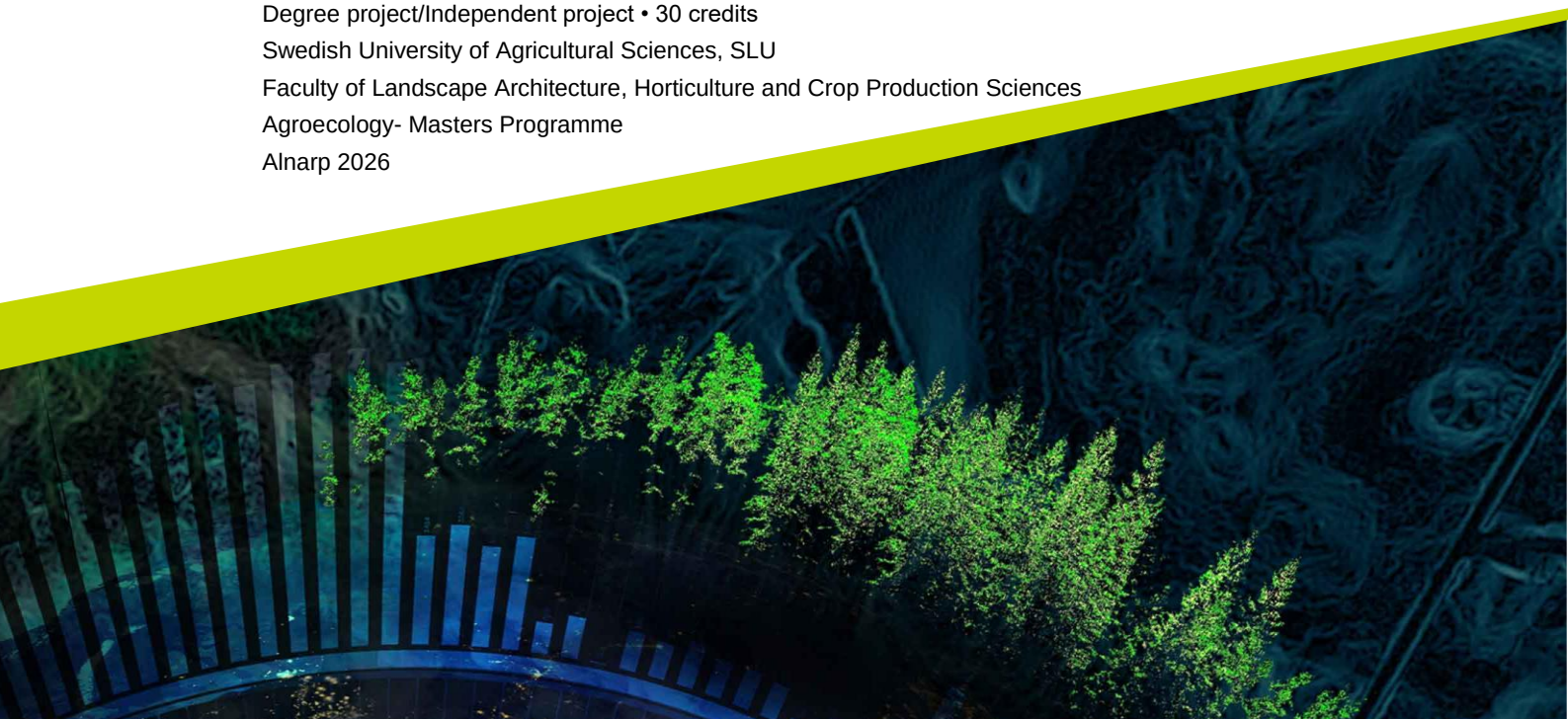
Assessment of Stakeholders' Knowledge, Attitudes, and Practices for Implementing Biological Control and Pesticide Risk Reduction Protocol in Tanzania

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Degree project/Independent project • 30 credits
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Agroecology- Masters Programme
Alnarp 2026



Assessment of Stakeholders' Knowledge, Attitudes, and Practices (KAP) for Implementing Biological Control and Pesticide Risk Reduction Protocol in Tanzania

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Credits:	30
Level:	Second cycle
Course title:	Independent Project in Agricultural Sciences,A2E
Course code:	EX0848
Programme/education:	Agroecology - Masters' Programme
Course coordinating dept:	Department of Biosystems and Technology
Place of publication:	Alnarp
Year of publication:	2026
Copyright:	All featured images are used with permission from the copyright owner.
Keywords:	biological control, knowledge-attitude-practice, pesticide risk-reduction, East African Community,harmonized protocols, Tanzania

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Abstract

Biological control, involving the use of living organisms such as parasitoids, predators and microbial agents to suppress pest populations, is one of the important methods of sustainable pest management and pesticide risk reduction. In Tanzania, its adoption remains low, and the stakeholders responsible for developing, regulating, supplying and using it remains poorly understood. This study therefore assessed the knowledge, attitudes and practices (KAP) of the four stakeholder groups in crop production: farmers, agro-dealers, regulatory officers and researchers. A cross-sectional mixed-methods design guided by the KAP framework was applied. Data were collected between April and May 2026, combining face-to-face interviews with 26 farmers in Mgera Village and 20 agro-dealers in Iringa Municipality with online questionnaires for five regulatory officers and two researchers of the Tanzania Plant Health and Pesticides Authority (TPHPA).

The results reveal a clear and consistent gap between awareness and understanding. Although 73% of farmers had heard of biological control, only 4% could define it in terms of living organisms, and not one of the 53 participants had received formal, specialised training covering both biological control and pesticide risk-reduction protocols. All farmers expressed willingness to adopt biological control, yet 88% relied exclusively on chemical pesticides, 85% applied pesticides without personal protective equipment, 88% did not consistently follow label instructions, and no farmer reported a safe method of disposing of pesticide containers. Among agro-dealers, 85% did not sell or communicate about biological products, and those who had received training were significantly more likely to sell biological products (Fisher's exact test, $p = 0.018$). Regulatory officers and researchers were familiar with Tanzania's Plant Health Act but showed weak familiarity with the harmonised guidelines of the East African Community (EAC), a regional body that Tanzania belongs to, which set common requirements for registering and testing biological control agents in East Africa.

The study concludes that the barriers to biological control adoption in Tanzania are structural rather than attitudinal; people are willing to adopt, but there are structural gaps in training, product availability, institutional capacity, and market development. From agroecological perspectives', pest management remains caught between simply replacing chemicals with biological products, and system redesign. A coordinated response is recommended, combining stakeholder-specific training, locally managed demonstration trials, improved availability and affordability of biological products, and strengthened regulatory and laboratory capacity, as the enabling conditions for an agroecological transition in Tanzanian pest management.

Keywords: biological control, knowledge-attitude-practice, pesticide risk-reduction, East African Community, harmonized protocols, Tanzania

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Foreword

My interest in sustainable agriculture is rooted in my personal, academic and professional experiences. I come from Malawi, an agriculture-based country where farming is central to food security and livelihoods. This background nurtured my passion for agriculture and led me to study Horticultural Sciences, which provided a foundation in crop production, plant health, and pest and disease management. Professionally, I am an Agricultural Officer with the Government of Malawi under the Ministry of Agriculture, specialising in cereal crop production and crop protection, with over eight years of experience working with farmers and agricultural production systems.

Agriculture is also part of my personal life. I own a small piece of land where I grow food mainly for household consumption. Through both my farming and professional work, I have observed increasing pest and disease pressures and the resulting overdependence on synthetic chemical pesticides. These experiences motivated my interest in safer, more sustainable and resilient approaches to crop protection.

My Master's studies in Agroecology broadened my perspective from crop production alone to understanding farms as interconnected ecological and social systems. In particular, the course on Integrated Pest Management in Sustainable Production Systems strengthened my interest in biological control and in approaches that use ecological processes to manage pests while reducing unnecessary reliance on chemical pesticides. The inspiration for this thesis therefore emerged from the connection between my experience as a farmer, my background in horticulture, my professional work in crop production and protection, and my studies in agroecology.

Conducting this research in Tanzania allowed me to connect academic knowledge with practical realities. Interacting with farmers, agro-dealers, researchers and regulatory officers deepened my understanding of the opportunities and challenges surrounding biological control and pesticide risk reduction. It also demonstrated that sustainable agricultural transitions depend not only on technologies, but also on knowledge, access, training, markets, institutional support and collaboration among stakeholders.

The fieldwork was an important journey of personal and professional growth, strengthening my research, communication, collaboration and problem-solving skills. Most importantly, it strengthened my commitment to contributing to sustainable agricultural development in Malawi and the wider African region. I hope the findings of this thesis contribute to discussions on sustainable pest management, biological control, pesticide risk reduction and agroecological transitions, and support efforts to build productive, resilient and environmentally sustainable agricultural systems.

This thesis represents more than the completion of my Master's degree; it brings together my journey as a farmer, horticulturist, agricultural professional, researcher and student of agroecology, and marks an important milestone in my continuing commitment to sustainable agriculture in Africa.

Acknowledgements

First and foremost, I give all glory and praise to Almighty God for His grace, wisdom, protection and strength throughout my academic journey in Sweden.

I express my deepest gratitude to my supervisors: Assoc. Prof. Paul Egan, Dr. Anna Manourova, Dr. Kristina Karlsson Green and Dr. Mesia John Ilomo, for their invaluable guidance, patience, encouragement and support throughout the project period.

I sincerely thank the Swedish Institute (SI) for the scholarship that supported my studies in Sweden. My special appreciation goes to SLU Global and the Erasmus+ Programme for the financial support that enabled me to undertake my research mobility and conduct thesis fieldwork in Tanzania. This opportunity greatly enriched my academic, professional and international research experience.

I extend my sincere appreciation to the Tanzania Plant Health and Pesticides Authority (TPHPA) for hosting me and facilitating this research. I am grateful to the Director General and the management team, with special thanks to Raphael Mwezi for his guidance and coordination. I also thank Mkwawa University College of Education (MUCE), particularly Dr. Juma Mmongoyo and Mr. Frank Mbanila, for their warm hospitality, logistical support and assistance during fieldwork in Iringa.

I am deeply grateful to all the farmers, agro-dealers, researchers and regulatory officers who participated in this study. Their willingness to share their experiences and perspectives formed the foundation of this research. I also thank my lecturers, classmates, colleagues and friends in Sweden, Malawi, Tanzania and elsewhere for their friendship, prayers, encouragement and support throughout this journey.

A very special appreciation goes to my beloved twin sister, Martha, for being my lifelong friend, supporter and constant source of encouragement.

My deepest gratitude goes to my family. To my husband, Kumbukani Manda, thank you for your unconditional love, patience, sacrifices, encouragement and unwavering support during my studies away from home. To my precious children, Urunji, Watanja and Akuzike, thank you for being my greatest source of joy, inspiration and motivation. I dedicate this achievement to you and hope it inspires you to pursue your dreams.

To my dear parents, siblings and extended family, thank you for your prayers, sacrifices, love, encouragement and belief in me. Finally, I sincerely appreciate everyone who contributed directly or indirectly to the successful completion of my studies and this thesis.

List of abbreviations

BCAs	Biological Control Agents
EAC	East African Community
FAO	Food and Agriculture Organization of the United Nations
HHPs	Highly Hazardous Pesticides
IPM	Integrated Pest Management
KAP	Knowledge, Attitude, and Practices
MUCE	Mkwawa University College of Education
PPE	Personal Protective Equipment
TPHPA	Tanzania Plant Health and Pesticides Authority
WHO	World Health Organization
PRR	Pesticide Risk Reduction

1. Introduction

Agriculture is the backbone of many economies in Sub-Saharan Africa (SSA), where it provides livelihoods for the majority of the rural population and contributes significantly to food security and economic development (World Bank, 2018). However, agricultural production across the region continues to face major challenges from insect pests, plant diseases, invasive species and climate variability, resulting in substantial crop losses and reduced productivity (Nega, 2025; Savary et al., 2019).

It is estimated that pests and diseases account for between 20% and 40% of annual crop losses worldwide, with particularly severe impacts on smallholder farming systems in developing countries (FAO, 2023; Savary et al., 2019). To minimise these losses, many farmers rely heavily on synthetic chemical pesticides because they provide rapid and effective pest control (Pretty & Bharucha, 2015).

Pest management decisions are not isolated technical choices; they are decisions about how an agroecosystem is designed and managed. Agroecology, as a field of study and practice, applies ecological concepts and principles to the design and management of sustainable food systems, treating farms as ecosystems in which crop production, biodiversity, and ecosystem services are interdependent (Gliessman, 2015; Wezel et al., 2020).

Within this perspective, the choice between synthetic pesticides and biological control is not simply a choice between two inputs but a choice between managing pests through external intervention and managing them through the ecological processes of the farming system itself. This study, conducted within the Agroecology Master's Programme at the Swedish University of Agricultural Sciences, adopts that agroecological perspective as its conceptual starting point.

Although synthetic pesticides have contributed to increased agricultural production, their widespread and often excessive use has created serious environmental, economic and public health concerns. In many African countries, including Tanzania, pesticide misuse has been associated with contamination of soil and water resources, loss of biodiversity, pesticide resistance, destruction of beneficial organisms and increased risks to human health through occupational exposure and pesticide residues in food (FAO & WHO, 2016; Ngowi et al., 2007). These challenges highlight the need for safer and more sustainable approaches to crop protection.

One promising alternative is biological control, which involves the use of living organisms such as predators, parasitoids, pathogens and other beneficial organisms

to suppress pest populations. Biological control forms an important component of Integrated Pest Management (IPM) because it works with natural ecological processes rather than relying solely on synthetic pesticides (van Lenteren, 2012; Kogan, 1998). Beyond reducing pesticide use, biological control contributes to biodiversity conservation, protects beneficial organisms and supports long-term ecosystem health (Bale et al., 2008).

From an agroecological perspective, biological control represents more than an alternative pest management technology; it is a way of strengthening the ecological foundations of production. Agroecology promotes farming systems that rely on biodiversity, ecological interactions, and ecosystem services to maintain agricultural productivity while reducing dependence on external chemical inputs (Wezel et al., 2020). Biological control is directly compatible with agroecological principles. It increases functional biodiversity in and around fields, it creates synergies among crop production, natural pest regulation, and conservation, and it reduces external input use (Altieri, 2002; Nicholls & Altieri, 2013).

When natural enemies suppress pest populations, the regulating service performed by the agroecosystem itself is enhanced, reducing the need for repeated chemical interventions and improving the resilience of the production system over time (Gliessman, 2015). Biological control therefore contributes to agroecological transitions by strengthening natural pest regulation, improving ecosystem resilience, and supporting more sustainable food production systems.

Across Sub-Saharan Africa, increasing pest pressure resulting from climate change, global trade and the spread of invasive pests such as fall armyworm (*Spodoptera frugiperda*), tomato leaf miner (*Phthorimaea absoluta*), and fruit flies (*Bactrocera spp.*) has renewed interest in biological control and integrated pest management (Abate et al., 2000). In response, governments and regional organisations have promoted biological control as part of broader efforts to reduce pesticide risks while maintaining agricultural productivity.

Within East Africa, the East African Community (EAC) has strengthened regional cooperation by developing harmonised efficacy testing protocols for macro-biological control agents to facilitate product registration and improve access to biological control technologies across member states (EAC, 2024). Tanzania has also strengthened its regulatory framework through the Plant Health Act No. 4 of 2020 (United Republic of Tanzania, 2020), which established the Tanzania Plant Health and Pesticides Authority (TPHPA) to oversee plant health, pesticide regulation and biological control implementation.

Despite these policy developments, the successful implementation of biological control depends not only on the availability of biological control products but also on the knowledge, attitudes and practices of the stakeholders responsible for developing, regulating, promoting and using these technologies. Farmers require sufficient knowledge and confidence to adopt biological control practices, agro-dealers influence farmers' decisions through product supply and technical advice, while researchers and regulators play essential roles in generating scientific evidence, developing policies and ensuring safe implementation (Kirui et al., 2023; Mweke et al., 2025).

Although several studies in Tanzania have examined pesticide use, pesticide exposure and pest management practices, relatively few have investigated the knowledge, attitudes and practices of the different stakeholder groups involved in biological control implementation. Most previous studies have focused primarily on farmers or on pesticide use rather than considering the broader institutional and value-chain actors that influence adoption (Kirui et al., 2023; Mulugeta et al., 2024; Mweke et al., 2025).

Agroecological transitions depend not only on ecological knowledge but also on the willingness and ability of people within the food system to change their practices. Agroecology emphasises the co-creation of knowledge and the participation of multiple actors, including farmers, input suppliers, researchers, and regulators, because sustainable change depends on what these actors know, believe, and do (Wezel et al., 2020). This study addresses the human dimension of an agroecological transition in Tanzanian pest management by examining the knowledge, attitudes, and practices of the stakeholders who develop, regulate, promote, and use pest management technologies.

This study therefore assessed the knowledge, attitudes and practices of farmers, agro-dealers, researchers and regulators regarding biological control and pesticide risk-reduction protocols in Tanzania. By identifying existing knowledge gaps, stakeholder perceptions, current implementation practices and barriers to adoption, the study provides evidence that can support capacity building, extension services and informed decision-making. The findings are also expected to help development of East Africa Community Harmonized guidelines, contribute to strengthening biological control implementation and promote more sustainable pest management within Tanzania.

2. Research objectives and questions

The main research objective was to assess key stakeholders' knowledge, attitudes, and practices regarding the implementation of biological control and pesticide risk reduction protocols in Tanzania.

1. To evaluate key stakeholders' knowledge of biological control methods and pesticide risk reduction efficacy protocol in Tanzania.
   1.1 What is the level of stakeholders' knowledge regarding biological control methods and pesticide risk-reduction protocols?

2. Examine key stakeholders' attitudes toward the adoption, effectiveness, and safety of biological control and pesticide risk-reduction measures.
   2.1 How do perceptions of safety and effectiveness shape stakeholders' willingness to adopt biological control?

3. To assess key stakeholders' implementation practices related to biological control and adherence to pesticide risk-reduction efficacy protocols.
   3.1 To what extent do current pest-management practices align with recommended biological control and pesticides risk-reduction protocols, what barriers affect adoption?

3. Literature review

3.1 Pesticide use in Tanzania

Tanzania's agricultural sector is highly dependent on chemical pesticides for pest and disease control, especially in the horticultural sector where high-value crops like tomatoes, onions, cabbages, and leafy vegetables face intense pest pressure (Kapeleka et al., 2021). As demand for food has grown and farming has become more intensive, pesticide use has increased substantially over the past few decades.

Unfortunately, the way many farmers use pesticides in Tanzania raises serious concerns. Studies have documented widespread unsafe and excessive practices, including spraying without first monitoring for pests, mixing multiple pesticide products together, applying far higher doses than recommended, not observing pre-harvest waiting periods, and failing to use protective equipment (Kapeleka et al., 2021; Lekei et al., 2014; Ngowi et al., 2007).

Kapeleka (2024) provided some of the most detailed evidence of this problem, finding that fungicide application rates in Tanzanian tomato production reached 17.18 kg of active ingredient per hectare. The figure was far above global average pesticides use of 1.2-1.8 kg a.i/ha of active ingredient per hectare, with similar over-application documented for insecticides and herbicides in Iringa, Arusha, and Kilimanjaro regions (Kapeleka, 2024). A broader study involving farmers, agro-input retailers, and healthcare providers found that limited farmer education, poor access to extension advice, weak regulatory enforcement, and the prevalence of informal pesticide markets all contribute to keeping these unsafe practices in place (Mwezi et al., 2026).

The continued circulation of Highly Hazardous Pesticides (HHPs) is another major concern. In 2025, the TPHPA identified 130 pesticide products that met international HHP criteria, and found that 675 products had been on the market without valid registration renewals for more than a decade, a significant regulatory failure that has left many farmers exposed to products that should have been phased out long ago (TPHPA, 2026).

Highly Hazardous Pesticides (HHPs) are “pesticides that present particularly high risks to human health or the environment according to internationally recognised hazard criteria developed by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO). These include pesticides that are highly toxic, carcinogenic, mutagenic, toxic to reproduction, persistent in the environment or highly toxic to non-target organisms such as bees, fish and beneficial insects” (FAO & WHO, 2016).

The overall picture is one of a harmful cycle: heavy pesticide use kills the natural enemies that would otherwise help control pests, which in turn leads to

more severe pest outbreaks, which then prompt even heavier pesticide use. Breaking this cycle requires a fundamental shift toward biological control and other sustainable pest management approaches. Consequently, many international organisations recommend promoting biological control and integrated pest management as part of broader efforts to phase out HHPs and reduce pesticide-related risks.

3.2 Pesticide risks and their implications

The risks associated with pesticide use in Tanzania and across Africa operate across several interconnected domains: human health, the environment, food safety, and farm economics. Understanding these risks helps explain why reducing pesticide dependence is not simply a matter of environmental idealism but a practical necessity for sustainable agriculture.

Farmers and farm workers are at the greatest risk from pesticide exposure, primarily through skin contact, breathing in spray droplets, and accidental ingestion. Short-term effects of acute poisoning include headaches, nausea, dizziness, skin irritation, and breathing problems, with severe cases requiring hospitalization or proving fatal (Damalas & Koutroubas, 2016). Many Tanzanian farmers apply pesticides without adequate protective clothing or equipment, increasing their risk considerably (Lekei et al., 2014; Ngowi et al., 2007) . Over the long term, regular exposure to pesticides, particularly organophosphates, which are common in Tanzanian farming, has been linked to nerve damage, hormonal disruption, reproductive problems, and increased cancer risk (Alavanja et al., 2013; Mwezi et al., 2026).

