BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENT OF CROP SCIENCE

EVALUATION OF HUMAN HEALTH HAZARDS ASSOCIATED BY SUMMER PRODUCED PESTICIDE APPLIED TOMATOES. A CASE STUDY ON GOROMONZI DISTRICT.

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A DISSERTATION SUBMITTED IN PARTIAL FULLFILMENT OF THE REQUREMENTS OF THE BACHELOR OF AGRICULTURAL SCIENCE HONOURS DEGREE IN CROP SCIENCE

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DECLARATION

Student

I, Simbarashe J Bobo, do hereby declare to the Senate of Bindura University of Science Education that this research project is a result of my original research work. It is being submitted for the fulfilment of the Bachelor of Agricultural Science Honours Degree in Crop Science and that to the best of my knowledge, the findings have never been submitted nor being concurrently submitted in any other institution.

Signature:……………………………… Date:……………………………………..

Supervisor

I have supervised the research project for the above mentioned student and I am convinced that the research project can be submitted.

Project Supervisor's Signature Date:

………………………………. …………………………………………..

I certify that I have checked the research project and I am satisfied that it confirms to the Department of Crop Science guidelines for project preparation and presentation. I therefore authorize the student to submit this dissertation for marking.

Quality Controller Signature

………………………………. ………………………………………......

DEDICATION

This dissertation is dedicated to the late Mr R.M Bobo and Family.

ACKNOWLEDGEMENTS

This piece of academic work is a result of combined efforts from both fellow human beings and definitely God (the life giver).

Special thanks goes to Mr K Mutsengi (first supervisor), Professor R Mandumbu (second supervisor), Mr Kamhapa (Laboratory Technician) and Crop Science Department Lecturers for always being patient with me, providing constructive criticism and guidance towards the accomplishment of this research project.

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ABSTRACT

Tomato is an essential constituent of human day to day diet due to its nutritional benefits. Since it is susceptible to pest infestation, the use of pesticides during production is inevitable so as to safeguard the crop and protect its economic value to the farmer. However, the usage of pesticides has reportedly raised health issues. This investigation was done to evaluate the methods used to apply pesticides and the amounts of residue found in Goromonzi District tomatoes after harvest. Using a systematic interviewing process, 36 farmers were questioned, and 40 tomato samples were collected from 36 farmers for laboratory examination. SPSS version 16.0 was used to analyse the data. Six insecticides and five fungicides were employed in the research region, according to the findings. There have been reports of non-recommended methods for applying pesticides including combining non-compatible pesticides, hasty pre-harvest intervals, and the use of ineffective personal protection equipment such as dust masks in place of respirators. Dizziness (50%), fatigue (38.89%), chest pain and respiratory tract irritation (both had 33.33%) and headache (30.56%) were among the reported health problems. The chemical part was done starting with extraction using quick, easy, cheap, effective, rugged, and safe (QuEChERS) methods where seven pesticides (Profenofos, Chlorpyrifos, Cypermethrin, Endrin, Lambdacyhalothrin, Sulphur, and Chlorothalonil) were detected in analysed tomato samples using Gas Chromatography Mass Spectrometry. The samples had unexpectedly Endrin residues found during laboratory examination. The analysis of fortified samples revealed that Profenofos residues were highest in the peels at day one and in pulp after six days. Only 17.1% of the Profenofos residues were lost after washing the tomato, which did not have a substantial impact. Depending on the kind of pesticides and the initial pesticide levels before peeling, tomato peeling reduced pesticide contamination by 35–100%. Ultimately, all of the samples had lower health risk scores, but over time, consuming tomatoes that have been exposed to pesticides at low levels would result in higher systemic concentrations. According to this study, farmers should adhere to the pesticide application recommendations, including the pre-harvest waiting period and safety precautions. To further lower pesticide residual levels, customers should peel tomatoes. Endrin is not registered in Zimbabwe, hence more research should be done to determine its origin.

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LIST OF ACRONYMS AND ABBREVIATIONS

DDT	Dichlorodiphenyl trichloroethane
DRSS	Department of Research and Specialised Services
EU	European Union
FAO	Food and Agriculture Organisation
Faostat	Food and Agriculture Organisation Statistics
GC-MS	Gas Chromatography Mass Spectrometry
IARC	International Agency for Research on Cancer
MRL	Maximum Residue Limit
NPIC	National Pesticide Information Centre
PHI	Pre-Harvest Interval
QuEChERS	Quick, Easy, Cheap, Effective, Rugged and Safe
WHO	World Health Organisation
ZFC	Zimbabwe Fertilizer Company
EC	Emulsion Concentrate
SC	Suspension Concentrate
WDG	Water Dispersible Granules
WG	Wettable Granules
WP	Wettable Powder
ZC	Mixture of Capsule Suspension (CS) and Suspension Concentrate SC)
µl	microliter
ml	millilitres
L	litre
mg	milligrams
g	grams
kg	kilograms
mT	metric tonnes
Ha	hectare
°C	Degrees Celsius

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of study

In daily life, vegetables play a significant role for people. They provide Vitamins C, E, and K. Tomatoes are among the most significant vegetables in terms of their nutritional value to human diet. Tomatoes (*Lycopersicon esculentum* L) are a source of carbohydrate, fibre, and other minerals like phosphorus, potassium, iron, and sulphur, according to Rajkumar et al. (2006). As more people became aware of its importance, the need for increased production became apparent, and many farmers are now striving to grow tomatoes commercially. This possibility has come with a variety of obstacles like weeds, pests and diseases. In response to this, farmers employ several pest management techniques that are cultural, biological, chemical and sometimes physical. The most common pest management practice in Goromonzi District is the use of chemical pesticides to keep weeds, insect pests and diseases at bay and enhance tomato yield while maximizing profit. These tactics have caused pesticide residues to contaminate and accumulate in harvested tomatoes, raising the possibility that consumers may have health problems, especially if the maximum residue levels are exceeded (Sajjad et al., 2009).

A pest is a living organism that has a negative impact on crop's health (Crop Serve, 2022). A pesticide is any substance that is utilized to control the number of pests (Akhabuhaya and Lodenious, 1988). Also, TPRI Act (1979) and Pesticides Regulations (2012) agree that, a pesticide is any formulation with an active ingredient, regardless of its type (including arboricides, acaricides, insecticides, herbicides, fungicides, rodenticides, molluscicides, hormonal sprays, snake repellants and defoliants), that is used or intended to be used alone or in combination with other substances to control weeds, pests, or diseases in plants. In this context, controlling means eliminating a pest or preventing its growth.

Pest control efforts have been ongoing for many years; the first evidence of them dates to ancient China, 2000 years ago. According to Ak'habuhaya and Lodenious (1988), during this period, the Chinese utilized fire or flame to suppress a locust infestation. Scientists made more significant advancements in the 19th century, and as a result, contemporary pesticides, beginning with the old and well known dichlorodiphenyl trichloroethane (DDT), were brought to the market.

Given that tomatoes are frequently consumed raw or after little to no storage, the issue of pesticide residues in tomatoes requires more attention. According to Wikipedia, pesticide residues are defined as the pesticides that remain on or in food substances after they are applied to food crops. In addition, most pesticides used to control pests in tomatoes are also linked to adverse health effects for consumers, particularly when farmers do not use the advised application techniques and when the maximum residues limit is exceeded. For instance, the pesticide Chlorpyrifos is registered for use in Zimbabwe to control tomato pests (ZFC, 2019), but it is a neurotoxin suspected to be an endocrine disruptor and has been linked to acute toxicity, asthma, and reproductive issues, according to the NPIC (2009).

So, it was crucial to conduct this study in order to evaluate the pesticide application procedures, determine the amount of pesticide residues in tomatoes cultivated in the Goromonzi District, and ultimately determine the safety of those tomatoes for customers.

1.2 Problem statement and Justification

The goal of utilising pesticides in tomato farming is to manage pests and fungal diseases to boost output without endangering consumer's health. This is mostly accomplished by adhering to correct and advised pesticide application procedures. However, a number of not-recommended practises in tomato growing have been documented in Mashonaland East Province, particularly in Goromonzi and Mutoko District. These include spraying tomatoes and selling them for consumption right away, not following application intervals, using excessive amounts of pesticide, and mixing multiple pesticides in one container for spraying. It is no doubt that with these and other not yet discovered unjustifiable procedures, there are higher chances that the consumers are getting potentially harmful tomatoes.

Specifically for tomatoes from Goromonzi District, little to nothing is known about the amounts of pesticide residues at both Provincial and at National level. According to AGENDA, a few researches have been done on the use of non-recommended pesticides on tomatoes and other plants (2006). Efforts of expanding the market from local to export for Goromonzi tomatoes have been made in early 2000s but failed because the tomatoes were not in compliance with the international standards for maximum chemical residue limit. Precisely, the harvested tomatoes had excessive amounts of pesticide residues (MoA, 2010). Even to the present day, less has been done to either dispute or support this limitation.

The purpose of this study's findings was to provide information to the government and the general public about the levels of pesticide residues in tomatoes grown in Goromonzi District that are ready for harvest or have already been harvested, the health effects of pesticide use, and farmers' knowledge of pesticide use. This information will help with recommendations for sustainable production that don't compromise public health and safety.

1.3 Objectives

1.3.1 General Objective

To evaluate tomato spraying techniques, pesticide residual levels, and the safety of the tomatoes for customers in Goromonzi District.

1.3.2 Specific objectives

i. To recognise the pesticides employed in tomato pest control,
ii. To learn about the methods used to apply pesticides during tomato-growing operations,
iii. To gauge farmers' knowledge of the negative consequences of pesticides applied on tomatoes on their health,
iv. To measure the amount of pesticide residues in tomato samples, and
v. To evaluate the connection between pesticide residual levels and application practices and related health risks.

