KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI
COLLEGE OF AGRICULTURE AND NATURAL RESOURCE
DEPARTMENT OF AGRIC ECONOMICS, AGRIBUSINESS AND EXTENSION

ASSESSING THE FACTORS INFLUENCING THE ADOPTION OF BIO-PESTICIDES IN VEGETABLE PRODUCTION IN THE ASHANTI REGION OF GHANA

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Thesis Submitted to the Department of Agricultural Economics, Agribusiness and Extension, Kwame Nkrumah University of Science and Technology in partial fulfillment of the requirements for the degree of

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BY

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DECLARATION

I hereby declare that this thesis is my own work towards the Master of Philosophy (MPhil) degree in Agricultural Economics and that, to the best of my knowledge, it contains no material previously published by another person or material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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DEDICATION

This research work is dedicated to my cherished supervisors, Dr Robert Aidoo and Dr Victor Owusu who contributed immensely to the success of this thesis. This dedication will be of glaciated errors if mention is not made of my late father, Mr. Mamudu Seidu and all my siblings, for the care, support and love they have given me throughout my education.

God richly bless them.

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ABSTRACT

The massive use of inorganic agrochemicals in vegetable production in Ghana that often leads to health and environmental hazards, demands bio-intensive as an alternative strategy. This study assessed the profitability, and examined factors that affect the adoption of bio-pesticides in vegetable production. Semi-structured questionnaire was used to elicit primary information from 300 vegetable farmers in the Offinso District and Mampong Municipality in the Ashanti Region of Ghana. The study employed both descriptive and inferential tools to analyse the data. Whereas gross margin analysis was conducted to assess the profitability of bio-pesticide adoption, a logistic regression model was used to determine the factors that influence adoption of bio-pesticides in the study areas. From the study, the over reliance of vegetable farmers on chemical pesticides as the major pest management strategy can be attributed to the relatively less profitable nature of bio-pesticide adoption. The gross margin analysis indicated that the adoption of bio-pesticide as pest management strategy in tomato production was less profitable compared to the conventional method. This situation vein, non-adoption of bio-pesticide was relatively profitable in cabbage and carrot production. The proportion of vegetable farmers in the studied districts who have adopted bio-pesticides was found to be fourteen percent irrespective of the positive perception and high awareness of the practice. The key bio-pesticides used by vegetable farmers were found to be neem, neem plus pepper and cinnamon. Neem adoption relative to cinnamon was found to be positively influenced by household size, education, experience, extension visitation, membership of FBOs, the less ill effect of bio-pesticide on human health, the accessibility of bio-pesticide; but negatively influenced by age, farm size and the specificity of bio-pesticide. With the exception of education, extension visitation, the less ill effect of bio-pesticide on human health, and the specificity of bio-pesticide; the factors that influenced neem adoption also influence neem plus pepper adoption relative cinnamon. The study recommends commercialization of bio-pesticides to make them readily available in packaged forms and training of farmers in preparation of bio-pesticides. It further recommends segmentation of the Ghanaian vegetable market to allow for price premiums to compensate adopters for the relatively lower yields associated with bio-pesticide adoption.

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LIST OF ABBREVIATIONS

ABBREVIATIONS	MEANING
BMP	Best Management Practices
BPC	Biological Pest Control
CRI	Crops Research Institute
DBM	Diamond Back Moth
DDT	Dichloro-Diphenyl-Trichloroethane
EPA	Environmental Protection Agency
FBO	Farm Based Organisation
HCB	Hexachloro Cyclo Benzene
IPM	Integrated Pest Management
MLE	Maximum Likelihood Estimate
MoFA	Ministry of Food and Agriculture
NGOs	Non-Governmental Organizations
SPSS	Statistical Software Programme for Social Sciences
TYLCV	Tomato Yellow-Leaf-Curl-Virus
US EPA	United States Environmental Protection Agency
USDA	United States Department of Agriculture
WHO	World Health Organisation

CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

Several vegetables are grown in Ghana for multiphaceted purposes. The major ones are onion, okra, garden eggs, tomatoes and pepper (Nsiah-Gyabaah, 2003). For the most part, these are not eaten fresh, but are cooked in soups and stews. There is a growing market for other vegetables, which are consumed primarily by urban dwellers and non-Ghanaian population. These include cabbage, carrot, lettuce and radish. Some of these are primarily consumed fresh. Presently some 100,000 acres of vegetables are grown in Ghana (MoFA, 2010). The average vegetable farmer operates on small scale of about 0.1ha to about 0.8ha (Nsiah-Gyabaah, 2003). Low vegetable yields are compounded in the long-run by production shocks caused by environmental stresses such as drought, pests and diseases.

It is estimated that as much as 45% of the world's crop, including vegetables is destroyed by pests and diseases (Bhanti and Taneja, 2007). In Ghana, pesticides are massively used in the agricultural sector to curb crop pests (Clarke *et al.*, 1997). Organochlorine pesticides for instance are extensively used by most Ghanaian farmers due to their low cost, high efficacy and wide range suitability for plants (Osafo and Frempong, 1998). These pesticides are greatly used in most farming communities in the Western, Ashanti and Brong Ahafo regions of Ghana in vegetable production (Gerken *et al.*, 2001; Ntow *et al.*, 2006; Amoah *et al.*, 2006). Of the synthetic chemical pesticides used by vegetable farmers in Ghana to control pests and diseases (Dinham, 2003), 44% are herbicides, 33% are insecticides and 23% are fungicides (Ntow *et al.*, 2006). Most farmers have little or no idea about the dangers these chemicals pose when misused or overused. There is evidence of pesticide residues in sediments, water and biota, crops, meat and human fluids (Osafo and Frimpong, 1998; Ntow, 2001; Kalantari and Ebodi, 2006; Khalid *et al*., 2007; Darko and Acquaah, 2007). Increased accumulation of these chemicals in the food chain may pose serious health hazards to the general populace (Jayashree and Vasudevan, 2007). The hazards caused by the misuse of chemical pesticides have driven scientists, policy makers, donors, development institutions, farmers and consumers to seek alternative practices and systems that will make agriculture more sustainable. Bio-pesticides were therefore introduced in the late 1990's as part of Integrated Management practices in vegetable production in Ghana.

Bio-pesticide adoption has the potential to alleviate poverty through combating yield losses from pests and diseases in these crops, while reducing health risks from application of hazardous chemicals. "Bio-pesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals" (US EPA Pesticides, 2008). For example, garlic, mint, neem, papaya and baking soda have pesticidal applications and are considered as bio-pesticides. The most commonly used bio-pesticides are living organisms (bacteria, viruses and fungi) which are pathogenic for the pest of interest. However, just because a farm is managed by adopting bio-pesticides does not mean that it is sustainable. To be sustainable, it must produce food of high quality, be environmentally safe, protect the soil, and be profitable (Reganold et al., 1990). This study therefore seeks to investigate the profitability and the factors affecting the adoption of bio-pesticides, an alternative to chemosynthetic pesticides, in the management and control of pests and diseases in vegetable production in the Ashanti Region.

1.2. Problem Statement

High incidence of diseases and pests is a major challenge in vegetable production. Some of the biotic constraints are the yellow-leaf-curl-virus in tomato, diamondback moth in cabbage, and shoot and fruit borers in garden egg. Management of these pest and diseases call for the use of pesticide. The use of agrochemicals in vegetable production in Ghana has however reached an alarming proportion especially where a large percentage of farmers are illiterate (Gerken *et al*., 2001). Chemical pest control is so frequently used in vegetables that crops such as African eggplant, cabbage, pepper and tomato have become indicator crops of inappropriate pesticide regimes in many vegetable agro ecosystems (Ahowe *et al*., 2009). Cabbage producers apply pesticides every 3 to 4 days within a 3-month period before harvesting, in order to control caterpillars on the crop. Farmers also apply 18 applications of pesticides on pepper within 10 weeks of crop growth to control aphids, mites and whiteflies; and 12 applications of pesticides on the African garden eggplant within 10 weeks of crop growth to control mites and root-knot nematodes. A recent survey carried out by Amoah *et al.* (2006) revealed that banned chemicals are greatly used in vegetable production in most farming communities in the Ashanti Region of Ghana. Although farmers in the region have been taught, and are aware of Integrated Pest Management of which bio-pesticide is inclusive, they still massively use chemical pesticides on their vegetable farms. Some of the chemicals used are Karate, Furadan, Topsin, Dursban, and Kocide. Sometimes these chemical preparations have some tincture of banned chemicals (DDT, Lindane, Thiodan Endosulfan) among others to meet their expected results.

The health implications associated with releases of residual agro-chemicals to surface and ground water are grave. The overuse and misuse of chemical pesticides in vegetable production pose serious threats to non-target organisms, human health and the environment. Ntow (2001) worked on organochlorine pesticide residues in human breast milk of some women in Akomadan, a farming community in the Ashanti region of Ghana and recorded 40: g/kg fats of Hexachloro Cyclo Benzene (HCB) and 490: g/kg fats of p,p'-DDE.

Unlike chemosynthetic pesticides, bio-pesticides have received increased attention as one of the superior pesticides of today because they are more environmentally friendly as well as reduce health hazards (Kasperczyk and Knickel, 2006). However, as more and more attention has been put on determining whether bio-pesticide farm management system is environmentally better or not, it is not clear whether bio-pesticide farm management practice could be economically attractive enough to trigger wide spread adoption. If bio-pesticide farm management practice offered a better environmental quality and potentially healthier foods but not sufficient economic returns to the majority of farmers; it would obviously remain a luxury way of food production available to a very tiny fraction of farmers. This obviously could be so because vegetable growers prefer to adopt management practices that optimize yield, maximize returns and profits, and minimize environmental and health hazards. In Ghana the general indication is that, when bio-pesticides were introduced to farmers in the late 1990's the country did not achieve a high level of success. To date the critical factors that account for the low level of adoption of bio-pesticides is still in the realm of speculation and conjecture. The purpose of this study is to determine the profitability of vegetable production under bio-pesticides and factors that affect the adoption of environmentally friendly pesticides.

1.3. Research Questions

The main research questions addressed in the study are:

1. What pest management strategies are currently used in vegetable farming?
2. What is the awareness level of vegetable farmers in Ashanti region about bio-pesticides?
3. What is the relative profitability of bio-pesticide adoption in vegetable production?
4. What specific socio-economic, technical and institutional factors affect the adoption of bio-pesticides as pest management strategy?
5. What are the factors influencing bio-pesticide adoption by specific vegetable farmers?

1.4. Objectives of the Study

The main objective of the study is to assess the factors that influence the adoption of bio-pesticide as pest management strategy in vegetable production in the Ashanti region of Ghana. However, the specific objectives are:

1. To identify the pest management strategies of vegetable farmers in the Ashanti region.
2. To determine the awareness level of vegetable farmers in the Ashanti region about bio-pesticides.
3. To assess the relative profitability of bio-pesticide adoption in vegetable production
4. To determine the specific socioeconomic, technical and institutional factors that affect the adoption of bio-pesticide as pest management strategy.
5. To determine the factors that influencing bio-pesticide adoption by specific vegetable farmers.

1.5. Hypotheses of the Study

The following hypotheses were tested in the study:

1. Membership of FBO, frequency of extension contact and experience of the vegetable farmer positively influence the adoption of bio-pesticides positively.
2. Farm size, non-farm income and distance to source of raw materials for bio-pesticides affect adoption negatively.
3. Extension visitation and membership of FBOs positively influences tomato farmer's adoption of bio-pesticide.
4. Cost of bio-pesticide negatively influences cabbage farmer's adoption of bio-pesticide.
5. Accessibility of bio-pesticide positively influences carrot farmer's adoption of bio-pesticide.
6. Customers' demands chemical free vegetables positively influence tomato farmer's adoption of bio-pesticide.
7. There is no significant difference between the gross margins obtained by farmers adopting bio-pesticide and those practicing conventional vegetable production.

1.6. Justification of the Study

Vegetables have become a major and important part of the Ghanaian agricultural economy in terms of food, income and employment. The production of vegetables varies from cultivating a few plants in the backyards for home consumption up to a large-scale production for domestic and export markets (Obuobie *et al*., 2006). Vegetable production is essential to all stakeholders including producers, middlemen, food vendors and consumers as well as the government. It provides the first three stakeholders mentioned, employment and income. It also provides the government tax revenues on farm produce. Moreover, findings of the study could create an avenue for commercialization of bio-pesticides and hence create jobs for people desiring to enter the bio-pesticide market.

However, the identification of enterprises that lead to the highest returns (rewards) from the farmer's resources is important. When enterprises are profitable, the use of inputs returns more to the farmer than the original investment. Higher profits result in increasing incomes and thereby lead to a sustainable improvement in the livelihoods of the farmers. An enterprise that is not profitable cannot survive in market-oriented production, given the limited resources and the number of competing alternative uses. On the contrary, an enterprise that is highly profitable rewards the farmers with returns on their investments that act as incentives to spur more production. Such enterprises indicate potential for improving the welfare of farmers in the long run. The objective of the current study therefore is to inform farmers on the consequences of choosing bio-pesticide in pest management and to inform policy makers on the advantages of spending more on bio-pesticide research (system profitability).

With an estimated one in forty Ghanaians suffering each year from serious foodborne disease (Amoah *et al*., 2006), poor food safety poses an important drain on the economy. Food safety issues are already playing an important role in the Ghanaian export sector of perishable products such as fruit and vegetables. The inability to meet the standards also has a serious impact on the domestic economy with major losses caused through a reduction in work output and an increase in medical costs from food-borne diseases and through losses in the production and post-harvest food chain caused by poor agricultural health situations. It is on this premise that the

Government of Ghana (GOG) with support from World Bank and FAO, prepared a number of studies covering key aspects of the food safety system between 1998 and 2005 i.e. the original Food Safety review prepared by Boateng (2007) and a commodity survey on vegetable safety (Graffham, 2005). The current study could therefore contribute to this effort by identifying thematic areas of bio-pesticide adoption in Ghana and measures that could be put in place to enhance the level of adoption.

The empirical findings of this study could help form the pivot in the design and implementation of appropriate policies to strengthen and give deep-root to the production and consumption of chemical free and safer vegetables, and also to plan a national incentive programme for the dissemination of more environmentally friendly agricultural practices. Moreover, Ramarethinam *et al*. (2003) and many other researchers did not significantly identify or assess the influence of socio-economic, technical and institutional factors on the various forms of bio-pesticides but lumps them together. However, the current study assesses the influence of the mentioned factors on adoption of bio-pesticides. The study could also serve as a reference material for researchers in the field of bio-pesticide adoption.

Moreover, as new technologies emerge into society daily, people's lifestyles and livelihoods are directly affected. The impact this phenomenon causes in individuals' lives generates a need for understanding and adjustment to the technology. Historically, technological progress has given rise to social change. As the needs of a society change, people are required to keep abreast with new innovations in both their personal and professional lives. Ultimately, the adoption of new technology is required as many of the emergent technologies become an integral part of the society. Therefore, it is important to understand and examine factors that influence a person's adoption of new technology, as well as both the positive and negative effects that technology can have on the user.

1.7. Scope of the Study

The study collected data in the 2012 main crop season with the main objective of assessing the profitability and identifying the factors affecting the adoption of bio-pesticde in vegetable production in both the Mampong Municipality and the Offinso-North District. The main crop season was chosen relatively to the minor season since it is more favourable period for measuring farmer's abilities under normal agricultural conditions in Ghana. Geographically, the study was limited to the Mampong Municipality and the Offinso-North District, both in the Ashanti region of Ghana. It should also be emphasized that the study was limited to only tomato, carrot and cabbage farmers in the study areas. These crops were chosen because of their predominance in the study area, and the predominant reliance on them as measurable indicators of chemical pesticide usage in the studied areas.

1.8. Organisation of the Study

The study is organized into five chapters. It begins with Chapter One that discusses the background of the study, the problem statement, research questions, objectives of the study, and the hypotheses tested in the study. The existing literature related to the study has been reviewed in Chapter Two. Data issues and methodology of the study have also been discussed in Chapter Three. Data analysis and discussions of the results are presented in Chapter Four, with the summary of findings, conclusion and recommendations covered in Chapter Five.

CHAPTER TWO

LITERATURE REVIEW

This chapter provides literature review on vegetable production in Ghana by focusing on vegetable production, disease and pest of vegetables and pest management strategies or practices. The chapter further discusses adoption of new technology and the major factors influencing the adoption of new technology.

2.1. Vegetable Production in Ghana

Vegetable production is an important economic activity in the forest and savanna zones in Ghana. It is successfully increasing food security and employment, especially among women (Braima *et al.*, 2010). Until recently, vegetable production was mainly female activity. Women produced vegetables as bases for soups and stews. Braima *et al*. (2010) posits that typically the most popular vegetables grown by farmers in West Africa include chilli peppers, onions, tomatoes, garden eggs and okra. Others are cocoyam leaves found mostly in the forest zone and leafy vegetables such as cowpea and Amaranthus sp., lettuce, carrots and neri, a type of melon that is common in the savannah areas.

In the last five years, vegetable production has become important male economic activity (MoFA, 2010). This has been driven by its contribution as a source of employment, nutrition and income. Vegetables have become an irreplaceable dietary component, not only as a side dish to add flavour to soups and stews, but they also break the nutritional cycle by providing critical ingredients that build a healthy body. The high medicinal and nutritional value, high prices of vegetables, especially during the dry season and increasing demand for vegetable in the urban areas have attracted men into vegetable production.

According to Ahowe *et al.* (2009) vegetable production for urban and peri-urban areas in Ghana is popular in rainfed upland ecologies. Rainfed upland ecologies occur on hillsides, usually above floodlines and have well-drained soils which are not usually covered by standing water. The vegetation is dominated by bushes of perennial shrubs and trees, with minimal grass cover. Vegetables are usually planted early in the rainy season, either by direct seeding or transplanting of seedlings. They are frequently intercropped with other staple food crops (e.g. rice), or planted as sole crops following the harvest of any other crop. Commercial farmers use irrigation systems that allow year-round production in upland ecologies, while smallholder farmers rely on rain and soil water to water their seasonally-grown crops. The quantity produced of selected vegetables in Ghana between 2001 and 2008 is shown in Table 2.1. The production level of the selected vegetables seems to follow a constant trend between 2001 and 2003, but decreased in the year 2006. However, in the ensuing year (2008), the volume of production of tomatoes increased whereas the rest of the vegetables in Table 2.1 decreased. Irrespective of this, figures provided by UN Comtrade (2007) indicates a growing trend of vegetable exports.

Table 2.1: Quantity of Selected Vegetable Produced in Ghana from 2001 to 2008 (1,000 metric tons)

Vegetables	2001	2003	2005	2006	2008
Tomatoes	200	200	200	176	284
Okra	100	100	100	105	46.6
Garden eggs	27.6	30.9	32	37.1	38.7
Shallot	100	100	120	99.4	39.3
Chilies and Peppers, Green	270	270	329	277	134

Source: FAOSTAT, accessed March 2013

Vegetables export from Ghana has been gradually growing, capturing a sizeable portion of the ethnic vegetable niche market in the UK, as a result of its clear advantage in terms of airfreight costs compared with current East African suppliers. Despite this commercial success, productivity remains low.

2.2. Pest of Vegetables

A pest is any organism that injures or damages crops, livestock and people to cause food and income losses and diseases. The term 'pest' refers to the role of any organism to aggravate hunger, poverty and disease (Huang and Huang, 1993). The term 'pest' is, therefore, more socioeconomic than biological, as it relates mainly to the social and economic aspects of human activities. An organism is not a pest in its natural habitat (e.g. insects in wild grasses and natural vegetation), but as soon as it comes into conflict with people and peoples' interests (e.g. insects in cultivated crops), it is treated as a pest.

Probably the most important pest of vegetables is the nematode, particularly the root-knot nematode (Braima *et al.,* 2010). Okra and garden egg are particularly susceptible to damage. Soil fumigation is the fastest way to eliminate this pest, but is expensive and is not likely to be widely used in Ghana for many years (Ntow *et al*., 2006). Rotation of susceptible crops with non-susceptible crops is the most practical method of nematode control for most farmers under these conditions. Table 2.2 shows the various pest groups, specific pest and vegetables that are susceptible to these pests.

Table 2.2: Pest of Vegetables

Pest Group	Pest	Vegetables
Moths, Butterflies	Cabbage Looper	Lettuce, spinach, beets, peas, and tomatoes
	Beet Armyworm	Asparagus, lettuce, cabbage, tomatoes, peppers, onions
	Corn Earworm	Peppers, eggplant, beans, okra, lettuce, and cabbage
	Cutworm	Asparagus, cabbage, squash, and tomatoes
	Diamondback Moth	Cabbage
	Cabbageworm	Cabbage, cauliflower, radish, and turnips
Beetles	Asparagus Beetle	Asparagus
	Blister Beetle	potatoes and tomatoes
	Potato Beetle	Tomatoes, eggplant, peppers, potatoes
	Cucumber Beetles	Asparagus, cabbage, peas, beets, tomatoes, and turnips
Sap-Feeding Insects	Harlequin Bug	Asparagus, okra, and tomatoes
	Eggplant Lace Bug	Egg plant
	Squash Bug	Squash and pumpkins
	Aphids	Most vegetables
Flies	Cabbage Maggot	Cabbage, cauliflower, broccoli, turnip
	Pepper Maggot	Pepper, egg plant
	Leaf-miner	Cucumbers, squash, tomatoes, and leafy vegetables

Source: Sorensen (2010)

The pests that destroy vegetables are divided into the following groups by Sorensen (2010): Moths, Butterflies, and Their Young (Caterpillars); Beetles; Sap-Feeding Insects (True Bugs, Aphids, Leafhoppers, and Whiteflies); Flies; Other Insects; and Non-insect Pests.

Sorensen (2010) explained that the moth and butterflies pest group include pest like Cabbage Looper, Beet Armyworm, Corn Earworm, Cutworm, Diamondback Moth, Corn Borer, Fall Armyworm, Cabbageworm and many others. Caterpillars, the larval stage of moths and butterflies, damage both the foliage and fruit of a number of vegetables. These insects chew holes in foliage and fruit and leave degrading excrement and silk on plants. The Beetle group also include pest like Asparagus Beetle, Bean Leaf Beetle, Blister Beetle, Colorado Potato Beetle, Cowpea Curculio, Flea Beetle, Spotted Cucumber Beetles and many others. The adult beetles are usually hard-bodied insects with thick forewings. The young are grubs, borers, or wireworms. Often adults feed on different host plants than do larvae, although both stages may be destructive to vegetables. The Sap-Feeding Insects of vegetable include Harlequin Bug, Eggplant Lace Bug, Squash Bug, Tarnished Plant Bug, Aphids, Potato Leafhopper and many others. The Flies group of pest also includes Cabbage Maggot, Pepper Maggot, Seed-corn Maggot, Vegetable Leaf-miner, among others. However, Moths and butterflies, beetles, sap-feeding insects, and flies are not the only insects capable of damaging vegetables. Grasshoppers, mole crickets, and thrips also attack vegetables. Non-insect Vegetable Pests like Spider mites and slugs, although not insects, are capable of inflicting severe damage on vegetables. These pests are managed by vegetable farmers through the adoption of different practices and strategies.

2.3. Pest Management Practices and Strategies of Vegetable Production

In Ghana the main methods of disease and pest control in vegetable production are cultural and physical method, biological control, integrated pest management practices, and chemo-synthetic pesticides. The mentioned management practices are discussed below.