Pesticides do not stay where they are applied. Runoff, leaching, and spray drift carry them into rivers, lakes, groundwater, and soils, where they can harm aquatic life and contaminate drinking water. Broad-spectrum pesticides also kill pollinators, particularly bees, and natural pest enemies such as predatory insects and parasitic wasps that play a vital role in keeping pest populations in check (Potts et al., 2010). When these beneficial organisms are removed, farmers lose a natural service that would otherwise reduce their need for pesticides, which is why heavy pesticide use often makes pest problems worse over time rather than better.

When the same pesticides are used repeatedly, pest populations gradually evolve resistance to them. Resistant pests survive and reproduce, passing on their resistance to the next generation until the pesticide no longer works. This has been documented in numerous insect pests, plant diseases, and weeds globally, and forces farmers to use higher doses or switch to more toxic products, making an already dangerous situation worse (Heimpel & Mills, 2017). Resistance is a growing concern in Tanzania's intensive vegetable production areas where pesticide applications are particularly frequent.

When pesticides are applied too close to harvest or in excessive amounts, residues remain in food products. This poses health risks to consumers and, for farmers who sell produce in export markets, can result in rejection of their products and loss of market access. At the farm level, the financial burden of buying pesticides, which can account for a large proportion of production costs, reduces profitability, especially for smallholders. Pesticide-related illness also means medical costs and lost working days, adding further economic strain to already vulnerable households. Taken together, these risks build a strong case for prioritizing biological control and pesticide risk reduction as essential components of Tanzania's agricultural development strategy.

3.3 Biological control

Across the globe, biological control is one of the most promising sustainable pest management approaches being promoted to reduce pesticides reliance. In simple terms, it involves using living organisms such as predators, parasitoids, pathogens, and competitors to keep pest populations at levels that do not cause significant crop damage (van Lenteren, 2012). Rather than killing pests directly through chemicals, biological control works with natural ecological processes to achieve long-term pest regulation. This makes it safer for human health and the environment, and well-suited to integration within broader IPM programs (Bale et al., 2008; Heimpel & Mills, 2017).

In addition to biological control agents, agricultural biologicals (agrobiologicals) are relevant to this study. The term covers biopesticides, biofertilizers, biostimulants and botanical pesticides, several of which are already widely used in sub-Saharan Africa. Botanical pesticides such as neem-based products are among the most accessible alternatives to synthetic pesticides for smallholder farmers (Copping & Menn, 2000; Mulugeta et al., 2024). Although this study focuses on biological control in the narrower sense, the boundaries between these categories are not always clear to stakeholders, and the survey instruments therefore referred to biological control products in a way that included agrobiological products available in local markets.

Although this study focuses on crop production, biological control is applied beyond agriculture. It is used in forestry against invasive insects, in stored-grain protection, in greenhouse horticulture where commercially produced natural enemies are routinely released, and in public-health contexts, for example the use of Bacillus thuringiensis israelensis against mosquito larvae.

The foundation of modern biological control was laid in the late 1800s when the vedalia beetle (*Rodolia cardinalis*) was successfully introduced to California to control cottony cushion scale (*Icerya purchasi*) in citrus orchards, the first major

demonstration that a natural enemy could provide effective and lasting pest control (van Lenteren, 2012). Since then, many successful programs have been documented around the world, particularly against invasive pests.

In Africa, a well-known example is the introduction of the parasitoid wasp *Apoanagyrus lopezi* to control cassava mealybug (*Phenacoccus manihoti*), an intervention that significantly reduced infestations across sub-Saharan Africa and delivered major economic and food security benefits (Neuenschwander, 2001). More recently, a large meta-analysis drawing on 99 studies from sub-Saharan Africa found that biological control interventions reduced pest abundance by 63%, crop damage by over 50%, and increased crop yields by over 60% compared to untreated controls, while also protecting natural enemy communities (Ratto et al., 2022).

These are significant results that strongly support the case for expanding biological control in African farming systems. These successes illustrate that biological control can deliver measurable agroecological outcomes, reducing pest damage while protecting the natural enemy communities on which resilient, low-input systems depend (Ratto et al., 2022).

In Tanzania specifically, FAO-supported research identified two locally adapted biological control agents, the beneficial insect *Trichogramma mwanzai* and a fungus *Aspergillus oryzae*, that achieved over 80% reductions in fall armyworm (*Spodoptera frugiperda*) infestation and a 45% increase in maize yields in field trials (FAO, 2025). This shows that Tanzania has the biological resources to develop effective home-grown solutions to emerging pest problems.

Despite these positive results, uptake by smallholder farmers remains low. Research has consistently pointed to the same set of barriers: limited awareness of available biological products, slow action compared to pesticides, weak supply chains, insufficient extension support, and poor regulatory frameworks (Mulugeta et al., 2024; Mweke et al., 2025). These challenges highlight why understanding what stakeholders know, believe, and actually do is so important; technology alone is not enough to drive adoption.

3.4 Institutional framework supporting biological control in Tanzania

The successful implementation of biological control depends not only on technological innovation but also on effective institutional support. In Tanzania, the Tanzania Plant Health and Pesticides Authority (TPHPA) is the national regulatory authority established under the Plant Health Act No. 4 of 2020 (United Republic of Tanzania, 2020). TPHPA plays a critical role in registering pesticides and

biological control products, inspecting agricultural inputs, monitoring pesticide use, enforcing pesticide regulations and promoting safe pest management practices.

The Authority also contributes to national and regional initiatives aimed at strengthening biological control adoption, such as the Plant Health Regulations of 2023, support the implementation of the Plant Health Act of 2020 and the development and implementation of the East African Community (EAC) harmonised Guidelines for the Registration of Biopesticides and efficacy testing protocols of Biological Control Agents for Plant Protection of 2024. These initiatives are intended to improve product registration procedures, facilitate regional trade and increase farmers' access to biological control technologies across EAC member states (EAC, 2024).

Beyond its regulatory mandate, TPHPA works closely with research institutions, universities, extension services and development partners to promote integrated pest management (IPM) and pesticide risk-reduction strategies. Through these collaborations, the authority supports research, field demonstrations, training programmes and awareness campaigns that encourage the safe and effective use of biological control as part of sustainable crop production.

In addition to regulatory institutions, universities and research organisations play an important role in advancing biological control research and developing the human capacity required for sustainable agriculture. Institutions such as Sokoine University of Agriculture (SUA), Tanzania Agricultural Research Institute (TARI) and Mkwawa University College of Education (MUCE) contribute to research, training and knowledge dissemination through collaboration with government agencies, development partners and farming communities (Sibuga et al., 2025). In this study, Mkwawa University College of Education (MUCE) chemistry department, served as a key collaborating institution during fieldwork in the Iringa region. Although primarily recognised for teacher education, MUCE actively supports agricultural and environmental research through partnerships with TPHPA in agricultural research and stakeholder engagement, demonstrating the importance of partnerships between academic institutions and regulatory agencies in supporting sustainable pest management.

Despite these institutional efforts, several studies have reported that challenges remain in translating policy and research into widespread adoption of biological control (Grzywacz et al., 2007). Kirui et al. (2023) similarly found that limited technical capacity, inadequate extension services, insufficient specialised training, financial constraints and restricted availability of biological control products continue to hinder implementation. These institutional challenges reinforce the need for stronger coordination among regulatory authorities, research institutions,

universities, extension services and the private sector to support the wider adoption of biological control and support towards more sustainable farming systems in Tanzania.

3.5 Pesticide risk reduction strategies

Pesticide risk reduction refers to actions taken to lower the harmful effects of pesticide use on people, animals and the environment, while still maintaining effective control of pests (FAO & WHO, 2016). It is not about eliminating pesticides entirely but about using them more carefully and replacing the most dangerous ones with safer alternatives wherever possible. Several interconnected strategies contribute to this goal.

IPM is an approach that reduces the risks of synthetic pesticides by combining biological, cultural, physical, and selective chemical methods and making control decisions based on actual pest monitoring rather than routine spraying, IPM significantly reduces the amount of pesticide applied. Research shows that effective IPM programs can cut pesticide applications by between 30% and 70% without reducing crop yields (Pretty & Bharucha, 2015). In Tanzania, IPM has been promoted mainly through Farmer Field Schools, where farmers learn practical pest management skills. Participants tend to show improved knowledge and more responsible pesticide use, though overall adoption remains limited due to knowledge gaps, weak extension systems, and poor access to biological alternatives (FAO, 2023; Kirui et al., 2023).

Biological control is itself a powerful pesticide risk reduction tool. When farmers use natural enemies to control pests, they reduce how often and how much pesticide they need to apply. This lowers the risk of pesticide residues in food, reduces farmer and consumer exposure to toxic chemicals, and helps protect the pollinators and natural enemies that make farming systems more resilient (Heimpel & Mills, 2017; Bale et al., 2008). Regional efforts to harmonize efficacy testing protocols for macrobials are expected to improve the availability of biological products and strengthen their role as part of Tanzania's pest management toolkit (EAC, 2024).

Many of the most dangerous pesticide practices observed in Tanzania; overuse, improper mixing, missing safety equipment, stem directly from limited knowledge. Farmers who receive proper training are significantly more likely to apply pesticides safely, use protective equipment, and consider non-chemical alternatives (FAO, 2023; Ngowi et al., 2007). Farmer Field Schools have proven to be an effective platform for this kind of practical, participatory education (Davis et al., 2012). Expanding access to good quality training, including on biological control,

is one of the most important investments that can be made in pesticide risk reduction.

Effective regulation determines which pesticide products are allowed on the market and how they can be used. Tanzania's Plant Health Act No. 4 of 2020 and the Plant Health Regulations of 2023 provide a legal framework for this under the TPHPA. However, weak enforcement, informal supply chains, and the presence of unregistered or counterfeit products continue to undermine the system (Mwezi et al., 2026). Internationally, FAO and WHO are pushing for the progressive elimination of HHPs and their replacement with lower-risk alternatives (FAO & WHO, 2016), a process Tanzania has recently begun, albeit belatedly.

Replacing the most hazardous pesticides with biopesticides, botanical pesticides, and biological control agents is a long-term but essential risk reduction strategy. These alternatives are generally much safer for farmers, consumers, and the environment, and they can be integrated effectively into IPM systems (Copping & Menn, 2000). Their wider promotion is particularly important in Tanzania, where HHPs have remained available for far longer than international guidelines would recommend.

3.6 Knowledge-Attitude-Practice (KAP) framework

The Knowledge-Attitude-Practice (KAP) framework provides the theoretical foundation for this study. Originally developed in public health research, it has since been widely used in agricultural research to understand how people's awareness and beliefs influence their actual farming behaviors (Launiala, 2009). The framework is built on a simple but important idea: people need to understand something before they can develop a favorable view of it, and they need a favorable view before they are likely to change their behavior. In other words, knowledge shapes attitudes, and attitudes shape practices.

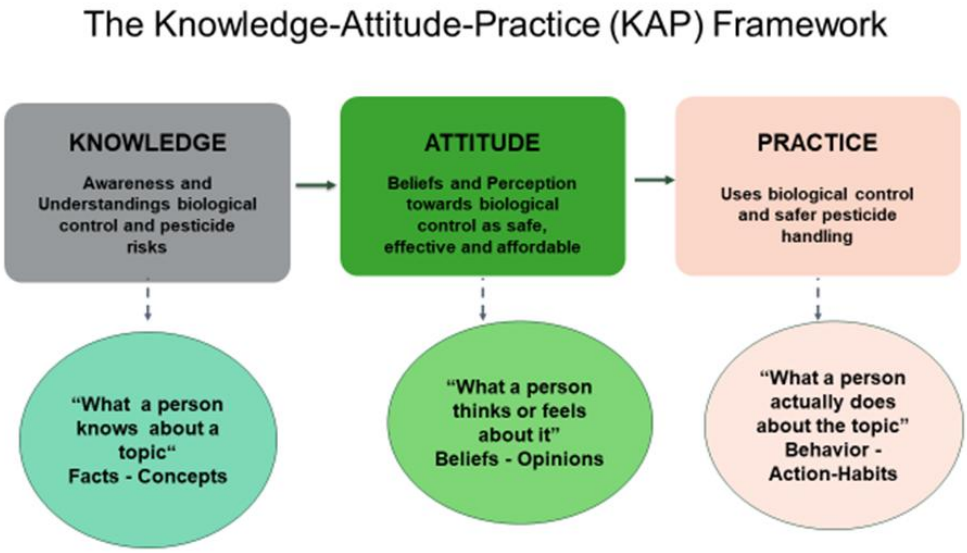


Diagram 1: The Knowledge–Attitude–Practice (KAP) framework illustrating how stakeholders' knowledge may influence their attitudes and practices regarding biological control adoption and safer pesticide management. Source: Author's illustration (2026)

In the context of this study, the KAP sequence works as follows. Stakeholders who understand how biological control works and appreciate the risks of chemical pesticides are more likely to develop positive attitudes toward adopting biological alternatives. Those who hold such positive attitudes are then more likely to actually use biological control methods and follow safer pesticide handling practices. This logical chain makes the KAP framework a practical and well-grounded tool for identifying where things are going wrong and what kinds of interventions are needed.

This study applies the KAP framework within an agroecological framing, in which stakeholder knowledge and participation are understood as part of the social conditions for an agroecological transition. The participatory, multi-stakeholder design reflects the agroecological principle of co-creation of knowledge, which recognises that sustainable pest management cannot be imposed through technology transfer alone but must be built with the actors involved (Wezel et al., 2020; Holt-Giménez, 2006).

Rogers' (2003) Diffusion of Innovations Theory supports this reasoning, arguing that awareness and understanding are the very first steps toward adopting any new technology. Recent studies from sub-Saharan Africa confirm the relevance of the KAP approach to this field: Mulugeta et al. (2024) found it a useful predictor of agrobiological adoption in Ethiopia, and Mweke et al. (2025) used it in Kenya to show that low knowledge was directly linked to negative perceptions of biological products and limited adoption.

In this study, knowledge refers to how well stakeholders understand biological control technologies, pesticide risks, and pesticide risk reduction measures. It is the starting point of the KAP sequence because people cannot make good decisions about something they do not understand. Studies from Kenya and Tanzania have found that fewer than one in four farmers has a good understanding of biological pest management practices (Kirui et al., 2023), and awareness of agricultural biologicals among East African smallholders ranges from just 18% to 47% (Mweke et al., 2025).

In Tanzania, many farmers have inadequate information about pesticide hazards, safe handling, and what biological alternatives exist (Lekei et al., 2014; Mwezi et al., 2026). An important gap in the existing research is that these knowledge studies have focused almost entirely on farmers. The knowledge levels of extension officers, agro-input dealers, regulators, researchers, and policymakers, all of whom play equally important roles in enabling or blocking biological control, have rarely been examined, particularly in the Tanzanian context.

With reference to other studies on biological control, studies from across the region consistently find that limited knowledge is one of the most important barriers to biological control adoption. Kirui et al. (2023) found that fewer than 25% of vegetable farmers in Kenya and Tanzania had adequate knowledge of biological pest management, while farmers who had participated in training programs were notably more willing to adopt sustainable practices.

In Kenya, Mweke et al. (2025) found that only 18% to 47% of smallholder farmers were aware of agricultural biological products, and over 70% had received no training on how to use them. Perhaps most concerning, agro-input dealers, rather than trained extension officers, were the main source of pest management information for most farmers, raising concerns about the accuracy of the advice being given. Mulugeta et al. (2024) found similar patterns in Ethiopia, where farmers with higher levels of education were more likely to be aware of biological products and to adopt them.

Within Tanzania, Lekei et al. (2014) found that many farmers lacked basic information on pesticide risks, safe handling, and biological alternatives. Mwezi et al. (2026) extended this finding beyond farmers, showing that knowledge gaps were also significant among agro-input retailers and healthcare workers, pointing to a system-wide information deficit rather than a problem confined to the farming level.

Extension services are a critical link between formal knowledge about sustainable pest management and what actually happens at the farm level. Farmer Field Schools run by FAO and development partners across East Africa have shown

measurable positive effects on farmers' knowledge, pesticide practices, and willingness to adopt IPM (Davis et al., 2012). However, extension systems in Tanzania and the wider region face significant structural challenges: understaffing, insufficient budgets, and limited technical expertise in biological control, which reduce their reach and effectiveness (Kirui et al., 2023).

At the policy and institutional level, FAO and WHO (2016) emphasize that effective pesticide regulation and active market monitoring are essential for reducing pesticide risks at scale. The EAC's harmonization initiative (EAC, 2024) is the most significant recent step toward creating a regional enabling environment for biological control. However, very little is known about whether the regulators, researchers, policymakers, and agro-input dealers who will need to operationalize this initiative actually have the knowledge and capacity to do so, a gap this study directly addresses.

Attitudes are the beliefs and feelings that stakeholders hold toward biological control and pesticide risk reduction. According to Ajzen's (1991) Theory of Planned Behavior, attitudes shape behavioral intentions, which in turn determine what people actually do. In farming, attitudes toward a new technology are typically influenced by perceptions of how well it works, how much it costs, how easy it is to use, and whether it fits into existing practices.

Research from East Africa consistently shows that farmers generally view environmentally friendly pest management positively in principle, but when it comes to biological control specifically, many remain skeptical about whether it works fast enough and reliably enough compared to chemical pesticides (Kirui et al., 2023; Mweke et al., 2025). This gap between broadly positive general attitudes and hesitation about specific biological products is an important finding, as it shows that changing attitudes requires more than simply raising awareness; it also requires building confidence in how biological control performs under real farming conditions.

On the whole, farmers and other stakeholders tend to hold broadly positive attitudes toward environmentally friendly pest management, but their attitudes toward biological control specifically are more mixed. Kirui et al. (2023) found that farmers who understood biological control viewed it favorably, particularly its ability to reduce pesticide costs and health risks. However, Mweke et al. (2025) found that many farmers saw biological products as slower to act, less reliable, and harder to access than conventional pesticides, which contributed to their continued reliance on chemicals even when they were aware of the risks.

Similar patterns have been observed in Kenya, Uganda, and South Africa, where practical concerns about effectiveness, cost, and labor requirements strongly

influenced decision-making (van Huis & Meerman, 1997). These findings suggest that shifting attitudes toward biological control requires more than information campaigns; farmers need to see biological control working in practice, in their own context and on their own crops, before their skepticism is likely to change.

Practices are what stakeholders actually do, the observable behaviors that result from their knowledge and attitudes combined with the practical realities they face. In this study, relevant practices include how pesticides are applied, whether protective equipment is used, whether biological control agents are being adopted, and how consistently pesticide regulations are followed. A recurring finding in Tanzanian research is a significant disconnect between what farmers know and believe on one hand, and what they actually do on the other. Farmers may know that certain pesticides are dangerous and may express interest in safer alternatives, yet continue applying chemicals in unsafe ways because biological products are not accessible, because markets reward high yields over safety, or because they lack practical technical support (Lekei et al., 2014; Ngowi et al., 2007). Identifying and addressing the sources of this disconnect is one of the central aims of this study.

Research across Tanzania and East Africa paints a consistent picture of unsafe pesticide practices. Ngowi et al. (2007) documented widespread misuse among Tanzanian vegetable farmers, including inadequate PPE use, improper storage, and poor disposal of empty containers. Kapeleka et al. (2021) found that mixing multiple pesticides, applying incorrect doses, and ignoring pre-harvest intervals were common. Kapeleka (2024) added important quantitative evidence, showing that pesticide dosages applied in Tanzanian vegetable production substantially exceed global averages across all major pesticide categories.

In neighboring Kenya, Macharia (2015) found that farmers routinely sprayed preventively rather than based on actual pest observations, resulting in unnecessary chemical use and heightened resistance risks. Across all these studies, the pattern is clear: safe and rational pesticide use is the exception rather than the rule, and this has direct implications for the urgency of promoting pesticide risk reduction programs in the region.

3.6.1 Strengths and limitations of KAP framework

The KAP framework is a practical and well-established tool for studying stakeholder behavior related to agricultural innovations. It makes it straightforward to identify where in the knowledge-attitude-practice chain things are breaking down. It also naturally points toward the kinds of interventions that would help: more education and information for knowledge gaps, demonstration and experience for attitude problems, and practical support and enabling conditions for practice gaps (Launiala, 2009; Rogers, 2003).

However, the framework has limitations worth acknowledging. It assumes that knowledge leads to attitude change, which leads to behavior change, a relatively linear path. In reality, people's behavior is shaped by many factors that exist outside this chain, including financial constraints, social norms, market incentives, institutional barriers, and policy environments (Launiala, 2009; Rogers, 2003). For this reason, this study does not rely on the KAP framework exclusively, but also pays attention to these wider contextual factors as mediating variables that can either enable or block behavioral change even when knowledge and attitudes are favourable (Launiala, 2009; Rogers, 2003).

3.7 Research gaps on biological control

The literature reviewed makes clear that the problems associated with heavy pesticide use in Tanzania are well documented, that biological control offers a credible and effective alternative, and that stakeholder knowledge, attitudes, and practices are central determinants of whether that alternative gets adopted. However, several important gaps remain.

First, almost all existing studies in Tanzania and East Africa focus exclusively on farmers. This is understandable, since farmers are ultimately the ones making pest management decisions at the field level. But the broader stakeholder landscape: extension officers, agro-input dealers, researchers, regulatory officials, and policymakers, plays an equally important role in determining whether biological control is promoted, made accessible, properly regulated, and supported. The knowledge, attitudes, and capacity of these groups in Tanzania are currently very poorly understood.

Second, most available studies examine either pesticide use or biological control adoption in isolation, rather than treating them as two sides of the same sustainable pest management challenge. Examining both together within a single framework, as this study does, provides a more complete picture of the barriers and opportunities facing the sector.

Third, there is almost no empirical evidence on how prepared Tanzanian stakeholders are to engage with the EAC's harmonized efficacy testing protocols for macrobials. This is a significant gap given that these protocols will require active participation and cooperation from a range of institutional actors. Without knowing where capacity gaps exist, it is very difficult to design the kinds of training and support programs that will be needed.

