

**Adoption of biological control methods in crop production by resettled smallholder farmers: Case study of ward 19, Goromonzi District Zimbabwe.**

**A dissertation submitted in partial fulfilment of the requirements for the Master of Science Degree in Food Security and Sustainable Agricultural (Production)**

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## DECLARATION

I hereby declare that the research project entitled “**Adoption of biological control methods in crop production by resettled smallholder farmers: Case study of ward 19, Goromonzi District Zimbabwe.**” submitted to Bindura University of Science Education, Department of Agricultural Economics, Education and Extension is a record of an original work done by me under the guidance and supervision of **Dr .A. Kanda** and this work is submitted in partial fulfilment of the requirements for the award of a Master of Science Degree in Food Security and Sustainable Agriculture. The results embodied in this thesis have not been submitted to any University or Institute for the award of any degree of diploma.

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## **DEDICATION**

This thesis is dedicated to my future kids as a reminder to go for their dreams especially the ones written down.

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## ABSTRACT

The biggest problem facing global agriculture will be feeding the 10 billion people who will be on the earth by 2050. Agricultural production should be increased through sustainable solutions to eradicate hunger but protect human and environmental health. The prevalence of synthetic chemical pesticides and their effects has raised concern. The use of biological methods for pest and disease control, currently emphasised is still negligible in resource-constrained settings. The study assesses the adoption of bio-control methods by resettled smallholder horticultural farmers in ward 19, Goromonzi district, Zimbabwe through a cross sectional survey. The adoption of biological control methods by farmers were studied using their knowledge, attitudes and practices by self-administering a closed-ended questionnaire to 30 randomly selected participants. Knowledge, attitudes and practices of participants were scored using Bloom's cut-off points. Factors influencing adoption of bio-control methods were determined by multinomial logistic regression. Results indicated that farmers had poor knowledge (38%) and practices (30.7%), and negative attitude (58%) regarding bio-control methods. Farmers with knowledge of bio-control were 177 times significantly more likely to adopt bio-control than those without (OR = 177.149,  $p = 0.002$ , 95%CI = 6.798; 4 616. 213). There was a decreased likelihood of famers who had used bio-control methods than those who had not to adopt bio-control methods for crop production although not significant (OR = 0.029,  $p = 0.076$ , 95% CI = 0.061, 1.439).

**Key words:** bio-control; crop production; Goromonzi; resettled; smallholder farmer

## **LIST OF ACRONYMS AND ABBREVIATIONS**

ABC	Augmentative Biological Control
CBC	Classical Biological Control
BCM	Biological Control Methods
EUCAP	European Union's Common Agricultural Policy
FAO	Food and Agriculture Association
IPM	Integrated Pest Management
IPDM	Integrated Pest and Disease Management

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# CHAPTER 1

## INTRODUCTION

### 1.1 Background of the study

The biggest challenge facing global agriculture will be feeding the 10 billion people who will be on the earth by 2050 (Jaiswal, 2022). This suggests that increased agricultural productivity, particularly crop production, is necessary to meet household needs. Smallholder farmers are especially important for feeding the world's population in developing nations as they produce the majority of food (Khan, 2015). Locally, Zimbabwe resettled over 210 520 smallholder farmers in 2 000 (Moyo, 2011). This has implications on plant productivity, particularly pests and plant diseases which affect productivity.

There are concerns about the over-utilisation of various synthetic pesticides (Kfir, 2019). However, recent developments point to bio-control methods. According to Jaiswal (2022) factors contributing to the expansion of bio-control methods under sustainable agriculture include: (i) emergence of new invasive species and pesticide-resistant pest strains, (ii) climate change, and (iii) specialty agriculture. Increased productivity comes with challenges of pest and diseases control, the biggest threat to food security. This includes pests that are both native and invasive, especially with biotic and abiotic stressors as the major limitation to food production (Woltz, 2018). These problems are important on a global scale (Ingram, 2011). However, effective and sustainable pest control interventions achieve sustainable development goals (SDGs) e.g., ensuring safety and improving living conditions, provided other factors are taken into consideration (Ratt et al., 2022).

The disadvantages of using pesticides were suggested by Machezano et al. (2020) include: (i) environmental degradation compromising the natural ecosystem and human health, (ii) the eradication of more aggressive pest populations, (iii) the reduction of pollinators and natural predators. Therefore, sustainable means are called for to boost yields, end hunger and protect the environment and human health (Barrat 2018). In view of sustainability, this has sparked the search for and implementation of pest control options that are friendly to human health and the environment such as the bio-control option (Nji et al, 2022).

### 1.2 Problem statement

The employment of biological management techniques which reduce pest populations by using natural enemies appears a promising sustainable approach. However, despite significant

benefits of utilising biological control methods to manage pests and diseases, the overall rate of reliance on biological control as the primary pest control method is still negligible (Farhana, 2017). The efficacy of bio-control agents under commercial field conditions has been questioned (Souza 2019; Instantine et al., 2020; Wallas, 2021). Further, the techniques have been successfully applied in large-scale agriculture for years, but smallholder farmers have not adopted them to the same extent (Van Lenteren, 2018). It then appears that there are no published studies on the adoption of pest bio-control methods for pests by resettled smallholder farmers in Zimbabwe under field conditions. The current study investigates factors influencing the adoption of bio-control methods using a case study setting involving resettled smallholder farmers.

### **1.3 Objectives**

#### **1.3.1 Main objective**

To assess the adoption of bio-control methods for pests and disease management by resettled smallholder farmers

#### **1.3.2 Specific objectives**

- To determine the knowledge, attitudes and practices of resettled smallholder farmers ward 19, Goromonzi district, Zimbabwe, in bio-control for insects pest control
- To establish perceived benefits and challenges associated with use of biological pest control methods under field conditions.
- To determine the likelihood of adopting bio-control methods for pests by resettled small-holder farmers.

### **1.4 Research questions**

1. What are the perceived factors influencing adoption of bio-control methods?
2. What characteristics of participants influence use biological control methods?
3. What is attitudes of resettled smallholder farmers on adopting biological control influenced the adoption?
4. What are the determinants to the adoption of biological control methods by smallholder farmers?

### **1.5 Justification**

Designing or reviewing agricultural policy and practice are key to sustainable crop production. It is important to assess the knowledge, attitudes and current practices of resettled smallholder farmers in order to establish training needs and plan for extension services. Understanding the factors influencing adopting a technology is key to tailor make training to meet their specific

needs. Resettling farmers in Zimbabwe was an adhoc process where farmers' knowledge and practices were not considered requiring a lot of investment in extension services. Findings from the study may be important to inform agricultural policy and practice regarding the adoption of sustainable agricultural technologies with context-specific field evidence which can be done at scale. They may also add to the growing literature on sustainable agricultural technologies, particularly, bio-control methods for pest and disease control.

### **1.6 Scope**

This project survey focuses on smallholder farmers in ward 19, Goromonzi district, Mashonaland East province producing horticultural crops with the aim to assess their adoption of biological control methods in controlling insects' pests and diseases in crop production. The study explored the characteristics of farmers, their knowledge of biological control methods, attitudes and agricultural practices. It also explored factors determining the adoption of biological control methods by smallholder farmers in ward 19.

### **1.7 Outline of thesis**

The purpose of this chapter is to explain why the researcher decided to carry out this study through a problem definition and problem articulation. This chapter also outlines the study's objectives and provides a framework for the procedures followed for this research project. The second chapter analyzes the material that is pertinent to the use of biological control techniques as a long-term substitute for managing pests and diseases. The technique, which covered research design, data collecting, and data analysis, was presented in Chapter 3. The findings for each of the research's three specific objectives are covered in Chapter 4. The findings are discussed in Chapter 5 with references to studies conducted by other researchers, and the findings are concluded in Chapter 6 with recommendations.

## 1.8 Reference List

Aldini, G. M., Martono, E., & Trisyono, Y. A. (2019). Diversity of natural enemies associated with refuge flowering plants of *Zinnia elegans*, *Cosmos sulphureus*, and *Tagetes erecta* in rice ecosystem. *Jurnal Perlindungan Tanaman Indonesia*, 23(2), 285-291.

Barratt, B. I. P., Moran, V. C., Bigler, F., & Van Lenteren, J. C. (2018). The status of biological control and recommendations for improving uptake for the future. *BioControl*, 63, 155-167.

Constantine, K. L., Kansime, M. K., Mugambi, I., Nunda, W., Chacha, D., Rware, H., et al. (2020). Why don't smallholder farmers in Kenya use more biopesticides? *Pest Manag. Sci.* 76, 3615–3625. doi: 10.1002/ps.5896

Farhana, J. A., Hossain, M. F., & Mowlah, A. (2017). Antibacterial effects of guava (*Psidium guajava* L.) extracts against food borne pathogens. *Int. J. Nutr. Food Sci*, 6, 1-5.

Ingram, J. (2011). A food systems approach to researching food security and its interactions with global environmental change. *Food security*, 3, 417-431.

Jaiswal, D. K., Krishna, R., Chouhan, G. K., de Araujo Pereira, A. P., Ade, A. B., Prakash, S., ... & Verma, J. P. (2022). Bio-fortification of minerals in crops: current scenario and future prospects for sustainable agriculture and human health. *Plant Growth Regulation*, 98(1), 5-22.

Khan, A., Khan, S., Khan, M. A., Qamar, Z., & Waqas, M. (2015). The uptake and bioaccumulation of heavy metals by food plants, their effects on plants nutrients, and associated health risk: a review. *Environmental science and pollution research*, 22, 13772-13799.