1.4 Hypothesis

i. Pesticide application practices in tomato production may pose health hazards to primarily the pesticide handler and secondarily the tomato consumers.
ii. Pesticide application practices in tomato production may not pose health hazards to primarily the pesticide handler and secondarily the tomato consumers.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Tomato production

One of the most widely grown and utilised vegetable crops globally is the tomato (*Lycopersicon esculentum* L.) (Rajkumar et al., 2006). 2005 statistics of FAO showed that on an area of around 4.2 million hectares, the yearly global production was about 125 million metric tonnes with China being the leading producer, accounting for one-quarter of the total output, followed by the United States of America and Turkey. With the advancement of technology and global demand, it is no doubt that the production has risen with more than fifty percent to date. In fact, According to data from Faostat, the world produced 186.821 million metric tonnes of tomatoes on 5,051,983 hectares in 2020, achieving an average yield of 37.1 ($mTha^{-1}$). In Zimbabwe, the production of tomatoes increased from 8 600 tonnes in 1972 to 25 300.98 tonnes in 2021 growing at an average annual rate of 2.71%. According to Mudhovi (2018), there is potential to increase yields to 40 000 tonnes per hectare or above with better farming methods; use of high yielding seed varieties; reduced input costs; better access to extension services and optimal use of labour.

2.2 Tomatoes' Nutritional Importance

Tomatoes and food made from them contain many beneficial nutrients, such as vitamins C, E K, fibre, folate, carbohydrates, flavonoids, iron, and some phosphorus, sulphur, and potassium. Among these nutrients, tomatoes are particularly rich in lycopene a potent antioxidant that can help to ward off the onset of several types of cancer, including core rectal, prostate, breast, endometrial, lung, and pancreatic cancers. This information comes from Rajkumar et al. (2006) and Werner (2000)

2.3 Pesticide Application in Tomato Production

Pesticides are chemicals used to eliminate or manage weeds, insects, fungi, and other harmful organisms. However, if not applied properly, these chemicals can leave behind harmful residues in or on the crops that can pose a serious threat to human health (Alain et al., 2023). Therefore, many countries have established national programs to monitor the levels of pesticide residues in domestic and imported food items. They aim to prevent the sale of food products that contain residues exceeding the specific tolerances set by regulations or for which no tolerances have been established. This measure is taken to safeguard the health of consumers.

Tomatoes are generally prone to insect pest attacks and some bacterial, fungal and sometimes viral diseases while they are in the field. Hence, using pesticides is a common method to eliminate pests and boost output without endangering consumer health (ANCAP, 2004). Only the correct use of pesticides can help achieve this objective. Nonetheless, a number of studies have noted non-recommended methods of applying pesticides during tomato-growing operations. According to Waswa and Kiremire (2004), fruits and vegetables are a subject to pesticide residue contamination because some of them (tomatoes) are sprayed just before being sold for consumption. According to Amoah, et al., (2006), various countries around the world have reported on studies that monitor the presence of pesticide residues on fruits and vegetables. As an example, Pakistan and India have reported on separate occasions the presence and related health effects of chemical residues contaminated tomatoes, other fruits and vegetables together with fish and livestock feed (Knezevic and Serdar, 2009).

Maximum Residue Limits (MRLs), which set limits on the quantity of pesticides in food, have been established by states and international organisations as a result of this issue. According to the FAO/WHO (2006), the MRL for several pesticides used on tomatoes is between 0 and 0.02 mg/kg body weight per day for cypermethrins and between zero and 0.06 mg/kg body weight per day for cyromazine. Then FAO/WHO (2007) mentioned that the Maximum Residues Limit for Profenofos is between zero and 0.03 mg/kg body weight per day with Chlorpyrifos at 0.01.

2.4 Pesticides Used in Goromonzi District

Usage of chemical pesticides in Goromonzi District is comparable to that in other regions of Mashonaland East and Zimbabwe at large (Table 1). A sample of Goromonzi District farmers who were observed by the Ministry of Lands, Agriculture, Fisheries, Water, Climate and Rural Development (2020) confirmed using large quantities of pesticides where some farmers even mixed more than double the recommended application rate with the aim of increasing efficacy against pests. This practise increases also the chances of accumulating relatively high pesticide residues in tomatoes that are ready for harvest, which could have an impact on consumer safety and health. Most of the approved insecticides and fungicides for use in tomato growing operations have negative health consequences if improperly applied (Crop Serve, 2022). Below is a table showing registered pesticides that are being commonly used by tomato farmers in Goromonzi District.

Table 1: Some pesticides that are used in Goromonzi District

Trade Name	**Active Ingredient**	**Applications in tomatoes**
Abamec 18EC	Abamectin 18g/L	Used as acaricides and insecticide
Ampligo 150ZC	Chloratranilprole (10%) + Lambdacyhalothrin (5%)	Control of Lepidoptera Caterpillars (American bollworm)
Bravo 720SC	Chlorothalonil 720g/l	Control of early and late blight
Chlorpyrifos 48EC	Chlorpyrifos 48g/L	Control of caterpillars, tuber moth, cutworm and dust beetles
Copper Oxychloride 85WP	Copper Oxychloride 850g/kg	Control of several fungal diseases
Dhonza 10WG	Emamectin Benzoate 5% + Indoxacarb 5%	Control of various insect pests mostly leaf miners
Karate 5EC	Lambdacyhalothrin 5g/L	Control of various insect pests
Profenofos 50EC	Profenofos 500g/L	Control of red spider mite
Ridomil Gold 68WG	Mancozeb 640g/kg and Metalaxyl 40g/kg	Control of early and late blight among other fungal diseases
Rogor 40EC	Dimethoate 400g/L	Control of white flies and mites
Sulphur 80WDG	Sulphur 800g/kg	Control of fungal diseases

2.4.1 Profenofos 50EC

It is a pale yellow to amber coloured organophosphate insecticide/ miticide that is used in cotton and vegetables (tomatoes) to control cotton bollworm, armyworm, aphids, whiteflies, spider mites, plant bugs and leafhoppers. Improper use of this pesticide may cause health risks such through the inhibition of cholinesterase enzyme activity specifically in the nervous tissue. Death or severe health problems may occur if the pesticide is swallowed, inhaled and or/ if pesticide to skin contact occurs (Dow AgroSciences LLC, 2002).

2.4.2 Lambdacyhalothrin 5g/kg (Karate 5EC)

This is a very effective rapid knockdown contact pyrethroid insecticide used in tomato production to control various insect pests ranging from flies to leaf miners (Syngenta Crop Protection, 2022). Other distributors call this formulation Karate. Irresponsible use of this chemical may be hazardous since it may cause lung damage if swallowed, respiratory problems when inhaled, skin irritation and may also cause unprecedented eye damage. Additionally, Lambdacyhalothrin has proved, in recent years, to be threatening aquatic life (GAT Microencapsulation AG, 2009).

2.4.3 Abamectin (Abamec 18EC)

This is a broad spectrum pesticide used in tomato production to control red spider mites, leaf miners and other flying insects (Ayestock Investments, 2023). Its properties are unique and have a tendancy of being systemic. Improper use or handling of this pesticide may be harmful (by swallowing), toxic (by inhalation) and cause chemical pneumonitis if large amounts are dissolved into the lungs (Villa Crop Protection, 2008). Moreover, in an event where small amounts are ingested and or eventually vomited, the victim may suffer mild to severe pulmonary injury. Due to its inert nature, the pesticide may be harmful by causing mild to severe skin irritation and a condition known as dermatitis through defatting the skin tissue.

2.4.4 Copper Oxychloride 850g/kg (Ordan)

Some farmers refer to this as Ordan and they often use this fungicide formulation to combat various fungal infections, including late blight in tomatoes. However, improper handling of this chemical can lead to potential adverse effects, such as severe eye irritation with corneal injury, redness of locally exposed skin, and allergic reactions (Syngenta, 2020). Dow Agro Sciences (2004) reiterates that inhaling the dust of this product can also cause irritation to the upper respiratory tract, including the nose and the throat, as well as lungs. According to research conducted on laboratory animals, this fungicide may cause cancer (DRSS, 2012)

2.4.5 Chlorpyrifos 50g/kg

Chlorpyrifos is an insecticide that farmers often use to control tomato fruit worms and other mites. It is crucial to follow the recommended application practices strictly, as any deviation can be dangerous. This pesticide can be harmful and toxic if it comes into contact with the skin or is swallowed (Gray and Co, 2000). Ingestion or feeding of the concentrate can cause body injury or even death, while inhaling it can lead to lung damage due to chemical pneumonia caused by petroleum-like solvents (Ayestock Investments, 2023). According to NPIC (2009), those children that were exposed to Chlorpyrifos during pregnancy or while in the womb have higher risk of experiencing delays in motor and mental development by the time they reach three years of age, as well as an increased likelihood of pervasive developmental disorders.

2.4.6 Chlorothalonil 720g/kg (Bravo)

Chlorothalonil, commonly known as Bravo in Zimbabwe, is an aromatic derivative fungicide used to manage fungal diseases in tomato plants. It has the ability to both prevent and treat fungal infections (Windmill, 2021). However, if it is not used or applied correctly, it can cause severe irritation in the eyes and skin. Also, at very high amounts, it can lead to loss of muscle coordination, vomiting, nose bleeding, hyperactivity, rapid breathing and even death (Ospray, 2010). Other potential side effects include vaginal bleeding, dermatitis, bright yellow or even bloody urine together with kidney tumours. The International Agency for Research on Cancer (IARC) has classified this fungicide in group 2B, indicating that it has the potential to be carcinogenic to humans (Ospray, 2010). Risk to aquatic life is not an exception.

