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MASTER'S THESIS

What determines the choice of control method for treating black sigatoka disease? Experience of small-scale banana farmers in the South-West region of Cameroon

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Declaration

I declare that this thesis entitled factors affecting the farmers' choice of Sigatoka Banana Disease control method among small-scale farmers in Cameroon is an original report of my research. It has been written by me and has not been submitted for any previous degree. All text in this thesis is original, and all the sources have been cited and acknowledged with complete references and in accordance with the citation rules of the FTA.

In Prague

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Sylvanus Agbor Tabi

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Abstract

Bananas are an important cash crop in Cameroon, contributing significantly to the national economy and the livelihood of local farmers. However, the production of the crop is seriously affected by the black and yellow (which is common in the temperate regions, reason why we focus on the black sigatoka because of geographical location which is in the tropic and sub tropic) sigatoka disease of banana, which has led to devastating effects, especially among smallholder farmers. This study investigates the control methods used and factors that influence the use of different control methods to manage sigatoka disease. The data used for the study was collected from 322 smallholder banana farmers in the Limbe and Buea districts of Cameroon in the year 2022. Descriptive statistics and multinomial logit were used in analysing the data. The majority of farmers (78.6%) have encountered sigatoka disease on their farms, with predominant symptoms reported as black dots and dry patches on the leaves (41.6%). Farmers reported a significant impact of black sigatoka on the price and yields (62.4% and 55.3%, respectively). There are three control mechanisms used by the farmers: chemical control, non-chemical control and no control at all. The use of chemical fungicides is the most preferred controlling mechanism among farmers (69.9%) as compared to other control methods. The results of the multinomial logistic regression indicate that the use of organic(agroecological) pest management is less likely among farmers who are older, religious, have more farming experience, own more land, have larger farms, and have access to extension services, compared to those who use chemicals. On the other hand, farmers with higher educating and better training who have agriculture as the main occupation and bananas as a prior income generating activity tend to apply more organic and or agroecological control methods, which are more sustainable and less harmful to the environment. Therefore, we suggest that farmers receive training in organic and agroecological control methods, and that extension workers are trained to effectively disseminate knowledge of these (agroecological) methods.

Keywords: sigatoka disease; socio-economic factors; chemical control; organic control; training; extension services.

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List of the abbreviations used in the thesis.

BLSD – Black Leaf Streak Disease

BPL – BOH Plantations Limited (BPL)

CDC – Cameroon Development Corporation

CRBP – Centre de Recherches Régionales sur Bananiers et Plantains

IITA – International Institute of Tropical Agriculture

PBC – Perceived Behavioural Control

RFLP – Restriction Fragment Length Polymorphism

SPM – Société des Plantations de Mbanga

1 Introduction

1.1 Background Statement

Bananas (Musa spp.) are the second largest fruit crop in the world, with an annual production of 130 million tonnes. It is ranked as the fourth most important staple food worldwide (Weber et al., 2017) and has long played an important role in agricultural production on all continents (Strobl and Mohan, 2020). In 2018, a total of 11.3 million hectares were used to grow 154.5 million tonnes of produce worldwide, of which 74% were bananas and 26% plantains (FAOSTAT, 2021). Bananas originated in Southeast Asia, Asia and the Western Pacific. However, over the centuries they spread to other tropical regions, namely sub-Saharan Africa, Latin America and the Caribbean, and the southern Pacific, where they gained in popularity and commercial importance (Ujat et al., 2021; Salas-Pascual and Cáceres-Lorenzo, 2022). In Africa in particular, countries such as Angola, Kenya, Tanzania and Rwanda are the continent's main banana producers (Scott, 2021). Africa produces 30-35 million tonnes of bananas annually, the majority of which are produced in Angola, Tanzania, Rwanda, Kenya, Egypt and Cameroon (Scott, 2021).

As in other West African countries, bananas are one of the most important staple crops in the humid forest areas of Cameroon. Banana production plays a key role in the livelihoods of the rural population, a significant proportion of whom are engaged in small-scale banana farming. Despite this, cultivation is severely affected by pests that affect production, including bacterial wilt (Addy et al., 2016), nematodes (Seenivasan, 2017), fusarium wilt (Dita et al., 2018), and the yellow and black sigatoka diseases (Salas-Pascual and Cáceres-Lorenzo, 2022). In particular, the relentless attacks of black Sigatoka disease are the most severe in Cameroon and other African countries (Kimunye et al., 2021; Kimunye et al., 2021). The disease is characterised by rapid leaf damage (Fig. 1). forming small black spots which turns to yellow patches that merges to form large black patches on the leaves as the disease grows. This results in yield losses, which has led to reduced incomes and increased vulnerability among smallholder farmers, who often lack access to advanced agricultural technologies and knowledge to mitigate the disease (Reuveni et al., 2020).

Figure 1: Black Sigatoka attack on plant leaves (Source, by author during field survey)

The parasite reduces the plant's capacity for photosynthetic activity, which has an impact on the production and growth of the plant and promotes premature ripening of the banana clusters which is a major cause of economic loss (Souleymane et al., 2022). Chemical control is thought to be effective, however issues can occur when it is used carelessly and harms both the environment and human health. The cost of agrochemical-based control is also high (Churchill, 2011). Large plantations spend about US $1,000 per hectare annually on disease control, which can account for up to 30% of overall production cost globally (Churchill, 2011; Alakonya et al., 2018). The potential medium- and long-term selection for pathogen strains acquiring fungicide resistance, potentially reducing effectiveness, should be taken into account with dependence on agrochemicals (Churchill, 2011; Chong, 2020).

Synthetic fungicides have primarily been used to manage Black Sigatoka, although there is recorded evidence that these fungal populations have become resistant to these chemicals (Reuveni et al., 2020). As a result, several strategies to lessen the severity of this illness have been put forth.

Biological management techniques are an option since, when used in conjunction with good agricultural practices, they are reasonable, dependable, and ecologically responsible (Mengesha et al., 2023). Most tropical crops, especially those with significant economic value like the banana, have not been extensively investigated in terms of using antagonist microbes. The use of biological agents to tackle this disease is now being studied in both the field and labs.

1.2 Problem Statement

Banana is an important crop, relevant to achieving food security and raising the livelihoods of many households in Africa, particularly in West Africa, where it has become a major staple and serves as a major source of income in various household in Africa (Ahohouendo et al., 2020). Bananas provide more than 25% of the carbohydrates for more than 70 million people in the region (Boris et al., 2023; Arora et al., 2022). However, a serious foliar disease called the Black Sigatoka is limiting farmers' output along with its production.

Black Sigatoka disease poses a significant threat to the profitability and sustainability of small-scale farmers in Cameroon, jeopardising their livelihoods and food security (Monono *et al*., 2023). Despite the importance of bananas in the country's agriculture and economy, the disease's relentless attacks have led to substantial crop losses and reduced yields (Olumba and Onunka, 2020). Conventional disease control measures, such as fungicide applications, have shown limited efficacy and raised concerns about environmental impacts and farmer health (Becker et al., 2021). Therefore, there is an urgent need to identify effective and sustainable strategies for combating black Sigatoka disease while enhancing the profitability and resilience of small-scale farmers.

The development and spread of black Sigatoka disease has been the most significant setback to banana production during the past three decades (Ahohouendo et al., 2020). The fungus attacks the leaves causing partial or complete necrosis and reduces the amount of photosynthetic foliage. Depending on the amount or severity of the disease, it leads to drop in yield. According to studies, black Sigatoka has been observed to reduce banana yields by about 20 to 50% over the course of a crop cycle (Ahohouendo et al., 2020). In addition to decreasing output, the disease also causes fruits to ripen too soon (Fullerton and Casonato, 2019). Bearing these problems in mind, this research examine the effect of various factors on the selection of different control methods of Sigatoka disease in the smallholder farms in Cameroon.

The existing literature offers limited insight into the most efficient and practical control methods tailored to the specific context of small-scale farmers in Cameroon. The lack of evidence-based

guidelines hampers the design and implementation of targeted interventions to empower farmers with the necessary knowledge and skills to tackle the disease effectively. Moreover, the economic viability and long-term sustainability of these control methods in the face of evolving challenges remain unclear. Thus, this study seeks to address these critical knowledge gaps by evaluating and comparing various methods for profitability and sustainable resistance control of black Sigatoka disease among small-scale farmers in Cameroon. By assessing the impact of different control methods on farmers' profitability, adoption of sustainable practices, and long-term agricultural sustainability, the research aims to provide practical and context-specific recommendations to support small-scale farmers in their battle against black Sigatoka disease and promote resilient and profitable agricultural practices in Cameroon.

2 Literature Review

This chapter presents a comprehensive review of relevant literature pertaining to the factors influencing small-scale farmers' choices of Sigatoka Banana Disease (SBD) control methods in the world and in Cameroon. This literature review explores various dimensions surrounding the adoption and selection of disease control methods within the specific context of banana farming in Cameroon. The review further navigates through existing scholarly works investigating the diverse array of factors that influence farmers' decision-making processes regarding SBD control methods. It synthesizes insights from studies examining socio-economic variables such as access to resources, financial constraints, and labor availability, alongside considerations of environmental factors and agricultural practices.

According to FAOSTAT (2018), banana (*Musa spp*) with an annual production of 130 million metric tons, rank as the second largest fruit crops in the world, respectively. According to the FAO, 2016, the major banana-producing nations in Africa are Cameroon, Kenya, Cote d'Ivoire, Tanzania, and Uganda. Additionally, there is proof that Africa is the top global producer of bananas, with 33 million metric tons produced globally (FAO, 2016). The top producing nations include Angola, Tanzania, Rwanda, Kenya, Egypt and Cameroon. In West Africa's humid forest zone, bananas are among the most important staple foods (Faturoti et al 2007).

Banana are one of the economically viable plants and different diseases, potentially affect the production of the plant. The main biotic factors limiting the yield of bananas have been identified as pests and diseases (Blomme et al., 2020). Generally, low banana yields have been due to a

number of factors, including pests (banana weevils and banana nematodes), drought, poor soils, and diseases such as Banana Bunchy Top Virus (BBTV), Fusarium wilt, burrowing nematode *Radopholus similis*, banana bacterial wilt, black Sigatoka, *Colletotrichum musae*, Banana Streak Virus(Gold et al., 1994; Churchill 2011; Blomme et al. 2013. Tushemereirwe et al., 2003; Ploetz et al. 2015; Wong et al. 2012). According to Tushemereirwe (1996), Black Sigatoka has been linked to yield losses of up to 37% for bananas in Uganda. A fungus known as Fusarium *oxysporum forma specialis cubense* causes major disease of Banana such as the Fusarium wilt (also known as Panama disease of banana) (Roberts et al., 2024). The disease is known to affect the plant's vascular system, leading to wilting, yellowing of leaves, and eventually death (Roberts et al., 2024). Another disease of banana is the banana bunchy top virus, which is caused by a virus and transmitted by banana aphids (*Pentalonia nigronervosa*) (Jekayinoluwa et al., 2020). One of the major effects of the disease is that it leads to stunted growth, abnormal leaf development, and a characteristic "bunchy" appearance of the leaves (Jekayinoluwa et al., 2020). Similarly, the anthracnose disease, which also has a very devastating effect on banana by causing post-harvest losses such as the rot of banana fruit (Al-Dairi et al., 2023). A fungus known as Colletotrichum musae causes the disease (Al-Dairi et al., 2023). Moko disease is also seen as a major disease of banana and this disease is caused by a bacterium (Ralstonia solanacearum) with signs such as wilting, yellowing, and rotting of pseudo stems and fruit of banana, which eventually leads to the death of the plant (Tinzaara et al., 2021). This disease spreads on farms through infected soil, water, and contaminated farming tools (Tinzaara et al., 2021). Apart from all the diseases that have been mentioned, Nematodes such as Radopholus similis (banana nematode) and Pratylenchus spp. (root lesion nematodes) affects the roots of nematodes causing stunting, root galling, and reduced nutrient uptake in plants (Bahadur, 2021). They also increase the susceptibility of the plant to other disease. Other disease of Banana includes the Banana bract mosaic virus, banana streak virus, stem end rot and Panama wilt (De-Souza and De-Goes, 2020). These diseases significantly limit banana production (Mendoza Rodriguez et al., 2018). However, the disease that is of importance in this study is the sigatoka disease of banana. The disease got its name since it was initially discovered in the Sigatoka district of Fiji in 1963 (Drenth and Kema, 2021). After that, black Sigatoka was discovered in southern Mexico and Central America between 1977 and 1980 and Honduras in 1972 and was initially identified in Africa in 1973 in Zambia and then1978 in Gabon (Avwerosuo, 2021). When describing the sigatoka disease, we have the yellow sigatoka disease and the black

sigatoka disease of banana (Nascimento et al., 2020). Although, both sigatoka disease has similar symptoms but their causative organism is different (Nascimento et al., 2020). For instance, a fungus known as *Mycosphaerella musicola* causes the yellow sigatoka disease while the fungus known as *Mycosphaerella fijiensis* causes black sigatoka disease (Arcilia-Galvis et al., 2020). Yellow sigatoka disease affects the leaves of the banana and start by forming small yellow stripes at the edges of the leaves then grows to the centre and merges to larger patches as the disease grows commonly found in the temperate regions where banana is grown as reported by (Jones 2000; Mourichon 2003). which is also the same as the black sigatoka disease which starts by forming small black spots which turns to yellow patches that merges to form large black patches on the leaves and is common in the tropics and sub tropics but what distinguishes the black Sigatoka disease is the development of dark, necrotic spots on the plants (De-Souza and De-Goes, 2020). Severe infection of the disease can lead to defoliation and reduced level of photosynthesis by the plant (Arcilia-Galvis et al., 2020).

Sigatoka disease affects both banana and it is spreading quickly in tropical coastal areas (Stover 1972; Carlier et al. 1994; Jones 2000). Black Sigatoka was first discovered outside of Asia and Oceania in Honduras in 1972 (Stover and Dickson 1976), however it is possible that species lived there much earlier. Black Sigatoka in Central America reached epidemic levels in the years preceding 1981. The disease first appeared in South America in 1981, and by 1998, it had spread to every region of Latin America where bananas are grown. The transfer of planting material from Asia contributed to the history of black Sigatoka's dispersion and spread in Africa (Pasberg-Gauhl et al., 2000). An unverified report of the disease was made in Zambia in 1973, almost simultaneously with the finding of black Sigatoka in Honduras. Black Sigatoka was not discovered in Africa until five years later in Gabon, and it moved fast up the West Coast until it reached Cameroun in 1981 (De-lapeyre et al., 2006) and Côte d'Ivoire in 1985. Primarily the main causative organism for the Black sigatoka disease is the Pseudocercospora fijiensis (formerly known as *Mycosphaerella fijiensis*). The fungus produces spores on infected leaves, which spread from plant to plant through water and wind (Strobi and Mohan, 2020). This fungus infects the banana plants through the stomata on the leaves thereby causing lesion on the leaves (Esguera et al., 2024). Various other factors contribute to the spread and severity of the disease globally and these include the environmental conditions of the vicinity where the banana is planted (Esguera et al., 2024). This is because it has been empirically proven that the diseases thrive in areas with high humidity

and temperature which ranges from 24 to 30 degrees Celsius while the presence of heavy rainfall enhances the spread of spores of the fungi (Kimunye et al., 2020). According to 2013 research by Luis Perez Vicente, there is a correlation between rainfall and the rate at which black sigatoka disease spreads across countries in Latin America and the Caribbean like Cuba, Costa Rica, and Ecuador. Contrarily, stringent precautions should be implemented during wet seasons to eradicate the disease's inoculum and so lessen the effects of epidemics (Avwerosuo, 2021). All these conditions are well evident in the Cameroonian climate thus predisposing farmer's plants to it. In addition, some cultivars of banana are known to be susceptible to the disease and most of these cultivars are common among the Cameroon farmers (Mbo et al., 2024). The susceptible species include the local varieties, Cavendish, apple banana, bluggoe banana, goldfish banana among others (Soares et al., 2021; Sumi et al., 2022). However, there are also resistant varieties like the Calcutta 4, Narita hybrids, Pisang Lilin, FHIA cultivars (including FHIA-17, FHIA-18, FHIA-21, FHIA-23, and FHIA-25), Paka and Tuu Gia among many others (Soares et al., 2021; Kimunye et al., 2021; Esquera et al., 2024; Bamaba and Alassane, 2021). It should be noted that even the resistant varieties are not completely resito the disease making the disease a major challenge for growers (Ahohouendo et al., 2020). Other causes of the disease include the farming system especially the use of the monoculture farming system where a large area of land is cultivated with a single cultivar of banana (Ahohouendo et al., 2020). This makes it easy for the disease to spread because of build-up of inoculum or spores in the soil. Disease management practices among the farmers also contributes to why the disease has continued to cause havoc and these include poor cultural practices by the farmers in the areas of weed control, sanitation, and pruning among others (Drenth and Kema, 2021). Likewise, the uncontrolled use of fungicides without proper use guidelines also contributes to the continuous development of new strains of the fungi on the farms thus making the use of chemical control of little or no effect on the farms (Sumi et al., 2022). Additionally, reliance on fungicides without proper rotation and application practices can lead to the emergence of resistant fungal strains, reducing the effectiveness of chemical control measures (Sumi et al., 2022).