2.3.1. Cultural and Physical Control

Physical control methods such as fly screens; physical means of proofing for birds, possums and rodents or physical means of pest detection, such as trapping, can sometimes be a more effective and appropriate means of pest control in gaining long term control over a particular pest infestation (Zschekel *et al*., 1997). Cultural control methods of pest control such as improving ventilation to deter attack by termites or improving hygiene and sanitation measures to reduce the risk of pest infestation should always be undertaken, where possible, to make conditions less favourable for nuisance pests. According to Ahowe *et al.* (2008) some of the methods of cropping often adopted to achieve certain level of pest and disease management and control are intercropping, mixed cropping, and crop rotation.

2.3.1.1. Intercropping

Adade *et al*. (2001) suggested that farmers frequently intercrop vegetables on the same bed. A single bed can hold as many as five different vegetables. Intercrops can be economically more profitable than sole crop vegetables. According to Loos *et al*. (2001) intercropping increases farmers' income per unit of land and labour and helps to maintain good soil moisture and reduce the incidence of weeds and other pests on vegetables.

2.3.1.2. Crop Rotation

Crop rotation enables farmers to maintain land under continuous cultivation by planting with one crop after another in successive seasons (Bonsu, 2001). The practice also helps farmers respond to seasonal market demands for certain crops. Where a rotation crop is a non-host plant of a pest that damaged a previous crop, crop rotation helps to control that pest by breaking its life cycle (Zschekel *et al*., 1997). Good knowledge of crop susceptibility to pests is therefore essential in the use of crop rotation for pest management (Zschekel *et al*., 1997; Frost, 2001). This is particularly the case with species of root-knot nematodes which attack a wide range of vegetables including the most economically important crops grown in many localities. Frost

(2001) noted that the wide range of host plants of the root-knot nematode makes it difficult to identify suitable crop rotation schemes for this pest, especially at sites under year-round vegetable production.

2.3.1.3. Soil Fertility

Soils nourish vegetables with mineral nutrients for vigorous, succulent and healthy growth; but continuous production of vegetables can deplete soil nutrients at production sites (Zschekel *et al*., 1997; Frost, 2001). Bonsu (2009) indicated that vegetable farmers use organic and mineral fertilizers to help soils to recover from nutrient losses, and in some cases, reduce pest problems. Both organic (composed of decayed plant/animal material), and inorganic fertilizers (composed of chemicals and minerals), improve soil fertility by adding nutrients to the soil, and are used in a number of different ways.

Mulching, for example, involves mixing plant materials into the soil during land preparation, or covering the bases and rows of the crops with dry grass or plastic sheets after planting (Loos, 2001). Dry grass or plastic sheets serve as physical barriers between the soil and the environment so the plant residues rot into the soil and increase its organic matter content. Plant foliage mixed into the soil help conserve moisture, suppress weeds, and reduce the spread of plant pathogen spores onto vegetable foliage through water or soil splashes.

According to Bonsu (2009) farmers use farmyard manure or humus from compost of plant residues as organic fertilizers. They avoid scorching of the plants by first thoroughly mixing the farmyard manure with soil or water. Where soils are poor, leafy vegetables such as African garden eggplant, amaranthus, cabbage, and lettuce will require additional levels of nitrogen and potassium (provided by inorganic fertilizers). High levels of nitrogen delay the onset of flowering and thereby favour leaf production.

2.3.2. Chemo-Synthetic Pesticides

Chemical control is a common coping strategy used by farmers to protect their investment in vegetables (Amoah *et al.,* 2006). Okorley and Kwarteng (2002) in their study indicated that vegetable farmer in the Central Region of Ghana rely almost entirely on chemical pesticides, a situation similar to the pest management practices of vegetable farmers in the Ashanti region. Ntow (2001) showed massive usage of chemical pesticide in controlling pest in vegetable farms in some major towns in the Offinso North district including Akomadan. The application of pesticide has been effective in controlling pest and reducing yield lost a situation reported by vegetable farmers in the Ashanti region (Ntow, 2001), and hence their massive usage and misusage. Carrasco-Tauber (1992) stated that for every dollar spent on pesticide, the farmer can reduce crop damage by 3-5 dollars. Shumway and Chesser (1994) reveal that pesticide application has contributed to a major increase in the productivity. Works or Noorwood and Marra (2003), Brorsen and Teague (1995) support by stating that pesticide use have a positive marginal product. Furthermore, because of the effectiveness of pesticide in controlling pest, its use has continued to increase over time (Olesen *et al.*, 2003), such that some vegetable crops have in recent times become indicators of chemical pesticide usage in the Ashanti region based on found chemical residues (Ntow, 2001). Due to this increase in pesticide use, its market has become a matured one with a growth rate of about 1-2% per year (Berenbalum, 2000).

Nevertheless, the list of pesticides currently used against vegetable pests in the Ashanti region of Ghana includes products that are banned for use or are extremely toxic, according to the WHO classification of pesticides (Bhavani and Thirtle, 2005), and hence the need for strategies to arrest the situation. Chemical pest control is so frequently used in vegetables that crops such as African eggplant, cabbage, pepper and tomato have become indicator crops of inappropriate pesticide regimes in many vegetable agro-ecosystems in the Ashanti region of Ghana (Ahowe *et al.*, 2009). Bhanti and Taneja (2007) posit that cabbage producers apply pesticides every 3 to 4 days within a 3-month period before harvesting, in order to control caterpillars on the crop. Farmers also apply 18 applications of pesticides on pepper within 10 weeks of crop growth to control aphids, mites and whiteflies; and 12 applications of pesticides on the African garden eggplant within 10 weeks of crop growth to control mites and root-knot nematodes (Bhanti and Taneja, 2007). Based on this, it is imperative for policy makers and other agencies to intensify efforts in enhancing the usage of bio-pesticide in controlling pest and diseases on vegetable farms.

Despite increasing fertilizer utilization and pesticide application, yields are declining; a situation currently witnessed in the some major vegetable growing communities in the Offinso North district and the Mampong municipality due to growing diseases and pest persistence to chemical application. Furthermore, farmers attribute low vegetable yields and poor quality to declining soil fertility, insects, pest and diseases (Bhanti and Taneja, 2007). Consequently, farmers have increased fertilizer consumption for vegetable production due to limited knowledge about available alternatives. Recent research in vegetable growing communities in Ashanti Region has revealed that although farmers who use agro-chemicals are able to increase their yield, they often develop illnesses as a result. This means that farmers who have fallen sick cannot produce vegetables and any profits they make have to be used for medical treatment. Consequently, agro-chemical users are often worse off both financially and physically. The common pesticides often used by vegetable farmers in controlling pest on their farms are presented in Table 2.3 below.

Table 2.3: Types of Pesticides Applied in Vegetable Production

Pesticide type (% of total number in use)	Active Ingredient (AI)	Chemical Group	Chemical AI Hazard Category (WHO)	Registered for use on
Herbicide(44%)	Pendimethalin	Dinitroaniline	III	Tomatoes
	Oxadiazon	Oxadiazole	III	Not registered
	Paraquat dichloride	Bipyridylium	II	Various crops
	Acifluorfen	Diphenyl ether	III	Not registered
Fungicide(23%)	Mancozeb	Carbamate	III	Vegetables
	Metalaxyl-M	Acylalanine	II	Not registered
	Thiophanate-methyl	Benzimidazole	III	Various crops
Insecticide(33%)	Endosulan	Organochlorine	II	Cotton
	Dimethoate	Organophosphorus	II	Not registered
	Cypermethrin	Pyrethroid	II	Not registered
	Deltamethrin	Pyrethroid	II	Various crops

Source: Ntow *et al*. (2006)

A total of 43 pesticides are in use in vegetable farming in the Ashanti region of Ghana (Ntow *et al*., 2006). The pesticides comprise insecticides (33%), fungicides (23%) and herbicides (44%). In Table 2.3 the classification of these pesticides by the type of pests they control, active ingredient, chemical group and WHO Hazard Category is presented. The herbicides and fungicides used are mostly under WHO Hazard Category III, with a few under Hazard Category II. All the insecticides used are under Hazard Category II, which WHO classifies as moderately hazardous. This category includes organochlorines (OCs), organophosphates (OPs) and pyrethroids. To expatiate on the three major hazard categories, chemical pesticides under category III are deemed more hazardous compare to both categories II and I; whiles chemical pesticides under category II are also more hazardous compare to Category I.

The large increase in the application of chemical pesticide by vegetable farmers could be attributed to the unabated increase in the importation of pesticides into Ghana. Imports of pesticides into Ghana for agricultural purposes have been on the increase due to high demand for these chemical pesticides. Between 2001 and 2009, large volumes of pesticide, mostly banned or illegal have been imported into Ghana (Darko and Acquaah, 2007). Table 2.4 shows an increasing trend for the importation of both legal and illegal (banned) chemical pesticides into Ghana.

Table 2.4: Imports of Pesticides, 2000-09 (Metric tonnes)

Pesticides	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Insecticides	1,195	907	4,130	5,974	8,418	10,006	12,728	9,979	5,121	5,078
Herbicides	224	598	2,186	2,939	4,578	8,566	10,718	8,932	10,835	4,525
Fungicides	673	618	1,079	1,249	2,402	2,205	3,195	2,575	2,767	1,248
Rodenticides	257	384	563	159	n.a.	13	78	123	n.a.	1,187
Others	139	153	368	496	544	707	1,224	1,356	n.a	n.a
Total	**2,488**	**2,660**	**8,326**	**10,817**	**15,942**	**21,497**	**27,943**	**22,965**	**18,723**	**12,038**

Source: Darko and Akoto (2009:3)

2.3.3. Biological Control (Bio-pesticide)

Bio-pesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals (US EPA Pesticides, 2008). The US EPA has specific definitions that apply to bio-pesticides in a regulatory context. However, within the agricultural community, common use definitions of the term "bio-pesticide" can vary significantly. In addition there are related and overlapping terms that can create misunderstandings with terminology. For example, the term "bio-rational pesticide" also refers to natural organisms or plant-derived products (Krischik, 2008). In addition to being categorized by the active ingredient, bio-pesticides can be categorized by the target pest, such as insecticides to manage insect populations and fungicides to manage fungus. While the former categorization system is more relevant from a scientific and regulatory perspective, the latter is more relevant in the context of marketing, sales, and grower use of bio-pesticides. The EPA separates bio-pesticides into three major classes based on the type of active ingredient used, namely microbial, biochemical, or plant incorporated protectants.

Microbial pesticides come from naturally occurring or genetically altered bacteria, fungi, algae, viruses or protozoans. They suppress pests either by producing a toxin specific to the pest, causing disease, preventing establishment of other microorganisms through competition, or various other modes of action (Clemson HGIC, 2007). For all crop types, bacterial bio-pesticides claim about 74% of the market; fungal bio-pesticides, about 10%; viral bio-pesticides, 5%; predator bio-pesticides, 8%; and "other" bio-pesticides, 3% (Thakore, 2006). At present there are approximately 73 microbial active ingredients that have been registered by the US EPA. The registered microbial bio-pesticides include 35 bacterial products, 15 fungi, 6 non-viable (genetically engineered) microbial pesticides, 8 plant incorporated protectants, 1 protozoa, 1 yeast, and 6 viruses (Steinwand, 2008). Microbial bio-pesticides may be delivered to crops in many forms including live organisms, dead organisms, and spores. The manufacture, regulation and use of microbial bio-pesticides differ most significantly from conventional chemical pesticides. To be effectively culture the organism, either in the field or during manufacture, requires an understanding of a broad range of ecological considerations. While microbial pesticides control a diverse array of pests, each specific microbial pesticide active ingredient is relatively specific to its target pest.

Biochemical pesticides are the most closely related category to conventional chemical pesticides. Biochemical pesticides are distinguished from conventional pesticides by their non-toxic mode of action toward target organisms (usually species specific) and their natural occurrence (Steinwand, 2008). Biochemical pesticides are chemicals either extracted from natural sources or synthesized to have the same structure and function as the naturally occurring chemicals. Harowitz (1999) suggested in his study that biochemical pesticides are distinguished from conventional pesticides both by their structure and by their mode of action (mechanism by which they kill or control pests). Plant incorporated protectants are substances produced by plants from genetic material that has been added to the plant. The resultant plant is commonly known as a transgenic crop or a genetically modified organism.

In practical terms, a non-toxic mode of action typically means that there is a delay between contact with the substance and death (Mandula, 2008). Some examples of non-toxic modes of action include suffocation or starvation. Distinguishing between biochemical and conventional pesticides can be complex, and is determined by an EPA committee on a case by case basis. Biochemical pesticides typically fall into distinct biologically functional classes, including semiochemicals, plant extracts, natural plant growth regulators, and natural insect growth regulators. There are almost 122 biochemical pesticide active ingredients registered with the EPA, which include 18 floral attractants, 20 plant growth regulators, six (6) insect growth regulators, 19 repellents, and 36 pheromones (Steinwand, 2008).

Various other organisms are also used as biological controls in integrated pest management systems. Protozoa are microscopic single-celled animal-like organisms rarely used as bio-pesticides (Vasantharaj, 2008).). As of 2002 there was only one insecticidal protozoan registered with the EPA (EPA, 2002). Harowitz *et al*. (1999) indicated that the use of macroscopic predators such as live insect releases is also a common biological control strategy that can be very effective, but must be well managed to prevent ecological imbalances that can result from introducing insects into areas where they may have no natural predators. Macroscopic predators are not regulated as bio-pesticides, and are outside the scope of this study. Nematodes are microscopic worms that are typically parasitic and commonly used as insecticides (Vasantharaj, 2008).). Although the EPA does not regulate them as bio-pesticides, they are often considered part of this category of control agents.

2.3.4 Opportunities and Challenges of Bio-pesticides

According to O'Brien *et al.* (2009) the field of bio-pesticides is deep; consequently they are a source of both optimism and concern. There is a tremendous amount of work and research occurring in this field, but like other biological control methods, developing safe, effective bio-pesticide products requires holistic thinking and multi-disciplinary approaches to establishing safety, which is a challenge for the bio-pesticide industry (Ware, 1994). Turning lab discoveries into profitable business products is also daunting. This mirrors what other inventors face when implementing biological control methods in other sectors. Also, it is important to note that bio-pesticides fall along a spectrum of toxicity (Nicholson, 2007). At one end are products that are extremely narrow in focus (e.g. targeting a single species in a specific window of its life cycle). At the opposite end are bio-pesticide products that are wider in effect (pyrethroids for example, derived from chrysanthemums, affect a relatively wide range of species and can have unintended toxic collateral effects). When highly specified, bio-pesticides can be almost utterly benign in their human and environmental effects (Palli and Retnakaran, 2001). When their impact is broader, however, bio-pesticides raise some of the same human and ecosystem impact concerns that conventional pesticides do.

2.3.5 General Pros and Cons of Bio-pesticide as Against Chemical Pesticides

Generally speaking, there are distinct benefits to using bio-pesticides in comparison with conventional chemical pesticides. These advantages also bring with them their own unique disadvantages. In sum, bio-pesticides tend to be less toxic, more quickly biodegradable, and more targeted to the specific pest (US EPA Pesticides, 2008). With a narrower target range of pests, they also tend to have a more specific mode of action (Clemson HGIC, 2007). Bio-pesticides are often designed to control a pest population to a manageable level rather than completely eradicate a target pest (Lewis *et al.*, 1997). These technical differences translate into benefits to humans and ecosystems including increased food safety, worker safety, and reduced concerns for development of pest resistance to existing control tools.

There are also some general challenges with use of bio-pesticides. They tend to be more slow-acting (Clemson HGIC, 2007) and may be very specific to the life cycle of the pest. Other attributes such as persistence in the environment have both a benefit and challenge that must be balanced. For example, a bio-pesticide that degrades very quickly in the environment (benefit) may also have a short shelf life or limited field persistence (Clemson HGIC, 2007) requiring multiple applications. Having a narrow target range and very specific mode of action can be seen as both a benefit and a challenge (Clemson HGIC, 2007). While one benefit of specificity is lower impact on non-target species, one challenge is that control of the dominant pests on a given crop may require more than one product and may be more costly. Also as noted, bio-pesticides fall on a continuum of breadth of specificity: some active ingredients are highly specific to a particular organism at a particular window of opportunity; others have a broader mode of action.

Furthermore, some attributes of bio-pesticides can be seen as both benefits and disadvantages (O'Brien *et al*., 2009). For example, the specificity of many bio-pesticides minimizes the negative impact on non-target organisms because they are designed to target a specific pest. The benefits of this can be profound: by focusing on an individual pest, bio-pesticides are generally much less toxic than conventional pesticides. However, some bio-pesticide products are broader spectrum actors and consequently can have negative impacts on non-target species. These broader systemic impacts could be better understood – and anticipated – if the right questions are asked.

2.3.6 The Economics of Biological Farming

Most studies from Europe and Canada report higher gross margins for biologically produced farm products, but besides lower costs, higher prices were required to compensate for reduced yields. In several cases (Fox *et al*., 1991; FAT, 1992-97; BMELF, 1991-98) lower variable costs resulted in similar or higher gross margins. Similarly, where premiums were available and the proportion of higher-value crops such as vegetables was bigger, gross margins were higher (BMELF, 1991-98). Overall, reduced costs and/or higher market prices and premiums were given as main explanations for higher profits on biologically managed farms. Yet, in several studies, the biologically managed farms profited equally or better even without premiums (Lampkin and Padel, 1994; Lotter, Seidel and Liebhardt, 2003; Hanson *et al*., 1997; Paine, 2003; Sullivan and Sheffrin, 2003; Pimentel *et al*., 2005).

Although yields in organic systems tend to be lower, input costs are usually lower, making these systems competitive with conventional systems, sometimes even before including organic price premiums. Welsh (1999) reviewed six long-term studies in the Midwest: without premiums, in three of the studies the more diverse organic systems were as profitable as the conventional systems; with premiums, however, in all six studies the organic systems had higher net returns. Thereafter, Sullivan and Sheffrin (2003) found in south-western Minnesota that a four-phase organic rotation (corn-soybean-oatalfalfa) had equal net returns to a two-phase conventional rotation (corn-soybean) even without price premiums. Sullivan and Sheffrin (2003) also had the same findings in Iowa. Pimentel *et al*. (2005) reported that in the Rodale study in Pennsylvania, a three-phase organic legume-based system had similar net returns as the conventional corn-soybean rotation, again before organic price premiums were factored in. Nevertheless, the impact of the organic price premiums is large. In other studies, price premiums were needed to break even the conventional income (Lampkin and Padel, 1994; Lotter, Seidel and Liebhardt, 2003; Paine, 2003). As Seidel and Liebhardt (2003) showed, when organic price premiums are included along with the government payment, returns to the organic grain system increased by 85 to 110 percent, and in the forage system by 35 to 40 percent, placing both of them with higher returns than any of the Midwestern standards of no-till corn-soybean, continuous corn, or intensive alfalfa production. Thus, looking at the economic performance of several studies, a common conclusion can be drawn that premium prices and/or lower variable costs most often compensate for reduced yields and give similar or higher net returns/gross margins.

Schlüter (1985), at the University of Stuttgart-Hohenheim, Germany, analyzed farm management, labour, yields, and profitability of 16 biodynamic farms from seven production regions in the southwest German state of Baden-Württemberg. Results from the biodynamic farms were compared with annual official statistics from the Baden-Württemberg Ministry of Food, Agriculture and Environment for conventional farms in each production region. The yields of all the cereal crops on biodynamic farms for 1979/1980 and 1980/1981 were lower by 13%; the average being almost equal to conventional farm yields on the good soils and considerably lower on the poorer soils. In the study of Schlüter, the biodynamic and conventional farms had similar gross revenues. Gross revenues in German marks (DM) per ha from all crops were higher on the biodynamic farms, whereas gross revenues from animal husbandry (beef, pork, milk and eggs) were 25 to 54% lower on the biodynamic farms (Koepf, 1986). However, because the biodynamic farmers had lower costs than the conventional farmers, their profits were higher. In the two years studied, biodynamic products received an average premium of 59% (range 15 to108%) over the price of similar conventional products (Koepf, 1986).

On a research plot at an experiment station in German, yields of all vegetable crops for a six-year period averaged 16% less on biodynamic plots than on conventional plots (Reinken, 1986). However, since the prices received were higher for biodynamic than for conventional vegetables, profits were significantly higher for most biodynamic vegetables, including spinach, celery, red beet, white cabbage, and carrot. Reinken (1986) found that average yields of three varieties of apples for the six-year period were 30 to 38% lower on the biodynamic plots than on the conventional plots. Profitability for apples was not reported. Labour requirements for apple growing were an average of 27% higher on the biodynamic plots, but the biodynamic apples received a premium of 27% over the price of conventional apples. An early study by the Baden-Württemberg Ministry of Food, Agriculture and Environment in Germany (MELU, 1977), as translated and reported in Koepf (1989) and Lampkin (1990), reported results similar to those of the Schlüter and Reinken studies on yields and economic performance. The MELU study surveyed pairs of biodynamic and conventional farms from 1971 to 1974. It found that although the biodynamic farms' grain yields were from 10 to 25% lower, their variable costs were lower and their net returns were about the same to about 40% higher than their conventional counterparts. If the premium prices received by the biodynamic farmers were replaced by the conventional prices, their net returns would have been about 0 to 20% lower than those of their conventional neighbors (Lampkin, 1990).

In the Netherlands, research on alternative and conventional farming systems began in 1979 on a 72-ha experimental farm in Nagele (Vereijken, 1990). Three farming systems were set up as whole farms: a 22-ha biological farm, a 17-ha conventional farm, and a 17-ha integrated farm (minimal inputs of fertilizers and pesticides). Economic data from 1982 to 1985 (Vereijken, 1986) and from 1985 to 1987 (Vereijken, 1990) indicated that gross revenue was the highest for the biological farm because of the high premiums paid for the biological farm products. However, total production costs also were higher for the biological farm than either the conventional or the integrated farm, which resulted in the biological farm having the lowest net income. As pointed out by Lampkin (1990), a major flaw in the Nagele study is that the biodynamic unit was established as a labor-intensive mixed dairy and arable system (11-year crop rotation) in an area that is almost exclusively arable. The conventional and integrated units were set up as arable farms with the same four-year crop rotation. Labor costs for the biodynamic farm were almost three times higher than for either the conventional or integrated farm, causing most of the difference in net returns. Lampkin (1990) concludes that a less labor intensive organic system could have been developed that would have been more competitive given the conditions in the region.

In Australia, a study conducted by Penfold (1993) showed that conventional yields were highest (3.5 ton/ha) and biodynamic yields were lowest (2.3 ton/ha) in 1992, when all four treatments were in wheat. However, the biodynamic treatment had the highest total gross margin per ha for the first four years (1989-1992), followed by the conventional, organic, and integrated treatments. This included a 20% premium on organic and biodynamic wheat from the 1992 harvest. The biodynamic and conventional treatments had the highest gross margins mainly because they had three cash crops, whereas the organic and integrated treatments had only two. Furthermore, Reganold *et al*. (1993) compared the economic performance of biodynamic and conventional farms and the result indicated that on a per hectare basis the biodynamic farms were as profitable as the neighbouring conventional farms and representative conventional farms. Most of their products were sold as certified organic or biodynamic at premium prices up to 25% above the market prices of similar conventional products. Most of the biodynamic farms had less year-to-year variability in gross revenue than the conventional farms (Reganold *et al*., 1993). Economic stability is a significant characteristic of sustainable farming systems.

