KNOWLEDGE AND PRACTICES OF PESTICIDES USE AGAINST THE BEAN FLY (*OPHYIOMYIA PHASEOLI*) AND ASSOCIATED HEALTH EFFECTS AMONG BEAN (*PHASEOLUS VULGARIS*) SMALLHOLDER FARMERS IN KABARU LOCATION, NYERI COUNTY

BERITAH MUMBI MUTUNE

MASTER OF SCIENCE

(PUBLIC HEALTH)

JOMO KENYATTA UNIVERSITY OF

AGRICULTURE AND TECHNOLOGY

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Knowledge and practices of pesticides use against the bean fly (*Ophyiomyia phaseoli*) and associated health effects among bean (*Phaseolus vulgaris*) smallholder farmers in Kabaru location, Nyeri County

Beritah Mumbi Mutune

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DECLARATION

This thesis is my own original work and has not been presented in any other university for a degree.

Signature………………………………… Date……………………………

Beritah Mumbi Mutune

This thesis has been submitted with our approval as University supervisors.

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

Dr. John Gachohi, PhD

JKUAT, Kenya

Signature…………………………………Date………………………………

Prof. Gideon Kikuvi, PhD

JKUAT, Kenya

DEDICATION

This work is dedicated to my beloved husband Stephen, my children Lucy, Precious and Gloria and all the members of the family including my dear parents for the love, encouragement and support during the entire period of my study. God bless you.

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I thank the Almighty God for giving me life, good health and energy to carry out this study.

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ABBREVIATIONS AND ACRONYMS

BSM	Bean Stem Maggot
BPS	Board of Postgraduate Studies
CI	Confidence Interval
CNS	Central Nervous System
ERC	Ethical Research Committee
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GIT	Gastrointestinal tract
ICIPE	International Centre of Insect Physiology and Ecology
IPM	Integrated Pest Management
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KAP	Knowledge, Attitudes, and Practices
KEMRI	Kenya Medical Research Institute
KNH	Kenyatta National Hospital
KSH	Kenya Shilling
OP	Organophosphates
PPE	Personal Protective Equipment
PCPB	Pest Control Products Board

SDGs Sustainable Development Goals

SPSS Statistical Package for the Social Science

UoN University of Nairobi

USAID United states Agency for International development

WHO World Health Organization

ABSTRACT

Farmers' knowledge on pesticides use, the practices and the associated health effects is of great importance. The effect of pesticides on human health and the environment is a major global public health issue. The main objective of this study was to determine the knowledge and practices on pesticide use against the bean fly and the associated health effects among bean smallholder farmers in Kabaru location, Nyeri County. A cross-sectional study design was used in which a semi-structured questionnaire was administered to three hundred and eighty-five study respondents who were selected using systematic random sampling method. The selection was based on whether they had used pesticides in the past and consented to participate in the study. A five-point Likert scale was used to measure knowledge and practices. Data were analyzed using SPSS software and summarized as contingency tables or graphs. Differences between response categories were determined using the Chi-square test at $p \leq 0.05$ level of significance. Majority of the respondents were male (74%) farmers aged between 26 and 58 years. More than half of the respondents had completed secondary education (52%) while 38% had primary education. Most (90%) of the respondents had crop production and livestock as their only sources of income. The pesticides used in this study were from the organophosphates, 18% (Diazinon, and Dimethoate) pyrethroids, 55% (Karate, Bull dock, Pestox, Brigade, Cyclone and Decis), neonicotinoids 18% (Actara and Confidor), and carbamate 9% (Pirimor) chemical families. All the pesticides belonged to the WHO class II which are moderately hazardous chemicals. Ninety-six percent of the respondents had good knowledge on pesticide use while 76% had safe practices. All the surveyed farmers used personal protective equipment and most of them read pesticide labels. Majority (94%) knew that pesticide containers have signs marking their toxicity levels, but only 60% did not know the signs marking the most dangerous pesticide. 72% stored their pesticides in their farm stores. Most of them (68%) disposed the empty pesticide containers in their garbage pit in and a few (20%) in the common self-group disposal pit. Moreover, majority of the respondents had received pesticide training in the past. The major self-reported clinical effects following pesticide use were headache, backache, dizziness, eye problem and sneezing. Most of the farmers did not go to hospital after experiencing signs and symptoms of pesticide poisoning and did not take medicine either but did wash their hands, took bath and removed PPE after experiencing the health effects of pesticide exposure. Although the farmers had a good knowledge of the hazards of pesticides, they utilized undesirable practices such as incomplete use of Personal Protective Equipment which made them experience the adverse health effects. In addition, they did not exercise the precautionary measures after experiencing the signs and symptoms of pesticide poisoning. Therefore, more training is recommended to promote pesticide knowledge and safer practices to all the farmers.

