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ASSESSING THE ECONOMIC VIABILITY AND MARKET DEMAND FOR ORANGE-FLESHED SWEET POTATO VINES: EVIDENCE FROM NORTHERN GHANA

MAXWELL ANAMDARE ASALE

2025

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FACULTY OF AGRICULTURE, FOOD AND CONSUMER SCIENCES

DEPARTMENT OF AGRICULTURAL AND FOOD ECONOMICS

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UDS/MEC/0007/22

THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL AND FOOD ECONOMICS, FACULTY OF AGRICULTURE, FOOD AND CONSUMER SCIENCES, UNIVERSITY FOR DEVELOPMENT STUDIES, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN AGRICULTURAL ECONOMICS

AUGUST 2025

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DECLARATION

I hereby declare that this thesis is the outcome of my own effort, and that no part or whole of it has been presented for another degree at this university or elsewhere.

.... Date 03/08/2025

Maxwell Anamdare Asale

(Student)

We hereby declare that the presentation of this thesis was supervised in accordance with the guidelines on the supervision of thesis laid down by the University for Development Studies.

.... Date 04/08/2025

Dr Isaac G. K. Ansah

(Principal Supervisor)

for. .... Date 04/08/2025

Prof. Michael Ayamga

(1st Co-Supervisor)

.... Date 19/08/2025

Dr. Birhanu Biazin

(2nd Co-Supervisor)

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DEDICATION

I dedicate this work to my late grandmother, Mrs. Asale Apaleyosige, and my family.

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ACKNOWLEDGEMENT

First, I am extremely grateful to God for the gift of life, guidance, and protection during my study.

My heartfelt gratitude goes to my supervisors, Dr. Isaac G. K. Ansah, Prof. Michael Ayamga and Dr. Birhanu Biazin, for believing and accepting me as a project student. In addition, their invaluable advice, comments, and patience made this writeup a success. I am particularly grateful to all of you for playing a fatherly role and for your motivation, continuous support, and training throughout this project. May the almighty God bless you, replenish your strength and wisdom, and endlessly reward your hard work.

I want to thank Prof. Samuel Donkoh, Dr. Abdul-Basit Tampuli Abukari, Prof. Mabe N. Franklin, Prof. Gideon Danso-Abbeam, Prof. Joseph Awuni, and all lecturers of the Department of Agricultural and Food Economics for their wonderful teaching and training. To my colleagues in the Department, thank you all for your contribution to making my study a success.

I would also like to acknowledge the International Potato Center (CIP) for funding this thesis as part of the action research "*Generating Revenues Opportunities for Women to Improve Nutrition in Ghana (GROWING) project*" funded by the Global Affairs Canada. I am grateful for all the support and resources that were provided during this period, and I learned and gained extensive experience through this project.

To the Directorate of the West African Center for Sustainable and Rural Transformation (WAC-SRT) and the German Academic Exchange Service, I deeply appreciate the funding opportunity offered to me to enroll in this MPhil programme. May God Almighty multiply your funds and continually use them to transform lives.

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ABSTRACT

Despite several attempts to combat Vitamin A deficiency through the production and consumption of orange-fleshed sweetpotato (OFSP), several bottlenecks hinder its adoption and scaling of production in northern Ghana. Lack of access to and availability of OFSP vines at the beginning of the rainy season is a key challenge against the production and marketing of the crop. This study analyzes the economic viability of OFSP vine production using solar-based irrigation and farmers' willingness to pay (WTP) using household data collected in July 2024 from two selected districts in northern Ghana. Combining economic viability assessment tools with various econometric models, the study examined the factors that influence farmers' WTP. The results showed that the production of OFSP vines under solar-based irrigation is economically viable in northern Ghana. Among the irrigation methods examined, drip irrigation offers superior financial returns compared to rain-tube irrigation. Farmers are willing to pay an average of GH₵38.83 for quality OFSP vines with variation across the selected district. The econometric results revealed that several factors influence WTP, especially education as well as access to credit, farmer-based group and extension. Policymakers, NGOs and Internation Center for Potato (CIP) could leverage on the economic viability of OFSP vine production to improve income and reduce poverty in northern Ghana. This could be achieved by establishing functional markets for vines and scaling up drip irrigation for OFSP vine production in northern Ghana. Second, government and CIP should strengthen farmers policies and programs to expand sensitization and logistics that can help farmers enhance their WTP. For instance, ready access to agricultural extension services from government or NGOs could provide farmers with insights to pay for OFSP vines.

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CHAPTER ONE

INTRODUCTION

1.1 Background

The global population is projected to exceed 9 billion by 2050 and 2.2 billion in Africa, Sub-Saharan Africa is expected to account for over half of this growth (FAO, 2017; United Nations, 2019). Ghana's population is projected to increase from 30.8 million in 2021 to 52.5 million in 2050 (GSS, 2021). The rapid population growth fueled by high fertility rates, is driving an increased demand for food. Thus, the second sustainable development goal to end hunger by 2030 is challenging. Compared to 2019, in 2022, an estimated 783 million of the global population was undernourished, representing an overall increase of 122 million people (WHO, 2023). Undernourishment is most prevalent in developing countries, with Asia and Africa having the highest rates (WHO, 2023). Furthermore, micronutrient malnutrition is a significant public health concern, with vitamin A deficiency (VAD) being a major issue in over half of the world's countries, primarily in Africa and Southeast Asia (Mitsunaga & Yamauchi, 2022; Wiseman et al., 2017). VAD is the primary cause of preventable blindness in children worldwide (Arumugam et al., 2020; Healy et al., 2018).

According to estimates, over 30% of children under 5 suffer from VAD, and approximately 2% of deaths in this age group are attributed to VAD globally (Song et al., 2023; Wirth et al., 2017). In Ghana, VAD affects 20% of children, with a higher prevalence in the northern belt (31%) and a lower prevalence among children residing in wealthier households (9%). So far, the trend indicates that food insecurity and micronutrient deficiency, especially VAD, have a severe impact in areas where poverty limits access to nutritious foods and supplements. Iheonu and Oladipupo (2024) notes that rising food prices worsen poverty and hunger, resulting in higher malnutrition rates. Households often prioritize buying affordable staples like cereals over nutrient-dense foods like fruits, vegetables, and meat. However, this shift towards staples like wheat, maize, and rice leads to deficiencies in essential micronutrients like vitamin A, iron, and zinc. FAO (2009) reported that the main cause of VAD in Ghana was low dietary diversity.

Over the past two decades, orange flesh sweetpotato (OFSP) has gained increasing importance in agriculture to combat food insecurity and malnutrition, particularly VAD, among children and women in Africa and parts of Asia (Low et al., 2017; Low et al., 2007; UNICEF, 2018; Van Jaarsveld et al., 2006; WHO, 2018). OFSP also serves as a source of income for local communities (Ezin et al., 2018). Sweetpotato is ranked as the 4th most important root crop in Ghana, being cultivated across several regions in Ghana by smallholder farmers (Bidzakin et al., 2014; Sugri et al., 2024). Annual production is estimated at 0.132 million tonnes cultivated on 9,622 hectares of arable land (Singh et al., 2023; SRID, 2013).

Biofortified OFSP varieties are rich in carotenoids, the precursor to vitamin A, making them a proven and sustainable source of this essential nutrient (Girard et al., 2017). OFSP is rich in phytochemicals and iron, which provide protection against peroxides and support women's fertility (Slavin & Lloyd, 2012). OFSP has various health benefits, including maintaining healthy blood pressure, preventing constipation, and reducing the risk of chronic diseases like cancer, obesity, diabetes, and heart disease, as well as supporting liver health (Anderson et al., 2009). Proof-of-concept studies in Africa have found strong evidence that OFSP can provide adequate quantities of vitamin A to eliminate VAD among

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vulnerable groups (HarvestPlus, 2012; Truayinet, 2020). van Jaarsveld et al. (2005) also found that moderate consumption of boiled OFSP by children at least 3 times a week significantly enhanced their vitamin A levels in the blood.

In 2005, the Crops Research Institute (CRI) in Ghana introduced the OFSP variety, Apomuden, to improve the nutritional status and livelihood of smallholder farmers. Later, from 2014 to 2017, the International Potato Center (CIP) and other partners promoted this variety through the "Jumpstarting, Orange-fleshed Sweetpotato in West Africa through Diversified Markets Project". The initiative included market sensitization, demand creation campaigns, nutrition education, and training on good agronomic practices in the Upper East and Northern regions. Furthermore, to improve access to planting materials, decentralized vine multipliers were established in communities where sweetpotatoes are extensively cultivated, creating linkages between breeding stations and seed multipliers (Adekambi, et al., 2020).

A more recent intervention is the "Generating Revenues and Opportunities for Women to Improve Nutrition in Ghana (GROWING)" project led by CIP. The project is being implemented in six districts in northern Ghana and involves integrated Climate-Smart Agriculture-Nutrition-Marketing interventions. As part of this initiative, the project aims to demonstrate solar irrigation for staggered production and supply of sweetpotato vines in northern Ghana.

Northern Ghana has enormous potential for solar energy. Sunshine and global irradiation are estimated to be 300h/year and 5.8 kWh/m^2 /day, respectively (Mbaye, 2019). Solar irrigation pumps are environmentally and economically sustainable alternatives to fossil fuel-powered pumps (Closas & Rap, 2017). They have longer lifetimes with lower

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maintenance costs and no fuel costs and energy sources can be found worldwide for free (Wazed et al., 2018).

While global concerns such as population growth and food insecurity underscore the urgency of agricultural innovation United Nations (2019) and WHO (2023), the specific challenges faced by smallholder farmers in northern Ghana highlight critical barriers to sustainable food production and nutritional security. The region grapples with significant hurdles, including inadequate access to high-quality planting materials and the sustainability of vine multiplication efforts (Temesgen & Gyan-Bassaw, 2023). Planting diseased low-quality seeds can result in high-yield challenges and welfare-reducing effects in developing countries including Ghana (Mann & Warner, 2017; Okello et al., 2017; Wossen et al., 2020). This can effectively compromise policy and development interventions targeted at achieving food and nutrition security in Ghana particularly the northern belt where food insecurity remains high (CFSVA, 2020). Addressing these local barriers is pivotal in harnessing the full potential of OFSP to improve livelihoods and nutritional outcomes in northern Ghana. To this end, this study aims to assess the economic viability of OFSP vine production under solar irrigation and farmers' willingness to pay in northern Ghana.

1.2 Problem Statement

Despite the importance of OFSP for improving the health, food security, and livelihoods of smallholder farmers (Abidin et al., 2017; Andrade et al., 2017; Low et al., 2020), several challenges hinder the adoption and scaling up of OFSP production. Key among these challenges is inadequate access to high-quality planting materials during the early rainy season (Ben-Chukwu et al., 2021; Coomes et al., 2015; McEwan et al., 2015; McGuire &

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Sperling, 2016; Sindi & Wambugu, 2012). As a result, farmers rely on their vines, borrow from friends and family Okello et al. (2015); Bentley et al. (2018), or use farmer-to-farmer networks (Kagimbo et al., 2018). This leads to lower productivity and increased pest and disease pressure (Almekinders et al., 2019; Etten et al., 2017; Kagimbo et al., 2018).

In response, several projects have been implemented jointly by the Ghana government and international organizations to curtail this menace. Notable examples include the USAID-Resilience in Northern Ghana project and the Transformational Africa Agricultural Technologies (TAAT) initiative. Additionally, CIP and CARE International Ghana, in partnership with the Ministry of Food and Agriculture (MOFA) and the Ghana Health Service (GHS), recently implemented the GROWING project. The project promotes various technologies, including Storage in Sand, then Sprouting (Triple S), which generates sweetpotato vine cuttings for the next season's planting (Temesgen & Gyan-Bassaw, 2023; Temesgen & Loriba, 2024). In addition, the project distributed sweetpotato vines that are early maturing, rich in Vitamin A, as well as pests and diseases free to approximately 1,131 farmers (300 vine cuttings each) in northern Ghana (Temesgen & Gyan-Bassaw, 2023; Temesgen & Loriba, 2024). Also, five district-level vine multipliers (DVMs) were identified, trained, and supplied with quality starter material.

Furthermore, as part of the project, CIP is introducing PumpTech climate-smart solar-powered irrigation pumps to DVMs to enable the multiplication of OFSP vines and the production of roots during the dry season. The project envisions harnessing the ample solar energy available in the northern belt to establish a consistent and reliable water supply for year-round OFSP production. Despite the positive trajectory of the initiative, there exists a notable gap in the literature regarding the economic viability of OFSP vine production

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under solar pump irrigation in Ghana and SSA at large. Studies like Curtis (2010) looked at the economic viability of solar photovoltaic irrigation for forage production in western Utah, observing that the solar PV irrigation system was a cost-effective alternative forage production in the area. Other studies such as Bolanos et al. (2015) in Colombia, Hossain et al. (2015) in Bangladesh, Gautam and Singh (2021) in India, Sarr et al. (2023) in Senegal, Copeland (2018) in Zambia, and Abu-Nowar (2020) in Jordan found crop production under solar pump irrigation to be economically viable. However, the economic viability of solar pump irrigation varies globally, with diverse payback periods reported in different regions and crops (Lamine, 2020). To this end, the present study seeks to assess the economic viability of OFSP vine production under solar pump irrigation.

Also, empirical studies revealed that though projects that support the multiplication of quality planting material are on the increase, vine commercialization is limited (Almekinders et al., 2019; Mwiti et al., 2020). NGO projects primarily purchase quality vines from Decentralized Vine Multipliers (DVMs) and subsequently distribute them to farmers at subsidized prices or free of charge (Ogero et al., 2016; Bentley, 2018). This raises concerns about the sustainability of the ongoing multiplication efforts including the GROWING project in the absence of project support and subsidies (Mwiti et al., 2020). These concerns are primarily driven by a lack of understanding of whether smallholder sweetpotato producers would be willing to pay for the cost of producing quality vines at a commercial level.

Willingness to pay for quality seeds studies in the literature thus far is skewed to cereals Ayedun et al. (2017); Kassie et al. (2017); Mastenbroek et al. (2021); Shee et al. (2019) and Waldman et al. (2017), legume seeds Maredia et al. (2019) and Waldman et al. (2017),

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yam seed Boadu et al. (2019) and other studies like Bartle and Maredia (2019); Fuglie et al. (2006); Kaguongo et al. (2014) and Okello et al. (2019) invetigated farmers willingness to pay for Irish potato. Research on WTP for quality sweetpotato planting material in SSA and Ghana has received little or no attention to date. Studies that examine WTP for OFSP have mainly focused on fresh roots (Masumba et al., 2007; Meenakshi et al., 2010; Naico & Lusk, 2010; Tumwegamire et al., 2007). The few studies including Labarta (2009) in Mozambique, Mwiti et al. (2020) in Tanzania, Adesina et al. (2017) in northern central Nigeria, and Mwangi et al. (2020) in Kenya assess the level and drivers associated with farmers' WTP for sweetpotato clean seeds. However, these empirical studies provide a limited understanding of how WTP compares to the costs of sweetpotato seed multiplication, which is an integral element in assessing the economic viability of a seed system (Pircher & Almekinders, 2021). Thus, a clear understanding of the difference between farmers' WTP for quality OFSP vines and the actual cost of production will form a foundation for investment in vine multiplication in Ghana.

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This study therefore combines both field experiments and surveys to make three vital contributions to the literature, particularly in the Ghanaian context. First, the study assesses the economic viability of OFSP vine production under solar irrigation using field experiment. Second, it explores the variation in WTP among farmers based on location in selected districts. Third, the study examines the drivers of farmers WTP for quality OFSP vines in northern Ghana.

1.2.1 Main research question

The main research question addressed in this study is framed as follows: Is it economical to produce OFSP vines under solar irrigation, and are farmers willing to pay for vine cuttings? The following specific research questions emerged from the main research question:

1. Is OFSP vine production economically viable under solar irrigation in northern Ghana?
2. Are farmers willing to pay for OFSP vine cuttings as planting materials in the selected districts in northern Ghana?
3. What are the factors influencing farmers' WTP for OFSP vine cutting in northern Ghana?

1.2.2 Main objective

The main research objective is to investigate the economics of OFSP vine production under solar irrigation and farmers' WTP in northern Ghana. This leads to the following specific research objectives:

1. To examine the economic viability of (OFSP) vine production under solar irrigation in northern Ghana.
2. To explore farmers' WTP for OFSP vine cuttings as planting materials in the selected districts.
3. To investigate the factors influencing farmers' WTP for OFSP vine cuttings in northern Ghana.

1.3 Significance of the study

This study contributes uniquely to the existing body of knowledge by investigating the economic viability of OFSP vine production under solar irrigation in northern Ghana, a critical aspect that has been overlooked in previous research. While previous studies have

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explored the nutritional benefits and agricultural potential of OFSP, none has examined the economic feasibility of producing OFSP vines using solar irrigation in this region. The findings of this study provide new insights into the cost-effectiveness of solar irrigation in OFSP vine production, shedding light on the potential returns on investment for smallholder farmers. The study also provides information on the potential viability of investing in the OFSP vine business. This knowledge will enable policymakers, researchers, and practitioners to develop targeted interventions that address the economic and environmental sustainability of OFSP production in northern Ghana.

Secondly, by identifying the key factors influencing farmers' willingness to pay for OFSP vines, this study contributes to the design of effective marketing and distribution channels that enhance the adoption and uptake of OFSP vines among smallholder farmers.

Thirdly, the study would benefit both vine multipliers and farmers as vine prices will be informed by the actual cost of production and farmers' willingness to pay. This study's novel contribution lies in its ability to bridge the gap between agricultural sustainability, economic viability, and nutritional security in the context of OFSP production in northern Ghana. By providing actionable insights and recommendations, this study aims to enhance the resilience and productivity of smallholder farmers, improve the nutritional well-being of local communities, and contribute to the achievement of the United Nations' Sustainable Development Goals (SDGs) of Zero Hunger (SDG 2), Gender Equality (SDG), and Responsible Consumption and Production (SDG 12).

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1.4 Organization of the study

This thesis is organized into five chapters. The first chapter is the introduction which presents the background of the study, the problem statement that informs the study, research questions and objectives, and the significance of the study. The second chapter, Literature Review, focuses on reviewing literature relating to key concepts (economic viability, WTP, Relevant theories, and approaches to measuring economic viability and WTP) used in the study, as well as empirical studies on OFSP. The study area, research design, data types, sources, sampling procedures, conceptual framework, measurement of key variables, and methods of data analysis are presented in chapter three of this thesis. The fourth chapter presents and discusses the results (descriptive and objective-based) of the study. Finally, the fifth chapter presents a summary of the study, key findings, and relevant policy recommendations for CIP, OFSP vine multipliers, government, and other relevant stakeholders.

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CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction to Orange-Fleshed Sweetpotato OFSP

Sweetpotato, *Ipomoea batatas*, is an important root crop belonging to the family of Convolvulaceae and ranks as the seventh most essential food crop in the world (Ahn et al., 2010). It is considered a secondary staple food and plays a critical role in the human diet in many developing countries (van Jaarsveld et al., 2005). Unlike staple food crops, sweetpotatoes have superior traits such as the ability to grow in less favorable conditions, adaptability in extensive topography, good productivity in short periods, and a balanced nutritional composition (Trancoso-Reyes et al., 2016). According to Yudhistira et al. (2022) some varieties of sweetpotatoes possess good sensory acceptability because of the sweet taste and attractive colours, hence are suitable in malnutrition management and improve food security in developing countries. Sweetpotato is classified as "poor man's food" or "famine crop" which has great potential to contribute significantly to promoting food security, reducing poverty, and supplement as a substitute to staple food for resource-poor farmers, due to its wide range of positive attributes such as high yield with limited inputs, tolerance to various production stresses and high nutritional value (Roy et al., 2012). Sweetpotato provides consumers with sizable amounts of minerals including potassium, magnesium and calcium, sugar, starch, vitamins, and many bioactive compounds such as phenolic acid and anthocyanin (Amagloh et al., 2021; Suárez et al., 2016). The colours of sweetpotato flesh vary from orange, yellow, white, and purple and are largely due to the presence of carotenoids (Namitha & Negi, 2010; Neela & Fanta, 2019). However, the three most common types are the orange-fleshed sweetpotatoes which are rich in β-carotene and used in interventions to reduce vitamin A deficiency, white-fleshed sweetpotatoes with no β-carotene and yellow-fleshed sweetpotatoes with limited β-carotenes (Laurie et al., 2022; Mwanga et al., 2021). Research has shown the diversity in sweetpotato flesh colours and its association with nutritional and sensory acceptability. For instance, the purple- and orange-fleshed cultivars possess higher quantities of anthocyanin and carotenes as compared to the white-fleshed cultivars (Van Jaarsveld et al., 2006). Among all the varieties, the demand for orange-fleshed sweetpotato has increased because of its high content of carotenoids and pleasant sensory characteristics with colours Neela and Fanta (2019) as well as its potential to contribute to a food-based approach to address the problem of vitamin A deficiency among the poor (Kurabachew, 2015; Roy et al., 2012)

From a nutritional point of view, OFSP ranked the topmost among all vegetables, due to the significant dietary resources of vitamin A carotenoid and non-pro-vitamin A carotenoids it possesses (Muhammad et al., 2022). OFSP is an important source of beta-carotene, which is a precursor of vitamins A, B6, and C as well as dietary fiber, complex carbohydrates, proteins, iron, calcium, and antioxidants (Baba et al., 2018; Dako et al., 2016; Korada et al., 2010; Robertson et al., 2018; Rodrigues et al., 2016). It provides the cheapest source of antioxidants having several physiological attributes such as anti-oxidation, anti-cancer, and protection against liver injury, and is most suitable as a bio-fortified crop to combat malnutrition in small and marginal farming communities (Roy et al., 2012). Several scientific studies have reported that OFSP is valued and promoted because of its vitamin A contribution and its role in combating malnutrition, including vitamin A deficiency in developing nations (Girard et al., 2017; Kurabachew, 2015; Mahmoud & Anany, 2014; van Jaarsveld et al., 2005).

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According to Tsou and Hong (1992), the consumption of 100 – 150 g of boiled tubers of OFSP can supply the daily requirement of vitamin A for young children which can protect them from blindness or vitamin A deficiency. A similar observation was made by Roy et al. (2012) that the ingestion of OFSP cultivars with high retinol equivalents can make a substantial contribution to alleviating vitamin A deficiency in poverty-stricken farming communities. Empirical studies conducted by Komakech et al. (2019) also revealed that OFSP contributed 68% of the daily vitamin A intake at the household level. In Ghana, Wongnaa et al. (2024) opined that the adoption of OFSP varieties presents a unique opportunity to tackle vitamin A deficiency and improve nutrition outcomes among the vulnerable population in Ghana. Apart from preventing vitamin A deficiency, Mbela et al. (2018) reported that the consumption of pro-vitamin A-rich OFSP plays a vital role in the normal functioning of the visual system, growth and development, and maintenance of the epithelial cellular integrity, immune function, and reproduction (Mbela et al., 2018). Moreover, the ingestion of carotenoid-rich OFSP protects the body against chronic diseases such as cancers, cardiovascular disease, diabetes, cataracts, some inflammatory diseases, and age-related muscular degeneration due to their antioxidant properties (Englberger et al., 2003; Etcheverry et al., 2012)

2.1.1 Role of OFSP in food security and livelihoods

Aside from the nutritional benefits, sweetpotato varieties including OFSP are critical for improving the livelihoods, food security, and income of many people in sub-Saharan Africa and the world as a whole (Escobar-Puentes et al., 2022; Olatinwo et al., 2023). The utilization of sweetpotatoes particularly the OFSP and its by-products or processed products enhances the economic value of the crop and provides supplementary income streams for farmers, hence, contributing to poverty reduction and rural development efforts (Wongnaa et al., 2024). It offers multiple economic opportunities as its storage organs and foliage can also be utilized for purposes such as industrial processing, livestock feed, and biofuel production (Katayama et al., 2017). OFSP can be utilized as a vegetable in the raw, roasted, or boiled form. It can also be processed into flour for the production of different food products such as chips, cake, porridge, bread, juice, etc. to improve household food intake (Alalade et al., 2019; Mohammed et al., 2023). The use of OFSP for bakery products such as bread as a potential substitute has been reported (Trejo-González et al., 2014). These process products of OFSP can be commercialized to generate income, and wealth or create job opportunities for all especially, women and youth, and also contribute to food security and health needs of people in developing countries (Bose et al., 2020). In Nigeria, studies carried out by Olatinwo et al. (2023) showed that the cultivation of OFSP had increased household income by 34.5% and improved food security by 47.5%. These findings support earlier studies by Okello et al. (2017) and Girard et al. (2021) that farming OFSP improved the socioeconomic well-being of farmers and ensured food security in Africa.