2.4.7 Mancozeb 640g/kg + Metalaxyl 40g/kg (Ridomil Gold)

This fungicide consists of two active ingredients namely Mancozeb (640g/kg) and Metalaxyl (40g/kg) (Jiangsu Qiaoji Biochem, 2010). This formulation, in Zimbabwe, is commonly known as Ridomil Gold and is used to manage fungal infections and diseases like late blight in tomato plants. However, if not used and applied correctly, it can cause some irritations specifically in the nose, throat and in extreme cases, lungs. Long period for exposure of skin to Ridomil Gold may lead to possible skin irritation (Jiangsu Qiaoji Biochem, 2010).

2.4.8 Wettable Sulphur 80WG

This fungicide formulation consist of Sulphur (800g/kg) as the active ingredient (Agricura, 2020). Kumullus and Sulphur 80WDG are other names that refer to the same chemical in Zimbabwe. It is used to manage fungal diseases, such as stem rot, and other stem related diseases in tomato cultivation. Although it has been classified as non-hazardous, regular exposure to this product can lead to chronic bronchitis and eye discomfort (Titan Ag Pty, 2009).

2.5 Recommended Pesticide Use in Tomato Production

The main aim of using pesticides is to suppress pest population thus insuring high yield in tomato production. Religious adherence of the recommended practices or procedure during handling the chemicals is of paramount importance to reduce health risks to both the handler and the tomato consumer (Kumari et al., 2003). Table 2 provides a summary of the recommended application practises for several pesticides that are registered for use in Zimbabwe. These pesticides are used to control pests and increase tomato production without causing any harmful effects on consumers, provided they are either applied or handled correctly. However, many studies have reported non-recommended practises related to pesticide use. For instance, in Pakistan, the random use of pesticides during the fruiting stage and failure to adhere to safe waiting periods have resulted in the accumulation of pesticide residues in vegetables that are meant for human consumption (Madan et al., 1996).

Table 2: General guide of pesticide use in tomato production

Pesticide Name	**Application Rate**	**Application Intervals**	**PHI (Days)**
Abamectin 18EC	12ml in 16L of water	Economic thresholds	Three
Chlorpyrifos 48EC	15ml in 10L of water	At least 7 Days	Four
Ampligo 150ZC	32ml in 16L of water	At least 7-10 Days	Seven
ZFC Deletor 32.5SC	10ml in 20L of water	At least 7-14 Days	Fourteen
Profenofos	32ml in 16L of water	At least 10-14 Days	Twenty one

AGENDA (2006) conducted a study in Zimbabwe and reported on non-recommended practises among farmers. The study found that many farmers relied on their experience to dilute pesticides, rather than following the recommended practices provided on the container labels. Additionally, 63% of farmers applied pesticides within a shorter time interval than recommended and mixed multiple pesticides to increase their efficacy, despite this being against the recommended practices. Similarly, according to The Ministry of Lands, Agriculture, Fisheries, Water, Climate and Rural Development (2020), some tomato farmers in Zimbabwe mix multiple pesticides together to increase their effectiveness and ensure maximum pest control. The report also notes that some farmers spray pesticides on ready-to-harvest tomatoes to prolong their shelf life and prevent damage during transportation to the market.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Description of Study Area

3.1.1 Location of Goromonzi District

Mashonaland East province in northern-eastern Zimbabwe is home to the Goromonzi Rural District Council. Along with Seke District to the south, Marondera District to the east, Murehwa District to the north east, Bindura District to the north, Shamva and Mazowe Districts to the north-west, it is bordered by these districts as well. The district and the capital city of Harare share the whole western border, and the region's near proximity to the capital offers fantastic potential for quick expansion in the real estate, agro-industries, mining, manufacturing, and associated downstream industries.

3.1.2 Selection of the Study Area

A total of 9100 square kilometres make up the Goromonzi district. The district is divided into 25 wards, 13 of which are commercial agricultural regions (6, 7, 8, 9, 13, 14, 17, 20, 21, 22, 23, 24 and 25), 11 are communal areas (1, 2, 3, 4, 5, 10, 11, 12, 15, 16, and 18), and 1 is a small-scale farming area (ward 19). From this, field data and samples for laboratory examination were gathered from six selected wards specifically Ruwa (25), Mandalay (24), Melfort (20), Goromonzi (17), Acturus (14) and Mwanza (12) based on the following reasons:

i. Relatively high rate of tomato production potential
ii. Intensive use of pesticides, and
iii. In Harare, which has a population of around more than 1,578,000 million, tomatoes from these wards account for a significant portion of the market.

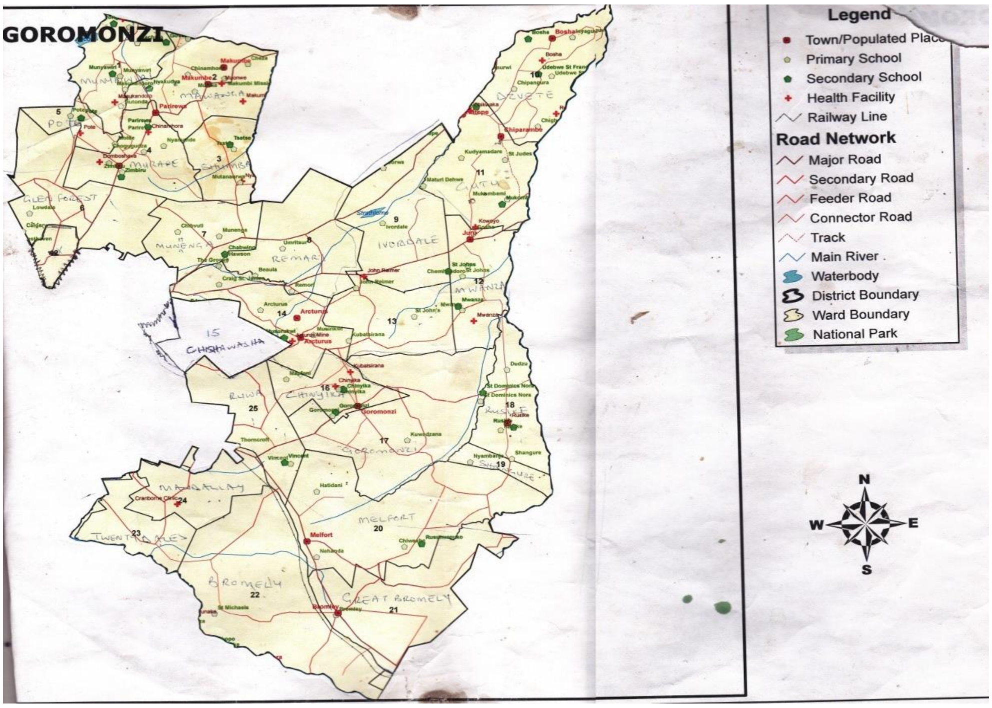

Figure 1: Goromonzi District Map

3.2 Research Design

The method for gathering data was a cross-sectional research design. Data may be gathered once, without repeating any steps, thanks to this architecture. According to Kothari (2004), the design was chosen because it produces results quickly while using the least amount of time and resources. To evaluate the quantities of pesticide residues in tomatoes, it required field surveys, organised interview schedules to detect pesticide use practises, sample collection, and lab analysis.

3.3 Sampling Techniques

The sample size (n) chosen from the study population was chosen in accordance with a sampling strategy so that n/N reflects a number more than or equal to 5% of the population size, which is the required minimum sample size to establish a representative sample (Boyd et al., 1981). The sample size is "n" and the population size is "N." Thirty six farmers were interviewed during the field survey to assess pesticides application practices. On the other hand, twenty tomato samples were taken from randomly selected farms and the other twenty from respective markets for laboratory analysis to determine pesticide residues levels and their respective distribution pattern within the different tissues of tomatoes. The sampling process used the formula nh = (Nh / N)*n (Snedecor and Cochran, 1989) to determine the number of respondents from each ward. nh represents the sample size for the stratum "h," Nh represents the population size for the stratum "h," N represents the total population size, and n represents the total sample size. 36 farmers were included in the field study to evaluate application practises after communities and individual farms were randomly chosen. According to the Codex Alimentarius Commission (2000), 1 kilogramme was considered the entire unit or package for defining a single sample.

3.4 Data Collection

3.4.1 Pesticide Application Practices

A systematic interview schedule made up of open- and closed-ended questions for face-to-face interviews was used to gather information on pesticide kinds and application procedures. The schedule is supplied in Appendix 1.

3.4.2 Chemical Analysis

Chemical analysis was used to acquire information on pesticide residues. The protocols outlined by Anastassiades et al. (2003) were followed while analysing tomato samples in the lab. The approach employs Gas Chromatography-Mass Spectrometry (GC/MS) to identify pesticide residues and is intended for the extraction of various pesticide residues from fruit, vegetables, and other low-fat meals.

However, the extraction medium was changed from acetonitrile to ethyl acetate, and florisil was used to remove the supernatant instead of the mini-column consisting of graphite carbon and ammonium acetate-salinized silica gel (500 mg/500 mg) that was originally suggested.