Fourthly, the methodological approaches used in most previous studies have been limited to typical farmer surveys focusing on a single crop or region, with little

attention to the institutional and systemic factors that shape behavior. A broader, multi-stakeholder approach is needed to generate the kind of evidence that can inform coordinated policy and capacity-building responses.

This study directly addresses all four of these gaps. By assessing the knowledge, attitudes, and practices of multiple stakeholders which includes farmers, extension officers, researchers, agro-input dealers, regulatory authorities and policymakers within a single analytical framework guided by the KAP theory, it aims to generate comprehensive evidence that can support more effective implementation of biological control and pesticide risk reduction protocols in Tanzania but also contribute to the broader regional harmonization agenda of the East African Community.

3.8 Agroecological perspectives on pest management

Agroecology applies ecological principles to the design and management of sustainable food systems and positions farming within broader social, economic, and institutional contexts (Gliessman, 2015; Wezel et al., 2020). Two implications follow for pest management. First, pest regulation is an ecosystem service that depends on functional biodiversity, including natural enemies, pollinators, and soil organisms. Farming systems that conserve this biodiversity are better able to regulate pests naturally and are more resilient to shocks such as pest outbreaks and climate variability (Altieri, 2002; Nicholls & Altieri, 2013). Second, the way pests are managed reflects the broader structure of the food system: heavy dependence on synthetic pesticides is characteristic of production systems designed around external inputs, whereas agroecological management seeks to re-design systems so that ecological processes, including natural pest regulation, do more of the work (Gliessman, 2015).

Agroecology therefore distinguishes between incremental input substitution and deeper system re-design. Replacing a hazardous pesticide with a biological product is a meaningful first step, but agroecological transition goes further, restructuring the farming system and its supporting institutions so that regulation of pests is achieved through biodiversity, synergy, and ecological balance rather than through repeated application of any single product (Gliessman, 2015; Wezel et al., 2020). The findings reported in this thesis are interpreted against this distinction between adoption of biological inputs and the longer agroecological transition in which biological control is embedded.

In Tanzania, the relevance of this perspective is increasingly recognised. Long-term agroecology research projects involving universities, regulatory institutions, and farming communities have documented the potential of biodiversity-based and participatory approaches to support more sustainable farming systems (Sibuga et

al., 2025). This study contributes to that agenda by examining the knowledge, attitudes, and practices that shape whether Tanzanian stakeholders move toward biodiversity-based pest management, that is, toward the input-reduction and synergy principles at the heart of agroecology.

4. Materials and Methods

4.1 Study area

The study was conducted in Tanzania, which is located in East Africa between latitudes 1° and 12° South and longitudes 29° and 41° East. The country covers approximately 945,000 km² and had a population of about 61.7 million people at the 2022 Population and Housing Census (United Republic of Tanzania, 2022). It shares borders with Kenya and Uganda to the north, Rwanda, Burundi, and the Democratic Republic of the Congo to the west, Zambia, Malawi, and Mozambique to the south, and the Indian Ocean to the east (United Republic of Tanzania, 2022).

(Figure 1) The study was conducted in Tanzania at two types of sites. Farmer and agro-dealer data were collected in Iringa Region, at two sites: Mgera Village (Iringa District Council) and Iringa Municipality. Regulatory officers and researchers of the Tanzania Plant Health and Pesticides Authority (TPHPA) were surveyed online from their duty stations in Arusha, Kagera and Morogoro. Study sites were selected purposively by the researcher, in collaboration with TPHPA and Mkwawa University College of Education (MUCE), to capture the perspectives of the four stakeholder groups (Patton, 2015). Mgera Village was selected for its active crop production and its prior engagement in sustainable pest-management research trials, and Iringa Municipality for its concentration of agro-dealers serving the region. TPHPA respondents were included because of their central role in pesticide regulation and biological control initiatives; because TPHPA serves the whole country, these respondents are treated as institutional rather than geographic study sites.

4.1.1 Iringa region

Data collection for farmers and agro-dealers was conducted in the Iringa Region, located in the Southern Highlands of Tanzania. Iringa experiences a subtropical highland climate characterized by moderate temperatures and unimodal rainfall patterns ranging between 500 mm and 1,600 mm annually (CGIAR,2018) . The region is an important agricultural production zone, with maize serving as the principal staple crop. Horticultural production, particularly tomatoes and onions, also contributes significantly to household incomes. These production systems are frequently challenged by insect pests and diseases, resulting in intensive pesticide use.

Iringa Municipality

Agro-dealer interviews were conducted in Iringa Municipality. Agro-dealers represent an important stakeholder within agricultural systems because they influence farmers' access to pesticides, biological control products, and technical

information related to crop production and pest management. Through their interactions with farmers, agro-dealers often provide advice regarding pest diagnosis, pesticide selection, application procedures, and dosages.

Mgera Village

Farmer interviews were conducted in Mgera Village, which was purposively selected because of its active engagement in crop production and the prevalence of pest management practices relevant to the study objectives. Farmers in the village cultivate both staple and horticultural crops and frequently encounter pest pressures that necessitate the use of various pest management strategies. The village was considered suitable for the study because it provided an opportunity to assess farmers' knowledge, attitudes, and practices regarding biological control and pesticide risk reduction within a real-world agricultural setting. In addition, the area had previously been exposed to sustainable pest management research trials conducted by the Swedish University of Agricultural Sciences (SLU) in collaboration with the Tanzania Plant Health and Pesticides Authority (TPHPA) and Mkwawa University College of Education, which tested pheromone traps for the control of fall armyworm and tomato leaf miner. This prior exposure made the village an appropriate location for exploring stakeholders' awareness and perceptions of biological control approaches.

4.1.2 TPHPA:Institutional respondents

Regulatory officers and researchers affiliated with TPHPA were included in the study because of their central role in pesticide regulation, biological control initiatives and pesticide risk-reduction interventions. Because TPHPA serves the entire country, these respondents are treated as institutional rather than geographic study sites. Data were collected through online questionnaires from respondents stationed in Arusha, Kagera and Morogoro, and findings for these groups are therefore interpreted as national-level institutional evidence rather than regional comparisons.

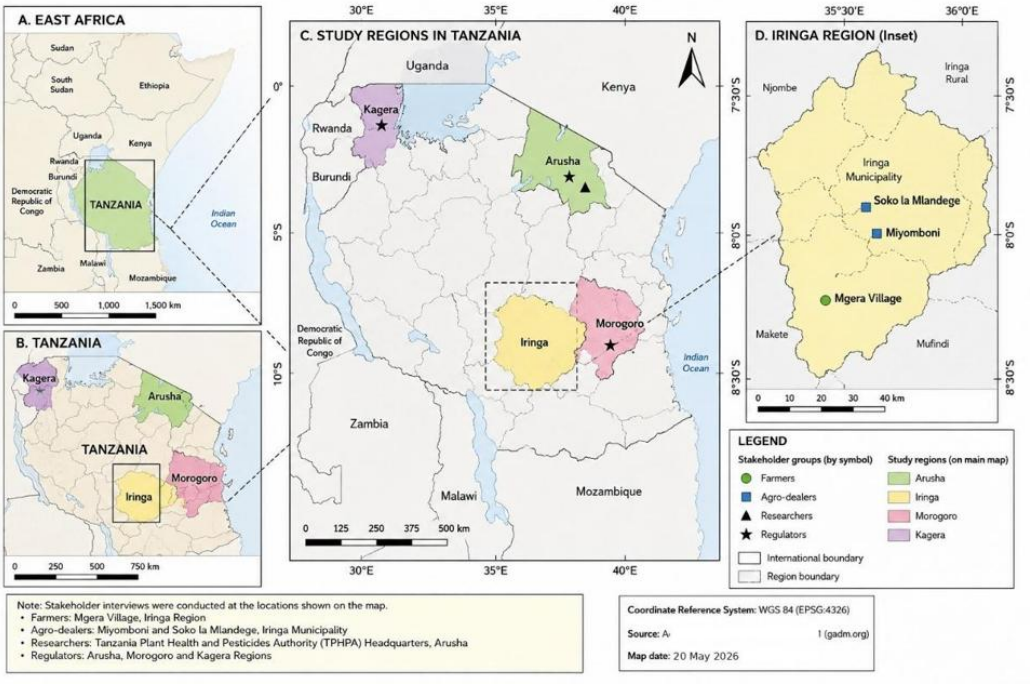


Figure 1. Location of the Study Area: (A) Tanzania within East Africa; (B) and (C) the Study sites within Tanzania of Iringa, Arusha, Kagera, and Morogoro within Tanzania; (D) Mgera Village and Iringa Municipality in Iringa Region. (Source: Generated by Author based on Google Maps imagery (Google, 2026), with AI-assisted preparation (OpenAI ChatGPT, 2026)).

4.2 Study design

The study used a cross-sectional mixed-methods design guided by the Knowledge, Attitude and Practice (KAP) framework. A cross-sectional design involves collecting data from participants at a single point in time and is considered appropriate for assessing existing levels of knowledge, attitudes, and practices within a population (Creswell & Creswell, 2018). The design enabled the researcher to obtain information from different stakeholder groups simultaneously and compare their perspectives regarding biological control implementation and pesticide risk reduction protocols.

The mixed-methods approach combined quantitative and qualitative techniques to provide a more comprehensive understanding of the research problem. Quantitative methods generated measurable indicators of stakeholder awareness, perceptions, and behaviors, while qualitative approaches facilitated exploration of participants' experiences, implementation challenges, and recommendations. Integration of multiple methods enhanced the credibility of findings through triangulation (Creswell & Creswell, 2018).

The study was further guided by the Knowledge-Attitude-Practice framework, which assumes that individuals' knowledge influences their attitudes and that

attitudes subsequently shape their practices and behaviors (Launiala, 2009). The framework was considered appropriate because the study sought to understand how stakeholder awareness of biological control and pesticide risks influences implementation of pesticide risk reduction interventions.

4.3 Data collection

Primary data were collected from April to May 2026 using face-to-face interviews and online questionnaires. The survey guides for all stakeholder groups are provided in the Appendix.

4.3.1 Face-to-Face interviews

Semi-structured interviews were conducted with farmers and agro-dealers using interview guides. The guides were prepared in English and translated into Swahili, the local language, with the translation verified by two experienced research assistants from Mkwawa University College of Education (MUCE). The interview guides contained closed-ended, open-ended, dichotomous, and multiple-choice questions. The questions were designed to capture information on socio-demographic characteristics, knowledge of biological control, awareness of pesticide risks, attitudes toward biological control adoption, current pest management practices, and training needs.

Face-to-face interviews were selected because they facilitate clarification of questions, reduce missing responses, and accommodate participants with varying literacy levels (Patton, 2015). A total of twenty-six (26) farmers and twenty (20) agro-dealers participated in the interviews.



Picture 1 (A&B): Showing face-to-face interviews with male and female farmers in Mgera Village, Iringa Region, Tanzania, during data collection for the study (April 2026). Source: Author's fieldwork photograph (2026).

4.3.2 Online questionnaires

Structured questionnaires developed using Google Forms were administered to regulators and researchers affiliated with TPHPA. The online approach was adopted because respondents were geographically dispersed and physically unavailable, which limited opportunities for in-person interviews. The questionnaires incorporated both closed-ended and open-ended questions addressing biological control awareness, pesticide regulations, implementation experiences, institutional challenges, and capacity-building requirements. A total of five (5) regulators and two (2) researchers participated in the online survey.

4.3.3 Observations

Field observations were conducted during interactions with farmers and agro-dealers to complement the interview findings. Observations focused on the availability of biological control products, pesticide storage practices, use of personal protective equipment, and general pest management practices.

4.4 Data analysis

Data collected through the KAP survey were analysed using a mixed approach combining quantitative descriptive statistics, inferential statistical tests, and qualitative thematic analysis. The analytical strategy was selected to match the predominantly categorical and ordinal nature of the data and the small sample sizes across stakeholder groups, which ranged from two researchers to 26 farmers. All quantitative analyses were conducted using the R statistical computing environment (R Core Team, 2023), a free and open-source platform widely used in agricultural and public health research. Qualitative open-ended responses were thematically analysed using the framework analysis approach (Gale et al., 2013).

4.4.1 Quantitative analysis: Descriptive statistics

For all four stakeholder groups, the first stage of analysis involved computing descriptive statistics in Microsoft Excel to summarise the distribution of responses across all survey items. These included frequencies and percentages for categorical variables such as gender, training received, biological control awareness, and pest management practices; means and ranges for Likert-scale attitude and knowledge items scored from 1 to 5; and cross-tabulations to examine the joint distribution of key variable pairs. Descriptive statistics were the primary analytical method for the regulatory officer (n = 5) and researcher (n = 2) sub-samples, for which sample sizes were insufficient to support inferential testing.

4.4.2 Quantitative analysis: Inferential statistical tests

For the farmer (n = 26) and agro-dealer (n = 20) samples, four inferential statistical methods were applied, all selected because of their suitability for small samples and non-normally distributed data.

Fisher's Exact test was used to examine associations between pairs of categorical variables, for example, whether training received was associated with biological control use, PPE use, or label compliance among farmers, and whether training or biological control awareness was associated with the sale of biological products among agro-dealers (Agresti, 2010). Fisher's Exact test was preferred over the Chi-square test because several contingency table cells contained fewer than five observations, violating the minimum frequency requirement for Chi-square to produce reliable results. A significance threshold of $p < 0.05$ was applied throughout.

The Mann-Whitney U Test (also known as the Wilcoxon Rank-Sum Test) was used to compare Likert-scale attitude scores between two independent groups, for example, comparing effectiveness perception, safety perception, and willingness to

adopt between trained and untrained respondents, and between those aware and unaware of biological control (Mann & Whitney, 1947).

Spearman's Rank Correlation Coefficient (ρ) was used to assess the strength and direction of associations between pairs of ordinal attitude variables, for example, whether perceptions of biological control effectiveness were associated with willingness to adopt, and whether safety perception was associated with willingness to reduce pesticide use (Spearman, 1904). Spearman's correlation was preferred over Pearson's because it does not require continuous, normally distributed data.

Binary Logistic Regression was used to model predictors of specific implementation practices among farmers, with PPE use and consistent label compliance as the binary outcome variables, and training received, biological control awareness, EAC guideline awareness, and TPHPA awareness as predictors (Hosmer, Lemeshow, & Sturdivant, 2013). Regression coefficients were converted to odds ratios to express the direction and magnitude of each association. Given the small farmer sample size (n = 26) and limited outcome variation, with only 15% of farmers using PPE and only 12% always following label instructions, the regression results are interpreted with caution and treated as exploratory rather than confirmatory.

4.4.3 Qualitative analysis

Open-ended survey responses were analysed using framework analysis. Framework analysis was selected because it is particularly well suited to studies with predefined research objectives, in this case the three KAP domains, and to small numbers of respondents whose responses can be examined individually as well as compared across cases (Gale et al., 2013).

4.4.4 Use of Artificial Intelligence tools

This study used three artificial intelligence (AI) language model tools, Claude AI (Anthropic), ChatGPT (OpenAI), and Anara (Anara.com) during the data analysis and manuscript preparation phases. Artificial intelligence tools were used to support literature searching, reference searching and verification, language editing, manuscript organisation, and the generation of preliminary analytical code. The generated code was subsequently run and verified in RStudio. In addition, AI tools were used to assist in the preparation of the study-area map (Figure 1); the map was generated and verified by the researcher, and the AI contribution was limited to technical assistance.The researcher verified the data, statistical outputs, citations, interpretations, and final text. The AI tools were not used to generate, interpret, or write up the study findings, and did not replace the researcher’s responsibility for analytical decisions, interpretation, or scientific conclusions.

4.5 Ethical permits

The study was conducted according to the ethical principles governing research involving human participants. An ethical permit was granted by the Swedish University of Agricultural Sciences (SLU, Alnarp campus), and the study was carried out in compliance with SLU's institutional research ethics guidelines. In Tanzania, permission to conduct fieldwork was obtained from the Tanzania Plant Health and Pesticides Authority (TPHPA) in Arusha and from Mkwawa University College of Education (MUCE) in Iringa, which served as the host in-country partner institution, before data collection commenced.

Before each interview, verbal informed consent was obtained from farmers and agro-dealers, while for the online questionnaires an informed consent statement was incorporated into the Google Forms. Participants were informed about the purpose of the study, the voluntary nature of participation, their right to withdraw at any stage without consequences, and the measures undertaken to ensure confidentiality. Participants' identities were anonymised; no personally identifying information was recorded, and all data were stored securely and accessible only to the research team.

5. Results

5.1 Socio-demographics characteristics of key stakeholders

Most respondents were male (92.3%, n = 24), while females accounted for 7.7% (n = 2) (Table 1). Respondents were mainly adults in the economically active age groups: 42.3% (n = 11) were aged 19–30 years, 42.3% (n = 11) were aged 31–50 years, and 15.4% (n = 4) were aged 51–80 years. Most farmers had completed primary education (84.6%, n = 22), while 15.4% (n = 4) had completed secondary education. Farming experience varied. Ten respondents (38.5%) had less than five years of experience, eight (30.8%) had 5–10 years, two (7.7%) had 11–20 years, and six (23.1%) had more than 20 years of experience.

The majority of respondents operated small farms. Fourteen farmers (53.8%) cultivated 2.5–5 acres, eight (30.8%) cultivated less than 2.5 acres, three (11.5%) cultivated more than 5–12 acres, and one respondent (3.8%) cultivated more than 12–25 acres. Regarding crop production, sixteen farmers (61.5%) cultivated maize together with horticultural crops such as tomatoes and onions. Four respondents (15.4%) cultivated horticultural crops only, four (15.4%) cultivated maize, horticultural crops and legumes, and two (7.7%) cultivated maize only (Table 1).

Table 1. Socio-demographic characteristics of farmer respondents in Mgera village (n=26).

Characteristic	Category	Frequency (n)	Percentage (%)
Age (years)	19–30	11	42.3
	31–50	11	42.3
	51–80	4	15.4
Gender	Male	24	92.3
	Female	2	7.7
Education level	Primary	22	84.6
	Secondary	4	15.4
Farming experience	Less than 5 years	10	38.5
	5–10 years	8	30.8
	11–20 years	2	7.7
	More than 20 years	6	23.1
Farm size	Very small (<2.5 acres)	8	30.8
	Small (2.5–5 acres)	14	53.8
	Medium (>5–12 acres)	3	11.5
	Large (>12–25 acres)	1	3.8

Main crops grown	Maize	2	7.7
	Horticulture (Tomato/Onion/etc.)	4	15.4
	Maize + Horticulture (Tomato/Onion/etc.)	16	61.5
	Maize + Horticulture (Tomato/Onion/etc.) + Legumes	4	15.4

The agro-dealer sample comprised twenty respondents operating mainly in the Miyomboni area of Iringa Municipality. Most agro-dealers were aged 31–50 years (75.0%, n = 15). Three respondents (15.0%) were aged 51–80 years, while two (10.0%) were aged 19–30 years (Figure 2). Although the respondents were generally in the economically active age group, many of their businesses were relatively new. Ten agro-dealers (50.0%) had operated for less than five years, five (25.0%) for 5–10 years, three (15.0%) for 11–20 years, and one (5.0%) for more than 20 years. The available data accounted for nineteen respondents in the final experience category (Figure 2).

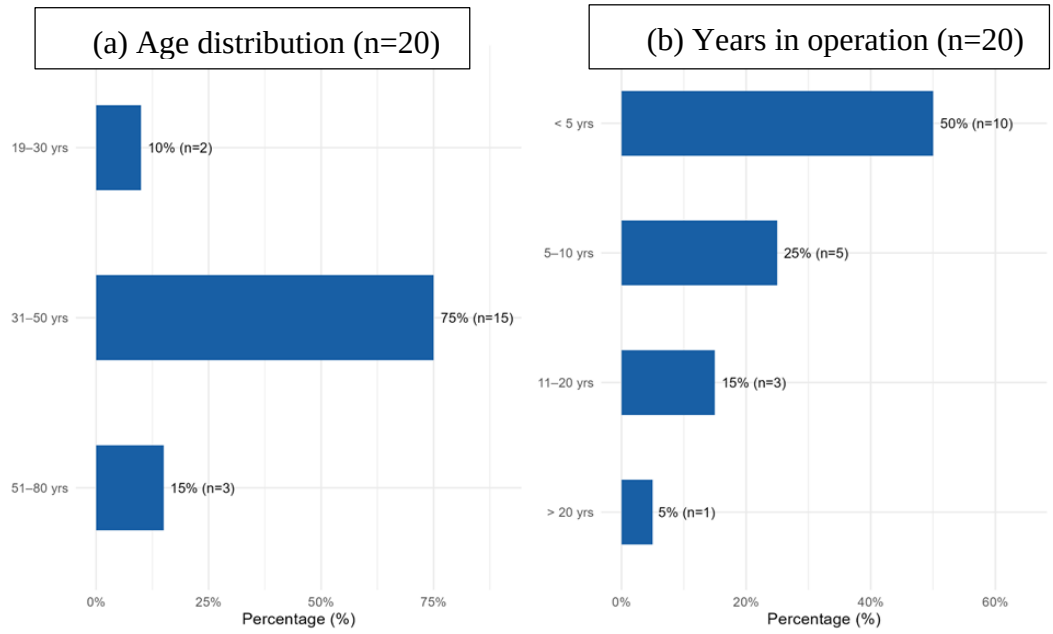


Figure 2. Dual panel of Agro-dealers' socio-demographic characteristics; (a) Age distribution and (b) years in operation (n=20).