Kfir, R., Overholt, W. A., Khan, Z. R., & Polaszek, A. (Eds.). (2019). *Biological control in Africa: enhancing research, development and implementation*. CABI

Machekano, H., Mvumi, B. M., & Nyamukondiwa, C. (2020). *Plutella xylostella* (L.): Pest status, control practices, perceptions and knowledge on existing and alternative management options in arid small-scale farming environments. *International Journal of Pest Management*, 66(1), 48-64.

Moyo, S. (2011). Three decades of agrarian reform in Zimbabwe. *Journal of Peasant Studies*, 38(3), 493-531.

Nji, Q. N., Babalola, O. O., Ekwomadu, T. I., Nleya, N., & Mwanza, M. (2022). Six main contributing factors to high levels of mycotoxin contamination in African foods. *Toxins*, 14(5), 318.

Ratto, F., Bruce, T. J. A., Chipabika, G., Mwamakamba, S., Mkandawire, R., Khan, Z., ... & Sait, S. M. (2022). Biological control interventions and botanical pesticides for insect pests of crops in sub-Saharan Africa: a mapping review. *Frontiers in Sustainable Food Systems*, 6.

Souza, D., Peterson, J. A., Wright, R. J., & Meinke, L. J. (2020). Field efficacy of soil insecticides on pyrethroid-resistant western corn rootworms (*Diabrotica virgifera virgifera* LeConte). *Pest management science*, 76(2), 827-833.

van Lenteren, J. C., Bolckmans, K., Köhl, J., Ravensberg, W. J., & Urbaneja, A. (2018). Biological control using invertebrates and microorganisms: plenty of new opportunities. *BioControl*, 63, 39-59.

Wallace J., Hammermeister A., Geldart, E. 2021. Biological pest control. Organic Agriculture Centre of Canada, Dalhousie University, Truro, N.S. 12 pp. <https://bit.ly/3C7qdmF>

Woltz, J. M., Isaacs, R., Landis, D. A., & Gratton, C. (2018). Integrating insect and disease resistance into pest management decision-making in diversified apple orchards. *Journal of Applied Ecology*, 55(1), 50-61.

## **CHAPTER 2**

### **LITERATURE RIVIEW**

#### **2.1 Introduction**

This chapter provides a review of related literature to the study. It highlights the importance of effective pest and disease control in crop production and reported pest and disease control in crop production by smallholder farmers. The chapter reviews work around integrated pest and disease management, biological control of pests and diseases in crop production (including benefits and limitations), and chemical control of pests and diseases in crop production. Finally, factors influencing the adoption of an agricultural technology by smallholder farmers in disease and pest control were reviewed considering knowledge, attitudes, and practices of smallholder farmers toward biological control methods.

#### **2.2. The importance of effective pest and disease control in crop production**

In crop production effectiveness of pest and disease management is of great importance in crop production due to significant damage to crops, ending with reduced yields and economic losses for farmers and in the worst scenario they cause total (Oerke, 2006). This in turn has effect on the household food security which feeds in to global food security causing food shortages. Effective pest and disease control in crop production are then key for sustainable crop production and global food security (Pimentel, 2005). According to FAO (2021), the world's population is expected to reach 9.7 billion by 2050, making the need to produce more food while lowering the impact of agriculture on the environment a pressing matter. Because of this, it is essential to design and execute sustainable pest and disease control measures, which might include cultural practices, the adoption of resistant crop varieties, and biological control techniques (FAO, 2021).

#### **2.3 Reported pest and disease control in crop production by smallholder farmers**

According to FAO, 2019, smallholder farmers in developing countries are deprived of an estimated 40% of their field crops because of invasive pests and diseases. Smallholder farmers were associated with use of traditional practices to manage pests and cultural practices like crop rotation and intercropping. However, due to green revolution there is intensive use of synthetic fertilisers and broad-spectrum pesticides which proved to be effective hence prevailing as modern technologies in crop production. Smallholder farmers around the world often rely on chemical inputs such as pesticides and fertilizers to enhance crop yields and protect their crops from pests and diseases. Recent research have brought attention to

smallholder farmers' use of pesticides. In Tanzania, for instance, smallholder maize farmers utilized a variety of pesticides to control pests and diseases, with 55% of farmers using insecticides and 51% using fungicides, according to a study by Van den Berg et al. (2019). The survey also showed that farmers have had a difficult time finding safe and suitable pesticides as well as learning about and receiving training in how to use them.

Another study by Chen et al. (2021) in China showed that smallholder farmers rely mostly on chemical pesticides for pest and disease control, which poses a significant environmental and health hazard. In agricultural practices a wide range of pesticides are employed to manage diseases and insects pests. A scenario for horticulture production in Uganda clearly shows that invasive pests and diseases are controlled by chemicals, with the majority of farmers (95.7%) using pesticides and fungicides and 4.3% using other control methods like roguing, hand picking, ash, organic extracts, urine, and frequent weeding (Ddamulira, 2021).

#### **2.4 Concerns about chemical control of pests and diseases in crop production**

Since ancient times, many fungicides and pesticides have been employed to preserve crops. However, their widespread usage has had a severe detrimental impact on the ecosystem, destroying biodiversity (Mahmood, 2016). Pesticides are a worry for the sustainability of the natural environment since this puts all life, both above and below the water, in danger. Another study supported the use of pesticides to increase crop yields and reduce crop complexity, but over-reliance on chemical control methods has been linked to environmental contamination and puts crop production in the future at serious risk due to the emergence of pest resistance (Barzman, 2015). A study by Puinean et al. (2018) also agrees with the notion found that pesticide resistance poses a huge threat to global crop production because of reduced possibilities of effective pest and disease control with resistance having developed in at least 586 insect species, and this number is likely to increase.

Use of pesticides is associated with risks to human health which is especially in the case of several developing countries where there is an inadequate regulatory environment and pesticides are poorly monitored and controlled (Andersson, 2021). In a research in Uganda findings show that smallholder farmers are undeniably exposed to the concern regarding negative health effects as many of them have encountered direct health implications due to the use of pesticides and these include skin irritations, dry cough, migraine headaches, dizziness, breathing problems and nausea (Andersson, 2021). Indeed, these are concerns which should be taken into consideration for suitability of human life and food security.

## **2.5 Integrated pest and disease management**

Integrated Pest and Disease Management (IPDM) is an approach that focuses on several or multiple methods in controlling pests and diseases in agriculture crop production whilst minimizing reliance on chemical pesticides (Manisseri, 2020). IPDM then incorporates use of, cultural, mechanical, chemical and biological control methods to suppress pests and disease pressure effectively (Manisseri, 2020). Cultural control involves crop rotations, soil tillage systems, and sanitation, which create unfavourable conditions for pests and diseases. Biological control is the use of natural enemies such as predatory insects, parasitic wasps, and microbes to control pests and diseases. Mechanical and physical control methods include trapping, insect nets, and use of repellents that aim at either removing or isolating pests and diseases. Chemical control uses pesticides as a last resort with more focus on green labelled chemical, ensuring they are used according to IPDM guidelines. According to Barzman, (2015) IPDM is in view of 8 guidelines which involve:

- Creating a cropping system by combining a variety of agronomic factors
- Utilizing regional forecasting, warning, and monitoring systems
- Making decisions to the creating long-term strategies
- Combining non-chemical techniques that produce beneficial synergies.
- Creating new biological choices and utilizing current databases to lessen effects on human health, the environment, and biological control of pests.
- Reducing the usage of pesticides and addressing the core causes of pesticide resistance are both essential for long-term crop protection strategies.
- Adding seasonal influences and trade-offs to the evaluation criterion

The use of biological control methods is an essential component of IPDM because it ensures sustainability of the environment and offers a cost-effective advantage (Chen et al., 2021). According to Meinke and Wong (2018), there are two basic categories of biological control: classical biological control (CBC) and augmentative biological control (ABC). ABC is the release of natural enemies in an existing ecosystem during a pest or disease outbreak to enhance their efficiency in their management as opposed to classical biological control, which entails the introduction of natural enemies into a new environment with pests and diseases causing damage to crop production (Meinke & Wong, 2018).

## **2.6 Biological control of pests and diseases in crop production**

Natural enemies like predators, parasites, and pathogens are utilized in biological control, a form of pest and disease management, to lower threshold populations of insects pests and diseases in crop production (Hanna, 2016). The concept of biological control is central on the use of natural balance of the ecosystems to control pests and diseases (Raman et al., 2017). This means it encourages preservation of natural the natural biodiversity whilst promoting development of more resilient and sustainable agroecosystems (Rosenheim & Poliakoff, 2018).

Other techniques, and strategies used in conjunction with biological control includes, pheromone traps, crop rotation, and intercropping so as to achieve maximum effectiveness in pests and diseases management. Several examples of successful biological control concepts include the use of predatory insects such as lady beetles, lacewings, and parasitic wasps has been effective in controlling aphids, mites, and other insect pests in many crops, including cotton, citrus, and vegetables (Lacey & Kaya, 2017). Whiteflies, thrips, and beetles are just a few of the insect pests that can be controlled with the help of fungus pathogens like *Metarhizium anisopliae* and *Beauveria bassiana* (Raman et al., 2017). Another illustration is the usage of parasitoids in greenhouse systems to biologically manage the tomato leaf miner (*Tuta absoluta*) as a more affordable and long-lasting alternative than chemical control (Biondi et al., 2018).

The principles of biological control in crop production depend on the specific approach and target pest or disease and according to Raman et al, (2017), the following are some key principles of biological control.