CHAPTER ONE

INTRODUCTION

1.1 Background information

Agriculture is the leading user of pesticides followed by vector control (Karunamoorthi *et al.,* 2011). Over the past years there has been an increase in the use of pesticides in developing countries (Oesterlund *et al.,* 2014). According to the World Health Organization (WHO 2010), the level of safe pesticide management in developing countries is low.

Insect pests such as the bean fly, *Ophiomyia spp*. (Diptera: Agromyzidae), is the most important field and storage pests, which can cause up to 100 % loss (Ochilo and Nyamasyo 2010). The management of bean fly is difficult because of the cryptic behavior of the pest. Most farmers do not believe that they can successfully cultivate bean crop without using pesticides. Farmers get less profits and low field harvests attributed to bean fly damage and greatest of all the risk of failing to contribute as expected towards the Gross Domestic Product (GDP) and the achievement of Sustainable Development Goals (SDGs), also referred to as the Global Goals were set by the United Nations General Assembly in 2015 for the year 2030 (UN, 2015). These goals are interconnected and were built on the successes of the Millennium Development Goals, while including new areas such as climate change, economic inequality, innovation, sustainable consumption, peace and justice, among other priorities.

The Food and Agriculture Organization of the United Nations (FAO, 2006), has highlighted the importance of rules on proper storage of pesticides in order to maintain product efficacy and to prevent contamination of the surroundings. WHO classification of pesticide toxicity has been used by regulators to help determine which pesticides should be restricted (WHO, 2010). According to WHO (2010), poor capacity to enforce regulations leads to the excessive and unsafe use of pesticides, which can result in the contamination of food, drinking water and the environment, as well as affecting birds and aquatic organisms.

Worldwide pesticide production increased at a rate of about 11% per year, from 0.2 million tons in 1950s to more than 5 million tons by 2000 (FAO, 2017). It was reported that unintentional poisonings kill an estimated 355,000 people globally each year, and such poisonings are strongly associated with excessive exposure and inappropriate use of toxic chemicals (WHO, 1990). Organophosphates, carbamates, organochlorines and pyrethroids are potentially hazardous pesticides that are widely used in various parts of East Africa (Mbakaya *et al.,* 1994; Ohayo-Mitoko *et al.,* 2000). Most commercial pesticides are very effective but are not eco-friendly to natural enemies, to human and wildlife safety, and have raised substantial global environmental concerns (Prakash *et al.,* 2008).

In Kenya, use of pesticides has been promoted to expand agricultural production and increase productivity. In 2005, Kenya imported approximately 7,000 metric tones of pesticides worth 50 million US dollars (PCPB, 2006) showing that their consumption is high. These pesticides are an assortment of insecticides, fungicides, herbicides fumigants, rodenticides, growth regulators, defoliators, proteins, surfactants and wetting agents (Macharia *et al.,*2009). Of the total pesticide imports, insecticides account for about 40% in terms of volume (2,900 metric tones) and 50% of the total cost of pesticide imports (Ngaruiya, 2004).

Studies in developing countries indicate that farmers usually source pesticide information from pesticide vendors and from other farmers (Sodavy *et al.,* 2000) who are not knowledgeable about pesticide risks. The knowledge and practices of pesticides use against insect pests and the adverse effects of pesticides on human health and the environment is of great importance (Mekonnen and Agonafir 2002b; Nalwanga and Ssempebwa 2011; Ngowi *et al.,* 2001a). The practices include the pest control measures used, the protective gear, storage of pesticides prior to use and the fate of empty pesticide containers (Ngowi *et al.,*2001b; Ntow *et al.,* 2006). The

WHO (2010) reported that storage of pesticides by small-scale farmers is still a major challenge in many developing countries.

The frequent exposure to pesticides results in both short-term (acute) and long-term (chronic) illnesses (Asfaw 2008; Maumbe and Swinton 2003). Self-reported signs and symptoms following pesticide use include headache, sneezing, vomiting, stomachache, backache, dizziness, skin rash and eye problems (Lekei *et al.,*2014; Ohayo-Mitoko *et al.,*2000). Other documented health effects include eye irritation, seizures, respiratory problems, neurological damage, birth defects (Farqurah *et al.,* 2009), coma, cancer and death (Antle and Pingali 1994; Harris *et al.,*2001; Macharia *et al.,*2009).