Furthermore, sweetpotato is an important food security crop founded on 1) its ability to produce under poor conditions such as low soil fertility, and drought with low input requirements compared to other crops, 2) its capacity to produce a large amount of energy per unit of land and time, and 3) a wider harvesting period which allow piecemeal harvesting of both roots and leaves throughout the year (Low et al., 2009; Mudege et al., 2019). Thus, sweetpotato vines are usually distributed to mitigate disasters (Kapinga et al., 1995; Motsa et al., 2015). Another important food security aspect of sweetpotato is that

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it can mature and be harvested during the hunger period (Motsa et al., 2015; Mudege et al., 2019). Literature indicated OFSP ability to reduce hunger and increase food security (Abewoy et al., 2024; CheIboi et al., 2024; Sugri et al., 2017). More so, while the OFSP provide vital micronutrients including vitamin A, poor households could sell surplus produce for cash to support livelihood (Andrade et al., 2017; Bao & Fweja, 2020; Jenkins et al., 2015; Labarta, 2009; Salawu et al., 2015; Suda et al., 2003; Zhu & Xie, 2018). Additionally, the sweetpotato value chain is dominated by women in most of the crop's production zones in sub-Saharan Africa as producers, intermediaries, and retailers (Echodu et al., 2019; Mulwa et al., 2024; Munyuli et al., 2022).

2.1.2 Current production levels and trends

Globally, about 119 million tons of sweetpotato varieties including OFPs are produced annually, thereby making it the seventh and sixth most important food crop in the world and in the tropics respectively, and also remains one of the most extensively cultivated root crops in sub-Saharan Africa (Hendebo et al., 2022; Low et al., 2009; Wongnaa et al., 2024). Sweetpotato is cultivated in over a hundred countries, yielding an average of 12.20 tons/ha from 8.62 million ha of land (FAO, 2016). Production reached 103 million tonnes in 2013 and 112.8 million tons in 2017 with China being the world's highest producer of sweetpotatoes, producing about 47.67 million tons (53.6%) of total global output whilst, in Africa, Malawi dominated with 8% of the overall global output followed by Tanzania with 5.6% and Nigeria 4% (Statista, 2021). In 2022, the total production output of sweetpotatoes in Africa (excluding the northern part of Africa) was 29.11 million tons, with Eastern Africa producing the highest (20.1 milli on tons) followed by Western African countries with 5.8 million tons (FAOSTAT, 2022).

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In Ghana, sweetpotato is widely cultivated in the Northern (including Savannah and North East), Upper East, Upper West, Central, and Volta (including Oti) regions by smallholder farmers (Bidzakin et al., 2014). The total volume of sweetpotatoes produced in 2016 was 143,111 tons (representing 0.10% of the global production volume) from 76,594 hectares of land, which placed Ghana in the 37th position in the world at the time (FAOSTAT, 2017). Meanwhile, the previous production volume was 90,000 tons from 65,000 hectares of land coverage according to Bidzakin et al. (2014) indicating an increase in the 2016 production output. However, the estimated sweetpotato production volume in 2020 stood at 139,439 MT (153,661.8 tons) from 73,940 ha of land, showing an increase in production levels and decreased hectares of land cultivation (FAOSTAT, 2022). The highest production volume was recorded in 2017 with an estimation of about 161,014.61 tons. The 2022 production volume stood at approximately 157,268.26 tons.

2.2 Economics of sweetpotato vine production

The quality of planting material has a significant impact on the cost of production, yields, and profit in sweetpotato farming. Research has shown that planting material constitutes a substantial portion of the total production cost. For instance, Kassali (2011) noted that planting material accounts for about 1.2 percent of the total production cost. Similarly, Adesina and Ogbonna (2020) reported that the cost of planting materials constitutes 40.1 percent of total production, followed by labor and fertilizer. Sugri et al. (2017) identified six key cost components, including ploughing, sowing/planting, seed, weeding, fertilizer, and insecticide spraying. Among these, the cost of ploughing constituted the major cost element, representing 33.4% of the total production cost.

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Studies have consistently shown that sweetpotato production is a profitable venture. Sugri et al. (2017) indicated that sweetpotato production yielded a gross margin percentage of 68.1% and 60.6% for early-season and late-season harvests, respectively. The benefit-cost ratio was 3.2 and 2.4 for early and late-season harvests, respectively. Other studies have reported similar findings, with Bidzakin et al. (2014) reporting gross margins of GHS 450, GHS 205, and GHS 450 for orange-fleshed sweetpotato vine production in the Northern, Upper West, and Upper East regions, respectively. In the Philippines, Lirag (2019) indicated that sweetpotato production was profitable with high financial returns of 144% to farmers. Tewe et al. (2003) and Adesina Adesina et al. (2017) observed that sweetpotato production was economically viable in Oyo State, Nigeria. In Benin, the cultivation of sweetpotato was economically and financially profitable, and the promotion of this crop could elevate its profitability (Paraïso et al., 2012). Again, Adesina and Ogbonna (2020) conducted a cost-benefit analysis of dry season production of OFSP in Nigeria. The results showed that dry season production of OFSP vine and roots was profitable and viable. Similarly, several empirical studies on sweetpotato production including Nabay et al. (2020) in Sierra Leone, Adewumi and Mahmud (2023); Onubogu et al. (2022) in Nigeria, Mfewou and Tchofo (2019) in Cameroon, Irfan, Mudassir, et al. (2021) in Indonesia and Lakra et al. (2018) in India all found sweetpotato production to be profitable and economically viable.

An assessment of the profitability gap between farmers and traders in sweetpotato production in Ghana revealed interesting insights. Amengor et al. (2017) reported a total production cost per hectare of GHS 2,452.00, with labor accounting for about 39% of the operational cost for farmers.

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2.2.1 Challenges faced by farmers in sweetpotato vine production.

Several studies have enumerated various constraints confronting farmers in the sweetpotato production sector. For example, Bidzakin et al. (2014) listed six challenges which include lack of planting materials, theft, weevils and termites, poor rainfall, poor market/prices, and storage challenges. Also, Sugri et al. (2017) identified sixteen (16) production constraints, out of this number, the five most prioritized constraints were access to improved seed/planting material, cost of chemical fertilizer, poor storage/short shelf-life, field pests, and diseases control and poor soil fertility. These constraints were classified into technical, production, socioeconomic, and sociocultural food habits, of which, the most prioritized technical constraints were pests and diseases, short shelf-life, and declining soil fertility. Empirical studies including Markos and Loha (2016) in Ethiopia; Muyinza et al. (2012) in Tanzania; Wang'ombe and van Dijk (2013) in Kenya; Nabay et al. (2020); Onubogu et al. (2022) in Sierra Leon; have reported similar findings. Also, lack of good markets and high perishability were reported as limiting factors to sweet production in Ghana (Abidin et al., 2015). Access to quality seed especially during critical periods of planting was identified as a major problem in Kenya (Wang'ombe & van Dijk, 2013). In Nigeria, low consumer preference, the prohibitive cost of labour, inadequate finance, poor extension service, and inadequate market information were mentioned as the most serious constraints to OFSP production (Omoare, 2018; Onubogu et al., 2022). During field production, a complex of biotic constraints, including nematodes, viral diseases, soil arthropods, weevils, and foliage-feeding insects have been reported (Muyinza et al., 2012; Okonya & Kroschel, 2016). Overall, the African sweetpotato weevils (*Cylas's brunneus* F. and *C. puncticollis* Boheman) pose the most threat, followed by the

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sweetpotato butterfly (*Acraea acerata* Hew.) and the clearwing moth (*Synanthedon* spp.) (Okonya & Kroschel, 2016). Preserving the fresh produce shelf-life remains a major challenge to farmers, traders, and consumers across sub-Saharan Africa (Abidin et al., 2017; Mutandwa & Gadzirayi, 2007; Sowley, 2015). Lack of improved cultivars, the weak attitude of producers toward sweetpotato production technologies, and lack of packaged agronomic recommendations were stated as the main causes of low yields in farmer's fields in Ethiopia (Markos & Loha, 2016). In Mozambique, constraints to increasing yields of sweetpotato that were reported by farmers include frequent drought and flooding, lack of market for sweetpotato roots, lack of animal traction, and low off-season propagation capacity of OFSP due to low rainfall during the dry season (Mazuze, 2007).

2.3 Overview of Solar Irrigation Technology and Its Adoption in Agriculture

Solar-powered irrigation systems (SPIS) have emerged as a sustainable and transformative technology, particularly in rural areas with limited electricity access and high diesel costs (Rentschler & Bazilian, 2017; Islam et al., 2017). Technologies like SPIS has been tagged as a promising solution for small-scale irrigation development (Falchetta et al., 2023; Shah et al., 2020; Schmitter, 2018). Solar powered irrigation offers a win-win solution, contributing to SDGs: poverty reduction and elimination of hunger in all forms Lefore et al. (2021), while also providing clean energy through climate-smart irrigation technologies (Patle et al., 2020). The adoption of SPIS is driven by its ability to reduce energy costs, increase agricultural productivity, and lower greenhouse gas emissions. Farmers in northern Benin adopting solar-powered drip irrigation systems achieved significantly higher yields and economic gains than non-adopters (Alaofè et al., 2016). In Pakistan, SPIS adoption reduced operational costs, saved water usage by 41%, and cut 17,622 tons of CO2 emissions annually, boosting farmer incomes (Raza & Lin, 2022). Similar benefits were observed in the Philippines, where SPIS adoption reduced greenhouse gas emissions by 26.5 tons CO_2eq/ha/year and provided a 315% return on investment (Guno & Agaton, 2022).

SPIS adoption also fosters social and environmental benefits. In water-scarce regions, these systems support drinking water supply and reduce the labor burden of women who traditionally manage diesel systems, enabling them to engage in more productive activities (Agrawal & Jain, 2019; Irena, 2019). Furthermore, integrating SPIS with efficient irrigation methods like drip irrigation enhances water and fertilizer use efficiency, contributing to sustainability (Sontake & Kalamkar, 2016). Studies also show that SPIS adoption improves technical efficiency in crop production. For instance, wheat farms in Pakistan, saw a 6.6% improvement in technical efficiency following SPIS adoption, contributing to enhanced food security and productivity (Ullah et al., 2023). Adoption of solar irrigation has been attributed to several reasons, for instance, farmers in Malaysia attributed their adoption of solar water pumping systems to perceived cost and maintenance, knowledge and experience of the product, social norms, government incentives and the benefits of the product (Aziz et al., 2017; Solangi et al., 2015; Malik, 2020). In Sri Lanka, Malaysia and Zambia, adoption of solar systems is influence by perceived ease of use, perceived trust, awareness of technology, relative advantage and perceived behavioural control (Cheam, 2021; Zulu et al., 2021; Bandara, 2018). In Pakistan, Nigeria, Uganda and Agra, adoption of solar systems was found to be determined by age, education, sex, ease of use, benefits, awareness, product knowledge, ecological life cycle, technology innovativeness, technology optimism, economic conditions, government

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policy and social exposure (Agarwal et al., 2023; Ali et al., 2019; Ashinze et al., 2021; Asif et al., 2023; Hasheem et al., 2022; Irfan, et al., 2021; Shahid et al., 2022; Zhou & Abdullah, 2017; Nazir, 2022; Zhou et al., 2017).

2.3.1 Benefits of Solar Irrigation

Solar-powered irrigation systems (SPIS) have emerged as a transformative solution for sustainable agriculture, offering numerous environmental, economic, and social advantages. This innovative technology addresses critical challenges in agricultural production while contributing to environmental sustainability. Closas and Rap (2017) noted that solar-powered pumps using photovoltaic (PV) technology can be an economically and environmentally sustainable alternative to fossil fuel-powered pumps. Kelley et al. (2010) found that solar-powered irrigation is economically viable in Saudi Arabia from the lifecycle cost analysis. Nonetheless, they indicated that the prohibitive costs of solar panels involve a high initial cash outlay which requires financing. According to Suman (2018), the implementation of solar pumps in agricultural practices is an increasing function of farmers' income. Several empirical studies such as Curtis (2010) in western Utah, Bolanos et al. (2015) in Colombia, Hossain et al. (2015) in Bangladesh, Gautam and Singh (2021) in India, Sarr et al. (2023) in Senegal, Copeland (2018) in Zambia, and Abu-Nowar (2020) found solar-powered irrigation to be economically viable. Furthermore, the advantages of solar PV irrigation systems encompass the potential for distributed, independent, off-grid power supply for both on-farm and household use by farmers in remote areas (Closas & Rap, 2017; Meah et al., 2008). Also, several empirical studies have reported that solar pumps have longer lifetimes with lower maintenance costs compared to fossil fuel pumps (Kolhe et al., 2002; Wazed et al., 2018). Moreover, solar-

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powered irrigation systems reduce reliance on unreliable power sources and provide a dependable source of water for agriculture (Biberci, 2023; Biberci et al., 2018; Deveci et al., 2015; Grant et al., 2022; Hartung & Pluschke, 2018). Moreover, GIZ in 2020 reported that solar panels, grid electricity, and diesel machines generate 16 to 32g, 600g, and 1000g of CO_2 gas respectively to produce 1kWh power (Sass & Hahn, 2020). This confirms that the solar system is the most environmentally friendly alternative to generating power among the three available options. Also, studies found solar irrigation to have a reduction effect on CO_2 emissions and thus, environment-friendly irrigation technology (Allen & McHughen, 2011; Hossain et al., 2015; Nikzad et al., 2019; Ould-Amrouche et al., 2010; Rathore et al., 2018).

2.3.2 Challenges of Solar-Powered Irrigation Systems (SPIS)

Solar-powered irrigation systems (SPIS) have garnered significant attention in recent years for their potential to revolutionize agriculture, particularly in regions where energy access is limited, and water resources are scarce. These systems offer an attractive return on investment by reducing dependence on conventional energy sources like diesel and grid electricity, thus lowering operational costs and promoting sustainability. However, despite their technical viability and competitive advantages, several challenges hinder the widespread adoption of SPIS, especially for smallholder farmers. These challenges primarily include the high initial investment cost, limited access to financing, and a shortage of skilled personnel for installation and maintenance. One of the most significant barriers to the adoption of SPIS is the high upfront cost associated with the installation of solar panels, pumps, and associated infrastructure compared to other pumps (Closas & Rap, 2017; Hjalmarsdottir, 2012; Irena, 2019; Lefore et al., 2021; Mashnik et al., 2017; Outlook, 2019; Shah et al., 2020; Soin, 1984; Xie et al., 2021; Yamegueu et al., 2019). The cost of purchasing and installing solar-powered irrigation systems can be prohibitive for smallholder farmers, particularly in developing countries where there is limited access to affordable funding for farmers (Barghouth et al., 2016; Closas & Rap, 2017; Flammini et al., 2019; Hartung & Pluschke, 2018; Panel, 2018; Piliso et al., 2021). In addition to the financial challenges farmers faced in their attempt to adopt solar-powered irrigation, there several market constraints including inadequate availability of appropriate or customized products in terms of size and pump type (Flammini et al., 2019; Hartung & Pluschke, 2018; Irena, 2019; Yamegueu et al., 2019). Lack of maintenance and repair services ecosystem (Flammini et al., 2019; Hartung & Pluschke, 2018; Irena, 2019; Yamegueu et al., 2019). Unavailability of spare parts (Closas & Rap, 2017; Hartung & Pluschke, 2018; Panel, 2018; Pavelic et al., 2021). Also, empirical studies reported difficulty in repairing solar panels and systems (Flammini et al., 2019; Hjalmarsdottir, 2012; Irena, 2019; Panel, 2018). Solar systems are susceptible to a lightning strike (Banerjee et al., 2017; Hjalmarsdottir, 2012; Mashnik et al., 2017; Pavelic et al., 2021). Poor product quality (Flammini et al., 2019; Hartung & Pluschke, 2018; Irena, 2019; Lefore et al., 2021; Pavelic et al., 2021; Wazed et al., 2018). Furthermore, the non-existence of advanced markets and quality assurance standards and benchmarks, results in poor protection of suppliers, developers, financiers, and farmers against low-quality products (Dalberg, 2019). Again, the absence of capacity building and training programs and institutions gives rise to a lack of trained technical professionals to spearhead energy transition in irrigation (Hartung & Pluschke, 2018; Lefore et al., 2021). More so, there is no regulatory system in place to ensure the quality

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and standardization of solar pumps in many countries including South Africa, Zimbabwe, and Ghana Durga et al. (2024), Kenya (Samoita et al., 2020).

2.4 Farmers' Willingness to Pay (WTP) for Agricultural Innovations

2.4.1 Theory underpinning WTP

The theory underpinning Contingency Valuation Method (CVM) and choice experiment per the literature is the utility maximization theory developed by McFadden in 1974 McFadden (1974) which is consistent with Lancaster's economic theory of value and neoclassical view that postulate economic agents would choose alternatives that maximize their utility (Hess et al., 2018; Hoyos & Mariel, 2010; Lancaster, 1966; Manski, 1977). Based on these theories, we would like to see if the production of OFSP vines under solar irrigation is beneficial or otherwise.

The utility theory has been used in several studies including assessing consumer preferences for organic food products Onyango et al. (2007), preferences for food safety Loureiro and Umberger (2007), WTP for locally produced food products Darby et al. (2006), purchases of genetically modified food Canavari and Nayga Jr (2009), the importance of bean attributes among farmers Katungi et al. (2011), and Cobbinah et al. (2018) on consumers' willingness to pay for safer vegetables in Tamale, Ghana.

Several willingness-to-pay studies used the utility maximization framework (Gao et al., 2024; Mulwa et al., 2023; Mulwa et al., 2024; Mwangi et al., 2022; Scholz et al., 2015). This framework is used in this study to examine farmers' willingness to pay for orange-fleshed sweetpotato vines.

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2.4.2 Methodologies for assessing WTP.

Willingness to pay is defined as the highest amount an individual is willing to pay for a good (Dimitri & Greene, 2002). This is consistent with Mersha et al. (2018), "who defined willingness to pay as the maximum amount a person would be willing to pay or sacrifice in exchange for a good". Similarly, Gunatilake (2007) defined WTP as "*the economic value of a good to a person or household under a given condition*." Likewise, the utmost price a customer of a product would be ready to pay for a particular amount of that good is known as willingness to pay (WTP) (Wertenbroch & Skiera, 2002). WTP, then, stands for the subjective value that a user puts on a particular amount of goods. WTP provides useful information for assessing project economic viability, establishing affordable tariffs, analyzing policy alternatives, determining financial sustainability, and providing socially equitable subsidies (Brookshire & Whittington, 1993). When determining a user's willingness to pay for a product or service, it is vital to examine the product's viability, production costs, and consumer demand (Kimenju & De Groote, 2008;Quagrainie, 2006). Several researchers have used various approaches to estimate user willingness to pay over the years. However, these diverse approaches to evaluating willingness to pay have been divided into two categories: a measure of consumer hypothetical or actual WTP and a measure of willingness to pay directly or indirectly (Mersha et al., 2018). The direct measure of WTP is often referred to as the preferred methods, which include; choice experiments (conjoint analysis and choice modeling) and contingent valuation, and the indirect methods are referred to as revealed preference methods which include hedonic pricing, travel cost method (Segerson, 2017; Shee et al., 2019). However, revealed preference methods have been challenged for being unsuitable for non-market valuation

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because they are limited to the individual's experience (Bennett & Blamey, 2001). Furthermore, revealed preference methods may be of little significance in cases when new conditions are foreseen because of the proposed adjustment. Empirical studies on users' willingness to pay show that, several researchers employed the traditional contingent valuation method to determine quantitative willingness to pay in monetary terms (Hanemann et al., 1991; Khainga et al., 2018; Labarta, 2009; Lieblein et al., 2008). This is a direct elicitation method in which an individual user is asked what he or she would be ready to pay if a product or service existed. Davis (1963) utilized contingent valuation for the first time to assess the benefits of outdoor recreation, and hundreds of studies in a wide range of fields have since applied the method to the assessment of several non-market products. For example, Boccaletti and Nardella (2000) employed the contingent valuation method to determine Italian consumers' willingness to pay for pesticide-free fresh fruit and vegetables.

The application of CVM has expanded to include valuing changes in product quality for producer and consumer goods in emerging markets, even though it has historically been used to assess WTP for goods without a market value, such as ecosystem services (Bhattarai, 2019; Chia et al., 2020; Kikulwe & Asindu, 2020). Furthermore, it is more adaptable and makes the task given to the users easier than it would have been with other approaches, like auction mechanisms, which are costlier, time-consuming, and difficult to plan and carry out, especially in cases where the respondents being targeted have low levels of education (Brebner & Sonnemans, 2018; Haab et al., 2013; Hoyos, 2010; Predmore et al., 2021). Haab et al. (2013) argue that contingent valuation is relevant, particularly as one

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of the few stated preference methods that can capture passive-use value, and that the key issues raised are debatable.

An experimental auction is another important technique for estimating user willingness to pay for non-market goods. Experimental auctions are designed to combine the advantages of both stated and revealed preference techniques by using real goods, real money exchange, and repeated market participation to simulate a real market situation where consumers' decision-making and purchase occur (Lee & Hatcher, 2001). In their book on experimental auctions, Lusk and Shogren (2007) report on more than eighty studies conducted between 1964 and 2004 that used the method to gauge consumer willingness to pay for a variety of non-market goods across multiple disciplines. They also provide instructions on how to plan, carry out, and analyze the results of experimental auctions. Since experimental auctions are based on actual behavior rather than intentions and employ real goods and money to remind users of their budgetary constraints, they tend to elicit more accurate estimates of willingness to pay. Researchers do not need to assume anything about the demand curve because they are willing to pay values from all respondents, indicating that the issue of nonresponse bias appears to have been addressed too. However, because all respondents are chosen and frequently receive participation fees, studies utilizing experimental auctions typically have limited sample sizes and potentially biased results. Numerous zero bids may also be received because of the recruited respondents' lack of interest.

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Another technique for determining a customer's willingness to pay for a good or service is the choice experiment. It has been widely employed in a variety of sectors, including marketing, environmental, and agricultural economics, to elicit users’ preferences for multi-attribute items. Users are usually presented with a non-market product's possibility, each of which varies in terms of price and quality, among other aspects. This process is based on Lancaster's random utility theory (Lancaster, 1966). In choice experiments, users can select a product over alternatives, simulating actual shopping situations. It also enables the researcher to put a number on the values of distinctive characteristics that a product contains, as well as the potential premium or discount the product may command. However, because choice experiments only observe respondents' discrete choices, calculating willingness to pay and market demand is complicated. Incorporating additional willingness-to-pay factors into the choice of experiment models is also comparatively challenging. Additionally, respondents find it challenging to select from a wide range of product profiles, which could cause discrepancies in the answers to multiple-choice questions.

Furthermore, economists have utilized discrete choice, stated choice experiments, and a variety of other elicitation approaches to obtain direct monetary estimates of willingness to pay for a commodity. For example, Goldberg and Roosen (2005) used choice experiments and contingent valuation methods to assess consumer willingness to pay for reducing Salmonellosis and Campylobacteria in Germany, Also, Travisi and Nijkamp (2004) used the stated choice experiment approach to assess Italians' willingness to pay for agricultural environmental safety. Empirical studies on WTP in health applied choice experiments (Fang et al., 2024; Hamouzadeh et al., 2019; Li et al., 2024; Mandeville et al., 2014; Sain et al., 2020; Shi et al., 2024; Soekhai et al., 2019). Likewise studies in environmental economics (Duijndam et al., 2020; Hindsley et al., 2021; Lew & Whitehead, 2020) and Jang et al. (2021) in marketing & transportation.

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The superiority of the approaches to measuring willingness to pay, particularly between choice experiment and contingency valuation in literature is divided. Indeed, Carson and Hanemann (2005) suggested no difference between the two methods. However, several studies used CVM to provide evidence that households are willing to pay a significant amount for the provision of certain nonmarketed services (Abebe, 2023; Abebe & Geta, 2014; Amare et al., 2016; Angella et al., 2014; Hao et al., 2023; Li et al., 2022; Ogunmodede et al., 2022; Shausi et al., 2019). Thus, the choice of method to use in a survey depends on the study context and the trade-off between the advantages and disadvantages of the two methods. This present study therefore adopts the contingency valuation method specifically the DBDC approach to estimate households WTP for OFSP vines.

2.4.3 Review of econometric models used in WTP.

Empirical studies have applied different econometric techniques to analyze factors influencing WTP. The type of econometric model used depends on the measurement of the WTP variable in question. For instance, Adesina et al. (2017) are assessing farmers' WTP for quality OFSP vines in Nigeria using descriptive statistics and a Tobit model. Kassie et al. (2017) used a generalized multinomial logit model on choice experiment data, to estimate the explicit prices farmers are willing to pay for drought tolerance in maize compared. Many studies Belay (2018); Yibeltal (2015); Ayenew et al. (2015) adopted probit, Bogale and Urgessa (2012); Ayana (2017); Tilahun and Tadesse (2022) used bivariate probit, Gulati and Rai (2015); Hilger et al. (2019); Sizya (2015) used logit, Mwiti et al. (2020) used seemingly unrelated regression model, Dagninet Amare et al. (2017); Ahmed et al. (2015) used Tobit, Cobbinah et al. (2018) used ordered logit regression model and King (2023) and Amare et al. (2016) used Heckman two steps model. However, this

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present study adopted the ordered probit model and the complementary log-log model for the estimation of factors influencing farmers' willingness to pay for quality OFSP vines.

