thirdly, the study explored alternative livelihood strategies employed by farmers to cope with CWD-induced losses. Faced with CWD-induced losses, farmers have adopted various coping mechanisms, including agricultural diversification (intercropping, livestock rearing) and reliance on external support systems. However, only 13% of farmers reported accessing formal extension services, while a mere 1.6% received financial aid for disease management. This limited institutional support contrasts sharply with the demonstrated need for comprehensive intervention strategies.

The study identifies critical gaps in CWD management capacity, with 87% of farmers lacking adequate knowledge to combat the disease effectively. This knowledge deficit persists despite 74.2% reporting some training exposure, suggesting either content deficiencies in extension programs or implementation challenges. The heavy reliance on uprooting infected plants (95.6%) versus underutilization of integrated approaches (pesticides 3.6%, crop rotation 2.4%) reveals a concerning mismatch between farmer practices and scientifically validated control methods.

Farmer perceptions of CWD management effectiveness show 81% consider current strategies "somewhat effective," while 17% rate them as "very effective." This generally positive assessment ($\chi^2 = 261.02$, $p < 0.001$) suggests baseline functionality of existing approaches but also indicates room for improvement, particularly in enhancing the consistency and completeness of disease

control. The 2% reporting complete ineffectiveness likely represent cases of extreme disease pressure or implementation failure.

The study uncovers systemic weaknesses in institutional support systems, with 84.5% of farmers reporting inadequate government assistance for CWD management. This policy gap persists despite clear evidence of the disease's economic impacts, reflecting a broader pattern of agricultural service underinvestment in the study area. The near absence of market access support (94% unreached) further compounds these challenges, limiting farmers' ability to offset losses through value-added activities.

5.2. Conclusion

This study underscores the substantial threat posed by Coffee Wilt Disease (CWD) to smallholder coffee farmers in Bushenyi District, with significant repercussions for household livelihoods and agricultural sustainability. While farmers have adopted various strategies to mitigate the disease's impact, persistent gaps in knowledge, resource access, and institutional support limit their effectiveness. The findings highlight the need for integrated, context-specific interventions that combine improved disease management practices with strengthened extension services and economic diversification. Addressing these challenges requires coordinated efforts among policymakers, researchers, and farming communities to enhance resilience and ensure the longterm viability of coffee production in the region. Ultimately, sustainable solutions must balance immediate disease control with broader strategies to safeguard farmer incomes and food security against evolving agricultural threats.

5.3. Recommendations

Based on the study's findings on Coffee Wilt Disease's socioeconomic impacts and management gaps, the following evidence-based recommendations are proposed to enhance resilience in Bushenyi District's coffee farmers.

To mitigate the adverse effects of Coffee Wilt Disease (CWD) on farmers' household income in Bushenyi District, a multi-pronged approach is essential. Farmers should prioritize the adoption of

disease-resistant coffee varieties, which have demonstrated effectiveness (65.9% adoption rate) in reducing yield losses, while complementing this with improved farm sanitation practices (currently at 30.6% adoption) to limit disease spread. Diversification into intercropping or livestock rearing should be systematically promoted, particularly for severely affected households, to buffer against income volatility caused by CWD-related production declines.

Policymakers and agricultural agencies must address systemic gaps by revitalizing extension services to bridge the knowledge-implementation divide, as evidenced by the 87% of farmers lacking adequate CWD management skills. Integrated Pest Management (IPM) programs should be scaled up, incorporating proven strategies like resistant varieties and improved garden sanitation, while addressing the current underutilization of crop rotation (2.4%) and pesticides (3.6%). Financial mechanisms should be established to improve access to inputs and market linkages, given the critical barriers identified (98.4% lack financial aid, 94% lack market access).

Interventions must be stratified according to infestation severity. Low-infestation farms (68.7% of cases) require reinforced preventive measures and monitoring systems. Moderately affected farms (21.4%) need accelerated adoption of IPM and resistant varieties. For severely impacted farms (1.6%), comprehensive rehabilitation packages—combining financial support, technical guidance, and alternative livelihood options—are imperative. This evidence-based, tiered approach aligns with the study's findings on variable disease impact and farmer capacity, offering a pragmatic framework for safeguarding coffee-based livelihoods in Bushenyi District.