The major effect of this disease banana is multifaceted and quite damaging because it affects not just the plant but also the economic value of the plant (Strobi and Mogan, 2020). Generally, the presence of black sigatoka disease on the plant leads to defoliation of the leaves of the plant by causing characteristic dark brown to black spots and as the disease progresses, these spots become

large causing necrotic areas on the leaves (Esguera et al., 2024). These can further lead to reduced photosynthetic capacity of the plant, which may eventually lead to reduced yield, stunted growth and the death of the plant (Esguera et al., 2024). Additionally, the black sigatoka disease typically reduces the yield of the plant and affect the fruit quality drastically because of non-production of fruits, early ripening of fruits and immature fruit development, which are characteristics of the disease on the plant. This could lead to losses on the part of the farmers due to reduction in harvest, bad fruits and reduction in the shelf life of the fruit (Ahoheundo et al., 2020). Furthermore, the effect of the disease could have economic impact on the livelihood of farmers who depend on it for their livelihood and could affect the earning generated from the export of the fruit to other countries due to loss of potential because of the disease infection (Kimunye et al., 2020). The impact of the disease can also be felt in the area of food security because it reduces the availability of the food in the market as result of destruction to the plant caused by the disease (Strobl and Mohan, 2020). Additionally, the disease also has effect on the cost of production because of the need to apply fungicide on a regular basis to control the disease especially for the farmers who can afford the cost of the fungicide (Sileshi and Gebeyehu, 2021). Farmers who cannot afford the use of fungicides rely on other labour intensive actions such as the use of cultural practices all, which affects the cost of production. This makes the smallholder farmers who are resource constrained more susceptible to the effects of the disease because of the lack of resources to mitigate against its effect (Jomanga and Lucas, 2021).

However, the fact that these crops are traded both locally and internationally, in addition to their contributions to food and nutritional security in both rural and urban regions (Olumba and Onunka, 2020), has made them important sources of income. There is a high potential for increasing banana productivity and yield stability if there are effective control methods for the disease. The effect of it being that there would be increased food security, increase in the GDP of the agricultural sector and improved standard of living for the farming community by raising their incomes.

2.1 Control of Sigatoka Disease in Bananas

Disease control is quite important in the management of any disease. For the management of any disease such as the black sigatoka disease, there are different approach, which are quite applicable.

2.1.1 Organic Control

The use of organic control methods for the control of sigatoka disease is an approach that eliminates the use of chemical but places emphasis on minimising the environmental impact and

ensuring sustainability (Kumakech et al., 2022). This method is beneficial because it prioritises ecological balance, soil health, and biodiversity conservation (Lim et al., 2023).

Organic control methods usually involve the use of cultural, biological, mechanical, and physical techniques to prevent or suppress disease on the farm without the use of chemicals (Costa et al., 2023). Some of the approach to organic control include the use of cultural practices, which is common among farmers in Cameroon and involves things like crop rotation, adequate spacing, mulching, and proper sanitation of the farms among other cultural practices. Mulching been considered a crucial method of soil management (Costa et al., 2023). Mulching the soil helps to improve the soil environment, which is necessary for healthy crop growth and yields. As an illustration, Ruhigwa (1993) also discovered that the first ration crop's banana output increased by 21% when *Pennisetum purpureum* mulch was applied. In addition to mulching, mechanical treatment or pruning focused on removing necrotic leaf tissue stops the disease from affecting nearby banana in the plantation. Necrotic banana leaf tissues should be removed because doing so can help to drastically minimise the amount of inoculum that is available to infect other plants (Rawat et al., 2021).

Biological control is also any approach where beneficial microorganisms, like *Trichoderma spp*. and *Bacillus spp*, which have potential in suppressing the Sigatoka disease are introduced on the farms (Dadrasnia et al., 2020). However, the challenge here is that the farmers may not have the expertise to implement this approach (Dadrasnia et al., 2020). Additionally, the use of organic Amendments such as compost, mulching and bio-fertilizers can enhance the health of the soil thus enhancing plant vigour and making them resistant to the disease (Chakraborty, 2020). It has been demonstrated that soil fertility affects banana growth, and thus, the severity of black Sigatoka (Tatsegouock et al., 2020). According to Mobambo and Naku (1993), there is a connection between soil fertility and banana black Sigatoka severity. On fertile land, Black Sigatoka severity is lower than on poor soil. For instance, fertile soils with increased soil organic matter concentration encourage root ramification, which improves water and nutrient intake and makes plants grow more vigorously. Black Sigatoka disease cause considerably less harm to plants that are growing vigorously (Mengesha et al., 2023).

Other control methods include the use of botanical extracts such as Neem oil and garlic extract among others, which have antifungal properties and are effective in the management of fungal

diseases like Sigatoka (Kumakech et al., 2022). We also make use of resistant varieties as part of the organic control methods (Kimunye et al., 2021).

2.1.2 Chemical Control

The application of chemicals, particularly fungicides, could be used to control the black Sigatoka disease in bananas. The definition of a fungicide is "agents of natural or synthetic origin, which act to protect plants against invasion by fungi and/or to eradicate fungal infection" (Hewitt, 1998). Protectant and systemic fungicides are the two main categories of fungicides. The first class of fungicides to be discovered and applied for crop protection were called protectors. They don't penetrate plant tissue since they are non-systemic. Since protective fungicides don't actually penetrate plant tissues, they are unable to combat fungi that have already established themselves there.

However, systemic fungicides were created in the late 1960s. These are more effective than the protectants since they can enter plant tissues and work to halt the development of fungal infections that are already present there (Hewitt, 1998; Marn, 2003). Black Sigatoka disease in bananas has been effectively controlled. with the application of fungicides (Fouré, 1983; Marín et al., 2003), particularly when protectant (mancozeb and chlorothalonil) and systemic fungicides (benomyl, benzimidazoles, dethiocarbamates, flusilazoles, imazaliles, methylthiophanates, nuarimols, prochloraz, propiconazoles, triazoles and tridemorph) are used in alternation (Fouré, 1983; Marín et al., 2003). To prevent the fungal pathogen (*M. fijiensis*) from acquiring resistance to the active component, it is advised to alternate between using protectants and systemic fungicides.

It has been demonstrated that mineral oil plays a number of significant roles in the chemical regulation of black Sigatoka. It has a significant impact on the pathogen inside the leaf and boosts the spreading and sticking capabilities of fungicides as well as the penetration of systemic fungicides (Stover, 1990). Oil also has fungicidal properties. Oil treatment slows the growth of pathogens inside the leaf, which prevents disease from developing in the leaf. When the pathogen is still developing, this control is primarily applied to the initial open leaves. Whether used alone or as an emulsion in water, oil is effective. However, the Sigatoka disease in bananas was the first to be controlled by this method. Because they penetrate through the top surface of the newest, unrolled leaves, where the pathogen is still in the early stages of infection, they are superior to protectant fungicides. The pathogen inside the leaf is also affected by benzimidazole and tridemorph, in addition to oil. Systemic fungicides offer better disease control during periods of

excessive rainfall when compared to protectants added later (Stover, 1990). Protective fungicides are more expensive and ineffective at controlling black Sigatoka when ascospore formation is high and rainfall is heavy. Contrary to protectants, systemic fungicides have the drawback of causing phytotoxicity in plants when used during dry seasons.

2.2 Factors Affecting the Control Methods of Sigatoka Disease

Various factors were hypothesised to have a significant impact on farmers' methods of controlling sigatoka disease, and these various factors were consequently examined.

2.2.1 Age

Age is an important factor in driving the use of control methods adopted by farmers especially in the control of sigatoka disease. This is because age plays a role in how farmers look at new approach to disease control and how they tend to adopt new approaches, which may not be in line with what they know and the experience they have gained over time. Their perception of risk and attitude towards change may also be affected by their age, as older farmers may be more averse to risk when compared to their younger counterpart (Khan et al., 2020). They may also be resistant to change. In the study of Serebrennikove et al. (2020), farmer's age was found to have a negative significance on the adoption of organic practices. This shows that age is a significant variable in the approach being used by the farmers in the control of the disease in the study area.

2.2.2 Sex

Sex is a major factor to be considered in any study. This is because of many reasons such as the role of gender in the African tradition thus giving women lesser chance and opportunity in decision making (Adom and Anambane, 2020). For instance, studies by Ankrah et al. (2020); Anderson et al., (2021), have shown that males have greater access to resources thus placing women at the back role. Additionally, the female sex are less autonomous in decision making thus affecting the type of control method applied in their farms when compared to their male counterpart who are more autonomous in their decision making.

2.2.3 Education

Education looks at the literacy level of the respondents and this is important because education has influence on the awareness level of the farmers about sigatoka disease and farmers who are educated about could be more inform on the approach to use in controlling the disease (Madalla, 2023). Additionally, education can help the farmers in gaining skills and capacity to effectively manage the disease and control it on their farmers while also enhancing their ability to access the

likely risks and severity they face from not using an effective method of control on their farm (Ahohouendo et al., 2020). Furthermore, access to information critical for the control disease on the farmers may be better accessible to farmers who are educated when compared to those with lower educational level (Mashi et al., 2022).

2.2.4 Occupation

Farmers who have farming as their main occupation have the tendency of adopting better control methods when compared to respondents who take it as a secondary occupation as seen in the study of Wole-Alo and Oluwagbemi (2020), who looked at how occupation influenced adoption among farmers. This is because farmers who take it as their primary occupation devote more time to the activity and thus through continuous practice gain more knowledge as to the best approach to use (Wole-Alo and Oluwagbemi, 2020). Additionally, farmers who take farming as their primary occupation tend to have versatile knowledge on different approach to the control of the disease (Jacquet et al., 2022). On the other hand, those who take it as a secondary occupation may lack the pre-requisite knowledge towards control and may lack decisiveness in making decision as to the control method to use in controlling the disease.

2.2.5 Religion

Religion do not have any restriction on the cultivation of Banana in Cameroon. This is because all religion fully accepts the cultivation and consumption of the crop (Udomkun et al., 2021). However, religion can play a significant role on the type of information that is available to the farmers (Wang et al., 2021). This is because of the social nature of the religious gatherings, which may bring people with similar challenges together and shape the values and norms of the farmers and how they perceive events (Wang et al., 2021). Through such process influencing the approach adopted by the farmers.

2.2.6 Years of banana farming

The years of banana, farming is synonymous to the farming experience of the farmers and this is important in shaping farmers' knowledge, skills, and their decision-making processes regarding disease control strategies. Some of the ways through which the experience of the farmers come to play in shaping control strategies include knowledge of control options which is better enhanced as the farmers year of experience increase (Osterman et al., 2021). Additionally, the years of experience give the farmers more advantage in understanding the symptoms of diseases and taking precautionary measures for the control of the disease (Doidge et al., 2020). It also gives them

leverage in terms of networking and building an information base which they can rely on to access different control methods (Shaikh et al., 2022).

2.2.7 Land Ownership

Land ownership is quite an important factor to consider in the control of the disease. This is because of the issue of land tenure, which limits the capacity of farmers to make long-term investment on lands (Adenug et al., 2021). For instance, farmers with insecure land tenure are less inclined to invest in long-term disease management strategies (Adenuga et al., 2021). This is because of the risk of losing access to land, which can deter them from taking on control methods with long-term effects. Thus, such farmers are more inclined towards short-term gains over long-term sustainability. This can lead to over-reliance on chemical inputs or unsustainable land management practices to maximize immediate yields.

2.2.8 Farm Size

The size of farms being kept by the banana farms could be critical in the adoption of control methods. This is because of size and scale, which the size of the farm confers. As such, farms with larger sizes have the tendency of placing more emphasis on control method that are effective and meet their scale of needs (Petit et al., 2020). When the organic control method and chemical control methods are placed side-by-side, large-scale farms have the tendency to adopt chemical control because of the efficacy of such approach and the need to protect the large scale of investment of investment using a cost-effective approach (Petit et al., 2020). However, small-scale farms may be thrown between the use of both approach depending on the level of resources that is available to the farmers. Additionally, the risk faced by larger farmers is much and thus influencing what strategies they might adopt or use in disease control (Marie et al., 2020).

2.2.9 Banana main income

Banana farming serves as a significant income source for many farmers, particularly in the tropical regions where Banana is a staple crop and have high market demand (Olumba and Onunka, 2020). As such, farmers who have it has a main income source may opt for a cost-effective approach to pest management to reduce the cost of production. Additionally, farmers who have it as a main income may give consideration for market preferences such as demand in determining the control method to use (Udomikun et al., 2021). For instance, a farmer whose aim is to supply a certain quantity of the fruit within a certain period may opt for the chemical control method but when the preference is to meet the consumer needs the farmers may opt for the use of organic control

methods. In addition, because it is their main source of income, farmers may choose an approach that ensures that production is maintained on the same land for a long time (Amakwah, 2023).

2.2.10 Getting Adequate Training

Adequate training is crucial in influencing the control methods used by farmers for managing Sigatoka disease in bananas. This is premised on the fact that training creates awareness about the disease and the possible control methods that is available to the farmers (Abiola et al., 2020). According to Abiola et al. (2020), farmers who receive training on the disease are likely to be aware about the possible control methods. As such, farmers who receive adequate training tend to have the necessary information to make decision on the control methods to adopt (Waseem et al., 2020). In addition, through training, farmers become familiar with various control methods available for managing Sigatoka diseases. As such, adequate training empowers the decision making process of the farmers and gives them the pre-requisite knowledge that is needed to take the right decision (Gratia and Fawzi, 2021).

2.2.11 Access to Extension Service

Extension services provide farmers with essential knowledge, technical advice, and support to implement effective disease management practices (Antwi-Agyei and Stringer, 2021). Extension services communicate knowledge on subject matters to farmers and through it farmers can gain knowledge as to what is to be done and what can be done to prevent the disease (Van-Campenhout et al., 2021). This is because access to extension services helps farmers understand the principles of disease control and it empowers them to know what to do when they are faced with the challenge (Livune, 2022). However, for the extension service to be effective, it must be accessible and have the right content for the farmers so that it can empower them to take the right decision (Antwi-Agyei and Stringer, 2021).

2.3 Aims of the Thesis

2.3.1 General objective

The main objective of this thesis is to document and analyse the control methods used by smallholder banana farmers to control Black Sigatoka disease and the factors that influence the choice of control method among smallholder banana farmers in Cameroon. This research seeks to identify the most efficient and practical strategies to empower farmers with the knowledge and skills necessary to combat the disease effectively. Additionally, the study aims to evaluate the long-

term sustainability and economic viability of these methods, ultimately contributing to the advancement of agricultural practices and the well-being of small-scale farming communities in the region.

2.3.2 The Specific Objectives

Specifically, the research is guided by the following objectives:

i. To examine the knowledge of Sigatoka Disease among the Farmers in the study area
ii. To explore farmers' perceptions of black sigatoka disease management.
iii. To examine the different control methods used for the disease by the farmers.
iv. To identify factors influencing the control method used by the farmers in the study area.

2.3.3 Research Question

i. What is the level of farmers' knowledge regarding black sigatoka disease in banana crops within the study region?
ii. Which control methods are used by the farmers in the study area for the control of the disease?
iii. What are the factors influencing the use of organic control for black sigatoka disease in the study area?

2.4 Theoretical framework

The theoretical underpinning guiding the analysis of farmers' decision-making regarding pest management strategies for black sigatoka disease in banana crops is grounded in Rational Choice Theory (RCT). Originating in the 1950s, RCT inherited the principle of the "economic man hypothesis" from classical economist Adam Smith, suggesting that individuals are rational actors who seek to maximize their utility by making choices that optimize their interests while minimizing costs (Li, 2001).