3.4.2.1 Method of Extraction and Determination

Out of 40 tomato samples, 15 were blended before washing and 15 were mixed following a complete wash in tap water. The remaining 10 samples were combined into two groups: the pulp after peeling and the peel itself. A 50 mL Teflon tube was filled with 15g of the blended sample, 100µl of heptachlor as an internal standard, and 15 mL of ethyl acetate as an extraction medium. Then, to extract the water, 6 gramme (g) of anhydrous magnesium sulphate ($MgS0_4$) and sodium acetate (CH_3COONa) were added. The combination was shook. A total of 300 mg of anhydrous magnesium sulphate ($MgS0_4$), 150 mg of florisil, and 2 millilitres (µL) of the supernatant were added to the 15 millilitre Teflon tube to further remove water and clean the sample. After giving the combination a gentle shake, it was put into a centrifuge and spun for 3 minutes at a speed of 4000 rpm. In 2µL out sampler screw cap vials, 1.5 to 2µL of the test solution were extracted.

A gas chromatography/mass spectrometry (GC/MS) system was used to separate, identify, and analyse the sample components by injecting 1µl of the concentrated extract into a high resolution fused silica capillary column. Comparing recorded mass spectra and retention times to reference spectra and retention times stored in a database allowed researchers to identify the compounds that were eluting from the GC column. The measurement of calibration standards under the same circumstances as for samples produced reference spectra and retention periods for analytes. Each identified component's concentration is determined by comparing the MS response of the quantitation ion it produces to the MS response of the quantitation ion it produces in comparison to a compound that serves as an internal standard.

Additionally, tomato samples were fortified with 5.2g of mancozeb in one litre of water, 2ml of Profenofos (2.92mg/kg), and 2ml of Lambdacyhalothrin (1.84mg/kg). Two kinds of fortification were used. One category involves spraying tomatoes first with a combination of Profenofos and Lambdacyhalothrin, then with mancozeb. In the other group, tomatoes were individually sprayed with Lambdacyhalothrin and Profenofos. In comparison to other pesticides, Profenofos and Lambdacyhalothrin are the most widely used, have significant health risks, and have lengthy recommended pre-harvest waiting times, especially for Profenofos. Mancozeb, however, was omitted from the extraction and determination process due to the short pre-harvest waiting period needed and the expense of the laboratory analysis's financial constraints. Then, using the same techniques as before, the Profenofos and Lambdacyhalothrin residues were extracted and determined. This fortification served the dual aims of evaluating the two pesticides' rate of degradation over time following application as well as the impact of washing and peeling on the level of residues in the sprayed tomatoes.

Using the GC-MS findings and the calibration curve created using the formula below, the residue levels of each pesticide were then calculated.

Residue (mg/kg) = [(A)(V)(P) / (C)(W)(CF)(100)] all multiplied by 10^6

Where: A is the analyte's peak area in the sample; V is the total millilitres of the concentrated extract; P is the purity of the applied standard; W is the sample's weight in grammes; Correction factor abbreviated as CF and from the calibration curve's (Area/ng) slope, C is the mean calibration factor.

The average Limit of Detection (LOD) was 1.0 picogram (pg)/microlitre (µl) and the average Limit of Quantitation (LOQ) was 1.0 nanogram (ng)/ µl.

3.4.2.2 Gas Chromatography Mass Spectrometry Measuring Conditions

The injection port temperature and splitless injection mode were both 230°C during the GC separation. The column temperature plan that was employed was 50°C for 1 minute, followed by a 5°C/min increase to 280°C for 10 minutes. Durabond, 35 Methyl Silicon (MS), 30m long, 0.250mm internal diameter, and 0.25m film thickness made up the column. The volume injected was 1microlitre, and the solvent utilised was ethyl acetate. More than 99.999% pure helium served as the carrier gas, and the flow rate was 1.2 ml per minute. The ion source's temperature was set at 2300C, while the transfer line's temperature was fixed at 280C. An electron impact ionisation mode with an ionising energy of 70 eV was used to operate the Mass Spectrometer detector. Using one target and two qualifier ions, the analysis was carried out in the SCAN mode. Retention durations, target ions, and qualifier ions were used to identify chemical substances.

3.4.3 Data analysis

The field survey results were entered into SPSS version 16.0, which produced descriptive statistics, including the minimum, maximum, means, and frequencies of individual variables.

3.5 Limitations of the Study

Primary data on pesticide application practises were mostly gathered through interviews with tomato growers and pesticide users, whose answers were susceptible to mistakes due to lack of understanding about correct pesticide applications or poor recollection. A laboratory investigation of tomato samples taken during one of three harvesting seasons also yielded the findings.

To address some of the major data shortcomings, additional data on the pesticides used in the research region, notably the accuracy of trade names known to farmers as opposed to common or chemical names, were gathered from pesticide dealers and merchants. In addition, as control samples, fortified tomato samples that had been exposed to pesticides used in the research region were also examined. The fortified samples, however, were maintained indoors at room temperature, thus the effects of the environment on tomatoes with regard to pesticide residues were not taken into consideration.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Characteristics of Respondents

The overall characteristics of the respondents are shown in Table 3 and include their gender, marital status, age and educational attainment. The respondents' ages varied from 21 to 58, with a mean age of 40. The majority of responders were between the ages of 31 and 40 and 41 and 50, making up 47.2 and 36.1 percent of the total population, respectively. Additionally, just 5.6% of respondents were between the ages of 21 and 30 years, compared to 11.1% of respondents who were between the ages of 51 and 60. These results suggest that the majority of those who participated in the research region were still in the tomato production age and had the potential to increase it, especially if the appropriate extension services were in place.

Table 3: Gender, marital status, age and educational attainment

Categories assessed	**Frequency**	**Percentage of cases**
Gender		
Male	33	91.7
Female	3	8.3
Marital Status		
Single	3	8.3
Married	31	86.1
Widowed	2	5.6
Age of respondents		
Minimum age (years)	21	
Maximum age (years)	58	
Mean age (years)	40	
21 to 30 years	2	5.6
31 to 40 years	17	47.2
41 to 50 years	13	36.1
51 to 60 years	4	11.1
Education attained		
No formal education	4	11.1
Primary level	24	66.7
Secondary Level	8	22.2
TOTAL	36	100

The research also reveals that females (including two widows) constituted just 8.3% of the total tomato growers questioned whilst males reached 91.7% of the respondents. These findings suggest that men dominated in the tomato-growing industry. Only 8.3% of the responders were single whilst 86.1% were married. Regarding education, 66.7% of the respondents had completed primary school, which is the lowest degree of education. This level of education for the majority of farmers and the dearth of extension personnel may be a contributing factor in the lack of understanding about the ideal methods for applying pesticides.

4.2 Application Practices for pesticides

4.2.1 Pesticide types used on tomatoes in the research area

The field survey's assessment of the different types of pesticides utilised was carried out using a systematic interview schedule. The kinds of pesticides applied in the research region were determined by the intended uses and the kinds of pests to be controlled commonly fungal infections and/ or insect pests. From the thirty six farmers (respondents) interviewed, all of them confirmed that they used pesticides in their tomato growing activities.

The Figure 2 below shows the percentage of respondents who used a specific pesticide.

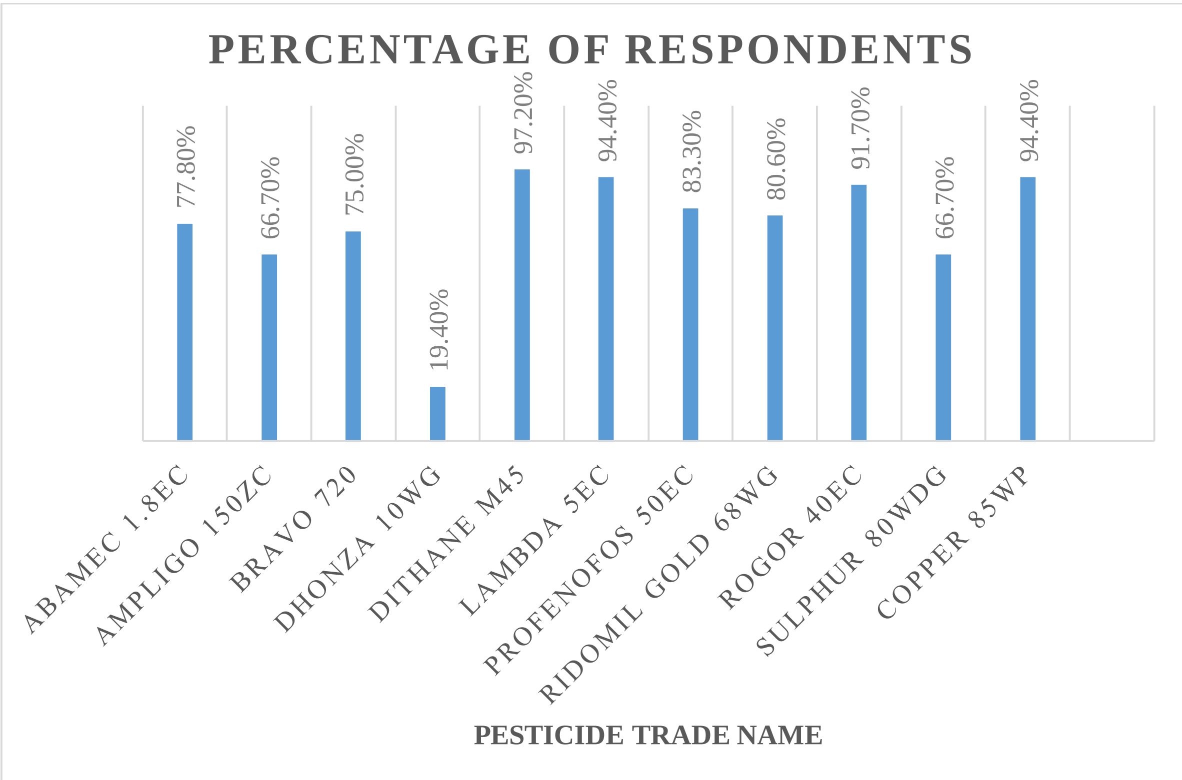

Figure 2: Pesticide types and their percentage of use by respondents

From the eleven pesticides mentioned by respondents, the researcher found out that there were only fungicides and insecticides that were being commonly used. Of these eleven pesticides, five were fungicides (Copper, Bravo, Ridomil Gold, Sulphur and Dithane M45) whilst six were insecticides (Dhonza, Rogor, Lambda, Abamec Ampligo and Profenofos)

According to the results in Figure 2, the respondents proved to be more familiar with Dithane M45 which was used by 97.20% of the total (36) respondents. This means that the probability of Dithane utilisation in almost every tomato production in Goromonzi District was very high. The same applies to Lambda and Copper which both had 94.40% together with Dimethoate which was being used by 91.70% of the total respondents. These four pesticides are not only common in Goromonzi District, but also in Zimbabwe and most probably in the world at large due to their effectiveness in their areas of specialisation.