All five regulatory respondents were employed by TPHPA. Their professional roles included a laboratory scientist attached to the National Plant Quarantine Service, a pesticide inspector, a senior officer, a field officer, and a regulatory officer with cross-cutting responsibilities. Three respondents were stationed in Arusha, one in

Kagera, and one in Morogoro. Professional experience: two reported 11–20 years of professional experience, one reported 21–30 years, and the remaining two reported less than five (<5) years of experience(Table 2)

Table 2 Socio-demographic characteristics of regulatory officers (n = 5)

Indicator	**Category**	**Frequency (n)**	**Percentage (%)**
Institution	TPHPA	5	100.0
Professional role	Laboratory scientist (National Plant Quarantine Service)	1	20.0
	Pesticide inspector	1	20.0
	Senior officer	1	20.0
	Field officer	1	20.0
	Regulatory officer (cross-cutting responsibilities)	1	20.0
Duty station	Arusha	3	60.0
	Kagera	1	20.0
	Morogoro	1	20.0
Professional experience	Less than 5 years	2	40.0
	11–20 years	2	40.0
	21–30 years	1	20.0

Table 3 illustrates the socio-demographic and professional characteristics of researchers. The sample comprised one male and one female respondent, representing 50 % each. The two researcher respondents were both aged 31–50 years, held college or university-level education, and were affiliated with TPHPA and based at its Arusha facility. Professional experience varied: one respondent had less than five years of experience, while the other had 5–10 years. Their reported roles included stakeholder engagement and farmer training on the proper use and safe handling of pesticides (Table 3).

Table 3 Socio-demographic and professional characteristics of researcher respondents (n = 2).

Indicator	Category	Frequency (n)	Percentage (%)
Gender	Male	1	50.0
	Female	1	50.0
Age	31-50 years	2	100.0
Education level	College/ University	2	100.0
Institution	TPHPA	2	100.0
Duty station	Arusha (TPHPA facility)	2	100.0
Professional experience	Less than 5 years	1	50.0
	5- 10 years	1	50.0

5.2 Stakeholders' knowledge of biological control and pesticide risk-reduction protocols

Knowledge was assessed using indicators covering awareness of biological control, understanding of its principles, familiarity with regulatory frameworks, participation in specialised training, and knowledge of implementation procedures.

5.2.1 Farmers' knowledge

In our analysis of farmers' knowledge, when asked to define biological control in their own words, we found that fourteen farmers (54.0%) described it exclusively in relation to pheromone traps. Three respondents (12.0%) referred generally to fall armyworm traps used in previous trials. Seven respondents (27.0%) could not provide a definition. Only one respondent (4.0%) gave a definition that referred to the use of living organisms, which approximated the scientific meaning of biological control (Figure 3).

These findings indicate that reported awareness was higher than conceptual understanding. Awareness was largely associated with a specific technology or local project rather than with the ecological principles underlying biological control.

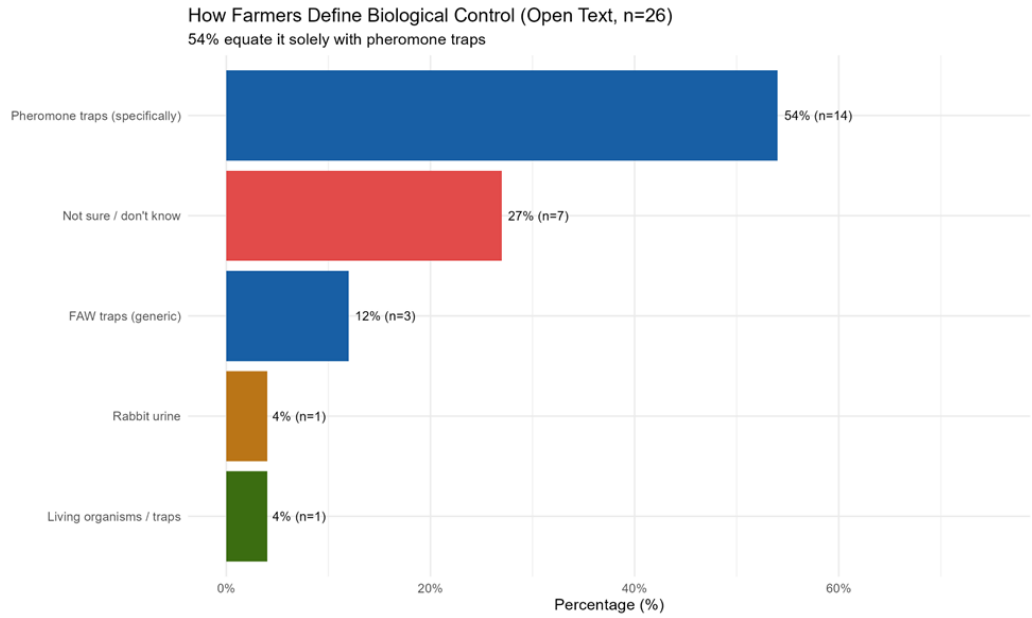


Figure 3. Farmers' awareness and definition of biological control in Mgera Village (n=26).

5.2.2 Agro-dealers' knowledge

Twelve agro-dealers (60.0%) had heard of biological control, while eight (40.0%) had not. Awareness was not primarily obtained through formal training. Some respondents reported learning about biological control through television and other communication channels (Figure 4).

Only six agro-dealers (30.0%) had received training in biological control or pesticide risk reduction, while fourteen (70.0%) had received no such training. All fourteen untrained respondents stated that training had not been offered to them. They did not attribute the absence of training to a lack of interest. Respondents reported that government training provided through TPHPA and the Ministry of Agriculture focused mainly on chemical pesticides (Figure 4).

Agro-dealers' familiarity with the Plant Health Act 2020 and TPHPA registration requirements had a mean score of 3.3 out of 5, based on a five-point Likert scale where 1 = Not at all familiar, 2 = Slightly familiar, 3 = Moderately familiar, 4 = Very familiar, and 5 = Extremely familiar. Overall, the mean score indicates a moderate level of familiarity among agro-dealers. Seventeen respondents (85.0%) scored between 3 and 5. Seven respondents (35.0%) scored exactly 3, indicating moderate familiarity, while ten (50.0%) scored 4 or 5, indicating relatively high familiarity. The remaining respondents scored below 3 (Figure 5).

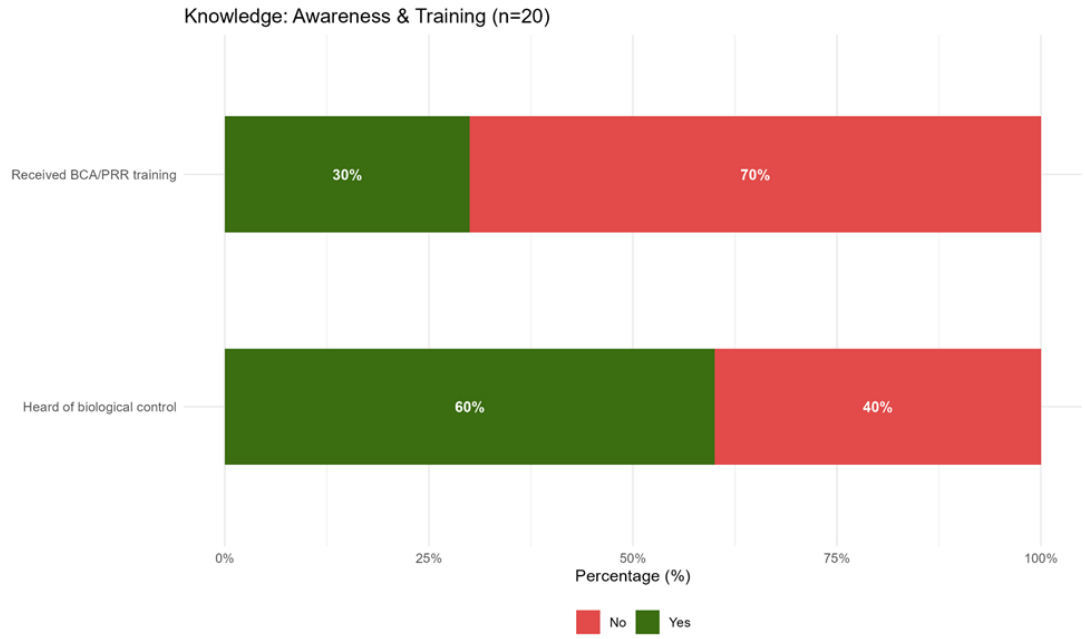


Figure 4. Agro-dealers' awareness of biological control agents (BCA) and reported training received in biological control or pesticides risk-reduction (PRR) in Iringa town (n=20).

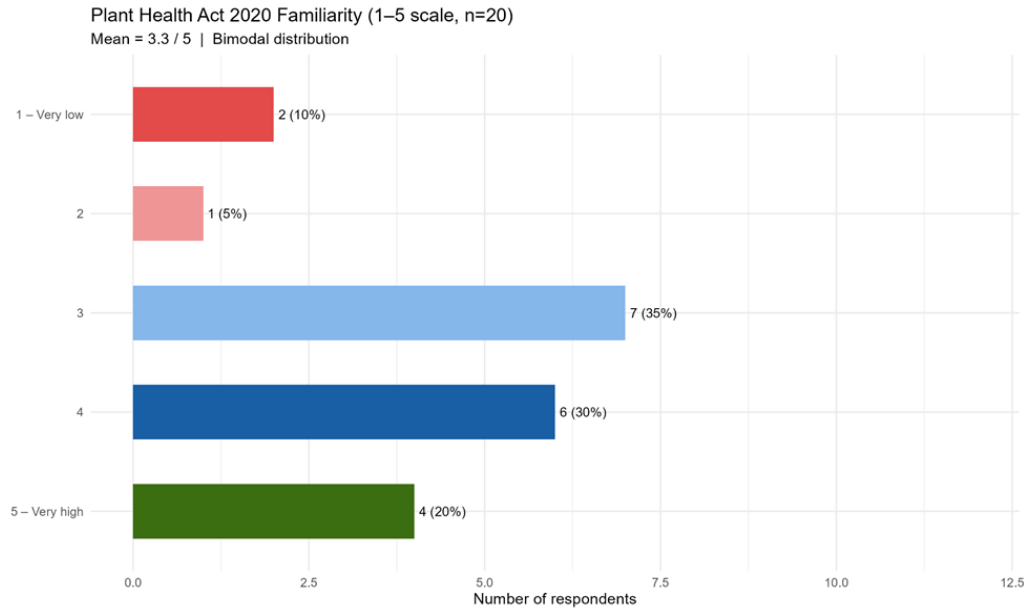


Figure 5. Agro-dealers' familiarity with the Plant Health Act (2020) and TPHPA registration requirements in Iringa town (n=20).

5.2.3 Regulators' knowledge

Four of the five regulatory officers (80.0%) had received no formal training in biological control agents or pesticide risk-reduction protocols. The remaining officer reported general undergraduate training in pest management but no specialised training in biological control agents (Figure 6).

Familiarity with the EAC harmonised guidelines was the weakest knowledge area, with a mean score of 2.4 out of 5. Two respondents scored 1, despite the reported institutional use of the guidelines (Table 10).

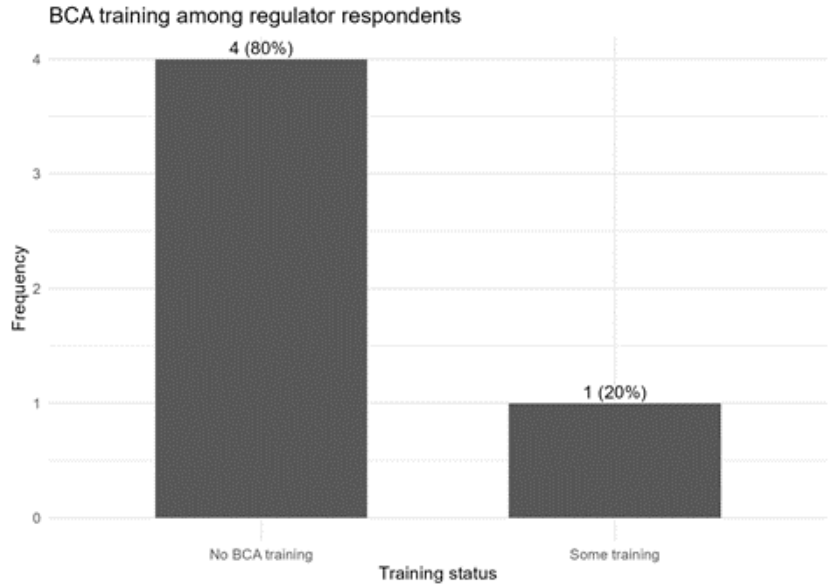


Figure 6. Regulators' awareness of biological control; training received on biological control agents and pesticide risk-reduction protocols (n=5).

5.2.4 Researchers' knowledge

The two researchers demonstrated moderate knowledge of the national policy and regulatory framework. Information accessibility received the highest mean score (M = 3.5). Familiarity with the Plant Health Act 2020 was moderate (M = 2.5), while familiarity with the EAC biological control guidelines was lowest (M = 2.0). These results indicate that the researchers had better access to information than familiarity with the regional technical guidelines.

5.3 Stakeholders' attitudes towards biological control

Attitudes were assessed using perceptions of effectiveness, safety, willingness to adopt biological control, willingness to reduce pesticide use, and willingness to pay for biological control products.

5.3.1 Farmers' attitudes

All twenty-six farmers (100.0%) indicated that they would use biological control if it were available. Twenty farmers (77.0%) agreed that reducing pesticide use was important for the environment, while six were uncertain (Figure 7).

Most farmers were uncertain about the practical performance and accessibility of biological control. Twenty-four respondents (92.3%) were unsure whether

biological products were too expensive or difficult to find, while two (7.69%) agreed with the statement. Seven respondents (26.9%) agreed that biological control worked as well as chemical pesticides, while nineteen (73.07%) were uncertain. The same pattern was observed for perceived safety: seven respondents (26.9%) considered biological control safer for people and the environment, while nineteen (73.07%) were uncertain. No respondent expressed a negative response to either statement.

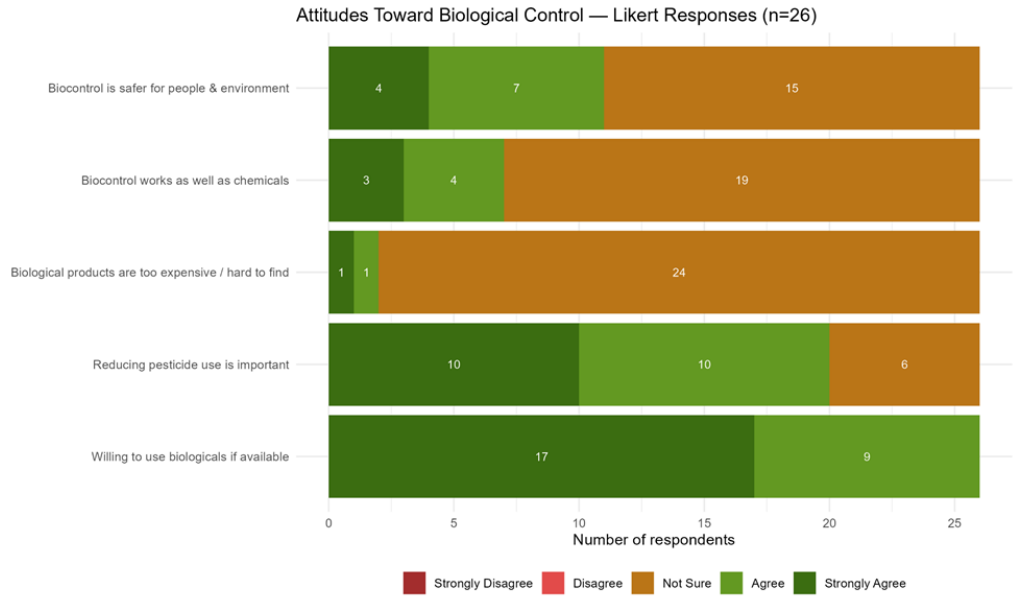


Figure 7. Farmers' attitudes towards using biological control; biological control is safer than chemicals, and willingness to adopt biological control products if available (n=26).

5.3.2 Agro-dealers' attitudes

Seventeen agro-dealers provided a safety rating. Of these, 15 respondents (88.0%) rated the safety of biological control at 4 or 5 out of 5. Two respondents (12.0%) gave a rating of 3. No respondent rated biological control below 3. The results indicate generally positive perceptions of safety, although the three missing ratings should be considered when interpreting the percentages (Figure 8).

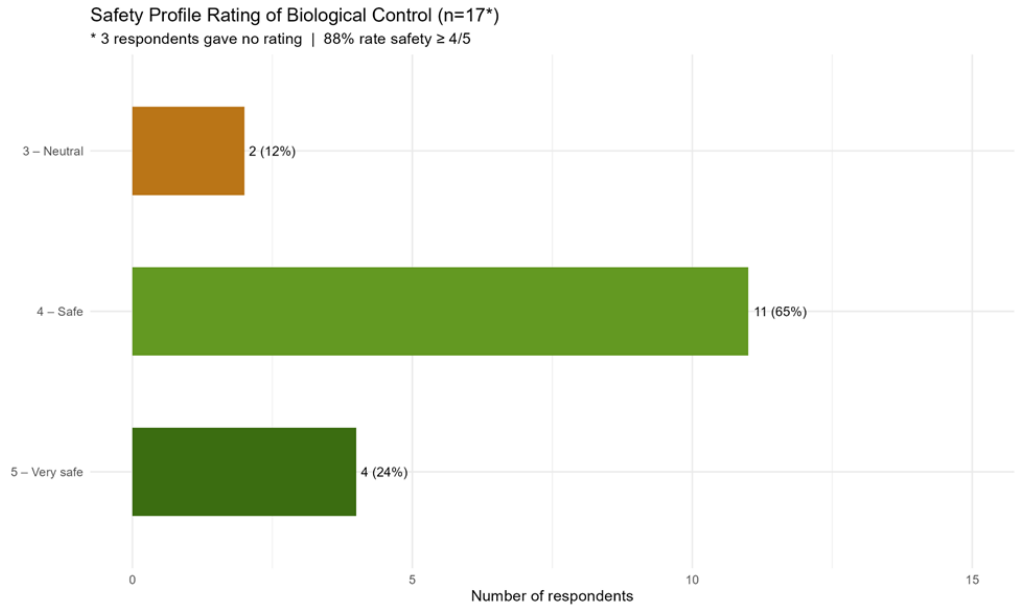


Figure 8. Agro-dealers' safety perceptions of biological control products (n=17).

5.3.3 Regulators' attitudes

Regulatory officers scored highest on familiarity with the Plant Health Act 2020 (M = 4.0) and access to technical information (M = 3.8). Familiarity with the EAC harmonised biological control guidelines was lower (M = 2.4). Three respondents reported that the guidelines were fully adopted and two reported partial adoption. This contrast suggests that institutional adoption had not been matched by equivalent individual-level familiarity (Figure 9).

Perceived speed of action (M = 2.8) and long-term sustainability (M = 2.8) were below the midpoint of the scale. Safety perception was moderate (M = 3.4), as was willingness to prioritise biological control (M = 3.0). Overall, the regulators showed stronger familiarity with national legislation than with regional technical guidelines, and they expressed greater confidence in safety than in practical performance (Figure 9).

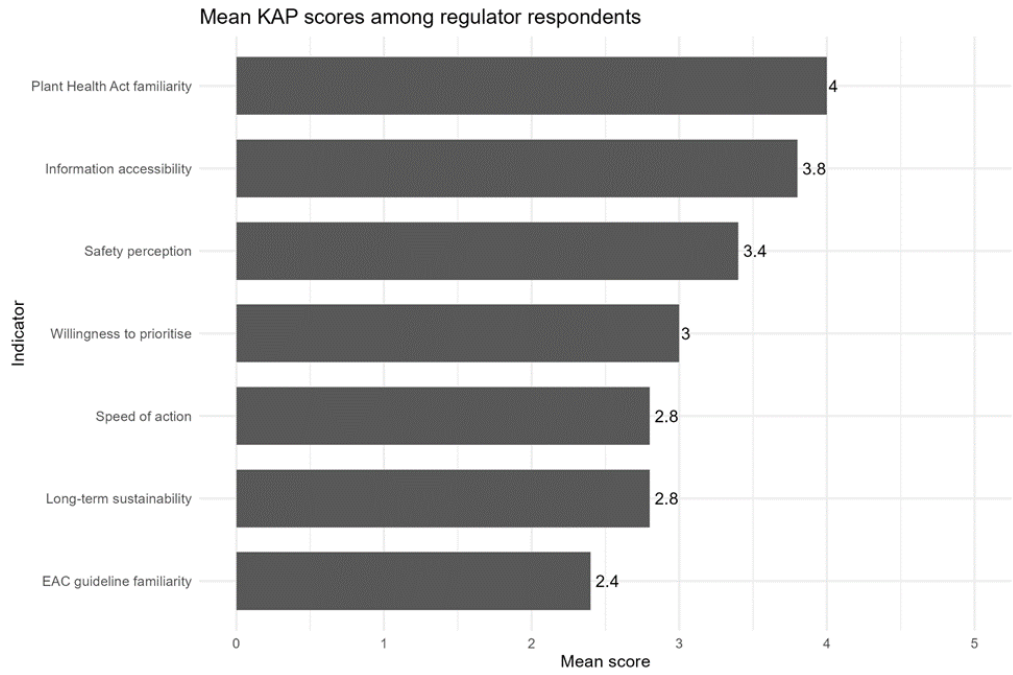


Figure 9. Regulators' attitudes towards biological control products and familiarity with the East African Community harmonized efficacy testing protocols (n=5).Using means of a five-point Likert scale where 1 = not at all and 5 = extremely.

5.3.4 Researchers' attitudes

Researchers expressed positive attitudes towards the safety of biological control.Using the same attitude categories assessed among regulators, researchers were asked to rate biological control in relation to safety, stakeholder coordination, speed of action, long-term sustainability, and willingness to prioritise biological control over chemical alternatives.Safety received the highest mean score (M = 4.5), while stakeholder coordination received a moderate score (M = 3.0). One respondent described biological control as "very safe."