The risk for and severity of adverse health effects from pesticide exposure varies significantly depending on many factors, including individual characteristics such as age and health status, the specific pesticide, and exposure circumstances (Farqurah *et al.,*2009; WHO 1990). Other impacts expected due to pesticide use include: - seeking medical treatment after experiencing the earlier outlined harmful effects due to pesticide use and reduction in labour and the potential for poisoning (Crissman *et al.,* 1994; Dung and Dung, 1999; Ngowi *et al.,* 1992).

1.2 Statement of the problem

Crop farming is considered as an important source of human food and income. Crop pests and diseases cause reduced productivity or even 100% loss (GOK, 2010). Bean Stem Maggot (BSM) infestation is a major drawback in bean production. Farmers get less profits and low field harvests attributed to bean fly damage and greatest of all the risk of failing to contribute as expected towards the GDP and the Sustainable Development Goals (UN, 2015).

The World Health Organization had estimated that a million people were being poisoned annually with 20,000 cases resulting in death (WHO, 2006). The Food and Agricultural Organization (FAO, 2008), has been concerned about various reports of ill health due to toxicity of the pesticides that are used by many farmers but without adequate knowledge and failure to wear appropriate protective clothing.

Worldwide, about 25 million agricultural workers experience unintentional pesticide poisonings each year, and it is estimated that approximately 1.8 billion people engage in agriculture and most use pesticides to protect food and commercial products that they produce (Alavanja, 2009). According to PCPB (2006), Kenya's demand for pesticides is relatively high with approximately 7,000 metric tones being imported annually.

The pesticide poisoning is mainly caused by poor handling practices when using pesticides in their farms to control pests. Continuous use of pesticides has resulted to resistance to pests, damage to the environment, caused human ill-health, negatively impacted on agricultural production and reduced agricultural sustainability (Pimentel and Greiner, 1997). Numerous short and long-term adverse health effects have been self-reported as a result of pesticide poisoning (Wilson and Tisdell, 2001).

1.3 Justification

According to PCPB (2006), the demand for pesticides in Kenya is high (approximately 7,000 metric tones per annum). Their import is further fueled by regional consumption in land locked countries like Uganda, Rwanda and Burundi.

Pesticides abuse and misuse is common in Kenya and Africa and is mainly caused by high illiteracy levels and inaccessibility to reliable protective clothing. Smuggled products, unregistered products, open air sales, sale of banned product, cases of decanting and reweighing, faking of pest control products using counterfeit labels, sale of expired products with modified expiry dates are among the misuse cases that have been reported in Kenya. Spraying mistaken products has led to the dead of hundreds of flock (PCPB, 2004).

For this reason, this study was done in order to understand the situation in Kabaru location, Nyeri County an area that has faced a lot of losses in the past due to bean fly damage (Farmer personal information). In addition, beans is one of the most grown staple crops in the area and a cash crop.

This study benefits include: reduced pesticide use by understanding the magnitude of the impacts of continued use of pesticides, reduced common bean losses, increased farmer income, improving research and education capabilities. This type of research will also help respondents, project planners, and funding agencies in their future decisions.

The generated information will also contribute to enhancing knowledge on health effects and practices of pesticide use such as the dilution measures, frequency of application of pesticides, protective clothing, equipment used, and post-spray practices (changing clothes, bathing, taking milk and washing hands), signs and symptoms and the effective way of managing such symptoms.

1.4 Research questions

i. What knowledge do bean smallholders have about pesticides used against the bean fly?
ii. What practices do bean smallholders have about pesticides used against the bean fly?
iii. What are the self-reported occurrences of health effects following pesticide use among bean smallholders in Kabaru location, Nyeri County?
iv. What are the management practices of the health effects following pesticide use among bean smallholders in Kabaru location, Nyeri County?

1.5 General Objective

To determine the knowledge and practices of pesticide use against the bean fly and the associated health effects among smallholder bean farmers in Kabaru location, Nyeri County.

1.5.1 Specific objectives

i. To determine the knowledge on pesticide use against the bean fly among smallholder bean farmers in Kabaru location, Nyeri County.
ii. To determine the practices surrounding pesticides use against the bean fly among smallholders bean farmers in Kabaru location, Nyeri County.
iii. To determine self-reported occurrence of health effects following pesticide use among smallholders bean farmers in Kabaru location, Nyeri County.
iv. To determine the management practices of the health effects following pesticide use among smallholders bean farmers in Kabaru location, Nyeri County.