2.4.4 Determinants of farmers' WTP for agricultural innovations

WTP for goods and services is determined by a diverse array of factors, which vary across studies depending on the context and the specific product or service assessed. For example, factors such as gender, age, education, farm size, access to credit, farmer-based organization membership, income, livestock ownership of household head and access to extension service were reported as the main determinants of farmers willingness to pay for technologies (Banka et al., 2018(Shee, 2019 #157)). Goldberg and Roosen (2005) discovered that the presence of children (under 18) in the household, gender, and household net income was negatively correlated with willingness to pay, while age and household net income were positively correlated. Likewise, Mersha et al. (2018) found that variables like education, livestock ownership, off-farm activity, sex, access to credit, extension services, and awareness of weather index insurance were significant determinants of farmers' willingness to pay for weather index insurance. Bani (2016) also discovered that while years of farming did not have a significant impact, the consumer's gender, age, education, perception of climate change, and availability of land are factors that affect the consumer's willingness to pay for environmental services. Moreover, Kakumanu et al. (2012) discovered that the major characteristics influencing farmers' willingness to pay were their age, education, farm size, annual income, and understanding of crop insurance. Equally, factors like farming experience and institutional credit availability were found to be irrelevant. Similarly, the age of the household head, cultivated area, and education were found to be major determinants of willingness to pay (Myyrä & Liesivaara, 2014).

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Additionally, according to Chai et al. (2020), age, gender, education, marital status, attitude towards insects, awareness of insects as feed, availability of agricultural inputs, availability of training and market information, distance to feed traders using commercial feeds, and use of commercial feeds all had a significant impact on the WTP.

Furthermore, Mwiti et al. (2020) also found that a farmer's age, number of children, taste, preferences, sweetpotato yields, and income were the main determinants of demand for clean vines. Likewise, Baidoo and Amoatey (2012) using CVM found that in West Akim District of Ghana, over 50 percent of farmers were willing to pay for improved cassava variety. WTP was also found to be affected by cassava variety, and family labour while the area under cassava cultivation was dependent on the total acre of land the farmer owns, the number of children, and the type of labour.

Tilahun and Tadesse (2022) using a bivariate probit model investigated the determinants of households' willingness to pay for improved teff seed in Yilmana-Dinsa Woreda, Northern Ethiopia. The study found that male-headed households were more willing to pay for teff seed compared to female-headed households. This was justified by cultural constraints and females' disposal to a less resource ownership legacy. Other literature such as Yegbemey et al. (2014); Belay (2018); Almansa et al. (2012) found similar results.

Moreover, Mersha et al. (2018) highlight the role of education in increasing WTP for weather index insurance, suggesting that educated individuals are more likely to recognize the value of risk mitigation. Other studies including Tapsoba et al. (2022) in Burkina Faso, and Nyangau et al. (2022) in Benin found education to be positively and significantly related to farmers' willingness to pay for biopesticides to preserve market garden crops. Again, the positive association between education and farmers willingness to pay for

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agricultural innovations agree with the findings in literature (Amin et al., 2020; Atreya, 2007; Aydogdu & Bilgic, 2016; Scaringelli et al., 2017). Similarly, other studies assessed farmers' willingness to pay for improved common bean seed, soil conservation practice, improved forage seed, and community-based potato cold storage facilities respectively reported education as a positive function of willingness to pay in their respective studies(Ahmed et al., 2016; Emuru, 2015; Mbugua, 2016; Munthali, 2013). Nevertheless, the relationship between education and WTP is not always linear. For instance, Boccaletti and Nardella (2000) found that higher education levels could lead to increased skepticism or more rational purchasing behavior, reflecting a deeper understanding of cost-benefit trade-offs. This finding was supported by the findings of (Ndunda, 2018).

Again, Research consistently demonstrate a positive correlation between farm size and WTP, with larger-scale operations often facing higher risks that necessitate investment in advanced agricultural technologies or insurance (Myyrä & Liesivaara, 2014; Baffoe, 2021). Several studies also found farmer size to have positive effect on farmers' WTP for agricultural innovation, irrespective of the type of innovations/technologies studied (Abu-Madi, 2009; Abugri et al., 2017; Bakopoulou et al., 2010; Fonta et al., 2018; Jamali Jaghdani & Brümmer, 2016; Ngango et al., 2022; Yedra et al., 2016). However, contrary results reported by Senapati (2020) revealed that farm size negatively influences willingness to insure and willingness to pay amounts for rainfall insurance products in India. Household income increases farm households' willingness to pay for new agricultural technologies (Gulati & Rai, 2015; Hite, 2009). Off-farm income reduces households' willingness to pay for agricultural technologies (Belay, 2018; Tilahun & Tadesse, 2022). However, on-farmer income increases farm households' willingness to pay for improved and new agricultural technology seeds and inputs (Kasaye, 2015; Muhammad et al., 2015; Tilahun & Tadesse, 2022; Workie, 2017).

More so, extension access increases farmers' willingness to pay for agricultural innovations (Arinloye et al., 2016; Belay, 2018; Mishra et al.; Negash, 2021; Shee et al., 2019; Tilahun & Tadesse, 2022). Furthermore, having access to credit increases farmers' willingness to pay for improved seed (Emuru, 2015; Tilahun & Tadesse, 2022).

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2.4.5 Studies on WTP for quality planting materials and irrigation technologies

Studies on WTP for quality planting materials and irrigation technologies are essential for understanding how farmers value agricultural inputs and their potential to enhance productivity and resilience in crop production. These studies assess the influence of a range of factors, including the quality attributes of planting materials and the availability of irrigation technologies, on farmers' investment decisions. Insights from these studies contribute to strategies for increasing the adoption of improved agricultural technologies and ensuring sustainable agricultural development. For example, In Ghana, Emuru (2015) used a choice experiment to evaluate farmers' WTP for orange-fleshed sweetpotato (OFSP) roots compared to traditional white- and yellow-fleshed varieties. The findings revealed a high WTP for OFSP due to its nutritional benefits. Interestingly, socioeconomic characteristics such as age, sex, and income had no significant impact on acceptance. Instead, the study highlighted the critical role of information on nutritional benefits in driving WTP, aligning with broader findings that awareness campaigns can significantly increase demand for biofortified crops. Also, Naico and Lusk (2010) explored consumer preferences for OFSP in Mozambique through choice experiments. Their findings demonstrated a preference for orange-fleshed varieties over traditional, white-fleshed

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varieties, with the dry matter content of the roots emerging as the most valued attribute. However, the study revealed heterogeneity in preferences based on rural versus urban residency. While health information had a limited effect on rural consumers, it underscored the importance of contextual factors, such as familiarity with local crops, in shaping WTP. Moreover, In Nigeria, Adesina et al. (2017) assessed WTP for quality OFSP vines in northern central Nigeria. The study found high WTP for the vines due to attributes such as shorter maturity periods, higher beta-carotene content, and superior yield potential. Key determinants of WTP included off-farm income, vine quality, disease resistance, and farm size. Likewise, Shee et al. (2019) used the contingent valuation method (CVM) to evaluate WTP for hybrid maize seeds and inorganic fertilizers in Northern Tanzania. The results showed that farmers' WTP for hybrid maize seeds exceeded market prices, indicating significant adoption potential, while WTP for fertilizers fell below market prices, suggesting the need for interventions to make fertilizers more affordable.

Furthermore, Mwiti et al. (2020) examined WTP for sweetpotato vines, comparing biofortified and non-biofortified varieties. Contrary to expectations, farmers exhibited a higher WTP for non-biofortified vines, citing superior taste, firmness, and root quality as influential factors. Socioeconomic variables such as age, household size, and income also emerged as significant determinants of WTP, highlighting the complex interplay between personal preferences and economic constraints. Also, the evaluation of WTP for irrigation technologies has been particularly important in addressing water scarcity challenges in agriculture. Studies on solar irrigation systems, for instance, have highlighted their potential to enhance economic viability by reducing costs and increasing crop yields. Kumar et al. (2022) demonstrated that solar irrigation systems for root and tuber crops offer

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long-term cost savings and productivity gains, emphasizing their profitability for smallholder farmers. Furthermore, Mersha et al. (2018) conducted field experiments in Tanzania and Ghana to assess WTP for certified bean and cowpea seeds. Their findings showed that farmers were willing to pay a premium for higher-quality seeds. However, WTP often fell short of the market price differential between certified and non-certified seeds, pointing to price sensitivity as a critical factor. Similarly, Boadu et al. (2019) used choice experiments to study farmers' preferences for certified yam seeds in Ghana. Farmers demonstrated a higher WTP for medium-sized certified yam seeds, with preferences influenced by farm size and labor availability. Moreover, Mastenbroek et al. (2021) investigated the impact of randomized information treatments on WTP for improved seed varieties. While the provision of information about seed certification enhanced farmers' knowledge, it did not significantly increase WTP, suggesting that knowledge alone may not be sufficient to drive investment without addressing other barriers such as affordability and market accessibility.

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2.4.6 Studies on farmers' adoption and sustained use of agricultural technologies

Contemporary agriculture, shaped significantly by the Green Revolution, has been instrumental in addressing global hunger and malnutrition. Central to this transformation is the intensive application of inputs such as fertilizers, pesticides, irrigation, and soil tillage practices. These methods have undeniably increased agricultural productivity and continue to underpin modern farming systems. However, they have also created profound environmental challenges, including soil degradation, erosion, and the depletion of organic matter (Shah & Wu, 2019). As the agricultural sector seeks to balance productivity with

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sustainability, the adoption of improved technologies has emerged as a cornerstone for achieving this equilibrium (Foguesatto et al., 2020).

The decision to adopt agricultural technologies, as well as the speed at which they are implemented, is shaped by a range of economic, social, cultural, and sectoral factors. Understanding these factors is crucial for designing strategies that encourage widespread and sustained use of sustainable agricultural practices. One of the key enablers of technology adoption is cooperative membership. Farmers who are part of cooperatives are more likely to adopt sustainable practices, such as the use of inorganic fertilizers and crop rotation, with adoption rates increasing by 11% and 24%, respectively (Manda et al., 2020). Agricultural extension services further enhance adoption by providing farmers with critical information and training on innovative technologies. These services serve as a conduit for knowledge transfer, helping farmers understand the long-term benefits of adopting and sustaining innovative practices (Ayenew et al., 2015; Anang, 2020). Also, access to credit plays a pivotal role in technological adoption. Financial constraints often hinder farmers from investing in high-quality inputs that are essential for productivity gains. Credit access alleviates these constraints, enabling farmers to adopt improved technologies such as high-yielding maize seeds and fertilizers (Ngango & Hong, 2021). This highlights the importance of financial inclusion and tailored credit solutions in facilitating technology adoption. Moreover, Socioeconomic factors, including education, landholdings, and household size, significantly influence the likelihood of technology adoption. Farmers with larger landholdings and livestock assets tend to adopt technologies more readily due to their greater capacity to absorb risks and invest in innovations (Beyene & Kassie, 2015; Dadi et al., 2004). Education enhances farmers' ability to comprehend and implement new

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practices effectively. However, the impact of age on technology adoption is less clear, as older farmers often exhibit both advantages, such as accumulated wealth, and disadvantages, such as risk aversion (Adegbola & Gardebroek, 2007; Kassie et al., 2013). Likewise, Infrastructure and market access also play critical roles in determining adoption rates. Farmers located far from input suppliers face higher transaction costs, which can delay the adoption of improved crop varieties (Matuschke & Qaim, 2008). Addressing these challenges through better infrastructure and reduced transaction costs is essential for facilitating faster adoption of technologies. In rural areas, social capital and community networks are invaluable in fostering technology adoption. Kinship ties and local networks provide farmers with access to information and resources, compensating for the lack of formal support systems. These networks encourage mutual learning and collective action, which are crucial for adopting and sustaining new agricultural practices (Beyene & Kassie, 2015; Kassie et al., 2013). Sustained use of adopted technologies is closely tied to their profitability and the continuous support provided to farmers. Research indicates that adopting improved technologies reduces production costs and increases household incomes, with smallholder farmers benefiting the most (Verkaart et al., 2017). However, long-term use often faces barriers such as limited access to credit, high input costs, and inadequate extension services (Adegbola & Gardebroek, 2007; Alcon et al., 2011). Addressing these barriers requires a multifaceted approach. Financial mechanisms such as credit facilities, targeted training programs, and supportive policy frameworks are essential to ensure that farmers not only adopt but also sustain the use of innovative technologies. Infrastructure improvements and the strengthening of social networks further enhance the enabling environment for adoption. Targeting smallholder farmers with appropriate

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technologies and support systems is particularly important for reducing poverty and achieving long-term sustainability (Jack, 2013).

2.5 Impact of Quality Vines on OFSP Production

In agricultural systems, particularly those dominated by smallholder farming in developing countries, the importance of quality planting materials cannot be overstated. These materials such as seeds, seedlings, and vegetative propagules form the foundation of healthy crop growth and optimal yield outcomes. In regions where food security and rural development are urgent priorities, ensuring access to high-quality planting materials is essential for achieving sustainable agricultural productivity, improving livelihoods, and fostering economic stability (Manhas et al., 2010; Sarolia et al., 2018).

Quality planting materials play a pivotal role in establishing healthy crops. Seeds and propagules that are free from diseases, pests, and genetic defects contribute significantly to plant vigor and resilience. In contrast, poor-quality planting materials often result in weak crops that are more susceptible to environmental stress, diseases, and pests (Begna, 2020). This not only reduces the productivity of the current crop but also jeopardizes the health of future crops by introducing pathogens into the soil. For example, seeds infected with pathogens can lead to widespread soil contamination, impacting both present and future yields. One of the most direct benefits of quality planting materials is their impact on yield improvement (Wimalasekera, 2015). Research consistently demonstrates that certified seeds and improved planting materials significantly outperform their non-certified counterparts. For instance, in staple crops such as maize, rice, and wheat, the adoption of improved varieties has led to remarkable yield increases, contributing to global food security (Lobell et al., 2008). Similarly, in root crops like sweetpotatoes, the quality of

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planting materials directly influences tuber yield. Studies have shown that the use of healthy, disease-free vines in Orange-Fleshed Sweetpotato (OFSP) production results in higher yields and improved nutritional content, such as elevated beta-carotene levels (J. Low et al., 2017; McEwan et al., 2015). Another crucial advantage of using quality planting materials lies in their role in pest and disease resistance. Improved seed varieties are often bred to withstand specific pests and diseases, reducing the need for pesticides and minimizing crop losses (Wimalasekera, 2015). For example, disease-resistant OFSP vines not only ensure better crop establishment but also reduce the risk of failure due to viral infections. Similarly, the adoption of cassava and maize varieties resistant to cassava mosaic virus and maize streak virus has significantly reduced crop losses in Sub-Saharan Africa (Chikoti & Tembo, 2022; Mafu, 2013). In contrast, poor-quality planting materials can exacerbate pest and disease problems, leading to significant yield losses and threatening the sustainability of farming practices.

Quality planting materials also enhance the efficiency of agricultural inputs such as fertilizers, water, and labor. Crops grown from robust seeds and propagules are better equipped to absorb nutrients and water, leading to more efficient use of these resources. This reduces input costs for farmers while promoting environmental sustainability by minimizing the overuse of chemicals. Additionally, uniform crop stands resulting from high-quality seeds simplify labor-intensive tasks like weeding and pest control, enabling farmers to maximize returns on their investments (McEwan et al., 2017). For instance, OFSP vines that are disease-free and of high quality enable farmers to reduce pesticide use and fertilizer application, as these plants are inherently more resistant to pests and more efficient in nutrient uptake. Sustainability is another key benefit of high-quality planting

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materials, particularly in the context of climate change. Improved, climate-resilient varieties are often designed to withstand environmental stresses such as drought, flooding, and soil degradation. For example, drought-tolerant maize and cassava varieties have enabled farmers to maintain productivity even under adverse conditions (Lobell et al., 2008). In the case of OFSP, the use of drought-resistant vines has proven instrumental in sustaining production in regions with erratic rainfall patterns, thereby promoting long-term food security and reducing the risk of crop failure. The economic benefits of using high-quality planting materials are substantial. Increased yields, better-quality crops, and more efficient input use translate into higher profitability for farmers. Farmers who invest in certified seeds or planting materials often gain access to premium markets where their crops fetch higher prices due to superior quality and uniformity (Adebisi et al., 2015). Furthermore, high-quality planting materials support crop diversification, reducing farmers' vulnerability to market volatility and price fluctuations. For example, OFSP farmers using certified vines are more likely to produce tubers that meet market standards for size, color, and nutritional content, allowing them to command premium prices and improve their livelihoods (McEwan et al., 2015).

2.6 Climate Change and Agriculture in Northern Ghana

Climate change has significant implications on agricultural systems as it affects both plant and animal health. Increased in temperature, particularly in the number of extremely hot days, as well as changes in rainfall, are the main climatic variables affecting agriculture in Africa (Pereira, 2017). Earlier studies noted that changes in climatic variables including amount of rainfall, temperature, wind speed, relative humidity, sunshine duration, among others are critical to crop yield (Chang, 2002; Horie, 1991Wu, 1996). In Ghana, climate

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scenarios reveal a rising trend in temperature, especially in the northern regions. Agricultural sector in Ghana is rain-fed with little technological inputs, which makes the sector sensitive and vulnerable to climate change (Naab et al., 2019). The low level of irrigation usage (only 0.89% of total cultivated land irrigated) in Ghana further worsens the problem. Furthermore, Ghana's agricultural sector is already grappling irregular rainfall patterns, water stress, desertification, rising temperatures, and seasonality disruption as well as increasing prevalence of crop and livestock pests and diseases (Arndt et al., 2015).

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2.6.1 Effects of climate change on crop production, particularly in drought-prone areas

Climate change presents critical challenges to agricultural productivity, particularly in drought-prone regions, where water scarcity and extreme weather threaten food security and livelihoods (Ahmad et al., 2022). These areas face complex and interrelated impacts, such as altered rainfall patterns, rising temperatures, and increased frequency of droughts, all of which worsen existing vulnerabilities. One of the most immediate consequences is the alteration of rainfall patterns. Drought-prone regions are increasingly experiencing erratic and unpredictable rainfall, characterized by prolonged dry spells and short, intense rainy periods. This variability often results in delayed or reduced precipitation, leading to water shortages that disrupt crop growth (Trenberth, 2011). Additionally, intensified rainfall during brief spells can cause flash flooding and soil erosion, further degrading agricultural land and productivity. Rising temperatures compound these challenges by inducing heat stress on crops, especially during critical growth stages such as flowering and grain filling. Prolonged exposure to extreme heat reduces yields, while increased evaporation rates deplete soil moisture, exacerbating water scarcity. Furthermore, higher temperatures may shorten growing seasons, making it difficult for farmers to cultivate crops that require longer maturation periods (Ahmad et al., 2022; Trenberth, 2011). Water scarcity is a particularly acute problem in drought-prone regions. Reduced rainfall, coupled with over-extraction of groundwater, threatens the sustainability of irrigation systems. As water sources dwindle, farmers face higher costs for irrigation and diminished access, leading to reduced agricultural output and income (Ahmad et al., 2022).

Soil health also deteriorates under the pressures of climate change. Intensified rainfall and prolonged droughts contribute to soil erosion, loss of organic matter, and salinization, reducing fertility and water-holding capacity (Sharma, 2018). These changes undermine crop productivity and increase the difficulty of land management in vulnerable areas. The effects of climate change also extend to pest and disease dynamics. Warmer temperatures and altered precipitation patterns create favorable conditions for pests and pathogens, leading to increased infestations and the spread of plant diseases (Abubakari & Abubakari, 2015; Bhengu & Onyeka, 2024; Kyei-Mensah et al., 2019). More so, an increase in global warming and droughts will occasion reduction in water availability, decrease in soil fertility, increase incidence of pests, diseases and weeds, thus decrease in crop productivity. Also, despite the yield gaps in crops like maize, cassava, sorghum, rice and yam currently recorded, these crops are expected to experience further reduction in yields due to climate change (Knox et al., 2012; Issahaku, 2014). Other studies reported on the projected changes in yields of cereals, legumes and tubers. For instance, Asante and Amuakwa-Mensah (2014) reported an expected reduction in cassava yield by 13.5% and 53% in the years 2050 and 2080 respectively. Freduah et al. (2019) also projected reduction in maize yield

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among smallholder farmers in the interior savannah of Ghana. On the contrary, groundnut yield is projected to increase due to carbon dioxide fertilization (Adiku et al., 2015; De Pinto et al., 2012).

2.6.2 Relevance of OFSP as a climate-resilient crop

In the face of climate change, agricultural systems worldwide are under increasing stress due to unpredictable weather patterns, prolonged droughts, shifting rainfall patterns, and more frequent extreme weather events. Climate change not only impacts agricultural productivity but also exacerbates existing nutritional deficiencies, particularly in regions where staple crops like maize and cassava dominate. OFSP, with its high beta-carotene content, offers significant nutritional benefits that can help address vitamin A deficiency, a major public health issue in many parts of Sub-Saharan Africa (Low et al., 2017).

Research has shown that OFSP can perform well in a variety of agroecological zones, from arid to semi-arid regions, making it adaptable to different climates and soil types (Low et al., 2020). It thrives under many soil types and under a wide range of temperature conditions, even under limited water availability and fertilizer input. OFSP is well-suited to grow in regions with low and erratic rainfall, as it has a deep root system that enables it to access water from deeper soil layers (Abidin et al., 2017). Besides, OFSP has a deep root system that makes it more drought-tolerant than staple crops such as rice or maize, as it can absorb water from the deeper levels of soil during water shortage, sustaining growth and yield during such times (Li et al., 2021). It reduces the impact of protracted dry spells or adverse weather occurrences that are likely to reduce crop losses arising from climate-related issues (Munda et al., 2019). Its development period is relatively short, lasting three to six months depending on several variables and environmental conditions (Low et al.,

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2017). Farming OFSP promotes soil conservation by enhancing the soil structure, reducing erosion, and gradually improving fertility.

2.6.3 Role of irrigation in mitigating climate risks for farmers

Ghana's increasing rainfall variability has underscored the importance of supplemental irrigation, particularly during the dry season, to stabilize crop yields and secure rural livelihoods (Abigail, 2019). Despite this, only an estimated 3.4% of Ghana's cultivable land is currently irrigated, with approximately 9,000 hectares covered by 22 formal irrigation schemes managed by the Ghana Irrigation Development Authority (GIDA). However, the rapid growth of informal, farmer-led irrigation systems, irrigating an estimated 185,000 hectares, has significantly outpaced formal schemes, proving the adaptability and ingenuity of smallholder farmers (De Fraiture & Giordano, 2014). These informal irrigation systems, often powered by petrol, diesel, or electric pumps, have allowed farmers to extend growing seasons, cultivate high-value crops, and meet the increasing demand for fruits and vegetables in urban markets (Dittoh et al., 2013). By providing a reliable water source during dry spells, farmer-led irrigation systems have enhanced productivity, supported multiple cropping cycles, and fostered the cultivation of drought-tolerant crops. These outcomes not only contribute to food security but also increase household incomes and enable crop diversification, reducing the vulnerability of smallholder farmers to climatic shocks.

2.7 Review of national policies on agricultural development in Ghana

Agriculture has historically served as the backbone of Ghana's economy, providing livelihoods for a substantial proportion of the population, particularly in rural areas. Despite its pivotal role, the sector has consistently grappled with challenges such as low

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productivity, environmental pressures, and limited access to modern technologies. In response, the government has implemented a range of national policies aimed at improving productivity, ensuring food security, and fostering sustainable agricultural development. This essay examines key national policies related to agricultural development in Ghana, their objectives, and their impact on the sector. The Ghana National Agricultural Policy Waldman et al. (2017), introduced in 2000, sought to address critical challenges within the agricultural sector. The policy's core objectives included enhancing productivity, ensuring food security, and improving the livelihoods of smallholder farmers (Azechum, 2017). It emphasized adopting improved agricultural technologies, fertilizers, and sustainable land management practices, alongside promoting environmentally sound strategies. However, challenges such as inadequate infrastructure, limited access to credit for smallholder farmers, and insufficient extension services constrained its implementation. Despite these hurdles, the NAP laid a solid foundation for subsequent agricultural reforms and interventions, underscoring its importance in Ghana’s agricultural policy landscape. The Ghana Shared Growth and Development Agenda (GSGDA) (2010–2013) represented a broader national development framework that prioritized agriculture as a driver of inclusive economic growth and poverty reduction (Danquah & Iddrisu, 2016). The GSGDA emphasized increasing productivity through modern farming techniques, mechanization, and irrigation. Additionally, it promoted agro-processing to add value to agricultural products and create employment opportunities. Recognizing the adverse impacts of climate change, the GSGDA also prioritized sustainable agricultural practices and the development of climate-resilient crop varieties. While the GSGDA achieved some notable progress, financial constraints and coordination challenges among stakeholders limited its full

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realization. The Medium-Term Agriculture Sector Investment Plan (METASIP) (2011–2015) focused on improving agricultural productivity, developing rural infrastructure, and strengthening extension services (Ministry of Food and Agriculture, 2010). METASIP emphasized agricultural modernization through mechanization and irrigation and sought to improve market access via enhanced transportation networks and storage facilities. Although METASIP attracted investments and improved infrastructure, its broader implementation was hindered by financial and coordination challenges. Nevertheless, METASIP underscored the centrality of agriculture in Ghana's development agenda. Introduced in 2014, the Agricultural Mechanization Policy aimed to boost productivity by increasing the use of mechanized farming equipment (Diao et al., 2018). The policy supported the adoption of tractors, plows, and modern tools while offering training and affordable financing mechanisms for smallholder farmers. Mechanization has enhanced the efficiency of large-scale farming operations. However, smallholder farmers continue to face significant barriers, including high equipment costs and limited access to credit facilities. Launched in 2017, the Planting for Food and Jobs (PFJ) program represents one of the most impactful recent initiatives aimed at revitalizing Ghana's agricultural sector (Prah et al., 2023). The PFJ seeks to enhance food security, create employment opportunities, and increase the production of staple crops such as maize, rice, and cassava. The program provides subsidized fertilizers and improved, drought-resistant seed varieties to farmers. While the PFJ has notably increased food production and created jobs, challenges such as inconsistent fertilizer distribution and limited access to credit have impeded its full potential. Despite these obstacles, the program has significantly strengthened Ghana's agricultural resilience. The National Irrigation Policy, introduced in

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2009, aimed to expand irrigation coverage, and improve water management, particularly in the northern regions of Ghana (Turral et al., 2010). The policy promoted efficient water use through technologies such as drip irrigation. Although the prohibitive cost of irrigation infrastructure has posed challenges, the policy has contributed to the development of large-scale irrigation systems, highlighting the importance of irrigation in bolstering food security and resilience against climate variability.