However, perceptions of practical performance were less positive. Speed of action received a mean score of 2.5, and long-term sustainability received a mean score of 2.0. Willingness to prioritise biological control over chemical alternatives received the lowest score (M = 1.0). The results therefore show a consistent difference between researchers' confidence in safety of biological control and their confidence in its practical performance and long-term effectiveness.

5.4 Stakeholders' implementation practices

Implementation practices included pest-control methods, use and promotion of biological control, pesticide safety practices, communication with farmers, and regulatory or research activities.

5.4.1 Farmers' practices

Only four farmers (15%) reported using personal protective equipment when applying pesticides, while 22 (85%) did not. Twenty-three farmers (88%) relied exclusively on chemical pesticides. Only three (12%) reported using some form of integrated pest management, including rabbit urine, sand, and biological control. Two farmers (8%) reported currently using pheromone traps and rabbit urine (Figure 10).

Only three farmers (12%) always followed pesticide label instructions. Eighteen (69.0%) followed them sometimes, four (15%) rarely, and one (4%) never followed them. Thus, 88% did not consistently follow label instructions. In addition, 81% of farmers relied on fellow farmers for pest-management advice (Figure 11).

Pesticide-container disposal practices were unsafe. Throwing containers away and burning them were each reported by 31% of respondents. Burying was reported by 19%, burning combined with burying by 15%, and burning combined with throwing away by 4%. No respondent reported using a formal or otherwise safe disposal method (Figure 12).

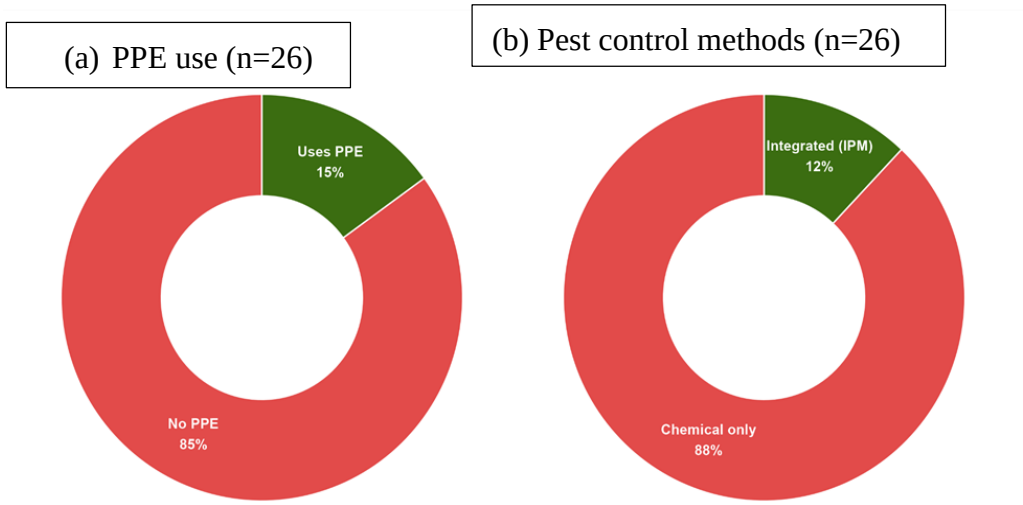


Figure 10. Dual pie charts on pesticide-safety practices; (a) farmers' use of Personal Protective Equipment (PPE) during pesticide application, and (b) pest-control methods by farmers in Mgera Village (n=26).

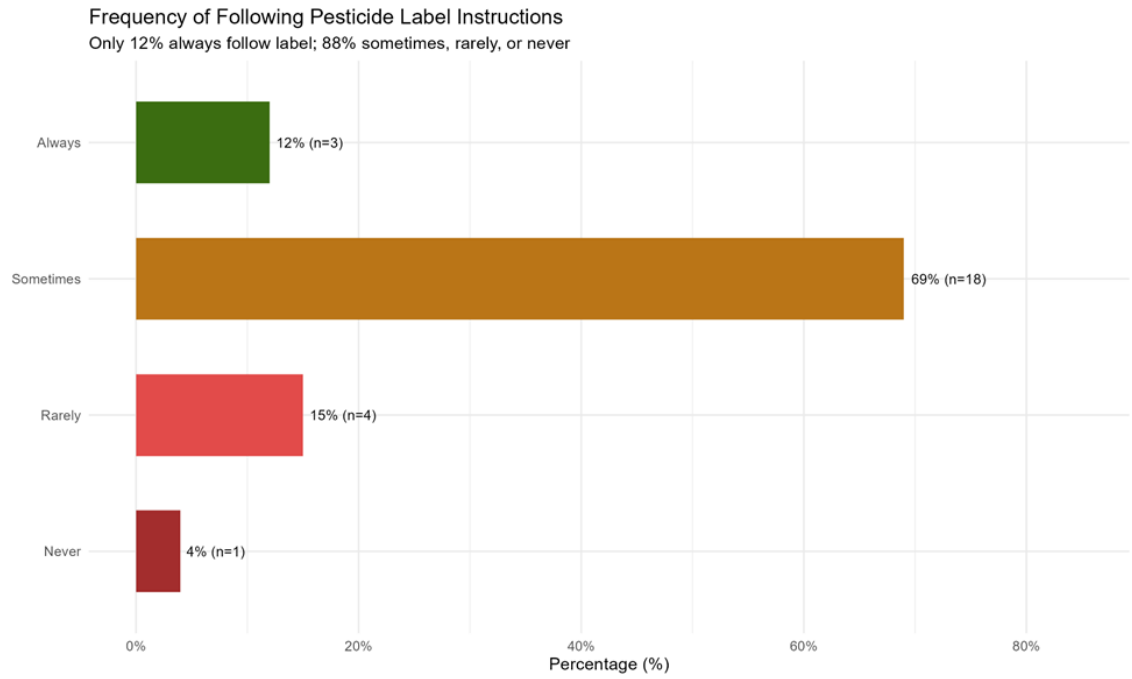


Figure 11. Farmers' compliance with pesticide label instructions (n=26).

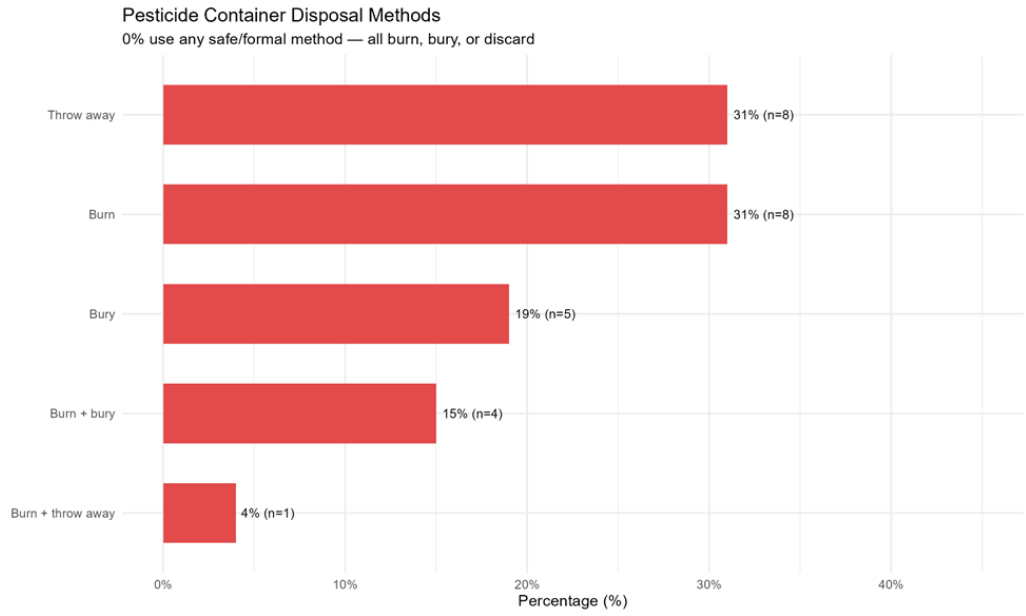


Figure 12. Farmers' methods of disposing of empty pesticide containers (n=26).

5.4.2 Agro-dealers' practices

Seventeen agro-dealers (85%) did not communicate with farmers about biological control. Two respondents (10%) used demonstrations, trials, or social media, while one (5%) combined advice with printed posters. All 20 agro-dealers

reported providing technical advice to farmers in their general advisory role (Figure 13).

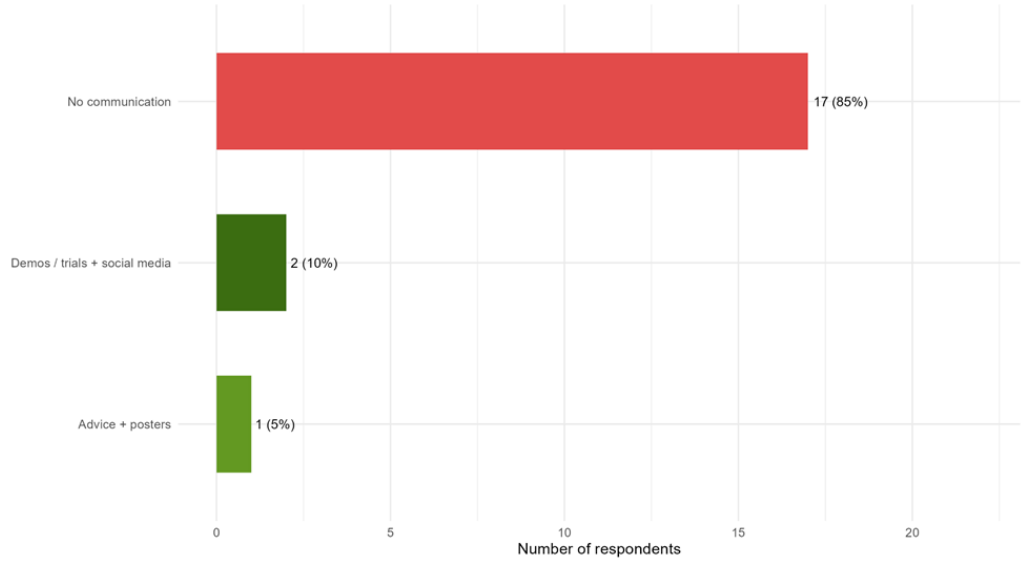


Figure 13. Agro-dealers' communication methods of biological control products information to farmers (n=20).

5.4.3 Regulators' practices

All five regulatory officers (100.0%) reported using demonstration plots to promote biological control. Four (80.0%) reported conducting training programmes. All five regulators identified farmer training as the most necessary intervention for improving adoption(Figure 14).

Policy advocacy and subsidy programmes were each reported by two respondents (40.0%). Other reported constraints included inadequate laboratory facilities and the cost of monitoring. The results indicate that demonstration and training were more common than policy advocacy or financial-support activities.

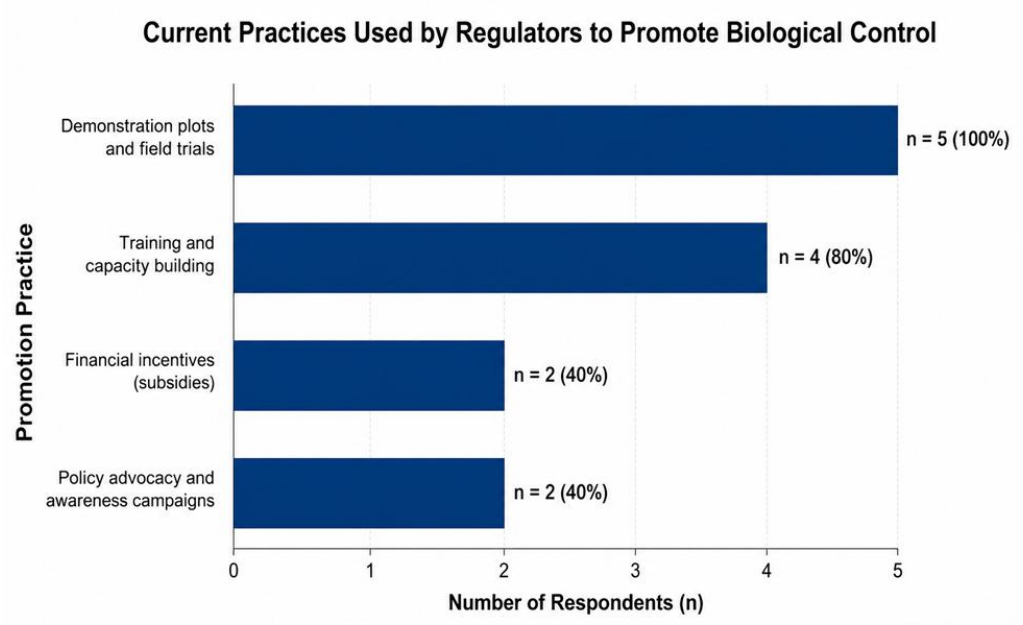


Figure 14. Regulators' current practices for promoting biological control (n=5).

5.4.4 Researchers' practices

Both researchers identified capacity building and demonstration plots as activities supporting biological control adoption. Policy advocacy and the preparation of technical briefs were each identified by one respondent. This suggests that researchers contributed mainly through capacity building and field activities, while policy engagement was less consistent.

5.5 Barriers to biological control adoption

5.5.1 Farmers' barriers

The most frequently reported challenge was the high cost of pest-management inputs, identified by eleven respondents (42%). Lack of knowledge was reported by four respondents (15%). Three respondents (12%) identified both high cost and lack of knowledge, while three (12%) identified high cost and limited access to pest-management products(Figure 15).

When responses involving cost were combined, cost was reported by 66% of respondents. Knowledge-related barriers, either alone or in combination with another barrier, accounted for 27%. Limited access to products and concerns about counterfeit products or associated health effects were each reported by 8%.

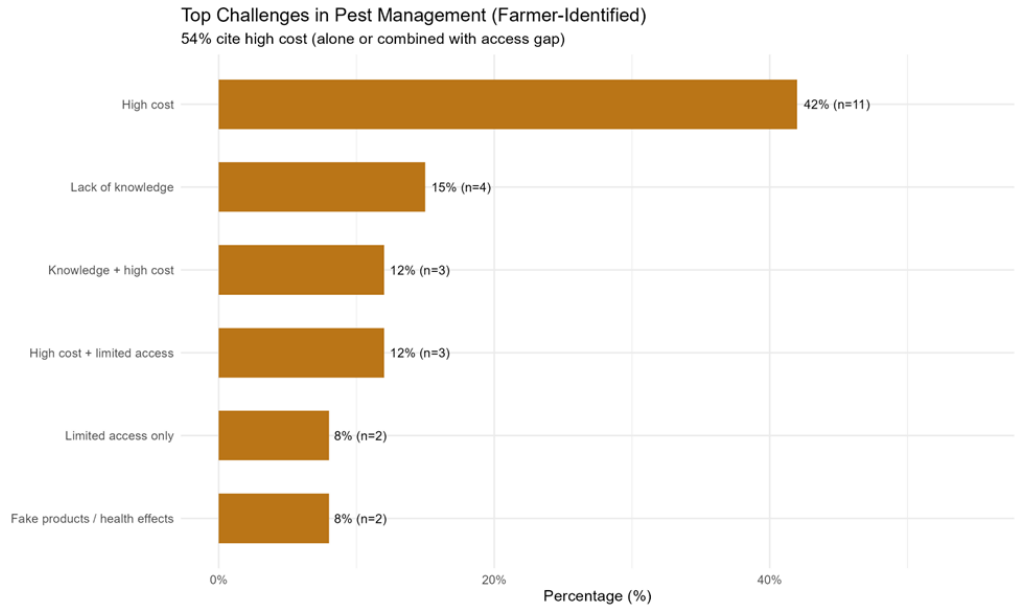


Figure 15. Farmers' challenges in pest management affecting biological control adoption (n=26).

5.5.2 Agro-dealers' barriers

Ten agro-dealers (50%) could not identify a specific barrier to biological control adoption. This result may reflect limited experience with biological products rather than the absence of barriers. Among respondents who identified barriers, cost combined with availability and lack of knowledge was the most common response (20%, n = 4). Cost combined with lack of knowledge and availability combined with lack of knowledge were each reported by 10% (n = 2). Cost alone was reported by one respondent (5%) (Figure 16).

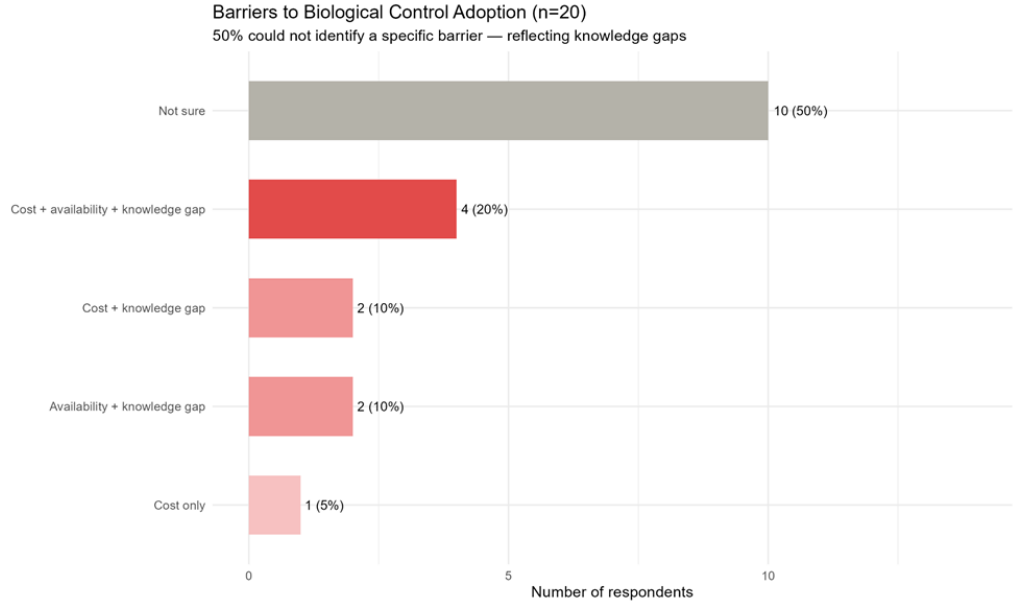


Figure 16. Agro-dealers' barriers to biological control adoption (n=20).

5.5.3 Regulators' technical challenges

Inadequate laboratory facilities were identified by four regulatory officers (80%). Monitoring challenges, limited technical expertise, and difficulties in field evaluation were each identified by three respondents (60%). Lack of protocols was reported by two respondents (40%) (Figure 17).

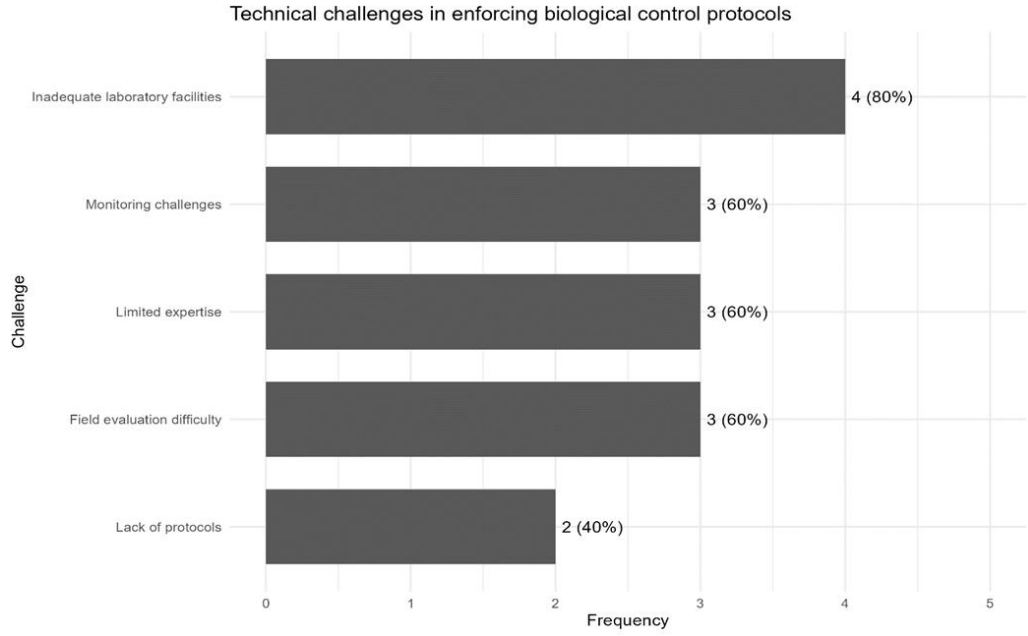


Figure 17. Regulators' technical challenges in enforcing biological control protocols (n=5).

5.5.4 Researchers' challenges

Researchers identified financial and policy barriers. Financial barriers accounted for 67% of the reported challenges and included the high cost of biological products and limited public funding for biological control research and infrastructure. Policy barriers accounted for 33%. These responses indicate that researchers viewed biological control adoption as constrained primarily by structural factors rather than by technical difficulties at the individual level.

5.6 Strategies for improving biological control adoption

Researchers identified four priority strategies, each proposed by both respondents: strengthening agricultural extension services, increasing government policy support and incentives, improving access to biological control products, and expanding farmer training and capacity-building programmes. Strengthening market linkages and expanding demonstration plots or field trials were each proposed by one respondent. Overall, the proposed strategies focused on the delivery system, regulatory environment, supply chain, and development of stakeholder capacity.

6. Discussion

6.1 Stakeholders' knowledge of biological control and pesticide risk-reduction protocols

The results revealed a clear difference between awareness and understanding among farmers. Although 73% of farmers reported having heard of biological control, only one respondent (4%) provided a definition referring to the use of living organisms. Most respondents associated biological control with pheromone traps or fall armyworm traps used in local projects. Parsa et al. (2014) reported that this pattern suggests that exposure to a specific intervention can create recognition of a technology without producing a broader understanding of biological control as an ecological pest-management approach.