CHAPTER TWO

LITERATURE REVIEW

2.1 Background

2.1.1 Classification of Pesticides

Pesticides can be classified based on different factors. They may be classified according to the type of pests they destroy; how hazardous they are and their mode of action or chemical properties (Dzobo, 2016).

2.1.1.1 WHO classification of pesticides by hazards

According to WHO (2009) pesticides are classified into: extremely hazardous (Class 1a), highly hazardous (Class 1b), moderately hazardous (Class II) and slightly hazardous (Class III).

2.1.1.2 Classification of pesticides based on chemical properties

Pesticides can be mainly classified into but not limited to Neonicotinoids, Organophosphates (OP), Carbamates and Pyrethroids which are the four major types of pesticides in use in Kenya (Ngaruiya, 2004).

2.1.1.3 Neonicotinoids

Neonicotinoids (also referred to as “neonics”) are insecticides derived from nicotine. They act by binding strongly to nicotinic acetycholine receptors in the central nervous system of insects, causing overstimulation of their nerve cells, paralysis and death. Neonicotinoids are highly water-soluble, persistent in the environment and systemic - the pesticides migrate into all parts of treated plants (Dzobo, 2016).

2.1.1.4 Organophosphates

These affect the nervous system by disrupting the acetylcholine regulator known as the acetylcholinesterase, which is a neurotransmitter. They cause acute muscarinic manifestations such as salivation, lacrimation, micturition, diarrhoea, vomiting, bradycardia, and some nicotinic symptoms such as muscle fasciculation and weakness. They are absorbed through the gastrointestinal tract (GIT), lungs and skin. (Dzobo, 2016). Central nervous system (CNS) toxicity is common, characterized by seizures, excitability, lethargy and coma. Long term effects include cognitive deficits and Parkinsonism (Lu, 2009).

2.1.1.5 Pyrethroids

They are developed as the man-made or artificial varieties of the naturally occurring Pyrethrin from the *Chrysanthemum* flowers. Some synthetic pyrethroids are toxic to the nervous system (Dzobo, 2016) They are degraded by the sunlight and atmospheric air and are not easily taken up by plant roots since they are bound to the soil. Exposure to large quantities may cause dizziness, headache, nausea and diarrhea. Fortunately, they are immediately excreted through the urine, feaces and breathe (Neghab *et al.,* 2014).

2.1.1.6 Carbamates

These are similar in action to the organophosphates, acting on the enzyme that regulates acetylcholine. Their effects are normally reversible (Dzobo, 2016).

2.2 Economic importance of Beans

Common bean, *Phaseolus vulgaris*, form an important food and cash crop in Africa, particularly in the eastern, southern, and Great Lakes regions (David *et al.,* 2000). It has high protein content and is a good source of energy and provides folic acid, dietary fiber and complex carbohydrates. Common beans (*Phaseolus vulgaris*) contribute up to 57% of recommended dietary protein and 23% of energy to the nutrition of African people (Tugce *et al.*, 2018). Regular consumption of common bean and other pulses is now promoted by health organizations because it reduces the risk of diseases such as cancer, diabetes or coronary heart diseases (Montoya *et al.,* 2006).

Bean production is constrained by several environmental stresses, notably biotic (field and post-harvest pests and diseases) and abiotic (drought, excessive rain/flooding, poor soil fertility, heat and cold). In recent years, crop production trend has not kept pace with the annual growth rate in population in some countries due to number of biotic, abiotic and socio-economic constraints (Katungi *et al.,* 2009). Amongst biotic constraints, insect pest infestation ranks higher in causing significant yield reduction in legumes. For example, the major important insect pest of this crop is bean stem maggot (*Ophiomyia phaseoli*) which is widely distributed pest of seedling bean in East Africa.

2.2.1 Bean fly biology, life cycle and control

Bean stem maggots also known as bean flies are often considered as the most important field pest of beans in Africa. They account for yield losses ranging from 80 % to 100% (Ochilo and Nyamasyo 2011). Bean stem maggot adult oviposit eggs in leaves, stems and hypocotyls of young seedlings. Emerging maggots mine their way to the root zone where pupation takes place and where feeding becomes concentrated between the woody stem and the epidermal tissue (Ochilo and Nyamasyo 2011). Such feeding interferes with water and nutrient transport and creates avenues for entry of disease organism (Mwanauta *et al.,* 2015).