Considering the necessity of agricultural policy environment, the economic performance of biological management practices in most developed countries is significantly influenced by the government support, which is not the case in developing countries where government support is lacking for biological farm practices (Offermann and Nieberg, 2000). Government payments to farmers in the developed world on average contribute 16-24 percent of profits in Germany, Austria, Switzerland and Denmark (Offermann and Nieberg, 2000). The 2003 CAP reform changed substantially the policy environment for biological and conventional farms. Similarly, the resumed Doha negotiations in 2007 aiming at agriculture liberalization policies are also expected to change the relative profitability of organic farming (Sanders, 2007). Furthermore, an important aspect of the profitability of organic or biological farms is the opportunity of receiving higher farm gate prices for organically produced goods than for conventionally produced ones. Prices vary between the different marketing channels and the quantities marketed via these sales channels. Organic farm gate prices also have to take into account part of the production that may be sold at conventional prices. Data from Great Britain and Germany showed that higher prices for organic products accounted for 40-73 percent of profits for arable farms, and 10-48 percent for dairy farms (Offermann and Nieberg, 2000). The incentive effect of market situation and organic prices are generally higher than of support payments (Offermann and Nieberg, 2009). In developing countries, for instance, where policy support does not exist, organic farmers are driven by the market opportunities of the developed world. Although hardly measured in economic studies, farmers' experience and decision-making abilities are one of the most crucial determinants for profitability. Farm success is often more dependent on the management ability of farmers, especially in the area of marketing, than on site-specific conditions.

2.4. Determinants of Adoption

Some studies have classified the adoption factors into broad categories: farmer characteristics, farm structure, institutional characteristics and managerial structure (McNamara, Wetzstein and Douce, 1991) while others classify them under social, economic and physical categories (Kebede, Gunjal and Coffin 1990). Others group the factors into human capital, production, policy and natural resource characteristics (Wu and Babcock, 1998) or simply whether they are continuous or discrete (Shakya and Flinn, 1985).

2.4.1. Socio-Demographic Factors

The various socio demographic factors reviewed included age, education, farming experience, gender, and household size. Empirical findings on these variables have been reviewed in sections.

2.4.1.1. Age of Farmer

Age is factor thought to affect adoption. Age is said to be a primary latent characteristic in adoption decisions. However there is contention on the direction of the effect of age on adoption. Age was found to positively influence adoption of IPM on peanuts in Georgia (McNamara, Wetzstein, and Douce, 1991), and chemical control of rice stink bug in Texas (Harper *et al*., 1990). The effect is thought to stem from accumulated knowledge and experience of farming systems obtained from years of observation and experimenting with various technologies. In addition, since adoption pay-offs occur over a long period of time, while costs occur in the earlier phases, age (time) of the farmer can have a profound effect on technology adoption.

However, age has also been found to be either negatively correlated with adoption, or not significant in farmers' adoption decisions. In studies on adoption of land conservation practices in Niger (Baidu-Forson, 1999), rice in Guinea (Adesina and Baidu-Forson, 1995), fertilizer in Malawi (Green and Ng'ong'ola, 1993), IPM sweep nets in Texas (Harper *et al.,* 1990), Hybrid Cocoa in Ghana (Boahene, Snijders and Folmer, 1999), age was either not significant or was negatively related to adoption. Older farmers, perhaps because of investing several years in a particular practice, may not want to jeopardize it by trying out a completely new method. In addition, farmers' perception that technology development and the subsequent benefits, require a lot of time to realize, can reduce their interest in the new technology because of farmers' advanced age, and the possibility of not living long enough to enjoy it (Caswell *et al*., 2001; Khanna, 2001). Furthermore, elderly farmers often have different goals other than income maximization, in which case, they will not be expected to adopt an income-enhancing technology. As a matter of fact, it is expected that the old that do adopt a technology do so at a slow pace because of their tendency to adapt less swiftly to a new phenomenon (Tjornhom, 1995). Dimara and Skuras (2003) reported that conversion of currant production from conventional into organic systems in Greece was negatively impacted by age. According to Feder *et al.* (1985) young farmers are usually more open to try new technologies because they are less risk averse than older farmers. From the review, the researcher of the current study expects age to influence adoption of bio-pesticide negatively due to the current phenomenon of increasing youth in agriculture. The youth are more willing to adopt new technologies as long as accrued benefits are relatively better than existing technologies. Furthermore, the youth in agriculture are relatively educated and likely to live to witness the development and benefits of new technologies.

2.4.1.2. Education of Farmer

Formal education or schooling is widely considered to be the most important form of human capital (Becker, 1994). Formal schooling plays a more prominent role for farm operators to constantly update their knowledge and farming practices to stay competitive. Generally, education is thought to create a favourable mental attitude for the acceptance of new practices, especially information-intensive and management-intensive practices (Waller *et al*., 1998; and Caswell *et al*., 2001). Higher level of education is often hypothesized to increase the probability of adopting new technologies (Adesina and Forson 1995). Indeed, education is expected to increase one's ability to receive, decode, and understand information relevant to making innovative decisions. Feder *et al*. (1985) provide empirical evidence on the importance of human capital (e.g., farmer's education) on technology adoption. They argue that education enhances the ability of farmers to acquire, synthesize, and quickly respond to disequilibria, thereby increasing their likelihood of adoption of new agricultural technologies. According to Adegbola and Gardebroek (2007), educated farmers are able to better process information, allocate inputs more efficiently, and more accurately assess the profitability of new technology, compared to farmers with no education. A number of empirical studies have shown positive effect of education on the adoption of various types of technology in agriculture. For example, a study on IPM practices on potatoes identified level of education as one of the major factors that positively affected the observed level of IPM practices with Ohio potato growers (Waller *et al*., 1998). However, in adoption of IPM insect sweep nets in Texas, higher education was negatively related to adoption (Harper *et al*., 1990). Education is thought to reduce the amount of complexity perceived in a technology thereby increasing a technology's adoption. According to Ehler and Bottrell (2000), one of the hindrances to widespread adoption of IPM as an alternative method to chemical control is that it requires greater ecological understanding of the production system. For IPM, the relevance of education comes to play in a number of ways. First, effective IPM requires regular field monitoring of pests conditions to identify the critical periods for application of a pesticide or other control measures (Adipala *et al*., 1999). The researcher of the current study also supports the direct relationship between education and adoption of new technologies. Higher schooling years, all other things being equal implies greater understanding of newer technologies and their practices.

2.4.1.3. Experience of Farmers

Experience is informal education. Variables relating to experience are found in many economic models, with mixed results. Experience may positively relate to technology adoption by increasing a decision maker's ability to assess whether a new technology will be profitable (Khanna, 2001). Lin (2001) finds experience to relate positively to the adoption of hybrid rice in China. On the other hand, experience may be related to age, which has often been shown to negatively relate to adoption (Saha, Love, and Schwart (1994); Zepeda (1987); Polson and Spencer, 1991). Caffey and Kazmierczak (1994), for example, found that experience in the aquaculture industry in Louisiana does not relate to the adoption of flow-through and recirculating technology in soft-shell crab production. The researcher of this study expects experience, as human resource built capacity to positively influence bio-pesticide adoption. All other things being equal, experience increases farmer's capacity to understand and practice new technologies.

2.4.1.4. Gender Concerns

Gender issues in agricultural production and technology adoption have been investigated for a long time. Most show mixed evidence regarding the different roles men and women play in technology adoption. Gender of the household head is hypothesized to influence the decision to adopt changes. The way gender influences adoption is location-specific. A number of studies in Africa have shown that women have lesser access to critical resources (land, cash, and labour), which often undermines their ability to carry out labour-intensive agricultural innovations (De Groote and Coulibaly 1998, Quisumbing *et al*., 1995). Furthermore, Gender is said to be a disputed characteristic when it comes to adoption. Studies have generally overlooked gender as an explanatory variable of technology adoption. This may be partially due to cultural differences among countries, with some where the gender issue is more pronounced than others. An illustration is provided by a comparison between maize producers in Ghana and Brazil. While in Ghana it is usual for both women and men (from different households) to manage their own maize plantation as a major part of their livelihood strategies (Doss & Morris, 2001), in Brazil maize production is by far a commercial activity (Garcia, Mattoso, Duarte, & Cruz, 2006) carried out mainly by men. This situation may be extrapolated to other agricultural produce since the Brazilian Agricultural Census showed men responded for 87.3 percent of the Brazilian farms (IBGE, 2006). For beef farming, a similar scenario is found as some empirical studies showed men were the main decision makers in 89% of beef cattle farms in *Mato Grosso do Sul* State, Brazil (Cezar, 1999; Costa, 1998). According to Cezar (1999), women were the main decision-makers when they were single, divorced or widowed.

Shadbolt (2005, as cited in Cullen, Warner, Jonsson, & Wratten, 2008) reported that female viticulturalists in a wine producing region of New Zealand were twice as likely to use pest biological control. Doss and Morris (2001) found that gender *per se* had no significant effect on the adoption of improved maize and fertiliser in Ghana. Their findings suggested, however, that the inequality of the levels of education, access to land ownership and to extension services between genders affected adoption accordingly. In Brazil, where both male and female farmers generally have similar levels of education, this inequality may be unimportant. The Brazilian agricultural census in 2006 (IBGE, 2006) reported around 54 percent of male and female farmers had at least primary education. Among secondary and tertiary educated farmers, females represented ten percent against nine percent of males. From the reviewed literature on gender, the researcher of this study expects males to adopt bio-pesticide in vegetable farming compare females since females are generally risk averse in trying newer technologies.

2.4.1.5 Household Size

The effect of household size on the decision to adopt technologies is ambiguous. Household size as a proxy to labour availability may influence the adoption of a new technology positively as its availability reduces the labour constraints (Gbegehn and Akubuilo, 2013). There is a possibility that households with many family members may be forced to divert part of the labour force to off-farm activities in an attempt to earn income to ease the consumption pressure imposed by a large family size. The researcher of the current study expects household size to positively influence bio-pesticide adoption in vegetable production in the study area. Farming households in the Ashanti region largely depend on family labour in managing farms and bio-pesticide usage is believed to be hampered by preparation difficulty and accessibility. Therefore, increasing household size could aid in bio-pesticide preparation and accessibility that would invariably increase adoption among vegetable farmers.

2.4.2 Economic Factors

Several economic factors that influence technology adoption have been discussed in literature. The extensively reviewed works (Kebede *et al.* 1990; Just and Zilberman ,1983; Feder *et al.*, 1985; Harper *et al.* 1990; Green and Ng'ongola, 1993; Adesina and Baidu-Forson, 1995; Nkonya, Schroeder and Norman 1997; Fernandez-Cornejo, 1998; Baidu-Forson, 1999; Boahene, Snijders and Folmer, 1999; Doss and Morris, 2001; and Daku, 2002) took into consideration factors like farm size, cost of technology, income level, level of expected benefits, and off-farm hours.

2.4.2.1 Farm Size

Several studies have found a positive correlation between farm size and technology adoption.

Furthermore, the effect of farm size has been variously found to be positive (McNamara, Wetzstein, and Douce, 1991; Abara and Singh, 1993; Feder, Just and Zilberman, 1985; Fernandez- Cornejo, 1996; Kasenge, 1998), negative (Yaron, Dinar and Voet, 1992; Harper *et al.*, 1990) or even neutral to adoption (Mugisa-Mutetikka *et al.*, 2000). Farm size affects adoption costs, risk perceptions, human capital, credit constraints, labour requirements, tenure arrangements and more. With small farms, it has been argued that large fixed costs become a constraint to technology adoption (Abara and Singh, 1993) especially if the technology requires a substantial amount of initial set-up cost, so-called "lumpy technology." In relation to lumpy technology, Feder, Just and Zilberman, (1985) further noted that only larger farms will adopt these innovations. With some technologies, the speed of adoption is different for small- and large- scale farmers. In Kenya, for example, Gabre-Madhin and Haggblade (2001) found that large commercial farmers adopted new high-yielding maize varieties more rapidly than smallholders.

Farm size was significant in explaining, and positively correlated with, the adoption of organic systems of currant production in Greece (Dimara & Skuras, 2003), improved wheat in Ethiopia (Negatu & Parikh, 1999), maize in Turkey (Boz & Akbay, 2005) and rice-wheat in Pakistan (Sheikh, Rehman, and Yates, 2003). In contrast, Pereira, Vale and Mâncio's (2005) results suggested farm size was negatively related to the adoption of human resources management practices among Brazilian beef cattle farmers. The adoption of sustainable practices among Brazilian farmers in Espírito Santo State similarly decreased with the farm size (De Souza Filho *et al.*, 1999). Likewise, Kaliba, Featherstone and Norman (1997) found an inverse relationship between farm size in Tanzania and the adoption of stall-feeding management for improved dairy cattle and other related technologies (technological package). Several other studies, however, found no statistical significance between farm size and technology adoption (Gillespie, Kim, & Paudel, 2007; Matuschke, Misha, & Qaim, 2007; Ramirez & Shultz, 2000; Sall *et al.*, 2000).

For Kaliba *et al.* (1997), farm size may be a proxy of farmers' wealth and, as such, relates directly to their investment capacity to adopt new technology. This explained the higher adoption of stall-feeding management among small dairy producers in Tanzania relative to large farmers: the latter were wealthy and had access to other, more suitable technologies. Moreover, Helfand and Levine (2004) noted that farm size may have an indirect influence on adoption as large farms generally have access to rural electricity, technical assistance and markets, which, in turn, facilitate adoption. The farm size may also relate to issues of production scale, labour organisation and farmers' prevailing objectives with impact on the suitability and subsequent adoption of technologies.

Based on the reviewed literature, the researcher expects farm size to negatively affect bio-pesticide adoption in the Ashanti region. A bio-pesticide preparation is deemed difficult by most farmers and so regards it as inaccessible technology. Therefore, farmers that operate larger vegetable farms would prefer readily available methods of controlling pest and diseases like chemical pesticides to preparing bio-pesticides for large farm size.

2.4.2.2. Cost of Technology

The decision to adopt is often an investment decision and as Caswell *et al*. (2001) note, this decision presents a shift in farmers' investment options. Therefore adoption can be expected to be dependent on cost of a technology and on whether farmers possess the required resources. Technologies that are capital-intensive are only affordable by wealthier farmers (El Osta and Morehart, 1999) and hence the adoption of such technologies is limited to larger farmers who have the wealth (Khanna, 2001). In addition, changes that cost little are adopted more quickly than those requiring large expenditures; hence both extent and rate of adoption may be dependent on the cost of a technology. Economic theory suggests that a reduction in price of a good or service can result in more of it being demanded.

Farmers, including vegetable farmers often prefer relatively less costly technologies that could yield the highest possible gross margin. Therefore, the perception of farmers about bio-pesticide been difficult in preparation could add to private cost and hence increase the perceived cost of preparing bio-pesticide relative to chemical pesticides. Based on this, the current study expects the cost of bio-pesticide to negatively influence its adoption in vegetable production in the Ashanti region of Ghana.

2.4.2.3. Income Level

Farmers' wealth has been often associated with technology adoption because wealthy farmers, in Doss and Morris' opinion (2001, p. 35), can better bear risks which facilitates the adoption of new technologies. The work by Gillespie *et al.* (2007) also illustrates that the farmers' income level increased the likelihood of adoption of several best management practices. Ward *et al.* (2008) also found a positive and significant association between income from beef farming, and adoption. Based on the reviewed past studies on technology adoption, the income level of vegetable farmers is expected by the current study to positively influence bio-pesticide adoption. Farmers with relatively higher income levels can employ the services of experts to prepare and apply bio-pesticides even on larger vegetable farms.

2.4.3. Institutional Factors

The various institutional factors that affect the adoption of technologies by farmers are discussed below. The factors discussed include membership of cooperatives, extension contacts and environmental regulations.

2.4.3.1. Membership to Cooperatives

This variable is expected to have positive coefficient with adoption (Gbegehn and Akubuilo, 2013). This is because farmers who are members of cooperatives pull resources together for their individual benefits which give them the opportunity to adopt more technologies than others who are not members. Also, members of cooperatives get more information about improved agricultural management practices from their association than non-members of cooperatives. Moreover, it links the individual to the larger society and exposes him to a variety of ideas. Members of cooperative societies are in a privileged position with respect to other farmers, in terms of their access to information on improved agricultural technologies. Being a member of a cooperative society is hypothesized to be positively associated with the adoption of improved agricultural technologies. From the reviewed past studies, the study expects vegetable farmers that are members of Farm-Based Organisations (FBOs) to relatively understand the benefits and practices of bio-pesticide adoption through discussions and receiving experts' advice through organized seminars and forums.

2.4.3.2. Extension Contacts

Good extension programs and contacts with producers are a key aspect in technology dissemination and adoption. A report by IFPRI (1998) stated that a new technology is only as good as the mechanism of its dissemination to farmers. Most studies analyzing this variable in the context of agricultural technology show its strong positive influence on adoption. In fact Yaron, Dinar and Voet, (1992) show that its influence can counter balance the negative effect of lack of years of formal education in the overall decision to adopt some technologies. Agricultural extension enhances the efficiency of making adoption decisions. Of the many sources of information available to farmers, agricultural extension is the most important for analyzing the adoption decision. Based on the innovation-diffusion literature (Adesina and Forson 1995), it is hypothesized that access to extension services is positively related to adoption of new technologies by exposing farmers to new information and technical skills.

Pattanayak *et al*. (2003) argue that access to extension services provided by the government, NGOs, and other stakeholders play a very important role in the adoption of new agricultural technologies. Farmers who are exposed to information about new technologies by extension agents (through training, group discussion, plots demonstration, and other form of information delivery) tend to adopt new technologies. An empirical study by Boughton *et al*. (2007) suggests that in Mali, the farm-level adoption rates for improved maize varieties could be significantly increased by an extension program that tailors varietal promotion to individual farmers' needs and circumstances.

If adoption spreads like a disease, through contact, the more contact one has with the outside, the more information one will have and the more likely it is that one will adopt. Hooks, Napier, and Carter (1983) find contact with an extension agent to be significantly related to the adoption of high and intermediate technologies. Harper *et al*. (1990) find attendance at field days to be related to the adoption of insect sweep nets in conjunction with treatment thresholds among Texas rice farmers. Polson and Spencer (1991) find the level of extension services to be positively related to the adoption of improved cassava in Nigeria. Zepeda (1990) finds industry involvement (membership in three or more industry organizations) to be positively related to the adoption of bST among California dairy farmers. Caffey and Kazmierczak (1994) do not find university extension services to relate to improved aquaculture practices in Louisiana. They hypothesize this lack of relationship is because there has been no contact for a long time. Caffey and Kazmierczak (1994) further speculate that if contact is reestablished, it may relate to quicker adoption. Feder and Slade (1984) examine information acquisition and its role in the adoption decision. So sure are they that increased extension activities speed adoption that they build this into their model as an assumption.

On the industry side, Gibbs and Edwards (1985) find that ties with the outside technical community relate positively to the adoption of technology in Britain. On the other hand, a number of studies find no statistical relationship between outside links and adoption. For example, Abd-Ella, Hoiberg, and Warren (1981) find the scale of extension contact to be insignificant in the adoption of recommended farm practices in Iowa. Kaliba *et al.* (1997) found extension contact to be insignificant in the adoption of inorganic fertilizer for maize production in western Tanzania, while Neill and Lee (2001) find extension to be insignificant in the adoption of cover crops in Honduras. A few other studies find outside links to be negatively related to adoption. Sheilkh, Rehman, and Yates (2003), for example, find the number of visits to an extension agent to be negatively related to the adoption of no-tillage practices in Pakistan. Dimara and Skuras (2003) find the number of contacts with organizations in one year to be negatively related to the adoption of new tobacco varieties in Greece.

From the reviewed literature, it is expected that extension visitation from officers would positively influence bio-pesticide adoption among vegetable farmers in the Ashanti region. Extension officers can promulgate the adoption of bio-pesticide among vegetable farmers by teaching them the pros and cons of bio-pesticide adoption and its essentiality to human and national development.

2.4.3.3. Environmental Regulations

Environmental regulations are environmental laws imposed by state and federal governments on agricultural industries (Isik, 2004). States can choose to set their regulations higher than the federal standard or keep it status quo with federal guidelines (Isik, 2004; Kraft and Vig, 1994; Lester, 1994). Several studies have examined the degree of environmental stringency on various agricultural production practices (Kara *et al*., 2006; Metcalfe, 2000; Mo and Abdalla, 1998). Kara *et al*. (2006) examined the adoption of environmental quality protection management practices such as erosion plans, grassed waterways, filter strips, and nutrient testing among corn growers operating in states with strict regulations and found an increase in adoption of best management and conservation practices. Therefore, growers operating in environmentally stringent states may be influenced to adopt best management practices, including sustainable practices. The current study expects environmental regulations in Ghana banning and limiting the use of certain chemical pesticides in farming to positively influence the adoption of bio-pesticides among vegetables farmers in the Ashanti region of Ghana.

2.4.4. Farmers' Perception of Characteristics of Technologies

Perceptions of the characteristics of new agricultural technology are also important factors that are associated with farmers' demand for new agricultural technologies (Adesina and Forson, 1995). Farmers may subjectively evaluate the technical and cultural aspects of technologies differently. Thus, understanding farmers' perceptions is important in designing and promoting agricultural technologies (Uaiene *et al*., 2009). In general, farmers' perceptions of the characteristics of new agricultural technologies are divided into three main categories: yield performance, cost requirements, and risks.

Feder *et al.* (1985) argue that yield performance (or expected yield of new varieties) is one of the characteristics of improved varieties that affect farmers' technological adoption behaviours. Several empirical studies show that the adoption rate of improved varieties is high, if the varieties meet farmers' expectations. An improved variety will be adopted at exceptionally high rates, if the new variety is technically and economically superior to local varieties. Improved varieties are technically superior if they produce higher yield relative to traditional varieties. For example, Adesina and Forson (1995) report that farmers in Burkina Faso adopted a modern sorghum variety because it gave high yield, compared to the traditional sorghum variety that farmers planted in previous agricultural years.

Neill and Lee (2001) argue that farmers' adoption of new agricultural technologies is also affected by farmers' perception of the amount of initial capital investment and labour requirements they will have to allocate if they adopt the underlying technology. Martel *et al.* (2000), who conducted a case study of the marketing of dry beans in Honduras, argue that farmers adopt new agricultural technologies because they perceive that a new technology could reduce labour requirements and other associated costs, and reduce losses due to risk (i.e., crop diseases) during production and/or post harvesting. Furthermore, they argue that bean farmers always compare the new bean variety to their current variety. Farmers are more likely to adopt a new bean variety if it performs well under different environmental conditions, shows economic profitability, and is resistant to disease and insects.

Adegbola and Gardebroek (2007), who analyzed the effect of information sources on technology adoption and modification in Benin, report that in addition to considering yields, direct costs, and profits associated with improved maize seeds, farmers also consider seed characteristics that reduce risks, because damages from insects and/or disease during maize production and storage can result in substantial yield losses and poor grain quality. In some circumstances, these losses not only increase the risk of food insecurity for the farmers' households, but may also decrease farmers' income -- if the losses in quantity are not sufficiently compensated for by a price increased due to deficit in national supply. With respect to risks, several other studies report that farmers also consider environmental aspects, such as whether or not the improved varieties were developed for local climate and soil fertility conditions (Ramirez, 2003), or for variations in local agro-ecological patterns (Doss, 2003). Based on the reviewed studies, the researcher expects positive perception of vegetable farmers about bio-pesticide characteristics to positively influence bio-pesticide adoption in the Ashanti region of Ghana.

2.4.5. Government Policies and Market Conditions

In this section, the focus turns to external factors (i.e., those where farmers have little, if any, control) affecting technology adoption, such as market conditions and government policies, including agricultural and credit policies, among others. These external factors provide the general investment environment for farming decisions, including adoption.

Government policies play a role in farming systems by developing farming regulations, supportive policies (e.g., subsidies) and providing the macro-economic environment, all of which affect farmers' decision-making. Whether policies are perceived by farmers as positive or negative depends on the focus of the policy. The compulsory characteristic of regulations sets boundaries to farming systems, and thus limits farmers' decision-making. The uptake of voluntary agricultural policies, in contrast, depends on farmers' perceptions of the advantages and disadvantages of joining the scheme (Defrancesco *et al.*, 2008).