2.7.1 Policies and programs that promote OFSP and solar irrigation technologies.

2.7.1.1 Policies and programs that promote OFSP.

The introduction of Orange-Fleshed Sweetpotato (OFSP) represents a groundbreaking solution to combat vitamin A deficiency (VAD), a persistent public health issue in sub-Saharan Africa (Rao, 2020). The International Potato Center (CIP) has spearheaded numerous initiatives across SSA through a multi-partner strategy to promote OFSP as part of efforts to address VAD and alleviate poverty. These initiatives are underpinned by rigorous scientific research and development projects, including in Ghana (Low & Thiele, 2020).

One flagship initiative is the Sweetpotato Action for Security and Health in Africa (SASHA) program, which links agriculture with nutrition to address VAD and poverty (Low & Thiele, 2020). Financed by the Bill & Melinda Gates Foundation and led by CIP, SASHA was implemented in two phases (2009–2019), focusing on OFSP variety improvement and the establishment of a commercial seed system. Building on the SASHA project, the "Jumpstarting OFSP in West Africa through Diversified Markets" project (2014–2017) targeted Ghana, Nigeria, and Burkina Faso. This market-driven initiative aimed to raise awareness about OFSP's nutritional value and introduce its utilization and

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processing (Abidin et al., 2017). The project also established decentralized vine multiplication centers in northern Ghana to improve smallholder farmers' access to disease-free planting materials (Adekambi., 2020). These strategies successfully increased OFSP adoption in Ghana, Burkina Faso, and Nigeria (CIP, 2017).

Similarly, the USAID-OFDA project (2013–2014) introduced sand storage innovation technologies, combining climate-smart agricultural practices with methods for storing OFSP roots in dry sand, such as stepped pits, sandboxes, or basins. This approach enhanced food security and provided planting materials when needed (Abidin & Carey, 2018). HarvestPlus has also promoted OFSP by supporting seed systems, raising awareness, and fostering value chain development. Through partnerships with local governments, NGOs, and research institutions, HarvestPlus integrated OFSP into public health campaigns and school feeding programs to improve dietary outcomes (de Barcellos MD & H., 2024).

Similarly, USAID's Resiliency in Northern Ghana (RING) Project targeted smallholder farmers in northern regions, emphasizing nutrition education and value chain development to enhance food security and household incomes through OFSP cultivation (Mensah, 2019). Additionally, the Technologies for African Agricultural Transformation (TAAT) program, managed by CIP, has supported Ghanaian farmers by improving access to quality planting materials and promoting entrepreneurship in sweetpotato value chains (Demo, 2020). Other initiatives, such as the Kofi Annan Foundation's OFSP program in collaboration with AGRA, have focused on awareness campaigns, capacity building, and policy advocacy to integrate OFSP into Ghana's food security strategies (Kofi Annan Foundation, 2021).

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The Ghanaian government has also implemented programs to promote OFSP production and consumption. For instance, the Planting for Food and Jobs program, introduced in 2017, distributed 320,000 OFSP vine cuttings to farmers (https://mofa.gov.gh/site/programmes/pfj). Furthermore, the WIAD Division of the Ministry of Food and Agriculture (MoFA), Ghana Health Services (GHS), the Ghana School Feeding Program, and local governments have incorporated OFSP into various interventions, including school feeding initiatives, due to its proven nutritional benefits and climate resilience.

These efforts have led to significant outcomes, including increased OFSP adoption among smallholder farmers, improved dietary outcomes for vulnerable populations (e.g., children and pregnant women), and enhanced income opportunities through value chain development. However, challenges remain, including limited access to quality planting materials, inadequate processing and storage infrastructure, and low awareness of OFSP's nutritional benefits in some regions (Adenle et al., 2019). Against this backdrop, this study seeks to assess the economic viability of OFSP quality vine production and farmers' willingness to pay in northern Ghana.

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2.7.1.2 Policies and programs that promote solar irrigation technologies.

In SSA and Ghana in particular, solar technology is gradually emerging as an alternative or a complement to grid-based electricity (Gebrezgabher et al., 2021). The potential benefits of solar technology have triggered the interest of governments, development agencies, and the private sector to roll out several initiatives. For instance, the African Development Bank (AfDB) is supporting the Scaling-up Renewable Energy Plan (Climate Investment Funds, 2015), which includes a significant investment in solar energy. More

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so, the German Agency for International Cooperation (GIZ) under the irrigation component of the Energising Development (EnDev) program (https://energypedia.info/wiki/Solar_Pumps_for_Irrigation_The_Success_of_EnDev_Approach_in_Ghana) is supporting small-scale farmers to access and use solar PV pumps for irrigation. Again, the Power Innovation in Commercial Agriculture (PICA) project co-founded by the United States Agency for International Development (USAID) and Integrated Water and Agricultural Development (IWAD) Ghana Limited, has installed a solar energy generation capacity of 0.8-megawatt peak (MWp) targeted at benefiting 300 smallholder farmers in northern Ghana (Gebrezgabher et al., 2021). Similarly, NewEnergy has installed solar-powered irrigation systems in four communities in northern Ghana, with funding support from the United Nations Development Programme (UNDP) and the Energy Commission of Ghana. Also, the Ghana Irrigation Development Authority (GIDA) is converting the electric pumps at existing irrigation schemes to solar-powered pumps (IGBADUN, 2022).

Furthermore, the Ministry of Energy and Energy Commission together develop and oversee solar energy projects under the auspices of the international SEforALL initiative (Gebrezgabher et al., 2021). This was followed by the launching of a new private sector framework to promote the installation of solar home systems, including solar irrigation. Additionally, the Ghana Shared Growth and Development Agenda II (GSGDA II), the medium-term (2014-2017) policy framework for overall national development (National Development Planning Commission, 2015), was aimed at building a ‘green’ economy. The Coordinated Programme of Economic and Social Development Policies 2017-2024 (Government of Ghana, 2017) has replaced GSGDA II, but continues to support

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sustainable natural resource management, mainstreaming climate change resilience, and the expansion of renewable energy. Similarly, the National Climate Change Policy, launched in 2014, and the Intended Nationally Determined Contribution aim to enhance the uptake of climate-smart technologies (Government of Ghana, 2015; Ministry of Environment, 2012). Solar PV irrigation was included within these policies as it addresses national development aims and is part of climate-smart agriculture.

2.7.2 Access to Credit and Subsidies for Adopting Innovative Agricultural Practices

Agriculture remains a cornerstone of economic growth, poverty alleviation, and food security in developing nations. Despite its critical importance, the sector continues to grapple with persistent challenges that constrain its productivity. Even in regions with comparable resource endowments, vast disparities in agricultural output per hectare persist. These productivity gaps are often attributed to inefficient resource management, limited adoption of modern agricultural technologies, and reliance on traditional farming methods (Maja & Ayano, 2021; Umer et al., 2024). Further compounding these issues are inadequate infrastructure, insufficient extension services, climate-induced crop failures, and restricted access to credit and markets methods (Maja & Ayano, 2021; Umer et al., 2024). Addressing these multifaceted challenges requires a strategic focus on financial empowerment, particularly through access to agricultural credit and subsidies.

Credit is widely recognized as a cornerstone of agricultural transformation. The research underscores its role in alleviating the systemic barriers of low productivity and persistent poverty (Dercon & Christiaensen, 2011). By providing farmers with the necessary financial resources, credit facilitates investments in key agricultural inputs such as fertilizers, seeds, and machinery, and it supports value-added activities that enhance market access. This transition from subsistence farming to commercially oriented agricultural practices not only increase productivity but also improves farmers' overall returns (Tadesse, 2014). However, the relationship between credit access and agricultural productivity is both complex and nuanced. Formal credit markets often require collateral, which excludes asset-poor farmers from participation (Dercon & Christiaensen, 2011). Additionally, credit programs tied to specific input purchases, such as fertilizers, may impose rigid repayment terms that deter farmers, particularly those with limited resources (Giné & Yang, 2009). Education and financial literacy also play pivotal roles in credit accessibility. Farmers with higher educational attainment are better equipped to navigate the loan application process and understand the associated requirements, thereby increasing their likelihood of securing and effectively utilizing credit (Giné & Yang, 2009). Beyond alleviating financial constraints, credit access is instrumental in promoting the adoption of Good Agricultural Practices (GAPs). Empirical studies highlight that access to credit significantly enhances farmers' ability to invest in modern agricultural technologies, including improved seeds, irrigation systems, and pesticides, thereby boosting productivity (Jerop et al., 2018; Mwangi & Kariuki, 2015). Research further shows that credit enables smallholder farmers to overcome input-related bottlenecks, contributing to food security and agricultural development (Abdallah & Kajuna, 2023; Hailu et al., 2014; Nyangau et al., 2022). Despite these advantages, the adoption of modern agricultural technologies remains suboptimal in many regions. Limited credit access, low awareness, and the excessive costs associated with new technologies hinder widespread adoption (Patil & Veettil, 2024). For instance, Ogundeji et al. (2018) found that credit access in Lesotho through banks and agricultural associations significantly increased the adoption of

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innovative technologies. Similarly, Rutten and Fanou (2015) documented positive correlations between credit availability and the use of critical agricultural inputs such as chemical fertilizers, which led to increased productivity. However, Jerop et al. (2018) and Odhiambo and Upadhyaya (2021) emphasize that credit availability alone is insufficient. Ayenew et al. (2020) revealed that access to credit and its intensity were intricately linked to farmers' decisions to adopt improved technologies, such as high-yield maize seeds and fertilizers. Similarly, Ngango and Hong (2021) found that credit availability positively influenced technology adoption in Rwanda, with subsidies providing critical support in reducing financial burdens.

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2.8 Research Gaps and Opportunities

Numerous studies have investigated the economic viability of solar-powered irrigation systems for various crops globally (Abu-Nowar, 2020; Copeland, 2018; Curtis, 2010; Bolanos, 2015; Gautam & Singh, 2021; Hossain et al., 2015; Sarr et al., 2023). However, the economic viability of solar pump irrigation for root and tuber crop and sweetpotato vine production remains unexplored in West Africa, particularly Ghana. Again, the economic viability of solar pump irrigation varies globally, with diverse payback periods reported in different regions and crops (Lamine, 2020). Moreover, existing studies on economic and financial viability of various crops and solar irrigation are survey-based. This may not give accurate estimates of the viability situation given that production by farmers may not follow standard practices.

Empirical literature further shows that adoption of solar irrigation systems abounds. For instance studies like Cheam WY (2021); Zulu et al. (2021) and Bandara (2018) in Sri Lanka, Malaysia and Zambia, Aziz et al. (2017); Solangi et al. (2015) and Malik et al.

(2020) in Malaysia, Agarwal et al. (2023); Ali et al. (2019); Ashinze et al. (2021); Asif et al. (2023); Hasheem et al. (2022); Irfan, Hao, et al. (2021); Shahid et al. (2022); Zhou and Abdullah (2017); Nazir and Tian (2022) and Zhou et al. (2017) in Pakistan, Nigeria, Uganda and Agra all looked at the adoption of solar irrigation systems among farmers.

However, studies on farmers' adoption and sustained use of these technologies are missing. The current study addresses some of the gaps in previous studies as it adopts experimental approach to estimating economic viability of OFSP vines production in northern Ghana.

Furthermore, literature focusing on farmers WTP for agricultural innovations abound but are skewed towards cereals Ayedun et al. (2017); Kassie et al. (2017); Mastenbroek et al. (2021); Shee et al. (2019) and Waldman et al. (2017), legume seeds Maredia et al. (2019) and Waldman et al. (2017), yam seed Boadu et al. (2019) and Irish potato (Bartle & Maredia, 2019; Fuglie et al., 2006; Kaguongo et al., 2014; Okello et al., 2019). Studies that examine WTP for OFSP have mainly focused on fresh roots (Masumba et al., 2007; Meenakshi et al., 2010; Naico & Lusk, 2010; Tumwegamire et al., 2007).

A few studies, including Labarta (2009) in Mozambique, Mwiti et al. (2020) Tanzania, Adesina et al. (2017) in northern central Nigeria, and Mwangi et al. (2020) in Kenya assess the level and drivers associated with farmers' WTP for sweetpotato clean seeds. However, these empirical studies provide a limited understanding of how WTP compares to the costs of sweetpotato seed multiplication, which is an integral element in assessing the economic viability of a seed system (Pircher & Almekinders, 2021). Thus, the current study addresses this gap by further comparing the cost of OFSP vine production by farmers' WTP pay, which is critical to commercialization. This allows investors and farmers to make informed decisions regarding pricing and any attempt to venture into OFSP vine production.

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CHAPTER THREE

METHODOLOGY

3.1 Study area

The study was conducted in northern Ghana, which comprises five administrative regions: the Upper East, Upper West, North East, Northern, and Savannah regions. Northern Ghana shares international boundaries with Burkina Faso to the north, Togo to the East, and Cote D'Ivoire to the lower southwest. To the south, northern Ghana shares regional boundaries with the Bono, Ahafo, and Volta regions (Ampim et al., 2021). The region is located between latitudes of 8°50′ and 10°N and stretches between 0°30′ and 1°30′W in the Guinea savanna zone (Braimoh, 2006). It has one cropping season that lasts 5 to 6 months, starting in May, with an average annual temperature of 28°C and annual rainfall of 900–1040 mm (Braimoh, 2006). Northern Ghana is considered a climate change vulnerability hotspot in West Africa (Antwi-Agyei & Nyantakyi-Frimpong, 2021). Among the impacts of climate change on agriculture in northern Ghana are unpredictable and variable rainfall, increasing temperatures, and longer dry periods and delays in the onset of rain seasons in some regions Farmers in this region experience variability in rainfall patterns, high temperatures, and increasing frequency of floods and droughts (File & Nhamo, 2023). These impacts of climate change can lead to poor crop yields, low production, and food insecurity (File & Nhamo, 2023), making irrigation a crucial aspect of agriculture in the region (Fontaine et al., 2019). Northern Ghana is characterized by a rural population engaged in agriculture, with OFSP being one of the essential crops grown in the area (Bidzakin et al., 2014). Solar-powered irrigation pumps have been proposed as cost-effective and sustainable alternatives to traditional energy sources for irrigation in the region (Wazed et al., 2018). The region

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faces challenges such as poverty, inequality, and malnutrition, which have led to efforts to strengthen the value chain for crops such as sweetpotato and enhance economic opportunities for resource-poor farmers (de Jager et al., 2018).

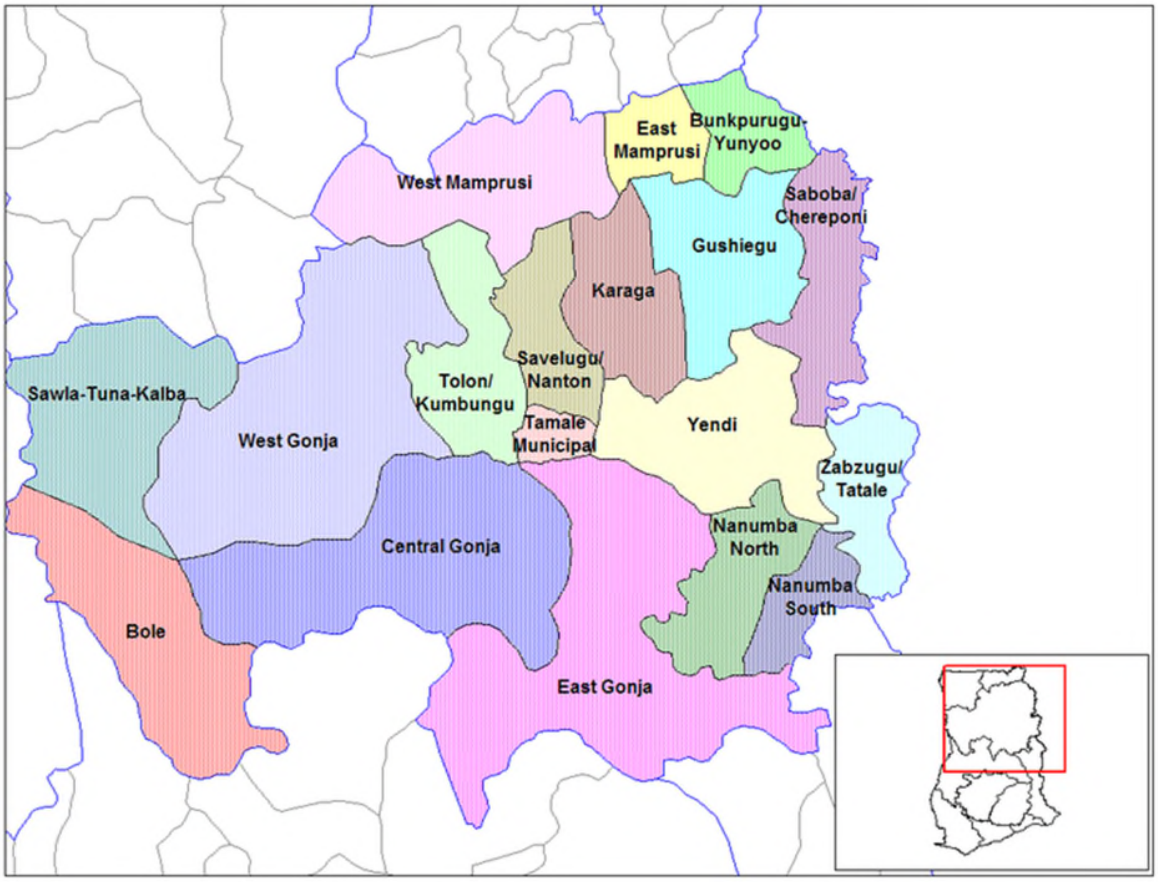

Figure 3.1: Map of the study area

Source: (GSS, 2010)

3.2 Research design

This study employs a twofold research design comprising a field experiment and a survey. The field experiment adopted a split-plot design, while the survey follows a quantitative research approach.

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3.2.1 Experimental design

The experimental split-plot design considered the main plots as the two irrigation methods (drip and rain tubes) and vines as the production purpose, while the subplots represent fertilizer treatments (with and without fertilizer application). Each main plot was further divided into two subplots, resulting in 12 experimental units (6 main plots × two subplots per plot).

The split-plot design is appropriate for this research because it allows for the investigation of both primary factors (irrigation methods and production purposes) and secondary factors (fertilizer treatments) simultaneously, while also considering the inherent variability within the system. This design accommodated the nested structure of the experiment, where the irrigation methods and production purposes represented the whole plot treatments, whereas the fertilizer treatments represented the subplot treatments within each main plot.

According to Montgomery (2017), split-plot designs are particularly useful when certain factors are more difficult or costly to change than others, as is the case with irrigation methods compared to fertilizer treatments. This design also accounted for potential interactions between the main and subplot factors, providing a more robust analysis of the experimental outcomes. Additionally, split-plot design is known to be efficient in terms of both time and resources, making it well-suited for agricultural experiments where practical constraints often exist (Smucker, 2023). The layout is presented in ***Table 3.1*** below.

Table 3.1: Layout of field experimental design

Drip irrigation				Rain Tubes irrigation			
	V1		V1		V1		V1
	V2		V2		V2		V2
	V3		V3		V3		V3
Fertilizer		Control experiment		Fertilizer		Control experiment	

Source: *Author's Field Experiment, 2024*

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3.2.2 Field survey

The field survey was conducted among sweetpotato farmers in the Saboba and East Mamprusi districts in the Northern and North East regions of Ghana respectively in July 2024. A multistage sampling technique was adopted to select farmers for this study. First, the study focused on the North East and Northern regions of Ghana, which were targeted by the GROWING Project, which sensitized farmers on the benefits of planting and consuming OFSP as well as using quality planting materials.

The project established vine multiplication centers in six districts across the selected regions for the multiplication of quality vines, which are disease-free and high yielding. Vines multiplied in these centers are purchased by CIP and distributed to households for free cultivation. Thus, these two regions were purposively selected. Second, one district was chosen from each of the two regions based on the concentration of project beneficiary communities. The M&E Officer of CIP aided in the generation of lists of beneficiary communities and households in the selected districts.

In each of the districts, communities were placed into three strata (cycle 1, 2, and cycle 3 communities). Cycle 1 comprises communities that received vines and training from CIP in the 2023 planting season, and Cycle 2 comprises communities that received some training from CIP but have yet to receive it for the 2024 planting season. In each stratum, 5 communities were randomly selected using a simple random sampling technique. Finally, a list of households was drawn with the aid of the M&E Officer of CIP, and in each community, 18 households were randomly selected for cycle 1 and 2 and 10 households, each for cycle 3 and interviewed using a semi-structured questionnaire. In total, 460 households were interviewed: 180 households each from cycle 1 and 2 and 100 households from cycle 3. The distribution of the respondents is displayed in Table 3.2.

The Yamane formula for sample size determination was employed to determine the sample size (Yamane, 1967). Using a sample frame of 1080 cycle 1 household, 2160 cycle 2 households, and 4320 cycle 3 households in Northern and North East regions making a total of 3240. Based on the Yamane's formula:

$$n = \frac{N}{1+N(e^2)} = \frac{7560}{1+7560(0.05^2)} = 379.899 \approx 380\ respondents \qquad (1)$$

However, 460 households were interviewed, given an excess of 80 households, to cater for missing observations and other irregularities. For instance, some households might refuse to participate or not respond to certain questions, leading to non-response bias.

Table 3.2: Distribution of respondents across the districts and communities

District/Community	Respondents	District/Community	Respondents
Saboba Cycle 1		***East Mamprusi Cycle 1***	
Sajigbaln	18	Bowku	18
Kubong	18	Tangbini A	18
Nachanyeni	18	Ziikaya Tun	18
Lower Butoen	18	Gbangu	18
Nayil	18	Sumniboma Sak	18
Saboba Cycle 2		***East Mamprusi Cycle 2***	
Sanguli 1	18	Kukugbini	18
Moagbar	18	Dindani B	18
Upper Butoen	18	Sakogu C	18
Kunkunzoli 2	18	Kpikparigbini	18
Tindando 2	18	Namasim	18
Saboba Cycle 3		***East Mamprusi Cycle 3***	
Jamoni	**10**	Nalerigu-D3	**10**
Nankpel Chakossi	**10**	Jerigitinga	**10**
Kpegu 2	**10**	Liman Fong	**10**
Unido	**10**	Tamboku- B	**10**
Ujando	**10**	Dagbiriboari- B	**10**
Subtotal	**230**	**Subtotal**	**230**
		Total	**460**

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Additionally, data entry errors can occur during data collection, recording, or entry, which can impact the overall quality of our data. Inconsistent responses from respondents, sampling frame issues, respondent bias, and instrument or measurement errors are other potential challenges that we can help address by increasing our sample size.

3.2.2.1 ***Data collection and instrument***

A semi-structured questionnaire designed to capture all relevant information required to achieve the research objectives was used to gather the data. The first and second parts (Sections A and B) of the questionnaire collected data on the socio-demographic and institutional characteristics of the sample respondents. The third and fourth sections contained questions on OFSP production and practices and households' perceptions of OFSP, respectively. Lastly, the fifth section elicited farmers' WTP for vine cuttings. For the WTP section, the study adopted the double-bounded contingent valuation method to elicit households' willingness to pay for quality OFSP vines.

3.3 Measurement of key variables

3.3.1 Experimental variables

3.3.1.1 Cost of production (in GH₵)

This encompasses all costs incurred right from the solar irrigation pump investment through the production process to harvest as well as other costs associated with getting the product to the market or final consumer. A breakdown of the cost components is illustrated below.