In agricultural contexts, RCT suggests that farmers make decisions regarding pest management strategies by evaluating available options and selecting the one that maximizes their utility, considering factors such as effectiveness, cost, and resource availability. This decision-making process is influenced by various factors, including demographic characteristics, socioeconomic status, agricultural experience, and access to resources (de Araújo et al., 2021). Furthermore, RCT has been extended to incorporate concepts such as bounded rationality, bounded willpower, and bounded self-interest, which recognize the limitations of human decision-making processes (Wang et al., 2022). Bounded rationality refers to individuals' limited cognitive abilities, leading them to

make decisions based on heuristics rather than exhaustive calculations. Bounded willpower acknowledges the challenges individuals face in maintaining self-control and adhering to long-term goals. Bounded self-interest recognizes that individuals may prioritize values other than pure self-interest, such as social norms and peer influence (Wang et al., 2022).

In the context of black sigatoka disease management, farmers' decision-making is influenced not only by socio-economic considerations but also by social interactions and norms within their communities. Social networks and peer effects can play a significant role in shaping farmers' preferences and behaviors (Gao et al., 2022). Therefore, understanding farmers' decision-making processes requires considering both economic interests and social dynamics. To analyze farmers' decision-making regarding pest management strategies, a multinomial logit model is employed, with dependent variables representing different control methods: no control, chemical control, and organic control. This model incorporates various independent variables representing demographic, socioeconomic, and experiential factors, allowing researchers to examine the factors influencing farmers' adoption of specific pest management strategies and test hypotheses derived from RCT and related theories (Kasargodu Anebagilu et al., 2021).

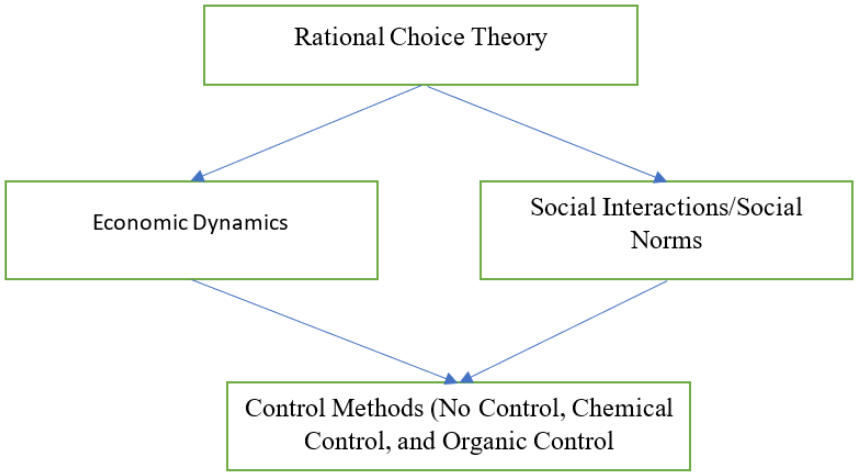

Figure 2: Theoretical framework Source: Authors' own creation, adapted from Wang et al. (2022)

2.5 Conceptual Framework

The conceptual model for this study delineates the multifaceted factors shaping farmers' decisions regarding disease control methods. Individual characteristics such as age, sex, marital status, education level, and farming experience intersect with farm-specific attributes like land ownership, farm size, and primary income sources to influence farmers' resource endowments and labour availability. This is evident in the studies of Marie et al. (2020), where age, gender, household size, farm income, and farm size were found to affect farmer's choice of climate change adaptation strategies. Bravo-Monroy et al. (2016), also identified socio economic factors and farm characteristics like land ownership, education of farmers, farm size among factors that affect the decision of farmers. These demographic and farm characteristics, in turn, interact with environmental factors such as planting methods, yield, and disease awareness, forming the backdrop against which economic considerations unfold. This is as shown in the study of Marie et al. (2020), where environmental factors such as crop failure, severe soil erosion and shortages of water influenced farmer's adoption of climate change adaptation strategies.

Economic factors, including access to training and awareness of disease impact, play a pivotal role in farmers' decision-making, affecting their willingness to invest in disease control measures and the adoption of management strategies such as extension services and labour allocation. Bravo-Monroy et al. (2016) noted that economic factors such as crop profitability influenced the decision of farmers to adopt organic and conventional coffee management practices. Therefore, the implementation of these strategies, in conjunction with environmental conditions, determines the effectiveness of disease control measures and overall farm productivity. Ultimately, the interplay of individual characteristics, farm attributes, environmental factors, economic considerations, and management strategies (Meijer et al., 2015; Zeweld et al., 2017; Huber et al., 2018) shapes farmers' choices of SBD control methods, highlighting the complexity inherent in agricultural decision-making processes.

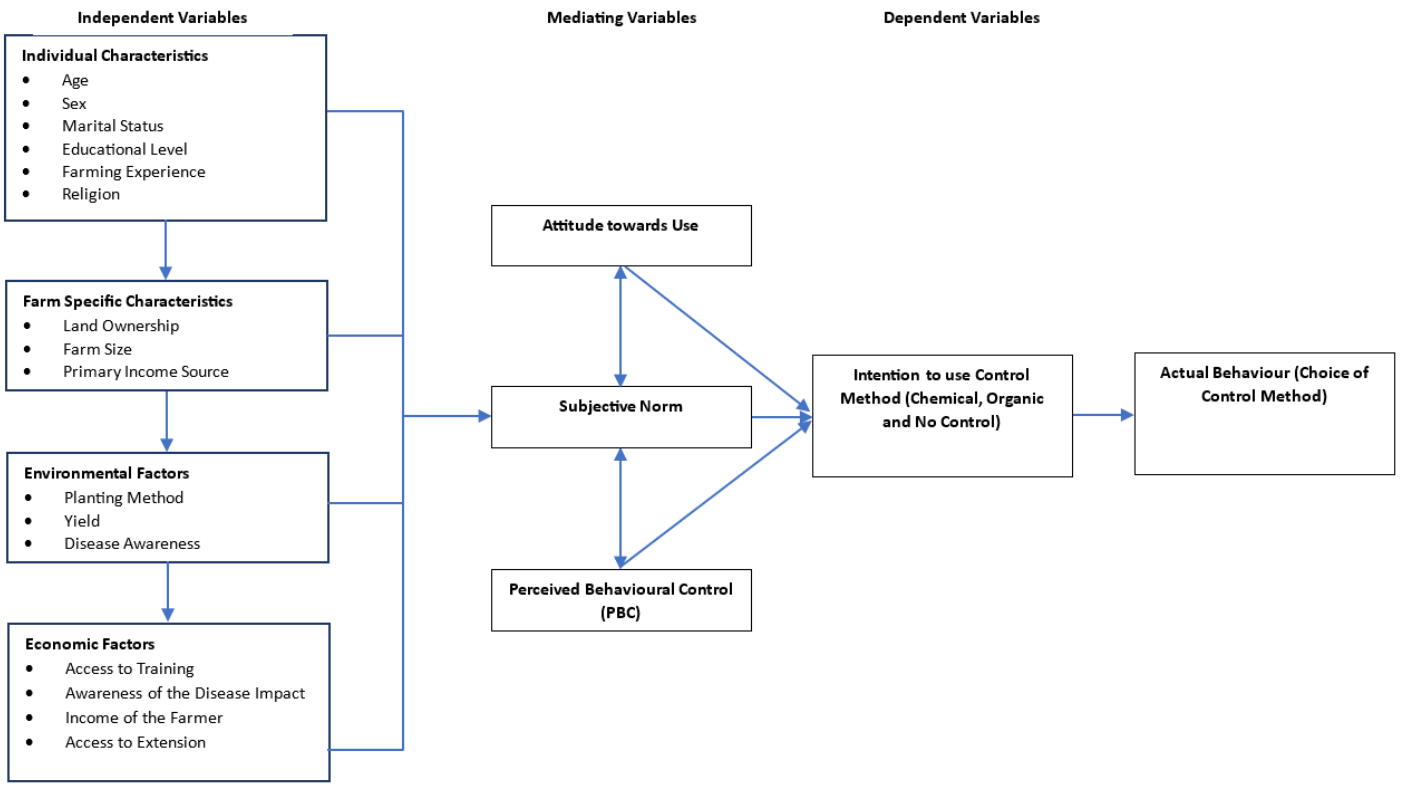

Figure 3: Conceptual Framework for the study

3 Methodology

Research Methodology is the systematic and theoretical analysis of the methods applied to a field of study or the theoretical analysis of the body of methods and principles associated with a branch of knowledge. It typically encompasses concepts such as paradigm, theoretical model, phases and quantitative or qualitative techniques. This chapter guides a researcher in the systematic process of collecting, analysing, and interpreting data to provide logical proofs from which the researcher can draw inferences concerning the relationship that exists between the variables under investigation.

3.1 Study area characteristics

The study was conducted in Cameroon with a focus on the communities of the Limbe and Buea districts of Southwest Region of the country located in the Mount Cameroon area of Fako Division (Sama et al., 2021). Cameroon is known for its vast population involving in agriculture and large arable land for farming compared to the other parts of the country like the northern regions (Chimi et al., 2022). One of the most common crops cultivated in the study area is banana (Olumba and Onunka, 2020). This crop serves as major source of income for farmers, and it helps in sustaining their livelihood (Olumba and Onunka, 2020). Two of the major districts in the country where banana is produced is the Limbe and Buea districts (Nkiaka, 2022). Buea is located on the eastern slopes of Mount Cameroon between longitude 4°10′ N and latitude 9°14′ and Limbe is at latitudes 30°31' and 40°15' N and longitudes 80°15' and 90°35' E. Limbe is bordered by Mount Cameroon to the north, Tiko Subdivision to the east, Idenau to the west and the Atlantic Ocean to the south (Adzandeh et al., 2020; Foncha et al., 2020; Sama et al., 2021). Buea district has a total land area of 870 km^2 made up of 67 villages, while Limbe has a land mass of 548 km^2 (Foncha et al., 2020). Due to the proximity of both locations, they have similar climate, which is made up of two seasons (Sama et al., 2021). The dry season occurs from mid-October to mid-March, with temperatures of between 20 to 28°C while the rainy season occurs between mid-March to October, with annual rainfall volume of between 2000 and 5000 mm (Foncha et al., 2020). However, because of the seaside nature of Limbe, it experiences a higher level of rainfall, which is about 7000 mm during the peak period. As such, Limbe is referred to as a wet city (Adzandeh et al., 2020). Both Limbe and Buea are characterised by fertile volcanic soils, which supports plantations such as oil palm, banana and tea plantations (Wung and Tokwa, 2019; Fonge et al., 2017). There are large presence

of banana plantation and agro industries in Limbe and Buea that have contributed to the livelihood of the people in that location (Akara, 2021).

The topography of the areas is also quite similar with Buea having an undulating topography made up of highlands and lowlands (Foncha et al., 2020). The topography in Limbe is characterised by low-lying coastal plain and slopes with various intensities with the highest points reaching 362 m above sea level (Adzandeh et al., 2020). Both areas have rich soils with the popular activities in these areas being agriculture, civil service, artisanship, tourism among others.

Figure 4: Map of Cameroon showing the study area.

3.2 Study Design

The study adopted a quantitative research design. This design allows for a comprehensive assessment of the effectiveness of various control methods for profitability and sustainable resistance control of black Sigatoka disease among small-scale farmers in Cameroon. The use of a quantitative study design in this research offers several advantages which include objective Data Collection, generalisability of result and statistical rigour in analysis.

3.3 Study Population

This comprehensively describes the total elements or people covered by the problem under investigation. The study population for the study includes small-scale banana farmers from the Limbe and Buea, southwest region of Cameroon. These regions represent some of the areas where we have large clusters of banana farmers in Cameroon. The selection of the small-scale banana farmers is because these crops are susceptible to black Sigatoka disease and the small-scale farmers often face unique challenges related to resource constraints and access to markets and information. In the study area, which is the Limbe and Buea in the southwest region of Cameroon, they have approximately 1671 small farmers who are doing banana farming (Cameroon Fako Divisional Delegation of Agriculture, 2022). The total number of smallholders growing bananas in the study area constitutes the population for the study.

3.4 Data Requirement

The data collected for this study is primary collected from households involved in banana farming in the study area. The relevance of the primary data for this study is to source the impact of Sigatoka disease on banana plantations of smallholder farmers in Cameroon and the factors affecting Sigatoka disease control measure.

3.5 Sample Size

The research employed a simple random sampling technique to collect data. A total of 322 questionnaires were administered to farmers in the Buea and Limbe subdivisions. The study population comprises approximately 1,671 farmers. The sample size was determined using Yamane's formula, a widely used method for sample selection (Ullah et al., 2020a; Ullah et al., 2020b). The sample size for the study was estimated using a 5% margin of error (confidence interval) and a 95% confidence level, resulting in the selection of three hundred and twenty-two small-scale banana farmers. The sample size based on the Yamane's formula is calculated as:

$$n = \frac{N}{1 + N\,(e)^2}$$

Where:

N = Total population of the study

e = The expected error (0.05)

1 = Constant

$$n = \frac{1{,}671}{}$$

$$1 + 1{,}671\ (0.05)^2$$

$$n = 322$$

Therefore, the required sample size for the study is 322.

3.6 Instruments for Data Collection

A well-structured questionnaire was used for data collection in the study. The questionnaire was structured to gather vital information from the respondents as it concerns the objectives of the study. The questionnaire made provision for capturing the factors affecting farmer's choice of SBD control method among small-scale farmers in Cameroon.

3.7 Data collection techniques

The study employed a multistage sampling procedure to sample participants of different ages, genders, educational qualifications, and job positions. The study was conducted in the Limbe and Buea regions, which were purposively selected due to the large presence of banana farmers in those areas. After selecting the area, stratification was performed based on specific characteristics, such as areas with high concentrations of banana farmers. Seven large clusters of banana farmers were then chosen from the region. Finally, banana farmers were randomly selected from each cluster, with equal selection across all clusters. The selection criteria for farmers were those who actively engaged in banana cultivation during the study period. This ensured that the respondents had relevant experience and had faced the challenges posed by black Sigatoka disease.

3.8 Hypothesis Testing

The following hypothesis was tested in the study in order to get a relationship between major constraints in the study.

Hypothesis 1: There is no significant relationship between the socio-economic characteristics of the farmers and the control method used in the control of Black sigatoka disease.

3.9 Method of Data Analysis

This section discusses data analysis techniques for data collected in any study. To achieve the objectives of this study, frequency distribution tables, means, percentages and graphs were used. These methods were adopted because they provide the basic distribution characteristics of the variables or data employed for instance, in a frequency report, one can analyse the different values from the highest to the lowest in terms of occurrence or terms of mean can be shown. All these are used to analyse and present the data collected. In addition, multinomial logit was used in analysing factors that influence the control method that is used by the farmers in the study area. The statistical

package for social scientist (SPSS) version 20 was used in analysing the descriptive statistics while STATA Version was used in analysing the multinomial logit for this study.

3.9.1 Multinomial Logit Model

To achieve the objectives of this study, we used frequency distribution tables, means, percentages, and graphs. These methods provide the basic distribution characteristics of the variables or data. For instance, in a frequency report, one can analyze the different values from the highest to the lowest in terms of occurrence, or terms of mean can be shown. All of these methods are used to analyze and present the collected data. The study area's farmers' choice of control method was analysed using multinomial logit. Descriptive statistics and multinomial logit were analysed using the Statistical Package for Social Scientist (SPSS) version 20.

The multinomial logit model is used when the dependent variable has categorical characteristics that do not follow a particular order. The multinomial logit model is an advancement of the binomial logit model, allowing for dependent variables with more than two categories. It is widely used in similar studies, as demonstrated by Mahmood et al. (2020) and Ullah et al. (2023).

In this study, the multinomial logit model was used to model different control methods, which were classified into three major categories: None, Chemical, and Organic. The equation for the multinomial logit can be given as

$$\text{Logit}\,(P(Y_i = j)) = \beta_{j0} + \beta_{j1}X_{i1} + \beta_{j2}X_{i2} + \beta_{j3}X_{i3} + \ldots\ldots + \beta_{j11}X_{i11} \ldots\ldots(1)$$

Where Y_i = is the dependent variable which has three categories J

J = the control methods which are used by the farmers with 0 representing none, 1 representing chemical control and 3 representing organic control methods.