Agri-environmental policies illustrate this case; these are governmental policies that promote, often through financial incentives, the conservation or sustainable use of natural resources (Edwards-Jones, 2006, p. 785). Defrancesco *et al*. (2008) identified that non-participating farms in agri-environmental schemes in Italy were labour intensive, highly reliant on income from farming, had high investments and a market orientation. In contrast, participating farmers had a positive attitude towards environmental protection. This attitude was particularly influenced by the opinions of society, in general, or neighbours, in particular (social influence). A study with Canadian farmers found that successful outcomes occurred because by joining environmental schemes these farmers could: publicise farm stewardship practices, improve relationships with non-farming neighbours and comply with government environmental regulations (Atari, Yiridoe, Smale, & Duinker, 2009).

The above results suggest the incompatibilities of the policies with farmers' values or farming conditions, as well as uncertainties around the impact of such policies to the household income, were important factors limiting the uptake. In contrast, the farmers' personal motivations and values, coupled with the role of their web of influencers' seem to be factors contributing to the uptake of voluntary policies. These factors must be accounted for to improve the efficiency of policy design and implementation.

Agricultural credit, which is another governmental policy, seems to impact on farmers' adoption decisions although to various degrees. Nyaribo and Young (1992) ran an *ex-ante* analysis of the impact of a credit programme on adoption of a dual-purpose goat in Kenya. They found the effect of credit, even in a highly subsidised scenario was low for small farmers given their main constraint was land, and not capital. However, medium and larger farmers strongly benefited. According to Sjah (2005, pp. 31-32), drawing on several authors, agricultural credit programmes allowed an overall increase in technology adoption and agricultural production in countries such as Taiwan, India and Botswana. Sjah (2005) reports that credit programmes can also aim primarily at farmers' income as happened in Bangladesh, Bolivia, India, Indonesia, Kenya, Malawi, and Sri Lanka. In this case, it has little effect on technology adoption.

Other government policies that influence technology adoption, discussed in Lee (2005), include: exchange rate policies (affects relative prices of exports and imports); domestic agricultural policies, including subsidies (both within a country and abroad); labour market policies; investment in public rural education and infra-structure, such as transportation, electricity, communication and access to markets; rights to land and water; and, investment in research and extension. The influence of these policies on adoption, however, occurs at a macro level, i.e., setting the overall environment for the farming businesses. Consequently, the impact of these policies on the adoption of particular technologies may be difficult, and somewhat, arbitrary.

Finally, market conditions are also an external factor farmers have to deal with in making decisions. Input and output prices, consumers' demands, processing sector requirements, infra-structure available for production flow, competitors' within and outside a countries are some examples of market aspects that farmers face (Guerin & Guerin, 1994). The extent to which these factors affect technology adoption at an individual level depends on farmers' objectives, socio-economic conditions, psychological traits, and overall perceptions and expectations regarding market conditions.

Based on the reviewed past studies, the researcher expects government policies such as banning or limiting chemical pesticide importation, provision of subvention for bio-pesticide application to compensate for crop yield loss, provision of niche markets for organically produced farm produce, and many others to positively influence bio-pesticide adoption in the Ashanti region of Ghana.

CHAPTER THREE

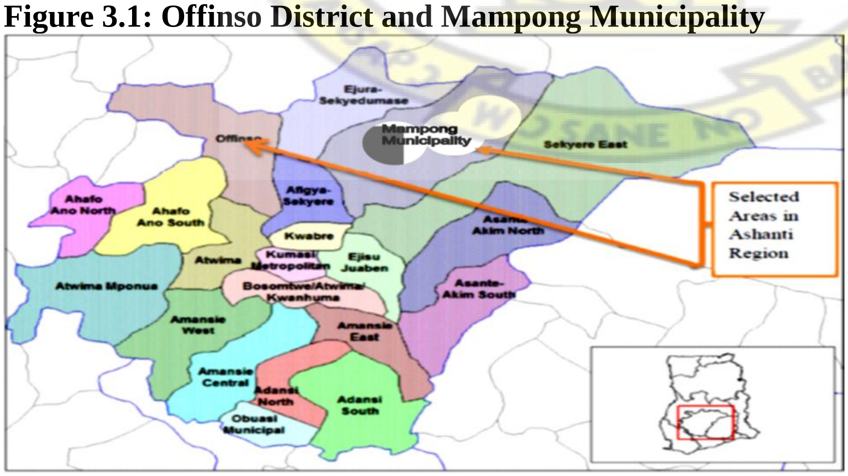
METHODOLOGY OF THE STUDY

This chapter describes in detail the study area and the methodology adopted for the study. The chapter elaborates on the population of the study, the sample size and sampling procedure, the data type and source of data, the data collection instruments, and the method of data analysis. The chapter further provides a detail account of the model or the empirical framework adopted for the study.

3.1. Study Area

The study was conducted in the Offinso North District and the Mampong Municipality in the Ashanti Region of Ghana. The selected areas are shown graphically in the map of Ashanti Region in Figure 3.1 below. These areas were chosen because of their predominance in vegetable production in the Ashanti Region. These areas are also noted for intensive use or misuse of chemical pesticides in vegetable production and form part of the areas in the Ashanti region that were introduced to bio-pesticide adoption in the late 1990s.

Figure 3.1: Offinso District and Mampong Municipality



Source: Town and Country Planning Department, Kumasi (2011)

Offinso North District is one of the 27 Administrative Districts of Ashanti Region created in the later part of 2007; it is located in the extreme North-Western part of the Region. The District lies within longitude 1˚45w and 1˚65w. It covers an area of about 6300 square kilometers which is about 2.6% of Ashanti Regions total surface area. The district is also made up of over 100 settlements. Almost all the major sized settlements are located along the Kumasi-Techiman road. The estimated current population is about 55,000 with a growth rate of 3.1%. Natural increase and migration are the main cause of the high population growth rate. The average household size is six (6). The Agricultural sector is the mainstay of the districts, economy in terms of employment, income and production. Farming is the predominant occupation of the people in the district. The sector engages over 70% of the economically active labour force. However about 60% of all engage outside the Agricultural sector still practice agriculture as a subsidiary activity. The current total farming population is around 30,000 comprising 15,030 male and 14,970 females (MOFA Offinso-North MIS Office, 2010).

Agriculture is predominantly on a small-medium holder basis in the district, although there are some relatively large farms for particularly maize, yam, tomatoes and tree crops. The main system of farming is the traditional system where hoes and cutlasses are the main tools. The major constraints or challenges of farming in the district includes increasing cost of farm inputs, high post-harvest losses especially in maize and tomatoes , pests and diseases on both crops and animals, Misuse of agro-chemicals particularly herbicides and pesticides on vegetables, among others.

Agriculture productivity in the district is however relatively good. Among the major crops grown in the district, vegetables including tomatoes, Okro, Onion/shallot have a total cropped areas of 20,049 (Ha), 112(Ha) and 40 (Ha) respectively (MOFA Offinso-North MIS Office, 2010). Offinso North District is one of the leading tomato producing districts in the Ashanti Region. It is grown all over the district with heavy concentration at Akomadan, Afrancho, Nkenkaasu, Asuoso, and lately Nsenua and Mantukwa areas.

Mampong Municipality is located North-East of Kumasi, the Ashanti Regional capital. It is bounded to the north by Atebubu District in the Brong Ahafo Region, east by Sekyere Central, south by Sekyere South and Ejura-Sekyedumasi to the West. The Municipality covers a total land area of 782km^2 with 69 settlements, 58% being rural. Mampong is the capital. The municipal is located within longitudes 0.05 degrees and 1.30 degrees west and latitudes 6.55 degrees and 7.30 degrees north, covering a total land area of 2346km^2. It has about 220 settlements with about 70 percent being rural. The rural areas are mostly found in the Afram Plains portion of the District where Communities with less than fifty (50) people are scattered here and there. The total population of the Municipal is projected at 75, 367 (2000 population census) with Growth rate projected at 1.4%.

The Municipality is part of the savannah transitional zone of Ghana, with the vegetation being savannah woodland, with patches of tall elephant grass to the north and mixed patches of dry forest and grassland to the South. 80% of land area is used for small-scale farming. Among the major crops grown in the area are Maize, Cassava, Plantain, Cocoyam, Yam and vegetables (tomatoes, garden eggs, Okra, carrot, cabbage, pepper and others) (*www.ghanadistricts.com*)

3.2 Data Type

Both primary and secondary data were used for this study. Primary data were collected from a survey of 300 vegetable farmers (100 tomato, 100 cabbage and 100 carrot farmers) from six communities in the Mampong municipality and six communities from the Offinso-North district in the major farming season of the year 2012. Secondary data for the study covered the use of bio-pesticides and chemical pesticides in vegetable production; and they were sourced from the Ministry of Agriculture, Research Institutes and Research Station Reports in addition to Internet sources, books and previous studies or existing literature.

3.3. Population, Sample and Sampling Technique

The targeted population of the study was all tomato, cabbage and carrot farmers in the two chosen districts (Mampong Municipality and Offinso North District) in Ashanti region of Ghana. For this study, 300 vegetable farmers were sampled. Individual vegetable farmers (growers of carrot, cabbage and tomatoes) were taken as sampling unit. A multistage sampling procedure was adopted for the study. The first stage involved the purposive selection of Mampong Municipality and Offinso North District in the Ashanti region. These areas were chosen because of their predominance in vegetable production in the Ashanti Region. These areas are also noted for intensive use or misuse of chemical pesticides in vegetable production and form part of the areas in the Ashanti region that were introduced to bio-pesticide adoption in the late 1990s. The vegetable producing communities in the study districts were stratified based on vegetable type mostly grown in conjunction with the authorities. With the help of the Agricultural Extension officers in the Offinso-North district and the Mampong municipality, the specific towns and production areas were identified and ranked according to the number of producers per area. This was followed by the selection of two communities from each group of communities producing the three selected vegetable types through a simple random sampling method by balloting. The communities selected from the Mampong municipality for the study included Beposo, Jeduako, Ninting, Amoamang, Bosofour and Kofiase. Also, those selected from the Offinso North district included Akomadan, Nkenkaasu, Nsenoa, Asuoso, Asempaneye and Kobreso. Finally, for each vegetable crop, a random sample of farmers was drawn after visiting the town and contacting producers. A total sample of 300 vegetable farmers comprising one hundred (100) tomato producers, one hundred (100) cabbage producers and one hundred (100) carrot producers were selected for the study. The various communities selected from the stratified vegetable types are shown by Table 3.1.

Table 3.1: Vegetable Farmers Sampled From Selected Communities

Veg. Type	Mampong Municipality	Sample size	Offinso North	Sample size
Tomato	Beposo	25	Akomadan	25
	Jeduako	25	Nkenkaasu	25
Cabbage	Ninting	25	Nsenoa	25
	Amoamang	25	Asuoso	25
Carrot	Bsofour	25	Asempaneye	25
	Kofiase	25	Kobreso	25
Total		150		150

Source: Field Survey, 2012

3.4. Data Collection

A questionnaire was developed by the researcher and it included a Likert scale, rank order, closed and open-ended questions based on initial reconnaissance survey and an extensive literature search. The questionnaire for the study was divided into several sections. The sections included vegetable farmer information, vegetable crop information, chemical pesticide usage information, farmers' awareness level of bio-pesticide and chemo-synthetic pesticides, farmer perception of pesticide usage and technical factors influencing the adoption of bio-pesticide among vegetable farmers. The 'Likert type' of questioning was adopted to seek for varying responses from farmers on various issues relating to their perception about bio-pesticides.

The initial questionnaire designed was pre-tested in one community in the Offinso-North District. This step enabled the researcher to revise the questionnaire for the main field survey. The revised structured questionnaire was used to conduct face-to-face interview with the selected vegetable producers. In addition to this formal interview, observation and key informant interviews were also conducted to obtain additional information.

3.5. Data Analysis

The Statistical Software Programme for Social Sciences was used for the descriptive analysis whereas the STATA 11 was used for the inferential analysis. Descriptive statistics (arithmetic mean, median, standard deviation and others), frequency tables and charts were used to summarize the farmers' characteristics. The Maximum Likelihood Estimation (MLE) procedure was used to estimate the both the binary Logit model and the multinomial logit models. The estimates gave an indication of the various factors that influences the adoption of bio-pesticides in the Ashanti region of Ghana. Pearson's chi-square test was used to measure whether there was some level of association or independence among categorical variables in two-way tables. Kendall rank test was also conducted to assess the reasons for the adoption and non-adoption of bio-pesticide in vegetable production. Kendall's coefficient of concordance (W) is a measure of the agreement among several (p) judges who are assessing a given set of n objects. In this study, the judges were the vegetable farmers assessing the various perceived reasons for using or not using bio-pesticide in controlling pest and disease. The W statistic was obtained from the formulas below:

$$W = \frac{12S}{p^2(n^3 - n) - pT}$$

where n is the number of objects, p the number of judges. T is a correction factor for tied ranks (Siegel 1956, p. 234). It was estimated with the aid of the non-parametric test of K-related sample which gave the various mean rank values attached to the perceived reasons. It also provided the Kendall's W, which is their agreement level and the associated p-value. The significance of the P-value indicates that the judges are in concordance or agreement. Also, to assess the viability of adopting bio-pesticide, the gross margins of adopters and non-adopters were computed. The economic performance of bio-pesticide adoption in pest management in vegetable production was assessed using gross margin analysis. Gross Margin (GM) is a useful planning tool in situations where fixed capital is negligible portion of the farming enterprises in the case of small scale subsistence agriculture (Olukosi and Erhabor, 1988). This analysis shows the difference between the total value of production per unit and the total variable cost incurred (Nix, 1998). The vegetable farmers Gross Margin is obtained by

$$GM = \sum_{j=1}^{m} P_j Y_j - \sum_{i=1}^{n} P_i Y_i$$

Where *GM*, gross margin; P_j, unit price of output of vegetable farmers, Y_j, quantity of outputs; P_i, unit price of variable inputs used in vegetable production; X_i quantity of variable inputs; i, j…n, m is the total sample size.

3.5.1. Empirical Analysis for Bio-Pesticide Adoption

In this study, a vegetable farmer was defined as an adopter if he or she was found to be using bio-pesticide only or together with other forms of pest management strategies. Thus, a vegetable farmer could be classified as an adopter and still use other forms of pest management strategies. The adoption variable was therefore defined as 1 if a farmer is an adopter of bio-pesticide and 0 if otherwise. This study adopted the logistic regression to assess the factors that determine farmers' adoption status. The independent variables were both continuous and discrete. The justification for using logit was based on its simplicity of calculation with its probability lying between 0 and 1, and its popularity in the empirical literature. Moreover, its probability approaches zero at a slower rate as the value of explanatory variable gets smaller and smaller, and the probability approaches 1 at a slower and slower rate as the value of the explanatory variable gets larger and larger (Gujarati, 1995). It is by far the most widely used analytical method for applied adoption research or studies.

Hosmer and Lemeshew (2000) pointed out that the logistic distribution (logit) has got advantage over the others in the analysis of dichotomous outcome variable in that it is extremely flexible and easily used model from mathematical point of view and results in a meaningful interpretation. The parameter estimates of the model are asymptotically consistent and efficient. The standardised coefficients correspond to the beta-coefficients in the ordinary least squares regression models. The binary logistic model does not make the assumption of linearity between dependent and independent variables and does not assume homoskedasticity (Doss, 2003). Another advantage of using the logit model is that it does not require normally distributed variables and above all, the logit model is relatively easy to compute and interpret. Hence, the logistic model is selected for this study. The probability that a farmer will adopt bio-pesticide as pest management strategy was postulated as a function of some socioeconomic, demographic characteristic and institutional factors. Therefore, the cumulative logistic probability model was econometrically specified as follows:

$$P_i = F(Z_i) = F(\beta_0 + \sum \beta_i x_i) = \frac{1}{1+e^{-z_i}} \qquad (1)$$

Hosmer and Lemeshew (2000) pointed out that the logit model could be written in terms of the odds and log of odds, which enables one to understand the interpretation of the coefficients. The odds ratio implies the ratio of the probability (P_i) that a farmer adopt to the probability ($1-P_i$) that the farmer is non-adopter.

$$(1-P_i) = \frac{1}{1+e^{z_i}} \qquad (2)$$

Therefore,

$$\frac{P_i}{1-P_i} = \frac{1+e^{z_i}}{1+e^{-z_i}} = e^{z_i} \qquad (3)$$

The natural log of equation (10), will give:

$$Z_i = \ln\left(\frac{P_i}{1-P_i}\right) = \beta + \beta_1 x_1 + \beta_2 x_2 + \ldots\ldots + \beta_m x_m \qquad (4)$$

If the disturbance term (ε_i) is taken into account, the binary logit model becomes:

$$Z_i = \beta + \sum^{m} \beta_i x_i + \varepsilon_i \qquad (5)$$

However, to further assess the factors that determine the farmers' choice of specific bio-pesticide type in managing pest in vegetable production, a multinomial logit regression model was estimated. This model is significant because relatively factors that would influence farmers' adoption of particular type of bio-pesticide would not necessarily be the same. Multinomial regression model is therefore estimated of farmer's choice of three major types of bio-pesticide in vegetable production. Multinomial logistic regression (also referred to as polychotomous logistic regression) is frequently used for the analysis of categorical response data with continuous or categorical explanatory variables. Technology adoption decisions are typically modeled as the outcome of a utility maximization problem. The framework assumes that if adoption of bio-pesticide is possible, it is expected that, in deciding to adopt one type of bio-pesticide, a farmer compares the indirect utility values associated with each bio-pesticide type. Consequently, to study the *i*th farmer's choice, random utility models were postulated, each being associated with the *j*th choice of bio-pesticide type in vegetable production, such that: U_{IC}, U_{iR}, and U_{iN} denote the i^{th} vegetable farmers expected utility from adopting Neem, Neem plus Pepper, and Cinnamon in managing pest. The observed variable in this case is not expected utility but technology choice decision Y_i, where

$$Y_i = \begin{cases} 0 \text{ if } U_{iC} > U_{iN} \text{ and } U_{iC} > U_{iR} \\ 1 \text{ if } U_{iR} > U_{iC} \text{ and } U_{iR} > U_{iN} \\ 2 \text{ if } U_{iN} > U_{iC} \text{ and } U_{iN} > U_{iR} \end{cases} \qquad (6)$$

Each individual vegetable farmer's expected utility under the alternative bio-pesticide type is assumed to be a function of a vector of explanatory variables, X_i, plus a random disturbance that captures unmodeled effects. It was therefore imperative to model the choice of bio-pesticide type using multinomial logit. A multinomial logit specification gives rise to a system of three probabilities (Maddala, 1990):

$$P_j \equiv \text{Prob}(Y_i = j) = \frac{e^{\beta_j' x_i}}{\sum_{m=0}^{2} e^{\beta_m'}} \quad j = 0,1, \text{ or } 2 \qquad (7)$$

Where β_j is a vector of parameters that relates the characteristics X_i of the various types of bio-pesticide to the probability that Y_i=j. because the three probabilities must sum to one, a convenient normalization rule is to see one of the parameter vectors, say β_0, equal to zero. The probabilities for three alternatives then become (Greene 1990). That is to employ one of the categorical dependent variables as the base (in the case of this study, Cinnamon was established as the base outcome):

$$P_j \equiv \text{Prob}(Y_i = j) = \frac{e^{\beta_j^{'} x_i}}{1+\sum_{m=1}^{2} e^{\beta_m^{'} x_i}} \quad \text{j = 1 or 2} \qquad (8)$$

$$P_0 \equiv \text{Prob}(Y_i = 0) = \frac{1}{1+\sum_{m=1}^{2} e^{\beta_m^{'} x_i}} \qquad (9)$$

The estimated parameters of a multinomial logit system are even more difficult to interpret that those in a bivariate choice model. Insight into the effect that the explanatory variables have on the bio-pesticide type adoption decision can be captured by examining the derivatives of the probabilities with respect to the K^{th} element of the vector of explanatory variables. These derivatives are defined as (Greene, 1990):

$$\frac{\partial \text{Prob}(Y_i = j)}{\partial x_{ik}} = P_j[\beta_{jk} - \sum_{m=0}^{2} \text{Prob}(Y_i = m)\beta_{ik}] \quad \text{j = 0, 1, 2; k=1,..., K} \qquad (10)$$

Clearly, neither the sign nor the magnitude of the marginal effects needed bear any relationship to the sign of the coefficients. The categorical variables of concern are the various bio-pesticide types such as Neem, Neem plus Pepper and Cinnamon that are possible alternatives for vegetable farmer's to adopt. The parameter estimates of both equation (5) (binary model) and equation (9) or (10) (multinomial model) were obtained by maximum likelihood method. This procedure does not require assumptions of normality or homoskedasticity of errors in predictor variables. This analysis was carried out using STATA version 11.0.

Table 3.2 below provides the description of the explanatory variables in both logit models with their expected *apriori signs*. The basis for the expected signs in Table 3.2 have been discussed and explained in Chapter two of the study.

Table 3.2: Description of Variables used in the Logit Model

Dependent variable for Binary Model: BIO adoption (1=Yes, 0=No)		
Dependent variable for Multinomial: Type of Bio-pesticide adoption (0=Neem, 1=Neem plus Pepper, 2= Cinnamon)		
Dependent variable for Multinomial: Type of vegetable farmer's (0=Tomato, 1=Cabbage, 2= Carrot)		
Explanatory variable	**Definition**	**Expected signs**
Farmers Characteristics:		
Age	Age of farmer in years	-
Gender	Male=1, 0=otherwise	-
Marital status	1=Married,0=Otherwise	+
Education	Educational level of farmer in years	+
Experience	Experience of vegetable farmer in years	+
Non-farm income	Annual non-farm income in GH¢	-
Technical/Institutional		
Extension	number of extension visits received per annum	+
State regulations	1=influenced by state reg., 0=otherwise	
Membership of FBOs	1=membership of FBOs,0=otherwise	+
Peer Influence	1=yes, 0=otherwise	
Farm size	Farm size (acres)	-
perception of farmer about bio-pesticides		
Bio-pesticides improves Yield	1= yes, 0=otherwise	+
Bio-pesticide has ill effect on human health	1= yes, 0=otherwise	+
Bio-pesticide is Environmental friendly	1= yes, 0=otherwise	+
Bio-pesticide is expensive	1= yes, 0=otherwise	-
Bio-pesticide are pest specific	1= yes, 0=otherwise	-
Other factors		
Accessibility of bio-pesticide	1=accessible,0=not accessible	+
Customers' demand for chemical free vegetables	1=customers pref. bio-pest. Veg., 0=otherwise	

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter is made up of two main sections. In section one, results of descriptive analyses based on the survey data are presented and discussed. The descriptive analyses cover the type of vegetable farmers interviewed, socio-demographic characteristics, farmers experience in vegetable production and operated farm size, problems of vegetable production and pest management strategies, the effectiveness of the methods of pest management, chemical pesticide usage in controlling pest, and bio-pesticide application in the study districts. Section two, discusses the empirical results on the factors affecting the adoption of bio-pesticides among vegetable farmers in the study districts.

4.1 Descriptive Analyses

This section is made up of the descriptive part of the results. In this section, socio-demographic characteristics; type of vegetable farmers interviewed; method of pest management and its effectiveness; problems of vegetable production, types of pest and methods controlling pest. Also, Bio-pesticide application in vegetable production with emphasis on areas like proportion of vegetable growers currently using bio-pesticide, source and type of bio-pesticide used, frequency of bio-pesticide application, and vegetable farmers' perception of bio-pesticide have been discussed. The perception of the vegetable farmers about bio-pesticide invariably indicates vegetable farmers' awareness of bio-pesticide.