When comparing the use of each group of pesticides, it is clear that the insecticides were used by a greater portion of farmers than the fungicides. This may be so because in summer (when the research was conducted), the problem of fungal infections or diseases is generally low due to less favourable conditions of the fungal development thus reducing the need to use fungicides. At the same time, warm to high temperatures experienced in summer accelerated the life cycle of insect pests thus justifying the need of having and using more insecticides.

There is only one outstanding result where only a few farmers (19.40%) mentioned that they used Dhonza. Dhonza is an insecticide that was designed to control a wide variety of pests specifically leaf miners and other Lepidoptera species. It accomplishes that through the power of its two way main active ingredients namely Indoxacarb and Emamectin Benzoate (CitChem, 2021). The low percentage use may be due to the fact that it is still new on the market but its safety (green triangle colour) and PHI of three days gives it more potential to be adopted by the farmers together with an added advantage of being effective and efficient.

The research also found out that only one (Profenofos) was not being directly distributed in Zimbabwe which brings a question whether it was registered or not. Profenofos suppresses the action of the cholinesterase enzyme in the nervous system when it comes into contact with skin. Spray is toxic and hazardous when consumed as well as when inhaled (Dow AgroSciences LLC, 2002). The same applies to insecticides like Lambdacyhalothrin, and Abamectin which are legal but they are also linked to a number of negative health impacts.

Lambdacyhalothrin is dangerous and can destroy the lungs if consumed. It is extremely harmful when inhaled and can have long-lasting negative impacts on the aquatic environment

(Syngenta, 2022). It also irritates the respiratory system (GAT Microencapsulation AG, 2009). When consumed, Abamectin is poisonous and hazardous when breathed. Because of its inert nature and potential for skin contact, it can irritate the skin in a mild to severe way. According to Villa Crop Protection (2008), the substance is a significant eye irritant and may harm eyes when exposed. Chlorothalonil can have fatal side effects at very high doses whilst in low doses might cause eye and skin irritation, loss of muscular coordination, fast breathing, nose bleeding, vomiting and hyperactivity, (Windmill, 2021). Additionally, it is listed as potentially carcinogenic to humans and is known to be extremely harmful to aquatic creatures, creating long-term negative consequences on the aquatic ecosystem (Ospray, 2010).

If these pesticides are not used and applied properly, the associated health impacts could endanger the health and safety of farmers and consumers. The aforementioned health consequences on farmers or other users could result from insufficient protection or poor application of safety measures during the application of pesticides. Consumers of tomatoes may be exposed to pesticide residues, particularly if the advised application procedures—such as using the proper quantity and waiting the recommended amount of time before harvesting—are not followed.

4.2.2 Source of information on pesticides use and applications

The knowledge that farmers used when growing tomatoes is summarised in Figure 3 below. The findings indicate that 80.60% of respondents learned about pesticide use from fellow farmers, 66.60% from pesticide retailers, 33.30% from pesticide package labels and only 25% from Agronomists.

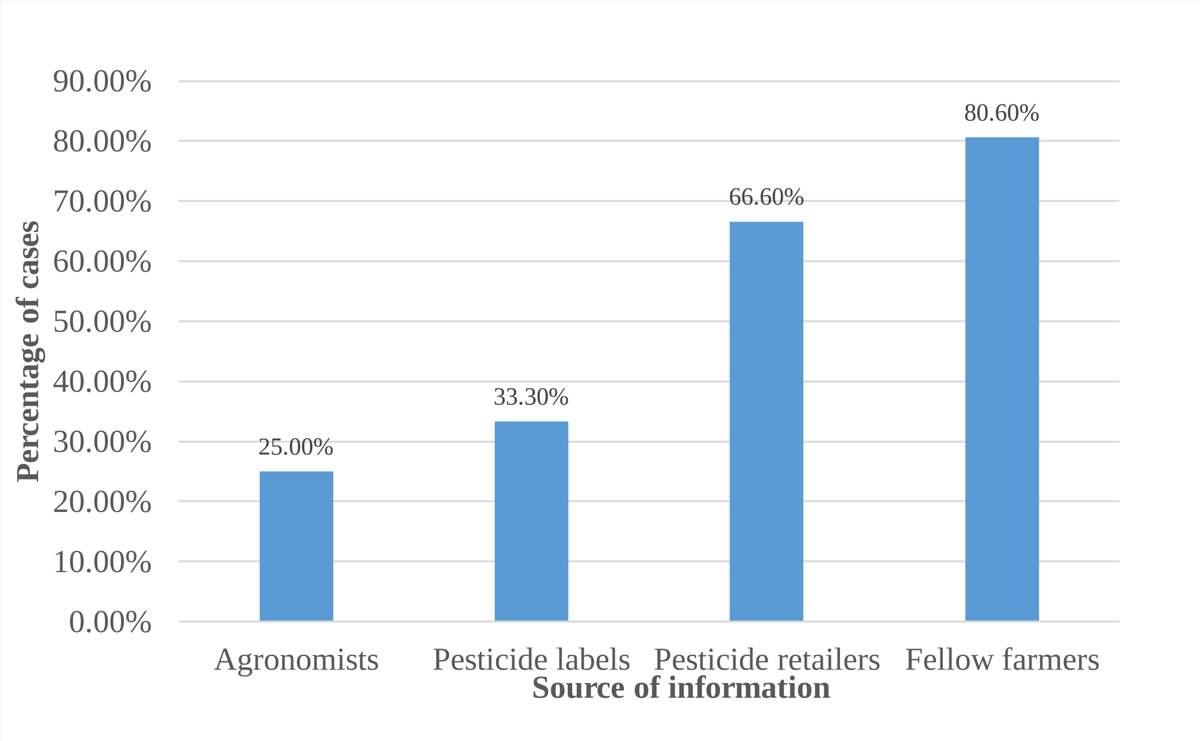

Figure 3: Sources of information on pesticide use and their application practices

The results in Figure 3 above clearly shows the much reliance of tomato farmers from each other. It is assumed that the sources of information on pesticide use is largely influenced by the level of education that the farmer acquired. It has been reviewed earlier in Table 3 that a total percentage of those who acquired no formal and primary level of education constituted 11.1% and 66.7% respectively making a total of 77.8% of the respondents. This justifies the high percentages in the reliance of the tomato farmers to fellow farmers and pesticide retailers because low levels of education make it difficult for them individually to read and understand pesticide labels. Moreover, some farmers also highlighted the cost of consulting agronomists and sometimes extension officers as a limitation to their reach when in need of information on pesticide use. They argued that the cost of consulting an independent agronomist significantly increased cost of production hence they end up turning to cheap alternatives like fellow farmers. This leaves only a few (25%) being able to reach agronomists for the information on pesticide use. Even the percentages of respondents who received secondary education (22.2%) and those who consulted agronomists (25%) seems to agree that they knew the significance of consulting agronomists who are well vested with the knowledge of pesticide use and tomato plant management in general.

However these sources that were largely used by farmers are not reliable. It is disturbing to note that the credibility of the sources was substituted by the cost of reach. Reliance on fellow farmers is untrustworthy in the sense that the information being shared might be heavily diluted to the extent that critical aspects like the application rates, practices and withdrawal periods are either compromised or completely forgotten. In some cases, farmers and even other pesticide retailers can share falsified information either for marketing or miscellaneous purposes.

4.2.3 Categories of pesticides mixing during application

The majority of pesticides used in tomatoes are recommended to be applied individually. However, the research findings show that the farmers also adopted a practices that found them mixing more than one pesticide for spraying. Figure 4 below shows the categories of pesticides mixing during application and their percentage based on respondents.