- Accurate identification of target pests and natural enemies
- Selection of appropriate effective natural enemies
- Habitat manipulation
- Monitoring and evaluation and making adjustments as necessary
- Integration with other pest management strategies

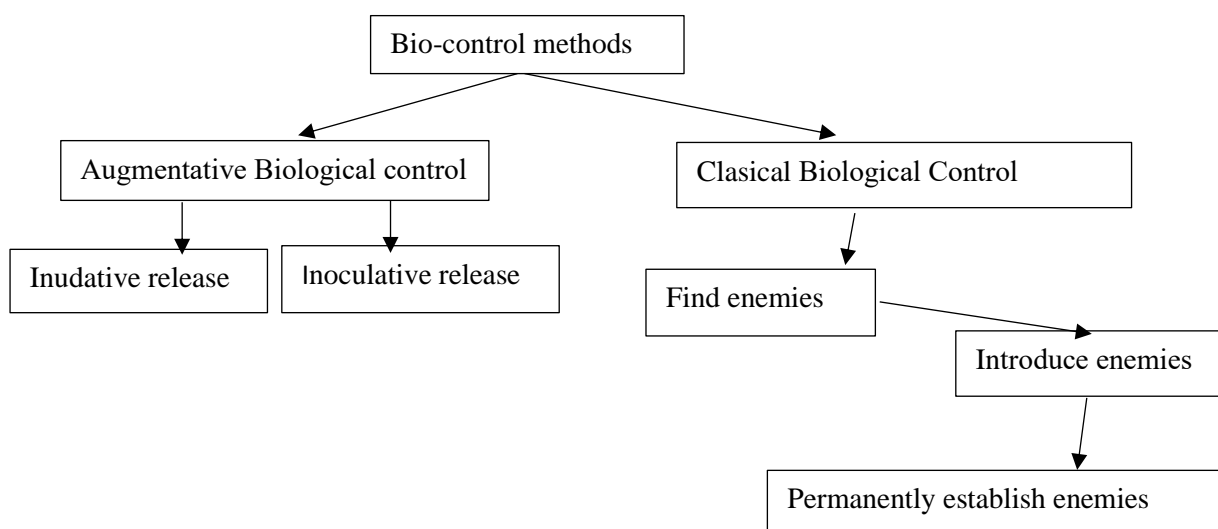


Fig. 2.1 Methods of bio-control methods in crop pest and disease control

### 2.6.1 Advantages and limitations of bio-control of pests and diseases for crop production

Table 2.1. Advantages and limitations of bio-control of pests and diseases for crop production

<i>Advantages</i>	Reference
✓ No residual effect in the environment or crops	Andersson (2021)
✓ Effective use of natural enemies	Ddamulira (2021)
✓ No effects on human health	Van Lenteren (2012)
✓ All preservation of the natural resources (sustainable)	FAO (2021)
<i>Limitations</i>	
✓ Not very effective under open field conditions	Zeweld (2017)
✓ High handling standards	Menassa et al. (2020)
✓ Require high technical support	Rajaonarison et al. (2018)

### 2.7 Factors influencing adoption of an agricultural technology by smallholder farmers in disease and pest control

A number of scholars have questioned why sub-Saharan Africa could not experience the same agricultural transformation that Europe and Southeast Asia did as a result of the Green

Revolution (Muzari et al., 2012). Smallholder farmers in rural areas make up the bulk of the victims of the agricultural crisis in the area, and an overwhelming number of farmers and their families have joined the poverty cycle in Africa, with many of them unable to support themselves. A food crisis that threatens millions of people in sub-Saharan Africa is uncharacteristic of a region where agriculture employs more than 70% of the labor force (Muzari et al., 2012). Low and unattractive prices, a lack of small-scale irrigation systems, particularly for the outlying areas, pest and disease issues, weak links between research and expansion, and other factors are barriers to increasing agricultural productivity in small-scale agriculture in sub-Saharan Africa. These factors are linked to the failure of smallholders to adapt to changing environments and adopt new technologies (Thar, 2021).

Muzari et al. (2012) noted that greater agricultural productivity can be attained by means of the adoption of technology through improved agricultural practices, the development of research and extension links, the expansion of rural financial markets, an increase in capital and machinery ownership by rural households, and so on. In light of this, the absence of sufficient research, funding, and land ownership are key variables impacting smallholders' adoption of technology.

According to studies done in sub-Saharan nations, assets, vulnerability, and institutions are the primary factors influencing smallholders' adoption of technology. These variables relate to whether farmers possess the concrete (material) and abstract (education) skills necessary for implementing the technology. The deployment of technology will be constrained by a shortage of resources (Baffoe-Asare, 2013). An excellent illustration is the use of crop insurance, which can lessen the risk that farmers face from exposure to outside shocks like storms, pest and disease attack, and drought. However, it is expensive and out of reach for smallholders. Indeed, one aspect influencing the adoption of farm technologies is financial capability.

Lower-risk technologies are more appealing to small farmers who are naturally risk-averse, and in a study by (Muzari et al. (2012) it was acknowledged that traditional small farmers have their reasons for not adopting unproven technologies were most of the time, such reasons are quite rational (Muzari et al., 2012). Vulnerability factors address the impact of technology on the extent of farmer exposure to economic, biophysical, and social risks (Muzari et al., 2012).

Institutional aspects discuss how much or how little institutions affect how small farmers use technology (Thar, 2021). Institutions cover all aspects of agricultural growth, including financing, insurance, and information sharing. This comprises organizations and systems that

increase farmers' access to markets for inputs and produce. Institutions also encompass the socially ingrained practices and behavioral norms (Thar, 2021).

## **2.8 Knowledge, attitudes and practices of farmers towards bio-control**

Smallholder farmers play a significant role in the agricultural however, they often face pests as a significant problem. In view of biological control methods, the knowledge, attitudes, and practices of smallholder farmers is of importance in the adoption of biological control methods. According to Hahn (2021) in Uganda a research on perceptions and use of biopesticides and other agrochemicals by smallholder farmers and it was found that farmers who had attended training programs on biopesticides were more likely to adopt and use this approach in pest management. Smallholder farmers' level of knowledge regarding biological control methods varies based on their education, access to agricultural extension services, and exposure to different farming technologies. Studies show that farmers who have higher levels of education and access to agricultural extension services are more knowledgeable about biological control methods (Loke, 2019).

Smallholder farmers' attitudes towards the adoption of biological control methods are shaped by their perceptions of their effectiveness, cultural beliefs, and experiences with other pest control methods. A study by Chakraborty et al. (2021) in India found that farmers' attitudes towards biological control were influenced by various factors such as perception of effectiveness, cost, and availability of alternative methods. The study found that farmers who perceived biological control methods as effective and cost-saving were more likely to adopt them. Additionally, the study found that farmers who had difficulty accessing chemical pesticides were more willing to adopt biological control methods (Chakraborty et al., 2021).

In relation to farmers practices, Bateman et al. (2020) alludes that smallholder farmers often rely on traditional agriculture practices that are passed down from generation to generation and these practices are often based on use of synthetic chemical pesticides hence less likely to adopt biological control methods in their farming practices.

## **2.9 Summary**

The review of literature appears to indicate biological control has a significant role promoting sustainable agriculture practices with evidence based on research on use of enemies of aphids and mites. However, the reviewed studies show that biological control is significant especially in developed countries because of technology advancements and available resources but its significance in Africa especially Sub-Sahara is not well reported in literature. Farmers seem to

have reservations, or are hesitant to adopt bio-control methods for various reasons shown. The adoption of bio-control methods for pest and disease control by resettled smallholder farmers in Zimbabwe appears not well documented. The aim of the Zimbabwean agricultural revolution which saw the resettlement of farmers was to boost agricultural production for food security. However, overuse of chemical may threaten food safety and degrade the environment. Sustainable agricultural methods appear to be the current global research focus.

## 2.10 Reference List

Andersson, E., & Isgren, E. (2021). Gambling in the garden: Pesticide use and risk exposure in Ugandan smallholder farming. *Journal of Rural Studies*, 82, 76-86.

Barzman, M., Bàrberi, P., Birch, A. N. E., Boonekamp, P., Dachbrodt-Saaydeh, S., Graf, B., ... & Sattin, M. (2015). Eight principles of integrated pest management. *Agronomy for sustainable development*, 35, 1199-1215.

Baffoe-Asare, R., Danquah, J. A., & Annor-Frempong, F. (2013). Socioeconomic factors influencing adoption of CODAPEC and cocoa high-tech technologies among small holder farmers in Central Region of Ghana.

Chakraborty, S., Sarkar, K., Bandyopadhyay, A., Roy, S. K., & Chatterjee, S. (2021). Adoption behavior of farmers towards biological control management of pests and diseases: an empirical investigation in India. *Journal of Crop Improvement*, 35(2), 237-246.

Chen, Q., Ma, R., He, J., Wu, L., & Liu, J. (2021). Integrated pest management of smallholder vegetable farmers in China: current status and future prospects. *Crop Protection*, 141, 105420.

Ddamulira, G., Isaac, O., Kiryowa, M., Akullo, R., Ajero, M., Logoose, M., ... & Ramathani, I. (2021). Practices and constraints of tomato production among smallholder farmers in Uganda. *African Journal of Food, Agriculture, Nutrition and Development*, 21(2), 17560-17580.

FAO. (2021). Integrated pest management. Retrieved from <http://www.fao.org/agriculture/crops/thematic-sitemap/theme/pests/ipm/en/>

Hanna, R., and El-Banhawy, E.M. (2016). Biological control of plant diseases: a sustainable alternative to chemical pesticides. *Egyptian Journal of Biological Pest Control*, 26(1), 1-7.