This pattern indicates that the technology reached farmers through exposure to a specific project rather than through participatory learning. In agroecological terms, this is the difference between technology transfer and participation: awareness spread through a single project, while the co-created, experiential learning through which farmers come to understand the ecological principles behind biological control (Holt-Giménez, 2006; Wezel et al., 2020) largely did not take place.

The finding is consistent with evidence that barriers to integrated pest-management adoption in developing countries include limited access to information, weak extension support, and inadequate practical experience (Parsa et al., 2014). However, the present results should be interpreted as evidence from Mgera Village rather than as a national estimate.

Awareness among agro-dealers was also limited. Only 60% had heard of biological control, and only 30% had received relevant training. The results suggest that commercial experience in agricultural inputs does not necessarily provide knowledge of biological control principles. This interpretation is consistent with evidence from Uganda showing that agro-input dealers may possess product-level knowledge while lacking adequate information about pesticide risks and safer alternatives (Staudacher et al., 2021). The same pattern was visible in the present data: although all agro-dealers provided general advice, only 15% stocked biological products and 85% never discussed them with farmers (Section 5.4.2). The low awareness in this specific context is also unsurprising given the supply side: with biological products rarely stocked or promoted in Iringa, farmers and dealers had few occasions to encounter them. Two considerations nevertheless qualify these consistencies: responses were self-reported and may be affected by

social-desirability bias, and Mgera Village had prior exposure to pheromone-trap trials, so the farmer sample may be more favourably disposed than villages without such exposure.

The most important knowledge gap occurred among regulators and researchers. Four of the five regulatory officers and both researchers had received no formal, specialised training in biological control or pesticide risk-reduction protocols. Familiarity with the EAC guidelines was also low among both groups. Because these stakeholders are involved in research, evaluation, registration, inspection, and implementation, the gap has institutional consequences (FAO & IPPC, 2025). A regulatory framework cannot be implemented effectively if the officers expected to apply it have limited access to specialised training.

The results also showed that knowledge was shaped more by exposure than by formal position. Farmers encountered biological control through local demonstration or research activities, some agro-dealers learned through television or informal communication, and regulatory officers were more familiar with the Plant Health Act because it relates directly to their daily work. This helps explain why familiarity with national legislation was higher than familiarity with the newer regional guidelines.

The findings support a training strategy that operates at all levels of the system. Farmer Field Schools and similar participatory approaches can link technical information with observation and practice, rather than relying only on classroom-based awareness activities (Holt-Giménez, 2006). Evidence from East Africa indicates that Farmer Field Schools can improve agricultural knowledge and practices when learning is experiential and adapted to local conditions (Davis et al., 2012).

Training should therefore be differentiated by stakeholder groups. Farmers need practical instruction on identifying pests, conserving natural enemies, using biological products, and applying pesticides safely. Agro-dealers need product-specific training, guidance on biological control and pesticide risk reduction, and information on regulatory requirements. Regulators and researchers need specialised training on efficacy evaluation, risk assessment, quality control, non-target effects, and the application of the EAC guidelines.

6.2 Stakeholders' attitudes towards biological control adoption

The attitude results showed a consistent safety-effectiveness gap. Farmers, agro-dealers, regulators, and researchers generally viewed biological control as safe, but they were less confident that it would work quickly, reliably, or as effectively as

chemical pesticides. This distinction is important because safety acceptance alone is unlikely to produce adoption when users remain uncertain about performance.

Biological control operates through ecological interactions, including the establishment, reproduction, and activity of natural enemies (Eilenberg et al., 2001). Its effects may therefore be slower or less immediately visible than the effects of a chemical pesticide. This difference in timescale can influence how users judge effectiveness and may contribute to uncertainty among stakeholders who are accustomed to rapid chemical control. The ecological basis of biological control has long been recognised as a sustainable alternative to chemical pest management in smallholder systems (van Huis & Meerman, 1997). At the same time, ecological control is harder to quantify than a chemical dose: users cannot easily determine how many natural enemies are needed or where to source them, a practical barrier that has contributed to the slow uptake of commercial biological control (van Lenteren, 2012).

All farmers stated that they would use biological control if it were available, yet only two reported using a biological control product. This difference between intention and practice indicates that willingness to adopt was constrained by availability, affordability, confidence, or access to technical support. It should not be interpreted as proof that all farmers would adopt a product once it became available, because stated intention does not always translate into future behaviour (Sheeran, 2002).

The agro-dealer results show a similar pattern. Most agro-dealers rated biological control as safe, but many were uncertain about its speed and duration of action. This suggests that agro-dealers may be willing to support biological control in principle while remaining hesitant to stock or recommend products whose performance they have not observed or whose demand is uncertain. Training, demonstrations, reliable supply, and commercial incentives may therefore be necessary to convert positive attitudes into practice. Evidence from Uganda likewise indicates that agro-dealer certification and training can support more sustainable pest-control advice (Tambo et al., 2024).Comparable perception patterns have been documented elsewhere in East Africa: in Ethiopia, limited exposure to agricultural biologicals was associated with negative perceptions and low adoption (Mulugeta et al., 2024), and in Kenya, perceived slowness and unreliability of biological products relative to chemicals sustained chemical reliance despite awareness of the risks (Mweke et al., 2025). Farmers' scepticism about biological control performance under real field conditions has likewise been reported for Kenya and Tanzania (Kirui et al., 2023).

Regulators and researchers also expressed greater confidence in safety than in effectiveness. Researchers gave safety the highest score but gave willingness to prioritise biological control over chemical alternatives the lowest score. This combination suggests that institutional stakeholders may recognise the environmental and health advantages of biological control while remaining unconvinced that sufficient performance evidence exists under local conditions. This hesitancy is not unique to Tanzania: uncertain and slow performance is a recognised constraint on agrobiologicals and biological control generally, where uptake has lagged behind technical potential (van Lenteren, 2012).

The most appropriate response is therefore not another general awareness campaign, because stakeholders already recognise biological control as safe. The more important intervention is to generate and communicate locally credible evidence through demonstration plots, participatory trials, field days, and technical reports. Observability is a recognised factor in innovation adoption for all four stakeholder groups: farmers judge a practice by seeing it on neighbouring fields, agro-dealers by observing customer demand, and regulators and researchers by reviewing local trial evidence (Rogers, 2003). This preference for locally observable evidence mirrors the agroecological emphasis on participation and co-creation of knowledge, in which practices are trusted when they have been tested and demonstrated in the users' own context (Nicholls & Altieri, 2013; Wezel et al., 2020).

6.3 Stakeholders' implementation practices and adherence to pesticide risk-reduction protocols

The results indicate simultaneous underuse of biological control and unsafe use of chemical pesticides. In Mgera Village, 88% of farmers relied exclusively on chemical pesticides, only 8% used a biological control product, and 85% did not use personal protective equipment. In addition, 88% did not consistently follow pesticide label instructions, and no respondent reported a safe or formal method of disposing of pesticide containers.



Picture 2: Display of some of the common chemical pesticides and other agricultural pest management products available for sale at an agro-dealer shop in Iringa Municipality, Tanzania, during fieldwork (April 2026). Source: Author's fieldwork photograph (2026).



Picture 3 (A,B & C): Showing some of the biological control products sold by agro-dealers in Iringa municipality, Tanzania (April 2026). Source: Author's fieldwork photograph (2026).

These results corroborate earlier research among vegetable farmers in Tanzania, which documented inadequate protective equipment (Lekei et al., 2014), unsafe pesticide handling, and poor disposal practices (Kapeleka et al., 2021). They also

correspond with evidence that Tanzanian farmers may experience gaps in knowledge, training, and access to reliable technical advice.



Picture 4: Showing the common unsafe methods of pesticides container disposal by farmers in Mgera village, Iringa, Tanzania (April 2026). Source: Author's fieldwork photograph (2026).

Kapeleka's quantitative study provides additional evidence of excessive pesticide use in Tanzanian vegetable production (Kapeleka et al., 2021). However, the present study cannot show which of these factors drove the unsafe practices observed in Mgera Village; cost, product availability, social norms, peer advice, limited extension support, and weak enforcement all coexisted with them, and these contributing factors emerged from participants' open-ended responses and field observations rather than from a statistical test of causes. The finding that 81.0% of farmers relied on fellow farmers for pest-management advice indicates that peer networks are important channels for information, but it does not by itself prove that peer advice causes unsafe practices.

The agro-dealer results reveal a communication gap. Although all agro-dealers reported providing general technical advice, 85% did not communicate with farmers about biological control. One apparent contradiction note: although most agro-dealers sold personal protective equipment (80%), 85% of farmers did not use it. PPE is therefore available in the supply chain but not used, suggesting that cost, discomfort, and low perceived risk, rather than availability, are the binding constraints, as reported among Tanzanian vegetable farmers (Lekei et al., 2014; Ngowi et al., 2007). This difference suggests that biological control was not yet integrated into routine advisory practice, which mirrors evidence from Uganda that dealers rarely advise on risk reduction or safer alternatives (Staudacher et al., 2021). The absence of training and limited availability of biological products may have reduced agro-dealers' capacity and incentive to discuss them.

A second implementation gap occurred between regulatory and farmer-level activities. All regulators reported using demonstration plots, yet most farmers reported limited exposure to biological control demonstrations. This discrepancy may reflect differences in the meaning of "conducting demonstration plots," the location of the demonstrations, or the effectiveness of communication and participation. It should not automatically be described as a failure of regulators without verifying whether the activities were intended for the sampled farmers or whether the farmers were aware of them.

Among the 20 agro-dealers interviewed, 30% (n = 6) reported having received training related to biological control and pesticide risk reduction. The reported association between agro-dealer training and the sale of biological products, in which trained agro-dealers were significantly more likely to sell biological products (Fisher's exact test, $p = 0.018$), is potentially important, but it should be presented cautiously because the sample was small. The result suggests that training may be associated with stocking biological products, but it does not prove that training alone caused agro-dealers to sell biological products. Similar findings were reported by Tambo et al. (2024) in Uganda, where certified agro-dealers were 8–10% points more likely to sell biopesticides than non-certified dealers. Other factors, including product availability, farmers' demand, product price, and access to supplier may also influence whether an agro-dealer stocks biological products. This is consistent with studies from Uganda and Kenya showing that limited awareness, access, demand and affordability can constrain agro-dealers' stocking of biological products (Ogutu et al.,2022).

Pesticide-container disposal requires both enforcement and infrastructure; unsafe disposal has been widely documented among Tanzanian vegetable farmers (Lekei et al., 2014; Kapeleka et al., 2021). The complete absence of a safe disposal method indicates that information alone may be insufficient if farmers have no accessible collection point, return scheme, or other approved disposal option. A practical risk-reduction programme should therefore combine community education with accessible disposal services and clear responsibilities for suppliers, agro-dealers, local authorities, and regulators.From an agroecological perspective, the unsafe handling practices and the near-total reliance on synthetic chemicals indicate a production system designed around external inputs rather than around ecological regulation. Such systems are more vulnerable to pest resurgence, resistance, and loss of natural enemies, which reinforces the cycle of chemical dependence (Altieri, 2002; Nicholls & Altieri, 2013). Moving toward biological control therefore requires not only the availability of alternative products but the re-design of the pest management system, including the social and institutional conditions that support it.

6.4 Cross-cutting themes and systemic implications

The findings across all three research objectives revealed a set of cross-cutting systemic patterns that apply to all four stakeholder groups.

First, there was a broad training deficit. No respondent reported formal, specialised training that covered both biological control agents and pesticide risk-reduction protocols, although several respondents reported informal exposure, such as learning from television, fellow farmers, or short project-based sessions, none of which covered both topics systematically. The deficit affected farmers, agro-dealers, regulators, and researchers, although the type of training required differs among the groups. This supports a systems approach in which capacity building extends across production, advice, research, regulation, and supply chains.

Second, the safety-effectiveness gap was evident across stakeholder groups. Positive perceptions of safety coexisted with uncertainty about speed, reliability, and effectiveness . This indicates that adoption strategies should prioritise locally relevant efficacy evidence and practical demonstrations rather than repeating general claims about safety.

Third, the main barriers were structural. High cost, limited availability, absence of training, inadequate laboratory facilities, monitoring difficulties, and insufficient technical expertise cannot be addressed by changing individual attitudes alone. They require coordinated investment in supply chains, extension, infrastructure, regulatory capacity, and professional development. This interpretation is consistent with the recognised limitation of the KAP framework: knowledge and attitudes may be necessary for behaviour change, but they are not sufficient when institutional and economic constraints remain. In agroecological terms, the barriers indicate that Tanzanian pest management is caught between the level of input substitution and the level of system re-design described by Gliessman (2015): the attitudinal and ecological preconditions for change exist, but the enabling conditions for a deeper transition do not. Comparable constraints on the uptake of agricultural biologicals have also been reported in Kenya (Mweke et al., 2025).

The results therefore support an integrated implementation strategy with four linked components: locally managed demonstration trials, stakeholder-specific training, improved availability and affordability of biological products, and strengthened regulatory and laboratory capacity. These components should be implemented together because weakness in any one part of the system can limit the effect of the others. Such a strategy is consistent with the agroecological principle that conserving plant biodiversity within and around farms enhances bees and other insect pollinators in agroecosystems (Nicholls & Altieri, 2013).

These four components correspond closely to agroecological principles in practice: locally managed demonstration trials embody participation and co-creation of knowledge; stakeholder-specific training builds the capacities on which input reduction and synergy depend; improved availability and affordability of biological products support the shift away from external inputs; and strengthened regulatory and laboratory capacity provides the institutional foundation that agroecological transitions require (Wezel et al., 2020). The findings therefore position biological control adoption not as an isolated technology change but as one element of an agroecological transition in Tanzanian pest management.

6.5 Limitations of the Study

The study has several limitations. First, the regulatory and researcher samples were small, comprising five regulators and two researchers. Statistical generalisation to all Tanzanian regulators and researchers is therefore not possible. However, the respondents hold roles that directly cover registration, inspection and research on biological control, and their insights were sufficiently informed to support analytical generalisation about how biological control is regulated in Tanzania, even though additional respondents would add breadth rather than depth. The farmer and agro-dealer samples were larger, but they were still selected from limited geographic areas and should not be treated as nationally representative.

Second, the study was conducted in one village, one municipality, and selected TPHPA locations. The findings may therefore differ in other villages and regions with different crops, agroecological conditions, pest pressures, market conditions, and extension systems.

Third, the farmer sample was predominantly male, with men accounting for 92.3% of respondents. The study therefore provides limited evidence about the experiences of female farmers, including their knowledge, attitudes, and roles in pesticide-use and pest-management decisions.

Finally, the cross-sectional design captured knowledge, attitudes, and practices at one point in time. It cannot establish causal relationships or determine whether reported willingness to adopt biological control would result in actual adoption after products became available.In addition, the study did not measure ecological outcomes, such as changes in biodiversity or pest regulation, that would more directly demonstrate agroecological transition.

Future research should include more sites across the country with different agroecological zones, use gender-stratified sampling, multiple TPHPA regional stations or officers, and other stakeholder groups, such as extension officers, NGO

field staff, policymakers, and produce buyers, who are involved in crop production and pest management.

7. Conclusion and Recommendations

This study assessed the knowledge, attitudes, and practices of farmers, agro-dealers, regulators, and researchers regarding the implementation of biological control and pesticide risk-reduction protocols in Tanzania. Guided by the Knowledge-Attitude-Practice (KAP) framework and a cross-sectional mixed-methods design, the study drew on interviews with 26 farmers in Mgera Village, 20 agro-dealers in Iringa Municipality, five regulatory officers, and two researchers attached to TPHPA. The study was framed within an agroecological perspective, in which biological control is understood not as a simple substitute for a chemical input but as a way of strengthening the ecological processes and social conditions on which a transition to more sustainable pest management depends (Gliessman, 2015; Wezel et al., 2020).

The findings on knowledge show that awareness of biological control exceeded genuine understanding, revealing that the first condition for an agroecological transition, the co-creation of knowledge, is not yet in place. Although 73% of farmers had heard of biological control, only one respondent (4%) could define it in terms of living organisms; most associated it with pheromone traps or fall armyworm traps from past research trials. Only 60% of agro-dealers had heard of biological control, and just 30% had received relevant training. The most serious gap was institutional: four of the five regulatory officers and both researchers had received no formal, specialised training in biological control or pesticide risk-reduction protocols, and familiarity with the EAC harmonised guidelines was the weakest knowledge area in both groups.

None of the study participants received formal, specialised training covering both biological control and pesticide risk reduction. Participatory learning, the form of knowledge creation that agroecology emphasises, has largely been replaced by exposure to isolated projects, which creates recognition of a technology without building understanding of the ecological principles behind it (Holt-Giménez, 2006; Wezel et al., 2020).

The findings on attitudes show that the attitudinal preconditions for an agroecological transition already exist, but they are constrained by uncertainty about performance. All four stakeholder groups perceived biological control as safe but were uncertain about its speed, reliability, and effectiveness. Farmers were almost uniformly willing to adopt it (100%), and agro-dealers rated its safety highly. Yet researchers scored willingness to prioritise biological control over chemical alternatives at the lowest level recorded in the study (M = 1.0), and regulators showed only moderate commitment (M = 3.0). The consistent safety-

effectiveness gap indicates that adoption strategies must generate and communicate locally credible evidence through demonstration and participation, consistent with the agroecological emphasis on knowledge co-created with the actors involved, rather than repeating general claims about safety (Nicholls & Altieri, 2013; Wezel et al., 2020).

The findings on practices show that the production system remains designed around external chemical inputs rather than around ecological regulation. In Mgera Village, 88% of farmers relied exclusively on chemical pesticides, 85% applied them without protective equipment, 88% did not consistently follow label instructions, and no farmer reported a safe method of disposing of pesticide containers. Most agro-dealers (85%) did not communicate with farmers about biological control, and a demonstration delivery gap was evident: all regulators reported conducting demonstration plots, yet most farmers had never seen one.

The statistical link between agro-dealer training and the sale of biological products (Fisher's exact test, $p = 0.018$) shows that the barrier to engagement is the absence of training, not resistance. From an agroecological perspective, such systems remain vulnerable to pest resurgence, resistance, and the loss of natural enemies, which reinforces the cycle of chemical dependence they are intended to break (Altieri, 2002; Nicholls & Altieri, 2013).

In conclusion, the study found that Tanzanian pest management in Iringa Municipality is caught between input substitution and system redesign as described by Gliessman (2015). Stakeholders already accept biological control as safe and largely want to adopt it; farmers want to use it, agro-dealers are willing to promote it, and regulators support it in principle. The central finding is therefore that the barriers to adoption are structural rather than attitudinal. Biological control has been left out of training programmes, supply chains, demonstration activities, and regulatory capacity development at every level, meaning the system has failed to provide the enabling conditions that an agroecological transition requires (Wezel et al., 2020).

A coordinated response is needed that builds training at all levels of the chain, brings demonstration plots into farming communities, makes biological products available and affordable, and strengthens the laboratory and enforcement infrastructure that regulation requires. The willingness and the ecological need are both present; what is missing is the coordinated systemic response to meet them. Biological control adoption, understood as one element of an agroecological transition, will only take hold when the surrounding system is redesigned to support it.

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Popular science summary

“Tanzanian farmers are ready to adopt biological pest control methods, but the system is not ready for them”

Pests, diseases and invasive insects destroying between 20% and 40% of the world's crops every year, and smallholder farmers in Sub-Saharan Africa feel this most. In Tanzania, every growing season, farmers in Mgera Village in Iringa Region spray synthetic chemical pesticides over their maize and tomato fields. These pesticides work fast, but their heavy and often unsafe use harms soil and water, kills beneficial insects, and leaves residues on food that threaten human health.

There is a safer alternative: biological control, which uses living organisms, such as predators, parasitoids, and beneficial fungi, to manage pest populations. Pheromone traps also support biological control by monitoring pests or disrupting their reproduction.Biological control is an important component of Integrated Pest Management, an approach that biological, cultural. Physical, and when necessary, chemical methods to manage pests while reducing risks to human health and the environment. It also fits within agroecology, which applies ecological principles to agriculture by promoting biodiversity, natural pest regulation, and sustainable farming practices. In simple terms, both approaches encourage farmers to work with natural processes rather than relying mainly on chemical pesticides. Tanzania has also established a legal and regional framework relevant to biological control, including the Plant Health Act of 2020 and harmonised testing guidelines within the East African Community (EAC).

In this study, I asked 53 participants what they know, think and do about biological control: 26 farmers in Mgera Village, 20 agro-dealers in Iringa Municipality who sell farm inputs, and 5 regulators and 2 researchers at the Tanzania Plant Health and Pesticides Authority (TPHPA), based in Arusha, Kagera and Morogoro duty stations.

The study found that awareness is not the problem: 73% of farmers had heard of biological control. However, only one farmer in 26 could explain what it actually is. All key stakeholders, from farmers to regulators, believed biological control is safe, but almost none was certain that it works fast or reliably enough. Every single farmer said they would use biological control if it was available, yet only one farmer actually do.

Meanwhile, chemical pesticide use is unsafe at almost every step. 88% of farmers rely exclusively on chemicals, 85% use no protective equipment, 88% do not consistently follow label instructions, and not one farmer reported a safe method for disposing of empty containers. The study also found a striking training gap: no participant had received formal, specialised training covering both biological

control agents and pesticide risk-reduction protocols, and most had received no relevant training at all.

Agro-dealers sell farm inputs and advise farmers, but 85% of the dealers interviewed never discussed biological control with their customers, and only 15% stocked biological products. Most importantly, those who had received training were significantly more likely to sell biological products. The only surprise came from the top of the chain: even the regulators and researchers responsible for the biological control policy framework had received no specialised training on it, and knew the regional East African Community guidelines only marginally.