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1. **Setup Cost (in GH₵):** Include the initial investment in the solar irrigation pump, including the cost of the pump, solar panels, installation, and any necessary infrastructure cost the study will incur.
2. **Maintenance Cost (in GH₵):** Estimation of the ongoing costs required for the regular maintenance of the solar irrigation system, including equipment maintenance, repairs, and any associated labour costs.
3. **Input Cost (in GH₵):** This will include a sum of all costs related to inputs for sweetpotato cultivation, such as seeds, fertilizers, pesticides, labour, and any other materials required for optimal production.
4. **Depreciation (in GH₵):** the study will account for the depreciation of the solar irrigation pump system over its useful life. This will be calculated per annum based on the initial setup cost and the expected lifespan of the equipment.
5. **Interest on Capital (in GH₵):** The interest payments on the funds used for the production as a cost. This reflects the opportunity cost of using capital for the solar irrigation system.
6. **Marketing Cost (in GH₵) (Transportation, Bagging, etc.):** Include costs associated with marketing the sweetpotatoes, such as transportation to market, packaging materials, and any other expenses related to getting the produce to consumers. This data will be obtained from the consultation of transporters, packaging suppliers, and other relevant stakeholders to estimate the marketing cost of OFSP.

3.3.1.2 Benefits (Revenue in GH₵)

Vine revenue: root revenue is the revenue obtained from the sales of harvested vines during production. The revenue is estimated by multiplying the quantity of vines harvested

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per plot by the market price of vines (GH₵/plot). Revenue per hectare is then calculated as follows.

$$\text{Vine Revenue (GH₵)} = \left(\frac{Total\ vine\ revenue\ per\ plot}{plot\ area}\right) \times 10000 \quad (2)$$

Other revenue: other revenue of vines encompasses revenue obtained from the sales of byproducts of vines and any other revenue generated from the production process apart from sales of vines.

3.3.2 Survey variables

3.3.2.1 WTP elicitation

Since quality OFSP vines are not readily available in the market for sale, a hypothetical market was conceptualized as described below.

OFSP vine cuttings in this study refer to vine segments taken from Orange-Fleshed sweetpotato (OFSP) plants, used as planting materials for cultivating OFSP roots. These vines are preferred to the locally produced fleshed sweetpotatoes due to their higher yield potential. They exhibit resistance to pests and diseases, tolerance to drought, and early maturity over the local variety. The roots produced from these vines have several desirable characteristics. They are sweeter in flavuor, possess a moist and creamy texture when cooked, and have a vibrant orange interior ranging from pale to deep orange. Importantly, they are rich in beta-carotene, a precursor to vitamin A which is low in local variety, and contain potassium, vitamin C, and fiber. Studies indicate that consuming OFSP roots is particularly beneficial for children under 5 years old, as well as pregnant and lactating mothers compared to the local variety. Additionally, these roots find application in the baking industry for making bread**.** If a bundle of 100 cuttings of OFSP vine cuttings of 30cm each were offered to you for planting this season, would you be willing to pay for it?

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The contingency valuation approach is in two folds. 1) the Open-ended elicitation approach (continuous method) and 2) the closed-ended method (discrete choice method). The closed-ended approach is made up of single-bounded dichotomous choice and double-bounded dichotomous choice contingent valuation methods which were developed by Hanemann (1984) and Hanemann et al. (1991) respectively. The open-ended elicitation approach is characterized by unrealistically large or small bids. It is against this backdrop that the National Oceanic and Atmospheric Administration (NOAA) panel recommended the dichotomous choice approach for eliciting WTP for non-market goods with some guiding principles (Arrow, 1993). The double-bounded dichotomous choice (DBDC) approach is more formative and achieves higher statistical efficiency compared to the single-bounded discrete choice format (Cameron, 1991). However, this study adopted both the single-bounded and the double-bounded dichotomous choice contingent valuation method. The study's choice of both single-bounded and double-bounded dichotomous choice contingent valuation methods is justified by the benefits each approach offers. The single-bounded approach is favored for its simplicity, making it easy for respondents to understand and answer the valuation question. This simplicity reduces the cognitive burden on respondents, potentially leading to more genuine responses. Additionally, the single-bounded approach minimizes the risk of bias that might arise from respondents anchoring their valuations on previously presented bid amounts.

On the other hand, the double-bounded approach is chosen for its ability to provide more precise estimates of willingness-to-pay. By presenting respondents with a follow-up bid that is contingent on their response to the initial bid, the double-bounded approach gathers more detailed information about the range within which a respondent's willingness-to-pay

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falls. This can lead to more accurate estimations of mean willingness-to-pay, enhancing the reliability of the study's findings. By combining both approaches, the study aims to leverage the strengths of each method. This dual approach allows for a comparison of results, validation of findings, and an assessment of consistency between the two methods, ultimately increasing the robustness and reliability of the study's conclusions.

A Reconnaissance survey was conducted to arrive at a realistic market price for OFSP vines. The DBDC was adopted to cater to the starting point bias that the double-bounded contingent valuation method is criticized for. The average price of OFSP vine obtained from the survey was GHS15.00 per bundle of 100 cuttings. This price was used as the basis for initial WTP bids. After a full description of the product to the respondents by the enumerator, four different bids (e.g., GHS15.00, GHS20.00, GHS25.00, and GHS30.00) were randomly administered to respondents. The respondents were then asked if they were willing to pay for quality OFSP vine cuttings at a randomly assigned bid price. Those who responded “yes” were asked if they would be willing to pay at another randomly assigned higher price that has been increased by 10%. However, each respondent was only offered a single-second bid. Those who answered “no” to the first bid were offered another randomly assigned lower price that was discounted by 5%. Finally, respondents who responded yes to both the first and second bids were asked to state the higher amount they were willing to pay. Those respondents who answered no for both were asked to state the amount they were willing to pay. Figure 3.3 illustrates the initial bids, the questions, and the responses. The bids are then arranged as “No-No,” “No-Yes,” “Yes-No,” and “Yes-Yes” with ordering scores of 0, 1, 2, and 3, respectively.

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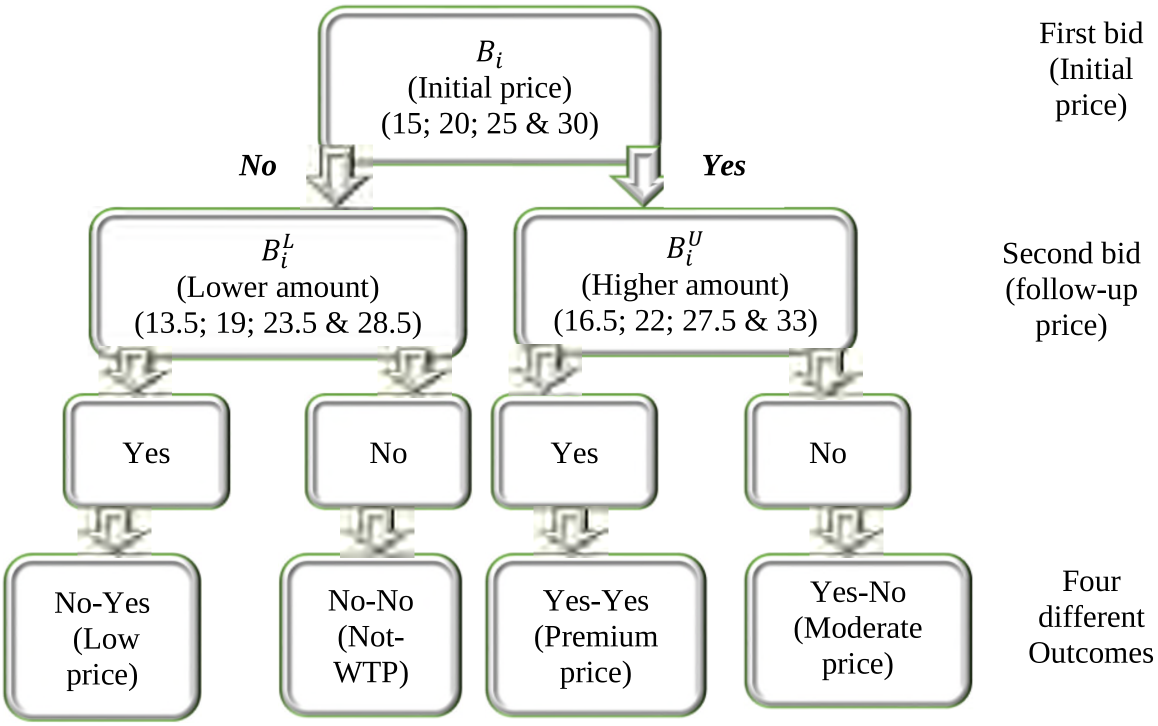

Figure 3.3: the bidding sequence for the double-bounded discrete choice format

Source: *Authors' conceptualization*

3.4 Theoretical frameworks

3.4.1 Production Theory for economic viability analysis (experiment)

According to the production theory, a firm is a decision-making unit that transforms input into outputs to maximise profits. The theory also assumes that technology and market constraints affect profit-maximizing property. The relationship between inputs and outputs is referred to as technological constraint, whereas market constraints are concerned with the impact of other players' actions outside the firm (Jehle & Reny, 2011). Hence, a firm's production function can be stated as:

$$y = f(x) \qquad (3)$$

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Where y is the amount of output produced from a set of inputs, which may include labour, fertilizer, and vines utilized in the sweetpotato vine production. The firm's profit maximization challenge may so be expressed as:

$$\pi(p, w) = max\, pf(x) - wx \qquad (3a)$$

Where p is the price of the output and w is a vector representing the prices of the inputs. The properties of the profit function are that it is increasing in p, decreasing in w, homogenous of degree one in (*p and w*), convex in (*p and w*) and differentiable in (*p and w*). The first order condition that maximizes profit is given as;

$$p\frac{dfx^*}{x} = w \qquad (3b)$$

This means that the firm's profits are maximized when the marginal value product is equal to the cost of each production input. $p\frac{dfx^*}{x} = w$ can be solved to yield the optimal input demand that maximizes profits as shown below.

$$x^* = x^*(p, w) \qquad (3c)$$

$x^* = x^*(p, w)$demonstrates that input and output prices are key arguments in the optimal input-demand function. As a result, the equation can be used to estimate input demand (such as labour, seed, and fertilizer). This theory was adopted for the economic viability of OFSP vine production under solar irrigation.

3.4.2 Utility maximization for measuring willingness to pay

WTP can be measured using the contingency valuation approach or the surrogate approach. This study adopted the contingency valuation for eliciting farmers' WTP for quality OFSP vines. The theory of consumer behaviour and random utility maximization theory better explain the rationale behind farmers' WTP. The utility maximization framework assumes that households make production and consumption decisions to maximize utility (Singh et

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al., 1986). The decision of a farmer to pay a certain amount of money to be able to obtain or use an economic good depends on the utility or satisfaction the farmer derives from the good. Thus, a farmer will only pay or be willing to pay an amount for OFSP vine, if and only if the utility drive is higher than the utility without the OFSP vine. However, the utility the farmer drives from purchasing OFSP vine cannot be readily observed and therefore the indirect utility function is to arrive at farmer WTP is more appropriate. The study assumes that sweetpotato farmers have two alternatives of sweetpotato vines to purchase for their production. These are quality OFSP vines (O) that are drought, pest, and disease tolerant, rich in vitamin A and other micronutrients, high yielding, and early maturing, and the traditional other vines (W). A rational farmer is expected to choose O if and only if the benefit of O minus the gains of W is greater than zero. Reference to (Lui, 2011), given the prices of vines and the income of the farmers, the net indirect utility function is given as:

$$U^* = U_o(P_0, Y, Z) - U_w(P_w, Y, Z) > 0 \qquad (4a)$$

$$U^* = U_o(P_0, Y, Z) - U_w(P_w - v, Y, Z) > 0 \qquad (4b)$$

Where U_0 is the indirect utility derived from quality OFSP vines, U_w is the utility derived from other sweetpotato vines, P_0 price of quality OFSP vines, P_w price of other vines, Y is the income of the farmers, Z is a vector of socioeconomic and policy variables and v is the amount farmers are willing to pay for quality OFSP vines.

As a rational decision-maker, one compares the marginal WTP with the price of quality OFSP vines and increases (decreases) the demand for the quality OFSP vine if the marginal WTP exceeds (is below) the price.

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3.5 Conceptual framework

The concept of the economic viability of OFSP vine production and farmers' WTP for vines are determined by several factors. These factors include socioeconomic factors, production factors, institutional factors, and households' perceptions about OFSP. As displayed in ***Figure 3.2*** both socioeconomic factors (age of household head, gender, household size, number of children under 5 years, educational status, income level, number of pregnant women, etc.) and institutional factors like (credit access, extension contacts, SP farmer association, NGO support, market access, motorable roads, etc.) affect farmers willingness to pay for OFSP vines.

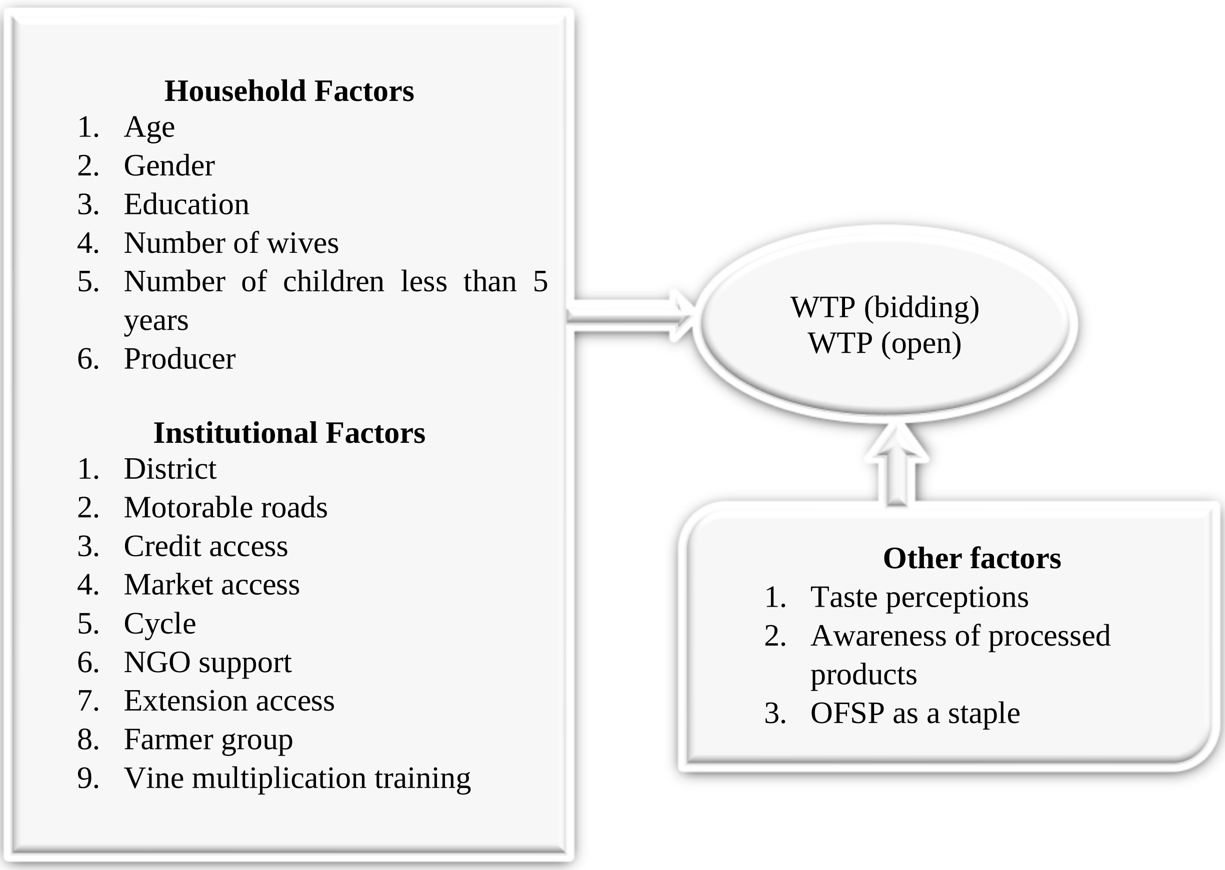

Figure 3.2 *Conceptual Framework*

Source: *Authors' conceptualization*

Also, households' WTP for OFSP vines is affected by their perception of the OFSP and their production characteristics such as farm size, yield, season of production, experience in OFSP production, and their source of planting materials (vines). However, households WTP pay for OFSP vines form the foundation for determining economic viability and investment in vine production. Moreover, the socioeconomic factors, institutional factors, production factors as well as households' perception of OFSP affect the economic viability of OFSP vine production.

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3.6 Method of Data Analysis

The analytical software STATA 17 and Excel 365 were used for analysis. For objective 1, a cost-benefit analysis was used to assess the economic viability of OFSP vines under different scenarios. With objective 2, descriptive and inferential statistics such as means, percentages, t-tests, and chi-square tests were used to compare households' willingness to pay for OFSP vines across the selected districts. Finally, for objective 3, the ordered probit and Complementary log-log models were adopted to assess factors influencing households' willingness to pay for OFSP vines. The ordered probit was used because dependent variable WTP, was categorical and ordered. However, the complementary log log model was adopted to check for the consistency of the results and correct for the skewness of the response.

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3.6.1 Analytical for experiment/al data

3.6.1.1 Operationalization of the economic viability of OFSP production in northern Ghana.

This objective is to examine the economic viability of OFSP vine production. In this study, standard economic indicators, such as (1) gross margin, (2) net present value (NPV), and (3) benefit-cost ratio (BCR) was be calculated to determine the economic viability of OFSP vine production in the study area.

Net present value (NPV): The NPV in this study is the sum of the discounted net cash inflows over ***n*** years.

$$NPV = \frac{p_1}{(1+i)^{r_1}} + \frac{p_2}{(1+i)^{r_2}} + \frac{p_3}{(1+i)^{r_3}} \ldots\ldots.. + \frac{p_n}{(1+i)^{r_n}} \qquad (5a)$$

$where,$ P = Net cash flow in $\mathrm{n^{th}}$ year(years) from OFSP vine production

i = Discount rate (29%) which is taken as the cost of capital recorded by the Bank of Ghana.

T = Time period(in years) is the total number of years OFSP vines are produced beginning from t = 1 to, n years in June 2024.

And C = Initial cost of investment. NPV >0 implies that the investment is viable or profitable.

Benefit-Cost ratio (BCR)

$$\text{BCR} = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+i)^n}}{\sum_{t=1}^{n} \frac{C_t}{(1+i)^n}} \tag{5c}$$

$where, B_t$ = Present worth of cash flow, C_t = Present worth of cost, r = discount rate, n = number of years. BCR > 1 implies that the worth of cash inflows exceeds that of outflows. Therefore, this project is viable.

Return on investment (ROI) is adopted to determine the proportion of the benefits that a project or investment can give. ROI is an investment performance indicator (Wahab, 2016). It is estimated to determine whether it is worth investing in a specific project.

To calculate ROI, the benefit (return) of an investment is divided by the cost of the investment; the result is expressed as a percentage or a ratio. The return-on-investment formula as:

$$ROI = \frac{Gain\ from\ Investment - Cost\ of\ Investment}{Cost\ of\ Investment} \tag{5d}$$

According to Goodrich (2013), the formula is:

ROI (%) = $ROI(\%) = \frac{Net\ income}{Total\ investment} \times 100$

After estimating ROI, if the estimate is greater than 100 percent, then the project has a positive return otherwise it has a negative return. If the ROI is equal to 100, then the project is breakeven.

3.6.1.2 Sensitivity analysis

Sensitivity analysis is a tool used to determine the effect of different values of input parameters (independent variables) on a certain dependent variable in predetermined conditions. Such an analysis allows the evaluation of results when the input parameters

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progress through the confidence intervals and these variations translate into a range of economic results also within confidence intervals. The sensitivity analysis considers various input variables with impact on the results while separating these variables and the corresponding range of outcomes. It is also known as the 'what-if analysis.' The sensitivity analysis conducted in this study measures whether a variation in the total cost of OFSP vine production discount rate or price of OFSP vines or the three combined makes OFSP vine production economically viable. It tests the robustness of profitability indicators conditioned on certain changes in the market. Prominent factors that are postulated to influence the economic viability of OFSP vine production are the price of vines, total cost, and discount rate. These variables have been identified in the literature to be sensitive to inflation over time (Asciuto et al., 2019; Benkovskis, 2011; Folorunso et al., 2023).

The Ghanaian economy is affected by both internal and external shocks. Prices of agricultural commodities are unstable. These prices drive inflation which affects the cost of capital (discount rate), cost of inputs, and labour used in OFSP vine production. Therefore, since the price of OFSP vine, the total cost of production, and the discount rate are key determinants of the profitability of OFSP vine production, they were the variables considered in the sensitivity analysis in this study. The average inflationary rate in Ghana for the past seven years (2017 to 2023) is 17% from Ministry of Finance, 2023 records (Perevyshin & Trunin, 2023). As such, the price of vines, the total cost of production, and the discount rate were each varied by 17% to determine whether NPV, BCR, and ROI still make OFSP vine production viable. How was this done?

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3.6.2 Analytical strategy for survey data

3.6.2.1 Exploring households' willingness to pay for OFSP vines in the selected districts.

Descriptive statistics such as percentage, frequency, mean, and standard deviation were applied, and the output was presented using tables and charts. Similarly, t-test and chi-square test were used to determine the statistical relationship of explanatory variables on households' level of willingness to pay across the selected districts.

3.6.2.2 Assessing the factors influencing households' willingness to pay for quality OFSP vine.

Examining the factors influencing households' willingness to pay for quality OFSP vines on a concept where households' willingness to pay is elicited using a contingency valuation approach (close-ended single-bounded and double-bounded dichotomous choice). This study adopted the ordered probit and the complementary log-log in the analysis. In the DBDC model, respondents were presented with two levels of bid where the second bid is contingent upon the response to the first bid. Let B^1be the initial bid price and B^2 be the second. The take-it-or-leave-it question with a follow-up approach starts with an initial bid B^1. The level of the second bid depends on the response to the first bid. Thus, if the respondent says "yes" to the initial bid, the second bid is some amount greater than the initial bid (B^2<B^1). Hence, the four possible outcomes: both answers are "yes," both answers are "no," a "yes" followed by a "no," and a "no" followed by a "yes." The bounds on the WTP are $B^1 \leq WTP < B^2$ for the yes-no answer; $B^1 > WTP \geq B^2$ for the no-yes, answer; $WTP \geq B^2$ for the yes-yes answer; and WTP < B^2 for the no-no answer.

WTP, in the double-bounded dichotomous choice approach, took the form of a multi-response variable that is ordinal, hence the ordered probit or the ordered logit models will

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yield better results for the analysis. Apart from the difference in the distribution of the error term where the probit model assumed normal and the logit, logistic distribution, the two models practically give comparable results (Dimitri & Greene, 2002). However, the ordered probit has gained a wider usage for ordered response data in econometric work (Davidson & MacKinnon, 2006). Thus, the ordered probit developed by McKelvey and Zavoina (1975) which is constructed on a latent (unobservable) random variable can be expressed as (Eq. 1):

$$WT\,P_i = \begin{cases} 0 & if\ -\infty < WTP_i^* < \mu_0 \\ 1 & if \mu_1 \leq WTP_i^* < \mu_1 \\ & \dots\dots\dots\dots.. \\ J & if \mu_J \leq WTP_i^* < \infty \end{cases} \qquad (6a)$$

Were $\mu_1, \mu_2, \ldots\ldots \mu_J$ Denote expected threshold parameters, j = 0, 1, 2, and 3 are WTP categories J (0 No-No Not willing to pay, 1 No-Yes low price, Yes-No Moderate price, and Yes-Yes premium price) & WTP_i^* Is the latent outcome (Willingness to pay).

The probabilities will therefore be given as.

$$(\text{Prob}\ [WT\,P_i = \text{j}] = \text{Prob}[\,\mu\text{j} - 1 < WTP_i^* \leq \mu\text{j}]\ )$$

$$= \text{Prob}\ [\mu\text{j} - 1 - X_i\beta < \text{ei} \leq \mu\text{j} - X_i'\beta]$$

$$= \Phi\ (\mu j - X_i'\beta) - \Phi\ (\mu j - 1 - X_i'\beta] \ldots\ldots\ldots\ldots\ldots\ldots (6b)$$

Where Φ (.) is the standard normal cumulative distribution function and J is the response categories, in this situation 0, 1, 2, and 3 since there are four categories for WTP.

Literature has shown that there is no meaningful qualified mean function and the marginal effects in the ordered probability models are not upfront, the influences of changes in the independent variables on cell probabilities are normally measured (Greene, 2007). The marginal effects of the ordered Probit model can be expressed as (Eq. 6c):

$$A = \delta_{ij} = \frac{\delta prob[WTP_i = j|X_i]}{\delta X_i} \qquad (6c)$$

The empirical model can be specified as follows (Eq.6d)

$$WT\ P_{ij} = \beta_i X_i + \varepsilon_i \qquad (6d)$$

Were $WT\ P_{ij}$ Is the willingness to pay, X_i Is a vector of explanatory variables, β_i is an estimated parameter, and ε_i Is an error term with a mean of zero and a constant variance. The subscript, j = 1, 2, 3, 4 denotes WTP categories as follows (Yes-Yes is Premium price, Yes-No is Moderate price, No-Yes is Low price, & No-No is Not willing to pay).