- Hahn, S. (2021). Perception and use of biopesticides and other agrochemicals by smallholder farmers in Uganda. *Agriculture*, 11(6), 552.
- Lacey, L. A., & Kaya, H. K. (2017). *Biological control of insects and mites: an introduction to beneficial natural enemies and their use in pest management*. John Wiley & Sons.
- Mahmood, I., Imadi, S. R., Shazadi, K., Gul, A., & Hakeem, K. R. (2016). Effects of pesticides on environment. *Plant, soil and microbes: volume 1: implications in crop science*, 253-269.
- Loke, W. H., Yusop, M. K., & Tan, S. G. (2019). Facilitating the adoption of biological control by vegetable farmers in Malaysia: An analysis of stakeholders' perspectives and willingness to pay. *Biological Control*, 129, 66-74.
- Manisseri, J. K., Paily, J., & Anitha, M. (2020). Biological control of pests and diseases in tomato production: A review. *Biological Agriculture & Horticulture*, 36(3), 129-144.
- Meinke, L. J., & Wong, T. T. (2018). Biological control demonstration project of codling moth by augmentative releases of a parasitic wasp in commercial apple orchards in Washington state. *Journal of Integrated Pest Management*, 9(1), 1-6.
- Muzari, W., Gatsi, W., & Muvhunzi, S. (2012). The impacts of technology adoption on smallholder agricultural productivity in sub-Saharan Africa: A review. *Journal of Sustainable Development*, 5(8), 69.
- Oerke, E. C. (2006). Crop losses to pests. *The Journal of Agricultural Science*, 144(1), 31-43.
- Pimentel, D. (2005). Environmental and economic costs of the application of pesticides primarily in the United States. *Environment, Development and Sustainability*, 7(2), 229-252.
- Puinean, A. M., Foster, S. P., Oliphant, L., Denholm, I., Field, L. M., Millar, N. S., ... & Williamson, M. S. (2018). Amplification of a cytochrome P450 gene is associated with resistance to neonicotinoid insecticides in the aphid *Myzus persicae*. *PLoS genetics*, 14(3), e1007756.
- Raman, A., Tyagi, R.K., and Sharma, A.K. (Eds.) (2017). *Biological Control of Insect Pests Using Egg Parasitoids*. Springer.
- Rosenheim, J. A., & Poliakoff, F. (2018). Biological control in integrated pest management programs. *Annual Review of Entomology*, 63, 139-158.
- Thar, S. P., Ramilan, T., Farquharson, R. J., Pang, A., & Chen, D. (2021). An empirical analysis of the use of agricultural mobile applications among smallholder farmers in Myanmar. *The Electronic Journal of Information Systems in Developing Countries*, 87(2), e12159.

## CHAPTER 3

### METHODS and MATERIALS

#### 3.1 Introduction

This chapter provides an overview of the study design, research instruments, data collection procedures and data management. It gives a reproducible methodology for data collection.

#### 3.2 Description of the study area

The study was done in ward 19 of Goromonzi District 17°51'22"S 31°22'48"E. Zimbabwe (Fig. 3.1). The district has 25 wards sub-divided into villages. The wards comprise commercial agricultural areas (52%) and communal areas (44%). Ward 19 has resettled small-scale farmers. It was purposively selected since the study focused on small holder farmers.



Fig.3.1 Location of Ward 19 (Shangure) in Goromonzi district

#### 3.3 Research design

The study assumed a cross sectional case study design which focused on horticulture resettled farmers in Goromonzi district ward 19. A cross sectional study is a kind of observational study in which the researcher simultaneously examines the study participants' exposures and outcomes (Setia, 2016). Findings from the study will give a snap shot of what was happening at the time of study in a specific area of study, ward 19 of Goromonzi district.

##### 3.3.1 Research framework

Adoption of biological control methods by small-holder farmers was considered the dependent variable with two categories (Yes, No). Predictor (independent) variables were based on demographic data, agricultural knowledge, attitudes and practices of respondents (Fig. 3.2).

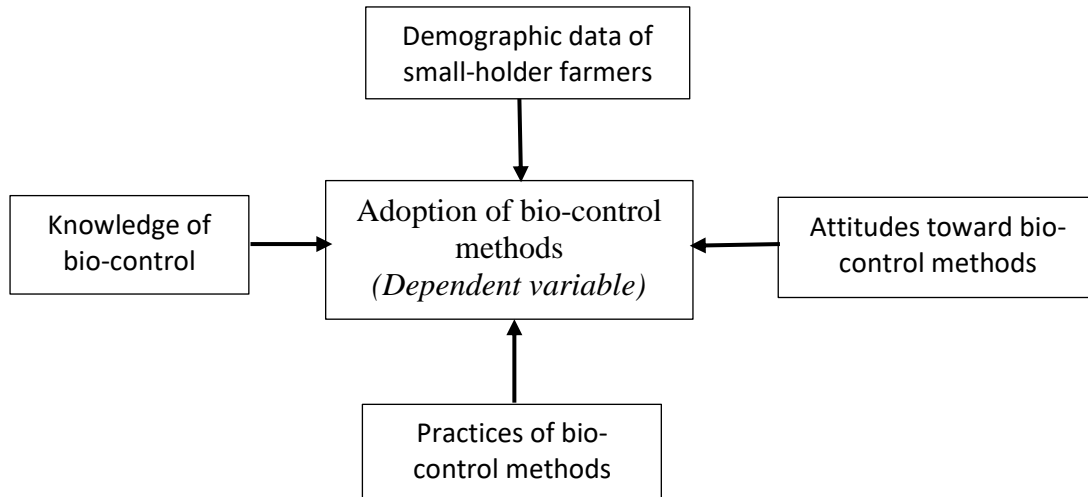


Fig. 3.2 Dependent-independent variables for the study

### 3.3.2 Research instrument

A pre-tested closed-ended questionnaire (Appendix 1) was used to solicit information from the selected small-holder farmers. The questionnaire was divided into four sections; demographic data, knowledge, attitudes and practises of smallholder farmers in ward 19 of Goromonzi district. A questionnaire was chosen to collect data because it can be used to collect a lot of information from a large sample size in a short period of time (Harvey and Land, 2016). It is easy to administer and relatively cheap. The questionnaire was evaluated and approved by the department of Agriculture Economics Education and Extension at Bindura University of Science Education through the supervisor and AGRITEX district office. It was pre-coded to allow easy data capture and analysis. Pre-testing the questionnaire to some non-participating farmers (5) allowed for refining it to ensure that it was easy to understand and that it collected the intended information.

### 3.4 Sampling procedure

A random sample of 30 farmers was selected from a list of 57 resettled farmers in ward 19 provided by the Agriculture Research and Extension Services (AGRITEX) district office. This was done by picking from a hat without replacement. The 30 farmers were ideal for the research because the farms are widely dispersed so we had to move long distances whilst administering the questionnaire. Informed consent was verbally obtained to selected farmers. Permission to carry out the study was obtained from village heads, the councillor and the district AGRITEXT

office. Selected farmers were asked to voluntarily participate in the study after describing to them the purpose of the study, how they were selected and how they to participate.

### **3.5 Data collection**

Data collection was conducted through self-administration of the questionnaire to selected and recruited participants using the pencil and paper technique. Respondents received a printed questionnaire which they filled using a pen and paper. The questionnaire was answered in the presence of the researcher and Agritex officer to explain to the respondents where they did not understand. The vernacular language was used to translate the information on the questionnaire. The survey was carried out in three days; that is from the 8<sup>th</sup> to the 10<sup>th</sup> of May. 2023

### **3.6 Data analysis procedure**

Questionnaires were checked for completeness and correctness before data capture in SPSS version 6. Demographic data were presented in cross tabulations for selected independent variables as characteristics of participants. Knowledge, attitudes and practices were scored using the Bloom's cut-off point (Seid a& Hussen, 2018). "Yes" scored 1 while "No" and "Not sure" scored 0 in the questions. The Blooms' cut off points for knowledge and practices were: 80 – 100% = Good; 50 – 79% = moderate; < 50% = poor, and for attitudes: 80 – 100% = positive; 60 – 79% = neutral; < 60% = negative. Data were analysed using binomial logistic regression to determine factors which influence the adoption of bio-control agricultural methods. Independent (predictor) variables were responses from the questionnaire items. Logistic regression was used for data analysis as the data were categorical (Boru, 2018). Data were analysed using multinomial logistic regression to determine factors which influence the adoption of bio-control agricultural methods. Independent (predictor) variables were responses from the questionnaire items. Logistic regression was used for data analysis as the data were categorical (Apuke, 2017). Multinomial logistic regression was used because the dependent variable had three categories; 'Yes', 'No' and 'Not sure' (So & Kuhfeld, 1995). A 'p' value of less than 0.05 ( $p < 0.05$ ) was considered for a factor to be significant.

### **3.7 Ethical issues**

The study adhered to high ethical standards to promote trust, accountability and mutual respect. Ethical issues that were considered include voluntary and informed consent. Respondents were to voluntarily and formally consent to participate in the study after having been informed of the benefits of their participation and could willingly withdraw from the research at any time (Clark-Kazak, 2017). Confidentiality to protect the respondents' personal information was

ensured. The questionnaire did not require personal information such as name, date of birth and plot or farm address.

### **3.8 Reference List**

Apuke, O. D. (2017). Quantitative research methods: A synopsis approach. *Kuwait Chapter of Arabian Journal of Business and Management Review*, 33(5471), 1-8.

Boru, T. (2018). Chapter Five Research Design and Methodology 5. 1. Introduction. *CHAPTER FIVE Res. Des. Methodol. 5.1. Introd*, 41.

Clark-Kazak, C. (2017). Ethical considerations: Research with people in situations of forced migration. *Refuge*, 33(2), 11-17.

Harvey, B. J. (2016). Human-caused climate change is now a key driver of forest fire activity in the western United States. *Proceedings of the National Academy of Sciences*, 113(42), 11

Seid MA & Hussen MS. Knowledge and attitudes towards antimicrobial resistance among final year undergraduate paramedical students at university of Gondar, Ethiopia. *BMC Infectious diseases*; 2018, 18(1):1-8. Doi: 10:1186/s12879-018-3199-1649-11650.