β = is the coefficient of the regression

X = the vector of explanatory variables which is made up is 11 independent variables $X_1 - X_{11}$

The multinomial logit equation can be re-written as:

$$P(Y_i = j) = \frac{\exp(\beta_j X_i)}{1+\sum_{j=1}^{3}\exp(\beta_j X_i)} \ldots\ldots(2)$$

Where j = 1,2,3 and X_i = 1,2,3,4,…., 18

3.10 Variable description

3.10.1 Dependent variable

The dependent variable used in the study is the different control methods used by the farmers in the study area. As such, the three major categories of the dependent variables were 0 when the farmers used no control method, 1 when the farmers use mainly chemical control methods and 2

when the farmer made use of mainly organic method for the control of disease on the farm. It should be noted that it was only farmers who had experienced the attack of sigatoka disease on their farms that were only included as part of the multinomial logit analysis.

3.10.2 Independent Variable

For the independent variable, 11 factors were considered with likelihood of having impact on the control methods used by the farmers in the study area. These factors include sex, age, Education, farm size, years of experience in banana farming, occupation, banana farming as main income, access to extension services, religion, land ownership and access to adequate training. These independent variables are chosen for the likely impact they might have on influencing the dependent variables of the study.

3.10.3 Gender

The gender of the banana farmers is a binary independent variable, which takes the value of 1 and 0 in the study. The gender of the farmers have been found to play a major part in decision making among farmers especially in within the study area in Africa where sex plays a role in the type of decision that farmers (Meijer et al., 2015). According to Wang et al. (2017) and Denkyirah et al. (2016), they found out that males are more likely to use chemical pesticides when compared to their female counterparts while Constantine et al (2020), found positive significant differences in the use of management practices for the control of armyworm among male and female farmers in Kenya. As such, it is hypothesised that the sex of the farmers had negative significant effect on the use of chemical control methods and a positive sign for the use of organic control methods in the study area.

3.10.4 Age

The influence of age on the decision of farmers have been explored in different studies such as Denkyirah et al. (2016), where age was found to have a negative effect on the use of chemical pesticide for the control of cocoa. This was also similar to the findings of kabir and Rainis (2015) which is also in line with the a-priori expectation for this variable as it is believed that younger farmers would be more disposed towards the use of chemical control methods while the older farmers adopted the use of organic control methods. As such, the expectation is that the chemical control method had a negative sign while the organic control method had a positive sign. Additionally, the variable is expected to be a continuous variable.

3.10.5 Education

The educational variable is a categorical variable, which recognises the various educational category of the farmers in the study. The educational status has been reported in studies such as Gao et al. (2017) where it was found to have a positive influence on the use of organic pesticide. It was also reported to have a positive influence for the use of chemical pesticide by Danso-Abbeam and Baiyegunhi (2018). As such, Education has influence on the adoption of more modern and sophisticated pest control methods due to better understanding of agricultural practices, technology, and potential environmental impacts. Therefore, farmers with higher education levels might are likely have better access to information that may affect the type of control method used. It is expected that educational level had negative for the use of chemical control and positive for the use of organic control method.

3.10.6 Farm size

Farm size is a continuous variable in the study. According to empirical studies, farm size could affect the method used for control of disease on the farms because of the size of the farm. According to Ren et al. (2019), the size of the farms can affect the decision to use whatever method because of the cost and effectiveness of such control method. This is because larger farms may have more resources available to invest in advanced pest control methods, such as hiring specialized labour or purchasing equipment. Conversely, smaller farms might rely more on traditional, labour-intensive methods or may have less access to capital for purchasing inputs. It is expected that the farm size had a positive sign for both the use of organic and chemical control methods.

3.10.7 Years of experience in banana farming

The years of experience in banana farming is a continuous variable and measures the number of years, which the farmers have spent in the cultivation of banana. Farmers with more years of experience in banana farming might have accumulated knowledge and skills related to pest management practices (Alagukannan et al., 2015). They may have developed strategies over time that could influence their choice of pest control methods. However, long-established practices might also be resistant to change, potentially leading to inertia in adopting new methods (Liu et al., 2023). Therefore, years of experience is expected to have a positive sign for the use of organic method and the use of chemical control methods. This is also reported by Denkyirah et al. (2016)

who reported a positive relationship between pesticide usage and the farming experience of cocoa farmers in Ghana.

3.10.8 Occupation

The main occupation variable is a categorical variable that explores the potential impact of the primary occupation of the farmers on the decision towards the use of control methods. It is expected that farmers who have agriculture as their main income invested more time and effort in ensuring that they use an effective pest control method when compared with those who do not take it as their main occupations (Midingoyi et al., 2019). Alternatively, those who do not take it as their main occupation may also have access to different resources or networks that could potentially have influence their pest control decisions (Berni et al., 2021). As such, it is expected that this variable had a negative sign for the use of chemical control methods and a positive sign for the use of organic control method.

3.10.9 Banana farming as Main Income

This variable is dichotomous categorical variable, which measures if farmers take the income from their banana farming source as their main income. Farmers who rely primarily on banana farming for income may prioritise effective pest control methods such as the use of chemicals to protect their primary source of livelihood (Sharifzadeh et al. 2018). As such, it is hypothesised that the variable had a positive sign for the use of chemical control methods and a negative sign for the use of organic control methods.

3.10.10 Access to Extension Services

Access to extension services is operationalised as a dichotomous categorical variable. Access to extension can affect the decision the farmers take towards using any control method as it impacts their knowledge. This is affirmed in the study of Singh et al. (2016), where farmer's future decision-making choices is affected by their access to extension agents. And Wuepper et al., (2021), where farmers access to extensions agents positively influenced their use of organic and chemical control methods. Therefore, farmers with access to extension services may have better knowledge of the use of non-chemical methods and are more likely to adopt modern and effective pest control methods compared to those without access to such services. It is hypothesised that this variable had a positive sign for the bot the use of chemical control method and organic control method.

3.10.11 Religion

Religion can be seen as a social variable which is measured as a dichotomous categorical variable. The religion variable has both direct and indirect impact on the pest control methods (Pereira et al., 2015). This is because it could have influence on the level of information that the farmers have access to and the type of practice, which the farmers adopt on their farms due to their beliefs. As such, it is expected that religion had a positive sign for the use of chemical method and organic method likewise.

3.10.12 Land Ownership

Land ownership is also measured as a dichotomous categorical variable in this study, which can take values of 1 and 0. Land ownership can be said to be correlated with the level of investment and commitment to farming activities (Aha and Ayitey, 2017). Therefore, farmers who own their land are more inclined to use long-term strategies for pest control when compared to those who leased or rented the land who are likely to prioritise short-term gains (Adusumilli and Wang, 2019). As such, it is expected that the land ownership variable had a positive sign for both the use of chemical and organic control method.

3.10.13 Access to adequate training

This variable is a dichotomous categorical independent variable. The variable measures the perception of the farmers about their level of training. It is expected that farmers with access to adequate training programs on pest management techniques would be more knowledgeable about effective and sustainable methods. Therefore, they are more likely to adopt advanced pest control strategies compared to those without proper training. This is because farmers who received training tend to put so many factors into their consideration when making decisions about the control method to use (Sharifzadeh et al., 2018). It is hypothesised that this variable had a positive sign for the use of organic and chemical control methods.

3.11 Ethical Consideration

The study aims to include participants from diverse demographic backgrounds, such as age, gender, education level, and farming experience and as such the need for ethical consideration.

Some of the major ethical consideration that were considered in this study include getting the informed consent of the farmers voluntarily before recruiting them for the survey. This included making the participants fully aware of the study's purpose, procedures, potential benefits, and risks involved in participating in the study. Also, the privacy and confidentiality of the participants'

personal information and data collected during the study would be made anonymous and securely stored to prevent unauthorised access.

In addition, there was strict adherence to the cultural norms and practices of the farming communities that were used in the study by ensuring that the study's approach aligns with their values and beliefs. The study was also conducted with integrity and adhered to ethical principles throughout the research process, in areas like data collection, analysis, and reporting of results.

4 Results

This section discussed the result of the findings from the field survey. The results discussed include the socio-economic characteristics of the respondents, Prevalence of sigatoka disease among the farmers, Perception of the farmers about the impact of sigatoka disease on production and pest, and disease control methods. The result also looked at the various socioeconomic characteristics that affected the choice of control methods by the farmers in the study area.

4.1 Socio-economic Characteristics of the Banana Farmers

This section is divided into four sections with each section focusing on the specific characteristics of the farmer in terms of their demographic, input and output, labour use and cost and as well as their various farm characteristics.

4.2 Demographic Characteristics of the Respondents

The result on table 1 shows the demographic of the respondents such as age, sex, religion, educational level, marital status, farming experience in banana cultivation and primary occupation of the respondents. The findings shows that the mean age of the respondent was 44.16 years and implying that majority of the farmers are within their productive age. The result further shows that the average of sex is 0.64 pointing to the fact that females were less involved in farming in the study area when compared to their male counterpart. This means farming activities in Cameroon is male dominated.

Table 1. Demographic Characteristics of the Respondents

Variable	Description	Mean	Std Dev.	Min	Max
Household Head Characteristics					
Age	Age of the Farmer (years)	44.16	7.86	28	62
Gender	0= Male, 1 = Female	0.64	0.48	0	1
Marital Status	1= Single, 2 = Married, 3 = divorced/separated, 4 = widow/widower	2.01	1.15	1	4
Religion	0 = Christian, 1 = Non-Christian	0.02	0.14	0	1
Educational Level	0 = No Education, 1 = Primary Education, 2 = Secondary Education, 3 = Vocational/ Technical Education, 4 = Tertiary Education	2.21	0.95	0	4
Farm Characteristics					
Experience in Banana Farming (years)	Number of Years spent in Farming (Years)	5.11	2.62	2	15
Primary Occupation	0 = Farming, 1 = Trading/Salary Job	0.47	0.81	0	2
Land Ownership	1 = Yes, 0 = No	0.63	0.48	0	1
Banana Farm Size (Acres)	Farm area for cultivating Banana	3.03	1.76	1	8
Banana Main Income	1 = Yes, 0 = No	0.61	0.49	0	1
Information Sources					
Extension Service	1 = Yes, 0 = No	0.48	0.50	0	1
Types of Planting	1= Line/row Planting, 2 = Pit Method	0.41	0.62	1	2
Access to Farm Labour	1 = Yes, 0 = No	0.74	0.44	0	1

Number of Farm Workers Perceptions	No of Farm workers employed on farm	3.09	1.99	0	7
Yield Harvested (Bunch)	Number of Banana Bunches Harvested	1299	784.20	150	3500
Getting Adequate Training	1 = Yes, 0 = No	0.12	0.32	1	2
Awareness of Disease Stage	1 = Yes, 0 = No	0.36	0.48	0	1
Awareness of the Economic Impact of the Disease	1 = Yes, 0 = No	0.74	0.44	1	2

Furthermore, the result reveals that the average value for marital status skewed towards being married with a moderate spread indicated by the standard deviation. This shows that married people make a sizeable part of the farming population that were sampled. In terms of the religious orientation, the mean value of 0.02 reveals that majority of farmers in the study area are Christians, with a smaller proportion being either Muslims or traditional religion followers. This shows that the dominant religion among the respondents is Christianity.

On average (2.21), farmers in the study were found to have attained at least secondary education with the standard deviation value suggesting some variability in educational levels. This shows a form of literacy among the farmers. Additionally, the mean experience of the farmers in banana farming was found to be 5.11 years. This point to the fact that most of the farmers are new to banana farming but still have valid experience useful for the study. An average of 0.47 of the banana farmers have farming as their primary occupation with the remaining involved in other activities as trading, artisan among others as their primary activities. However, it should be noted that those who do not have farming as their primary occupation do it as a secondary occupation. However, majority of the farmers noted that an average of 0.61 of the farmers reported banana

farming as their main sources of income which could imply the relative importance of banana farming to their income.

The average farm size of the farmers that is used in the cultivation of banana is 3.03 ha with the common range of farm sizes for the farmers falling between 2 to 4 ha. Results on availability of extension services for the farmers revealed that based on the average value of 0.48, majority of the farmers did not have access to extension service. This could imply poor access of extension services for majority of the farmers.

Furthermore, it was discovered that with a mean value of 0.74, majority of the farmers had access to farm labour with an average of three workers employed and this has implication on their ability to increase production and effectively manage their farms. Additionally, the yield of the farmers from the farm shows an average yield of 1,299 bunches with some level of variation as revealed by the value of the standard deviation. In the areas of the access of the farmers to training, it was discovered that about 88% of the farmers which formed the majority did not have access of any form of training as related to the management and control of sigatoka disease and as well as the management of banana. In addition, as regards the awareness of the farmers about the economic impact of the disease, it was discovered that an average 74% of the farmers were aware of the economic impact of the Sigatoka disease.

4.3 Prevalence of Sigatoka disease in banana plantations of farmers

The result in Figure 4 shows the prevalence of sigatoka disease among farmers in the study area. As shown in the figure, a significant majority (78.6%) of the farmers have experienced Sigatoka disease on the farm. This shows that the farmer's crop has been infected by the disease and implies that the disease is widespread among the farmers.

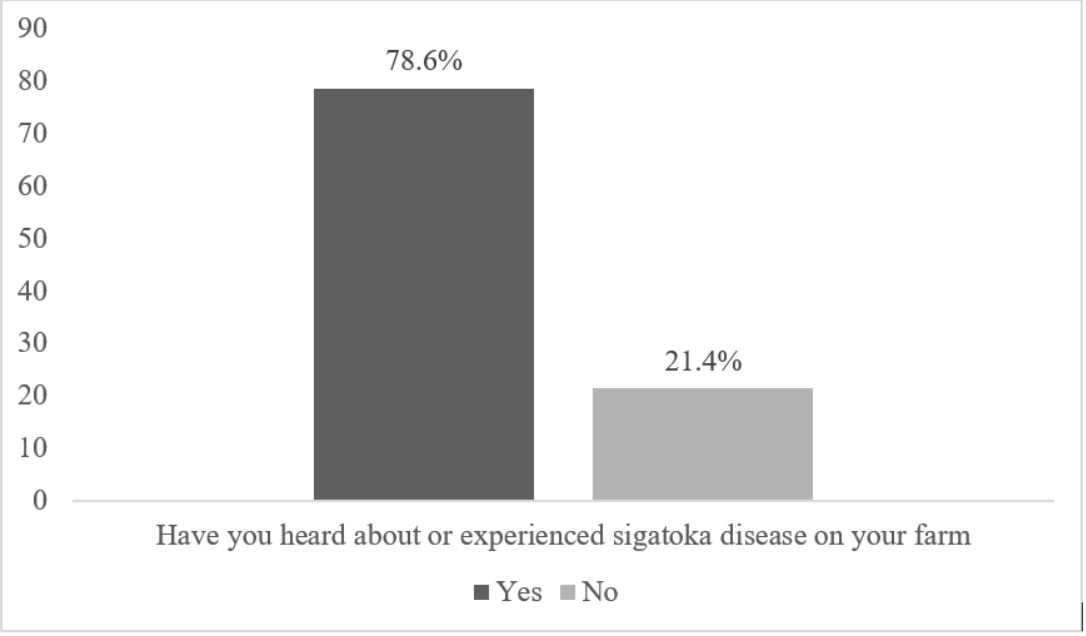

Figure 5: Prevalence of Sigatoka disease among farmers

As shown in Figure 5, the main physical indicator observed by farmers to identify Sigatoka disease varies. A significant proportion of respondents (41.6%) indicated that the main sign was black dots/dry spots on the leaves. About 18.7% said that the main sign of Sigatoka disease is that the plants have folded yellow leaves, 6.5% of them said that the signs they see include folded leaves with black and yellow dry patches, while 7.1% said that when the plant is infected they see yellowish and brownish dark spots on the leaves of their plants. However, 26.1% of respondents (in which 21.4% has not experienced it) said they did not see any signs.