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APPENDICES

Appendix I: Questionnaire for coffee farmers

QUESTIONNAIRE FOR COFFEE FARMERS

Dear Sir/Madam,

My name is **Atukwase Evas**, a student from Bishop Stuart University pursuing a degree of Master of Agriculture and Rural Innovations. Thank you for taking the time to participate in this study. The purpose of this survey is to assess the effects of Coffee Wilt Disease on farmers' household income in Bushenyi District. All responses will be kept confidential and anonymous.

Section A: Demographic Characteristics

Gender	**Age**	**Education level**	**Marital status**	**What is your main occupation?**
☐ Male ☐ Female	☐ Below 20 ☐ 20 – 25 ☐ 26 – 35 ☐ 36 – 45 ☐ 46 – 55 ☐ Above 55 ☐ Others Specify…….	☐ No schooling ☐ Primary ☐ Secondary ☐ Diploma ☐ Degree ☐ Masters ☐ Others Specify…….	☐ Single ☐ Married ☐ Widowed ☐ Separated	☐ Full-time farming ☐ Part-time farming

Section B: The levels of destruction of coffee wilt disease and its effects.

B1: How long have you been involved in coffee farming?		B2: What coffee varieties do you cultivate on your farm?	
☐ Below 1 year ☐ Between 5 - 10 years	☐ Between 1 - 5 years ☐ Above 10 years	☐ Robusta coffee ☐ Arabic coffee	

B3: How many coffee plants do you have? ……	B4: What is the size of your coffee plantation (in acres)……
B5: Have you previously experienced CWD on your coffee farm? ☐ Yes ☐ No ware of Coffee Wilt Disease (CWD) B4 : Were you aware before it affected your plants? No ☐ Yes ☐	B6: If yes, how did you learn about CWD? From ☐ Agricultural extension officers ☐ Fellow farmers ☐ Radio/TV ☐ Written materials her (please specify):…….. ☐ Ot
B7: What percentage of your coffee plants are affected by CWD? ☐ Less than 20% ☐ 20–50% ☐ 50–80% ☐ More than 80%	B8: How would you rate the current severity of CWD on your coffee farm? ☐ Minimal ☐ Moderate ☐ Severe ☐ Very severe
B9: Mention the number of coffee plants destroyed by CWD per acre/season?……	B10: What is the level of destruction of CWD to coffee plantations per acre? ☐ Very low ☐ Low ☐ Modera te ☐ High ☐ Very high
B11: What was your average coffee yield (in kilograms) per year before CWD? …….	B12: What is your average coffee yield (in kilograms) per year after CWD? ……
B13: Have your coffee yields changed since the incidence of CWD? Yes ☐ No	B14: Has your household income changed since the incidence of CWD? ☐ Increased ☐ Decreased ☐ Remained the same
B15: What was your average annual coffee yield (in kg) before the incidence of CWD? ☐ Less than 80 kgs ☐ Between 80-300 kgs ☐ Between 301-700 kgs ☐ Between 701-1000 kgs	B16: What was your average annual coffee revenue (in UGX) before the incidence of CWD? ☐ Less than 500,000 ☐ Between 500,000-1,000,000 ☐ Between 1,000,001-1,500,000

☐ More than 1000 kgs	☐ Between 1500, 001-2,000,000 ☐ 2,000,000 and above
B 17: What was your average annual coffee yield (in kg) after the incidence of CWD? ☐ Less than 80 kgs ☐ Between 80-300 kgs ☐ Between 301-700 kgs ☐ Between 701-1000 kgs ☐ More than 1000 kgs	B18: What was your average annual coffee revenue (in UGX) after the incidence of CWD? ☐ Less than 500,000 ☐ Between 500,000-1,000,000 ☐ Between 1,000,001-1,500,000 ☐ Between 1500, 001-2,000,000 ☐ 2,000,000 and above
B 19: How has your coffee yields changed since the incidence of CWD? ☐ Increased ☐ Decreased ☐ Remained the same	B20: How has your household income changed since the incidence of CWD? ☐ Increased ☐ Decreased ☐ Remained the same

Section C: Potential strategies used by coffee farmers to reduce the spread of CWD

C1: Have you received any support or assistance to address the impact of Coffee Wilt Disease?