The damage caused by bean stem maggot is more serious during the seedling stage of the bean plant. The pest attack the plant at the beginning of the unfolding of the first pair of leaves, and it begin to attack as other new leaves unfold (Odendo *et al.,* 2005). Bean stem maggot oviposits directly in the plant tissue and the emerging maggots feed in the stem and disrupt water and nutrient transport (Karou, 2006).

Due to high yield loss caused by this insect, and the inability of small-scale farmers to afford expensive chemical pesticides, there is a need of developing a sustainable strategy for controlling this pest.

Figure 2.1: Bean fly stages (ICIPE, 2016)

2.2.2 Management of Bean Stem Maggot

According to Mwanauta *et al.,* (2015), various control methods have been proposed for the management of BSM in beans; these include: chemical control, seed dressing, cultural practices biological control and host plant resistance

2.2.2.1 Chemical control

Farmers tend to prefer chemical approach as it is very easy and is more dramatic in their effects. According to Mwanauta *et al.,* (2015), chemical seed dressing is especially useful when used in combination with other approaches such as organic amendments to enhance soil fertility. However, most of these recommended chemicals are too expensive, unavailable and are environmentally unfriendly.

These applications may effectively control the pest but many of the recommended chemicals are either banned, too expensive or unavailable to the average small-scale bean grower in Africa. Synthetic pesticides are reported to be effective, reliable against a wide range of insect pests, quick acting and easily tested for effectiveness on new insect pest (Mwanauta *et al.,* 2015). In spite of the usefulness and effectiveness, synthetic pesticides have limited distribution in rural areas, often adulterated or applied at inappropriate application rate due to illiteracy, poor labeling or use of old, expired products which lead to rapid evolution of pesticide resistance (Struart, 2003).

Human health and safety are also threatened by use of commercial pesticides with no mechanism to ensure food safety for consumers, and concern for the chronic effects of exposure (Hart and Pimentel, 2002). Environmental impacts to wildlife, crop pollinators and natural enemies are also severe (Struart, 2003). Awareness regarding the food safety has increased the demand for organically produced food, which necessitates evaluating the performance of biopesticide as safer alternatives to conventional insecticides (Prakash and Nandagopal, 2008).

2.3 Pesticide Use in Kenya

As an agricultural economy, Kenya's demand for pesticides is relatively high. The import demand is further fueled by regional consumption in land locked countries like Uganda, Rwanda and Burundi. Kenya imports approximately 7,000 metric tones of pesticides worth billions of Kenya shillings (US$ 50 million). These pesticides are an assortment of insecticides, fungicides, herbicides fumigants, rodenticides, growth regulators, defoliators, proteins, surfactants and wetting agents. Of the total pesticide imports, insecticides account for about 40% in terms of volume (2,900 metric tones) and 50% of the total cost of pesticide imports (Ngaruiya, 2004).

2.4 Peasant knowledge about effects of pesticides on human health and livestock

Overuse of pesticides has negative effects to human, livestock and the environment. The knowledge on the pests affecting the common bean, importance of controlling pests, the role of pesticides, the appropriate ways of applying pesticides and the adverse effects of pesticides on human health and the environment (Karunamoorthi *et al.,* 2011; Lekei *et al.,* 2014; Ngowi *et al.,* 2001a) is of great Public health importance.

A study in Uganda also showed that farmers on a small-scale basis often farmed without proper means or the knowledge to properly use pesticides. Some farmers, even though had high knowledge levels on health effects, did not practice according to the knowledge they had (Ousterlund *et al.,* 2014). Also, high illiteracy rates contribute to farmers' difficulty in understanding and following instructions and safety advice on pesticide use (Remoundou, 2011). Farmer education is therefore vital in the increase in knowledge in safety practices (Dey, 2010).

Overuse of pesticides leads to both direct and indirect costs for farmers and the society (Ajayi 2000; Atreya 2005; Brethour & Weersink 2001; Muriithi *et al.,* 2016). The direct costs include the pesticide purchase, cost of PPE and labour for application. Indirect costs include negative externalities such as effects on human health, degradation of the environment, loss of bio-diversity, irreversible changes in the natural ecosystems, leading to even greater future costs for controlling pests (Ajayi 2000; Antle *et al.,* 1998; Pingali *et al.,* 1995; Sheikh 2011).

2.4.1 Effects of pesticides on the environment

Pesticide use results into entry into water bodies, air, or even food. It has also caused livestock poisonings, the death of useful predators and parasites, residues in air, fishery and aquatic body losses, the damage of flora and fauna, unintentional crop exposures, death of birds and bees and undesirable residue in food items have all been due to pesticide poisoning (Dzobo, 2016). It has been recognized that the chemical pesticide residues are the key contributor to the destruction threats facing many endangered species (Khan, 2012).