Setia, M. S. (2016). Methodology series module 3: Cross-sectional studies. *Indian journal of dermatology*, 61(3), 261.

So, Y., & Kuhfeld, W. F. (1995). Multinomial logit models. In *SUGI 20 conference proceedings* (Vol. 1995, pp. 1227-1234).

## CHAPTER 4

### RESULTS

#### **Abstract**

The adoption of biological control in crop production by resettled smallholder farmers was investigated. A closed-ended questionnaire was self-administered to 30 randomly selected respondents solicit demographic, knowledge, attitudes and practices on biological control. Knowledge, attitudes and practices of respondents were scored using Bloom's cut-off points. To determine factors which influence the adoption of bio-control methods multinomial logistic regression was used. Scoring of knowledge, attitudes and practices indicated that the smallholder farmers had poor knowledge (38%) and practices (30.7%) on bio-control methods. They also had negative attitude (58%) on it. Multinomial logistic regression analysis indicated that farmers with knowledge of bio-control were 177 times significantly more likely to adopt bio-control than those without (OR = 177.149,  $p = 0.002$ , 95%CI = 6.798; 4 616. 213). There was a decreased likelihood of famers who had used bio-control methods than those who had not to adopt bio-control methods for crop production although not significant (OR = 0.029,  $p = 0.076$ , 95% CI = 0.061, 1.439).

**Key words:** bio-control; crop production; Goromonzi; resettled; smallholder farmer

#### **4.1 Introduction**

Smallholder farmers are crucial to the production of agriculture, particularly in developing nations. However, growing worries about the widespread use of synthetic chemical pesticides and their side effects, along with an increase in internal pests and pathogens, have led to the withdrawal of a number of chemical pesticides, including soil fumigants (Eilenberg, 2001). The emergence of new invasive species, pesticide-resistant insect strains, climate change, and specialty cultures are all factors that have prompted people to look for more environmentally and health-conscious options (Mkindi et al., 2017).

Due to its environmental sustainability and potential to lower production costs, the use of biological control as an alternative to chemical pesticides has gained popularity recently (Ratto, 2022). This has caused the interdisciplinary control of plant protection to expand under the sustainable agriculture goal (Nji et al., 2022). Despite its claimed advantages in managing crop

pests and diseases, the adoption of bio-control technologies, particularly in Zimbabwe, remains minimal and underreported.

In Goromonzi ward 19, Zimbabwe, 30 smallholder farmers who had recently relocated were surveyed using a closed-ended questionnaire. The results are presented in this chapter. Based on the demographic information, beliefs, and behaviours of the respondents, it demonstrates factors influencing the adoption of biological control approaches.

## **4.2 Materials and Methods**

### **4.2.1 Description of study area**

Refer to 3.2

### **4.2.2 Research Design**

Refer to 3.3

### **4.2.3 Sampling procedure**

Refer to 3.4

### **4.2.4 Data collection procedure**

Refer to 3.5

### **4.2.5 Data analysis procedure**

Refer to 3.6

### **4.2.6 Challenges encountered during data collection**

The challenges encountered during the study included delayed permission from the counsellor and local authorities to administer the questionnaire. This could have been due to the current era where the country is about to hold national elections. The questionnaire was closed ended. It did not allow enough information to be collected through probing which could have been done using focus group or in-depth interviews. Permission to use these was not granted.

## **4.3 Characteristics of participants**

Table 4.1 shows the characteristics of smallholder farmers in ward 19 of Goromonzi district. Results show that respondents were mainly male (83.3%), 50% of them had tertiary education and had 301 – 400 USD as monthly household income. About 2/3 of them did not possess mechanised farm equipment and slightly. Above 50% of them had received agricultural training.

Table 4.1 Characteristics of 30 resettled smallholder farmers in Ward 19, Goromonzi district, April 2023

Variable	Category	Frequency	%
Village of residence	Chigodora	6	20.0
	Chirozva	8	26.7
	Mapfeni	8	26.7
	Rupara	8	26.7
Gender	Male	25	83.3
	Female	5	16.7
Age group (years)	< 30	6	20.0
	30 – 40	7	23.3
	41 – 50	8	26.7
	> 50	9	30.0
Highest level of formal education reached	None	1	3.3
	Primary	4	13.3
	Secondary	10	33.3
	Tertiary	15	50.0
Religion	Christianity	22	73.3
	Traditional	6	20.0
	None	2	6.7
Approximate monthly household income (USD)	101 – 200	3	10.0
	201 – 300	10	33.3
	301 – 400	15	50.0
	> 400	2	6.7
Period household involved in crop Production (years)	< 5	7	23.3
	5 – 10	14	24.7
	11 – 15	2	6.7
	> 15	7	23.3
Possession of mechanised Farming equipment	Yes	10	33.3
	No	20	66.7
Received agricultural training	Yes	16	53.3
	No	14	46.7

#### 4.4 Reported knowledge, attitudes and practices of smallholder famers

Table 4.2 shows the reported knowledge, attitudes and practices of 30 smallholder famers in ward 19 of Goromonzi district. Results indicate that the smallholder farmers had poor knowledge (38%) and practices (30.7%) on bio-control methods. They also had negative attitude (58%) on it.

Table 4.2 Reported knowledge, attitudes and practices of 30 resettled smallholder farmers in Ward 19, Goromonzi district, April 2023

Blooms taxonomy	Yes	No	Not sure
<i>Knowledge</i>			
1. Do you know BC?	16 (53.3)	13 (43.3)	1 (3.3)
2. Do you know any BC methods?	13 (43.3)	14 (46.7)	3 (10.0)
3. Do you know advantages of BC methods?	13 (43.3)	12 (40.0)	4 (10.0)
4. Do BC methods help reduce chemical use?	13 (43.3)	17 (56.7)	0 (0.0)
5. Did you receive any training in BC methods?	2 (6.7)	28 (93.3)	0 (0.0)
<i>Score = 38% (poor knowledge)</i>			
<i>Average score per question = 1.9 (possible = 5)</i>			
<i>Attitudes</i>			
1. Do you prefer BC over other methods?	4 (13.3)	6 (20.0)	20 (66.7)
2. Do you believe you have a role to promote BC?	16 (53.3)	8 (26.7)	6 (20.0)
3. Are you willing to acquire new skills that allow BC?	28 (93.3)	0 (0.0)	2 (6.7)
4. Do you believe the adoption of BC should be government incentivised?	15 (50.0)	0 (0.0)	15 (50.0)
5. Are you satisfied with the assistance from AGRITEX?	24 (80.0)	6 (20.0)	0 (0.0)
<i>Score = 58% (negative attitude)</i>			
<i>Average score per question = 2.9 (possible = 5)</i>			
<i>Practices</i>			
1. Did you use BC only for the past 2 years?	0 (0.0)	30 (100.0)	0 (0.0)
2. Have you used BC methods in pest control?	10 (33.3)	20 (66.7)	0 (0.0)
3. Did you encounter many challenges in using BC?	9 (30.0)	1 (16.7)	N/A
4. Do you prioritise preserving nature and sustainability?	25 (83.3)	5 (16.7)	0 (0.0)
5. Do you receive adequate training for BC methods?	2 (6.7)	28 (93.3)	0 (0.0)
<i>Score = 30.7% (poor practices)</i>			
<i>Average score per question = 1.5 (possible = 5)</i>			

BC: biological control, Figures in brackets denote % of the total

#### 4.5 Perceived factors influencing use of bio-control methods

Fig. 4.1 shows reported perceived factors that influence the use of biological control in crop production by 30 farmers in ward 19 of Goromonzi district. Results indicate that only a few farmers responded to the question (30%). The main influencing factor was knowledge of bio-control methods (8 out of 10 respondents).

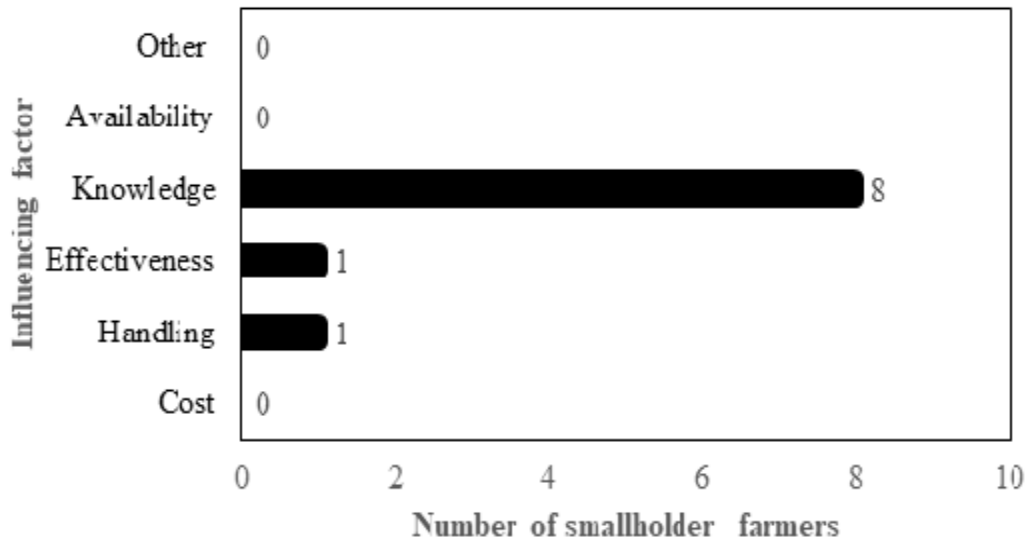


Fig. 4.1 Perceived factors that influence the use of biological control in crop production

#### 4.6 Perceived challenges from using bio-control methods

Fig 4.2 shows perceived challenges that were reported by smallholder farmers in using bio-control methods in crop production. Results indicate that only a few farmers (9 out of 30) indicated that they had used bio-control methods in pest and disease management for crops. A few respondents doubted the effectiveness of the methods (2) while most of them indicated that they lacked knowledge of bio-control methods.