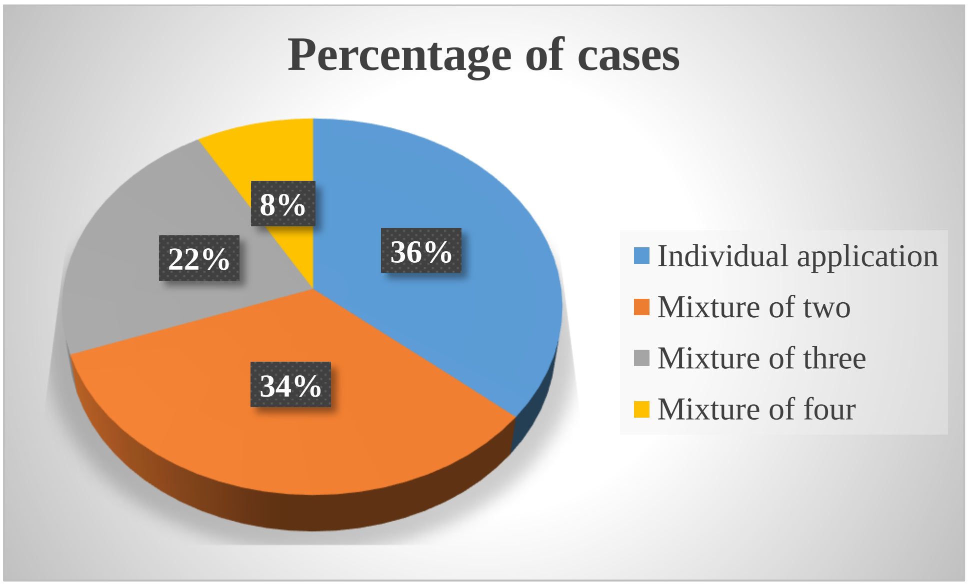

Figure 4: Categories of pesticides mixing during application and their percentage of incidence

Out of all the respondents, only 36% followed the standard procedure for pesticide application which is applying each pesticide individually. The rest confirmed the mixing of two (34%), three (22%) and four (8%) pesticides when spraying. These practices have some implications especially if they are done recklessly.

In the case of combining two or more pesticides, the farmer is required to perform a standard procedure called the compatibility test or consult a horticulturist, agronomist or an expert in pesticide handling (Crop Serve, 2022). This tests the small amounts of the chemicals to be mixed and see if they are miscible and still perform the specified function. However, it was depressing to realise that only three respondents knew about the compatibility test suggesting that almost all of the farmers who mixed pesticides were unaware of this crucial procedure.

The respondents justified their practice of mixing two or more pesticides on the bases of increased effectiveness (killing capability to pests) reduced labour and time needed in spraying. Due to these reasons, some important aspects were overlooked for example in the case where Ampligo 150ZC and Lambdacyhalothrin 5EC were mixed together. According to Syngenta (2022), Ampligo 150ZC has two active ingredients namely Chlorantraniliprole (100g/L) and Lambdacyhalothrin (50g/L). This was unjust because the mixture was literally the amplification of Lambdacyhalothrin. This is not only a waste but also a life threatening practice to both the handler (through acute poisoning by skin contact, inhalation or even swallowing) and also the consumer through swallowing tomatoes with high levels of Lambdacyhalothrin.

Another aspect of withdrawal periods was also compromised by the mixing of two or more pesticides when spraying. This is based on the fact that plants (specifically tomatoes) have a known biodegrading capacity that is known by pesticide manufacturers that is considered when stating a withdrawal period of a specific pesticide. For example, Profenofos has a withdrawal period of 21 days and Lambdacyhalothrin with 7 days in tomatoes. Mixing the pesticides, like in extreme cases of four pesticides, severely undermines the capability of tomato plant to degrade the applied pesticides leading to accumulation of pesticide residues exceeding the Maximum Residues Limit (MRL). This calls for farmers to have longer withholding periods but somehow they harvest and sell the tomatoes which are pesticide contaminated leading to the increase in the risk of causing chronic and sub chronic poisoning to the consumer.

It is an indispensable fact that when one or more pesticides are mixed, there is possibility of either synergy or antagonism in their efficacy towards the intended pests depending on the chemical reactions which occur when mixed together.

4.2.4 Reported pesticide related health effects

According to the respondents' comments, there are eleven health impacts, as indicated in Table 4. It was observed that 50% of respondents reported dizziness, 38.89% reported fatigue, and 33.33% claimed respiratory tract irritation and other mentioned effects as a result of using or applying pesticides, with symptoms appearing right away after spraying.

Table 4: Reported health effects as a result of pesticides application

Health effects	Frequency	Percentage of cases
Chest pain	12	33.33%
Death	3	8.33%
Dizziness	18	50.00%

Eye irritation	7	19.44%
Fatigue	14	38.89%
Flu	9	25.00%
Headache	11	30.56%
Respiratory tract irritation	12	33.33%
Skin irritation	6	16.67%
Skin burns	4	11.11%
Stomach ache	4	11.11%
TOTAL (Respondents)	**36**	

Table 4 shows some signs and symptoms of acute and sub chronic poisoning linked to pesticides employed in the research area. These results are supported by a number of literatures. Lambdacyhalothrin can be harmful to the lungs if consumed, is poisonous when inhaled, irritates the skin and respiratory system, and presents a significant risk to the eyes, according to GAT Microencapsulation AG (2009). Additionally, prolonged or repeated skin contact as well as incorrect application of a solution containing the chemicals mancozeb (64%) and metalaxyl (8%) may cause nasal, throat, and lung irritation (Jiangsu Qiaoji Biochem, 2012).

According to Villa Crop Protection (2008), Abamectin is toxic when it comes into touch with the skin and can cause mild to severe skin irritation as well as serious eye irritation and damage. According to Bayer Crop Sciences (2012), Chlorothalonil can irritate the skin and respiratory tract when it is exposed to the eyes. This product irritates and has the potential to briefly obscure the cornea.

4.2.5 Personal pesticide protection measures

As a protection measure from potentially harmful health consequences of pesticides, it is advised that appropriate protective gear be properly used when using pesticides for example respirators, rubber gloves, overalls or work suits, gumboots, goggles and many more. Figure 5 below shows the protection measures and their percentage of adoption by respondents in a study area.

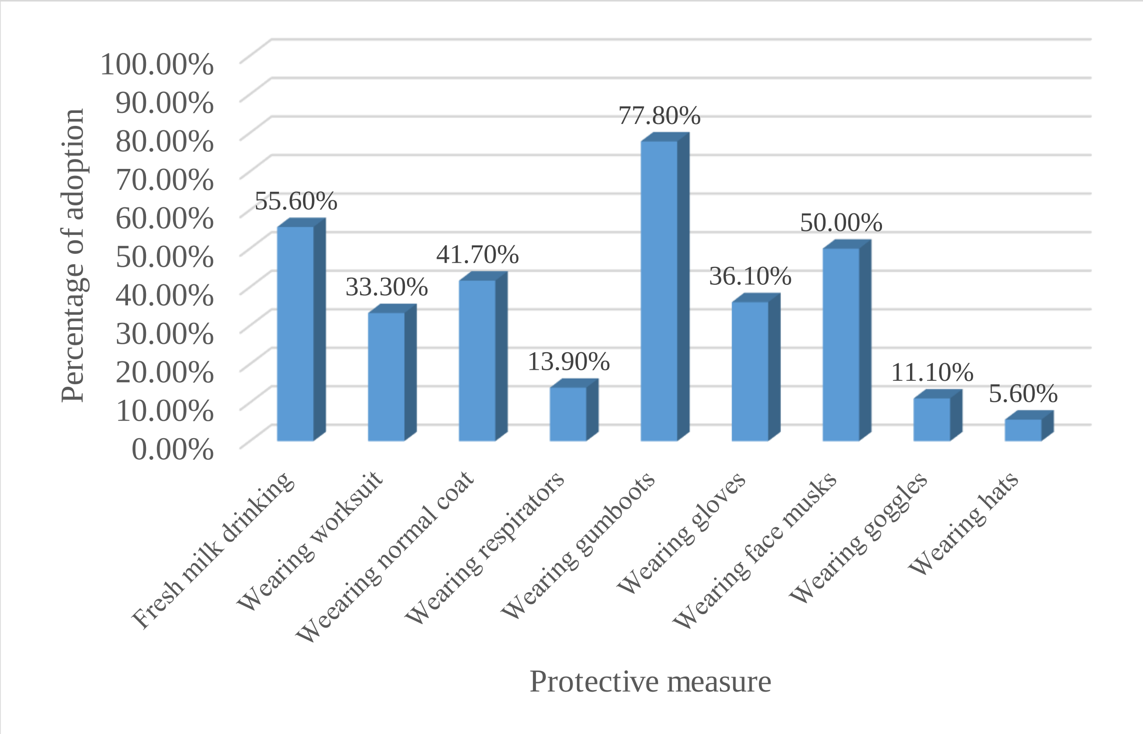

Figure 5: Protection measures against pesticides health effects

According to the results in Figure 5, it is self-portraying that the farmers used inadequate protection measures when handling pesticides. This is evidenced by the majority of the respondents showing the use of either inappropriate or less effective protective measures.

For example, the wearing of gumboots as a protection measure was highly (77.80%) adopted whist the wearing of gloves was low (36.10%). This shows that the farmers were either less careful or concerned during handling the pesticides. It is disturbing to note that hands being the primary organs for handling pesticides were not safeguarded whilst making the legs a priority. Less protection on hands increase the chances of pesticide poisoning by skin contact thus causing skin irritation or in some cases skin burns.

Secondly, the wearing of face masks (50%) was more common than that of wearing respirators (13.90%). Both face masks and respirators were reportedly used with the aim of reducing farmers' exposure to pesticides through inhalation of spray or formulations. However, the aim proved to be hard to achieve as evidenced by high incidences of respiratory related health effects like respiratory tract irritation, chest pain, fatigue, dizziness, flu and headache. Better adoption for proper wearing of respirators can significantly reduce respiratory problems.

The general findings of this study show that large number of farmers were not conscious to either the harmful effects of pesticides or the importance of individual and unanimous adoption and use protective equipment when handling pesticides. In the end, it is hard to separate three deaths reported in Table 4 from the less protection measures in pesticide handling.