2.5 Farmers' practices on pesticide use

The practices include the pest control measures, frequency of pesticide application, type of pesticide applicators used, the use of protective gear, bathing, washing hands, storage of pesticides prior to use and the fate of empty pesticide containers (Ngowi *et al.,* 2001a). The use of appropriate protective clothing, including face masks, is strongly recommended. Inappropriate or lack of PPE (personal protective equipment) can lead to pesticide exposure through ingestion (Zimba *et al.,*2016).

2.5.1 Pesticide labels and colour coding

According to Edson (1982), the colour codes banding precautionary pictograms relating to the toxicity of the product indicate toxicity in declining levels as follows: (i) PMS (Pantone Matching System) Red 199C for products classified under WHO class Ia and Ib; (ii) PMS yellow C for products classified under WHO class II; (iii) PMS Blue 293C for products classified under WHO class III; (iv) PMS Green 347C for unclassified products under the WHO classification (WHO, 2009).

2.5.2 Exposure to pesticides

Types of exposures and their biological effects may be divided into: Acute, moderate and low. The exposure transport media consist of air water, soil, dust, food, product or items. Pathways for exposure include eating contaminated food, breathing contaminated workplace air or touching home surfaces. Routes of exposure comprise nasal (inhalation), integumentary/skin (dermal), mouth/oral (Ingestion) or multiple routes and the duration of an exposure could take seconds, minutes, hours, days, weeks, months, years or even a generation (Dzobo, 2016).

Occupational exposure may occur acutely as a result of mixing, loading, application or contact with sprayed crops. The risk of exposure increases when farmers ignore safety instructions on the proper use of pesticides, PPE use and adapting sanitary practices (Damalas, 2008). Spraying in the wrong direction with respect to the wind increases exposure, poor maintenance of equipment and not checking for leakage of applicators.

2.5.3 Pesticides application and application equipment

According to Dzobo (2016), pesticides can be applied to seeds prior to planting i.e. seed treatment or coating which helps protect seed/plant against soil-borne threats. The equipment used in their application are important to successfully control pests and eventually better crop yield. This therefore calls for the proper selection of application equipment, knowledge of pest behavior, skillful dispersal methods and knowledge of the most susceptible stage of the pest, helps determine the time of pesticide application (Pal and Gupta, 1996).

It is also aimed at avoiding pollution. Pesticides are dispersed by different methods like spraying or dusting. Most pesticides are applied as sprays, in liquid formulation (dilution), with water or oil being the diluent. Spraying may be done in high, low or ultralow volumes. One of the most common forms of pesticide application is the use of mechanical sprayers. Most of these sprayers are operated manually in Kenya (Onyango *et al.,* 2014).

Figure 2.2: WHO recommended knapsack sprayer (WHO, 2010).

2.5.4 Disposal and transportation of pesticides

Health hazards such as empty pesticides containers pose as a threat to environmental contamination. Accidental and intentional poisonings have been encouraged by the presence of undesirable and outdated pesticides. These undesirable pesticides hence contribute to unsafe disposal of pesticides (Dzobo, 2016).

Most farmers burn pesticide containers. In Africa lack of national capacity and farm worker training lead to unsafe practices (Dalvie, Africa and London, 2006). Re-spraying surplus mixtures have been said to be risky as it doubles the recommend dosages on the crops leading to toxicity, residues in soil and harvested crops. This also includes the disposal of rinsates on uncultivated lands. The best way recommended to dispose of left -over is to find other similar farms that will need application of the same chemical. Dalmalas *et al.,* (2008) thought that disposal of containers onto nearby fields, streams, canals is unsafe practice totally; burning will undoubtedly release other chemicals into our atmosphere and should be discouraged. Pesticide wastes should be buried; the site must be chosen carefully to prevent contamination of surface water, runoff or groundwater.

According to Dzobo (2016), there is the need to keep them in their original containers with the labels securely attached when transporting pesticides. They should be placed in such a way to prevent spillage or leakage, in a plastic material to hold the spillage in case of an accident. Passengers must also not share any compartment of the vehicle with pesticides.

2.5.6 Storage of pesticides, PPEs and equipment

Unsafe practices are prevalent among farmers and operators in developing countries. For example, in Egypt, almost all farmers stored pesticides in bedrooms; likewise, in Kenya (Remoundou, 2014). Leftover spray mixture was sometimes used to spray already sprayed cacao trees or was emptied into streams or near a well at the village (Sosan and Akingbohungbe, 2009).