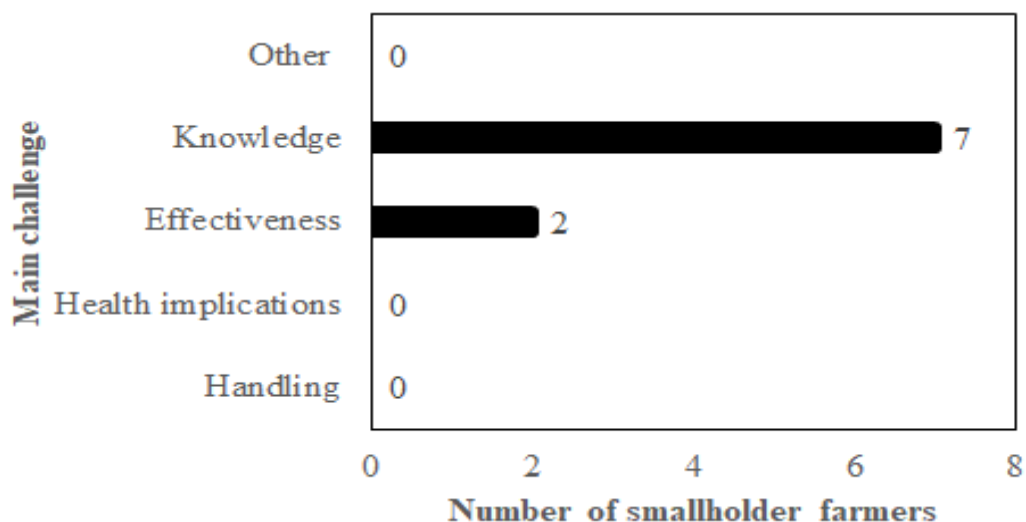


Fig. 4.2 Perceived main challenges reported for using bio-control in crop production.

#### 4.6 Determinants of use of bio-control for crop production by smallholder farmers

After several unsuccessful combinations of independent variables to get model fitting data, seven variables were finally included in the model. Table 4.3 shows the model fitting information. Results indicate that the final model with all selected predictor (independent) variables was significant ( $p < 0.05$ ). This implies that the Null hypothesis of the model, that is, lack of relationship between the dependent and independent variables was therefore rejected.

Table 4.3 Model fitting data

Model	Model fitting criteria		Likelihood ratio tests	
	-2 log likelihood	Chi-Square	Degrees of freedom	Sig.
Intercept only	57.600			
Final	218.864	38.736	24	0.029

Table 4.4 shows information on the goodness of fit. Results show that the Null hypothesis of the model (model is adequately fit) is accepted ( $p > 0.05$ ). The data showing the model is not adequately fit. This implies that the data showing the model is adequately fit. The Nagelkerke value (0.843) used to estimate the Pseudo R-square indicated that included independent variables adequately impact on the use of bio-control methods in pest and disease control.

Table 4.4 Goodness of fit data

	Chi-square	Degrees of freedom	Sig.
Pearson	17.549	30	0.965
Deviance	17.478	30	0.966

Table 4.5 shows likelihood ratio tests. Results suggest that only the education level of the participant and prior use of biological control methods had significant effect ( $p < 0.05$ ) on the use of bio-control methods.

Table 4.5 Likelihood ratio tests information

Effect	Model fitting criteria		Likelihood ratio tests	
	-2 Log likelihood of reduced model	Chi-square	df	Sig.
Intercept	18.864	0.000	0	
Gender	19.056	0.200	2	0.905
Religion	21.972	3.108	4	0.540
Level of education	31.998	13.134	6	<b>0.041</b>
Agricultural training	20.143	1.279	2	0.528
Knowledge of bio-control	21.602	2.738	4	0.603
Previous use of bio-control	25.788	6.923	2	<b>0.031</b>
Satisfied with assistance from AGRITEX officers	26.051	7.187	4	0.126

Table 4.6 shows the parameter estimates of the multinomial logit bio-control adoption model for smallholder farmers in Ward 19 of Goromonzi district. The results indicate that farmers with knowledge of bio-control were 177 times significantly more likely to adopt bio-control than those without (OR = 177.149,  $p = 0.002$ , 95%CI = 6.798; 4 616. 213). There was a

decreased likelihood of famers who had used bio-control methods than those who had not to adopt bio-control methods for crop production although not significant (OR = 0.029,  $p = 0.076$ , 95% CI = 0.061, 1.439).

Table 4.6 Parameter estimates of the multinomial logit bio-control adoption model

Willing to adopt bio-control	B	Wald	SE	df	Sig.	Exp (B)	95% CL for Exp (B)		
							Lower bound	Upper bound	
Yes	Intercept	7.335	6939.382	0.000	1	0.999			
	<i>All variable were not significant (<math>p &gt; 0.05</math>)</i>								
No	Intercept	-1.995	3.020	0.436	1	0.509			
	Knowledge of bio-control (Yes)	5.177	9.686	1.663	1	<b>0.002</b>	177.149	6.798	4 616.213
	Prior use of bio-control (Yes)	-3.534	3.158	1.989	1	<b>0.076</b>	0.029	0.061	1.439

*Reference category for the dependent variable = Not sure*

*P values in bold indicate significant difference ( $p < 0.05$ )*

#### 4.7 References

Eilenberg, J., Hajek, A., & Lomer, C. (2001). Suggestions for unifying the terminology in biological control. *BioControl*, *46*, 387-400.

Mkindi, A., Mpumi, N., Tembo, Y., Stevenson, P. C., Ndakidemi, P. A., Mtei, K., & Belmain, S. R. (2017). Invasive weeds with pesticidal properties as potential new crops. *Industrial Crops and Products*, *110*, 113-122.

Nji, Q. N., Babalola, O. O., Ekwomadu, T. I., Nleya, N., & Mwanza, M. (2022). Six main contributing factors to high levels of mycotoxin contamination in African foods. *Toxins*, *14*(5), 318.

Ratto, F., Bruce, T., Chipabika, G., Mwamakamba, S., Mkandawire, R., Khan, Z., ... & Sait, S. M. (2022). Biological control interventions reduce pest abundance and crop damage while maintaining natural enemies in sub-Saharan Africa: a meta-analysis. *Proceedings of the Royal Society B*, *289*(1988), 20221695.

## **CHAPTER 5**

### **DISCUSSION**

#### **5.1 Introduction**

Chapter 5 discusses findings of the study in view of relevant literature and knowledge of the area studied. Results from characteristics of participants, their reported knowledge, attitudes and practices (KAP) and factors influencing the adoption of bio-control methods by smallholder farmers were discussed.

#### **5.2 Characteristics of participants**

The attributes of farmers are critical to their willingness to adopting an agricultural production technology (Zhang, 2028; Li, 2021). Age, gender, education level, farm size, and access to information and resources were identified to contribute towards adoption of biological control technology (Toma (2016). Farmers who are old have a high possibility to be resistant to change. This was demonstrated in Uganda (Kansiime et al., 2020) and Malawi (Akinnifesi et al., 2010) where young farmers had a higher likelihood of adopting biological control technology than older farmers.

The current study showed that the level of education of a smallholder farmer significantly influenced adoption of bio-control technologies. Education can enhance the rate of acceptance of new technologies (Hamide et al., 2022). The study found out that smallholder farmers with higher levels of education were better able to spread information and technologies from extension agencies.

Access to knowledge and training influences acceptance of biological control measures. In Uganda, Kansiime et al. (2020) reported that the adoption of bio-control technology was favourably connected with agricultural training on crop production and new technologies provided by tertiary institutions and extension services. Similar findings were reported from Ethiopia (Abate et al., 2015) where training played a significant role in the adoption of integrated pest control approaches which includes the use of biological techniques. The current study indicated that about half of the participants had received agricultural training which lasted more than two weeks. However, their knowledge concerning biological control methods was scored poor, suggesting the need for training. Extension services did not include training of farmers on biological control methods. Training on new technologies can help inform policy

makers and extension workers to design effective strategies for promoting the adoption of sustainable agricultural practices (Kansiime et al., 2020).

### **5.3 Reported knowledge, attitudes and practices of resettled smallholder farmers on adopting biological control**

Resettled smallholder farmers in Ward 19 of Goromonzi district showed poor knowledge (score of 38%) of biological control. One of the most critical variables influencing the use of biological control strategies is knowledge. In the Philippines' Mazandaran area, farmers were hesitant to accept and apply biological control in their IPM plans if they have inadequate understanding regarding the technology's effectiveness (Abdollahzadeh, 2015; Launio, 2020). Educating the smallholder farmers through training programmes may increase awareness and understanding of the methods (Mkenda et al., 2020). In this study the poor knowledge of farmers could be a result of poor awareness of the sustainable option of managing pests and diseases.

Resettled smallholder farmers in Ward 19 of Goromonzi district had negative attitude towards the adoption of biological methods. This could be attributed to lack of confidence in biological control. A study in Ethiopia (Rajaonarison et al., 2018) showed that lack of confidence by farmers to use bio-control was due to lack of knowledge and skills to effectively implement it. Training farmers in Ward 19 of Goromonzi district on bio-control may help them develop positive attitudes. Lack of awareness on the effectiveness of a technology in controlling pests and disease was also reported to cause negative attitude (Zeweld, 2017). Lack of extension services on bio-control in this study could have influenced their attitude. Training of farmers was associated with positive attitude towards bio-control (Awuah et al., 2018).