3.6.2.3 Complementary log-log model

The complementary log-log model (clog-log) is an alternative to logit and probit analysis, but unlike the other estimators, the transformation of the complementary log-log is not symmetric. Typically, this model is used when the positive (or negative) outcome is rare. The general form of a clog-log model is given as:

$$g\big(E(y)\big) = X\beta \qquad (7a)$$

where: - g(·) is the clog-log link function $g(u) = log\big(-log(1-\mu)\big) - E(WTP_I)$ is the expected value of the response variable (WTP), X is the design matrix of predictors β is the vector of coefficients in a clog-log model,

The response variable (WTP) is binary, taking values 0 or 1. Hence the model can be written in terms of the probability of WTP=1 as:

$$P(WTP_i = 1) = 1 - exp(-exp(X_i\beta) \qquad (7b)$$

The marginal effects (β) in a clog-log model can be interpreted as: βj represents the change in the log of the odds of y=1 for a one-unit change in xj, holding all other predictors constant.

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3.6.2.4 Description of variables used in the models in estimating determinants of farmers' WTP.

Table 3.3 presents the socioeconomic and institutional variables that are hypothesized to influence farmers' willingness to pay decisions. As illustrated, the description of the variable, the measurement as well and the priori expectations for each of the variables against farmers' WTP.

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Table 3.3: *Description of variables used in estimating determinants of farmers' WTP.*

Variable	Description	Measurement	priori expectations
Age	Age of the farmer	Years	+
Sex	Gender of the farmer	1= Male 0 = Female	+
Credit access	Whether farmers have access to credit	1 =Yes 0 = otherwise	+
Extension contacts	Whether farmers have extension contacts	1 =Yes 0 = otherwise	+
Access to output market	Whether the farmer has access to a market for his produce	1 =Yes 0 = otherwise	+
Awareness of OFSP processed products	Whether farmers are aware of processed products of OFSP in the market	1 =Yes 0 = otherwise	+
Education	The educational level of farmers in years	Years	+
Motorable roads	Whether farmers have access to good farm roads	1 =Yes 0 = otherwise	+
Vine multiplication training	Whether farmers receive training on SP vine multiplication	1 =Yes 0 = otherwise	+
SP association membership	Whether the farmer is a member of the SP association	1 =Yes 0 = otherwise	+
SP staple	Whether farmer SP is a staple	1 =Yes 0 = otherwise	+
Number of children <5 years	Number of children less than 5 of the farmers	No. of children	+
Taste perception	Farmer perception about the taste of OFSP	index	-
NGO support	Whether farmers receive support from NGOs to cultivate OFSP	1 =Yes 0 = otherwise	+
District	District of the farmer	1 East Mamprusi, 0 Saboba	+/-
Producer/related to a producer	Whether the farmer produces OFSP or is related to OFSP farmer	1 =Yes 0 = otherwise	+

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CHAPTER FOUR

RESULTS AND DISCUSSIONS

3.7 Experimental results

4.1.1 Economic viability and sensitivity analysis of OFSP vine production

Table 4.1 and ***Table 4.2*** show the economic viability analysis of OFSP vine production under solar drip irrigation with and without fertilizer whilst ***Table 4.3*** and ***Table 4.4*** show the economic viability analysis of OFSP vine production under solar rain-tube irrigation with and without fertilizer. The second and third columns of the respective tables show values of the various cost and revenue components in year 1 and year 2, respectively. The study projected 2 years of production of OFSP. The 2 years costs and revenues were calculated based on certain assumptions. These assumptions include (1) Fixed depreciation is assumed for fixed inputs (poly tank, HDPE pipe, Solar panel, solar pump, poly tank stands in the second year. This was based on the straight-line depreciation of the inputs used for OFSP vine production. (2) The cost of labour, planting materials, fertilizer, and pesticides will increase by 17% each in the second year due to inflation. The 17% inflationary rate is based on the average inflation in Ghana for the past 7 years starting from 2017 to 2023 (Wahab & Tashie, 2024). (3) The discount rate is 29%. Thus, the average cost of capital is expected to increase by 17% based on the 7-year average inflation rate. (4) The output in terms of bundles on vines obtained is expected to decrease by 5% both with fertilizer and without fertilizer due to loss of soil fertility during the first year and changes in climatic conditions.

For actual price estimation, the following assumptions were also made: (1) The price of fertilizer increased from 300 in 2023 to 350 in 2024 representing a 17% increase. (2)

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Labour cost increased from 55 cedis in 2023 to 60 cedis in 2024 representing an 18.18% increase. (3) Pesticides price from 60 cedis to 70 cedis representing a 16.67% increase. (4) The Bank of Ghana policy rate of 29% was used. Thus, it is assumed that the price of fertilizer, pesticides, and labour will increase by the same magnitude next year.

The analysis of economic viability in this study is in two folds. The difference arises from the price adjustment using a 7-year average inflation and real market price change as illustrated in the assumptions above. These two approaches to price adjustment were to ensure the robustness of the projections made. From the results presented in this section, there is no significant difference in the economic viability indicators for both price adjustments. Thus, the result of the inflation adjustment is discussed here while the actual price adjustment is presented in the appendix section. Also, the sensitivity analysis was based on the inflation price adjustment.

4.1.2 Economic viability of drip irrigation with fertilizer (using inflation)

Table 4.1 shows that the total present value of cash inflow for OFSP vine production under drip irrigation is GH₵0.90 million per hectare while that of the cash outflow is GH₵0.11 million. Hence, the net present value realized from one hectare of OFSP vine production under drip irrigation is GH₵0.79 million.

Furthermore, the estimated BCR is 8.14 and the return on investment (ROI) per hectare for two years is 708 percent. The BCR is greater than 1 which implies that the production of OFSP vines is economically viable. The NPV greater than zero also implies that OFSP vine production under solar irrigation is economically feasible. More so, the per hectare returns on investment of 708 percent indicates that farmers can recover more than 700 percent of the cost incurred in OFSP vine production. Imamsaheb et al. (2014) who found that drip irrigation and fertigation for different vegetable crops were economically viable.

Table 4.1: Economic viability of drip irrigation with fertilizer

Variable	*Year 1*	*Year 2*	*Total*	*Per Ha*
PV of total cash inflow (000,000)	4.13	3.04	7.17	0.90
PV of total cash outflow (000,000)	0.48	0.40	0.88	0.11
NPV (000,000)	3.65	2.64	6.29	0.79
BCR	8.60	7.59	8.14	8.14
ROI	760%	659%	708%	708%

Source: *Field Experiment, 2024*

Akinyi et al. (2022) reported that improved seeds in the sweetpotato value chain were the most viable option among the climate-smart agricultural practices in Nigeria. Likewise, Hussain et al. (2022) employed a cost-benefit analysis in drip irrigation to produce high-value crops and found that the drip irrigation method was economically viable.

As can be observed in ***Table 6.1 in the Appendix***, the results show estimates for OFSP vine production under solar irrigation with fertilizer. The average number of bundles of 100 cuttings of OFSP vines obtained per hectare is 67,084.88 for the entire two-year period. Also, the average fixed and variable cost for two hectares for the entire year is GH₵25,242.75 and GH₵99,359.56, respectively.

4.1.3 Economic viability of drip irrigation without fertilizer (using inflation)

Having assessed the economic viability of vine production with fertilizer, the study also looked at the situation without fertilizer. ***Table 4.2 in*** shows that the total presented value of cash inflow is GH₵0.46 million per hectare whilst that of the cash outflow is GH₵0.97 million. Hence, as illustrated in ***Table 4.2***, the net present value realized from one hectare

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is GH₵0.37 million. Thus, the estimated BCR is 4.75 and the return on investment (ROI) per hectare for two years is 366 percent. The BCR is greater than 1 which implies that the production of OFSP vines is economically viable.

The NPV greater than zero also implies that OFSP vine production under solar irrigation is economically feasible.

Table 4.2: Economic viability of drip irrigation without fertilizer

Variable	Year 1	Year 2	Total	Per Ha
PV of Total Cash Inflow (000,000)	2.36	1.35	3.70	0.46
PV of Total Cash Outflow (000,000)	0.47	0.31	0.78	0.97
NPV (000,000)	1.89	1.04	2.92	0.37
BCR	5.02	4.34	4.75	4.75
ROI	402%	334%	366%	366%

Source: *Field Experiment, 2024*

Narayanamoorthy et al. (2018) found that drip irrigation in vegetable production is an attractive and viable option for sustainable management of irrigation water as it reduces the use of inputs (fertilizer) and enhances crop yield. Similarly, an earlier study by Narayanamoorthy (2005) also found that the drip method of irrigation in sugarcane cultivation was economically viable without subsidy. More so, the per hectare returns on investment of 366 percent indicates that farmers can recover more than 360 percent of the cost incurred in OFSP vine production. Thus**,** vine production under solar irritation with fertilizer showed superior financial rewards to farmers than the without fertilizer against indicators.

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The results illustrated in ***Table 6.2*** *in the Appendix* revealed that the average quantity of OFSP vines obtained per hectare is 38,288.25 bundles of 100 cuttings of 30 cm length each for two years period. Also, the average fixed and variable cost for two hectares for two years is GH₵25,242.75 and GH₵97,976.40, respectively.

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4.1.4 The economic viability of Rain-tube irrigation with fertilizer (using inflation)

The results in ***Table 4.3*** indicated that the estimated total presented value of cash inflow and outflow for two years is GH₵0.69 million and GH₵0.90 million respectively and this translates to an NPV of GH₵0.60 million for the same period. More so, as presented in ***Table 4.3*** the estimated BCR is 7.72 and ROI 656 percent. The NPV greater than zero, and BCR greater than 1 both meet the conditions of economic viability. Hence, OFSP vines under solar raintube irrigation with fertilizer are viable. The ROI of 656 percent indicates that farmers can regain over 650 percent of the cost of their investment in OFSP vine production.

Table 4.3: Economic viability of Rain-tube irrigation with fertilizer

Variable	**Year 1**	**Year 2**	Total	Per Ha
PV of Total Cash Inflow (000,000)	3.52	2.01	5.54	0.69
PV of Total Cash Outflow (000,000)	0.43	0.29	0.72	0.90
NPV (000,000)	3.09	1.72	4.82	0.60
BCR	8.21	6.99	7.72	7.72
ROI	721%	599%	656%	656%

Source: *Field Experiment, 2024*

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As in ***Table 6.3*** *in the Appendix***,** the average output of OFSP vines per hectare is 57,271.50 bundles with fixed and variable costs of GH₵15,663.38 and GH₵97,918.76 respectively for two years period of production. More so,

4.1.5 Economic viability of Rain-tube irrigation without fertilizer (using inflation)

The analysis in ***Table 4.4*** revealed that the estimated total presented value of cash inflow and outflow for two years is GH₵0.53 million and GH₵0.87 million respectively and this translates to an NPV of GH₵0.44 million for the same period.

Table 4.4: Economic viability of Rain-tube irrigation without fertilizer

Variable	**Year 1**	**Year 2**	Total	Per Ha
PV of Total Cash Inflow (000,000)	2.70	1.54	4.25	0.53
PV of Total Cash Outflow (000,000)	0.42	0.28	0.70	0.87
NPV (000,000)	2.28	1.26	3.55	0.44
BCR (ratio)	6.45	5.49	6.07	6.07
ROI (%)	545%	449%	495%	495%

Source: *Author's Field Experiment, 2024*

Furthermore, as demonstrated in ***Table 4.4*** the estimated BCR is 6.07, ROI is 495 percent. The NPV greater than zero, and BCR greater than 1 both meet the conditions of economic viability. Hence, OFSP vines under solar raintube irrigation without fertilizer are viable. The ROI of 495 percent indicates that farmers can regain 495 percent of the cost of their investment in OFSP vine production.

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Also, from the analysis as presented in ***Table 6.4*** *in the Appendix***,** the average output of OFSP vines per hectare is 43918.88 bundles with fixed and variable costs of GH₵15,663.38 and GH₵95,127.15 respectively for two years period of production.

4.1.6 Sensitivity analysis

This section explores the sensitivity analysis of the economic viability of OFSP vines. This was achieved by considering certain scenarios. The findings are discussed based on the following scenarios.

Scenario 1: ***Sensitivity analysis for a 17% increase in the total cost of OFSP vines***

Under this scenario, it was assumed that the total cost of OFSP vine production increased by 17%. The results as in ***Table 4.5*** show that the BCR, after the 17 percent increment in total cost for drip with and without fertilizer was 7.81 and 4.41 respectively. Also, the net present value for with and without fertilizer under drip irrigation was GH₵0.78 million and GH₵0.36 million, respectively.

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Table 4.5: Economic Viability Indicators Response to 17% Increase in total cost of OFSP vines production

Variable	**Drip Irrigation**				**Rain Tube Irrigation**			
With Fertilizer	***Year 1***	***Year 2***	***Total***	***Per Ha***	***Year 1***	***Year 2***	***Total***	***Per Ha***
PV of Total Cash Inflow (000,000)	4.13	3.04	7.17	0.90	3.52	2.01	5.54	0.69
PV of Total Cash Outflow (000,000)	0.52	0.40	0.92	0.11	0.47	0.29	0.76	0.10
NPV (000,000)	3.61	2.64	6.25	0.78	3.05	1.72	4.77	0.60
BCR	8.01	7.56	7.81	7.81	7.51	6.86	7.26	7.26
ROI (%)	708%	657%	682%	682%	659%	588%	623%	623%
Without fertilizer								
PV of Total Cash Inflow (000,000)	2.36	1.35	3.70	0.46	2.70	1.54	4.25	0.53
PV of Total Cash Outflow (000,000)	0.50	0.33	0.84	0.10	0.46	0.29	0.74	0.09
NPV (000,000)	1.85	1.01	2.86	0.36	2.24	1.26	3.50	0.44
BCR	4.67	4.02	4.41	4.41	5.90	5.39	5.70	5.70
ROI	374%	309%	340%	340%	498%	441%	469%	469%

Source: *Field Experiment, 2024*

Again, the returns on investment for drip with fertilizer was 682%, and without fertilizer was 340%. The results further revealed that the net present value for rain tube irrigation with fertilizer was GH₵0.60 million and without fertilizer was GH₵0.44 million. Similarly, the BCR for fertilizer and without rain tube irrigation was 7.26 and 5.70, respectively. The return on investment in the case of raintube irrigation was 623% for fertilizer and 469% for without fertilizer. The findings in totality showed a reduction in all three indicators (BCR, NPV, and ROI) after the increase in total cost of 17 percent. However, the finding indicates a BCR above 1, and an NPV greater than zero for both types of irrigation and fertilizer treatment. The ROI also shows a minimum value of 340% under drip without fertilizer and a maximum of 682% for drip with irrigation. This implies that despite the 17 percent increment in total cost, OFSP vine production under solar irrigation is still economically viable.

Scenario 2: ***Sensitivity analysis for a 17% increase in discount rate***

This scenario assumed an increase in the cost of capital by 17% from 29% to 33.93%. The finding revealed in the drip irrigation case, a BCR of 8.15 and, NPV of GH₵0.77 million which are greater than 1 and 0, respectively. The ROI was 708 percent, implying that even with an increase in the discount rate, OFSP vines production will still return more than 700% to the cost of investment. Compared to the drip without fertilizer, the results as in Table 4.6 show a BCR of 4.76 greater than 1, NPV of GH₵0.36 million which is greater than 0, and an ROI of 366% indicating a return to investment of over 360 percent.

This means production of OFSP vines under drip irrigation with or without fertilizer is economically viable though drip with fertilizer shows superior financial rewards for farmers.

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Table 4.6: Economic viability indicators respond to a 17% decrease in price and a 17% increase in discount rate.

Variable	Drip Irrigation				Rain Tube Irrigation			
Part A	***17% increase in discount rate***							
With Fertilizer	***Year 1***	***Year 2***	***Total***	***Per Ha***	***Year 1***	***Year 2***	***Total***	***Per Ha***
PV of Total Cash Inflow (000,000)	4.12	2.93	7.06	0.88	3.52	1.87	5.39	0.67
PV of Total Cash Outflow (000,000)	0.48	0.39	0.87	0.11	0.43	0.27	0.70	0.09
NPV (000,000)	3.65	2.54	6.19	0.77	3.09	1.60	4.69	0.59
BCR	8.60	7.59	8.15	8.15	8.21	6.99	7.74	7.74
ROI (%)	760%	659%	708%	708%	721%	599%	656%	656%
Without fertilizer								
PV of Total Cash Inflow (000,000)	2.36	1.25	3.60	0.45	2.70	1.43	4.13	0.52
PV of Total Cash Outflow (000,000)	0.47	0.29	0.76	0.09	0.42	0.26	0.68	0.08
NPV (000,000)	1.89	0.96	2.85	0.36	2.28	1.17	3.45	0.43
BCR	5.02	4.34	4.76	4.76	6.45	5.49	6.08	6.08
ROI	402%	334%	366%	366%	545%	449%	495%	495%
Part B	***17% decrease in price***							
With Fertilizer	***Year 1***	***Year 2***	***Total***	***Per Ha***	***Year 1***	***Year 2***	***Total***	***Per Ha***
PV of Total Cash Inflow (000,000)	3.43	2.52	5.95	0.74	2.93	1.67	4.60	0.57
PV of Total Cash Outflow (000,000)	0.48	0.40	0.88	0.11	0.43	0.29	0.72	0.09
NPV (000,000)	2.95	2.12	5.07	0.63	2.50	1.38	3.88	0.48
BCR	7.14	6.30	6.76	6.76	6.81	5.80	6.41	6.41
ROI (%)	614%	530%	570%	570%	581%	480%	528%	528%
Without fertilizer								
PV of Total Cash Inflow (000,000)	1.96	1.12	3.07	0.38	2.24	1.28	3.52	0.44
PV of Total Cash Outflow (000,000)	0.47	0.31	0.78	0.10	0.42	0.28	0.70	0.09
NPV (000,000)	1.49	0.81	2.29	0.29	1.82	1.00	2.82	0.35
BCR	4.16	3.60	3.94	3.94	5.35	4.56	5.04	5.04
ROI	316%	260%	287%	287%	435%	356%	394%	394%

Source: *Field Experiment, 2024*

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Also, regarding rain tube irrigation, the results indicate a BCR of 7.74 for fertilizer, an NPV of GH₵0.59 million, and an ROI of 656 percent. Furthermore, rain tubes without fertilizer revealed a BCR of 6.08, NPV of GH₵0.43 million, and ROI of 495 percent. The BCR and NPV greater than 1 and zero respectively imply OFSP vine production after a 17 percent increase in cost of capital is economically viable. Also, the ROI of more than 700 percent for fertilizer and 656 percent without fertilizer further confirms the viability of OFSP vine production under solar rain tube irrigation.

Scenario 2: *Sensitivity analysis for a 17% decrease in price*

The price of OFSP vines is another key factor that is believed to influence the economic viability of OFSP vine production. Under this scenario, as in ***Table 4.6,*** we look at a 17 percent reduction in the price of vines. The finding indicates a BCR of 6.76, ROI of 570 percent, and NPV of GH₵ 0.63 million for drip irrigation with fertilizer and a BCR of 3.94, ROI of 287 percent for drip without fertilizer. More so, the rain tube irrigation shows a BCR of 6.41, an NPV of GH₵0.48 million, and an ROI of 528 percent. The BCR and NPV in both with and without fertilizer for drip and rain tube irrigation are greater than 1 and 0, respectively. This implies that OFSP vine production under drip and rain tube irrigation is economically viable even after a reduction in output price by 17%. Again, the ROI of 570 percent and 287 percent for drip with fertilizer and without and 528 percent and 394 percent for rain tube with and without fertilizer signify a higher return on investment despite the 17 percent decrease in the price of output.

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Scenario 2: ***Sensitivity analysis for a 17% increase in total cost, a 17% decrease in price, and a 17% increase in discount rate.***

Having assessed the response of economic viability indicators to changes in price, total cost of production, and increase in discount rate separately in ***Table 4.5 & Table 4.6***, the study further looks at a change in the three variables at the same time in ***Table 4.7***.

The results revealed a BCR of 6.49, NPV of GH₵0.62 million, and ROI of 532 percent for drip with fertilizer and a BCR of 3.67, NPV of 0.27 million greater than 1 and 0 respectively, and ROI of 266 percent for drip without fertilizer. Additionally, the rain tube with fertilizer revealed a BCR of 6.03, an NPV of GH₵0.47 million, a ROI of 501 percent, a BCR of 4.74, an NPV of GH₵0.34 million, and an ROI of 373 percent. The results in totality indicate that OFSP vine production under solar drip and rain tube irrigation is economically viable irrespective of the treatment and the changes in key variables like price, discount rate (cost of capital), and cost of production. Also, the results show that drip irrigation with fertilizer shows superior economic viability for all indicators (BCR, NPV, and ROI) compared to drip irrigation without fertilizer as well as raintubes irrigation with and without fertilizer. However, the results indicate that raintube without fertilizer does better than drip without fertilizer in all indicators (BCR, NPV, and ROI) holding all else constant.

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Table 4.7: Economic viability indicators response to a 17% increase in total cost, 17% decrease in price, and 17% increase in discount rate.

Variable	Drip Irrigation				Rain Tube Irrigation			
With Fertilizer	*Year 1*	*Year 2*	*Total*	*Per Ha*	*Year 1*	*Year 2*	*Total*	*Per Ha*
PV of Total Cash Inflow (000,000)	3.43	2.43	5.86	0.73	2.93	1.55	4.47	0.56
PV of Total Cash Outflow (000,000)	0.52	0.39	0.90	0.11	0.47	0.27	0.74	0.09
NPV (000,000)	2.91	2.04	4.95	0.62	2.46	1.28	3.73	0.47
BCR	6.65	6.28	6.49	6.49	6.23	5.69	6.03	6.03
ROI (%)	572%	528%	550%	550%	532%	471%	501%	501%
Without fertilizer								
PV of Total Cash Inflow (000,000)	1.96	1.04	2.99	0.37	2.24	1.19	3.43	0.43
PV of Total Cash Outflow (000,000)	0.50	0.31	0.81	0.10	0.46	0.27	0.72	0.09
NPV (000,000)	1.45	0.73	2.18	0.27	1.79	0.92	2.71	0.34
BCR	3.88	3.34	3.67	3.67	4.90	4.48	4.74	4.74
ROI	295%	241%	266%	266%	398%	349%	373%	373%

Source: *Field Experiment, 2024*

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4.2 Survey results

4.2.2 Demographic characteristics

4.2.2.1 Farmer's age and number of children less than 5 years old

The age of a household head plays a significant role in agricultural production due to its linkage with the level of farm experience, knowledge, and attitudes towards the uptake of agricultural technologies (Mwangi & Kariuki, 2015). The results in ***Table 4.8*** shows the ages in the sample range from a minimum of 17 years to a maximum of 93 years. The age distribution implies that most farmers are at their youthful age.

Table 4.8: Farmer's age and number of children less than 5 years old.

Variable	*Mean*	*Std. Dev.*	*Min*	*Max*
Age	33.89	10.71	17	93
Children <5	2.33	2.06	0	10

Source: *Field Survey, July 2024*

Vitamin A deficiency is a significant public health problem worldwide, particularly among children under 5 years old. Vitamin A is an essential nutrient that plays a critical role in maintaining healthy vision, immune function, and skin health. The results presented in Table 4.8 show that on average, the sampled farmers have 2 children under 5 years old, with a range of 0 to 10 children. This suggests that many of these farmers have young families and are likely to be concerned about the health and well-being of their children. Thus, this may have implications on farmers WTP for OFSP vines

4.2.2.2 Sex distribution of household head

The sex of the household head significantly influences decision-making and resource allocation within the household (Kang et al., 2020). As depicted in ***Table 4.9***, 63 percent of the households surveyed were headed by females and this can be attributed to the project focus on women. Despite this, most of the farmers interviewed (60.7 percent) indicated that decisions regarding sweetpotato planting materials were made jointly by both genders. In contrast, 37.12 percent reported that men solely made these decisions, and only 2.18 percent indicated that females were the sole decision-makers. This finding contradicts previous research, which suggested that women make decisions for crops like sweetpotato, considered orphan crops, while men typically focus on more profitable or high-value enterprises (Jepkemboi et al., 2016).

Table 4.9: Sex distribution of household head

Sex of respondent	***Frequency***	***Percentage***
Female	289	63.10
Male	169	36.90
Decision making on OFSP planting materials	***Frequency***	***Percentage***
Both	278	60.70
Man	170	37.12
Woman	10	2.18
Total	458	100.00

Source: *Field Survey, July 2024*

4.2.2.3 Educational qualification distribution of household head

Education is crucial in farming, influencing crop selection, technology adoption, and the implementation of proper agronomic practices. According to the findings in ***Table 4.10***, a significant portion of the household heads (62 percent) lack formal educational qualifications. Following this, 16.16 percent of farmers hold basic education certificates (BECE) or middle school leaving certificates (MSLC), with only 2 percent possessing training, polytechnic, or university certificates. This indicates a low level of education

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among the household heads, as evidenced by an average of just 3.5 years spent in school among the sampled household heads.