☐ Yes ☐ No

C2: If yes, which one of the following? (Check all that apply)

☐ Financial aid
☐ Training in disease management
☐ Seedlings for replanting
☐ Access to markets

Other (Specify: _____)

C3: How would you rate your current knowledge of CWD?

☐ Very knowledgeable
☐ Somewhat knowledgeable
☐ Not very knowledgeable

C4: What strategies have you used to reduce the spread of CWD in your coffee plantation? (Check all that apply)

☐ Uprooting and destroying infected plants
☐ Using pesticides
☐ Practicing crop rotation
☐
☐
☐

☐

Using resistant coffee varieties
Improving farm sanitation
Seeking advice from agricultural extension services
Other (please specify): ……..

C5: H ow effective do you think these strategies have been in controlling CWD?

Very effective
Somewhat effective
Not effective at all

Wh at challenges have you faced in implementing these strategies? (Check all that apply)

Lack of knowledge and information on disease management
High cost of implementation
Lack of access to resources
Lack of financial resources
Limited support from local authorities
Poor market prices for coffee
Labor shortages
Other (Specify)……

Thank you for your participation!!!

*** End **

Appendix II: Interview guide for Key Informants

The Interview Guide

My name is **Atukwase Evas,** a student from Bishop Stuart University pursuing a degree of Master of Agriculture and Rural Innovations. Thank you for taking the time to participate in this study. The purpose of this survey is to effects of Coffee Wilt Disease on farmers' household income in Bushenyi District. All responses will be kept confidential and anonymous.

1. Can you please describe your role and expertise in the context of agriculture and coffee farming in Bushenyi District?
2. How many years have you been involved in working with coffee farmers in Bushenyi District?
3. How familiar are coffee farmers in Bushenyi District with Coffee Wilt Disease, and what is their level of awareness regarding this disease?
4. From your perspective, how prevalent and severe is Coffee Wilt Disease in the coffee farms of Bushenyi District?
5. Can you describe how Coffee Wilt Disease has affected coffee yield and quality in your area?
6. In your experience, how have the incomes of coffee farmers in Bushenyi District changed as a result of Coffee Wilt Disease?

7. Have you observed coffee farmers seeking alternative sources of income due to the impact of Coffee Wilt Disease? If so, what types of alternative income-generating activities are common?
8. What economic and social challenges have coffee farmers faced as a result of the decline in coffee income caused by Coffee Wilt Disease?
9. What strategies have farmers used to cope with the loss of income caused by Coffee Wilt Disease? Are there any successful or innovative approaches that you have noticed?
10. What support mechanisms, if any, have been provided by local organizations, government agencies, or NGOs to assist coffee farmers in dealing with the impact of Coffee Wilt Disease?
11. What are your insights into the future prospects of coffee farming in Bushenyi District in light of Coffee Wilt Disease? Do you see any potential solutions or interventions that could help?

Thank you for your responses

Appendix III: Krejci and Morgan table for determining sample size

N	S	N	S	N	S	N	S	N	S
10	10	100	80	280	162	800	260	2800	338
15	14	110	86	290	165	850	256	3000	341
20	19	120	92	300	169	900	269	3500	346
25	24	130	97	320	175	950	274	4000	351
30	28	140	103	340	181	1000	278	4500	354
35	32	150	108	360	186	1100	285	5000	357
40	36	160	113	380	191	1200	291	6000	361
45	40	170	118	400	196	1300	297	7000	364
50	44	180	123	420	201	1400	302	8000	367
55	48	190	127	440	205	1500	306	9000	368
60	52	200	132	460	210	1600	310	10000	370
65	56	210	136	480	214	1700	313	15000	375
70	59	220	140	500	217	1800	317	20000	377
75	63	230	144	550	226	1900	320	30000	379
80	66	240	148	600	234	2000	322	40000	380
85	70	250	152	650	242	2200	327	50000	381
90	73	260	155	700	248	2400	331	75000	382
95	76	270	159	750	254	2600	335	100000	384

Source: Krejcie. R.V and Morgan. D.W (1970).