In the current study, the majority of smallholder farmers acknowledged using broad-spectrum insecticides to manage diseases and pests. They had inadequate agricultural practices, and relied more on chemical control. According to Ray et al. (2020) bad (which does not encourage sustainability) agricultural practices, such as the use of chemical pesticides and monoculture farming, have a significant impact on the efficacy of biological control approaches in apple orchards.

### **5.4 Perceived factors influencing adoption of bio-control methods**

The study considered for factors influencing the use of biological control in crop production. Knowledge of bio-control methods was outstanding (80%). This highlights the importance of educating farmers about the benefits and effectiveness of biological control in order to increase confidence and adoption. In China, it was found that knowledge was a significant factor influencing the adoption of biological control as smallholder farmers who had awareness about biological control were more likely to use it as a pest management strategy (Zhang et al., 2020).

In this study ‘effectiveness’ did not significantly influence the adoption of biological control. However, literature appears to consider bio-logical control as an effective tool for managing pests in crop production for specified horticultural crops (e.g., Aliakbarpour et al., 2021; Hani et al., 2021). There is a need for research with reference to local context (environment and climate) on the effectiveness of bio-logical control methods. Handling, as a perceived factor influencing the use of biological control was poorly reported in the current work. In a study that examined how storage conditions affected the quality of entomopathogenic fungi used as biological control agents for insect pests, it was discovered that high temperature and humidity significantly decreased the fungi's ability to control insect pests (Liu et al., 2020).

### **5.5 Determinants of adoption of bio-control for crop production**

The results of the current study showed that farmers who had prior knowledge of bio-control techniques were much more likely than those without to adopt and usage the technologies. Knowledge-based factors account for the majority of the variables influencing the adoption of bio-control in Ward 19 of the Goromonzi district. Similar results were reported elsewhere (Li & Feng, 2019) including smallholder farmers in Ethiopia (Mekonen et al., 2021) and Kenya (Wekesa et al., 2020) received formal agricultural instruction, and workshops or training (Parker et al., 2020) on biological control. To meet the requirements and preferences of smallholder farmers, the training must be relevant and easily available (Mbabazi et al., 2020).

Other studies reported that adoption of biological control techniques for pest management is also influenced by monthly household income (Asante et al., 2021). Households of low income will have less access to resources which prevents them from learning about biological control measures and ultimately prevents adoption. This finding contradicts results of the current study where this variable was found insignificant to influence adoption of bio-control.

Another determinant of the adoption of biological control which was found not significant in the current study is government support in form of incentives. The researcher's opinion is that most of these smallholder farmers rely on government inputs and they are probably going to carry the same attitude even when it comes to adoption of sustainable practices like biological control. Government incentivised initiatives were reported in India (Srivastava et al., 2020) and the European Union (European Commission, 2021).

## **5.6 Summary**

The knowledge of resettled smallholder farmers appears to be a missing link to its adoption. Prior use of bio-control appeared not to significantly influence the adoption of bio-control which could have been attributed to their negative attitude. The overall adoption of biological control appears to be central to awareness and training of farmers. However, there are other areas that contributed to influencing adoption of bio-control in this study but were reported in other studies such as efficiency of biological agents in suppressing pest populations and handling.

## **5.7 Reference list**

Abate, T., Shiferaw, B., Menkir, A., Wegary, D., Kebede, Y., Tesfaye, K., & Kassie, M. (2015). Factors that transformed maize productivity in Ethiopia: A tale of two mixed- crop-livestock systems. *Environmental Development*, 15, 92-106.

Abdollahzadeh, G., Sharifzadeh, M. S., & Damalas, C. A. (2015). Perceptions of the beneficial and harmful effects of pesticides among Iranian rice farmers influence the adoption of biological control. *Crop Protection*, 75, 124-131.

Akinnifesi, F. K., Ajayi, O. C., Sileshi, G., Chakeredza, S., Matakala, P., Kwesiga, F. R., ... & Mng'omba, S. (2010). Adoption of agroforestry innovations in southern Africa: A review. *African Journal of Agricultural Research*, 5(22), 3051-3063.

Aliakbarpour, H. R., et al. (2021). Biological control of *Tuta absoluta* in greenhouse tomato using *Neoseiulus californicus* and Mako botanical insecticide. *Biological Control*, 160, 104597.

Asante, E., et al. (2021). Assessing factors influencing the adoption of biological control practices among smallholder vegetable farmers in the Ashaiman Municipality of Ghana. *Heliyon*, 7(2), e06420.

Awuah, K.G., Addo-Quaye, A.A., Yawson, D.O., 2018. Factors Affecting Farmers' Perceptions on the Use of Biological Control: The Case of Cocoa Farmers in Ghana. *Agriculture* 8, 132.

Hani, N., et al. (2021). Biological control of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) by egg parasitoids and natural enemies on maize crops. *Biological Control*, 157, 104521.

Hill, M. P., Hoffmann, A. A., Rostás, M., & Umina, P. A. (2021). Barriers to the adoption of biological control by Australian grape growers. *Biological Control*, 104673.

Kansiime, M. K., Rwomushana, I., Mugambi, I., Makale, F., Lamontagne-Godwin, J., Chacha, D., ... & Day, R. (2020). Crop losses and economic impact associated with papaya mealybug (*Paracoccus marginatus*) infestation in Kenya. *International Journal of Pest Management*, 1-14.

Launio, C. C., Labon, K. O., Bañez, A. A., & Batani, R. S. (2020). Adoption and economic analysis of using biological control in Philippine highland farms: Case of *Trichoderma koningii* strain KA. *Crop protection*, 136, 105177.

Li, Y., & Ma, J. (2021). Analysis of Income Effect Differences of Scientific Fertilization Technology—An Empirical Estimation Based on farmers' Initial Endowment. *J. Agrotech. Econ*, 7, 18-32.

Liu, Y., et al. (2020). Effects of different handling and transportation methods on *Phytoseiulus persimilis* and *Tydeus californicus*. *Journal of Economic Entomology*, 113(3), 1067-1074.

Mbabazi, R., Kaboggoza, J. R. S., & Wesonga, J. M. (2020). Effectiveness of Agriculture Training on the Adoption of Biological Control by Smallholder Farmers in Uganda. *Journal of Agricultural Extension and Rural Development*, 12(6), 153-162.

Mekonen, M., Haji, J., & Boelee, E. (2021). Farmers' perception, knowledge and adoption of biological control of pests in Ethiopia. *Journal of Pest Science*, 1-12.

Menassa, R., et al. (2020). Storage temperature and relative humidity affect the viability, virulence and shelf-life of entomopathogenic fungi used as biocontrol agents of the red palm weevil. *Biological Control*, 153, 104403.

- Ray, A., Ray, R., & Sreevidya, E. A. (2020). How many wild edible plants do we eat—their diversity, use, and implications for sustainable food system: an exploratory analysis in India. *Frontiers in Sustainable Food Systems*, 4, 56.
- Shah, Z., et al. (2021). The factors affecting the adoption of biological control agents: A case study of vegetable farmers in Khyber Pakhtunkhwa, Pakistan. *Agricultural and Biological Sciences Journal*, 2(6), 370-376.
- Wang, X., Biondi, A., Nance, A. H., Zappalà, L., Hoelmer, K. A., & Daane, K. M. (2021). Assessment of *Asobara japonica* as a potential biological control agent for the spotted wing drosophila, *Drosophila suzukii*. *Entomologia Generalis*, 41(1).
- Wekesa, V. W., Mutisya, D. L., & Mugo, H. M. (2020). Determinants of the adoption of biological control among smallholder vegetable farmers in Kenya. *Acta Horticulturae*, (1273), 169-174.
- Zeweld, W., Van Huylbroeck, G., Tesfay, G., & Speelman, S. (2017). Smallholder farmers' behavioural intentions towards sustainable agricultural practices. *Journal of environmental management*, 187, 71-81.
- Zhang, W., Wang, G., Li, X., Liu, Y., & Chen, X. (2020). Adoption of biological control practices among vegetable farmers in China: a structural equation modeling approach. *Journal of Cleaner Production*, 242, 118538

## **CHAPTER 6**

### **CONCLUSION and RECOMMENDATIONS**

#### **6.1 Conclusion**

The adoption of biological control methods by resettled smallholder farmers appears to be at its infancy stage due to lack of knowledge and awareness. Understanding the knowledge, attitudes and practices of farmers informs agricultural policy and practice. Resettled smallholder farmers in the study area had poor knowledge and practices, and negative attitudes towards bio-control which are assumed to be influenced by training. Findings from the current work may not be generalised to other contexts. For further research there is a need to consider other contexts and increase potential predictors of adopting bio-control methods. It will be interesting to find out why farmers think the way they do for bio-control methods they do, a major limitation of the questionnaire.

#### **6.2 Recommendation**

Based on the results of the study, training of smallholder farmers on biological control is critical.

## Appendices

### Appendix 1. Research instruments

The researcher used a semi structured questionnaire and the questionnaire is attached below:

QUESTIONNAIRE ID:

Date: .....

#### QUESTIONNAIRE FOR SMALLHOLDER FARMERS IN WARD 19, GOROMONZI DISTRICT

##### Introduction

My name is Munashe Maravanyika, a masters' student (reg. No: B211427B) in the department of Agriculture economics education and extension at Bindura University of Science Education. It is a requirement that in the second year of my studies I carry out a research. My research topic is: Adoption of biological control methods in crop production by resettled smallholder farmers: Case of wards 19, Goromonzi district, Zimbabwe. The motivation to my study is based on understanding that biological control methods in pest and disease management are more beneficial both to the environment and human health than the use of chemicals. However, they are still not commonly used by resettled smallholder farmers in Zimbabwe.

You are invited to voluntarily participate in the study. Participating in this study may not benefit you directly, but it will help us learn and contribute to knowledge. Information shared will be confidential. Anonymity of participation assured. Completing the questionnaire takes about 15 minutes. I assume that by agreeing to participate in the study I have your informed consent.