4.1.1 Socio-Demographic Characteristics of Respondents

The vegetable producers interviewed had different socio-demographic characteristics, and these have been summarized in Table 4.1. From Table 4.1, majority (96%) of the vegetable farmers interviewed in the study areas were males. This finding is consistent with a study by Agyarko and Adomako (2007) who noted that most vegetable farmers in Ghana are males.

Table 4.1: Socio-Demographic Characteristics of Respondents

Variables	Frequency (N=300)	Percent (%)	Mean	Std. Dev.
Gender				
Male	289	96.3		
Female	11	3.7		
Age			44.65	14.09
Below 20yrs	13	4.3		
20-39yrs	113	37.6		
40-49yrs	162	54.0		
50-59yrs	12	4.0		
Farm Income (GH¢/Annum)			1,733.26	1,440.50
Non-Farm Income (GH¢/Annum)			979.24	1,210.23
Marital Status				
Married	119	66.1		
Otherwise	61	33.9		
Household Size			5.2	2.08
One	10	3.3		
2-4 persons	184	61.3		
5-7 persons	95	31.7		
Above 7 persons	11	3.7		
Educational Level			8.9	2.17
No Formal Education	30	10.0		
Elementary	187	62.3		
SHS	83	27.7		
Tertiary	0	0.0		
Ethnicity				
Asante	203	67.7		
Fante	24	8.0		
Others	73	24.3		
Religion				
Christianity	217	72.3		
Islamic	69	23.0		
Others	14	4.7		

Source: Field survey, 2012

The average age of the interviewed vegetable farmers was 44.65 years. The majority (54%) of the vegetable farmers were within the economic age bracket of 40 years to 49 years. This is partly due to the labour intensive nature of vegetable production. The average farm income per annum (GH¢1,733.26) of the interviewed vegetable farmers was relatively higher than their average non-farm income of about GH¢979.24 per annum. This implies that the major source of income for the vegetable farmers is sales from the vegetable farm produce.

About 62% of the interviewed vegetable farmers in the study districts had elementary school education and 28% had senior high school education. However, about 10.0% of the interviewed vegetable growers had no formal education. The average number of years of education among the respondents was 9, which is relatively higher than the average Ghanaian schooling years of 5.16 (GLSS, 2000). The average household size was 5.2 members per household, and this compares favourably with the national average of 5.5 members per household (Ghana Statistical Service, 2000). The majority (61%) of the number of children of the respondents were between 2 to 4 persons in the study areas. The ethnic background of the vegetable farmers in the study areas indicates that the majority of the vegetable farmer respondents (68%) were Asante's, and this probably could be attributed to the setting of the study which was conducted in the Ashanti region of Ghana.

4.1.2 Farmers Experience in Vegetable Production and Operated Farm Size

Table 4.2 below presents descriptive statistics on the experience of vegetable farmers interviewed and their farm sizes operated.

Table 4.2: Farm Size and Experience of Vegetable Farmers

	Adopters			**Non-Adopters**			**All farmer**
	Tomato	Cabbage	Carrot	Tomato	Cabbage	Carrot	
Farm Size (acres)							
Min	1.26	1.10	0.92	4.47	1.89	1.12	0.92
Max	4.36	3.53	3.21	6.40	2.70	1.90	6.40
Mean	3.81	2.91	2.68	5.39	3.38	2.96	2.53
Std. Dev	0.95	0.93	0.92	0.97	0.61	0.93	0.86
Farm Experience							
Min	5	3	3	7	5	6	3
Max	9	6	7	18	6	7	18
Mean	6.89	5.21	5.34	8.12	5.89	5.87	6.33
Std. Dev	4.56	3.10	3.11	5.88	3.34	3.23	4.22

Source: Field survey, 2012

From Table 4.2, the mean vegetable farm size was estimated to be 2.53 acres per season. Relatively, tomato farmers that have not adopted bio-pesticide cultivated larger acreages (5.39 acres) of farm size than the farm size (3.81 acres) of adopters of bio-pesticide. The mean farm size (2.91 acres) of cabbage farmers that have adopted bio-pesticide was relatively smaller than the farm size (3.38 acres) of non-adopters. In a similar vein, the non-adopters of bio-pesticide in carrot production operated relatively larger mean farm size (2.96 acres) than the mean farm size (2.68 acres) of adopters. Therefore, generally non-adopters of bio-pesticide in vegetable production relatively operated larger mean farm size than the adopters of bio-pesticide.

From Table 4.2, a typical vegetable farmer in the study area was found to have about 6.3 years of experience in vegetable production. Relatively, tomato farmers that have not adopted bio-pesticide (8.1 years) in production have higher average vegetable farming experience than adopters (6.9 years) of bio-pesticide in tomato farming. The non-adopters (5.9 years) of bio-pesticide in cabbage production also relatively have higher experience in vegetable production than the adopters (5.2 years) of bio-pesticide in cabbage production. In a similar vein, the non-adopters (5.9 years) of bio-pesticide in carrot production have relatively higher vegetable farming experience than the adopters (5.3 years) in carrot production. Generally, the non-adopters of bio-pesticide in vegetable production relatively have higher vegetable farming experience than adopters.

4.1.3 Problems of Vegetable Production and Pest Management Strategies

This section of the study presents results on problems vegetable farmers encounter in production, the types of pest that often attack vegetables, the methods or strategies of controlling pest and diseases and the level of effectiveness of the methods of control. The result is presented in Table 4.3.

From Table 4.3, the major problem of vegetable growers in the study areas was disease and pest attack as indicated by majority (72%) of the respondents. The disease and pest attack was a major problem for the majority (88%) of the non-adopters of bio-pesticide. The main type of pest that often attacks vegetables in the study areas was identified to be bufferfly/Moth. Butterfly or Aphid was a major problem for the majority (89%) of the adopters of bio-pesticide compared to non-adopters in vegetable production. Other pests such as aphids, caterpillar and beetles also attack vegetables in the study areas.

Table 4.3: Problems, Pest and Means of Controlling Pest in Vegetable Production

Variables	Adopters	Non-Adopters	Total
Problems farmers encounter in vegetable production			
Input inadequacy	9(25.0)	27(75.0)	36(12.0)
Post-harvest losses	4(10.3)	35(89.7)	39(13.0)
Pest and diseases	27(12.4)	190(87.6)	217(72.3)
Storage problems	2(28.6)	5(71.4)	7(2.3)
Type of pest that often attack vegetables			
Caterpillar	2(10.0)	18(90.0)	20(6.7)
Aphids	11(19.3)	46(80.7)	57(19.0)
Butterfly/Moths	23(10.9)	187(89.1)	210(70.0)
Beetles	7(53.8)	6(46.2)	13(4.3)
Extensiveness of pest and disease attack			
Very extensive	3(15.0)	17(85.0)	20(6.7)
Extensive	28(12.4)	198(87.6)	226(75.3)
Less extensive	12(22.2)	42(77.8)	54(18.0)
Means of controlling pest and diseases			
Physical and cultural control	0(0.0)	26(100.0)	26(8.7)
Chemo-synthetic pesticides	0(0.0)	231(100.0)	231(77.0)
Bio-pesticide	43(100.0)	0(0.0)	43(14.3)
Source of pesticide			
Dealers in community	0(0.0)	25(100.0)	25(8.3)
Dealers in district	0(0.0)	219(100.0)	219(73.0)
Dealers outside district	0(0.0)	13(100.0)	13(4.3)
Self-Prepared	37(100.0)	0(0.0)	37(12.3)
Friends	6(100.0)	0(0.0)	6(2.0)
Effectiveness level of means of pest and disease control			
Very effective	7(20.0)	28(80.0)	35(11.7)
Effective	23(14.9)	131(85.1)	154(51.3)
Less effective	10(12.5)	70(87.5)	80(26.7)
Not effective at all	3(9.7)	28(90.3)	31(10.3)
Ever encountered problems in method usage			
Yes	12(5.9)	208(94.1)	220(73.3)
No	31(57.4)	49(42.6)	80(26.7)
Problems encountered			
High cost	3(7.5)	37(92.5)	40(18.2)
Pest persistence	0(0.0)	141(100.0)	141(64.1)
Health hazards	0(0.0)	30(100.0)	30(13.6)
Difficulty in preparation	9(100.0)	0(0.0)	9(4.1)

Percentages are in Parentheses
Source: Field survey, 2012

The majority (75%) of the vegetable farmers perceived the pest and disease attack as extensive. Relatively, the majority (88%) of the non-adopters of bio-pesticide in vegetable production experienced more extensive pest and disease attack. Chemical pesticides were predominantly applied by the non-adopters whereas bio-pesticide was used by adopters in vegetable production in the study areas as a means of controlling or managing the pest and disease attack. The major method of controlling these pest and diseases was found to be through synthetic chemical pesticides as indicated by the majority (77.0%) of the respondents. This finding is consistent with a study by Amoah *et al.* (2006) which reported that chemical control is the most common strategy used by farmers to protect their investment in vegetable production. Bhanti and Taneja (2007) posit that cabbage producers in Northern India apply pesticides every 3 to 4 days within a 3-month period before harvesting, in order to control caterpillars on the crop. Consistent with the finding of this study, Okorley and Kwarteng (2002) also revealed in their study that vegetable farmer in the Central Region of Ghana rely almost entirely on chemical pesticides. The non-adopters predominantly obtained chemical pesticides from dealers in the districts whereas the adopters self-prepared the used bio-pesticides. Other sources of chemical pesticides for farmers were dealers in the farming communities and dealers outside the farmer's home district.

Also, for 14.3% of the respondents, bio-pesticides were the main pest control method adopted in vegetable cultivation. The practiced methods of controlling pest and diseases were perceived to be effective by about 51.3% of the respondents. Relatively, the majority (85%) of the non-adopters perceived their methods of controlling disease and pest as effective. However, for 26.7% of the surveyed farmers, their current methods of pest and disease control were deemed less effective. Relatively, the majority (88%) of the non-adopters of bio-pesticide perceived their method of controlling pest and disease as less effective. The majority (73%) of the surveyed respondents have encountered problems in their main method of controlling pest and diseases in vegetable production. Relatively, the majority (94%) of the non-adopters of bio-pesticide encountered problems in the main method adopted in controlling disease and pest. The major problem encountered by the non-adopters of bio-pesticide was pest persistence whereas that encountered by the adopters was the slow to work nature of bio-pesticides.

From Table 4.4, the majority (64%) of the vegetable growers that adopted physical and cultural practices deemed it less effective. The majority (53%) of the vegetable growers who applied chemical pesticide in controlling pest and diseases in vegetable production deemed it effective. Carrasco-Tauber (1992) stated that for every dollar spent on pesticide, the farmer can reduce crop damage by 3-5 dollars; and also perceived to contribute immensely to increase in farm productivity (Shumway and Chesser, 1994). Based on the effectiveness of pesticide in controlling pest, its use has continued to increase over time (Olesen *et al.*, 2003), such that some vegetable crops have in recent times become indicators of chemical pesticide usage in the Ashanti region based on found chemical residues (Ntow, 2001). Similarly, vegetable growers that applied IPM deemed it effective. However, the majority (61%) of the vegetable growers who applied bio-pesticide as the major means of controlling pest and disease in vegetable production deemed it less effective. This therefore can possibly explain the low adoption level of bio-pesticide among vegetable growers in the two studied districts in the Ashanti region. Pest persistence was reported as the main challenge faced in disease and pest control in vegetable production. The continual application of chemical pesticides in the study districts could have contributed to the pest persistence.

Table 4.4: Method of Pest Control and Their Level of Effectiveness

Method of Pest Control	Effectiveness of Method			
	Very Effective	**Effective**	**Less Effective**	**Not Effective at All**
Physical and Cultural	0(0.0)	8(36.4)	14(63.6)	0(0.0)
Chemical Pesticide	23(11.4)	108(53.4)	40(19.8)	31(15.4)
Bio-Pesticide	12(27.9)	5(11.6)	26(60.5)	0(0.0)
IPM	0(0.0)	33(100.0)	0(0.0)	0(0.0)
Total	**35(11.7)**	**154(51.3)**	**80(26.7)**	**31(10.3)**

Percentages are in parentheses
Source: Field survey, 2012

Furthermore, Table 4.5 provides the results of the Chi-square test of independence between methods of pest control and level of effectiveness. The result show that, the Pearson chi-square test value of 117.314 is statistically significant at 1%, and hence indicates dependency of the two cross tabulated variables because of the need of 'rejecting' the null hypothesis of independency. The significance of the relationship between the method of controlling pest and the effectiveness of the methods is a statistical proof of the dependency of the two variables. This implies that the methods of pest control statistically influence the effectiveness of the methods in the two study districts. In support of this finding, existing literature indicates that the market of chemical pesticide has become matured with a growth rate of about 1-2% per annum (Berenbalum, 2000), because of the effectiveness of chemical pesticides in controlling pest (Olesen *et al*, 2003).

Table 4.5: Chi-Square test of methods of pest control and effectiveness

Pearson Chi-Square	
N	300
Chi-Square	117.314
Df	9
Asymp. Sig. (2-sided)	0.000

Source: Field Survey, 2012

4.1.4 Chemical Pesticide Usage in Controlling Pest

This section presents results and discussion on the types of chemical pesticides applied by vegetable farmers, period and season of chemical usage, reasons for chemical pesticide usage, protective measures adopted during spraying and the source of chemical pesticide control advice. The results are presented in Tables 4.6 and 4.7.

Table 4.6: Frequency and Volume of Chemical Pesticide Usage

Type of Vegetables	Tomatoes	Cabbage	Carrots
Name of (major) pesticide	Karate	Mektin	Karate
Frequency (no. of time per season)	2-10	2-8	7-10
Mean volume (Litres per acre) [Mean=0.83]	0.99	0.77	0.63

Source: Field survey, 2012

From Table 4.7, it is evident that the most frequently applied chemical pesticide in controlling pest in vegetable production is karate as indicated by the majority (60%) of the respondents. This finding is consistent with a study by Egyir *et al.* (2010) that suggest the dominance of karate in controlling pest and diseases in tomato and carrot production in Ghana. Karate is applied between seven (7) and ten (10) times per season on carrots with a mean volume of 0.63 litres per acre. Likewise, Karate is applied on tomatoes between two (2) and ten (10) times per season with a mean volume of 0.99 litres per acre. Karate is a pyrethroid insecticide active against a wide range of foliar insects and mites at low concentrations (Obeng-Ofori and Ankrah 2002). Mektin, as the common chemical pesticide often applied on cabbage was applied between two (2) and eight (8) times per season with a mean volume of 0.77 litres per acre. Karate can be found on the market under 2 formulations: Karate 2.5 EC (contains 25g of active ingredient/1L of Karate) and Karate 5 EC (contains 50g of active ingredient/1L of Karate). On vegetables such as cabbage, tomato and carrots, the current recommendation in Ghana is to apply Karate 2.5 EC at the rate of

200-800 ml/ha or 0.2-0.88 litres per hectare. Weekly applications are recommended to combat pest and diseases. These amounts add to a total of 12 to 16 for a crop that last 90 to 100 days in the field. While some farmers applied chemical pesticides at a higher rate than recommended doses, others used at below recommended doses. From Table 4.8, other chemical pesticides also applied by vegetable farmers in the study areas include dursban and DDT which were reported by less 10.0% of the respondents respectively. About 72.8% of vegetable farmers noted that these chemical pesticides are often applied during severe pest attack. However, 20.3% reported that the chemical pesticides were applied during initial pest attack.

From Table 4.7, the chemical pesticides are also commonly applied during the raining season as indicated by the majority (85%) of the respondents. Other vegetable farmers also apply chemical pesticides in the dry season and both the dry and wet season as indicated by 9.4% and 5.4% of the respondents respectively. These chemical pesticides were often applied in vegetable production for treatment purposes as indicated by 78.7% of the respondents. However, 17.3% of the respondents also indicated that they apply chemical pesticides for productivity improvement. The main protection measure adopted in pesticide spraying by vegetable farmers in the study areas was covering of face with cloth as indicated by the majority (81%) of the respondents. About 19% of the respondents also cover body and face with cloth when praying the chemical pesticides. Chemical pest control information was predominantly obtained from pesticide dealers as indicated by the majority (65%) of the respondents. Others also received pest control information from their neighbours and extension officers as indicated by 8.4% and 21.8% of the respondents respectively.

Table 4.7: Chemo-Synthetic Pesticide Usage

Variables	Frequency	Percent (%)
Use chemical pesticides		
During severe attack	147	72.8
During initial attack	41	20.3
Before attack	14	6.9
Season of chemical pesticide application		
Raining	172	85.2
Dry	19	9.4
Both	11	5.4
Type of chemo-synthetic pesticide used		
Karate	121	59.9
Mektin	49	24.3
Dursban	17	8.4
DDT	15	7.4
Reason for using chemical pesticide		
Treatment purpose	159	78.7
Productivity improvement	35	17.3
Other reasons	8	4.0
Protective measure adopted in pesticide spraying		
Cover face with cloth	164	81.2
Cover body and face with cloth	38	18.8
Source of pest control information		
Neighbours	17	8.4
Extension officers	44	21.8
Relatives	7	3.5
Pesticide dealers	131	64.9
Media	3	1.4

Source: Field survey, 2012

4.1.5 Bio-Pesticide Application in Vegetable Production

This section of the study identifies the proportion of the vegetable farmers in the study areas currently using bio-pesticide as a major means of controlling pest and also the volumes of bio-pesticide applied as shown by Table 4.8. The section also further looks at the source and the type of bio-pesticides used by vegetable farmers in the study districts (Table 4.9).

From the table (4.8), out of the total surveyed vegetable farmers, the majority (81.3%) are aware of bio-pesticide application in controlling pest and diseases in vegetable production. However, 14.3% of the surveyed vegetable farmers are currently using bio-pesticide in the study areas. Among the vegetable farmers currently using bio-pesticides in controlling pest and diseases, the majority are cabbage farmers. Relatively, the vegetable farmers yet embrace the pesticidal acumen of bio-pesticide are tomato farmers. The less usage of bio-pesticides could be attributed to several factors including their difficulty in preparation and accessibility and their perceived relative ineffectiveness as well as their pest specificity.

Table 4.8: Vegetable Farmers Currently Using Bio-Pesticide and Volumes of Application

	Frequency(Percent)			
Aware of bio-pesticides				
Yes	244(81.3)			
No	56(18.7)			
Total	**300(100.0)**			
Currently using bio-pesticide				
	Tomato	Cabbage	Carrot	**Total**
Yes	9 (9.0)	20(20.0)	14(14.0)	**43(14.3)**
No	91(91.0)	80(80.0)	86(86.0)	**257(86.7)**
Total	**100**	**100**	**100**	**300(100.0)**
Volumes of bio-pesticide application				
Mean (Litres per acre)	3.6	3.9	2.4	**3.3**
Std. Dev.	0.80	0.67	0.81	**1.63**
Minimum	2.3	2.4	1.0	**1.0**
Maximum	5.2	5.2	4.3	**5.2**

Percentages are in parentheses
Source: Field survey, 2012

The majority (84%) of vegetable farmers who used bio-pesticide prepared it themselves, with only about 16.3% sourcing from fellow farmers. The mean volume of bio-pesticide applied by vegetable growers was estimated to be 3.3 litres per acre with a standard deviation of about 1.63 litres per acre.

From Table 4.9, out of the total 43 vegetable growers currently applying bio-pesticides as their major means of controlling pest, the majority were found to be cabbage growers. The result of Table 4.8 shows that the cabbage growers applied an average volume of about 3.9 litres per acre with a standard deviation of about 0.67 litres per acre. The average volume of bio-pesticide applied by the carrot growers in controlling pest was about 2.4 litres per acre with tomato farmers applying 3.6 litres per acre. There is no defined volume per hectare of bio-pesticide usage in controlling pest in vegetable production (Lewis *et al.*, 1997). However, the amount of volume required to be applied in the event of disease and pest attack depends on the extent of the attack (Clemson HGIC, 2007).

Table 4.9: Source and Type of Bio-Pesticide Used By Vegetable Farmers

Variable	Frequency	Percent (%)
Form of Bio-Pesticide Used		
Neem	31	72.1
Neem plus pepper	9	20.9
Cinnamon	3	7.0
Total	**43**	**100.0**
Source of Bio-Pesticide		
Self-prepared	36	83.7
From colleagues	7	16.3
Total	**43**	**100.0**

Source: Field survey, 2012

4.1.5.1. Frequency of Bio-pesticide Application in Vegetable Production

This section of the study assesses the frequency of bio-pesticide application by vegetable growers per season in the two studied districts in the Ashanti region. The result of the section is presented in Table 4.10.

Table 4.10: Frequency of Bio-pesticide Application by Vegetable Farmers in Previous Season

Frequency of Application	Type Of Vegetable Grown			Total
	Tomatoes	Cabbage	Carrot	
Once	0(0.0)	0(0.0)	0(0.0)	**0(0.0)**
2-4 times	3(30.0)	1(5.2)	1(7.1)	**5(11.6)**
5-6 times	7(70.0)	12(63.2)	9(64.3)	**28(65.1)**
Above 6 times	0(0.0)	6(31.6)	4(28.6)	**10(23.3)**
Total	**10(23.3)**	**19(44.3)**	**14(32.4)**	**43(100.0)**

Percentages are parentheses
Source: Field survey, 2012

From Table 4.10, out of the total 43 vegetable farmers that apply bio-pesticide; 3 tomato farmers, 1 cabbage farmer and 1 carrot farmer apply it two to four times per season. Also, 7 tomato farmers, 12 cabbage farmers and 9 carrot farmers apply bio-pesticide five to seven times per season. However, 6 cabbage farmers and 4 carrot farmers apply bio-pesticide more than seven times per season. It is therefore evident that cabbage farmers frequently apply bio-pesticides relative to both tomato and carrot farmers. However, carrot farmers also frequently apply bio-pesticides relative to tomato farmers. This frequency pattern of bio-pesticide application among the vegetable farmers could be due to the fact that tomato is more traditional vegetable, and is often grown on a larger scale than both carrot and cabbage. This finding is in consonance with the study of Egyir *et al*. (2006) that suggest that farmers deem chemical pesticides more effective for larger farm sizes. However, generally, there is no defined frequency of bio-pesticide application per hectare in controlling pest and disease in vegetable production (Lewis *et al.*, 1997) due to their less likelihood of causing damage to crops, humans and the environment (Lewis *et al.*, 1997). However, the frequency of application largely relies on the extent of the attack the disease and pest attack on the farm (Clemson HGIC, 2007)

4.1.5.2. Vegetable Farmers' Perception and Awareness of Bio-Pesticide

There is association between attitudes and perceptions. Farmers' adoption of bio-pesticide in vegetable production is influenced largely by their attitudes, and as such farmers 'perception are important in their decisions making. This section of the study therefore investigates vegetable growers perception on the quality, benefit and environmental risk associated with application of bio-pesticides in controlling pest in vegetable production. Table 4.11 below, therefore assesses the perception of vegetable farmers in the study area about the application of bio-pesticides. Each perception response was measured on a three point 'Likert scale' with score of 1 for agree, 0 for undecided, -1 for disagree. As indicated in Table 4.12, vegetable farmers' perception of bio-pesticide was generally positive. The table further assessed vegetable farmer's awareness level of bio-pesticide adoption in controlling pest in the studied areas. Vegetable growers generally agreed (78%) that bio-pesticides as a method of controlling pest are less harmful to human health. This agreement level is shown by their perception score of 0.72. The vegetable growers also agreed (77%) to the statement that bio-pesticides are environmentally friendly. This agreement level is also shown by their perception score of 0.70. Respondents' perception on the ability of the application of bio-pesticide to improve the yield of vegetable produce was also positive. The majority of the vegetable farmers (74%) agreed that bio-pesticide application improves crop yields. This is evident from the level of agreement as shown by the perception score of 0.59. Also, the respondents (76%) unanimously agreed that bio-pesticides reduce crop loss and this is shown by the mean perception score of 0.64.