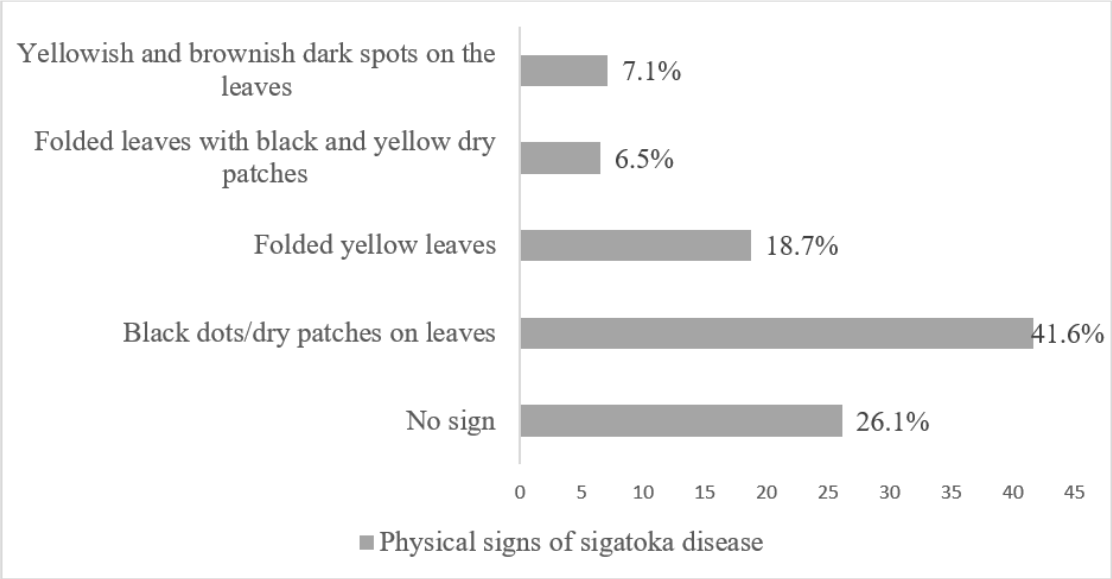

Figure 6: Physical Symptoms of Sigatoka Disease

4.4 Farmers' Perceptions of the Impact of SBD on Production

4.4.1 The impact of sigatoka disease on the productivity and income of farmers

Figure 6 shows the perceived impact of Sigatoka disease on the yield and income of banana farmers in the study area. The results showed that the disease affected the yield of the majority of farmers to some extent, with 17.4% noting that it had a small effect, 55.3% of farmers, which is the modal group nothing that the effect is large, while 14% reported that a very large effect. On the contrary, 7.5% of the farmers replied that it had no effect. In addition, price reduction was another area where the disease affected farmers, as the majority (62.4%) of them indicated that it had a great effect on the price of their product, with 14.0% going further to say that it had a very great effect on their price, while 16.1% said that it had a small effect. However, it can be seen that for a larger proportion of farmers it has affected the price in one way or another.

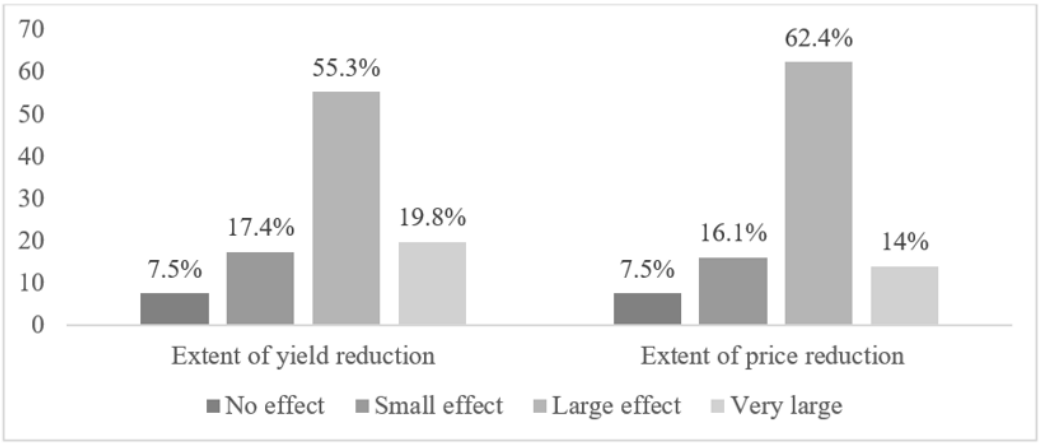

Figure 7: Impact of Sigatoka Disease on Yield and Price of Banana

4.5 Farmers Pest Control Methods

Figure 7 shows the pest and disease control methods used by farmers. The results show that 69.9% of the farmers use the chemical and pesticide treatment method, while 19.2% use the organic control method. Those not using any form of pest control were 10.9%.

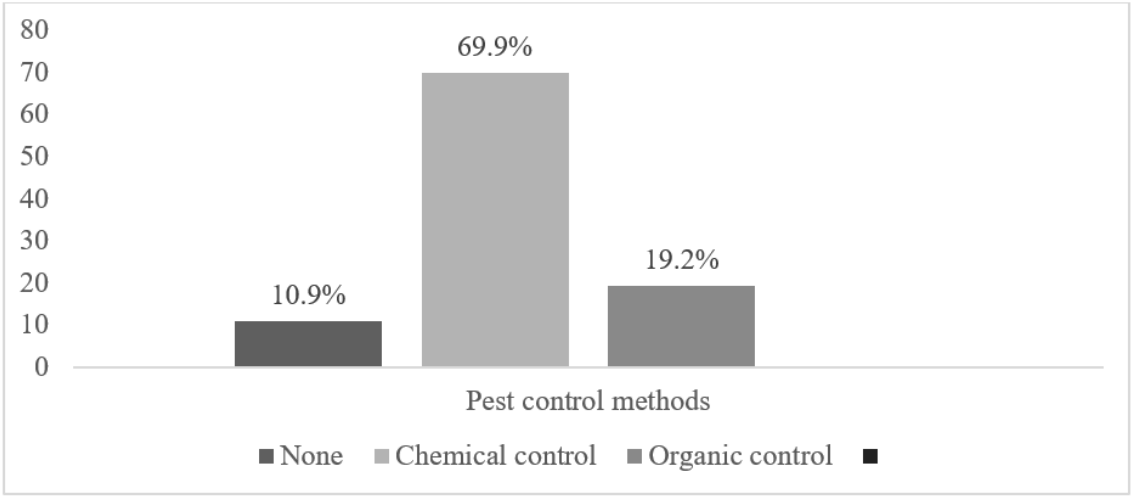

Figure 8: Pest and Disease Control Methods used by the Farmers

4.6 Factors influencing farmers' choice of Sigatoka control method

The results of the multinominal logit model in Table 2 show the factors that influence the choice of a control method by farmers in the study area. Robust standard errors were used in the estimation because of their consistency in estimation as the sample size increases. The regression analysis was carried out using multinomial logit because of the categorical nature of the dependent variable. The value of pseudo-R2 for the model was 0.8907, which means that 89.07% of the variation in the dependent variable is influenced by the independent variable in the equation. The chi-square statistic was significant at 1%, which shows that the model used fits our data.

The dependent variable was divided into three categories. The base category for the analysis was the respondents who did not use any form of control method, while the other category was those who used organic control method and those who used chemical control method. From the analysis, gender had a significant effect ($p<0.01$) with negative significance on the use of chemical control methods. This means that males have a higher tendency to use chemical control methods compared to other control methods. Age ($p<0.01$) significantly influenced the farmer's use of both chemical and organic control methods. For chemical control, age was positively significant while for organic control, age was negatively significant. This means that as farmers get older they are more likely to use chemical methods at the expense of not using any form of control. On the other hand, for organic control, the decision to use it was skewed towards the younger farmers. Thus, the younger farmers are more likely to use organic control rather than no control at all.

Table 2: Results of Multinominal Logit Model

	Organic Control			Chemical Control		
Variable	**Coefficient**	**Standard Error**	**z value**	**Coefficient**	**Standard Error**	**Z value**
Household Head Characteristics						
Age	-3.733***	0.143	-26.17	0.523***	0.097	5.40
Gender	-2.118	3.978	-0.53	-2.789***	0.582	-4.79
Educational Status	2.738***	1.144	2.39	-3.635***	0.827	-4.39
Religion	-101.096***	2.615	-38.65	19.451***	1.072	18.14
Farm Characteristics						
Years of banana farming	-1.211***	0.183	-6.63	-0.820***	0.147	-5.56
Occupation	11.608***	1.647	7.05	-1.470***	0.508	-2.89
Land Ownership	-62.273***	1.710	-36.42	5.985***	1.200	4.99
Farm Size	-40.100***	0.658	-60.97	-0.197	0.146	-1.34
Banana main income	91.461***	2.380	38.43	2.388	1.559	1.53
Institutional sources						
Getting Adequate Training	90.119***	1.419	63.52	8.630***	1.409	6.13
Access to Extension Service	-35.961***	2.880	-12.49	3.357***	0.891	3.77
Constant	75.436***	5.876	12.84	-24.646***	3.199	-7.70
Wald Chi Square	92,979.33					
Chi Square Significance	0.0000					
Log Likelihood Value	-28.472					
Pseudo R^2	0.891					

Number of Observation	322

*** Significant at 1% (P<0.001), **Significant at 5% (P<0.05), *Significant at 1% (P<0.1)

The variable for educational level was significant at 1% for the use of organic and chemical control methods, with a positive sign for organic control and a negative sign for chemical control. This means that the higher the level of education, the greater the tendency to use organic control. On the other hand, for chemical control, those who are illiterate are more likely to use this method. This indicates the importance of education in decision making. The occupation of the farmer variable was also significant for both the use of chemical and organic control methods, with a positive coefficient for the use of organic methods and a negative coefficient for the use of chemical methods. This means that those who choose farming as their main occupation are more likely to use chemical control methods, while those who choose other occupations are more likely to use organic control methods. This is due to the commercial nature of chemical control.

Farmer's with higher experience in banana farming/More experienced farmers in banana farming increases, the likelihood of using either chemical or organic control methods decreases. Land ownership was also a significant variable for both the use of organic and chemical control methods. For the use of the organic control method, the coefficient was negative and this means that those who own their land for farming are less likely to use the organic control method, whereas for the chemical method, farmers who own their land have a high likelihood of using the chemical control method. This shows that land ownership influences the choice of control method used.

Farm size use for banana was significant with a negative coefficient at 1% for the factors influencing the use of organic control methods. This means that as farm size increases, the likelihood of using organic control methods decreases. This implies that organic control methods

are not used in commercial pest control methods. The tendency of those using banana farming as their main source of income was significant at 1% with a positive coefficient. This means that those who use bananas as their main source of income are more likely to use organic control methods. However, this does not rule out the use of chemical control methods, but rather suggests that farmers who use it as their main source of income tend to use other sources, such as organic sources, which may be more cost-effective for them.

Furthermore, access to extension services positively influenced the decision to use chemical control methods and negatively influenced the use of organic control methods, both at 1% in the study area. This shows that extension services tend to promote the use of chemical control methods but are less likely to promote organic control methods. This could be due to the lack of verifiable evidence on the effectiveness of organic control methods. This could be an argument for reviewing the extension services training manual and the need to update extension agents on effective organic control methods for sigatoka disease.

The variable for receiving adequate training shows that farmers who received adequate training were more likely to use either chemical or organic control methods than to do nothing. This is because the variable was significant and had a positive coefficient at 1%.

5 Discussion

The study has been able to outline various issues that were discussed critically in this section. To get better understanding of the implication and findings from the result of the study.

5.1 Socio Economic Characteristics of the Respondents

From the study, most of the respondents are within their productive age, and this is similar with the findings of Abdulrahman et al. (2019) who reported a mean age of 48.12 years for banana farmers in Nigeria. This implying that the farmers in the study area are in their productive stage of

production. Also, the sex of the respondents in the study has shown that banana farming in Cameroon is male dominated. This could be because of a male dominated culture that exist in such area and because of the tasking nature of maintaining banana plantation which requires energy. According to Nkengla-Asi et al. (2020), who reported that male had larger fields than females in Cameroon. Additionally, education plays an important role for the farmers, most of them had some form of education, which implies some level of literacy among the farmers, and this could have implication on the farmer's ability to comprehend training content and put them to use. According to Ishola and Arumagam (2019), education increases the ability of the farmers to assimilate, interpret and make judicious use of the information gotten through training. The farmer's experience in the management of banana farms was quite low as most of the farmers are new to banana farming. This could be an important factor in the farmer's acceptance of any of the control methods as they are in the stage of farming when they are willing to explore different options as far as it tested and proven to be effective (Rezaei et al., 2020).

Also, the farm size being kept by the farmers showed that most of them were smallholder farmers as they operate on a relatively small to moderate-sized farms and might face challenges related to economies of scale, access to resources, and mechanization. This was similar to the findings of Nkwain et al. (2022) who found out that banana farmers in Cameroun kept farms between 0.1 and 2 hectares and the findings of Jacobsen et al. (2004), who also found out that farm sizes for banana farmers in the western highlands of Cameroon was averaging at about 0.9ha. Additionally, extension visits among the farmers was found to be low and this could affect on-field assessment of farmers and other on field trainings, which can further help the farmers in gaining more knowledge on the control and prevention of sigatoka disease. This is similar to the findings of Amungwa (2018) who reported a disproportionate number of extension to farmers in Cameroon

and Chimi et al. (2022) who reported a low level of extension visit among banana farmers in Cameroon. Furthermore, access to labour was high and this could imply that the availability of labour for the farmers is not a major constraint for them and thus being able to use them for labour intensive activities such as weeding, harvesting, planting among others. However, the skills of the labourers can come to play in farming activities that requires skilled labour, and this may affect their productivity. This finding is contrary to that of Chinee et al. (2018) in a study done in the southwest region of Cameroon where it was discovered that farmers could not expand their farms because of limited access to labour. In addition, Okolle (2019) reported that farmers rely more on family labour due to high cost and non-availability of hired labour.

Additionally, lack of training opportunities as seen in the result might hinder farmers from adopting modern agricultural practices, improving yield, and accessing better markets. This is because training plays a vital role in enhancing productivity, sustainability, and profitability. This is in line with the findings of Kenfack et al. (2019) who identified training limitation of farmers in Cameroon and that of Nji and Engwali (2020) who confirmed the same.

5.2 Prevalence of Sigatoka Disease among the Farmer's.

The study documented the prevalence of black Sigatoka disease in the South-Western region of Cameroon. Additionally, the findings show a high proportion of farmers that experienced both the prevalence and negative effect of the disease on their economic performance and livelihood. This is supported by the studies on similar topic from the region, such as Benin (Ahohouendo et al., 2020), or other African countries, such as Ethiopia (Gurmu et al., 2017). This may be because farmers in the research region knew when a plant was sick with sigatoka disease and the financial cost of the illness because of the high prevalence of the disease among them.

The high prevalence of the disease indicates that black Sigatoka disease represents a critical challenge for banana farmers, who are aware of negative effects like reduced yields, lower quality of final production and consequently economic and social deprivation (Jomanga and Lucas, 2021). From the symptoms that farmers identified as signs of black Sigatoka disease, it was clear that farmers had experienced both black and yellow sigatoka disease on their farms and could identify the signs to look out for on their farms. This clearly shows that farmers' knowledge is not just a perception, but that they know about the disease and can identify it on their farms. The signs of black sigatoka disease include small dark brown spots on the leaves of plants and leaf curling, while the signs of yellow sigatoka disease include yellow to yellowish brown oval leaf spots (Raja and Rajendran, 2022). Banana farmers in Benin could identify the symptoms of the disease but could not determine the criticality of the disease because of the different physical signs observation showed the different ways in which Sigatoka disease can occur (Ahohouendo et al., 2020). This could also indicate different stages of infection or different responses of the plant to the disease depending on the plant variety, environmental conditions, and farming practices (Kimunye et al., 2021). Thus, the widespread presence of these symptoms among farmers highlights the need for urgent disease management strategies, which could include the use of disease-resistant varieties, cultural practices, and improved farmer education.

5.3 Perception of the Farmers on the Impact of Sigatoka on the Productivity of the farmers.

Farmers' perceptions of the disease indicate the destructive nature of the disease on their farms and the need for proactive measures to help farmers control it. For example, the marketability of the farmers' produce, its yield, and its price were found to be affected by the disease. The impact of the disease as perceived by the farmers is supported by the study of Mengesha et al. (2023) who

reported the negative impact of the disease on banana growth and yield and Gurmu et al. (2017) who reported its devastating effect on yield and fruit quality. This is due to the fact that when the disease affects the leaves of the plant, it reduces the size of the bunch produced by the plant and sometimes even hinders production, which is how farmers perceive the disease. Farmers' perceptions indicate that the presence of Sigatoka disease could potentially reduce the quality, appearance and quantity of bananas, making them less attractive to buyers or consumers. Nelson (2020), who noted that it could pose a food safety risk to consumers, further confirmed this position. This perception can affect market prices, demand, and overall profitability for farmers. In addition, the perceived impact of Sigatoka disease on market prices further emphasises its detrimental effect on farmers' profitability and productivity. This can consequently reduce farmers' income and affect production. This was confirmed by the study of Mbo Nkolou et al. (2022), who also found that black Sigatoka disease was the most destructive disease of banana among leaf spot or leaf streak diseases and affected farmers' profitability. The findings of Reuveni et al. (2020), who reported that the disease is characterised by rapid leaf damage, yield loss, reduced income, and increased vulnerability among smallholder farmers, further supported farmers' perceptions.