##### Instruction

Please encircle/strike an "X" against the number corresponding to your response for each question

##### Section A: Demographic information

1. Village of residence  
1. Chirozva    2. Rupara    3. Chigodora    4. Mapfeni
2. Your gender  
1. Male    2. Female
3. Your age category (years)  
1. < 30    2. 30 – 40    3. 41 – 50    4. > 50
4. Highest level of education completed  
1. No formal education    2. Primary    3. Secondary    4. Tertiary
5. Do you have any formal agricultural training lasting more than two weeks?  
1. Yes    2. No
6. Your religion  
1. Christianity    2. Traditional belief    3. No religion    4. Other  
*If other, please specify* .....
7. Approximate monthly household income (USD)  
1. < 100    2. 101 – 200    3. 201 – 300    4. 300 – 400    5. > 400
8. How many cattle does the household own?  
1. < 5    2. 5 - 10    3. 11 - 15    4. > 15
9. Does the household own mechanized agricultural equipment?  
1. Yes    2. No
10. Length of time (duration) you have been involved in crop production here (years)?

1. < 5      2. 5 – 10      3. 11 – 15      4. > 15

**Section B: Knowledge**

Q1. Do you know about biological control as a method to control pests and diseases in crop production?

1. Yes      2. No      3. Not sure

Q2. Do you have and an understanding about biological control methods are used?

1. Yes      2. No      3. Not sure

Q3. Have you used biological control methods in your farming practices?

1. Yes      2. No      3. Not sure

Q4. Do you receive extension assistance and trainings from the AGRITEX OFFICE?

1. Yes, always when needed      2. Yes, at times      3. No

Q5. If yes to the above, are you satisfied with the assistance that you get from AGRITEX officers?

1. Yes, very much      2. Yes, at times      3. No

Q6. Have you received any training or extension services on biological control methods?

1. Yes      2. No

Q7. Do you understand the advantages of biological control over chemical methods?

1. Yes      2. No      3. Not sure

Q8. If answer to above is yes, do you think the use of biological control methods can help reduce the use of chemicals in crop production?

1. Yes      2. No      3. Not sure

Q9. Would you recommend the use and adoption of biological control in crop production?

1. Yes      2. No      3. Not sure

**Section C: Agricultural Practice**

Q10. What is the approximate size of land under crop production? (ha)

1. < 5      2. 5 – 10      3. > 10

Q11. Which is the main/common type of crop that you grow on a large land area?

1. Horticultural      2. Grains      3. Fodder      4. Fibre

Q12. Your output of the main crop that you grow/year (tonnes)

1. < 10      2. 11 – 20      3. 21 – 30      4. > 30

Q13. At which stage of the growing season do you think you lose most of your crop yield?

1. Planting      2. Growing      3. Post-harvest      4. Other

*If other, please specify:* .....

Q14. Which is the main challenge which you face during the agricultural cycle for crop production?

1. Inadequate planning      2. Lack of fertilizer's      3. Pests and diseases      4. Poor rainfall  
5. Lack of adequate inputs      6. Other

*If other, please specify:* .....

Q15. How do you commonly control pests and diseases?

1. Chemical      2. Biological      3. Integrated pest management      4. Other

*If other, please specify* .....

Q16. Would you prefer to use biological control methods for pest and disease control to other control methods?

1. Yes      2. No      3. Not sure

- Q17. If yes to the above, why would you prefer using biological control of pests and diseases?  
 1. Increases yield    2. Improves soil quality    3. Cost-effective    4. Efficient  
 5. Safety issues    6. Other

*If other, please specify* .....

- Q18. For how long have you used biological control in crop production (years)?  
 1. Never    2. < 1    3. 1 – 5    4. 6 -10    5. > 10

- Q19. Did you encounter any challenges in using biological control methods for pest and diseases?  
 1. Yes    2. No    3. Do not know

- Q20. If yes to the above, which is the main challenge that you experienced?  
 1. Handling    2. Health implications    3. Effectiveness    4. Lack of knowledge    5. Cost    6. Other

*If other, please specify* .....

**Section D: Attitudes**

- Q21. Are you willing to acquire new skills that allow adoption of biological control?  
 1. Yes    2. No    3. Not sure

- Q22. Do you think you have a role to contribute in promoting biological control methods in crop production.?  
 1. Yes    2. No    3. Not sure

- Q23. Do you believe that biological control methods are sustainable approach to pest management?  
 1. Yes    2. No    3. Not sure

- Q24. Do you think you need support to successfully adopt and implement biological control methods?  
 1. Yes    2. No    3. Not sure

- Q25. Do you believe adoption of biological control methods should be incentivized by the government?  
 1. Yes    2. No    3. Not sure

- Q26. Is the profit the first and major factor you consider during decision making on crop production activities?  
 1. Yes    2. No    3. Not sure

- Q27. Are you concerned about preserving the natural resources so that future generation can enjoy them in agriculture production?  
 1. Yes    2. No    3. Sometimes

- Q28. What major factor influences your decision to use biological control methods?  
 1. cost    2. Handling    3. Effectiveness    4. Knowledge    5. Availability

- Q29. What major factor influences your decision not to use biological control methods?  
 1. cost    2. Handling    3. Effectiveness    4. Knowledge    5. Availability

*Thank you very much for participating in this interview*

## Appendix 2. Multinomial logistic regression output

### Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	57.600			
Final	18.864	38.736	24	.029

### Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	17.549	30	.965
Deviance	17.478	30	.966

### Pseudo R-Square

Cox and Snell	.725
Nagelkerke	.843
McFadden	.657

### Likelihood Ratio Tests

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	18.864 <sup>a</sup>	.000	0	.
Education	31.998 <sup>b</sup>	13.134	6	.041
Religion	21.972 <sup>b</sup>	3.108	4	.540
Agrictraining	20.143 <sup>b</sup>	1.279	2	.528
KnowledgeBC	21.602	2.738	4	.603
UsedBC	25.788 <sup>b</sup>	6.923	2	.031
SatisfiedAO	26.051 <sup>b</sup>	7.187	4	.126
Gender	19.065 <sup>b</sup>	.200	2	.905

Parameter Estimates

Willing to adopt bio-control	B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval	
							Exp(B)	
							Lower Bound	Upper
Yes	Intercept	7.335	6939.382	.000	1	.999		
	[Education=1]	22.986	2945.354	.000	1	.994	9613164772.32	.000
	[Education=2]	3.893	4497.436	.000	1	.999	49.073	.000
	[Education=3]	-23.430	512.632	.002	1	.964	6.677E-011	.000
	[Education=4]	0 <sup>c</sup>	.	.	0	.	.	.
	[Religion=1]	2.503	1221.352	.000	1	.998	12.217	.000
	[Religion=2]	-21.446	1379.593	.000	1	.988	4.856E-010	.000
	[Religion=3]	0 <sup>c</sup>	.	.	0	.	.	.
	[Agrictraining=1]	11.163	255.391	.002	1	.965	70450.046	2.875E-213
	[Agrictraining=2]	0 <sup>c</sup>	.	.	0	.	.	.
	[KnowledgeBC=1]	-49.260	8135.335	.000	1	.995	4.043E-022	.000
	[KnowledgeBC=2]	-31.329	6836.415	.000	1	.996	2.476E-014	.000
	[KnowledgeBC=3]	0 <sup>c</sup>	.	.	0	.	.	.
	[UsedBC=1]	21.964	613.686	.001	1	.971	3456932269.03	.000
	[UsedBC=2]	0 <sup>c</sup>	.	.	0	.	.	.
	[SatisfiedAO=1]	20.047	4510.271	.000	1	.996	508419050.182	.000
	[SatisfiedAO=2]	-2.167	4499.214	.000	1	1.000	.115	.000
	[SatisfiedAO=3]	0 <sup>c</sup>	.	.	0	.	.	.
[Gender=1]	-2.506	968.296	.000	1	.998	.082	.000	
[Gender=2]	0 <sup>c</sup>	.	.	0	.	.	.	
No	Intercept	-1.995	3.020	.436	1	.509		
	[Education=1]	12.287	1417.326	.000	1	.993	216879.850	.000
	[Education=2]	14.718	661.075	.000	1	.982	2466628.301	.000
	[Education=3]	-2.968	2.001	2.199	1	.138	.051	.001
	[Education=4]	0 <sup>c</sup>	.	.	0	.	.	.
	[Religion=1]	.736	1.859	.157	1	.692	2.088	.055
	[Religion=2]	-.437	2.954	.022	1	.882	.646	.002
	[Religion=3]	0 <sup>c</sup>	.	.	0	.	.	.
	[Agrictraining=1]	.698	1.453	.231	1	.631	2.010	.116
	[Agrictraining=2]	0 <sup>c</sup>	.	.	0	.	.	.
	[KnowledgeBC=1]	5.177	1.663	9.686	1	.002	177.149	6.798
	[KnowledgeBC=2]	2.614	.000	.	1	.	13.653	13.653
	[KnowledgeBC=3]	0 <sup>c</sup>	.	.	0	.	.	.
[UsedBC=1]	-3.534	1.989	3.158	1	.076	.029	.001	
[UsedBC=2]	0 <sup>c</sup>	.	.	0	.	.	.	

[SatisfiedAO=1]	-3.714	3.048	1.485	1	.223	.024	6.206E-005
[SatisfiedAO=2]	-1.353	2.231	.368	1	.544	.258	.003
[SatisfiedAO=3]	0 <sup>c</sup>	.	.	0	.	.	.
[Gender=1]	.871	1.940	.201	1	.654	2.388	.053
[Gender=2]	0 <sup>c</sup>	.	.	0	.	.	.

The reference category is: Not sure.