The vegetable growers further (74%) agreed that bio-pesticides are pest specific. This agreement level is shown by the perception score of 0.70. The overall perception score was found to be

0.67. This is an indication of overall positive perception which also implies that the vegetable producers in the study areas are well aware of the benefits and disadvantages of bio-pesticide application in controlling pest. The vegetable farmers were found to be generally aware that bio-pesticides are less harmful and environmental friendly, bio-pesticides reduce crop loss and increase crop yield, and are also pest specific as the mean awareness scores of all these variables were greater than 0.5. This is further emphasized by the overall mean awareness score of 0.76. Irrespective of the positive perception and high level of awareness of vegetable farmers about bio-pesticide application in controlling pest in vegetable production, the adoption level is still very low (14%).

Table 4.11: Vegetable Farmers Perception of Bio-Pesticide Application

Statements about bio-pesticides	Awareness			Perception			
	Aware (1)	**Unaware (0)**	**Awareness Mean Score**	**Agree (1)**	**Undecided (0)**	**Disagree (-1)**	**Perception Mean Score**
Bio-pesticides are less harmful to human health	235(78.3)	65(21.7)	**0.78**	235(78.3)	47(15.7)	18(6.0)	**0.72**
Bio-pesticides are environmentally friendly	232(77.3)	68(22.7)	**0.77**	232(77.3)	45(15.0)	23(7.7)	**0.70**
Bio-pesticides improve crop yield	223(74.3)	77(25.7)	**0.74**	223(74.3)	30(10.0)	47(15.7)	**0.59**
Bio-pesticides reduce crop loss	229(76.3)	71(23.7)	**0.76**	229(76.3)	35(11.7)	36(12.0)	**0.64**
Bio-pesticides are pest specific	221(73.7)	79(26.3)	**0.74**	221(73.7)	69(23.0)	10(3.3)	**0.70**
Total			**0.76**				**0.67**

Rating: (Mean score ≥ 0.5 = Agreed, 0 = undecided, Mean score < 0.5 = Disagreed)
Rating: (Mean score ≥ 0.5 = Aware, Mean score < 0.5 = Unaware)
Note: Percentages are in parentheses
Source: Field survey, 2012

4.1.5.3. Perceived Reasons for Adoption and Non-Adoption of Bio-Pesticide

This section of the study assesses the reasons behind the adoption and non-adoption of bio-pesticide in controlling pest in vegetable production in the study districts. The perceived reasons for the adoption of bio-pesticides are ranked in Table 4.12 whereas the perceived reasons for non-adoption of bio-pesticide are also ranked in Table 4.13.

Table 4.12: Perceived Reasons for Adoption of Bio-Pesticide

Variables	**Mean Rank**	**Rank**
Less ill effect on human health	4.85	1
Environmental benefits	4.68	2
Improved produce quality	4.42	3
Reduction in crop loss	4.29	4
Increased crop yield	4.17	5
Demands of customers	4.13	6
Presentation in small packages	2.32	7
Quick action	2.01	8
Easy to get	1.67	9
Less costly	1.09	10
Consideration of regulations	1.01	11
Test Statistics		
N		43
Kendall's W^a		0.713
Chi-Square		1283.78
df		10
Asymp. Sig.		0.000
a = Kendall's Coefficient of Concordance		

Ranking [Strongly Agree (5), Agree (4), Indifferent (3), Disagree (2) and Strongly Disagree (1)]
Source: Field survey, 2012

From Table 4.12, the Kendall's coefficient of concordance (W^a), testing the null hypothesis that there is no agreement among the vegetable growers with respect to the reasons for adoption of bio-pesticide in controlling pest was rejected at a 1% significance level. The degree of agreement as measured by the W-statistics is about 71% since the score is zero for random ranking and 1 for perfectly unanimous ranking. The vegetable growers in the study areas can therefore, be said to unanimously agree that the most contributing factors to their adoption of bio-pesticide in controlling pest are more related first to less ill effect on human health and secondly to environmentally friendly nature and bio-pesticides ability to improve product quality. This finding is consistent with a study by Adetonah *et al*. (2007) that suggests that cotton farmers in Benin perceived biological pest management strategies to be more environmentally friendly and also have less ill effect on human health.

Table 4.13: Perceived Reasons for Non-Adoption of Bio-Pesticides

Variables	**Mean Rank**	**Rank**
Difficulty in preparation of bio-pesticide	3.68	1
Cost of bio-pesticide	3.54	2
Slow to work	3.48	3
Pest specific	2.90	4
Lack of technical know-how	1.41	5
Test Statistics		
N		257
Kendall's W		0.433
Chi-Square		138.498
df		4
Asymp. Sig.		0.000
a = Kendall's Coefficient of Concordance		

Ranking [Strongly Agree (5), Agree (4), Indifferent (3), Disagree (2) and Strongly Disagree (1)]
Source: Field survey, 2012

From Table 4.13, the Kendall's coefficient of concordance (W^a), testing the null hypothesis that there is no agreement among the vegetable growers with respect to the reasons for non-adoption of bio-pesticide in controlling pest was rejected at a 1% significance level. The degree of agreement as measured by the W-statistics is about 43% since the score is zero for random ranking and 1 for perfectly unanimous ranking. The vegetable growers that have not adopted bio-pesticide in controlling pest in the study areas can therefore, be said to agree that the most contributing factors to their non-adoption of bio-pesticide are more related first to the difficulty in the preparation of bio-pesticide and secondly, to cost of bio-pesticide and the 'slow to work' nature of bio-pesticides. This finding is consistent with a study by Adetonah *et al*. (2007) that suggests as major disadvantages the cash cost involved in the preparation of bio-pesticides and the slow action nature of bio-pesticides in cotton production in Benin. The least two ranked factors contributing to non-adoption of bio-pesticide among the vegetable producers in the study districts are pest specific nature of bio-pesticide and lack of technical know-how on the part of the farmers. The pest specificity of bio-pesticide generally translate into benefits to humans and ecosystems including increased food safety, worker safety, and reduced concerns for development of pest resistance to existing control tools (Clemson HGIC, 2007), and hence the low rank.

4.1.6 Gross Margin of Non-Adopters and Adopters of Bio-Pesticide Application

This section of the study analyses the gross margins of non-adopters and adopters of bio-pesticide in controlling pest in vegetable production in the studied areas. It further assessed the statistical differences between the mean gross margin per hectares of adopters and non-adopters of bio-pesticide in pest management as shown in Table 4.15. The variable cost components of production and the gross returns obtained by the sampled farmers of the selected vegetables are shown in Table 4.14. The table further computes the gross margins by subtracting the total variable cost from the total gross revenues. From Table 4.14, the gross margin per hectare (GH¢1,371) of tomato farmers that are currently employing chemical pesticide methods only in controlling pest and diseases in vegetable production was relatively higher than the gross margin (GH¢1,206) of the adopters of bio-pesticide.

Table 4.14: Gross Margin of Non-Adopters and Adopters of Bio-Pesticide per Hectare of Vegetable Farm

Pest Mgt. Strategy	**Bio-pesticide**			**Chemical Pesticide**			**Physical & Cultural (P&C)**		
	Tomato	**Cabbage**	**Carrot**	**Tomato**	**Cabbage**	**Carrot**	**Tomato**	**Cabbage**	**Carrot**
Variable Inputs									
Land Preparation (ha^{-1})	310	300	270	307	297	265	289	270	280
Seed in GH¢ per ha	96.1	58	55.5	96.1	58	55.5	96.1	58	55.5
Fertilizer cost in GH¢ per ha	97.3	85.7	77.5	101.7	92.1	83.5			
Insecticide cost in GH¢ per ha	12	18.1	25.1	19.2	21.2	30.3			
Herbicide cost in GH¢ per ha	17	15	12	17.3	16.1	13			
Bio-pesticide in GH¢ per ha	16.8	16.2	13.6						
Labour cost in man-days/ha	308	193.6	184	302	191.1	182.2	300	194.3	184.8
Cost of water in GH¢/ha	11.8	20.4	10.2	11.1	16.9	10.9	11.6	13.1	10.3
Inputs for P&C GH¢/ha							8.3	5.1	8.2
Variable Cost (GH¢/ha)	**869**	**707**	**647.9**	**854.4**	**692.4**	**640.4**	**705**	**540.5**	**538.8**
Revenues									
Average Yield (Mt/ha)	8.3	10.7	12.3	8.9	11.2	12.9	5.4	7.3	9.9
Farm gate price	250	175	112	250	175	112	250	175	112
Gross Revenue (GH¢/ha)	**2,075**	**1,873**	**1,378**	**2,225**	**1,960**	**1,445**	**1,350**	**1,277.5**	**1,108.8**
Gross Margin (GH¢/ha)	**1,206**	**1,166**	**730**	**1,371**	**1,268**	**804**	**645**	**737**	**570**

Note: Cost and Revenues are in GH¢

Source: Authors' computations (2012)

However, the gross margins per hectare (GH¢1,206) of tomato farmers that have adopted bio-pesticide was relatively higher than the gross margins per hectare (GH¢645) of the tomato farmers that largely depend on cultural and physical modes of controlling pest and diseases. The test for significance in the results presented by Table 4.15 reveal that, gross margin per hectare of bio-pesticide adopters in management of pest in tomato farming is significantly different from non-adopters at a 1% level of significance (t-value of -9.13).

The gross margin per hectare (GH¢1,268) of the cabbage farmers that also rely only on chemical pesticides as pest management strategy was relatively higher than the gross margin per hectare (GH¢1,166) of adopters of bio-pesticide. However, the gross margin per hectare of the cabbage farmers that depended on bio-pesticide in controlling diseases and pest was relatively higher than the gross margin per hectare (GH¢737) of the cabbage farmers that depended on physical and cultural practices. The differences so recorded between bio-pesticide adopters and non-adopters in management of pest in cabbage farming subsequently leads to a significant difference over the year recorded at 1% level of significance. In a similar vein, the gross margin per hectare of the carrot farmers that relied on chemical pesticides in controlling pest was comparatively higher than the carrot farmers that relied on bio-pesticide only. However, the gross margin per hectare of the carrot farmers that relied on bio-pesticide was relatively better compared to the carrot farmers that relied on physical and cultural practices in controlling disease and pest. From Table 4.15, the test of statistical difference in the mean gross margin per hectares of adopters of bio-pesticide and non-adopters in pest management in carrot farming was statistically significant at 5%. Evident from Table 4.15, there is statistical difference between the gross margin per hectares of adopters of bio-pesticide in vegetable farming and non-adopters.

The relatively higher gross margins per hectare of vegetable farmers that applied chemical pesticides in production could be attributed to their relatively higher yields. The higher yield of vegetable farmers that relied only on chemical pesticides relative to adopters of bio-pesticides is not surprising since the result of a study conducted by Schlüter (1985) at the University of Stuttgart-Hohenheim on farm management, yields, and profitability of 16 biodynamic farms from seven production regions in the southwest German state of Baden-Württemberg revealed that yields of biodynamic farms were lower by 13%. In the nutshell, profit of bio-pesticide adoption in vegetable production in the studied areas was lower compared to the conventional means of controlling pest largely because of yield differences. Unlike Ghana, the yield difference that often reduces the relative gross returns of biological methods of farm management is compensated by government payments in many European countries. Government payments to farmers in the developed world on average contribute 16-24 percent of profits in Germany, Austria, Switzerland and Denmark (Offermann and Nieberg, 2000). Moreover, with the presence of a niche market for organic produce in Europe, the relative differences in yield are further compensated for by higher prices or price premiums for organic farm produce. These facts are evident in the study of Lotter, Seidel and Liebhardt (2003) that showed that organic price premiums along with the government payment can compensate for lower yields of organic farm produce. It is therefore not surprising that the adoption of bio-pesticide in vegetable production in the studied areas was found to be low (14%) irrespective of the positive perception and high awareness level of bio-pesticide.

Table 4.15: Comparison of Mean Gross Margin of Adopters and Non-adopters of Bio-pesticide in Pest Management

Vegetable Farmers	No. of Farmers	Mean	t-statistic	P-Value	Decision
Tomato					
Adopters	9	1,206	-9.13	0.000	Significant at 1%
Non-Adopters	91	1,371			
	100	**-165**			
Cabbage					
Adopters	20	1,166	-8.89	0.000	Significant at 1%
Non-Adopters	80	1,268			
	100	**-102**			
Carrot					
Adopters	14	730	-2.13	0.035	Significant at 5%
Non-Adopters	86	804			
	100	**-74**			

Source: Authors' computations (2012)

4.2. Factors Affecting the Adoption of Bio-Pesticide

This section of the study empirically assesses the factors affecting the adoption of bio-pesticide in the study districts. Table 4.16 reports the descriptive results of the major variables used in the empirical model. Considering some of the major variables considered, the average age of the adopters of bio-pesticide of 42.21 years was significantly different from the mean age of the non-adopters of 44.43 years. The average household size of the adopters of bio-pesticide of 5.2 persons was significantly different from the mean household size of the non-adopters of 5.0 persons. Also, the mean schooling years of the adopters of bio-pesticide of 8.9 years was significantly different from the mean schooling years of the non-adopters of bio-pesticide of 6.7 persons. The mean farming experience of the adopters of bio-pesticide of 6.73 years and that of the non-adopters of bio-pesticide of 5.81 were significantly different at 1%. Furthermore, the mean annual non-farm income of the adopters of bio-pesticide of GH¢979.21 was not significantly different from that of the non-adopters of GH¢979.24. The descriptive values of some of the other categorical variables estimated are also shown in Table 4.16.

Table 4.16: Variables Used In the Regression Models

Dependent variable: BIO adoption (1=yes, 0= no)		**Adopters**	**Non-adopters**		
Explanatory variable	**Definition**	**Mean**	**Mean**	Mean diff.	P-Value
Farmers Characteristics:					
Age	Age of farmer in years	42.21	44.43	2.22	0.00
Gender	Male=1, 0=otherwise	0.92	0.65	0.27	0.01
Marital status	1=Married,0=Otherwise	0.96	0.97	-0.01	0.16
Household Size	Household size of respondents	5.2	5.0	0.20	0.04
Education	Educational level of farmer in years	8.9	6.7	2.20	0.00
Experience	Experience of vegetable farmer in years	6.73	5.81	0.92	0.00
Non-farm income	Annual non-farm income in GH¢	979.21	979.24	-0.03	0.19
Technical/Institutional					
Extension	Number of extension visits received annually	3.77	3.95	-0.22	0.05
State regulations	1=Influenced by state reg., 0=otherwise	0.87	0.33	0.50	0.07
Membership of FBOs	1=Member of FBOs,0=otherwise	0.93	0.61	0.32	0.05
Farm size	Farm size (acres)	3.21	3.91	-0.70	0.00
Perception of farmers'					
Bio-pesticides improves Yield	1= yes, 0=otherwise	0.99	0.36	0.63	0.01
Bio-pesticide has less ill effect on human health	1= yes, 0=otherwise	0.99	0.58	0.41	0.06
Bio-pesticide is Environmentally friendly	1= yes, 0=otherwise	0.99	0.56	0.43	0.06
Bio-pesticide is expensive	1= yes, 0=otherwise	0.38	0.85	-0.47	0.06
Bio-pesticide act quickly on pest	1= yes, 0=otherwise	0.59	0.23	-0.36	0.09
Other factors					
Accessibility of bio-pesticide	1=Accessible,0=not accessible	0.86	0.38	0.48	0.07
Customers' demand chemical free vegetables	1=Customers pref. bio-pest. Veg., 0=otherwise	0.89	0.54	0.35	0.09

Source: Field survey, 2012

4.2.1 Binary Logistic Regression Result of Bio-Pesticide Adoption

The result from the binary logit model has been presented in Table 4.17. The Pseudo R^2 of the estimated model was 26.0%, which means that 26% of the variation in the dependent variable (adoption of bio-pesticide) is explained by the model or the explanatory variables. To further study the explanatory power of the model, a statistic based on likelihood ratio (LR) is appropriate. The significance of the likelihood ratio statistic indicates that the model follows a chi-square distribution (χ^2) with 24 degrees of freedom. The Hosmer-Lemeshow statistics (df = 8, p = 0.2656) for the Logit model is insignificant. This is because, the observed probability did not reach significance at $\alpha = 0.05$ on χ^2 distribution with 8 degrees of freedom. Hosmer and Lemeshow (2000: 145-147) suggests that insignificant statistics indicates a goodness of fit of a model. Thus, it can be concluded that the Logit model sufficiently explains the data. That is, there is enough evidence to suggest that the goodness of fit of the overall model is very good.

From the logistic regression model, farmer characteristic that affected bio-pesticide adoption negatively was age. The study revealed that age was statistically significant at 5%. The negative relationship between age and the adoption of bio-pesticide indicates that the younger vegetable farmers have higher or greater probability or odds (0.9372) of adopting bio-pesticide in controlling pest relative to their aged counterparts, all other things being equal. Older farmers, perhaps because of investing several years in a particular practice, may not want to jeopardize it by trying out a completely new method.

Table 4.17: Binary Logit Estimates of the Adoption of Bio-Pesticides

Bio-Adoption	Odds Ratio	Std. Err.	Z	P>|Z|
Farmers Characteristics:				
Age	0.9372	0.0238	-2.55	0.011
Gender	9.8176	12.8252	1.75	0.080
Marital status	1.0922	0.4126	0.23	0.815
Household Size	6.1657	3.9699	2.83	0.005
Education	14.7910	1.1013	2.45	0.014
Experience	2.8789	1.2919	2.36	0.018
Non-farm income	0.9995	0.0003	-1.55	0.121
Technical/Institutional:				
Extension	3.7254	4.5712	3.31	0.001
State regulations	6.1218	6.1102	1.82	0.069
Membership of FBOs	1.7110	5.1443	2.79	0.005
Farm size	0.5039	0.1997	-1.73	0.084
Perception of Farmers' about Bio-pesticides:				
Bio-pesticides improves Crop Yield	3.6690	1.2865	1.01	0.312
Bio-pesticide has less ill effect on human health	1.435	0.1220	2.96	0.003
Bio-pesticide is Environmental friendly	2.3602	1.1148	1.82	0.069
Bio-pesticide is expensive	0.1426	0.0912	-3.05	0.002
Bio-pesticide are pest specific	0.0673	0.0684	-2.65	0.008
Other factors:				
Accessibility of bio-pesticide	6.7207	6.0651	2.11	0.035
Customers' demands chemical free vegetables	3.0250	2.2021	1.52	0.128
Goodness Of Fit Of The Model				
Number of Observations				300
LR Chi^2 (24)				75.77
Prob > Chi^2				0.000
Pseudo R^2				0.2608
Log likelihood				-107.396
Number Of Groups				10
Hosmer-Lemeshow $chi^2(8)$				9.99
Prob > chi^2				0.2656

Source: Output from STATA 11

Also, young farmers are usually more open to try new technologies because they are less risk averse than older farmers. This finding is consistent with a study by Harper *et al.* (1990) that revealed a negative relationship between age and IPM sweep nets adoption in Texas. However, the current study was inconsistent with a study by McNamara *et al*. (1991) that found a positive relationship between age and adoption of IPM on peanuts in Georgia.

Gender was found by the current study to affect bio-pesticide adoption positively at a statistical significance level of 10%. This therefore indicates that male vegetable farmers in the study districts have higher probability or odds (9.8176) of adopting bio-pesticide in controlling pest than their female counterparts. This could be due to the fact that females prefer easily accessible technologies, and so could be discouraged by the difficulty in obtaining raw materials and preparation of bio-pesticides. Moreover, several studies in Africa also have shown that women have lesser access to critical resources (land, cash, and labour), which often undermines their ability to carry out labour-intensive agricultural innovations (De Groote and Coulibaly 1998, Quisumbing *et al*., 1995). Contrary to the finding of this study, Shadbolt (2005, as cited in Cullen, Warner, Jonsson, & Wratten, 2008) reported that female viticulturalists in a wine producing region of New Zealand were twice as likely to use pest biological control. Household size of vegetable farmers also affected bio-pesticide adoption positively at a statistical significance level of 1%. This could be explained by the fact that other family members could be tasked to engage in the preparation of bio-pesticide that is generally regarded as difficult. This is consistent with a study by Gbegehn and Akubuilo (2013) that indicated that household size as a proxy for labour availability may influence the adoption of a new technology positively as its availability reduces the labour constraints. Furthermore, education was also found to positively affect the adoption of bio-pesticide in vegetable production at a statistical significance level of 5%. This implies that vegetable farmers with higher level of education have a higher probability or odds (14.7910) of adopting bio-pesticide. Education is thought to create a favourable mental attitude for the acceptance of new practices especially of information-intensive and management-intensive practices (Waller *et al*., 1998; Caswell *et al*., 2001). The present study empirically revealed positive relationship between vegetable farmers experience and bio-pesticide adoption in the studied area at a statistical significance level of 5%. This finding is expatiated by the fact that experience positively relates to technology adoption by increasing a decision maker's ability to assess the profitability of new technologies (Khanna, 2001).

Technical or institutional factors that affect adoption of bio-pesticide positively in the two districts include extension visitation, state regulations and membership of farmer-based organisations. State regulations banning the use of some chemical pesticides positively affect the adoption of bio-pesticide at a statistical significance level of 10%, holding other factors constant. This implies that vegetable farmers that adhere to state regulation have greater probability or odds (6.1218) of adopting bio-pesticide in controlling pest. This finding is consistent with a study by Kara *et al*. (2006) that also found a positive relationship between adoption of new technologies and state environmental regulations. Membership of farmer-based associations also positively affects bio-pesticide adoption at a statistical significance level of 1%. This implies that vegetable farmers who are part of farmer-based associations have greater probability or odds (1.7110) of adopting bio-pesticide in controlling pest. This is because such association could afford the farmers the knowledge in the area of new technologies and therefore enhance their ability of adoption. This finding is consistent with a study by Gbegehn and Akubuilo (2013) that posit a positive relationship between farmer-based association and adoption of new technologies.

Farm size was also found to negatively affect the adoption of bio-pesticides in vegetable production at a statistical significance level of 10%. This indicates that vegetable farmers with smaller farm sizes relatively have greater probability or odds (0.5039) of adopting bio-pesticide in controlling pest, *Ceteris paribus*. This finding is consistent with a study by Yaron, Dinar and Voet (1992) that demonstrated that a small land area may provide an incentive to adopt a technology especially in the case of an input-intensive innovation such as a labor-intensive or land-saving technology. However, it is inconsistent with studies by McNamara, Wetzstein, and Douce (1991); Abara and Singh (1993); Feder, Just and Zilberman (1985); Fernandez- Cornejo (1996) and Kasenge (1998).