The study revealed that the barriers are structural, not attitudinal. Farmers are willing to change, agro-dealers are willing to promote biological control, and regulators support it in principle. What is missing is the system to make it happen: biological products that are available and affordable, training programmes at every level, demonstration plots in farmers' own fields, and the laboratory and enforcement capacity to support them. The willingness and the ecological need are both there. What is missing is the coordinated response to connect them.

From an agroecological perspective, the study describes Tanzanian pest management as stuck between two stages: swapping one bottle of chemical pesticide for one bottle of biological product, and redesigning the farming system so that nature itself keeps pests and diseases in check. The second stage will take more than new products. It will take training for every link in the chain, demonstration plots in farming communities, affordable products in the shops, and stronger regulatory and laboratory capacity.

Appendix 1

This appendix presents supplementary tables and figures of the four stakeholder groups (farmers, n = 26; agro-dealers, n = 20; regulators, n = 5; researchers, n = 2). The tables and figures complement the results presented in Chapter 5 by reporting additional indicators that were collected but not fully reported in the main results section.

Table 4. Farmers' awareness of regulatory frameworks and training (n = 26)

Indicator	Category	n	%
Aware of EAC regional guidelines	Yes	7	26.9
	No	19	73.1
Aware of recent TPHPA regulation changes	Yes	1	3.8
	No	25	96.2
Received training on pest management or biological control	Yes	7	26.9
	No	19	73.1
Source of training (n = 7 trained)	NGO	3	42.9
	University	2	28.6
	Extension officer	1	14.3
	Fellow farmers	1	14.3

Table 5. Farmers' familiarity with biological control methods and current use (n = 26)

Indicator	Category	n	%
Familiar with semiochemical methods (pheromone traps)		17	65.4
Familiar with predators (e.g., lady beetles)		1	3.8
Familiar with rabbit urine		1	3.8
None/ No method identified		7	26.9
Currently use biological control products	Yes	2	7.7
	No	24	92.3
Biological product used (n = 2)	Pheromone traps	1	50.0
	Rabbit urine	1	50.0

Reason for not using (n = 25)	Not aware	20	80.0
	Not available	5	20.0

Table 6. Farmers' sources of pest-management advice (n = 26)

Source of advice	n	%
Fellow farmers	15	57.7
Agro-dealer and fellow farmers	6	23.1
Agro-dealer	2	7.7
Extension officer	1	3.8
Fellow farmers and NGOs	1	3.8
Fellow farmers and university	1	3.8

Fellow farmers were mentioned as a source of advice in 23 of the 26 responses (88.5%).

Table 7. Farmers' attitudes towards biological control (Likert scale, n = 26)

Statement	Strongly agree	Agree	Not sure/undecided	Disagree	Strongly disagree
Works as well as chemical pesticides	3	4	19	0	0
Safer for people and the environment	4	7	15	0	0
Chemical pesticides act faster than biological methods	0	1	19	4	2
Willing to use biological control if available	17	9	0	0	0
Biological products are too expensive and hard to find	1	1	24	0	0
Reducing pesticide use is important for the environment	10	10	6	0	0

Table 8. Agro-dealers business portfolio and biological control products handling (n=20)

Indicator	Category	n	%

Farmer categories served	Smallholder and medium-scale	11	55.0
	Small, medium and large-scale	4	20.0
	Smallholder only	3	15.0
	Small and large-scale	2	10.0
Crop systems served	Maize, horticulture and legumes	11	55.0
	Maize and horticulture	9	45.0
Sell both chemical and biological inputs	Yes	3	15.0
	No (chemicals only)	17	85.0
Share of biologicals in inventory	Do not sell biologicals	17	85.0
	5-20% of inventory	3	15.0
Sell personal protective equipment (PPE)	Yes	16	80.0
	No	4	20.0
Interaction with TPHPA or extension officers	Weekly	2	10.0
	Monthly	4	20.0
	Quarterly	8	40.0
	Rarely	6	30.0

Table 9 Agro-dealers' perceptions of biological control and Familiarity with Plant Health Act and TPHPA requirements (n=20)

Indicator	Category	n	%
Familiarity with Plant Health Act and TPHPA requirements (1-5)	1 (not familiar)	2	10.0
	2	1	5.0
	3 (moderate)	7	35.0
	4	6	30.0
	5 (extremely familiar)	4	20.0
Effectiveness: speed of action	Highly effective	1	5.0
	Slightly effective	3	15.0
	Not sure / don't know	16	80.0

Effectiveness: long-term sustainability	Highly effective	4	20.0
	Not sure / don't know	16	80.0
Farmers willing to pay for safer products	Yes	7	35.0
	Maybe or not sure	12	60.0
	No	1	5.0
Government and manufacturers provide enough support	Yes	3	15.0
	No	14	70.0
	Maybe or not sure	3	15.0

The mean familiarity score with the Plant Health Act and TPHPA registration requirements was 3.45 out of 5.

Table 10. Regulators perceptions of biological control and Familiarity with EAC harmonised guidelines, Plant Health Act and TPHPA requirements (n=5)

Indicator	Category	n	%
Familiarity with Plant Health Act and TPHPA requirements (1-5)	Mean score	4.00	
	3 (moderately familiar)	2	40.0
	4 (quite familiar)	1	20.0
	5 (extremely familiar)	2	40.0
Familiarity with EAC harmonised guidelines (1-5)	Mean score	2.40	
	1 (not at all familiar)	1	20.0
	2 (slightly familiar)	2	40.0
	3 (moderately familiar)	1	20.0
	4 (quite familiar)	1	20.0
Accessibility of information (1-5)	Mean score	3.80	
Status of EAC guidelines in Tanzania	Fully adopted	3	60.0
	Partially adopted	2	40.0
Registration fees encourage private sector investment	Encourage	2	40.0
	Neutral	3	60.0

Effectiveness (speed of action), mean (1-5)	Mean score	2.80	
Effectiveness (long-term sustainability), mean (1-5)	Mean score	2.80	
Safety perception, mean (1-5)	Mean score	3.40	
Willingness to prioritise biologicals, mean (1-5)	Mean score	3.00	

Table 11. Regulators' and Researchers' challenges and strategies to biological control adoption (n=7)

Stakeholder	Challenge or strategy	n	%
Regulators (n = 5)	Challenges limiting adoption: High cost	4	80.0
	Limited availability	4	80.0
	Lack of knowledge	4	80.0
	Low awareness	3	60.0
	Lower effectiveness	2	40.0
	Farmer resistance	1	20.0
	Technical challenges: Inadequate laboratory facility	4	80.0
	Limited expertise	3	60.0
	Field evaluation difficulty	3	60.0
	Monitoring challenges	3	60.0
	Lack of protocols	2	40.0
	Strategies: Farmer training	5	100.0
	Extension services	4	80.0
	Access to products	4	80.0
	Demonstration trials	4	80.0
	IPM integration	4	80.0
	Market linkages	4	80.0
	Policy support	4	80.0
Researchers (n = 2)	Challenges limiting adoption: Lack of technical knowledge or skills	2	100.0

	Limited awareness among farmers	2	100.0
	Lower effectiveness	1	50.0
	Higher cost or limited affordability	1	50.0
	Practices: Training and capacity building	2	100.0
	Demonstration plots or trials	2	100.0
	Policy advocacy and briefs	1	50.0
	Strategies: Farmer training and capacity building	2	100.0
	Strengthening extension services	2	100.0
	Improved access to biocontrol products	2	100.0
	Policy support and government incentives	2	100.0
	Demonstration plots or trials	1	50.0
	Market linkages	1	50.0

Multiple responses were allowed, so percentages do not sum to 100.

Table 12. Stakeholders' outlook on the future of biological control in Tanzania (n=27)

Stakeholder	Outlook	n	%
Agro-dealers (n = 20)	Steady growth	7	35.0
	Significant growth	3	15.0
	Not so sure	10	50.0
Regulators (n = 5)	Steady growth	3	60.0
	Significant growth	2	40.0
Researchers (n = 2)	Steady growth	1	50.0
	Significant growth	1	50.0

Appendix 2

This appendix presents the four data-collection instruments used in the study: the farmer questionnaire, agro-dealer interview guide, regulatory officer questionnaire, and researcher questionnaire.

Appendix 2.1. Farmer questionnaire

Assessment of Stakeholders' Knowledge, Attitudes, and Practices (KAP) for Implementing Biological Control and Pesticide Risk Reduction Protocols in Tanzania

* Required question

1. Date

Enter date (example: January 7, 2019).

_____

2. Location

_____

3. Consent obtained

Select one response.

○ Yes

○ No

Section 1. Background information

4. Age

Select one response.

○ 0–18 years

○ 19–30 years

○ 31–50 years

○ 51–80 years

○ More than 80 years

5. Gender

Select one response.

○ Male

○ Female

6. Education level

Select one response.

○ None

○ Primary

○ Secondary

○ College/University

7. How long have you been farming?

Select one response.

○ Less than 5 years

○ 5–10 years
○ 11–20 years
○ More than 20 years
8. Which crops do you mainly grow?
Select all that apply.
☐ Maize
☐ Horticulture (tomato, onion, etc.)
☐ Legumes
☐ Export crops
☐ Other: _____
9. Farmland size
Select one response.
○ Very small (<2.5 acres)
○ Small (2.5–5 acres)
○ Medium (>5–12 acres)
○ Large (>12–25 acres)
○ Very large (>25 acres)
10. Have you ever received any training on pest management or biological control?
Select one response.
○ Yes
○ No
11. If yes, from whom?
Select one response.
○ Extension officer
○ NGO
○ Government
○ Agro-dealer
○ Other: _____
Section 2. Knowledge
12. Have you ever heard of biological control?
Select one response.
○ Yes
○ No
13. In your own words, what is biological control?

_____

14. Which methods are you familiar with?
Select all that apply.
☐ Predators (e.g., lady beetles)
☐ Parasitoids
☐ Microbial agents (e.g., bacteria, fungi)

☐ Semiochemical methods (e.g., pheromone traps)
☐ Botanical pesticides (e.g., neem)
☐ Other: _____
15. Do you currently use biological control products?
Select one response.
○ Yes
○ No
16. If yes, which one?
_____
17. If no, why?
Select one response.
○ Not available
○ Expensive (high cost)
○ Hard to access
○ Not effective
○ Not aware
○ Other: _____
18. Are you aware of the EAC regional guidelines on safe pesticide use?
Select one response.
○ Yes
○ No
19. Are you aware of recent pesticide regulation changes in Tanzania by TPHPA?
Select one response.
○ Yes
○ No
20. Where do you usually get pest-management advice?
Select all that apply.
☐ Extension officer
☐ Agro-dealer
☐ Fellow farmers
☐ NGOs
☐ Other: _____
Section 3. Attitudes
Using a Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Not sure/undecided, 4 = Agree, and 5 = Strongly agree.
For each statement below, select one response.
21.1. Biological control works as well as chemical pesticides.
Select one response.
○ Strongly disagree
○ Disagree
○ Not sure/undecided

○ Agree
○ Strongly agree
21.2. Biological control is safer for people and the environment.
Select one response.
○ Strongly disagree
○ Disagree
○ Not sure/undecided
○ Agree
○ Strongly agree
21.3. Chemical pesticides act faster than biological methods.
Select one response.
○ Strongly disagree
○ Disagree
○ Not sure/undecided
○ Agree
○ Strongly agree
21.4. I am willing to use biological control if it is available.
Select one response.
○ Strongly disagree
○ Disagree
○ Not sure/undecided
○ Agree
○ Strongly agree
21.5. Biological products are too expensive and hard to find in local shops.
Select one response.
○ Strongly disagree
○ Disagree
○ Not sure/undecided
○ Agree
○ Strongly agree
21.6. Reducing pesticide use is important for environmental sustainability.
Select one response.
○ Strongly disagree
○ Disagree
○ Not sure/undecided
○ Agree
○ Strongly agree
Section 4. Practices
22. What pest-control methods do you use?
Select one response.
○ Chemical only

○ Integrated Pest Management (IPM)
○ Mostly biological
○ None
○ Other: _____

23. Do you follow label instructions when using pesticides?
Select one response.
○ Always
○ Sometimes
○ Rarely
○ Never
○ Other: _____

24. Do you use protective equipment (PPE)?
Select one response.
○ Yes
○ No

25. How do you dispose of pesticide containers?
Select all that apply.
☐ Burn
☐ Bury
☐ Throw away
☐ Reuse
☐ Return
☐ Other: _____

26. What challenges do you face when using chemical pesticides or biological control practices?
Select all that apply.
☐ Lack of knowledge
☐ High cost
☐ Limited access
☐ Labour intensive
☐ Time consuming
☐ Other: _____

Section 5. Recommendations

27. What would help adoption of biological control methods?
Select all that apply.
☐ Training
☐ Demonstration plots
☐ Subsidies
☐ Swahili manuals
☐ Better access to products
☐ Other: _____

28. What should the government improve regarding availability of biological products?

_____

29. Any comments

_____

End of interview. Thank you for your participation.

Appendix 2.2. Farmer questionnaire (Swahili version)

Tathmini ya Maarifa, Mitazamo na Vitendo (KAP) vya Wadau kuhusu Utekelezaji wa Udhibiti wa Kibayolojia na Itifaki za Kupunguza Hatari za Viuatilifu nchini Tanzania

* Swali la lazima

1. Tarehe

Weka tarehe (mfano: 7 Januari 2019).

_____

_____

2. Eneo

_____

_____

3. Ridhaa imepatikana

Chagua jibu moja.

○ Ndiyo

○ Hapana

Sehemu ya 1. Taarifa za msingi

4. Umri

Chagua jibu moja.

○ Miaka 0–18

○ Miaka 19–30

○ Miaka 31–50

○ Miaka 51–80

○ Zaidi ya miaka 80

5. Jinsia

Chagua jibu moja.

○ Mwanaume

○ Mwanamke

6. Kiwango cha elimu

Chagua jibu moja.

○ Hakuna

○ Elimu ya msingi

○ Elimu ya sekondari

○ Chuo/Chuo Kikuu

7. Umekuwa ukifanya kilimo kwa muda gani?
Chagua jibu moja.
○ Chini ya miaka 5
○ Miaka 5–10
○ Miaka 11–20
○ Zaidi ya miaka 20
8. Ni mazao gani unayolima zaidi?
Chagua majibu yote yanayohusika.
☐ Mahindi
☐ Mazao ya bustani (nyanya, vitunguu, n.k.)
☐ Mikunde
☐ Mazao ya kuuza nje
☐ Mengine: _____
9. Ukubwa wa shamba
Chagua jibu moja.
○ Dogo sana (chini ya ekari 2.5)
○ Dogo (ekari 2.5–5)
○ Wastani (zaidi ya ekari 5–12)
○ Kubwa (zaidi ya ekari 12–25)
○ Kubwa sana (zaidi ya ekari 25)
10. Je, umewahi kupata mafunzo kuhusu udhibiti wa wadudu waharibifu au udhibiti wa kibayolojia?
Chagua jibu moja.
○ Ndiyo
○ Hapana
11. Kama ndiyo, mafunzo yalitolewa na nani?
Chagua jibu moja.
○ Afisa ugani
○ Shirika lisilo la kiserikali (NGO)
○ Serikali
○ Muuzaji wa pembejeo za kilimo
○ Mwingine: _____
Sehemu ya 2. Maarifa
12. Je, umewahi kusikia kuhusu udhibiti wa kibayolojia?
Chagua jibu moja.
○ Ndiyo
○ Hapana
13. Kwa maneno yako mwenyewe, udhibiti wa kibayolojia ni nini?
_____
_____
14. Ni mbinu zipi unazozifahamu?

Chagua majibu yote yanayohusika.
☐ Wadudu/maadui asilia walao wadudu waharibifu (mfano, lady beetles)
☐ Vimelea vya wadudu (parasitoids)
☐ Viumbe vidogo vya kudhibiti wadudu (mfano, bakteria na fangasi)
☐ Mbinu za kemikali za mawasiliano (semiochemicals), mfano mitego ya pheromone
☐ Viuatilifu vya mimea (mfano, mwarobaini/neem)
☐ Nyingine: _____

15. Je, kwa sasa unatumia bidhaa za udhibiti wa kibayolojia?
Chagua jibu moja.
○ Ndiyo
○ Hapana

16. Kama ndiyo, ni bidhaa/mbinu ipi?
_____
_____

17. Kama hapana, kwa nini?
Chagua jibu moja.
○ Hazipatikani
○ Ni ghali (gharama kubwa)
○ Ni vigumu kuzipata
○ Hazina ufanisi
○ Sina ufahamu nazo
○ Sababu nyingine: _____

18. Je, unafahamu miongozo ya kikanda ya Jumuiya ya Afrika Mashariki (EAC) kuhusu matumizi salama ya viuatilifu?
Chagua jibu moja.
○ Ndiyo
○ Hapana

19. Je, unafahamu mabadiliko ya hivi karibuni ya kanuni za viuatilifu nchini Tanzania yanayosimamiwa na TPHPA?
Chagua jibu moja.
○ Ndiyo
○ Hapana

20. Kwa kawaida unapata ushauri kuhusu udhibiti wa wadudu waharibifu kutoka wapi?
Chagua majibu yote yanayohusika.
☐ Afisa ugani
☐ Muuzaji wa pembejeo za kilimo
☐ Wakulima wenzangu
☐ Mashirika yasiyo ya kiserikali (NGOs)
☐ Chanzo kingine: _____

Sehemu ya 3. Mitazamo
Tumia kipimo cha Likert: 1 = Sikubaliani kabisa, 2 = Sikubaliani, 3 = Sina uhakika/Sijaamua, 4 = Nakubaliana, na 5 = Nakubaliana kabisa.
Kwa kila kauli hapa chini, chagua jibu moja.
21.1. Udhibiti wa kibayolojia hufanya kazi vizuri sawa na viuatilifu vya kemikali.
Chagua jibu moja.
○ Sikubaliani kabisa
○ Sikubaliani
○ Sina uhakika/Sijaamua
○ Nakubaliana
○ Nakubaliana kabisa
21.2. Udhibiti wa kibayolojia ni salama zaidi kwa watu na mazingira.
Chagua jibu moja.
○ Sikubaliani kabisa
○ Sikubaliani
○ Sina uhakika/Sijaamua
○ Nakubaliana
○ Nakubaliana kabisa
21.3. Viuatilifu vya kemikali hufanya kazi kwa haraka zaidi kuliko mbinu za kibayolojia.
Chagua jibu moja.
○ Sikubaliani kabisa
○ Sikubaliani
○ Sina uhakika/Sijaamua
○ Nakubaliana
○ Nakubaliana kabisa
21.4. Niko tayari kutumia udhibiti wa kibayolojia iwapo utapatikana.
Chagua jibu moja.
○ Sikubaliani kabisa
○ Sikubaliani
○ Sina uhakika/Sijaamua
○ Nakubaliana
○ Nakubaliana kabisa
21.5. Bidhaa za kibayolojia ni ghali sana na ni vigumu kuzipata katika maduka ya eneo hili.
Chagua jibu moja.
○ Sikubaliani kabisa
○ Sikubaliani
○ Sina uhakika/Sijaamua
○ Nakubaliana
○ Nakubaliana kabisa

21.6. Kupunguza matumizi ya viuatilifu ni muhimu kwa uendelevu wa mazingira.
Chagua jibu moja.
○ Sikubaliani kabisa
○ Sikubaliani
○ Sina uhakika/Sijaamua
○ Nakubaliana
○ Nakubaliana kabisa

Sehemu ya 4. Vitendo

22. Unatumia mbinu gani za kudhibiti wadudu waharibifu?
Chagua jibu moja.
○ Kemikali pekee
○ Udhibiti Jumuishi wa Wadudu (IPM)
○ Kwa kiasi kikubwa mbinu za kibayolojia
○ Situmii mbinu yoyote
○ Nyingine: _____

23. Je, unafuata maelekezo yaliyo kwenye lebo unapotumia viuatilifu?
Chagua jibu moja.
○ Kila mara
○ Wakati mwingine
○ Mara chache
○ Kamwe
○ Jibu jingine: _____

24. Je, unatumia vifaa vya kujikinga binafsi (PPE)?
Chagua jibu moja.
○ Ndiyo
○ Hapana

25. Unatupaje/unaondoaje vyombo vilivyotumika vya viuatilifu?
Chagua majibu yote yanayohusika.
☐ Kuchoma
☐ Kufukia
☐ Kutupa
☐ Kutumia tena
☐ Kurudisha
☐ Njia nyingine: _____

26. Ni changamoto gani unazokutana nazo unapotumia viuatilifu vya kemikali au mbinu za udhibiti wa kibayolojia?
Chagua majibu yote yanayohusika.
☐ Ukosefu wa maarifa
☐ Gharama kubwa
☐ Upatikanaji mdogo
☐ Inahitaji nguvu kazi nyingi

☐ Inachukua muda mwingi
☐ Changamoto nyingine: _____
Sehemu ya 5. Mapendekezo
27. Ni nini kingesaidia kuongeza matumizi ya mbinu za udhibiti wa kibayolojia? Chagua majibu yote yanayohusika.
☐ Mafunzo
☐ Mashamba/viwanja vya maonesho
☐ Ruzuku
☐ Miongozo kwa Kiswahili
☐ Upatikanaji bora wa bidhaa
☐ Jambo jingine: _____
28. Serikali inapaswa kuboresha nini kuhusu upatikanaji wa bidhaa za udhibiti wa kibayolojia?

_____
_____
29. Maoni mengine

_____
_____
Mwisho wa mahojiano. Asante kwa ushiriki wako.

Appendix 2.3. Agro-dealer interview guide

Assessment of Stakeholders' Knowledge, Attitudes, and Practices (KAP) for Implementing Biological Control and Pesticide Risk Reduction Protocols in Tanzania
1. Date
Enter date (example: January 7, 2019).