5.4 Farmers Pest Control Method.

Similarly to other studies, farmers in our study sites predominantly relied on chemicals to control pests and diseases (Shah and Yadav, 2018; Gutierrez-Monsalve, 2015, Becker et al., 2021). However, this high prevalence of chemical control raises concerns about the sustainability of the pest control practices. Studies proved the strong association between environmental degradation and posing significant health risks to farmers and consumers if chemicals are not used properly (Rani et al., 2021). In addition, overuse of misuse of chemical pesticides leads to the contamination of land and water resources (Özkara et al., 2016). On the

other hand, the cost of using the chemical method may not be economically friendly for the farmers (Lamichane et al., 2016) as most of them are subsistence farmers.

5.5 Factors Influencing Farmers Choice of Sigatoka Disease Control Method

The result of the multinomial logit indicated that the age of the farmer played a significant role in the type of control method used by the farmer in the study. The analysis revealed different signs of the coefficients for the chemical control method, which has a positive sign, and the organic control method, which has a negative sign. The positive sign of the chemical control method may be due to the level of exposure of the farmers, which correlates with their age, making them more dependent on the conventional pest control methods rather than the new methods with which they are unfamiliar due to their perception of risk (Khan et al., 2020). However, the preference of younger farmers for the organic control method suggests that younger farmers are more likely to use sustainable control methods. This may be due to their exposure to the effects of climate change and their awareness of the need to use sustainable control methods. This shows the importance of age in reaching farmers on the control methods to be used to control sigatoka disease. The result confirms the findings of Serebrennikove et al. (2020) where the age of the farmer was found to have a negative significance on the adoption of organic practices, but contrary to the findings of Denkyirah et al. (2016) where age was found to have a negative effect on the use of chemical pesticides among cocoa farmers.

The importance of education in the choice of control method was demonstrated by the fact that educated farmers were more likely to use organic pest control, which is more environmentally friendly. This could reflect their level of awareness of the dangers of chemical control methods, which is more prevalent among the uneducated in the study area. On the contrary, the less educated were found to be more likely to use the chemical control method. The effect of educational status

is confirmed by Gao et al. (2017) where education had a positive effect on the use of organic pesticides, but the study by Danso-Abbeam and Baiyegunhi (2018) did not support this as education had a positive effect on the use of chemical pesticides. This may be due to the fact that education plays an important role in improving the ability of farmers to assess the likely risks and severity that they face by not using an effective control method on their farm (Ahohouendo et al., 2020).

In addition, the analysis showed that those who run agriculture as their main occupation were more likely to use the chemical control method, while those who chose other occupations were more likely to use the organic control method. The reason for this may not be far-fetched, as those who choose farming as their main occupation are more likely to use a method that has a far-reaching effect, such as chemical control methods. This is also observed by Wole-Alo and Oluwagbemi (2020) who looked at how occupation influences adoption among farmers and found that farmers who take farming as their main occupation are more likely to adopt a better approach to farming. This is because they devote more time to the activities, thereby gaining more knowledge and experience. Those who use it as their main occupation may also have been able to explore different approaches to the disease through training, observation and social groups (Jacquet et al., 2022).

Years of banana farming were also found to reduce the likelihood of using organic and chemical control methods. The reason for this may be that these farmers may have found other effective alternative control methods through their experience, or there may be a tendency for farmers to become unconvinced of the effectiveness of both approaches to disease control over the years of their use. This is quite surprising based on our a priori expectation and the empirical findings of Denkyirah et al. (2016) who found a positive relationship between pesticide use and farming

experience of cocoa farmers in Ghana. This is due to the farmers' knowledge of control options, which improves as the farmers' experience increases (Osterman et al., 2021). This gives farmers an advantage in understanding disease symptoms and taking precautions to control the disease, limiting their reliance on any one control method (Doidge et al., 2020).

The issue of land ownership is also critical to the use of control methods, and the results give a good insight into the fact that farmers who own their own land use chemical control methods, while farmers who do not own their own land use more organic control methods. This may be due to the temporary nature of the use given to those who do not own the land and their tendency to use a less expensive method. Similar to our study, a study by Aha and Ayitey (2017) noted that land ownership is correlated with the level of investment and commitment to agricultural activities. Furthermore, Adenuga et al. (2021), in agreement with our findings, reported that farmers with temporary land use were less likely to invest in long-term disease management strategies. This was also echoed by Adusumilli and Wang, (2019) who opined that farmers with land ownership were more likely to adopt long-term pest management strategies compared to those with lease or rental arrangements.

The effect of farm size on the use of control methods provides some information on the fact that farmers with large farm sizes are less likely to use organic control methods. According to Ren et al. (2019), farm size determines the control methods used on the farm due to the cost and efficiency associated with them. This is essentially due to the nature of the large investments in their farms, and therefore the unwillingness to adopt a method that may not be economically viable for them. As such, larger farms tend to place more emphasis on control methods that are effective and fit their scale of need (Petit et al., 2020), such as the chemical approach. This could mean that organic control methods still need improvement or further research before they can be used on a larger

scale. This is confirmed by Jousi et al. (2017), where the organic approach was found to be more suitable for small farms.

Those who use bananas as their main source of income are more likely to use organic control methods, but this does not eliminate the use of chemical control methods. However, this supports the fact that farmers who use it as a main source of income are more likely to use organic sources, which are more cost-effective for them, as suggested by Baker et al. (2020). This may be due to the fact that most of these smallholder banana farmers are resource constrained (Muthee et al., 2019). In addition, farmers who rely on this as their main source of income may take into account market preferences which determine the control method used (Udomikun et al., 2021). They may also consider an approach that ensures that their production is sustained for a long time on the same land (Amakwah, 2023).

In addition, the presence of extension agents increased farmers' use of chemical control methods, but not organic control methods. This is similar to the findings of Wuepper et al. (2021) for chemical control methods, but the opposite for the use of organic control methods. This may be due to the lack of verifiable evidence on the effectiveness of organic control methods. This shows that extension education plays an important role in educating farmers on the use of chemical control methods but fails to introduce farmers to organic control methods. According to Singh et al. (2016), farmers' future decisions are largely influenced by their access to extension agents. This argues for a review of the extension training manual and the need to update extension agents on effective organic control methods for sigatoka disease. Although extension outreach in the study area was low, with improvements, more farmers in the study area may be able to adopt more sustainable and effective pest control methods. This is because it helps farmers understand the principles of disease control and empowers them to know what to do if they are challenged by

sigatoka disease (Livune, 2022). However, the extension service must be accessible and have the right content to improve farmers' decision making (Antwi-Agyei and Stringer, 2021).

The study also shows that adequate training of farmers helped them to use either chemical or organic control methods, implying that training plays an important role in providing farmers with the necessary knowledge to manage Sigatoka disease on their farms. According to Abiola et al. (2020), farmers who receive training on the disease are more likely to be aware of the possible control methods. It also improves their decision-making (Sharifzadeh et al., 2018) and creates awareness about the disease and the possible control methods available to farmers (Abiola et al., 2020). Therefore, proper training empowers farmers in their decision-making process and provides them with the necessary knowledge to make the right decision (Gratia and Fawzi, 2021).

The gender variable was also significant with a negative coefficient on the factors influencing the use of chemical control methods, implying that male banana farmers are more likely to use the chemical control method. This is not surprising as it is in line with our a priori expectation and consistent with the findings of Wang et al. (2017), Denkyirah et al. (2016) and Constantine et al. (2020) who found that males are more likely to use chemical pesticides compared to their female counterparts. This could indicate an inequality in access to resources between female and male farmers, hence the advantage of males in using chemical control methods when compared to their male counterparts. Findings from the Ankrah et al. (2020) and Anderson et al. (2021) studies support this, with males having greater access to resources when compared to their female counterparts.

All religious groups (Udomkun et al., 2021) accept banana cultivation. Thus, the variable for religion was significant for both the use of chemical control and organic control, but with different signs. For chemical control, religion had a positive effect, while for organic control it had a

negative effect. This means that Christians were more likely to use chemical control while non-Christians were more likely to use organic control. This is due to the type of information farmers have access to due to their religious orientation and beliefs (Pereira et al., 2015) as a result of the social nature of religious groups (Wang et al., 2021).

6 Conclusion

This study looked at the factors affecting farmers' choice of Sigatoka Disease control method among small-scale banana farmers in Cameroon. The main objective of the study was to document and analyse the control methods used by smallholder banana farmers for the control of sigatoka disease. In achieving the overall objective of the study, the study looked at the Prevalence and occurrence of Sigatoka Disease among the Farmers in the study area. Additionally, the study explored farmers perceptions of black sigatoka disease and management, examined the different control method used for the disease by the farmers and then identified factors influencing the control method used by the farmers in the study area.

It was found out from the study that majority of the farmers have experienced black sigatoka diseases on their farms and there is the need for an effective means of controlling the disease on their farm, which would be acceptable, by all. It was also observed that black sigatoka disease poses a significant threat to the livelihood of the farmers by limiting their production, the yield on their farms and the price of their commodity. Results of our MLM showed that factors such as age, religion, years of banana farming, land ownership, farm size and access to extension service negatively influenced the use of organic control method while educational status, occupation of the farmers, banana main income and getting adequate training positively affected it. On the other hand, the results showed that age, religion, land ownership, getting adequate training, access to

extension services had a positive effect on the use of chemical control method while sex, educational status, occupation and years of banana farming has negative effect.

The study recommends that there is a need to raise awareness among farmers about sustainable means of controlling Sigatoka disease. In essence, information should be provided on the use of organic(or agroecological) control methods that are better suited to the environment, taking into account the socio-economic characteristics of the farmers. Moreover, there is the need for adequate trainings that address the issue of sustainability in controlling the disease among the farmers, identify the different stages of the disease and pinpoint to the farmers the need to adopt sustainable control methods. Extension services should be improved to inform the farmers about the use of organic control methods while extension agents should be strengthened to follow-up the farmers. This is to ensure that what the farmers are doing are in line with what they were taught, and this were included on field visits by the extension agents and organisation of community schools where farmers are able to share their challenges in implementing what they have learnt.

6.1 Limitation of the study

The use of cross-sectional data limits the information to a particular point time and thus limited in accounting for changes that may occur in the choices of the control methods of the farmers over time. There is also limitation from the responses of the farmers due to their perception of events, which can be subjective and lack the accuracy required for the study.

7 References

Abdulrahman, O. L., Ogunlade, I., & Omotesho, K. F. (2019). Assessing the adoption of macro propagation technology (MPT) among plantain and banana farmers in Ondo State, Nigeria. *South African Journal of Agricultural Extension*, *47*(4), 96-105.

Abiola, A., Zandjanakou-Tachin, M., Aoudji, K. N. A., Avocevou-Ayisso, C., & Kumar, P. L. (2020). Adoption of roguing to contain banana bunchy top disease in south-east Bénin: Role of farmers' knowledge and perception.

Addy, H. S., Azizi, N. F., & Mihardjo, P. A. (2016). Detection of bacterial wilt pathogen and isolation of its bacteriophage from banana in Lumajang area, Indonesia. *International journal of agronomy*, *2016*.

Adenuga, A. H., Jack, C., & McCarry, R. (2021). The case for long-term land leasing: a review of the empirical literature. *Land*, *10*(3), 238.

Adom, K., & Anambane, G. (2020). Understanding the role of culture and gender stereotypes in women entrepreneurship through the lens of the stereotype threat theory. *Journal of Entrepreneurship in Emerging Economies*, *12*(1), 100-124.

Adusumilli, N., & Wang, H. (2019). Conservation adoption among owners and tenant farmers in the Southern United States. *Agriculture*, *9*(3), 53.

Adzandeh, E. A., Alaigba, D., & Nkemasong, C. N. (2020). Application of Geospatial Techniques and Logistic Regression Model for Urban Growth Analysis in Limbe, Cameroon. *Nigerian Journal of Environmental Sciences and Technology (NIJEST) Vol*, *4*(1), 138-151.

Aha, B., & Ayitey, J. Z. (2017). Biofuels and the hazards of land grabbing: Tenure (in) security and indigenous farmers' investment decisions in Ghana. *Land use policy*, *60*, 48-59.

Ahohouendo, F. A., Togbe, C. E., Agbovoedo, F. R., & Ahohuendo, B. C. (2020). Farmers' knowledge, perceptions and management of black sigatoka in small plantain-based farms in southern Benin. *American Journal of Life Sciences*, *8*(5), 172-182.

Ajzen, I. (2020). The theory of planned behavior: Frequently asked questions. *Human behavior and emerging technologies*, *2*(4), 314-324.

Ajzen, I., & Schmidt, P. (2020). Changing behavior using the theory of planned behavior. *The handbook of behavior change*, 17-31.

Akara, D. T. (2021). Agro-industries in Cameroon and Welfare-related Services to Non-labourers in Operational Neighbourhoods: The Case of the Cameroon Development Corporation and the Societe Camerounaise de Palmeraies, 1968-2019. *Cross Current Int J Peer Reviewed J Human Soc Sci*, *7*(6), 117-127.

Alagukannan, G., Velmurugan, P., & Ashokkumar, M. (2015). Impact of interventions on knowledge and adoption of improved technologies in banana cultivation. *Journal of Krishi Vigyan*, *3*(2), 54-58.

Alakonya, A.E., Kimunye, J., Mahuku, G., Amah, D., Uwimana, B., Brown, A. and Swennen, R. (2018), Progress in understanding Pseudocercospora banana pathogens and the development of resistant Musa germplasm. Plant Pathol, 67: 759-770. https://doi.org/10.1111/ppa.12824

Al-Dairi, M., Pathare, P. B., Al-Yahyai, R., Jayasuriya, H., & Al-Attabi, Z. (2023). Postharvest quality, technologies, and strategies to reduce losses along the supply chain of banana: A review. *Trends in Food Science & Technology*, *134*, 177-191.

Alhamad, H., & Donyai, P. (2021). The validity of the theory of planned behaviour for understanding people's beliefs and intentions toward reusing medicines. *Pharmacy*, *9*(1), 58.

Al-Mamary, Y. H. S., Abdulrab, M., Alwaheeb, M. A., & Alshammari, N. G. M. (2020). Factors impacting entrepreneurial intentions among university students in Saudi Arabia: testing an integrated model of TPB and EO. *Education+ Training*, *62*(7/8), 779-803.

Álvarez, E., Pantoja, A., Gañan, L., & Ceballos, G. (2015). Current status of Moko disease and black sigatoka in Latin America and the Caribbean, and options for managing them. *Publicación CIAT*.

Amankwah, A. (2023). Climate variability, agricultural technologies adoption, and productivity in rural Nigeria: a plot-level analysis. *Agriculture & Food Security*, *12*(1), 7.

Amoutchi, A. I., N'nan-Alla, O., & Thiemele, D. E. F. (2020). Agro-morphological diversity of plantain accessions from different part of the world. *International Journal of Biological and Chemical Sciences*, *14*(4), 1308-1321.

Amungwa, F. A. (2018). Appraisal of innovations in agricultural extension and advisory services in Cameroon. *Journal of Advancements in Plant Science*, *1*(2), 1-9.

Anderson, C. L., Reynolds, T. W., Biscaye, P., Patwardhan, V., & Schmidt, C. (2021). Economic benefits of empowering women in agriculture: Assumptions and evidence. *The Journal of Development Studies*, *57*(2), 193-208.

Ankrah, D. A., Freeman, C. Y., & Afful, A. (2020). Gendered access to productive resources–evidence from small holder farmers in Awutu Senya West District of Ghana. *Scientific African*, *10*, e00604.

Antwi-Agyei, P., & Stringer, L. C. (2021). Improving the effectiveness of agricultural extension services in supporting farmers to adapt to climate change: Insights from northeastern Ghana. *Climate Risk Management*, *32*, 100304.

Apasieva, T. J., Cabuleva, K., & Mitreva, M. (2020). Theory of planned behavior: Personal attitude and perceived behavioral control as key determinants in creation of entrepreneurial societies and social inclusion of young people. *Balkan Social Science Review*, *15*, 275-297.