To further elaborate on the factors affecting the adoption of bio-pesticide among vegetable farmers in the study districts, perceived bio-pesticide characteristics like environmental friendliness and less ill effect on human health were found to have positive influence on the adoption of bio-pesticides. However, the perceived pest specific nature and cost involved in bio-pesticide preparation were found to have negative influence on the adoption of bio-pesticide. The adoption level of bio-pesticide among vegetable farmers in the study districts is affected positively by its perceived ability to improve crop yield at a statistical significance level of 1%. This implies that vegetable farmers that perceive bio-pesticide to improve crop yield have greater probability or odds (3.7254) of adopting bio-pesticide in controlling pest in production. This finding is consistent with studies by Feder *et al.* (1985) and Adesina and Forson (1995) that found out that yield performance is one of the major characteristics that affect technology adoption positively. Also, the perception of bio-pesticides as being less harmful to human health by vegetable farmers affects bio-pesticide adoption positively at a statistical significance level of 1%. This implies that vegetable farmers that perceive bio-pesticide to have less ill effect on human health have a greater probability or odds (1.435) of adoption. Adegbola and Gardebroek (2007) reported that farmers have greater probability of adopting technologies that reduce risks. Furthermore, the perception of bio-pesticide by vegetable farmers as being expensive negatively affects the adoption level at a statistical significance level of 1%. This implies that vegetable growers that deem bio-pesticide preparation as being expensive have a lesser probability (0.1426) of adoption. This finding is consistent with a study by Khanna (2001) that indicates that there is negative relationship between technology adoption and cost of adoption. This is evident from the fact that farmers that do not have the required resources cannot afford expensive technologies. The pest specific nature of bio-pesticides also negatively affects bio-adoption among vegetable farmers in the study areas at a statistical significance level of 1%. This therefore implies that vegetable farmers that perceive bio-pesticide application in controlling pest as pest specific have lesser probability (0.0673) of adoption. This is because the specific nature of bio-pesticides implies that different forms of bio-pesticides would be required for eradicating different types of pest which therefore makes the technology more expensive.

The availability or accessibility of bio-pesticide in the study areas also positively affects bio-pesticide adoption at a statistical significance level of 5%. This implies that the more accessible bio-pesticide is to vegetable growers, the higher the probability (6.7207) of adoption. This is because the more available the raw materials needed for the preparations of bio-pesticides are in the community, the lesser the cost involved in the preparation.

4.2.2 Factors Influencing Vegetable Farmer's Choice of Pest Management Strategy

The result of Table 4.18 provides the multinomial logit-estimation for the factors influencing vegetable farmer's choice of specific pest management strategy. The base outcome for the model was non-application of pesticide. This implies that the following discussion of the results focuses on the impact of the explanatory variables on a specific pest management strategy choice relative to non-application of pesticide in vegetable farming. Because these relative effects are difficult to interpret, the study provides an alternative description of the estimation results. Table 4.18 lists estimates of the marginal effects of the independent variables on the probabilities associated with outcomes. The pseudo-R square for the model was 0.323 and the Likelihood Ratio Chi-Square test was significant. This implies that 32.3% of the variation in the dependent variable is explained by the explanatory variables. Thus, the independent variables offer a good explanation for vegetable farmers' decision to adopt one of the three alternatives methods of pest management in vegetable production in the Ashanti region.

Table 4.18: Marginal Effect of Factors Influencing Vegetable Farmer's Choice of Pest Management Strategy

Pesticide Mgt. Strategy	Bio-Pesticide Application	Chemical Pesticide Application	Non-Pesticide Application
Farmers' Characteristics:			
Age	-0.53***	0.07**	0.01
	(0.14)	(0.02)	(0.17)
Gender	-0.08	-0.20**	0.11
	(0.10)	(0.04)	(0.08)
Marital status	-0.14***	0.01	0.01*
	(0.05)	(0.55)	(0.01)
Household Size	-0.07**	0.04	-0.64

	(0.2)	(0.50)	(1.02)
Education	0.51***	0.16	-0.07
	(0.16)	(0.23)	(0.09)
Experience	0.38*	-0.25***	0.02
	(0.22)	(0.00)	(0.06)
Non-farm income	0.53***	-0.12**	0.05*
	(0.14)	(0.02)	(0.03)
Technical/Institutional:			
Extension Visitation	-0.01	-0.01	0.51
	(0.12)	(0.16)	(0.62)
State Regulations	0.01	-0.01*	0.18
	(0.17)	(0.01)	(0.12)
Membership of FBOs	0.08***	-0.57***	0.15
	(0.01)	(0.22)	(0.18)
Farm size	-0.02	0.58	0.57***
	(0.14)	(0.00)	(0.23)
Farmers' perception of pesticides:			
improves Crop Yield	0.51***	-0.52	0.04**
	(0.16)	(0.15)	(0.02)
less ill effect on human health	0.38*	-2.39*	0.21***
	(0.22)	(0.07)	(0.01)
Environmental friendliness	0.21***	0.01	0.05
	(0.05)	(0.55)	(0.11)
Cost of acquisition	0.05***	0.004	-0.02
	(0.01)	(0.50)	(0.43)
Pest specific	0.02	-0.07**	-0.01
	(0.15)	(0.03)	(0.70)
Other factors:			
Accessibility of pesticide	0.06***	0.14**	0.001
	(0.01)	(0.05)	(0.55)
Customers' demands chemical free vegetables	0.02**	-0.30***	0.004
	(0.01)	(0.00)	(0.50)
Goodness of Fit of the Model			
Number of Observations			300
LR Chi^2(54)			87.15
Prob > Chi^2			0.000
Pseudo R^2			0.323
Log Likelihood			-511.07

Note: ***,** & * denotes significance at 1%, 5% & 10% respectively
Reference or Base category for the Model is non-usage of pesticide
Standard errors in parentheses

From Table 4.18, on the average the young are 0.53 times more likely to adopt bio-pesticide in controlling pest in vegetable production than the aged relative to non-users of pesticides at a statistical significance level of 1%, keeping all other factors constant. This finding could be attributed to farmers' perception that technology development and the subsequent benefits require a lot of time to realize and the possibility of not living long enough to enjoy benefits discourages adoption by the aged (Caswell *et al*., 2001; Khanna, 2001). On the average an additional increase in the household size results in 0.07 marginal increases in the probability of adopting bio-pesticide in vegetable production relative to non-users of pesticide at a statistical significance level of 5%. The marginal increase in adoption of bio-pesticide associated with increase in household size can be attributed to the difficulty in bio-pesticide preparation. Therefore, the positive relationship between bio-pesticide adoption and household size could be attributed to its preparation difficulty relative to cinnamon. Moreover, household size as a proxy to labour availability may influence the adoption of a new technology positively as its availability reduces the labour constraints (Gbegehn & Akubuilo, 2013).

On the average, an increase in the educational level or schooling years of vegetable farmers results in 0.51 times increase in the probability of adopting bio-pesticide relative to non-users of pesticide as pest management strategy at a statistical significance level of 1%, all other factors constant. In a similar trend, a marginal increase in the experience of vegetable farmers results in 0.38 time probability of adopting bio-pesticide as pest management strategy in vegetable farming relative to vegetable farmers not currently applying pesticides, holding other factors constant. Education and farming experience is thought to increase farmer's knowledge of farming practices and reduce the amount of complexity perceived in a technology thereby increasing bio-pesticide adoption. This finding is consistent with a number of empirical studies (Huffman and Mercier, 1991; Putler and Zilberman, 1988) that have shown positive effect of education on the adoption of various types of technology in agriculture. The positive relationship between farming experience and bio-pesticide adoption is expatiated by the fact that experience positively relates to technology adoption by increasing a decision maker's ability to assess the profitability of new technologies (Khanna, 2001). The finding is consistent with the study of Lin (2001) that suggested positive relation between the adoption of hybrid rice in China and farmers experience. Membership of FBOs was found to have a positive marginal effect of 0.08 on bio-pesticide adoption at a statistical significance level of 1%. Membership of FBOs increases farmers knowledge and understanding of new technologies and hence the positive relationship with bio-pesticide adoption. This finding is consistent with a study by Gbegehn and Akubuilo (2013) that posit a positive relationship between farmer-based association and adoption of new technologies.

On farmers perception of bio-pesticide, the more vegetable farmers perceive bio-pesticide to have less ill effect on human health, improve crop yield and environmentally friendly the higher their probability of adopting bio-pesticide as pest management strategy relative to not using pesticide. Feder *et al.* (1985) argue that yield performance (or expected yield of new varieties) is one of the characteristics of improved varieties that affect farmers' technological adoption behaviours. This finding is consistent with the report of Adesina and Forson (1995) that farmers in Burkina Faso adopted a modern sorghum variety because it gave high yield, compared to the traditional sorghum variety that farmers planted in previous agricultural years. On the average, each additional increase in cost of acquisition of bio-pesticide results in 0.05 times reduction in the probability of adopting bio-pesticide in managing pest relative to non-usage of pesticide in managing pest at a statistical significance level of 1%. It is asserted that changes that cost little are adopted more quickly than those requiring large expenditures; hence both extent and rate of adoption of bio-pesticide is negatively dependent on the cost of a technology. Other factors such as accessibility of bio-pesticide and customers demand for chemical free vegetables were also found to have positive marginal effect on bio-pesticide adoption relative to non-usage pesticides at a statistical significance level of 1%, keeping other factors constant.

The result of Table 4.18 showed that gender, farming experience, and non-farm income have negative marginal effect on chemical pesticide application in vegetable production relative to non-pesticide application. On the average an increase in the age of vegetable farmers results in 0.07 marginal increases in the probability of adopting chemical pesticide in managing vegetable farms relative to non-application of pesticide at a statistical significance level of 5%, *Ceteris parabus*. Membership of FBOs and state regulations were found to have negative marginal effect on chemical pesticide application as pest management strategy relative non-application of pesticides, keeping other factors constant. Furthermore, less ill effect of pesticide and its specificity negatively influences chemical pesticide application as pest management strategy relative to non-usage of pesticide, keeping other factors constant. Customers demand for chemical free vegetables was found to have negative marginal effect of 0.30 on chemical pesticide application relative non-application of pesticide keeping other factors constant. However, chemical pesticide accessibility was found to have positive marginal effect on chemical pesticide application relative non-pesticide application keeping other factors constant.

The result of Table 4.18 showed that gender and non-farm income have positive marginal effect of 0.01 and 0.05 respectively on non-application of pesticide in vegetable production, keeping other factors constant. On the average, an increase in farm size of non-adopters of pesticide in managing pest in vegetable farming results in 0.57 marginal increases in the probability of non-adoption of pesticide in vegetable production keeping other factors constant. Furthermore, improvement in crop yield and environmentally friendliness were found to positively influence vegetable farmer's non-adoption of pesticide in controlling pest, keeping other factors constant.

4.2.3 Multinomial Logit Estimates on the Factors Influencing Adoption of Bio-Pesticide

Table 4.19 gives the multinomial logit-estimation results for the factors influencing vegetable farmer's choice of specific bio-pesticide type in pest management. The base outcome for the model was Cinnamon. This implies that the following discussion of the results focuses on the impact of the explanatory variables on a specific bio-pesticide choice relative to Cinnamon. Because these relative effects are difficult to interpret, the study provides an alternative description of the estimation results. Table 4.19 lists estimates of the marginal effects of the independent variables on the probabilities associated with outcomes. The pseudo-R square for the model was 0.261and the Likelihood Ratio Chi-Square tests was significant. This implies that 26.1% of the variation in the dependent variable is explained by the explanatory variables. Thus, the independent variables offer a good explanation for vegetable farmers' decision to adopt one of the three alternatives of bio-pesticide type in pest management.

Table 4.19: Marginal Effect of Bio-Pesticide Adoption

Bio-Adoption	**Neem**	**Neem +Pepper**	**Cinnamon**
Farmers' Characteristics:			
Age	-0.58***	-0.12**	-0.06*
	(0.21)	(0.06)	(0.03)
Gender	0.11	0.05	0.03
	(0.08)	(0.13)	(0.06)
Marital status	-0.02	-0.23	0.02
	(0.04)	(0.21)	(0.12)
Household Size	0.03*	0.06***	0.02
	(0.02)	(0.01)	(0.02)
Education	0.21***	0.02**	0.01
	(0.05)	(0.01)	(0.01)
Experience	0.05***	0.03***	0.03***
	(0.01)	(0.01)	(0.01)
Non-farm income	0.02	0.24	0.15
	(0.15)	(0.17)	(0.18)
Technical/Institutional:			
Extension Visitation	0.004***	0.06***	0.10
	(0.001)	(0.01)	(0.07)
State Regulations	0.50***	0.05	0.11
	(0.17)	(0.12)	(0.08)
Membership of FBOs	0.024***	0.03**	0.01*
	(0.01)	(0.02)	(0.01)
Farm size	-0.06*	-0.10*	-0.64
	(0.04)	(0.06)	(1.02)
Perception of Farmers' about Bio-pesticides:			
Bio-pesticides improves Crop Yield	0.12	0.38	0.02
	(0.07)	(0.70)	(0.06)
Bio-pesticide has less ill effect on human health	0.02***	0.07**	0.03**
	(0.01)	(0.03)	(0.01)
Bio-pesticide is Environmental friendly	0.53***	0.70***	0.05
	(0.14)	(0.20)	(0.06)
Bio-pesticide is expensive	-0.08	-0.27	-0.07
	(0.10)	(0.23)	(0.09)
Bio-pesticide are pest specific	-0.14***	-0.10*	-0.07**
	(0.05)	(0.05)	(0.2)
Other factors:			
Accessibility of bio-pesticide	0.51***	0.52**	1.46**
	(0.16)	(0.23)	(0.67)
Customers' demands chemical free vegetables	0.01	0.15	0.18
	(0.01)	(0.18)	(0.12)

Goodness of Fit of the Model	
Number of Observations	300
LR Chi^2(54)	74.13
Prob > Chi^2	0.002
Pseudo R^2	0.261
Log Likelihood	-104.87

Note: ***,** & * denotes significance at 1%, 5% & 10% respectively
Reference or Base category for the Model is Cinnamon
Standard errors in parentheses

From Table 4.19, on the average the young are 0.58 times more likely to adopt neem in controlling pest in vegetable production than the aged relative to cinnamon, keeping all other factors constant. Considering neem plus pepper relative to cinnamon adoption in vegetable production, on the average a decrease in age results in 0.12 times increase in the probability of adopting neem plus pepper in controlling pest, keeping all other factors constant. This finding could be attributed to farmers' perception that technology development and the subsequent benefits require a lot of time to realize and the possibility of not living long enough to enjoy benefits discourages adoption by the aged (Caswell *et al*., 2001; Khanna, 2001). On the average an additional increase in the household size results in 0.03 marginal increases in the probability of adopting neem in vegetable production relative to cinnamon. On the average, an increase in the household size of vegetable farmers results in 0.06 times increase in the probability of adopting neem plus pepper relative to cinnamon, all other factors constant. The marginal increase in adoption associated with increase in household size can be attributed to the difficulty in bio-pesticide preparation. Therefore, the positive relationship between neem adoption and household size could be attributed to its preparation difficulty relative to cinnamon. Moreover, household size as a proxy to labour availability may influence the adoption of a new technology positively as its availability reduces the labour constraints (Gbegehn & Akubuilo, 2013).

On average, each additional year of schooling results in 0.21 times increase, in the odds of adopting neem in managing pest relative to cinnamon adoption. On the average an increase in the schooling years of vegetable farmers results in 0.02 marginal increases in the probability of adopting neem plus pepper relative to cinnamon adoption, *Ceteris parabus*. Education is thought to reduce the amount of complexity perceived in a technology thereby increasing a technology's adoption. Studies have shown that one of the hindrances to widespread adoption of IPM as an alternative method to chemical control is that it requires greater ecological understanding of the production system. The result of this study is consistent with other studies reviewed, including Daku (2002) and Doss and Morris (2001), which revealed that education positively affected technology adoption, and the level of influence depended on the nature and type of the technology.

On the average, each additional years of experience in vegetable farming results in 0.05 times increase in the odds of adopting neem in controlling pest in vegetable production relative to cinnamon adoption, all other factors constant. Also, on the average an increase in the experience of vegetable farmers results in 0.03 marginal increase in the probability of adopting neem plus pepper relative to cinnamon in managing pest in vegetable production, all other factors constant. Vegetable farmers are relatively more experienced in the preparation of neem because of its easy accessibility and emphasis placed on it by governmental organisations during the early part of the diffusion process of bio-pesticide in Ghana in the late 1990s. Farmers experience may positively relate to technology adoption because it increases the farmer's ability to assess whether a new technology will be profitable (Khanna, 2001). The positive relationship of farmers experience in the adoption of neem or neem plus pepper relative to cinnamon is consistent with the study of Lin (2001) that showed that experience positively relates to the adoption of hybrid rice in China.

With regard to the influence of technical or institutional factors on bio-pesticide adoption, on the average, each additional increase in membership of farmers in Farmer Based Organisations (FBOs) results in 0.024 marginal increases in the probability of adopting neem relative to cinnamon in vegetable production, all other factors constant. On the average, an increase in farmers members of FBOs results in 0.03 marginal increases in the probability of adopting neem plus pepper in controlling pest relative to cinnamon keeping other factors constant. The commonest bio-pesticide source often introduced to farmers by governmental organisations in Ghana is neem, probably because of its relative accessibility and varying uses. Furthermore, vegetable farmers who are members of FBOs pull resources together for their individual benefits which give them the opportunity to adopt more technologies than others who are not members. The result of the current study is consistent with study by Gbegehn and Akubuilo (2013) that revealed positive relationship between cooperatives and technology adoption. On the average, a decrease in farm size results in 0.06 marginal increases in the probability of adopting neem relative to cinnamon in vegetable production keeping other factors constant. On the average, a decrease in farm size results in 0.10 marginal increases in the probability of adopting neem plus pepper relative to cinnamon in controlling pest keeping other factors constant.

Extension visitation marginally influenced the adoption of neem and neem plus pepper relative to cinnamon adoption keeping other factors constant. This implies that extension visitation increases the adoption of neem and neem plus pepper compared to cinnamon. State regulations had positive marginal effect on only neem adoption relative to the base outcome (Cinnamon). Extension programs and contacts with farmers are significant aspect in technology adoption. Much emphasis was placed on neem by agricultural extension officers during the introduction of bio-pesticides to farmers in the late 1990s. A report by IFPRI (1998) stated that a new technology is only as good as the mechanism of its dissemination to farmers. The result of this study is consistent with a study by Adesina and Forson (1995) that revealed positive relationship between extension visitation and technology adoption.

With regard to the farmer's perception of bio-pesticide, on the average, an additional increase in perception of bio-pesticide's less ill effect on human health results in 0.02 marginal increases in the probability of adopting neem relative to cinnamon, keeping other factors constant. On the average, an increase in farmer's perception of the less harmful effect of bio-pesticide on human health results in 0.07 times increase in the odds of adopting neem plus pepper relative cinnamon in vegetable production keeping other factors constant.

On the average, an increase in farmer's perception of the environmental friendly nature of bio-pesticides results in 0.53 marginal increases the probability of adopting neem relative to cinnamon in vegetable production keeping other factors constant. On the average, an increase in farmer's perception of the environmental friendly nature of bio-pesticides results in 0.07 marginal increases the odds of adopting neem plus pepper relative to cinnamon in vegetable production keeping other factors constant. In Ghana, there is ban on some conventional methods of controlling pest and this indirectly could encourage the adoption of newly introduced methods. Like the current study, many other studies have also found positive relationship between environmental regulations and the adoption of newly introduced technologies (Kara *et al*., 2006; Metcalfe, 2000; Mo and Abdalla, 1998).

Bio-pesticide specificity issues seem to be of more concern in the decision to adopt bio-pesticide in pest management. The probability of adopting neem, relative to cinnamon, decreased with the degree of bio-pesticide specificity in controlling pest. Also, on the average, a decrease in farmer's perception of the pest specificity of bio-pesticides results in 0.14 marginal increases in the odds of adopting neem in vegetable production relative to cinnamon, all other factors constant. On the average, a decrease in farmer's perception of the pest specificity of bio-pesticides results in 0.10 marginal increases in the odds of adopting neem plus pepper in vegetable production relative to cinnamon, all other factors kept constant. Bio-pesticide specificity in managing pest requires the employment of more and different forms of bio-pesticide in controlling different types of pest. This therefore increases adoption difficulty and cost involved in the adoption of bio-pesticide. Though neem like cinnamon is specific to pest treatment relatively enhance soil fertility and thus increase crop yields and enhance agriculture sustainability.

Considering another factor like farmer's accessibility of bio-pesticides, on the average, an increase in farmer's accessibility of bio-pesticide results in 0.51 marginal increases in the odds of adopting neem relative to cinnamon in controlling pest, keeping other factors constant. On the average, an increase bio-pesticide accessibility to farmers results in 0.52 increase in the probability of adopting neem plus pepper relative to cinnamon in vegetable production keeping other factors constant. Neem and pepper are relatively common materials than cinnamon in

Ghana, and hence the probability of their adoption compared to cinnamon. neem's utility far exceeds its common use as bio-pesticide to maintain agricultural yields with fewer synthetic inputs, and hence the emphasis on its planting. Neem has been used for thousands of years as a homeopathic cosmetic and health aid (Sharma *et al*., 2007), with both traditional and scientifically proven antibacterial, antiviral, anticancer, antimalarial, contraceptive, and dermatological applications. Moreover, bio-pesticides are predominantly self-prepared by vegetable farmers, and hence the difficulty in the preparation increases the difficulty in accessing them. The difficulty in accessing bio-pesticides therefore reduces the possibility of adoption among vegetable farmers.

4.2.4 Multinomial Logit Estimate on Factors Influencing Bio-Pesticide Adoption by Specific Vegetable Farmers

Table 4.20 presents the multinomial logit-estimation results of the factors influencing tomato, cabbage and carrot farmers' adoption of bio-pesticide in pest management. The base outcome for the model was Carrot farmers. This implies that the following discussion of the results focuses on the impact of the explanatory variables on tomato and cabbage farmers relative to carrot. Relatively, tomato and cabbage are common eating vegetables than carrot. Moreover, because the ordinary coefficients of the model are difficult to interpret, the study provides an alternative description of the estimation results. Table 4.20 provides estimates of the marginal effects of the independent variables on the probabilities associated with outcomes. The pseudo-R square for the model was 0.282 and the Likelihood Ratio Chi-Square test was significant. This implies that 28.2% of the variation in the dependent variable is explained by the explanatory variables. Thus, the independent variables offer a good explanation for the different vegetable farmers' decision to adopt bio-pesticide in pest management.