_____
2. Location

_____
3. Business name

_____
4. Consent obtained
Select one response.
○ Yes
○ No
Section 1. Background information
5. Age
Select one response.
○ 0–18 years
○ 19–30 years
○ 31–50 years
○ 51–80 years

○ Above 80 years

6. Gender

Select one response.

○ Male

○ Female

7. Years in operation

Select one response.

○ Less than 5 years

○ 5–10 years

○ 11–20 years

○ More than 20 years

8. Which category of farmers do you primarily work with?

Select all that apply.

☐ Smallholder

☐ Medium-scale

☐ Large-scale/Commercial

☐ Export-oriented

☐ Other: _____

9. Which crop system do you work with?

Select all that apply.

☐ Maize

☐ Horticulture

☐ Legumes

☐ Export crops

☐ Other: _____

10. Have you or your staff received specialised training in Biological Control Agents (BCAs) or pesticide risk reduction?

Select one response.

○ Yes

○ No

11. If yes, by whom?

Select one response.

○ Government

○ NGOs

○ Private sector

○ Other: _____

12. If no, why?

_____

Section 2. Business portfolio

13. Do you sell both conventional (chemical) and biological inputs?

Select one response.
○ Yes
○ No (chemicals only)
14. What is the estimated share of biologicals in your total inventory?
Select one response.
○ Less than 5%
○ 5–20%
○ 21–50%
○ More than 50%
○ Other: _____
Section 3. Knowledge
15. Have you ever heard of biological control?
Select one response.
○ Yes
○ No
16. How do you define biological control in your professional context?

---

17. How familiar are you with the Plant Health Act (2020) and current TPHPA registration requirements for chemical and biological inputs?
Select one response.
○ 1
○ 2
○ 3
○ 4
○ 5
Scale: 1 = Not at all familiar; 5 = Extremely familiar.
Section 4. Attitudes and perceptions
18. How would you rate the effectiveness of biologicals versus chemicals?
Select one response for each row.
Speed of action: Ineffective | Slightly effective | Moderately effective | Effective | Highly effective | Not sure / do not know
Long-term sustainability: Ineffective | Slightly effective | Moderately effective | Effective | Highly effective | Not sure / do not know
19. What is your opinion on the safety profile of biological control for your customers and the environment?
Select one response.
○ 1 = Very unsafe
○ 2 = Unsafe
○ 3 = Moderately safe
○ 4 = Safe
○ 5 = Very safe

20. In your experience, are farmers willing to pay for safer products even if they work slower than conventional chemicals?
Select one response.
○ Yes
○ No
○ Maybe or not sure
21. Do you feel the government and manufacturers provide enough support to agro-dealers to promote biologicals?
Select one response.
○ Yes
○ No
○ Maybe or not sure
22. What are the top barriers to adoption of biological control protocols?
Select all that apply.
☐ Higher cost
☐ Availability
☐ Knowledge gap
☐ Resistance
☐ Other: _____
Section 5. Practices
23. How do you communicate the benefits of biologicals to farmers?
Select all that apply.
☐ Demonstrations or trials
☐ Advice
☐ Posters
☐ Training
☐ Other: _____
24. What is the biggest challenge in convincing farmers to switch from chemicals to biological products?

_____

25. Do you coordinate with other stakeholders?
Select one response.
○ Yes
○ No
26. Please specify the stakeholders you coordinate with.
Select all that apply.
☐ Researchers/University
☐ Government (TPHPA/Ministry)
☐ Private sector
☐ Farmers/Farmer groups
☐ Other: _____

27. How frequently do you interact with TPHPA or agricultural extension officers regarding product monitoring?
Select one response.
○ Daily
○ Weekly
○ Monthly
○ Quarterly
○ Rarely
28. Do you provide technical advice to farmers?
Select one response.
○ Yes
○ No
29. What kind of advice do you provide?

---

30. Do you sell PPE?
Select one response.
○ Yes
○ No
Section 6. Recommendations and future perspectives
31. What is the biggest challenge of conducting business in biologicals in Tanzania (e.g., shelf life, registration, cost)?

---

32. What single policy change would make biologicals the primary choice for farmers?

---

33. What do you think is the future of biologicals in the Tanzanian market over the next 10 years?
Select one response.
○ Significant growth
○ Steady growth
○ Stagnant/declining
○ Not so sure
○ Other: _____
34. Any comments

End of interview. Thank you for your participation.

Appendix 2.4. Regulatory officer questionnaire

Assessment of Stakeholders' Knowledge, Attitudes, and Practices (KAP) for Implementing Biological Control and Pesticide Risk Reduction Protocols in Tanzania

You are invited to participate in a study conducted by Maria Manda, a Master's student in Agroecology at the Swedish University of Agricultural Sciences (SLU-Alnarp). The study responds to the growing need for sustainable pest management in tropical agriculture. In Tanzania, heavy reliance on synthetic pesticides continues to pose environmental and health risks, including contamination, pest resistance, and farmer exposure. To address these challenges, Tanzania and the East African Community (EAC) are prioritising biological control as a safer alternative. This study assesses stakeholders' knowledge, attitudes, and practices concerning biological control and pesticide risk-reduction measures in Tanzania. As a key stakeholder in the agricultural sector, your professional insights are essential for identifying the current status, challenges, and opportunities for sustainable pest management. The findings will be used to develop evidence-based policy recommendations aimed at strengthening harmonised regulatory protocols and improving regional pest-management strategies within the EAC framework. Your participation is voluntary and confidential.

1. Consent obtained

Select one response.

○ Yes

○ No

Section 1. Background and professional role

2. Location

_____

3. Date

Enter date (example: January 7, 2019).

_____

4. Name of organisation

_____

5. Gender

Select one response.

○ Male

○ Female

6. Age

Select one response.

○ 0–18 years

○ 19–30 years

○ 31–50 years

○ 51–80 years

○ More than 80 years

7. Education level

Select one response.

○ None

○ Primary
○ Secondary
○ College/University
8. Briefly describe your current role in pest management, crop protection, or agricultural regulation.

_____

9. How long have you been working in pest management, crop protection, or agricultural regulation?
Select one response.
○ Less than 5 years
○ 5–10 years
○ 11–20 years
○ 21–30 years
○ More than 30 years
10. Which crops do you primarily work with?
Select all that apply.
☐ Cereals (maize, rice, etc.)
☐ Horticulture (tomato, onions, etc.)
☐ Legumes
☐ Export crops
☐ Other: _____
11. Have you received training on biological control?
Select one response.
○ Yes
○ No
12. If yes, please specify.

_____

Section 2. Knowledge
13. Understanding of biological control

_____

14. How familiar are you with the Plant Health Act of 2020 and current TPHPA registration requirements for both chemical and biological inputs?
Select one response.
○ 1 = Not at all familiar
○ 2 = Slightly familiar
○ 3 = Moderately familiar
○ 4 = Quite familiar
○ 5 = Extremely familiar
15. How familiar are you with the EAC harmonised guidelines for the registration and efficacy testing of biopesticide protocols?
Select one response.

○ 1 = Not at all familiar
○ 2 = Slightly familiar
○ 3 = Moderately familiar
○ 4 = Quite familiar
○ 5 = Extremely familiar

16. How accessible is information on the Plant Health Act 2020 and EAC guidelines for other stakeholders?

Select one response.

○ 1 = Very difficult
○ 2 = Difficult
○ 3 = Moderate
○ 4 = Easy
○ 5 = Very easy

Section 3. Regulatory module

17. Differences in registration requirements (biological control agents versus chemical pesticides)

_____

18. What is the status of the EAC guidelines in Tanzania?

Select one response.

○ Fully adopted
○ Partially adopted
○ Under review
○ Not initiated

19. Do registration fees and timelines for biopesticides encourage or discourage private-sector investment in Tanzania?

Select one response.

○ 1 = Strongly discourage
○ 2 = Discourage
○ 3 = Neutral
○ 4 = Encourage
○ 5 = Strongly encourage

20. What are the barriers to enforcement of pesticide risk-reduction protocols in rural areas?

Select one response.

○ Lack of inspectors
○ High monitoring costs
○ Lack of laboratories
○ Illegal imports
○ Other: _____

Section 4. Attitudes

21. Effectiveness of biologicals (speed of action)

Select one response.
○ 1
○ 2
○ 3
○ 4
○ 5
Scale: 1 = Ineffective; 5 = Highly effective.
22. Effectiveness of biologicals (long-term sustainability)
Select one response.
○ 1
○ 2
○ 3
○ 4
○ 5
Scale: 1 = Ineffective; 5 = Highly effective.
23. Safety perception of biologicals
Select one response.
○ 1 = Very unsafe
○ 2 = Unsafe
○ 3 = Moderately safe
○ 4 = Safe
○ 5 = Very safe
24. Willingness to prioritise biologicals
Select one response.
○ 1
○ 2
○ 3
○ 4
○ 5
Scale: 1 = Not willing; 5 = Very willing.
25. What challenges limit biological control adoption?
Select all that apply.
☐ Lower effectiveness
☐ High cost
☐ Limited availability
☐ Lack of knowledge
☐ Farmer resistance
☐ Low awareness
☐ Other: _____
Section 5. Practices
26. What are the current promotion practices for biologicals in the field?

Select all that apply.
☐ Training
☐ Demonstration plots
☐ Subsidies
☐ Policy advocacy
☐ Other: _____
27. How frequently do you interact with other stakeholders on the practical use and monitoring of biologicals?
Select one response.
○ Daily
○ Weekly
○ Monthly
○ Quarterly
○ Rarely
28. What technical challenges do you face when enforcing biological control protocols?
Select all that apply.
☐ Limited expertise
☐ Inadequate laboratory facilities
☐ Field-evaluation difficulty
☐ Lack of protocols
☐ Monitoring challenges
☐ Other: _____
Section 6. Recommendations
29. What strategies could improve adoption of biologicals among farmers and other stakeholders?
Select all that apply.
☐ Farmer training
☐ Extension services
☐ Access to products
☐ Demonstration trials
☐ IPM integration
☐ Market linkages
☐ Policy support
☐ Other: _____
30. What is the future of biologicals in Tanzania over the next 10 years?
Select one response.
○ Significant growth
○ Steady growth
○ Stagnant
○ Decline

31. Additional insights regarding stakeholder capacity or implementation barriers in Tanzania

_____

32. Comments

_____

End of interview. Thank you for your participation.

Appendix 2.5. Researcher questionnaire

Assessment of Stakeholders' Knowledge, Attitudes, and Practices (KAP) for Implementing Biological Control and Pesticide Risk Reduction Protocols in Tanzania

You are invited to participate in a study conducted by Maria Manda, a Master's student in Agroecology at the Swedish University of Agricultural Sciences (SLU-Alnarp). The study responds to the growing need for sustainable pest management in tropical agriculture. In Tanzania, heavy reliance on synthetic pesticides continues to pose environmental and health risks, including contamination, pest resistance, and farmer exposure. To address these challenges, Tanzania and the East African Community (EAC) are prioritising biological control as a safer alternative. This study assesses stakeholders' knowledge, attitudes, and practices concerning biological control and pesticide risk-reduction measures in Tanzania. As a key stakeholder in the agricultural sector, your professional insights are essential for identifying the current status, challenges, and opportunities for sustainable pest management. The findings will be used to develop evidence-based policy recommendations aimed at strengthening harmonised regulatory protocols and improving regional pest-management strategies within the EAC framework. Your participation is voluntary and confidential.

1. Consent obtained

Select one response.

○ Yes

○ No

2. Location

_____

3. Date

Enter date (example: January 7, 2019).

_____

4. Name of organisation

_____

Section 1. Background and professional role

5. Gender

Select one response.

○ Male
○ Female

6. Age

Select one response.

○ 0–18 years
○ 19–30 years
○ 31–50 years
○ 51–80 years
○ 80+ years

7. Education level

Select one response.

○ None
○ Primary
○ Secondary
○ College/University
○ Other: _____

8. Briefly describe your current role in pest management, crop protection, or agricultural regulation.

_____

9. How long have you been working in pest management, crop protection, or agricultural regulation?

Select one response.

○ Less than 5 years
○ 5–10 years
○ 11–20 years
○ 21–30 years
○ More than 30 years

10. Which specific crops or agricultural systems do you primarily work with?

Select all that apply.

☐ Cereals (maize, rice, etc.)
☐ Horticulture (tomato, onion, etc.)
☐ Legumes
☐ Export crops
☐ Other: _____

11. Have you received specialised training regarding biological control agents (BCAs) and pesticide risk-reduction protocols?

Select one response.

○ Yes
○ No

12. If yes, please specify.

_____

Section 2. Knowledge

13. How do you understand biological control?

_____

14. How familiar are you with the Plant Health Act of 2020 and current TPHPA registration requirements for chemical and biological inputs?

Select one response.

○ 1 = Not at all familiar
○ 2 = Slightly familiar
○ 3 = Moderately familiar
○ 4 = Quite familiar
○ 5 = Extremely familiar

15. How familiar are you with the EAC harmonised guidelines for the registration and efficacy testing of biopesticide protocols?

Select one response.

○ 1 = Not at all familiar
○ 2 = Slightly familiar
○ 3 = Moderately familiar
○ 4 = Quite familiar
○ 5 = Extremely familiar

16. How accessible is information on the Plant Health Act 2020 and EAC guidelines for other stakeholders?

Select one response.

○ 1 = Very difficult to access
○ 2 = Difficult to access
○ 3 = Moderately accessible
○ 4 = Easy to access
○ 5 = Very easy to access

Section 3. Researchers' module

17. Which specific biological control methods or pesticide risk-reduction protocols are you currently working on?

Select all that apply.

☐ Predators (e.g., lady beetles)
☐ Parasitoids
☐ Microbial agents (e.g., bacteria, fungi)
☐ Semiochemical methods (e.g., pheromone traps)
☐ Botanical pesticides (e.g., neem)

18. What main ecological risks do you assess when introducing or promoting a new pest-management method?

Select all that apply.

☐ Non-target effects
☐ Biodiversity loss

☐ Persistence
☐ Resistance
19. How would you rate coordination with other stakeholders in supporting biological control adoption?
Select one response.
○ 1 = Poorly coordinated
○ 2 = Weakly coordinated
○ 3 = Moderately coordinated
○ 4 = Well coordinated
○ 5 = Excellent coordination
20. Which stakeholders do you coordinate with?
Select all that apply.
☐ Researchers/University
☐ Government (TPHPA/Ministry)
☐ Private sector
☐ Extension services
☐ Farmers/farmer groups
☐ Agro-dealers
☐ Other: _____
21. What are the key challenges in recommending a new biological control method from research to end users or consumers?
Select all that apply.
☐ Financial
☐ Technical
☐ Policy
☐ Extension services
☐ Farmer acceptance
☐ Environmental factors
☐ Other: _____
Section 4. Attitudes and perceptions
22. Effectiveness of biologicals (speed of action)
Select one response.
○ 1
○ 2
○ 3
○ 4
○ 5
Scale: 1 = Ineffective; 5 = Highly effective.
23. Effectiveness of biologicals (long-term sustainability)
Select one response.
○ 1

○ 2
○ 3
○ 4
○ 5
Scale: 1 = Ineffective; 5 = Highly effective.
24. Safety perception of biologicals
Select one response.
○ 1 = Very unsafe
○ 2 = Unsafe
○ 3 = Moderately safe
○ 4 = Safe
○ 5 = Very safe
25. Willingness to prioritise biologicals
Select one response.
○ 1
○ 2
○ 3
○ 4
○ 5
Scale: 1 = Not willing; 5 = Very willing.
26. What challenges limit biological control adoption?
Select all that apply.
☐ Lower effectiveness
☐ Higher cost or limited affordability
☐ Limited availability
☐ Lack of technical knowledge or skills
☐ Farmer resistance to change
☐ Limited awareness among farmers
☐ Other: _____
Section 5. Practices and implementation
27. What practices do you use to implement or promote biological control or pesticide risk-reduction measures in the field?
Select all that apply.
☐ Training and capacity building
☐ Demonstration plots or trials
☐ Subsidies/incentives for biocontrol products
☐ Policy advocacy and briefs
☐ Other: _____
28. How frequently do you interact with other stakeholders on the practical use and monitoring of biologicals?
Select one response.

○ Daily
○ Weekly
○ Monthly
○ Quarterly
○ Rarely

29. What technical challenges do you face when enforcing biological control protocols?

Select one response.

○ Limited expertise
○ Inadequate laboratory facilities
○ Field-evaluation difficulty
○ Lack of protocols
○ Monitoring challenges
○ Other: _____

Section 6. Recommendations and future perspectives

30. What strategies could improve adoption of biological control methods among farmers and other stakeholders?

Select all that apply.

☐ Farmer training and capacity building
☐ Strengthening extension services
☐ Improved access to biocontrol products
☐ Demonstration plots or trials
☐ Integration with existing practices (IPM)
☐ Market linkages
☐ Policy support and government incentives
☐ Other: _____

31. What is the future of biologicals in the East African Community (EAC) over the next 10 years?

Select one response.

○ Significant growth
○ Steady growth
○ Stagnant
○ Decline

32. Additional insights regarding stakeholder capacity or implementation barriers in Tanzania

_____

Comments

_____

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Factsheet

KNOWLEDGE, ATTITUDES AND PRACTICES (KAP) OF STAKEHOLDERS

"Tanzanian farmers are ready for biological control, but the system is not ready?"

Pests and diseases cause between 20% and 40% of annual crop losses worldwide, with particularly severe impacts on smallholder farming systems in developing countries (FAO, 2023; Savary et al., 2019). In Tanzania, every growing season, farmers in Mgera Village in Iringa Region spray synthetic chemical pesticides over their maize and tomato fields, to minimize losses. Heavy and unsafe pesticide use in Tanzania threatens human health, biodiversity, and the environment. In Mgera Village, every farmer said they would use biological control if it were available. What is missing is understanding, supply and support.

AWARENESS IS NOT UNDERSTANDING

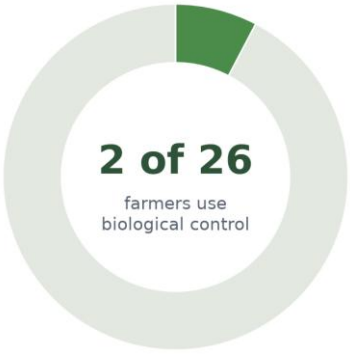
Most farmers have heard of biological control. Only one of 26 could correctly explain it.

73%	4%	0 of 53
of farmers had heard of biological control	could define it correctly (1 farmer in 26)	No participants trained on both biological control and risk reduction

From interviews and surveys with 26 farmers, 20 agro-dealers, 5 regulators and 2 researchers (TPHPA), April–May 2026.

WILLING BUT NOT USING

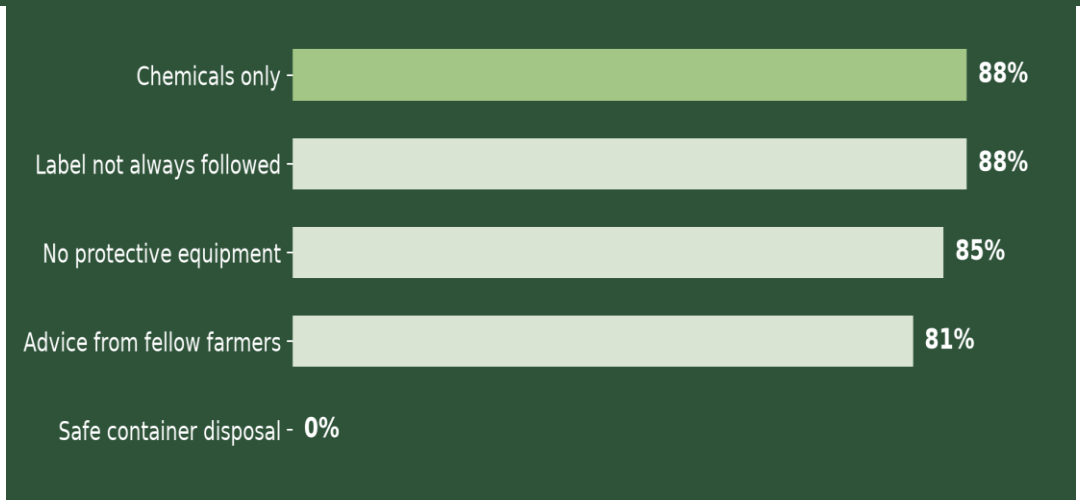
All 26 farmers would use biological control if it were available. Only two farmers currently using biological control methods.



Only 8% (n=2) of farmers are currently using biological control products (a pheromone trap and rabbit urine).

RELIANCE ON CHEMICAL PESTICIDES REMAIN HIGH

Most Farmers rely exclusively on chemicals pesticides, handle them unsafely, and get advice from each other.



THE SUPPLY SIDE IS ALMOST ABSENT

Farmers cannot buy what shops do not stock, and regulators know national law better than the regional guidelines.

85% of agro-dealers sell chemicals only	**15%** stock biological products, just 5–20% of inventory	**p = 0.018** trained agro-dealers were significantly more likely to sell biologicals

WHAT SHOULD HAPPEN NEXT

The willingness and the ecological need are both there. What is missing is the system to connect them.

RECOMMENDATIONS

Conduct specialized training	Participatory on-farm trials	Improved product access	Infrastructure development

References

Food and Agriculture Organization of the United Nations (FAO). (2023). World Food and Agriculture Statistical Yearbook 2023. FAO. https://doi.org/10.4060/cc8166en

Savary, S., Willocquet, L., Pethybridge, S. J., Esker, P., McRoberts, N., & Nelson, A. (2019). The global burden of pathogens and pests on major food crops. Nature Ecology and Evolution, 3(3), 430–439. https://doi.org/10.1038/s41559-018-0793-y

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