Table 4.10: Educational qualification distribution of household heads

Educational status	*Frequency*	*Percentage*	*Mean*
JHS/MSLC	74	16.16	
None	284	62.01	
Primary	57	12.45	
Tech/Voc	35	7.64	
Training/Poly/University	8	1.75	
Total	**458**	**100**	**3.45**

Source: *Field Survey, July 2024*

4.2.2.4 Aware of processed products of OFSP in the market

The adoption, production, and consumption of a product starts with awareness. From the results in ***Table 4.11***, about 40 percent of the farmers in the sample were aware of processed products of OFSP in the market. Farmers who are aware of processed products of OFSP are likely to have information about their nutritional and health benefits and this may translate to the production and consumption of OFSP.

Table 4.11: Aware of processed products of OFSP in the market

Aware of processed products of OFSP in the market	*Frequency*	*Percentage*
No	274	59.83
Yes	184	40.17
Total	458	100.00

Source: *Field Survey, July 2024*

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4.2.3 Institutional Characteristics

Farmer groups or associations in farming communities often provide training and information on good agronomic practices and inputs. The results in ***Table 4.12*** indicate that 36 percent of farmers are members of such groups or associations implying a low level of farmer participation such groups and this may have implications on their farming activities and by extension WTP for improved seeds including quality OFSP vines. The results also revealed that approximately 80 percent of the farmers interviewed lack access to motorable farm roads, and over 94 percent do not have access to markets. Additionally, about 56 percent of the sampled farmers received training in vine multiplication, and 59 percent reported receiving NGO support for producing OFSP in the study area. The study also found that 40 percent of the farmers consider sweetpotato a staple, and around 60 percent were either producing OFSP or had a family member who did. A significant challenge for farmers is accessing credit to support their production, the results showed that about 52 percent of the farmers interviewed have access to credit.

Table 4.12: Institutional characteristics distribution

Variables	**Yes**		**No**	
	Freq.	Percent	Freq.	Percent
Farmer group or association membership	164	35.81	294	64.19
Motorable farm roads	93	20.31	365	79.69
Market access	26	5.68	432	94.32
Vine multiplication training	255	55.68	203	44.32
NGO support	268	58.52	190	41.48
SP as a staple	187	40.83	271	59.17

Credit access	236	51.53	222	48.47
Producer of OFSP	273	59.61	185	40.39

Source: *Field Survey, July 2024*

4.2.4 Farmers WTP for OFSP vines in northern Ghana

4.2.4.1 Check the quality (disease-free) of the sweetpotato seeds/planting materials.

To assess farmers' willingness to pay for quality OFSP vines, they were asked if they check for vine quality when making a purchase. According to the analysis presented in ***Table 4.13***, about 69 percent of the farmers (315 farmers) reported that they do check for vine quality. Among the 315 farmers who check for vine quality, 93 percent look for *signs of disease such as rot, canker, and leaf size*. Additionally, about 92 percent of farmers *inspect pest damage from aphids, whiteflies, or spider mites*, 77 percent *verify that the vines come from certified disease-free sources*, 82 percent *check leaf color*, and approximately 79 and 82 percent *examine sprouting* and the *presence of several nodes* on the vines, respectively. Overall, most farmers check for vine quality when purchasing vines for their farming needs.

Table 4.13: **C**heck on the quality (disease-free) of the sweetpotato seeds/planting materials.

VARIABLES	Yes		No	
	Freq	**%**	**Freq**	**%**
I usually check on the quality (disease-free) of the sweetpotato seeds/planting materials.	315	68.78	143	31.22
How do you check for quality vines	**Freq**	**%**	**Freq**	**%**

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I check for signs of disease like rot, canker, leaf size, etc.	294	93.33	21	6.67
I check for damage from pests, like aphids, whiteflies, or spider mites	291	92.38	24	7.62
Consider vines from certified disease-free vines from a reputable source	241	76.51	74	23.49
Check for leaf color (vines with healthy green leaves)	259	82.22	56	17.78
Check for the sprouting (e.g select vines with multiple sprouts)	248	78.73	67	21.27
I check vines with several nodes	257	81.59	58	18.41

Source: *Field Survey, July 2024*

4.2.4.2 WTP for OFSP vines and the payment modalities

WTP for OFSP vines

The study assessed farmers' willingness to pay in two parts. The first part involved an open-ended question to determine whether farmers were willing to pay for quality OFSP vines and the amount they were willing to pay. According to the analysis in ***Table 4.14***, approximately 89% of the farmers interviewed were willing to pay for quality OFSP vines. The findings also indicate that, on average, farmers were willing to pay GH₵38.93 for a bundle of 100 cuttings of OFSP vines, with the minimum and maximum amounts being GH₵2.00 and GH₵200.00, respectively. Additionally, when farmers were asked about the highest amount, they would be willing to pay for a bundle of 100 cuttings, the average amount stated was GH₵47.78, with the minimum highest amount being GH₵6.00 and the maximum GH₵200.00.

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Table 4.14: WTP for OFSP vines

Willing to pay OFSP	Yes		No	
	Freq	**%**	**Freq**	**%**
Are you willing to pay for quality seeds of OFSP?	405	88.53	53	11.57

Variable	Obs	Mean	Std. dev.	Min	Max
WTP amount	405	38.93	32.78	2	200
WTP highest amount	405	47.78	38.06	6	200

Source: *Field Survey, July 2024*

Payment Modalities

Having assess farmers' willingness to pay for quality vines, farmers were asked to choose the payment modalities that they would prefer to make payment with. From the results in ***Table 4.15***, 89% of the farmers prefer to make an advance payment covering the entire cost of the vines before planting. This indicates a strong inclination towards settling costs upfront, reflecting a desire to avoid debt or to simplify the transaction process.

About 19% of the farmers sampled favor payment on a credit basis. This suggests that farmers might prefer spreading out costs over time, which could help manage cash flow or align payments with income periods. Also, 6% of the farmers choose to pay in kind. This could involve bartering goods or services instead of monetary payment, which might be preferred farmers in communities where such practices are common or where cash liquidity

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is a challenge. However, 1% of the farmers opted for other unspecified payment modalities. This small percentage indicates a minor preference for alternative payment methods not captured by the primary categories.

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Table 4.15: Payment Modalities

Payment Modalities (If yes)	***Yes***		***No***	
	Freq	***%***	***Freq***	***%***
Advance payment of the whole cost	362	89.38	43	10.62
Credit basis to pay when the roots are harvested	75	18.52	330	81.48
In-kind payment	26	6.42	379	93.58
Others	5	1.23	400	98.77
If No: Why are you not willing to pay	***Freq***	***%***	***Freq***	***%***
No vine marketing in my area	36	69.23	16	30.77
Not quality vines available in the market	10	19.23	42	80.77
The price of vines is high	17	32.69	35	67.31
Others	14	26.92	38	73.08

Source: *Field Survey, July 2024*

Farmers who were not willing to pay for OFSP vines provided several reasons for their reluctance. The majority, *approximately 69%,* cited the *unavailability of vines in their area* as a primary factor. Another *19% mentioned the scarcity of quality vines in the market*, while *32% felt that the high price* of vines deterred them from making a purchase. Additionally, *27% of these farmers* identified *other unspecified reasons* for their unwillingness to pay for OFSP-quality vines.

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4.2.4.3 Comparing WTP for OFSP and WFSP (traditional sweetpotato)

One significant challenge in promoting the production and consumption of orange-fleshed sweetpotato (OFSP) is encouraging farmers to adopt OFSP over the traditional, white-fleshed varieties (WFSP). Our study found as in ***Table 4.16*** that approximately 75 percent of farmers were willing to pay more for OFSP compared to WFSP, indicating that about 8 out of every 10 farmers are inclined to pay more for OFSP. A deeper analysis revealed that 74 percent of these farmers were motivated by the crop's *drought tolerance*.

Table 4.16: Comparing WTP for OFSP and WFSP

WTP	***Yes***		***No***	
	Freq	***%***	***Freq***	***%***
Are you willing to pay more for the OFSP than the WFSP?	345	75.33	113	24.67
Reasons for paying more for OFSP	***Freq***	***%***	***Freq***	***%***
Better drought tolerance	249	73.67	89	26.33
Better yield	302	89.09	37	10.91
Better nutrition and health contribution	337	97.68	8	2.32
Better shelf life (storage)	215	63.80	122	36.20
Better market demand	238	70.41	100	29.59
Others (Specify)	29	8.61	308	91.39

Source: *Field Survey, July 2024*

Additionally, over 89 percent cited *better yields* as their reason, 98 percent were driven by OFSP's *nutritional and health benefits*, 64 percent valued its *superior storage qualities*, and 70 percent were influenced by *better market demand for OFSP*. A smaller percentage of farmers mentioned other reasons for their willingness to pay more for OFSP.

4.2.4.4 The bidding pattern observed across the treatment bids presented to farmers.

The second part of the willingness to pay (WTP) assessment employed a double-bounded dichotomous contingent valuation method. ***Table 4.17*** illustrates the distribution of farmers across different treatments and their bidding patterns. According to the data in the total column of ***Table 4.17***, 17 percent of the farmers were initially offered GH₵15.00, 20 percent were offered GH₵20.00, 24 percent were offered GH₵25.00, and 39 percent were offered GH₵30.00.

The highest positive responses were observed for the GH₵25.00 bid, with a 90.99 percent acceptance rate, followed by the GH₵30.00 bid, then the GH₵20.00 bid, and finally the GH₵15.00 bid, which had the lowest acceptance rate at 74.36 percent. These findings suggest that the second-highest bid amount received the most positive responses, while the lowest bid had the fewest.

Table 4.17: Bidding pattern observed across the treatment bids presented to farmers.

Initial bid/second bid	***WTP***					
Treatment	***Yes***	***Yes/Yes***	***Yes/No***	***No/Yes***	***No/No***	***Pooled***
15(16.5/14.25)	58	48	10	0	20	78
	74.36	10.48	2.18	0.00	4.37	17.03
20(22/19)	82	74	8	3	7	92
	89.13	16.16	1.75	0.66	1.53	20.09
25(27.5/23.75)	101	93	8	1	9	111
	90.99	20.31	1.75	0.22	1.97	24.24

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30(33/28.5)	159	127	32	2	16	177
	89.83	27.73	6.99	0.44	3.49	38.65
Total	400	342	58	6	52	458
	87.34	74.67	12.66	1.31	11.35	100.00

Source: *Field Survey, July 2024*

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Additionally, the proportion of positive responses tends to decrease as the bid amount increases. This observed pattern aligns with demand theory, which posits that rational individuals aim to minimize expenditure (Pierson, 2002). However, this finding contradicts previous literature, which indicates that the lowest bid amount typically attracts the highest proportion of positive responses (Khainga et al., 2018).

4.2.4.5 Explore farmers' willingness to pay across the selected district.

Table 4.18 presents the difference in willingness to pay for quality vines of OFSP across the selected districts. The independent t-test was adopted to test the difference in WTP across the districts. The results from the dichotomous double-bound contingency valuation approach revealed no significant difference between the take-it or leave-it response from farmers in the two districts. However, the test revealed that 83.41 percent of the farmers sampled in Saboba were willing to pay for the initial and follow-up bids presented to them as compared to 65.94 percent in East Mamprusi and this was significant at 1 percent. This implies that farmers in Saboba are willing to pay higher for OFSP vines as compared to their counterparts in East Mamprusi. Thus, vine multiplication in Saboba has more financial rewards than in East Mamprusi. The results further revealed that only 2.62 percent of farmers in Saboba rejected the second bid after accepting the initial bid compared to 22.71 percent in East Mamprusi who rejected the second bid after accepting the first bid and this was statistically significant at 1 percent. This implies that farmers in Saboba who accept the initial bids were less likely to reject the second bid which is a 10 percent increase from the initial bid. Ironically, it was also noted that farmers who rejected both bids were more in Saboba (13 percent) than in East Mamprusi (10 percent) though not significant across the districts.

Furthermore, the study tests the difference in WTP using the open-ended contingency valuation approach. As illustrated in ***Table 4.18***, the results also show no significant difference in WTP between the 2 districts for the yes or no response. However, the average amount that farmers were willing to pay was revealed to be 35 cedis in Saboba as against 43 cedis in East Mamprusi and the mean difference was significant at 5 percent.

Table 4.18: A t-test of farmers' willingness to pay across the selected districts.

Variable	Saboba	East Mamprusi	df	t
Bidding WTP (DBDCVM)				
Take-it or leave-it (%)	86.03	88.64	456	-0.84
Yes-Yes (%)	83.41	65.94	456	4.38***
Yes-No (%)	2.62	22.71	456	-6.77***
No-No (%)	13.10	9.61	456	1.18
No-Yes (%)	0.87	1.75	456	-0.82
Bid (Mean)	24.17	24.28	456	-0.21
Open-ended WTP				
WTP (open) (%)	89.96	86.90	456	1.02
Amount (Mean)	35.36	42.62	403	-2.24**
Highest amount (Mean)	41.97	53.80	403	-3.16***

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Payment Modalities				
Advance payment (%)	91.75	86.93	403	1.57
Credit basis (%)	23.79	13.07	403	2.80***
In-kind payment (%)	10.19	2.51	403	3.18***
Other modes (%)	0.97	1.51	403	-0.488

Source: *Field Survey, July 2024*

Also, when farmers were asked about the highest amount, they would be willing to pay for OFSP vines, the results show that the highest average amount farmers were willing to pay for quality OFSP vines was higher in East Mamprusi than in Saboba and this difference was significant at 1 percent level.

Having assessed farmers' readiness to pay for quality OFSP vines, the study further looked at the payment modalities that farmers will prefer to make payments for vines across the two districts. The results revealed no significant difference among farmers in both districts in the choice of advance payment for the whole cost as a modality. However, in the case of in-kind payment and credit basis, 24 and 10 percent of farmers in Saboba prefer credit basis and in-kind payment respectively as compared to 13 percent for credit basis and 3 percent for in-kind payment in East Mamprusi. This implies that credit and in-kind payment implementation as payment modalities for OFSP vines will be more patronized in Saboba than in East Mamprusi.

4.2.5 Factors influencing farmers' willingness to pay for OFSP vines.

To inestigate factors influencing farmers' willingness to pay for quality OFSP vines, the ordered probit, and Complementary log-log models (cloglog). As presented in ***Table 4.19***, the ordered probit model produced a Pseudo R-squared value of **0.2749**, suggesting that

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the model provides a reasonably good fit compared to a null model containing only an intercept. Additionally, the **Adjusted McFadden R-squared**, which accounts for model complexity by penalizing for the number of estimated parameters, was calculated to be **0.2102**. This slightly lower value reflects the impact of including multiple explanatory variables, some of which may contribute marginally to the overall explanatory power of the model.

It is worth noting that R-squared values in discrete choice models such as the ordered probit tend to be lower than those in linear regression models. Nevertheless, McFadden R-squared values between **0.2 and 0.4** are generally regarded as acceptable indicators of model fit. However, as Wooldridge (2010) emphasizes, less attention should be placed on R-squared in nonlinear models, where the **statistical significance** and **economic relevance** of the explanatory variables are more critical for interpretation. Therefore, while the model demonstrates a good overall fit, emphasis should be placed on the robustness and relevance of the individual coefficients in explaining variations in farmers' willingness to pay.

The ordered probit showed a Likelihood Ratio test statistics of 197.28 and a probability chi-square value of 0.000 while the cloglog produced Zero outcomes = 53 Nonzero outcomes = 405, Log-likelihood = -99.307321 and LR chi2(17) = 95.90 with Prob > chi2 = 0.0000 implying that the regressors used contributes significantly to explaining WTP in both models. Again, the cut-offs in the ordered model when significant imply the independence of the categories in other words it means the categories can distinguish themselves. From our model, apart from cut-off 1, cut-offs 2 and 3 were both significant at 5 percent. However, cut-off 3 was not statistically significant, which may be attributed to the highly skewed distribution of responses **only 5 out of 458 respondents (1.1%)** fell

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into category 3. The sparse representation in this category limits the model's ability to accurately estimate the boundary between categories 3 and 4. The coefficients of the ordered probit do not represent the magnitude of the effects of the explanatory variables; thus, the marginal effects are discussed. The marginal effects of the ordered probit are interpreted based on the sign and category. The WTP pay categories are defined as *YesYes* is Premium price, *YesNo* is Moderate price, *NoYes* is Low price and *NoNo* is Not willing to pay. An estimated positive coefficient for a category implies that an increase in that variable increases the probability of being in that category, while a negative coefficient means a decrease in the probability of being in that category. The marginal effects corresponding to the significant variable are also significant. Also, the coefficient for complementary log-log model just like binary logit or probit does not give the magnitude of change but just the direction of change. Thus, the marginal effects were estimated and discussed concurrently with the ordered probit results. Out of the seventeen explanatory variables used in the analysis, fifteen variables were statistically significant to WTP in both models.

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The sex of household heads was positive and significant at 5 percent to WTP in the cloglog model. This implies that male farmers are more likely to pay for OFSP vines than female farmers holding all other factors constant. This does not conform with prior expectations because orphan crops like sweetpotato productions are usually female dominated as males turn to focus on more profitable and valuable crops. However, the finding is logical because male farmers have upper hand in terms of resource access and control including land access and use. Thus, they are more likely to have the financial ability to afford OFSP vines. This finding is in line with Yegbemey et al. (2014); Demont et al. (2017); and Belay (2018) who reported that male-headed households had higher WTP than female households. However, the results contradicts the findings of Pearson et al. (2013) who found male respondents and male-headed households to have lower WTP compared to females. Other studies like the work of Mwiti et al. (2020); Adesina et al. (2017); and Thorne et al. (2017) also found sex has a significant effect on farmers' WTP for quality vines.

Also, the ordered probit showed that one more year in school (level of education) is associated with an increase in the probability of paying a premium price and a decrease in the probability of paying moderate and low prices as well as a farmer not willing to pay. This implies that by holding all other factors constant, if a farmer spent an additional year in school, the WTP of the farmer will also increase. A plausible explanation for this finding is that higher educational attainment of a household head could lead to their awareness of the nutritional and health benefits of OFSP. The finding resonates well with empirical studies by Ahmed et al. (2015), Emuru (2015), Mbugua (2016), and Tilahun and Tadesse (2022) on farmers' WTP for improved common bean seed, soil conservation practice, improve forage seed, community-based potato cold storage facilities, and improved teff seed respectively.

Moreover, at a 10 percent level of significance, the ordered probit revealed that farmers who have access to extension services are more likely to pay premium prices and less likely to pay moderate and low prices as well as not willing to pay. This implies that all else equal, having access to extension services increases farmers' willingness to pay premium prices for OFSP vines. This is in line with expectations because farmers who have access to extension are likely to have access to information about OFSP vines, and the productivity gains of using quality vines that are free from disease and pests. Thus, would be more

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willing to pay for quality vines of OFSP compared to their counterparts who do not have access to the extension. The result has stayed with the results of Amare et al. (2016), Belay (2018), and Negash (2021) who found extension access to be positively related to farmers' willingness to pay for improved seeds. Again, the result of this current study agrees with the findings of Shee et al. (2019) who found that access to improved extension services influenced farmers' WTP positively for agricultural technologies (hybrid maize seed and inorganic fertilizer). Likewise, Mishra et al. (2018) also opined that frequency of contact with extension agents positively and significantly contributes to farmers' WTP for an improved variety of maize seeds. The finding is also in line with Arinloye et al. (2016) who found extension contact as a positive factor in pineapple farmers' WTP for market information received by mobile phone in Benin. Similarly, earlier studies like those of Yu et al. (2014) and Fadare et al. (2014) found a positive relationship between extension access and adoption of agricultural technology.

Furtherance to the above, farm group members show a positive and significant relation with WTP for OFSP vines according to the cloglog model. This implies that farmers who are members of farmer groups are more likely to pay for OFSP vines than those who are not members. This finding is plausible because being a member of a farmer group exposes farmers to information about agricultural technologies and the possible rewards of adoption. Thus, farmers who are members may receive training or participate in nutritional programs and may have foreknowledge of OFSP hence their positive WTP. This finding corresponds to the findings of Mwiti et al. (2020); Adesina et al. (2017) who found farmer group membership as a positive function of WTP.

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Access to motorable farm roads was positively and significantly related to premium prices in the Oprobit model. This implies that farmers who have access to good farm roads are more likely to pay premium prices as compared to those who do not. This finding is logical because access to motorable roads implies that farmers can easily cart inputs to the farm during planting and output to the market during harvest which could boost their productivity and earnings from OFSP production. Thus, such farmers would be more willing to pay premium prices for quality OFSP vines. The result confirms the work of Shee et al. (2019) whose findings revealed that improved access to roads had a positive effect on farmers' WTP for hybrid maize seed although not statistically significant.

Also, access to the output market was negative to the premium price and positive to all other categories of WTP in the Oprobit. This means that having access to the market decreases the probability of a farmer being willing to pay a premium price and increases the probability of paying the lower price categories holding all other factors constant and this was significant at 10 percent. This is unexpected and contrary to the finding of Negash (2021) who found market access to be a positive function of farmers' WTP for improved teff seed. However, the finding is not implausible, farmers who have market access are likely to be more commercial farmers and would be less motivated by the gains of purchasing at a premium price, and as rational individuals, they would always want the least cost/price possible.

Additionally, farmers were grouped into cycles. Cycle one captured farmers who received training and vines from International Potato Center (CIP) produce and harvested OFSP, cycle 2 contained farmers who received training and were yet to receive vines for planting, and cycle 3 captured farmers who were selected and yet to receive both training and vines

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from CIP. The results in the ordered probit showed that farmers in cycles 2 and 3 were less likely to pay premium price for OFSP vines and more likely to pay the lower price categories compared to the based category (cycle 1) holding all other factors constant and this was significant at 5 and 1 percent levels respectively. The cloglog model also showed a negative relation between WTP and a farmer being cycle 3. However, cycle 2 was positive and non-significant. This makes scientific sense given that farmers in cycle 1 have received OFSP vines, planted and harvested, they are more likely to have a good understanding of the attributes of OFSP vines being disease resistance, high yielding, early maturing, as well as richness in Vitamin A compared to their counterparts.

Furthermore, vine multiplication training according to the cloglog was positive to WTP which means that farmers who receive training on vine multiplication were more likely to pay for OFSP vines than their counterparts who had no training. This is against priori expectations because we expected farmers who receive training would be able to produce their vines for their production and sell them to other farmers for extra income. As noted by Mishra et al. training on improved farming or production practices increases awareness and builds farmers' confidence in the adoption of innovation. However, the finding is not implausible because farmers who received training may not have the financial ability to produce vines during the dry season to meet their early planting needs. Nonetheless, these farmers have good knowledge and information on OFSP and the need to purchase quality vines to ensure disease and pest-free farms and by extension high productivity.

More so, sweetppotato as a staple crop in the study area was considered. A staple crop is grown and consumed in larger quantities, serving as a main source of energy, nutrition, or income for a population. From the analysis as presented in ***Table 4.19*** at a 5 percent level

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of significance, farmers who consider sweetpotato as a staple showed a higher probability of paying a premium price for OFSP vines and a lower probability of paying the lower price categories as compared to their counterparts who do not consider OFSP as a staple and this was true for both models. This finding is understandable because farmers or households who take sweetpotao as a staple, that is, their main source of livelihood in terms of income and nutrition, are expected to be willing to pay more for OFSP vines as planting materials.

In terms of credit, which has been a major constraint among smallholder farmers, the results of the cloglog revealed that having access to credit increases the probability of the farmer WTP for OFSP vines compared to not having access. This is expected because farmers who access credit support their production with the credit through the purchase of inputs including the OFSP vines as planting materials. This is so because the credit will supplement the household budget and reduce financial burden allowing for the allocation of funds for farm activities including the purchase of FSP vines. This finding lends support to the results of Emuru (2015) on the willingness of smallholder farmers to pay for enhanced forage seed in the case of Tigray, Ethiopia. Similarly, Tilahun and Tadesse (2022) and Negash (2021) found credit access to enhance farmers' willingness to pay for improved seeds.