4.3 Pesticide Residues in Tomato Samples

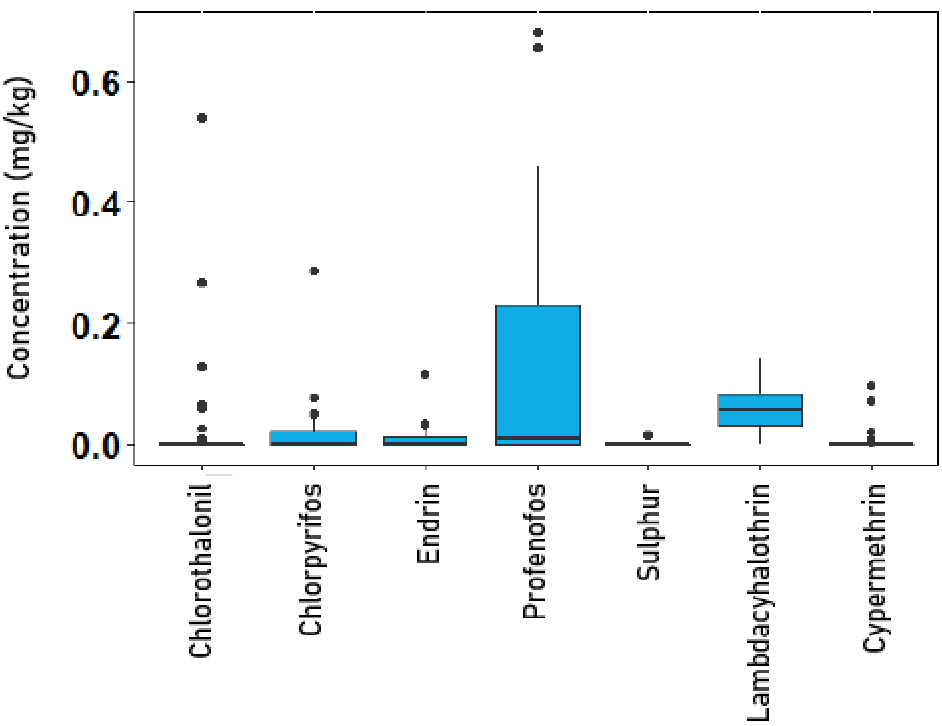

Figure 6: Boxplot showing a trend of pesticide residues (mg/kg) in tomato samples (n=40) analysed using Gas Chromatography Mass Spectrometry

Figure 6 displays the basic patterns of pesticide residues in tomato sample. The results showed that Profenofos had the highest concentration, with a range of 0 to 0.681 mg/kg and a mean of 0.135 mg/kg. Second, the range for Chlorothalonil was 0 to 0.540 mg/kg. Following this was Chlorpyrifos, which ranged from 0 to 0.285 mg/kg, and then Lambdacyhalothrin, which went from 0 to 0.144 mg/kg. Endrin concentration ranged from 0 to 0.119 mg/kg, while that of the other two pesticides on the graph was less than 0.01 mg/kg.

Some research done in other parts of Africa also found higher concentrations of pesticide residues in tomato samples, such as Ethiopia, where 2.5% of the sample had Profenofos and Sulphur levels above the EU MRLs (Loha et al., 2020). Higher levels of pesticides may have been caused by improper pesticide application, which has been documented by numerous researchers. Examples include the use of fake pesticides (Zikankuba et al., 2019), the use of multiple pesticides with same active ingredients (Nonga et al., 2011), and the inappropriate dosage and combination of pesticides (Kiwango et al., 2018).

However, Lambdacyhalothrin levels were lower (0.144 mg/kg) than those found in Senegal (0.293 mg/kg) (Diop et al., 2016), Profenofos levels were lower (0.135 mg/kg) than in Egypt (Ahmed et al., 2016), and Chlorothalonil levels were lower (0.21 mg/kg) in Nigeria (Oyeyiola et al., 2017). The discrepancy between the observed results and those of other researchers may be explained by growing farmer awareness and adherence to ethical agriculture practises.

The Gas Chromatography Mass Spectrometry results also shows the contamination of tomato samples by two active ingredients that were not mentioned by respondents during interviews. Of these two active ingredients, Endrin concentrations exceeds the considerable levels. Endrin is a systemic organochlorine insecticide that leads to bioaccumulation in people due to its non-biodegradability, low solubility in water, and high solubility in body lipids (URT-NIP, 2005). Being at the top of the food chain and therefore at increased danger due to the tendency for bio magnification, these particular traits are of major concern to both humans and wildlife.

According to Santa Cruz Biotechnology (2008), long-term exposure to this pesticide may result in cumulative health effects affecting organs or biochemical systems, as well as irritation, drowsiness, appetite loss, a decrease in blood cell count, leukaemia, and anaemia. Similar materials offer some evidence of impaired fertility without toxic effects, or evidence of impaired fertility occurring at roughly the same dose levels as other toxic effects, but which are not secondary non-specific effects of other toxic effects, which raises concerns for human fertility. Particles smaller than 0.5 microns can penetrate the lung and stay there for an extended period of time, changing lung function and leading to pneumoconiosis.

The Stockholm Convention forbids the use of this herbicide in all Parties due to health concerns and systemic consequences related to it. As a Party to the Convention, Zimbabwe immediately prohibited its use in all associated applications after ratifying the Convention in 2004. As a result, no residue of this pesticide, at any concentration level, should be discovered in the food chain (URT-NIP, 2005).

These results warrant further investigation to determine whether Endrin is being illegally imported and used, whether it has been used in the past, particularly in the early 1990s, and is still being absorbed from contaminated soil, or whether, during laboratory analysis, some components of the samples revealed similar properties to those of Endrin, particularly retention time.

The findings related to pesticide contamination in tomato samples particularly those that exceed the stipulated Maximum Residue Limits (MRLs) have a significant risk to consumers' health due to residues contributing to either chronic or sub chronic poisoning.

4.4 Pesticide Residues for Fortified Tomato Samples

4.4.1 Fortified with a mixture of Profenofos and Lambdacyhalothrin

Prior to fortification and spraying, two pesticides were mixed together in order to simulate farmer application techniques and measure the degree of pesticide residues and their degradation over time. The results of tomato samples fortified with a mixture of Profenofos and Lambdacyhalothrin at Day 1 and after 6 days are shown in Table 5 below.

Table 5: Pesticide residues (mg/kg) following fortification of tomato with Profenofos and Lambdacyhalothrin mixed together

Types of Pesticides	**Tomato constituents**	**Day 1 (mg/kg)**	**%RC**	**ISTD %RC**	**Day 6 (mg/kg)**	**%RC**	**ISTD %RC**
Lambdacyhalothrin	Peels	ND		50.0	0.60	36.0	85.0
	Pulp	ND		98.0	ND		91.0
Profenofos	Peels	2.00	73.1	50.0	1.30	46.0	85.0
	Pulp	0.30	9.5	98.0	ND		91.0

ND – Not Detected; %RC – Percentage Recovery from fortified samples with 2.92mg/kg Profenofos and 1.84mg/kg Lambdacyhalothrin; ISTD %RC – Internal Standard Percentage Recovery

The results show that after 1 day, no residues of Lambdacyhalothrin were found in the tomato peels or pulp, but after 6 days, 0.60mg/kg (36% recovery) residues of Lambdacyhalothrin were found in the peels. The two findings are in conflict with one another; it was anticipated to discover Lambdacyhalothrin residues in tomato peels examined after one day but not in tomato peels examined after six days. This paradox can be the result of uneven pesticide content distribution from tomato to tomato within the same batch of treated tomatoes during spraying. The peels of five tomatoes were examined after one day, and the peels of the remaining five tomatoes were examined after six days.

However, Profenofos residues of 2.00 mg/kg (73.1% recovery), 1.30 mg/kg (46.0% recovery), and 0.30 mg/kg (9.5% recovery) were found in tomato pulps after 1 and no detection at 6 days. These findings support Abou-Arab's (1999) findings that the efficient role of the peeling process in eliminating pesticide residues of Profenofos led to a residues loss of about 83.3% and highlight the critical role of peeling as one of the key processes in the reduction of pesticide residues in tomatoes. Since no residue was found in the pulp of the peeled tomatoes, if the tomatoes according to these findings must be peeled on the sixth day, it ensures consumer safety.

After the first day, the Profenofos residual level in the peels dropped by 33.30%, from 2.00 mg/kg to 1.30 mg/kg. This demonstrates how crucial it is to adhere to the suggested pre-harvest waiting period for Profenofos, which is 21 days as reported and advised by TPRI (2010). If the advised pre-harvest waiting period, particularly for Profenofos, is not adhered to, it is possible that harvested tomatoes may contain residues (as found in Figure 6), which could then pose a health risk to consumers, especially if consumed without peeling. This is because, according to FAO/WHO's 2007 report, Profenofos' Maximum Residues Limits (MRLs) varied from 0 to 0.03 mg/kg per day.

4.4.2 Lambdacyhalothrin and Profenofos applied individually.

The results of tomato samples fortified with Lambdacyhalothrin and Profenofos are summarised in Table 8 below. Each pesticide was administered individually as prescribed, and residue levels were analysed at 1 and 6 days after spraying. The distribution of residues and their corresponding percentage recovery in the whole tomatoes, peels, and pulp for the two pesticides are also summarised in Table 6.

Table 6: Pesticide residues (mg/kg) in tomato samples following fortification by Profenofos and Lambdacyhalothrin applied individually.