In order to protect the content of pesticide, containers are made of materials that have the capacity to withstand the chemical. These containers are to be stored with their original labelling including directions on application and disposal, names of the components, emergency information in case of spillage or exposure (Dzobo, 2016). It also includes temperatures at which the pesticides should be stored, since extremes of temperatures can change the chemical structures of the product or damage the container. For safety reasons, it is advisable to mix only what you will use in a day. It is not advisable to store pesticides in food and drink containers for the safety of children.

Personal protective equipment must be kept and washed daily, separately from other clothes. Plenty of clean water must be available and accessible for eye flushing in case of splashes on the face. A clean pesticide-free area for changing into and out of PPEs and for storing of clean clothes and personal belongings must be available, with soap and water (Dzobo, 2016).

2.5.7 Farmers' protective and safety practices

In many African countries, the poor utilization of protective clothing is a serious problem among small-scale farmers. Pesticide sprayers report greater signs and symptoms of exposure more than other farm workers (Atreya, 2008). This is because farmers use a protection for one part of the body such as gloves and not for all parts (nose, hand, body and legs). Pesticides enter the body through inhalation, ingestion and through the skin. This is important because protective clothing is meant to prevent entry of pesticides into the body which can lead to acute pesticide poisoning (APP).

Figure 2.3: Use of personal protective equipment (Agrochemical Association of Kenya)

2.6 Self-reported clinical effects following pesticide exposure

Exposure to pesticides at any point in the life has the potential for causing a range of short-term or long-term health problems (Asfaw, 2008). The risk for and severity of adverse health effects from pesticide exposure varies significantly depending on many factors, including individual characteristics such as age and health status, the specific pesticide, and exposure circumstances (Farquhar *et al.,* 2009; WHO, 1990).

The frequent exposure to pesticides results in both short-term (acute) and long-term (chronic) illnesses (Maumbe and Swinton, 2003). Scientifically confirmed pesticide related acute illnesses include: headaches, stomach pains, vomiting, skin rashes, respiratory problems, eye irritations, sneezing, seizures, and coma (Antle and Pingali, 1994). congenital defects (Farquhar *et al.,* 2009), cancer and even death (Harris *et al.,* 2001; Macharia *et al.,* 2009)**.**

2.7 Management effects following pesticide poisoning

Other impacts expected due to pesticide use include:- seeking medical treatment after experiencing the earlier outlined harmful effects due to pesticide use and reduction in labour and the potential for poisoning (Crissman *et al.,* 1994; Dung and Dung 1999; Ngowi *et al.,* 1992).

2.8 Alternatives to pesticide use (Integrated Pest Management

The food and agriculture organization (FAO), defines IPM as the consideration of all pest control techniques and other measures available that discourage the pest population development or emergence, while in the meantime minimizing the risks to human health and the environment. Being the best combination of cultural, biological control such as the use of fungal endophytes as entomopathogens (Mutune *et al.,* 2016) and chemical measures used in the management of diseases insects and IPM is the best for farmers.