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Table 4.19: Determinants of WTP using ordered probit model

Variables	WTP	Premium price N (342)	Moderate price N (58)	Low price N (6)	Not willing to pay N (52)	*WTP*	*Dy/dx*
	WTP	*Yes/Yes*	*Yes/No*	*No/Yes*	*No/No*	*WTP*	*Dy/dx*
Age of the farmer	0.01	-0.00	0.00	0.00	0.00	0.00	0.00
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Sex of the farmer	-0.25	0.05	-0.02	-0.00	-0.03	0.56**	0.07**
	(0.19)	(0.04)	(0.01)	(0.00)	(0.02)	(0.26)	(0.03)
Years of education	-0.03*	0.01*	-0.00	-0.00	-0.00	0.02	0.00
	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.00)
Extension access	-0.51*	0.10*	-0.03*	-0.00	-0.07*		
	(0.26)	(0.05)	(0.02)	(0.00)	(0.03)		
Farmer group membership	0.12	-0.03	0.01	0.00	0.02	0.45	0.07*
	(0.19)	(0.04)	(0.01)	(0.00)	(0.03)	(0.32)	(0.04)
Motorable farm road	-0.51*	0.12*	-0.03*	-0.00	-0.07*	0.29	0.07
	(0.29)	(0.06)	(0.02)	(0.00)	(0.04)	(0.41)	(0.05)
Market Access	0.61*	-0.12*	0.04*	0.01	0.08*		
	(0.35)	(0.07)	(0.02)	(0.00)	(0.04)		
Cycle 2	0.42**	-0.08**	0.03**	0.00	0.05**	0.06	0.02
	(0.19)	(0.04)	(0.01)	(0.00)	(0.03)	(0.28)	(0.03)
Cycle 3	1.63***	-0.33***	0.11***	0.01**	0.21***	-0.71*	-0.09**
	(0.34)	(0.06)	(0.02)	(0.01)	(0.04)	(0.39)	(0.05)
Vine multiplication training	0.05	-0.01	0.00	0.00	0.01	0.35	0.06*
	(0.23)	(0.05)	(0.02)	(0.00)	(0.03)	(0.29)	(0.04)
NGO support	0.38	-0.08	0.03	0.00	0.05	-0.28	-0.04
	(0.28)	(0.06)	(0.02)	(0.00)	(0.04)	(0.28)	(0.03)
SP staples	-0.53**	0.11**	-0.04**	-0.01*	-0.07**	1.81***	0.23***
	(0.24)	(0.05)	(0.02)	(0.00)	(0.03)	(0.41)	(0.04)
Credit	-0.05	0.01	-0.00	-0.00	-0.01	0.41**	0.05**
	(0.14)	(0.03)	(0.01)	(0.00)	(0.02)	(0.19)	(0.03)
Producer or related to a producer	-0.49***	0.10***	-0.03***	-0.00*	-0.06***	0.29	0.05**
	(0.16)	(0.03)	(0.01)	(0.00)	(0.02)	(0.19)	(0.02)
No. children < 5 years	0.14***	-0.03***	0.01***	0.00*	0.01**	-0.11	-0.01
	(0.05)	(0.01)	(0.00)	(0.00)	(0.01)	(0.08)	(0.01)
District	0.54***	-0.11***	0.04**	0.01**	0.07***	-1.18***	-0.13***
	(0.20)	(0.04)	(0.01)	(0.00)	(0.02)	(0.36)	(0.03)
Aware of processed products	-0.58***	0.12***	-0.04***	-0.01*	-0.07***	-0.01	0.01
	(0.20)	(0.04)	(0.01)	(0.00)	(0.03)	(0.24)	(0.03)
Constant						-1.20	
						(0.75)	
/cut1	0.41						
	(0.50)	*LR chi2(19)*			*= 197.28*		
/cut2	1.13**	*Prob > chi2*			*= 0.0000*		
	(0.52)	*Log-likelihood*			*= -260.2374*		
/cut3	1.22**	*Pseudo R2*			*= 0.2749*		
	(0.52)	Obser			458		

*Note: *** p<0.01, ** p<0.05, * p<0.1*

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Source: *Field Survey, 2024*

Being a producer or related to a producer of OFSP at a 1 percent level of significance shows an increase in the probability of a farmer paying a premium price for OFSP vines and a decrease in the likelihood of paying the lower price categories holding other factors constant. Also, the cloglog results showed that being a producer increases the probability of a farmer WTP for sweetpotato vines compared to being a non-producer. The plausibility of this finding lies in the fact that producers or farmers who are related to producers of OFSP are likely to have good knowledge of the importance of OFSP, through either production experience or information sharing from relatives and friends. Also, these farmers are likely to benefit from nutritional training programs directly or indirectly and for that matter would be most likely to pay more for OFSP vines. This result conforms with the findings of a recent study which showed that experience in sweetpotato production had been a critical factor that positively influenced WTP (Mwangi et al., 2022). Similarly, Ainembabazi and Mugisha (2014); Mastenbroek et al. (2021), and Mwiti et al. (2020) also found that the period of farming experience has been an important factor in influencing initial adoption and WTP for agricultural technologies.

Again, OFSP is being promoted as a solution to address VAD among children under 5 years of age. Training programs and supports prioritize households with this age group thus, it is expected that households with children in this age category would be more willing to pay for OFSP vines to meet the nutritional needs of these children. From our analysis, at a 1 percent level of significance, farmers with children under 5 were less likely to pay premium prices for OFSP vines and more likely to pay the lower price categories holding all other factors constant. This is contrary to expectation but explainable because having more children under 5 implies more dependence and pressure on household resources.

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Thus, farmers may not have the financial capacity to pay premium prices for OFSP vine even though it is critical to the nutritional needs of the children.

The locational difference has implications for farmers' WTP for vines. This could be cultural, and financial among other reasons. As pointed out by Mwangi et al. (2022) differences in characteristics of counties (districts) such as sweetpotato production systems, income levels of households, market and institutional arrangements for roots or vines could influence one's level of WTP for clean sweetpotato seed, suggesting that geographical context tends to impact farmers' WTP for sweetpotato vines. From the results as in ***Table 4.21*** at a 1 percent level of statistical significance, the district which is coded 1 for East Mamprusi and 0 for Saboba was negative to the premium price and positive to the lower price categories. Similarly, being in East Mamprusi District was negative to WTP in the cloglog model. This implies that being a farmer in East Mamprusi decreases the probability of paying a premium price and increases the likelihood of paying a lesser price for OFSP vines holding all other things constant. These findings imply that policies to encourage the use of sweetpotato vines should take into consideration differences in a geographical context and farmers' characteristics when designing their pricing plans as suggested by (Mwangi et al., 2022).

Awareness of processed products of OFSP in the market was significant at 1 percent and positive to premium price. This means that keeping all else constant farmers who are aware of processed products of OFSP in the market are more likely to pay premium prices for quality OFSP vines and less likely to pay lower price categories as compared to their counterparts who are not aware. This is in line with prior expectations because such farmers are likely to be more knowledgeable of OFSP, its income-generating capacity, nutrition,

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and its health benefits and therefore would be more willing to pay higher prices for OFSP vines. This result aligned with the findings of (Asrat et al., 2004) who found that farmers' awareness level of available options for agricultural technology influenced their WTP positively.

4.2.6 Comparing cost OFSP vine production and amount farmers are willing to pay for OFSP vines.

Having assessed the viability of OFSP vine production, farmers' willingness to pay, and the factors that influence their willingness to pay, we now compare the cost of producing the vines and the amount farmers are willing to pay. From the results as presented in ***Table 4.20***, the average cost of producing a bundle of 100 cuttings of OFSP vines was GH₵*1.86* for drip irrigation with fertilizer and GH₵*3.22* for drip irrigation without fertilizer. Also, under rain-tube irrigation, the results showed GH₵*1.98* and GH₵2.52 as the average cost of producing a bundle of OFSP vines for fertilizer and without fertilizer, respectively. On the other hand, the WTP results revealed that farmers were willing to pay as much as GH₵*38.93* on average for a bundle of OFSP vines with GH₵*2.00 and GH₵200.00* as the minimum and maximum WTP amounts, respectively. A t-test for WTP amount between farmers who are trained on OFSP vines and untrained farmers show an average WTP amount of 36.91 and 40.45 for trained and untrained respectively. However, the difference in WTP amount between trained and untrained farmers was not significant as shown in ***Table 4.20*** This result suggests that what farmers are willing to pay for OFSP vines far outweighs the cost of production across irrigation systems and fertilizer applications. Thus, the OFSP vine production business could be economically feasible. However, it is worth noting that costs such as marketing and distribution costs were not included in the analysis

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because sales of OFSP vines are being done at the farmgate level. At a commercial level, these costs would be incurred and thus an efficient system of marketing and distribution would need to be put in place. Also, the average WTP amount should be considered as the highest price farmers would pay for a bundle of OFSP vines (Lusk & Hudson, 2004). Furthermore, it is worth noting that decentralized vine multiplication centers supported by CIP during the study were selling a bundle of OFSP vines at GH₵*15.00* which is still far higher than the cost of producing a bundle of OFSP vines. This by extension implies that in the absence of vine multiplication support, vine multipliers could sell even below the subsidized price and still make a profit.

Table 4.20: Cost of OFSP vine production and the average amount farmers are willing to pay.

Drip irrigation	***The average cost of producing a bundle of OFSP vines (GH₵)***			
Treatment				
Fertilizer	1.86			
No	3.22			
Rain-tube irrigation	***The average cost of producing a bundle of OFSP (GH₵)***			
Fertilizer	1.98			
No	2.52			
Willing to pay OFSP amount	Mean	Std. dev.	Min	Max
How much WTP	38.93	32.78	2	200
t-test	Trained	Untrained	t-value	p-value
Means	36.91	40.45	1.075	0.2830

Source: *Field Survey, July 2024*

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The results demonstrate that quality OFSP vine production could be economically feasible and sustainable, depending on WTP among farmers. However, the commercialization of OFSP vines business will require the establishment of effective distribution systems to address challenges associated with the vines bulkiness and perishability. To leverage on these insights, stakeholders should focus on creating efficient commercialization strategies that resolve logistical issues and enhance seed delivery processes.

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CHAPTER FIVE

SUMMARY OF KEY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of key findings

Despite several attempts to combat Vitamin A deficiency through the production and consumption of orange-fleshed sweetpotato (OFSP), several bottlenecks hinder its adoption and scaling of production in northern Ghana. Lack of access and unavailability of OFSP vines at the beginning of the rainy season is a key challenge against the production and marketing of the crop. This study analyzes the economic viability of OFSP vine production using sola-based irrigation split-plot field experiment data and with the aid multistage sampling technique, cross-sectional data were obtained from 458 households in July 2024 from two selected districts in northern Ghana using semi-structured questionnaires. The willingness to pay was elicited using both single and double-bounded dichotomous contingency valuation approaches. A cost-benefit analysis was adopted for estimating the economic viability of OFSP vines production (NPV, BCR, and ROI). T-test to explore farmers' willingness to pay for OFSP vines across the selected districts. The ordered probit model and the complementary log-log models were then used to analyze factors influencing farmers' willingness to pay for OFSP vines. The key findings of emanating from the data analyses are summarized in the proceeding paragraphs.

The findings from this study demonstrate that OFSP vine production under solar-based drip and rain-tube irrigation is economically viable, with positive net returns and a favorable benefit-cost ratio. Nevertheless, drip irrigation tends to possess more beneficial economic parameters than rain-tube irrigation. Also, the sensitivity analysis still proved that OFSP vine production is economically viable under any unforeseen circumstances.

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The results also showed majority (90%) of the farmers are willing to pay an average of GH₵38.93 for a bundle of 100 cuttings of OFSP vines. However, willingness to pay varies across the selected districts, with 86% of farmers in Saboba and 89% in East Mamprusi willing to invest in OFSP vines. The results further revealed that demographic, socioeconomic, infrastructural, and institutional factors significantly impact WTP. Male farmers exhibited a higher WTP with education being a positive function of farmers WTP for OFSP vines. Also, participation in farmer group increased the likelihood of farmers' WTP. Again, having access to extension services is associated with increased probability of farmers' WTP. Similarly, credit access and motorable roads positively impact farmers' WTP. The results further showed that WTP increased with prior sweetpotato production experience, training in vine multiplication. Households with children under five years old demonstrated higher WTP. On the other hand, market access showed a mixed influence on WTP. In comparison of results on WTP with costs of OFSP vine production revealed that costs of vine production were far lower (GH₵3.22 per a bundle of 100 cuttings of OFSP vines) than the amount farmers were willing to pay.

5.2 Conclusions

The key findings from the study demonstrate that the production of OFSP vines under solar-based irrigation is economically viable and sustainable in northern Ghana. Among the irrigation methods examined, drip irrigation offers superior financial returns compared to rain-tube irrigation, underscoring its potential as a more profitable and efficient system for OFSP vine production in the region.

The study also concludes that farmers are willing to pay for quality OFSP vines and the average WTP for a bundle of quality vines (GH₵38.93) which exceeds the costs of vine production. This implies strong demand for high-quality vines and underscore the economic potential for scaling up OFSP vine production in northern Ghana. It is also concluded that locational disparity has a significant impact on farmers' WTP for quality OFSP vines.

Additionally, the study concludes that WTP for quality OFSP vines is affected by farmer-specific factors (e.g., education), institutional factors (e.g., farmer group membership, credit access, extension access)

5.3 Recommendations

Based on the conclusions, several policy recommendations can be made. First policymakers, NGOs and CIP could leverage on the economic viability of OFSP vine production to improve income and reduce poverty in northern Ghana. This could be achieved by establishing functional markets for vines and scaling up drip irrigation for OFSP vine production in northern Ghana through targeted subsidies, training programs, and technical support. Second, Investors could partner with local farmers or farmer cooperatives to establish a contract farming model for OFSP vine production. This could ensure a consistent supply of high-quality OFSP vines while also providing farmers with financial incentives and technical support. Targeted pricing models and localized awareness campaigns regarding the nutritional and economic benefits of OFSP vines should be adopted to whip up demand.

Third, government and development agencies (CIP) should strengthen farmers policies and programs to expand sensitization and logistics that can help farmers enhance their WTP. For instance, readily access to agricultural extension services from government, NGOs or private institutions could provide farmers with insights to pay for OFSP vines, since

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extension access significantly and positively impact farmers WTP for OFSP vines. Provision of tailored credit schemes to meet the financial needs of smallholder farmers through the Village savings and loans associations (VSLAs) and other credit alternatives with flexible payment modes for farmers could enhance farmers' WTP for OFSP vines, as it has significant effect on farmers WTP. CIP should encourage the formation and strengthening of farmer groups or cooperatives to improve farmers WTP, since group membership is found to have positive influence on farmers' WTP for quality vines. Government and CIP should consider introducing non formal education, trainings and capacity building programs for farmers in northern Ghana to improve their WTP since education is a positive function of farmers WTP.

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APPENDIX

Table 6.1: Economic viability of drip irrigation with fertilizer

Drip irrigation with fertilizer				
	Year 1	Year 2	Total	Per Ha
Total Output	275,220.00	261,459.00	536,679.00	67,084.88
Price Of Vines	15.00	15.00	15.00	15.00
Gross Income (1)	4,128,300.00	3,921,885.00	8,050,185.00	1,006,273.13
Fixed Cost (2)	103,560.00	98,382.00	201,942.00	25,242.75
Variable Cost	-	-	-	-
Site Clearing	1,000.00	1,000.00	1,000.00	1,000.00
Irrigation	68,000.00	68,000.00	136,000.00	17,000.00
Opportunity Cost(Maize)	53,998.00	53,998.00	107,996.00	13,499.50
Land Preparation (Beds)	1,666.00	1,666.00	3,332.00	416.50
Cost Of Vines	198,000.00	230,808.60	428,808.60	53,601.08
Cost Of Fertilizer	7,000.00	8,159.90	15,159.90	1,894.99
Cost Of Fertilizer Application	2,664.00	3,105.42	5,769.42	721.18
Cost First Weeding	4,000.00	4,662.80	8,662.80	1,082.85
Cost Of Second Weeding	4,000.00	4,662.80	8,662.80	1,082.85
Pesticides (Littres)	1,600.00	1,865.12	3,465.12	433.14
Cost Input Transportation	2,640.00	3,077.45	5,717.45	714.68
Cost Of Harvesting	16,000.00	18,651.20	34,651.20	4,331.40
Cost Of Packaging Materials	-	-	-	-
Cost Of Planting	16,000.00	18,651.20	34,651.20	4,331.40
Total Variable Costs (3)	376,568.00	418,308.49	794,876.49	99,359.56
Gross Margin (4) = (1)-(2)-(3)	3,648,172.00	3,405,194.51	7,053,366.51	881,670.81
Total cash inflow	4,128,300.00	3,921,885.00	8,050,185.00	1,006,273.13
Total cash outflow	480,128.00	516,690.49	996,818.49	124,602.31
PV of total cash inflow	4,128,300.00	3,040,220.93	7,168,520.93	896,065.12
PV of total cash outflow	480,128.00	400,535.27	880,663.27	110,082.91
NPV	3,648,172.00	2,639,685.66	6,287,857.66	785,982.21
BCR	8.60	7.59	8.14	8.14
ROI	760%	659%	708%	708%

Source: *Field Experiment, 2024*

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Table 6.2: Economic viability of drip irrigation without fertilizer

Drip without fertilizer				
	Year 1	Year 2	Total	Per Ha
Total Output	157,080.00	149,226.00	306,306.00	38,288.25
Price Of Vines	15.00	15.00	15.00	15.00
Gross Income (1)	2,356,200.00	2,238,390.00	4,594,590.00	574,323.75
Fixed Cost (2)	103,560.00	98,382.00	201,942.00	25,242.75
Variable Cost	-	-	-	-
Site Clearing	1,000.00	1,000.00	1,000.00	1,000.00
Irrigation	68,000.00	79,267.60	147,267.60	18,408.45
Opportunity Cost	53,296.20	53,296.20	106,592.40	13,324.05
Land Preparation (Beds)	1,666.00	1,666.00	3,332.00	416.50
Cost of Vines	198,000.00	230,808.60	428,808.60	53,601.08
Cost First Weeding	4,000.00	4,662.80	8,662.80	1,082.85
Cost Of Second Weeding	4,000.00	4,662.80	8,662.80	1,082.85
Pesticides (Littres)	1,600.00	1,865.12	3,465.12	433.14
Cost Input Transportation	2,640.00	3,077.45	5,717.45	714.68
Cost of Harvesting	16,000.00	18,651.20	34,651.20	4,331.40
Cost of Packaging Materials	-	-	-	-
Cost of Planting	16,000.00	18,651.20	34,651.20	4,331.40
Total Variable Costs (2)	366,202.20	417,608.97	783,811.17	97,976.40
Gross Margin (3) = (1)-(2)	1,886,437.80	1,722,399.03	3,608,836.83	451,104.60
Total cash inflow	2,356,200.00	2,238,390.00	4,594,590.00	574,323.75
Total cash outflow	469,762.20	515,990.97	985,753.17	123,219.15
Present value of total cash inflow	2,356,200.00	1,345,105.46	3,701,305.46	462,663.18
Present value of total cash outflow	469,762.20	310,072.09	779,834.29	97,479.29
NPV	1,886,437.80	1,035,033.37	2,921,471.17	365,183.90
BCR	5.02	4.34	4.75	4.75
ROI	402%	334%	366%	366%

Source: *Field Experiment, 2024*

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Table 6.3: Economic viability of Rain-tube irrigation with fertilizer

Rain tube With Fertilizer				
	Year 1	**Year 2**	Total	Per Ha
Total Output	234,960.00	223,212.00	458,172.00	57,271.50
Price Of Vines	15.00	15.00	15.00	15.00
Gross Income GH₵ (1)	3,524,400.00	3,348,180.00	6,872,580.00	859,072.50
Fixed Cost GH₵ (2)	64,260.00	61,047.00	125,307.00	15,663.38
Variable Cost GH₵	-	-	-	-
Site Clearing GH₵	1,000.00	1,000.00	2,000.00	250.00
Irrigation	68,000.00	79,267.60	147,267.60	18,408.45
Opportunity Cost(Maize)	42,601.00	42,601.00	85,202.00	10,650.25
Land Preparation (Beds)	1,666.00	1,666.00	3,332.00	416.50
Vines	198,000.00	230,808.60	428,808.60	53,601.08
Fertilizer	7,000.00	8,159.90	15,159.90	1,894.99
Fertilizer Application	2,664.00	3,105.42	5,769.42	721.18
First Weeding	4,000.00	4,662.80	8,662.80	1,082.85
Second Weeding	4,000.00	4,662.80	8,662.80	1,082.85
Pesticides (Littres)	1,600.00	1,865.12	3,465.12	433.14
Input Transportation	2,640.00	3,077.45	5,717.45	714.68
Harvesting	16,000.00	18,651.20	34,651.20	4,331.40
Packaging Materials	-	-	-	-
Planting	16,000.00	18,651.20	34,651.20	4,331.40
Total Variable Costs (2)	365,171.00	418,179.09	783,350.09	97,918.76
Gross Margin (3) = (1)-(2)	3,094,969.00	2,868,953.91	5,963,922.91	745,490.36
Total cash inflow	3,524,400.00	3,348,180.00	6,872,580.00	859,072.50
Total cash outflow	429,431.00	479,226.09	908,657.09	113,582.14
Present value of total cash inflow	3,524,400.00	2,012,006.49	5,536,406.49	692,050.81
Present value of total cash outflow	429,431.00	287,979.14	717,410.14	89,676.27
NPV	3,094,969.00	1,724,027.35	4,818,996.35	602,374.54
BCR	8.21	6.99	7.72	7.72
ROI	721%	599%	656%	656%

Source: *Field Experiment, 2024*

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Table 6.4: Economic viability of Rain-tube irrigation without fertilizer

Rain tube without fertilizer				
	Year 1	**Year 2**	Total	Per Ha
Total Output	180,180.00	171,171.00	351351	43918.875
Price Of Vines	15.00	15.00	15	15
Gross Income GH₵ (1)	2,702,700.00	2,567,565.00	5270265	658783.125
Fixed Cost (2)	64,260.00	61,047.00	125307	15663.375
Variable Cost	-	-		
Site Clearing	1,000.00	1,000.00	1,000.00	1,000.00
Irrigation	68,000.00	79,267.60	147267.6	18408.45
Opportunity Cost (Maize)	41,899.20	41,899.20	83798.4	10474.8
Land Preparation (Beds)	1,666.00	1,666.00	3332	416.5
Vines	198,000.00	230,808.60	428808.6	53601.075
First Weeding	4,000.00	4,662.80	8662.8	1082.85
Second Weeding	4,000.00	4,662.80	8662.8	1082.85
Pesticides (Littres)	1,600.00	1,865.12	3465.12	433.14
Input Transportation	2,640.00	3,077.45	5717.448	714.681
Harvesting	16,000.00	18,651.20	34651.2	4331.4
Planting	16,000.00	18,651.20	34,651.20	4,331.40
Total Variable Costs (2)	354,805.20	406,211.97	761,017.17	95,127.15
Gross Margin (3) = (1)-(2)	2,283,634.80	2,100,306.03	4,383,940.83	547,992.60
Total Cash Inflow	2,702,700.00	2,567,565.00	5,270,265.00	658,783.13
Total Cash Outflow	419,065.20	467,258.97	886,324.17	110,790.52
PV of Total Cash Inflow	2,702,700.00	1,542,915.09	4,245,615.09	530,701.89
PV of Total Cash Outflow	419,065.20	280,787.79	699,852.99	87,481.62
NPV	2,283,634.80	1,262,127.30	3,545,762.10	443,220.26
BCR (ratio)	6.45	5.49	6.07	6.07
ROI (%)	545%	449%	495%	495%

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Table 6.5 Economic viability of OFSP production under drip and raintube irrigation using real market price

variables	Drip Irrigation				Raintube Irrigation			
With fertilizer	***Year 1***	***Year 2***	***Total***	***Per Ha***	***Year 1***	***Year 2***	***Total***	***Per Ha***
Total cash inflow	4,128,300.00	3,921,885.00	8,050,185.00	1,006,273.13	3,524,400.00	3,348,180.00	6,872,580.00	859,072.50
Total cash outflow	480,128.00	529,739.78	1,009,867.78	126,233.47	429,431.00	484,195.58	913,626.58	114,203.32
PV total cash inflow	4,128,300.00	13,523,741.38	17,652,041.38	2,206,505.17	3,524,400.00	39,811,890.61	43,336,290.61	5,417,036.33
PV total cash outflow	480,128.00	1,826,688.91	2,306,816.91	288,352.11	429,431.00	5,757,379.11	6,186,810.11	773,351.26
NPV	3,648,172.00	11,697,052.47	15,345,224.47	1,918,153.06	3,094,969.00	34,054,511.50	37,149,480.50	4,643,685.06
BCR	8.60	7.40	7.65	7.65	8.21	6.91	7.00	7.00
ROI	760%	640%	697%	697%	721%	591%	652%	652%
Without fertilizer	***Year 1***	***Year 2***	***Total***	***Per Ha***	***Year 1***	***Year 2***	***Total***	***Per Ha***
Total cash inflow	2,356,200.00	2,238,390.00	4,594,590.00	574,323.75	2,702,700.00	2,567,565.00	5,270,265.00	658,783.13
Total cash outflow	469,762.20	517,729.77	987,491.97	123,436.50	419,065.20	468,997.77	888,062.97	111,007.87
PV total cash inflow	2,356,200.00	26,615,814.51	28,972,014.51	3,621,501.81	2,702,700.00	30,529,904.88	33,232,604.88	4,154,075.61
PV total cash outflow	469,762.20	6,156,120.90	6,625,883.10	828,235.39	419,065.20	5,576,667.87	5,995,733.07	749,466.63
NPV	1,886,437.80	20,459,693.60	22,346,131.40	2,793,266.43	2,283,634.80	24,953,237.00	27,236,871.80	3,404,608.98
BCR	5.02	4.32	4.37	4.37	6.45	5.47	5.54	5.54
ROI	402%	332%	365%	365%	545%	447%	493%	493%