Arcila-Galvis, J. E., Arango, R. E., Torres-Bonilla, J. M., & Arias, T. (2021). The mitochondrial genome of a plant fungal pathogen Pseudocercospora fijiensis (Mycosphaerellaceae), comparative analysis and diversification times of the Sigatoka disease complex using fossil calibrated phylogenies. *Life*, *11*(3), 215.

Arinaitwe, I. K., Teo, C. H., Kayat, F., Tumuhimbise, R., Uwimana, B., Kubiriba, J., ... & Othman, R. Y. (2019). Evaluation of banana germplasm and genetic analysis of an F1 population for resistance to *Fusarium oxysporum* f. sp. *cubense* race 1. *Euphytica*, *215*, 1-11.

Arkorful, V. E., Hammond, A., Lugu, B. K., Basiru, I., Sunguh, K. K., & Charmaine-Kwade, P. (2022). Investigating the intention to use technology among medical students: An application of an extended model of the theory of planned behavior. *Journal of Public Affairs*, *22*(2), e2460.

Arli, D., Badejo, A., Carlini, J., France, C., Jebarajakirthy, C., Knox, K., ... & Wright, O. (2020). Predicting intention to recycle on the basis of the theory of planned behaviour. *International journal of nonprofit and voluntary sector marketing*, *25*(2), e1653.

Arora, M., Rasane, P., Singh, J., Kaur, S., Bakshi, M., & Kaur, J. (2022). Reinventing Plantain as a Functional Food: A Processing Based Approach. *Current Nutrition & Food Science*, *18*(8), 752-764.

Avwerosuo, E. (2021). A Review on Research Trend on Sigatoka Diseases from 1965-2018: Bibliometric Approach. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *12*(12), 3952-3965.

Bahadur, A. (2021). Nematodes diseases of fruits and vegetables crops in India. *Nematodes-Recent Advances, Management and New Perspectives*, 1-18.

Baker, B. P., Green, T. A., & Loker, A. J. (2020). Biological control and integrated pest management in organic and conventional systems. *Biological Control*, *140*, 104095.

Bamba, B., & Alassane, A. (2021). ASSESSING THE AGRONOMIC PERFORMANCE OF TWO PLANTAIN HYBRIDS IN CÔTE D'IVOIRE. *Top Academic Journal of Environmental and Agricultural Sciences*, *6*(2), 17-33.

Becker, P., Esker, P., & Umaña, G. (2021). Incorporation of microorganisms to reduce chemical fungicide usage in black sigatoka control programs in Costa Rica by use of biological fungicides. *Crop Protection*, *146*, 105657.

Berni, I., Menouni, A., El, I. G., Duca, R. C., Kestemont, M. P., Godderis, L., & Jaafari, S. E. (2021). Understanding farmers' safety behavior regarding pesticide use in Morocco. *Sustainable Production and Consumption*, *25*, 471-483.

Blomme, G., Ocimati, W., Felde, A. Z., Amwonya, D., & Kantungeko, D. (2020). A literature review on yield gaps of various root, tuber and banana crops as a background for assessing banana yield reductions due to pests and diseases at a field site in western Burundi. *African Journal of Agricultural Research*.

Blomme, G., Ploetz, R., Jones, D., De Langhe, E., Price, N., Gold, C., ... & Buddenhagen, I. (2013). A historical overview of the appearance and spread of Musa pests and pathogens on the African continent: highlighting the importance of clean Musa planting materials and quarantine measures. *Annals of Applied Biology*, *162*(1), 4-26.

Boris, N. T. J., Laurette, N. N., & Modestine, K. S. M. (2023). Plantain (Musa paradisiaca L.): Production, Consumption and Processing in Cameroon. *American Journal of Food Science and Technology*, *11*(1), 8-14.

Bravo-Monroy, L., Potts, S. G., & Tzanopoulos, J. (2016). Drivers influencing farmer decisions for adopting organic or conventional coffee management practices. *Food policy*, *58*, 49-61.

Cauthen, J., Jones, D., Gugerty, M. K., & Anderson, C. L. (2019). Banana and plantain value chain: West Africa. *Gates Open Res*, *3*(39), 39.

Chakraborty, B. (2020). Adoption of Bio and Organic Amendments: A New Perspective in Crop Protection. *Advances and Trends in Agricultural Sciences*, 27.

Chenaa, T. A., Maria, A. G., & Teno, M. N. (2018). Determinants of access to credit and performance of smallholder farmers in Kumba Municipality, South West Region of Cameroon. *Asian Journal of Agricultural Extension, Economics & Sociology*, *25*(1), 1-12.

Chimi, P. M., Mala, W. A., Essouma, F. M., Ngamsou, A. K., Matick, J. H., Fobane, J. L., ... & Bell, J. M. (2022). Family Farming Systems in Northern Central Cameroon: Challenges and Prospects for Food Security. *ESI Preprints*, *11*, 678-678.

Chimi, Pierre Marie, William Armand Mala, François Manga Essouma, Abdel Karimou Ngamsou, John Hermann Matick, Jean Louis Fobane, Forbi Preasious Funwi, Michele Elodie Kouoguem Kamdem, Lethicia Flavine Feunang Nganmegni, and Joseph Martin Bell. "Family Farming Systems in Northern Central Cameroon: Challenges and Prospects for Food Security." *ESI Preprints* 11 (2022): 678-678.

Chong, P. A., & Santos-Ordoñez, E. (2020). New biotechnology promising approaches for disease control on bananas and plantains. *Agricultural, Forestry and Bioindustry Biotechnology and Biodiscovery*, 13-23.

Churchill, A.C.L. (2011). *Mycosphaerella fijiensis*, the black leaf streak pathogen of banana: progress towards understanding pathogen biology and detection, disease development, and the challenges of control. Molecular Plant Pathology, 12, 307-328. https://doi.org/10.1111/j.1364-3703.2010.00672.x

Constantine, K. L., Kansiime, M. K., Mugambi, I., Nunda, W., Chacha, D., Rware, H., ... & Day, R. (2020). Why don't smallholder farmers in Kenya use more biopesticides?. *Pest management science*, *76*(11), 3615-3625.

Costa, C. A., Guiné, R. P., Costa, D. V., Correia, H. E., & Nave, A. (2023). Pest control in organic farming. In *Advances in Resting-state Functional MRI* (pp. 111-179). Woodhead Publishing.

Dadrasnia, A., Usman, M. M., Omar, R., Ismail, S., & Abdullah, R. (2020). Potential use of Bacillus genus to control of bananas diseases: Approaches toward high yield production and sustainable management. *Journal of King Saud University-Science*, *32*(4), 2336-2342.

Danso-Abbeam, G., & Baiyegunhi, L. J. (2018). Welfare impact of pesticides management practices among smallholder cocoa farmers in Ghana. *Technology in Society*, *54*, 10-19.

de Araújo, T. L. K., Sousa, P., de Miranda Azeiteiro, U. M., & da Maia Soares, A. M. V. (2021). Brazilian Amazônia, deforestation and environmental degradation: Analyzing the process using game, deterrence and rational choice theories. Environmental Science & Policy, 117, 46-51.

De Lapeyre de Bellaire, L., Essoh Ngando, J., Abadie, C., Carlier, J., & Fouré, E. (2006). Management of black sigatoka in Cameroon.

De Souza-Pollo, A., & de Goes, A. (2020). Banana pathology and diseases. *Handbook of Banana Production, Postharvest Science, Processing Technology, and Nutrition*, 45-59.

Denkyirah, E. K., Okoffo, E. D., Adu, D. T., Aziz, A. A., Ofori, A., & Denkyirah, E. K. (2016). Modeling Ghanaian cocoa farmers' decision to use pesticide and frequency of application: the case of Brong Ahafo Region. *SpringerPlus*, *5*, 1-17.

Dépigny, S., Wils, E. D., Tixier, P., Keng, M. N., Cilas, C., Lescot, T., & Jagoret, P. (2019). Plantain productivity: Insights from Cameroonian cropping systems. *Agricultural Systems*, *168*, 1-10.

Desdoigts, E., Kwa, M., Fogain, R., Temple, L., Lang, P. S., Bikoï, A., & Achard, R. (2005). A multidisciplinary monitory centre by smallholders in Cameroon to identify factors limiting plantain production. *Fruits*, *60*(4), 237-244.

Dita, M., Barquero, M., Heck, D., Mizubuti, E. S., & Staver, C. P. (2018). Fusarium wilt of banana: current knowledge on epidemiology and research needs toward sustainable disease management. *Frontiers in Plant Science*, *9*, 1468.

Doidge, C., Ruston, A., Lovatt, F., Hudson, C., King, L., & Kaler, J. (2020). Farmers' perceptions of preventing antibiotic resistance on sheep and beef farms: risk, responsibility, and action. *Frontiers in Veterinary Science*, *7*, 524.

Drenth, A., & Kema, G. (2021). The vulnerability of bananas to globally emerging disease threats. *Phytopathology®*, *111*(12), 2146-2161.

Esguera, J. G., Balendres, M. A., & Paguntalan, D. P. (2024). Overview of the Sigatoka leaf spot complex in banana and its current management. *Tropical Plants*, *3*(1).

FAO. (2016). Food and Agriculture Organization of the United Nations. Production Yearbook. FAO Rome. 2016.

FAOSTAT (2021). FAOSTAT Online Database. Available at http://faostat.fao.org/ (accessed January 2021).

FAOSTAT. (2018) Food and Agriculture Organization of the United Nations Statistics Database. http://www.fao.org/faostat/en/#data/QC. Accessed 25th June, 2023

Faturoti BO, Madukwe MC, Tenkouanoand A and AE Agwu (2007). A review of policy acts and initiatives in plantain, and banana system in Nigeria. African J Biotechnology. 2007; 6: 2297-2302.

Ferreira, C. F., Silva, S. O., Sobrinho, N. P. D., Cristina, S., Damascena, S., Alves, F. S. D. A. A. O. & Paz, O. P. D. (2004). Molecular Characterization of Banana (AA) Diploids with Contrasting Levels of Black and Yellow Sigatoka Resistance. American Journal of Applied Sciences, 1(4), 276-278. https://doi.org/10.3844/ajassp.2004.276.278

Foncha, J. N., Assonwa, E. F., & Mokenge, D. E. (2020). Organic agriculture and its implications to food security: The case of the Likove farmers simplified cooperative society, Sasse, Cameroon. *Journal of Agricultural and Crop Research*, *8*(8), 159-168.

Fonge, B. A., Nkoleka, E. N., Asong, F. Z., Ajonina, S. A., & Che, V. B. (2017). Heavy metal contamination in soils from a municipal landfill, surrounded by banana plantation in the eastern flank of Mount Cameroon. *African Journal of Biotechnology*, *16*(25), 1391-1399.

Fullerton, R. A., & Casonato, S. G. (2019). The infection of the fruit of 'Cavendish'banana by Pseudocercospora fijiensis, cause of black leaf streak (black Sigatoka). *European Journal of Plant Pathology*, *155*, 779-787.

Gao, Y., Zhang, X., Lu, J., Wu, L., & Yin, S. (2017). Adoption behavior of green control techniques by family farms in China: Evidence from 676 family farms in Huang-huai-hai Plain. *Crop protection*, *99*, 76-84.

Gratia, N. S., & Fawzi, I. L. (2021). The Impact of Empowering Pisang Mas Banana Farmers through Partnership with PT. Great Giant Pineapple. *JPPM (Jurnal Pendidikan Dan Pemberdayaan Masyarakat)*, *8*(2), 118-130.

Gurmu, T., Adugna, G., & Berecha, G. (2017). Black Sigatoka leaf streaks of banana (Musa spp.) caused by Mycosphaerella fijiensis in Ethiopia. *Journal of Plant Diseases and Protection*, 124, 245-253.

Gutierrez-Monsalve, J. A., Mosquera, S., González-Jaramillo, L. M., Mira, J. J., & Villegas-Escobar, V. (2015). Effective control of black Sigatoka disease using a microbial fungicide based on Bacillus subtilis EA-CB0015 culture. *Biological control*, *87*, 39-46.

Hasan, H. N., & Suciarto, S. (2020). The influence of attitude, subjective norm and perceived behavioral control towards organic food purchase intention. *Journal of Management and Business Environment (JMBE)*, *1*(2), 132.

Heydari, M., Xiaohu, Z., Keung, L. K., & Shang, Y. (2020). Entrepreneurial intentions and behaviour as the creation of business: Based on the theory of planned behaviour extension evidence from polish universities and entrepreneurs. *Propósitos y representaciones*, *8*(2), 46.

Huber, R., Bakker, M., Balmann, A., Berger, T., Bithell, M., Brown, C., ... & Finger, R. (2018). Representation of decision-making in European agricultural agent-based models. *Agricultural systems*, *167*, 143-160.

Ishola, B. D., & Arumugam, N. (2019). Factors preventing the adoption of agricultural technology among banana and plantain growers: A mapping review of recent literature. *JoMOR 1 (1): 1*, *11*.

Jacobsen, K., Fogain, R., Mouassom, H. & De Waele, D. (2004). Musa-based cropping systems of the Cameroon highlands: a case study of the West and Northwest provinces of Cameroon, with emphasis on nematodes. Fruits, 59 (5): 311–318

Jacquet, F., Jeuffroy, M. H., Jouan, J., Le Cadre, E., Litrico, I., Malausa, T., ... & Huyghe, C. (2022). Pesticide-free agriculture as a new paradigm for research. *Agronomy for Sustainable Development*, *42*(1), 8.

Jekayinoluwa, T., Tripathi, L., Tripathi, J. N., Ntui, V. O., Obiero, G., Muge, E., & Dale, J. (2020). RNAi technology for management of banana bunchy top disease. *Food and Energy Security*, *9*(4), e247.

Jomanga, K. E., & Lucas, S. S. (2021). The Effects, Distribution and Management Options for Major Banana Diseases in Tanzania. International Journal of Current Science Research and Review, 04 (10), 1276-1295.

Jouzi, Z., Azadi, H., Taheri, F., Zarafshani, K., Gebrehiwot, K., Van Passel, S., & Lebailly, P. (2017). Organic farming and small-scale farmers: Main opportunities and challenges. *Ecological economics*, *132*, 144-154.

Kabir, M. H., & Rainis, R. (2015). Adoption and intensity of integrated pest management (IPM) vegetable farming in Bangladesh: an approach to sustainable agricultural development. *Environment, development and sustainability*, *17*, 1413-1429.

Kenfack Essougong, U. P., Fongang Fouepe, G. H., & Degrande, A. (2019). Can community-based organisations deliver adequate agricultural information to farmers? Evidence from rural resources centres in Cameroon. *Information Development*, *35*(3), 435-446.

Khan, N. A., Gao, Q., Iqbal, M. A., & Abid, M. (2020). Modeling food growers' perceptions and behavior towards environmental changes and its induced risks: evidence from Pakistan. *Environmental Science and Pollution Research*, *27*, 20292-20308.

Kimunye, J. N., Were, E., Mussa, F., Tazuba, A., Jomanga, K., Viljoen, A., ... & Mahuku, G. (2020). Distribution of Pseudocercospora species causing Sigatoka leaf diseases of banana in Uganda and Tanzania. *Plant Pathology*, *69*(1), 50-59.

Kimunye, J., Jomanga, K., Tazuba, A. F., Were, E., Viljoen, A., Swennen, R., & Mahuku, G. (2021). Genotype X environment response of 'Matooke'hybrids (Naritas) to Pseudocercospora fijiensis, the cause of black Sigatoka in banana. *Agronomy*, *11*(6), 1145.

Kimunye, J., Were, E., Swennen, R., Viljoen, A., & Mahuku, G. (2021). Sources of resistance to Pseudocercospora fijiensis, the cause of black Sigatoka in banana. *Plant pathology*, *70*(7), 1651-1664.

Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and psychological measurement*, *30*(3), 607-610.

Kumakech, A., Jørgensen, H. J. L., Collinge, D. B., Edema, R., & Okori, P. (2022). Plant extracts as potential control agents of Black Sigatoka in banana. *Journal of Plant Pathology*, *104*(4), 1303-1314.

La Barbera, F., & Ajzen, I. (2020). Control interactions in the theory of planned behavior: Rethinking the role of subjective norm. *Europe's Journal of Psychology*, *16*(3), 401.