Types of Pesticides	**Tomato samples**	**Day 1 (mg/kg)**	**%RC**	**ISTD %RC**	**Day 6 (mg/kg)**	**%RC**	**ISTD %RC**
Lambdacyhalothrin	Whole				ND		86
	Peels	0.80	48.0	100	0.60	36.0	77
	Pulp	ND		94	ND		99
Profenofos	Washed				0.60	18.0	105
	Unwashed				0.60	18.0	107
	Peels	2.71	96.0	100	1.10	40.5	93
	Pulp	0.80	25.0	99	1.20	46.1	90

ND – Not Detected; %RC – Percentage Recovery from fortified samples with 2.92mg/kg Profenofos and 1.84mg/kg Lambdacyhalothrin; ISTD %RC – Internal Standard Percentage Recovery

The outcome demonstrates that Lambdacyhalothrin residues were exclusively found in the peels, with a modest decrease from the first day (0.80 mg/kg) to the sixth day (0.60 mg/kg), with a recovery of 48% and 36.0%, respectively. According to this finding, consumer safety will be ensured by peeling tomatoes and adhering to the suggested pre-harvest waiting time. These findings are consistent with those made by Powell et al. (1970) and Chirila and Florll (1985), who indicated that peeling effectively eliminated the majority of pesticide residues.

The recovery of Profenofos residues after washing with tap water indicated no discernible difference between washed and unwashed whole tomato samples. These results are consistent with those of Abou-Arab (1999), who said that washing with tap water was the least successful at reducing Profenofos residues, with a loss of only 22.7%. Tomatoes are often cleaned in tap water according to standard household procedures. Consumers shouldn't solely rely on this approach, according to these studies. To further ensure safety, additional procedures like peeling should be used.

At day 1, there were significantly more Profenofos residues in the peels than in the pulp. After 6 days, however, the residues were essentially dispersed equally among the peels and pulp. The results after one day are consistent with those of Abou-Arab (1999), who claimed that the peeling procedure effectively eliminated pesticide residues on Profenofos and resulted in a loss of 83.3% of residues. After 5 days, however, these results diverge, suggesting that Profenofos may not be evenly distributed throughout the tomato tissue. This suggests that farmers should adhere to the recommended pre-harvest waiting period of 21 days to protect consumer safety.

The fact that Profenofos was found to be the most dominant contaminant in tomato samples poses many threats to the consumers. According to the research area's existing practises, depending on how many pesticides were combined—two, three, or four—the average pre-harvest waiting period for all pesticides ranged from 5 to 7 days. When comparing the Profenofos residue values from the enriched samples to the actual pre-harvest waiting period, it is possible that unsafe tomatoes will be picked, which will have an impact on tomato consumers' health. This study's fortified sample results and average short pre-harvest waiting period raise questions about whether tomatoes from the study area were completely safe. It has been highlighted that consumption of lesser doses of pesticide, such as the one found in this study, may cause a variety of adverse effects, including nose bleeds, allergic dermatitis, itching, nausea, headaches, diarrhoea, abdominal pain, and vomiting (Reigart and Roberts, 2018).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

According to the study's findings, eleven pesticides were applied to the study region to combat fungus and insect problems. There was improper handling and application practises of the majority of the pesticides employed which contributed to negative health impacts on farmers who apply them and tomato consumers as well as. The tomato samples were contaminated with pesticide residues as a result of this. The investigation identified a number of improper methods for applying pesticides, such as mixing different pesticides, applying them too soon before harvest, short application intervals, and using insufficient farmer protection equipment when handling pesticides. According to the type and initial concentration of the pesticides, peeling dramatically reduces pesticide levels by 35–100%. The majority of farmers relied on their fellow farmers rather than extension agents when it comes to different aspects of pesticide applications, indicating that farmers have very little understanding about the safe use of pesticides. Farmers reported a variety of health issues that were directly related to the pesticides that had been used in the research region because of the inadequate protection measures used when handling pesticides.

Other unexpected pesticide ingredients were discovered with a major threat of Endrin. Endrin is an organochlorine pesticide that acts as a systemic insecticide. It is non-biodegradable, has a low solubility in water, but a high solubility in body lipids, and as a result, causes bio magnification in people. Endrin is prohibited by all Parties to the Stockholm Convention on Persistent Organic Pollutants (POP) because of its unique qualities, which make it extremely dangerous to both humans and wildlife due to its position high in the food chain.

5.2 Recommendations

5.2.1 Recommendations to farmers

- Farmers are recommended to source information pertaining use of pesticides from the appropriate personnel like agronomists, extension officers and other skilled and reputable institutions.
- When buying pesticides, farmers are recommended to focus much on the active ingredient not the trade name so as to promote pesticide diversity and reduce the risk of wasting hard earned capital through buying one pesticide with different trade names.
- Farmers and all pesticide handlers should always wear appropriate personal protective equipment properly so that the possibility of exposure to pesticides gets reduced thus reducing the risk of mostly acute poisoning.
- Farmers should adhere to the stipulated application intervals and withdrawal periods of specific pesticides so as to reduce accumulation of pesticides and facilitate the bio degradation of applied pesticides of tomatoes ready for the market.
- Farmers should always and by all means let the love of one another overwhelm the love of money so as to reduce all the malpractices done in tomato production so as to ensure both good consumer health and good returns through good reputation of supplier in the tomato industry.
- Pesticide use being one of the Integrated Pest Management techniques, it is advised that farmers engage other (cultural, biological and physical) techniques so as to reduce pesticide load on the tomatoes thus minimising the health risks associated by pesticide use.

5.2.2 Recommendations to Institutions

- Through its appropriate departments, government should increase the availability of extension officers in almost every ward so as to increase the ease of access of quality information on safe pesticide use.
- Relevant and complying Non-Governmental Organisations should freely employ qualified agronomists and other relevant skilled personnel who can help in the dissemination of good management of tomatoes specifically on pesticide use to safeguard both the farmer and the consumer
- Government and all other relevant stakeholders are recommended to improve their surveillance and monitoring work in regulating pesticide use so as to ensure compliance of safe pesticide use in tomato production.

- Relevant institutions should facilitate advancement and access of technology which measure the precise amounts of pesticide residues in harvested tomatoes so as to block all unsafe (contaminated) tomatoes from reaching the consumers.
- The retail industry should adhere to guidelines of Hazard Analysis and Critical Control Points (HACCP) principles provided from Food Services so as to increase quality control of tomatoes thus reducing the incidences of food (tomato) borne diseases.

5.2.3 Recommendations to Consumers

- Firstly, the consumers are advised to buy tomatoes or tomato products from a reputable supplier who proves to uphold and adhere to food safety regulations.
- Peeling the tomatoes before eating or processing it is advised as this technique significantly lowers consumer exposure to pesticide residues.
- Although washing tomatoes did not prove to reduce pesticide residues significantly, it is important to note that washing is necessary to as to reduce other germs that might be on the skin of the tomato.

5.2.4 Recommendations for Further Research

- Due to the discovered pesticide contamination levels in harvested tomato samples, it is necessary to keep the like researches ongoing so as to help in determining the fitness of farmers or even markets in providing safe food for the general public.
- Since Endrin and Cypermethrin were detected in the assessed tomato samples, it is important to further determine whether these pesticides are properly being used. Endrin registration in Zimbabwe being questionable, it is essential to determine whether it is being used legally or maybe due to its systematic and slow degradability properties it was previously used for other purposed and eventually got in contact with the soils.
- The fortified samples were fortified, stored and evaluated indoors under room temperatures thus bringing the necessity of an experimental control plot that assist in addressing the effects of environment to the results obtained with respect to pesticide degradation.
- The research findings were limited to tomato production. This brings the necessity of the evaluation of other enterprises that constitute the food industry so as to increase quality assurance in the food safety.

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APPENDICES

Appendix 1: An Interview Schedule for Research on Pesticide Application Practices

BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENT OF CROP SCIENCE

AN INTERVIEW SCHEDULE FOR RESEARCH ON

EVALUATION OF HUMAN HEALTH HAZARDS ASSOCIATED BY SUMMER PRODUCED PESTICIDE APPLIED TOMATOES. A CASE STUDY ON GOROMONZI DISTRICT.

BY

BOBO SIMBARASHE JAMAINE

B190675A

CROP SCIENCE (HONOURS)

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a) Respondent's Information

1. Name of respondent:____
2. Year of Birth: ____
3. Village: ____
4. Ward:____
5. Gender: ____
6. Marital status: ____
7. Highest Level of Education Attained:_____________________________

b) Pesticide Application Practices

1. List the pesticides you use in tomato production

   ____
   ____
   ____
   ____
   ____
   ____
   ____
   ____
   ____
   ____

2. What are the sources for pesticide handling and application practices?

   ____
   ____
   ____
   ____

3. Name pesticides applied individually and their application intervals.

   Name______________________________ ________________________days
   Name______________________________ ________________________days
   Name______________________________ ________________________days
   Name______________________________ ________________________days
   Name______________________________ ________________________days

4. Name pesticides applied in combination (mixture) and their ratio.

   ____
   ____
   ____
   ____
   ____
   ____
   ____
   ____
   ____
   ____
   ____
   ____
   ____

5. Name pesticides that are usually sprayed before tomato harvesting.

   Name:_________________________ PHI:_________________________
   Name:_________________________ PHI:_________________________
   Name:_________________________ PHI:_________________________
   Name:_________________________ PHI:_________________________
   Name:_________________________ PHI:_________________________
   Name:_________________________ PHI:_________________________
   Name:_________________________ PHI:_________________________
   Name:_________________________ PHI:_________________________

c) Health Related Issues in Pesticide Handling and Application

1. Are you aware of any health effects related to pesticide use?
   Yes:___________________ No:__________________
2. List any health effects that have been recorded to be associated with pesticide handling and application.
   ____
   ____
   ____
   ____
   ____
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   ____
   ____
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   ____
3. List the protection measures used when handling the pesticides.
   ____
   ____
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   ____
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   ____
4. Write any remarks that are linked to the pesticide use in tomatoes or even health issues being reported to be linked to pesticides in tomato production.
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