Table 4.20: Multinomial Logit Marginal Effect Estimates of Specific Vegetable Farmers Adoption of Bio-Pesticide

Bio-Adoption	**Tomato Farmers**	**Cabbage Farmers**	**Carrot Farmers**
Farmers Characteristics:			
Age	-0.02***	-0.02*	0.03
	(0.01)	(0.01)	(0.01)
Gender	-0.23	-0.01	-0.14
	(0.18)	(0.03)	(0.42)
Marital Status	0.16	0.06	-0.07
	(0.16)	(0.09)	(0.12)
Household Size	0.32**	0.75**	0.02
	(0.15)	(0.34)	(0.06)
Education	0.20**	0.05	0.06
	(0.10)	(0.05)	(0.07)
Experience	1.15*	0.10***	0.06***
	(0.59)	(0.03)	(0.02)
Non-farm income	0.64	0.41	0.43
	(0.44)	(0.34)	(0.33)
Technical/Institutional:			
Extension Visitation	0.54**	0.31	0.40
	(0.23)	(0.42)	(0.50)
State Regulations	0.06	0.02	0.01
	(0.05)	(0.05)	(0.02)
Membership of FBOs	0.44**	0.58**	0.02**
	(0.20)	(0.27)	(0.03)
Farm Size	-0.30***	-0.16*	-1.35***
	(0.11)	(0.09)	(0.37)
Perception of Farmers' about Bio-pesticides:			
Bio-pesticides improves Crop Yield	0.02	0.02	0.01
	(0.03)	(0.02)	(0.04)
Bio-pesticide has less ill effect on human health	0.58**	0.04	0.04
	(0.28)	(0.07)	(0.44)
Bio-pesticide is Environmental friendly	0.02	0.11	0.13
	(0.03)	(0.08)	(0.18)
Bio-pesticide is expensive	-0.07	-0.07	-0.57
	(0.12)	(0.19)	(0.21)
Bio-pesticide are pest specific	-0.78**	-0.06	-0.38
	(0.32)	(0.12)	(0.28)
Other factors:			

Accessibility of bio-pesticide	0.08**	0.61**	0.02
	(0.03)	(0.29)	(0.02)
Customers' demands chemical free vegetables	0.45	0.54	0.63
	(0.39)	(0.44)	(0.33)
Goodness of Fit of the Model			
Number of Observations			300
LR $Chi^2(54)$			80.15
Prob > Chi2			0.0057
Pseudo R^2			0.2823
Log Likelihood			-101.86

Note: ***,** & * denotes significance at 1%, 5% & 10% respectively
Reference or Base category for the Model is Carrot Farmers
Standard errors in parentheses

From Table 4.20, an increase in the age of tomato farmers (holding the age of other vegetable farmers constant), results in a 0.02 decrease in the probability of tomato farmers adoption of bio-pesticide over carrot farmers. Similarly, if the age of cabbage farmers increases (holding the age of other vegetable farmers constant), then the probability of cabbage farmers adoption of bio-pesticide over carrot farmers decreases by 0.02. This therefore implies that the young tomato and cabbage farmers adopted bio-pesticide in vegetable production relative to carrot farmers. This is not surprising since younger farmers are more profit motivated and bio-pesticide adoption was found to be more profitable in both tomato and cabbage farming compare to carrot farming. On the average, each additional increase in the household size of tomato farmers results in 0.32 marginal increases in the probability of adopting bio-pesticide in tomato farming relative to carrot farmers in the study area, holding other factors constant. Also, on the average, each additional increases in the household size of cabbage farmers results in 0.75 marginal increases in the probability of adoption of bio-pesticide in cabbage farming relative to carrot farmers, holding other factors constant. The positive relationship between tomato and cabbage farmers' adoption of bio-pesticide and household size is attributed to the labour intensive nature of production. Moreover, tomato and cabbage farmers relatively operate larger farm sizes compare to carrot farmers and hence are more labour intensive.

On average, each additional year of schooling results in 0.20 times increase, in the odds of adopting bio-pesticide in tomato farming relative to carrot farming, all other factors constant. Ehler and Bottrell (2000) indicate that one of the hindrances to widespread adoption of IPM as an alternative method to chemical control is that it requires greater ecological understanding of the production system and hence the unsurprising influence of education on the adoption of bio-pesticide by tomato farmers.

From Table 4.20, an increase in the farming experience of tomato farmers (holding the experience of other vegetable farmers constant), results in 1.15 marginal increase in the probability of tomato farmers adopting bio-pesticide over carrot farmers. The positive marginal effect of the farming experience of cabbage farmers' relative to carrot farmers on bio-pesticide adoption increases by 0.10, keeping other factors constant. The positive influence of farmers experience on adoption of bio-pesticide by vegetable farmers is because it increases the farmer's ability to assess whether a new technology will be profitable (Khanna, 2001).

Technically, an increase in the extension visitation of tomato farmers (holding the extension visitation of other vegetable farmers constant), results in 0.54 increases in the probability of tomato farmers over carrot farmers in the adoption of bio-pesticide, keeping other factors constant. The result of the effect of extension visitation on the adoption of bio-pesticide by tomato farmers is consistent with the finding of Yaron, Dinar and Voet, (1992) that showed that the influence of extension services can counter balance the negative effect of lack of years of formal education in the overall decision to adopt some technologies. The positive marginal effect of tomato farmer's membership of FBOs relative to carrot farmers in the adoption of bio-pesticide is 0.44 keeping other factors constant. Similarly, on the average, each additional increase in the cabbage farmer's membership of FBOs results in 0.58 marginal increases in the probability of adopting bio-pesticide in vegetable production relative to carrot farming, keeping other factors constant.

Furthermore, an increase in the farm size of tomato farmers (holding the farm size of other vegetable farmers constant), results in 0.30 decreases in the probability of tomato farmers over carrot farmers in the adoption of bio-pesticide. On the average, each additional increase in the farm size of cabbage farmers results in 1.35 marginal decreases in the probability of adopting bio-pesticide relative to tomato and cabbage farmers, all other factors constant. The negative relationship between farm size and adoption of bio-pesticide by tomato and cabbage farmers relative to carrot farmers is not surprising because vegetable farming in the country is predominantly labour intensive. Yaron, Dinar and Voet, (1992) demonstrated that a small land area may provide an incentive to adopt a technology especially in the case of an input-intensive innovation such as a labor-intensive.

Considering the influence of the perception of vegetable farmers about bio-pesticide on adoption, each additional increase in the tomato farmer's perception of bio-pesticides having less ill-effect on human health results in 0.58 marginal increases in the probability of tomato farmer's adoption of bio-pesticide relative carrot farmers, keeping other factors constant. On the average, each additional increase in tomato farmer's perception of bio-pesticide being specific in pest control results in 0.78 decreases in tomato farmer's adoption of bio-pesticide relative to carrot farmers, all other factors constant. An increase in bio-pesticide accessibility to tomato farmers results in 0.08 increases in the probability of adopting bio-pesticide relative to carrot farmers, holding the accessibility of bio-pesticide to other vegetable farmers constant. In a similar vein, on the average, each additional increase in the accessibility of bio-pesticide to cabbage farmers results in 0.61 marginal increases in the probability of adopting bio-pesticide relative to carrot farmers, other factors constant.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

In this chapter, the summary of findings from the study and policy recommendations is presented. The limitations of the study and suggestions of future research are also provided.

5.1. Conclusion

Based on the findings of the study, several conclusions are made on the pest management strategies, chemical pesticide usage, farmer's perception of bio-pesticides and factors influencing their adoption level of bio-pesticide in the study districts which are explicitly summarized below.

The major pest management strategies revealed by the study included bio-pesticide application, chemical pesticide application and physical and cultural practices. The vegetable farmers however predominantly relied on chemical pesticides in controlling pest and diseases because of their relative effectiveness. Moreover, chemical pesticide application in controlling pest and diseases was relatively profitable compare to both bio-pesticide application and cultural and physical practices. Furthermore, the chemical pesticide users in vegetable production were relatively confronted with more problems in handling pest and diseases so perceived to require more effective methods. The heavy reliance on chemical application can therefore be attributed to the relatively extensive nature of disease and pest attack. The differences in the pest management strategies could therefore be attributed to differences in the severity of pest and disease attack. Whereas the chemical pesticide users frequently obtained their chemical pesticides from dealers in the district, the adopters of bio-pesticide prepared it themselves. This could be explained by the fact that whereas chemical pesticides are readily available in the market, bio-pesticides are yet to be commercialized in Ghana. Relatively, the majority of the users of chemical pesticide often encountered problems in the usage of chemical pesticides in controlling pest and diseases. The major problem encountered by the users of chemical pesticides was pest persistence. However, the major problem encountered by the adopters of bio-pesticide application was the difficulty in the preparation of bio-pesticides.

The study further concluded that though majority of the vegetable farmers were aware of bio-pesticide, only 14 percent adopted it as the main pest management strategy. The low level of bio-pesticide adoption was attributed to the relative less effectiveness level compared to chemical pesticide application. Moreover, the gross margin per hectare of chemical application was relatively higher than the gross margin per hectare of bio-pesticide application. The relatively higher gross margin of chemical pesticide users in vegetable production is attributed to their relatively higher yields in the short run. In Ghana, the yield difference that often reduces the relative gross margins of biological methods of farm management is not compensated by government payments and price premiums as in many European countries. The low level of adoption can further be attributed to the difficulty in preparation of bio-pesticide, cost of bio-pesticide; slowness to work, pest specificity and lack of technical know-how were identified as the main reasons that hinder adoption of bio-pesticide.

The estimated binary logit demonstrated that male gender, household size and the educational level of the vegetable farmers positively influenced the adoption of bio-pesticides. However, age of farmers was found to influence bio-pesticide adoption negatively. The institutional or technical factors that affect bio-pesticide adoption include state regulations and membership of FBOs. Both state regulations and membership of FBOs were found to affect bio-pesticide adoption positively. However, consistent with a priori expectation, farm size was found to affect bio-pesticide adoption negatively. Farmer perception variables such as bio-pesticides' environmental friendliness and its lower ill effect on human health were found to influence adoption positively. However, farmer's perception of bio-pesticides as being pest specific and expensive in terms of preparation and accessibility were found to influence adoption negatively.

The result of the study revealed that, vegetable farmers application of bio-pesticide as pest management strategy was influenced by age, household size, education, farm experience, membership of FBOs, crop yield improvement, less ill effect on human health, environmental friendliness and cost of acquisition, accessibility of pesticide and customers' demands chemical free vegetables. Contrary to bio-pesticide adoption, chemical pesticide application by vegetable farmers was found to be influenced negatively by perceived chemical pesticide characteristics such as ill effect on human health and pest specificity. Non-application of pesticide as pest management strategy was found to be influenced by farm size, improvement in crop yield, and less ill effect on human health.

From the multinomial logit estimates, the factors that positively influenced the adoption of neem relative to cinnamon in vegetable production were household size, education, experience, extension visitation, state regulations, membership of FBOs, accessibility of bio-pesticides and bio-pesticides less ill effect and environmental friendly nature. Apart from state regulations, all these factors also positively influenced vegetable farmer's adoption of neem plus pepper relative to cinnamon. The factors that negatively influenced neem adoption in vegetable production relative to cinnamon were age, farm size, and the specificity of bio-pesticides. These factors also negatively influenced the adoption of neem plus pepper relative to cinnamon in vegetable production.

From the study, the major factors that positively influenced tomato farmer's adoption of bio-pesticide relative carrot farmers included household size, education, farming experience, extension visitation, membership of FBOs, the less ill effect of bio-pesticide on human health, the environmental friendliness of bio-pesticide, and the accessibility of bio-pesticide. The factors that negatively influenced tomato farmer's adoption of bio-pesticide relative to carrot were age, farm size and the specificity of bio-pesticides. The major factors that also positively influenced cabbage farmer's adoption of bio-pesticide relative to carrot farmers included household size, farming experience, membership of FBOs, and bio-pesticide accessibility to the farmers. However, only farm size and age negatively influenced cabbage farmer's adoption of bio-pesticide relative to carrot farmers. Based on these findings, the study can conclude that a number of factors have to be considered as policy targets if the adoption of bio-pesticides in vegetable production is to be improved in the study districts.

5.2. Policy Recommendations

Based on the findings of the study, a number of policy recommendations that could possibly enhance the adoption level of bio-pesticides in controlling diseases and pest among vegetable farmers in the two districts in the Ashanti region of Ghana are made.

To begin with, based on the positive relationship between bio-pesticide adoption among vegetable farmers and membership with Farmer Based Organisations (FBOs), the vegetable farmers in the survey districts should be encouraged to join Farmer Based Organisations (FBOs). This would make information on bio-pesticide adoption readily accessible and available to farmers and hence enhance their probability of adoption of bio-pesticides in controlling pest and diseases in vegetable production.

The government should put measures in place to encourage the creation of separate market for organically produced vegetables. A relatively higher prices for organically produced vegetables would encourage supply and hence production. Education of consumers on the benefits of organically produced vegetables could also spur on demand and further encourage supply. Both demand and supply side policies would spur on bio-pesticide adoption among vegetable growers in the study areas.

Moreover, farmers in the study districts should be trained in the preparation and usage of bio-pesticides as well as the importance of adopting environmentally friendly pesticides. The vegetable farmers should be trained on the right amount of litres of bio-pesticides to apply per land acre. Moreover, at present the bulk of the bio-pesticides used are self-prepared. Regulations should be put in place to encourage the production of biological pesticides for commercial purposes in Ghana. Commercialization of biological pesticides would also improve its accessibility and hence encourage its adoption in Ghana. Rural unemployed and educated youths should be encouraged to establish small-scale bio-pesticide production units at village or block level by making soft loans available to them. Farmer organisations could produce them through comparative effect measures, such as training to the potential entrepreneurs, provision of institutional credit, subsidies and exemption from taxes and duties would stimulate production of bio-pesticides. Further, the government at the initial stages of this effort should relax bio-pesticide manufacturing units' registration and quality control requirements. The process of registration should be less cumbersome and relatively cheaper so as to encourage potential entrepreneurs. Commercialization could make the product readily available to farmers with larger farm operations who are often discouraged by preparation difficulty.

Based on the result of the study that extension visitation positively influences bio-pesticide adoption in vegetable production, the government should put in place measures to increase extension visitation to farmers. There is the need to provide vehicles to extension officers, enhance roads leading to farms, and provide other incentives to extension officers to increase their visitation to farmers. This policy could enhance tomato farmer's adoption of bio-pesticide relative to carrot farmers.

The government of Ghana should encourage bio-pesticide application by making payments to adopters to compensate for the relatively lower yields of farmers. The government payments coupled with price premiums for adopters of bio-pesticide would make adoption of bio-pesticide more economically profitable compared to the conventional methods of controlling pest in vegetable production. This therefore will trigger farmers interest in adoption and therefore increase the level of bio-pesticide adoption in vegetable production in Ghana.

In recent years, the central government has banned a number of pesticides for use in agriculture in consideration of their adverse effects on environment and human health. Despite this, many of these are available in the market. For example, DDT, Lindane, Thiodan and Endosulfan, which are permitted for use for malaria control, are widely used in agriculture. Further, many pesticides that have been banned elsewhere in the world are available to Ghanaian farmers. Lower prices of such pesticides induce farmers to use them. A number of spurious pesticides are available in the market because of lack of strict enforcement of regulations and/or regulatory loopholes. Strict enforcement of the regulations governing production, use, distribution and quality of pesticides would help weed out spurious elements from the industry and would benefit the farmers.

5.3. Limitations and Suggestions for Further Study

The current study relied heavily on the memory of vegetable farmers for the data used in the analysis. Inaccuracies in their recall of issues during the past cropping season are likely to affect the results to some extent. Moreover, there is also the likelihood of perception errors. Further studies in this area should include other regions and other vegetable types so as to reduce the extent of perception errors. The recall errors can also be reduced by conducting the study in several periodic years and widening the geographical scope and the sample size. The current study was limited to three vegetable types and three bio-pesticide types, hence future study could expand the scope by including other vegetable types and bio-pesticide types.

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APPENDIX

QUESTIONAIRE

COLLEGE OF AGRICULTURE AND NATURAL RESOURCE

DEPARTMENT OF AGRIC ECONOMICS, AGRIBUSINESS AND EXTENSION

MPHIL AGRIC ECONOMICS

This questionnaire assesses the factors influencing farmer's adoption of bio-pesticide in the Mampong Municipality and Offinso North District. You are rest assured that the study is for only academic purposes; all and every information provided will therefore be treated with the needed confidentiality. Where responses have been provided, please tick the most appropriate to you. Thanking you in advance for your corporation.

VEGETABLE FARMERS

PERSONAL DATA

Name:……………………………………..

1. Gender:
   1. Male [ ] 2. Female [ ]

2. a. Actual age: ……………..(yrs)

   b. Age:
   1. Below 20 yrs [ ] 2. 20-39yrs [ ] 3. 40-49yrs [ ] 4. 50-59yrs [ ]
   5. 60yrs and above [ ]

3. Annual Income in the year 2011:
   a. On farm income (GH¢)……………………………………………………………
   b. Off-farm income (GH¢)……………………………………………………………

4. Marital status:
   1. Single [ ] 2. Married [ ] 3. Divorced [ ] 4. Separated [ ]

5. Household size (as of 2011):
   …………………………………………………………………..

6. Educational level in years: …………………………………………

7. Ethnic group:
   1. Asante [ ] 2. Fante [ ] 3. Others specify……………………

8. Religion:
   1. Christianity [ ] 2. Islamic [ ] 3. Traditional [ ] 4. Others specify……………

VEGETABLE CROP INFORMATION FOR THE YEAR 2011

9. Experience in vegetable production (in years)……………………………………………

10. Vegetable and Pest Attack [choose the major vegetables grown and provide information accordingly][write code where necessary]

Vegetable grown	Size (acre)	Output	Cost of production	Price per unit(GH¢)	Common pest	Extent of pest attack (acreage)	Problems on farm
1.Carrot							
2.Cabbage							
3.Tomato							
4.Others							

Common Pest [1. Caterpillar 2. Aphid 3. Butterfly/Moth 4. Beetles
5. Others specify………………………………………………]
Problems [1.Input Inadequacy 2.Post Harvest Losses 3.Pest and Disease 4.Storage Problem]

11. Indicate the cost per hectares of the listed Variable Inputs in the table

	Tomato (GH¢)	Cabbage (GH¢)	Carrot (GH¢)
Variable inputs			
Land preparation			
Planting Material			
Fertilizer cost			
Insecticide cost			
Bio-pesticide			
Labour			
Water cost			
Miscellaneous			

12. What was the yield per hectares in the production of the following vegetables?
    1. Tomato …………………...
    2. Cabbage ………………….
    3. Carrot …………………….

13. What was the farm gate price per hectares in the production of the following vegetables?
    1. Tomato GH¢ …………………...
    2. Cabbage GH¢ ………………….
    3. Carrot GH¢ …………………….

14. Pest Control Information[choose the method of pest control and provide information accordingly][write code where necessary]

Method Of Pest Control	Source of information on method	Effectiveness	Ever encountered problem	If yes, what problem	Solution
1.No Control					
2.Physical Control					
3.Chemical Pesticide Usage					
4.Bio-Pesticide					
5.Cultural					
6. IPM					
7. Others					

Source of method information [1.Own Experience 2.Pesticide Dealers 3.Extension Officers 4. Others specify]
Effectiveness [1.Very effective 2.Effective 3.Less effective 4.Not effective at all]
Ever encountered problem [1.Yes 2. No]
Problems [1.cost 2. Pest persistence 3. Health hazards 4. Difficulty in preparation 5. Accessibility 6. Others specify]
Solution [1.Wearing of cloves and covering mouth with cloth 2.Purchase of already prepared bio-pesticides 3.Less cost alternatives 4. More effective alternatives 5. More accessible alternatives 6.Others specify]

CHEMICAL PESTICIDE USAGE

15. Do you use chemical pesticides to control pest and diseases on your vegetable farm?
    1. Yes [ ] 2. No [ ]

16. When do you use chemical pesticides?
    1. During severe attack [ ]
    2. During initial attack [ ]
    3. Before attack [ ]
    4. Other practices [ ]

17. In which particular season do you apply chemical pesticide?
    1. Dry season [ ]
    2. Raining season [ ]
    3. Both seasons [ ]

18. If yes to (question 12), why do you use chemo-synthetic pesticides?
    1. Toxic compounds for pests [ ]
    2. Treatment purpose [ ]
    3. Productivity improvement [ ]
    4. Other reasons specify…………

19. How do you spray the chemical pesticide(s)?
    1. With sprayer [ ] 2. Other means (please specify):……..

20. If you use a sprayer machine, from where do you get it?
    1. Personally owned [ ]
    2. Rented from other source (please specify):………

21. Who sprays the pesticide on the crops?
    1. Yourself [ ]
    2. Hired labour [ ]

22. What protective measures do you adopt during pesticide spraying?
    1. Cover face with cloth [ ]
    2. Cover body and face with cloth [ ]
    3. Other means [ ]

23. From where do you get pest control advice?
    1. Neighbor [ ]
    2. Extension technical/block supervisors [ ]
    3. Relatives [ ]
    4. Pesticide dealers [ ]
    5. Radio [ ]
    6. Television [ ]
    7. Other sources [ ]

24. Chemical pest usage information[rank chemical pesticides used in terms of amount of usage and provide information accordingly][write code where necessary]

Chemical pesticide	Major type of chemical pesticide used	Source of pesticide	Volume (litres)	Amount used per acre	Cost Per Litre	Frequency(no. of times per season)
Tomato						
Cabbage						
Carrot						

Type of chemical pesticide [1. Karate 2.DDT 3. Mektin]
Source [1.dealer in community 2.dealer in district 3. Dealer outside district 4.MoFA
5. Others………………]

25. Indicate the trend of chemo-synthetic pesticide usage for the past decade by your household?
1. Increasing Trend [ ] 2. Constant Trend [ ] 3. Decreasing Trend [ ]

26. Are you confronted with any challenges in the usage of chemo-synthetic pesticides in controlling pest and diseases?
1. Yes [ ] 2. No [ ]

27. What challenges do you often face in the usage of chemo-synthetic pesticides to control pest?
1. Pest Persistence [ ] 2. Lack of Funds [ ] 3. High Cost [ ] 4. Others specify….

PERCEPTION AND AWARENESS OF BIO-PESTICIDES

28. Indicate your awareness and perception level on the application of bio-pesticide

Variables	Aware	Unaware	Agree	Not Sure	Disagree
	1	0	1	0	-1
bio-pesticides are less harmful to human health					
bio-pesticides are environmentally friendly					
bio-pesticides produce a higher crop yield					
bio-pesticides are pest specific					

29. Have you ever used bio-pesticides in vegetable production before?
1. Yes [ ] 2. No [ ]

30. If yes, which forms of botanical pest control have you ever used or continue to use in vegetable production?
1. Neem [ ] 2.Neem plus Pepper 3.[ ] Cabbage [ ] 4.Garlic [ ]
4. Others specify………

31. If yes, what is your source?

1. Self-prepared [ ] 2. From colleagues [ ] 3. Chemical shops [ ] 4. MoFA [ ]
5. Other specify……….

PERCEPTION TOWARDS PESTICIDE USAGE

32. Reasons for Bio-pesticides Usage [Tick Your Level of Agreement]

Variables	Strongly Agree [5]	Agree [4]	Indifferent [3]	Disagree [2]	Strongly Disagree [1]
Expect a reduction in crop loss					
Perceived better environmental benefits					
Presentation in small package					
Easy to get					
Quick action					
Effective pest control					
Increased yield					
Less costly					
Improved produce quality					
Sustained yield					
Consideration of state regulations					
Consideration of customers' demands					
Less ill effect					
Don't know					

33. Reasons for not Using Bio-Pesticides[Tick Your Level of Agreement]

Reasons	Strongly Agree [5]	Agree[4]	Indifferent[3]	Disagree[2]	Strongly Disagree[1]
Cost of bio-pesticide					
Difficulty in preparation					
Effectiveness of bio-pesticide					
Slow to work					
Not effective for all insect pest					
Specific in action					
Lack of technical knowledge					

TECHNICAL FACTORS INFLUENCING ADOPTION OF BIO-PESTICIDES

34. Do you belong to any formal farming association?
    1. Yes [ ]   2. No [ ]

35. If yes, does the association provide any technical advice?
    1. Yes [ ]   2. No [ ]

36. What form of technical advice is provided by the association?
    1. Appropriate usage of pesticides [ ] 2. Application of biological methods [ ]
    3. Application of cultural practices [ ] 4. Other forms of training specify………

37. How far is the Distance of bio-pesticide source from farm?
    ………………………………………….. (Km)

38. Do you encounter any challenges in the usage of bio-pesticides?
    1. Yes [ ] 2. No [ ]

39. If yes, what is/are the Challenges?
    1. Difficulty in preparation [ ]
    2. Difficulty in obtaining raw materials [ ]
    3. Health hazards [ ]
    4. Low yield of vegetables [ ]
    5. Different kinds of bio-pesticides are required for different pests on the same farm [ ]
    6. Not effective [ ]

40. Do you receive any form of extension services on bio-pesticide usage?
    Yes [ ] No [ ]

41. If yes, what is the number of times of extension agents' visitation in a week?
    1. Once in a week [ ] 2. Twice in a week [ ] 3. Thrice in a week [ ]
    6. more than thrice in a week [ ]