Lamichhane, J. R., Dachbrodt-Saaydeh, S., Kudsk, P., & Messéan, A. (2016). Toward a reduced reliance on conventional pesticides in European agriculture. *Plant Disease*, *100*(1), 10-24.

Lienou, J. A., Ngatat, S., Nanga Nanga, S., Doumtsop Fotio, A. R. P., Abang Fomumbod, A., Fotso Kuate, A., ... & Hanna, R. (2022). Plantain hybrids for the humid forest agroecology of Central Africa–diseases and pests load, fruit yield and farmers perception. *Plant Production Science*, *25*(4), 484-500.

Lim, J. A., Yaacob, J. S., Mohd Rasli, S. R. A., Eyahmalay, J. E., El Enshasy, H. A., & Zakaria, M. R. S. (2023). Mitigating the repercussions of climate change on diseases affecting important crop commodities in Southeast Asia, for food security and environmental sustainability—A review. *Frontiers in Sustainable Food Systems*, *6*, 1030540.

Liu, W., Du, C., Yang, T., & Jin, S. (2023). Farm level adaptation to climate change in north China: behavioural practices and potential drivers. *Environmental Sociology*, *9*(2), 216-231.

Livune, D. (2022). *An establishment of strategies that can make the agriculture extension education programme provided in Zambia effective: a case of Kazungula district* (Doctoral dissertation, The University of Zambia).

Machaka-Mare, Z. M., Mpinganjira, M., & Maduku, D. K. (2023). Understanding binge drinking quitting intention and behaviour using an extended TPB. *Social Marketing Quarterly*, *29*(2), 107-126.

Madalla, N. A. (2021). Farmers' traits preferences for improved banana cultivars in Tanzania and Uganda. *Alnarp, Sweden: Swedish University of Agriculture Science*.

Mahmood, N., Arshad, M., Kaechele, H., Shahzad, M. F., Ullah, A., & Mueller, K. (2020). Fatalism, climate resiliency training and farmers' adaptation responses: Implications for sustainable rainfed-wheat production in Pakistan. *Sustainability*, *12*(4), 1650.

Marie, M., Yirga, F., Haile, M., & Tquabo, F. (2020). Farmers' choices and factors affecting adoption of climate change adaptation strategies: evidence from northwestern Ethiopia. *Heliyon*, *6*(4).

Mashi, S. A., Inkani, A. I., & Oghenejabor, O. D. (2022). Determinants of awareness levels of climate smart agricultural technologies and practices of urban farmers in Kuje, Abuja, Nigeria. *Technology in Society*, *70*, 102030.

Mbo Nkoulou, L. F., Fifen Nkouandou, Y., Bille Ngalle, H., Cros, D., Martin, G., Molo, T., ... & Achigan-Dako, E. G. (2024). Screening of triploid banana population under natural and controlled black sigatoka disease for genomic selection. *Plant Disease*, (ja).

Mbo Nkoulou, L. F., Ngalle, H. B., Cros, D., Adje, C. O., Fassinou, N. V., Bell, J., & Achigan-Dako, E. G. (2022). Perspective for genomic-enabled prediction against black sigatoka disease and drought stress in polyploid species. *Frontiers in Plant Science*, *13*, 953133.

Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W., & Nieuwenhuis, M. (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. *International journal of agricultural sustainability*, *13*(1), 40-54.

Meijer, S. S., Sileshi, G. W., Kundhlande, G., Catacutan, D., & Nieuwenhuis, M. (2015). The role of gender and kinship structure in household decision-making for agriculture and tree planting in Malawi. *Journal of Gender, Agriculture and Food Security (Agri-Gender)*, *1*(1), 54-76.

Mendoza-Rodríguez, M. F., Portal, O., Oloriz, M. I., Ocaña, B., Rojas, L. E., Acosta-Suárez, M., ... & Jiménez, E. (2018). Early regulation of primary metabolism, antioxidant, methyl cycle and phenylpropanoid pathways during the Mycosphaerella fijiensis-Musa spp. interaction. *Tropical plant pathology*, *43*, 1-9.

Mengesha, G. G., Jambo, A., Terefe, H., Mekonnen, S., Simion, T., Mensa, A., ... & Woldesilassie, A. B. (2023). Agronomic practices and environmental factors influenced the distribution and severity of black Sigatoka (Mycosphaerella fijiensis Morelet) of banana in southern Ethiopia. *Journal of Plant Pathology*, *105*(4), 1371-1390.

Midingoyi, S. K. G., Kassie, M., Muriithi, B., Diiro, G., & Ekesi, S. (2019). Do farmers and the environment benefit from adopting integrated pest management practices? Evidence from Kenya. *Journal of Agricultural Economics*, *70*(2), 452-470.

Monono, E. Y., Egbe, A. E., Monono, E. M., Levai, L. D., & Asiedu, E. (2023). Influences of organic waste and inorganic fertilizer for sustainable production of plantain (Musa spp. AAB) in a humid forest zone of Cameroon.

Muthee, A. I., Gichimu, B. M., & Nthakanio, P. N. (2019). Analysis of banana production practices and constraints in Embu County, Kenya. *Asian Journal of Agriculture and Rural Development*, *9*(1), 123.

Nascimento, F. D. S., Sousa, Y. M., Rocha, A. D. J., Ferreira, C. F., Haddad, F., & Amorim, E. P. (2020). Sources of black Sigatoka resistance in wild banana diploids. *Revista Brasileira de Fruticultura*, *42*, e-038.

Nayar, N. M. (2010). 2 The Bananas: Botany, Origin, Dispersal. *Horticultural reviews*, *36*(3), 117-164.

Nelson, R. (2020). International plant pathology: past and future contributions to global food security. *Phytopathology*, *110*(2), 245-253.

Nji, P. M., & Engwali, F. D. (2020). Determinants of success and sustainability of farmer organizations in the North West Region of Cameroon. *Asian J. Agric. Ext. Econ. Sociol*, *4*, 1-13.

Nkengla-Asi, L., Omondi, A. B., Che Simo, V., Assam, E., Ngatat, S., & Boonabaana, B. (2020). Gender dynamics in banana seed systems and impact on banana bunchy top disease recovery in Cameroon. *Outlook on Agriculture*, *49*(3), 235-244.

Nkiaka, E. (2022). Water security assessment in ungauged regions using the water balance and water footprint concepts and satellite observations. *Hydrology Research*, *53*(2), 336-352.

Nkwain, K. T., Odiaka, E. C., & Ikwuba, A. A. (2022). Assessment of pre-harvest losses of banana and the social wellbeing of farmers in Boyo Division, North West Region of Cameroon.

Okolle, J. N. (2019). Research Notes on Current Issues in Cameroon Agriculture. *FARA Research Results*, *4*(14), 169.

Olumba, C. C., & Onunka, C. N. (2020). Banana and plantain in West Africa: Production and marketing. *African Journal of Food, Agriculture, Nutrition and Development*, *20*(2), 15474-15489.

Osterman, J., Landaverde-González, P., Garratt, M. P., Gee, M., Mandelik, Y., Langowska, A., ... & Howlett, B. G. (2021). On-farm experiences shape farmer knowledge, perceptions of pollinators, and management practices. *Global Ecology and Conservation*, *32*, e01949.

Özkara, A., Akyıl, D., & Konuk, M. (2016). Pesticides, environmental pollution, and health. In *Environmental health risk-hazardous factors to living species*. IntechOpen.

Pereira, J. M., Oom, D., Pereira, P., Turkman, A. A., & Turkman, K. F. (2015). Religious affiliation modulates weekly cycles of cropland burning in sub-Saharan Africa. *PloS one*, *10*(9), e0139189.

Petit, S., Muneret, L., Carbonne, B., Hannachi, M., Ricci, B., Rusch, A., & Lavigne, C. (2020). Landscape-scale expansion of agroecology to enhance natural pest control: a systematic review. *Advances in ecological research*, *63*, 1-48.

Raja, N. B., & Rajendran, P. S. (2022). Comparative Analysis of Banana Leaf Disease Detection and Classification Methods. In *2022 6th International Conference on Computing Methodologies and Communication (ICCMC)* (pp. 1215-1222). IEEE.

Rani, L., Thapa, K., Kanojia, N., Sharma, N., Singh, S., Grewal, A. S., ... & Kaushal, J. (2021). An extensive review on the consequences of chemical pesticides on human health and environment. *Journal of cleaner production*, *283*, 124657.

Rawat, L., Bisht, T. S., & Naithani, D. C. (2021). Plant disease management in organic farming system: strategies and challenges. *Emerging trends in plant pathology*, 611-642.

Ren, C., Liu, S., Van Grinsven, H., Reis, S., Jin, S., Liu, H., & Gu, B. (2019). The impact of farm size on agricultural sustainability. *Journal of Cleaner Production*, *220*, 357-367.

Reuveni, M., Barbier, M., & Viti, A. J. (2020). Essential tea tree oil as a tool to combat black Sigatoka in banana. *Outlooks on Pest Management*, *31*(4), 180-186.

Rezaei, R., Safa, L., & Ganjkhanloo, M. M. (2020). Understanding farmers' ecological conservation behavior regarding the use of integrated pest management-an application of the technology acceptance model. *Global Ecology and Conservation*, *22*, e00941.

Roberts, J. M., Carvalhais, L. C., O'Dwyer, C., Rincón-Flórez, V. A., & Drenth, A. (2024). Diagnostics of Fusarium wilt in banana: Current status and challenges. *Plant Pathology*.

Salas-Pascual, M., & Cáceres-Lorenzo, T. (2022). The dispersal of bananas (Musa spp.) to the Americas in the sixteenth century. Economic Botany, 76(4), 354-367.

Sama, S. O., Chiamo, S. N., Taiwe, G. S., Njume, G. E., & Ngole Sumbele, I. U. (2021). Microcytic and malarial anaemia prevalence in urban children≤ 15 years in the mount cameroon area: a cross-sectional study on risk factors. *Anemia*, *2021*.

Scott, G. J. (2021). A review of root, tuber and banana crops in developing countries: past, present and future. International Journal of Food Science & Technology, 56(3), 1093-1114.

Seenivasan, N. (2017). Evaluation of different solid media for mass production of native entomopathogenic nematodes Heterorhabditis bacteriophora and Steinernema carpocapsae isolated from cotton fields. *International Journal of Research Studies in Zoology*, *3*, 45-50.

Serebrennikov, D., Thorne, F., Kallas, Z., & McCarthy, S. N. (2020). Factors influencing adoption of sustainable farming practices in Europe: A systemic review of empirical literature. *Sustainability*, *12*(22), 9719.

Shah, K., & Yadav, B. P. (2018). Major diseases of banana and their management practices adopted by the farmers in Chitwan district.

Shaikh, T. A., Rasool, T., & Lone, F. R. (2022). Towards leveraging the role of machine learning and artificial intelligence in precision agriculture and smart farming. *Computers and Electronics in Agriculture*, *198*, 107119.

Sharifzadeh, M. S., Abdollahzadeh, G., Damalas, C. A., & Rezaei, R. (2018). Farmers' criteria for pesticide selection and use in the pest control process. *Agriculture*, *8*(2), 24.

Sileshi, G. W., & Gebeyehu, S. (2021). Emerging infectious diseases threatening food security and economies in Africa. *Global Food Security*, *28*, 100479.

Singh, C., Dorward, P., & Osbahr, H. (2016). Developing a holistic approach to the analysis of farmer decision-making: Implications for adaptation policy and practice in developing countries. *Land use policy*, *59*, 329-343.

Soares, J., Rocha, A. J., Nascimento, F. S., Miller, R. N., Ferreira, C. F., Haddad, F., & Amorim, E. P. (2021). Genetic improvement for resistance to black Sigatoka in bananas: A systematic review. *Frontiers in plant science*, *12*, 657916.

Souleymane, S., Gnenakan, Y., Brahima, C., Leonard, O. S., & Daouda, K. (2022). Alternative Strategy to the Chemical Control of Mycosphaerella fijiensis Morelet, Causative Agent of Banana Trees Black Sigatoka by the Use of Biopesticides. *American Journal of BioScience*, *10*(3), 106-117.

Strobl, E., & Mohan, P. (2020). Climate and the global spread and impact of bananas' black leaf Sigatoka disease. *Atmosphere*, *11*(9), 947.

Sumi, K., Banik, S., & Chakruno, P. (2022). Current Status of Banana (Musa Paradisiaca L.) Diseases and Their Management. In *Diseases of Horticultural Crops: Diagnosis and Management* (pp. 109-140). Apple Academic Press.

Tama, R. A. Z., Ying, L., Yu, M., Hoque, M. M., Adnan, K. M., & Sarker, S. A. (2021). Assessing farmers' intention towards conservation agriculture by using the Extended Theory of Planned Behavior. *Journal of Environmental Management*, *280*, 111654.

Tatsegouock, R. N., Ewané, C. A., Meshuneke, A., & Boudjeko, T. (2020). Plantain bananas PIF seedlings treatment with liquid extracts of Tithonia diversifolia induces resistance to black Sigatoka disease. *American Journal of Plant Sciences*, *11*(5), 653-671.

Tinzaara, W., Mutambuka, M., Oyesigye, E., Blomme, G., Dita, M., Gold, C. S., ... & Karamura, E. (2021). Banana wilt diseases: Current status and future research strategies for their management. *International Journal of Pest Management*, 1-20.

Udomkun, P., Masso, C., Swennen, R., Innawong, B., Fotso Kuate, A., Alakonya, A., ... & Vanlauwe, B. (2021). Consumer preferences and socioeconomic factors decided on plantain and plantain-based products in the central region of cameroon and oyo state, nigeria. *Foods*, *10*(8), 1955.

Ujat, A. H., Vadamalai, G., Hattori, Y., Nakashima, C., Wong, C. K. F., & Zulperi, D. (2021).

Ullah, A., Mishra, A. K., & Bavorova, M. (2023). Agroforestry adoption decision in green growth initiative programs: Key lessons from the billion trees afforestation project (BTAP). *Environmental Management*, *71*(5), 950-964.

Van Bruggen, A. H., Gamliel, A., & Finckh, M. R. (2016). Plant disease management in organic farming systems. *Pest Management Science*, *72*(1), 30-44.

Van Campenhout, B., Spielman, D. J., & Lecoutere, E. (2021). Information and communication technologies to provide agricultural advice to smallholder farmers: Experimental evidence from Uganda. *American Journal of Agricultural Economics*, *103*(1), 317-337.

Vieira, A. H., & Leles, C. R. (2014). Exploring motivations to seek and undergo prosthodontic care: an empirical approach using the Theory of Planned Behavior construct. *Patient preference and adherence*, 1215-1221.

Wang, J., Xu, Y., Zou, L., & Wang, Y. (2021). Does culture affect farmer willingness to transfer rural land? Evidence from Southern Fujian, China. *Land*, *10*(6), 594.

Wang, W., Jin, J., He, R., & Gong, H. (2017). Gender differences in pesticide use knowledge, risk awareness and practices in Chinese farmers. *Science of the Total Environment*, *590*, 22-28.

Waseem, R., Mwalupaso, G. E., Waseem, F., Khan, H., Panhwar, G. M., & Shi, Y. (2020). Adoption of sustainable agriculture practices in banana farm production: A study from the Sindh Region of Pakistan. *International Journal of Environmental Research and Public Health*, *17*(10), 3714.

Weber, O. B., Garruti, D. dos S., Norões, N. P., & Silva, S. de O. e .. (2017). Performance of banana genotypes with resistance to black leaf streak disease in Northeastern Brazil. Pesquisa Agropecuária Brasileira, 52(Pesq. agropec. bras., 2017 52(3)), 161–169. https://doi.org/10.1590/S0100-204X2017000300003

Wole-Alo, F. I., & Oluwagbemi, I. O. (2020). Adoption and utilization of ICT through Farmers. NG technology in Ondo State, Nigeria. *International Journal of Applied Agricultural Sciences*, *6*(1), 7-15.

Wuepper, D., Roleff, N., & Finger, R. (2021). Does it matter who advises farmers? Pest management choices with public and private extension. *Food Policy*, *99*, 101995.

Wung, G. B., & Tongwa Aka, F. (2019). Enhancing resilience against floods in the Lower Motowoh community, Limbe, Southwest Cameroon. *Disaster Prevention and Management: An International Journal*, *28*(1), 76-83.

Zeweld, W., Van Huylenbroeck, G., Tesfay, G., & Speelman, S. (2017). Smallholder farmers' behavioural intentions towards sustainable agricultural practices. *Journal of environmental management*, *187*, 71-81.