2.9 Conceptual framework

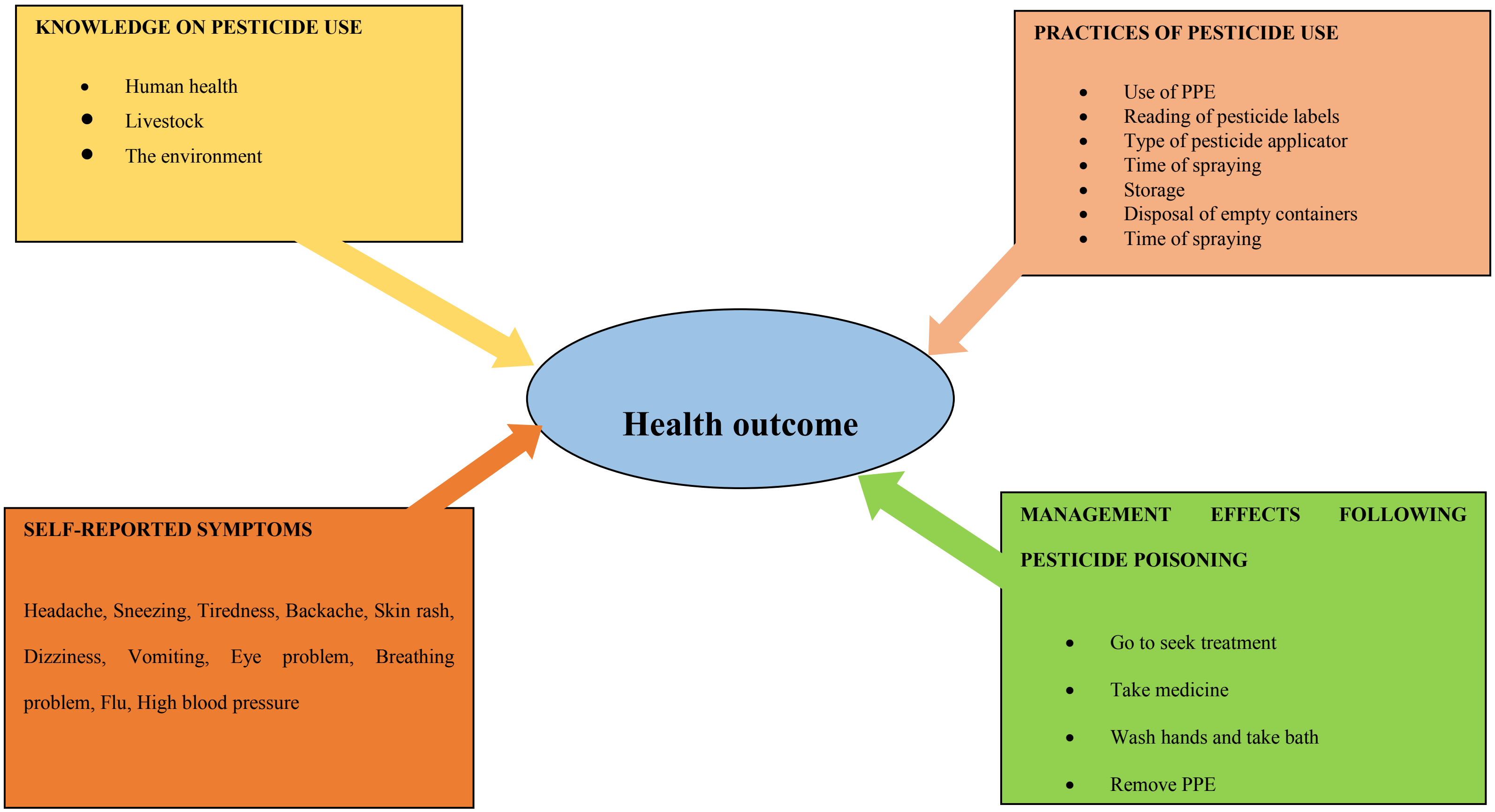

Figure 2.4: Conceptual framework

Knowledge can make farmers become more aware of pesticide risks and will not be involved in harmful behaviors. Knowledge is also directly related to education and training and thus well-educated and skilled farmers are expected to be less likely to be involved in high-risk behaviors and improving farmers' knowledge could possibly reduce pesticide use (Dzobo, 2016). Training and provision of consistent practical support through visits are tremendously important to tackle risks of pesticide poisoning (Waichman *et al.,* 2007). This makes them to be aware of the precautionary measures to take when they experience symptoms of pesticide poisoning like seeking treatment, taking medicine, taking bath or even removing PPE.

Most pesticides are toxic to non-target species including humans, animals and the environment and can result in negative health effects which may be short term or long-term effects (Remoundou, 2014). Occupational exposure may occur acutely as a result of mixing, loading, application or contact with sprayed crops. The risk of exposure increases when farmers ignore safety instructions on the proper use of pesticides, PPE use and safety practices (Damalas, 2008).

Consequently, the level of knowledge could also affect practices related to pesticide use; indirectly the number of farming experience, training received or undergone, and level of education can affect practices. All these factors on knowledge and practices may have a direct impact on the self-reported symptoms of exposure to pesticides such as skin irritations, redness of the eyes, headache, sneezing, tiredness, backache, skin rash, dizziness, vomiting, eye problem, breathing problem and flu (Dzobo, 2016).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study site

This study was conducted in households at Kabaru location (0.2833°S, 37.1667°E, 2309 m.a.s.l.) in Nyeri County. Kabaru location is one of the four locations in Kieni East sub-county in Nyeri County. It has an estimated population size of 17,500 people according to Kenya National Bureau of statistics (KNBS, 2009). It has five Sub-locations as shown in Figure 3.1 with a total of seven villages. The major crops grown in the study area include maize, beans, Irish potatoes and vegetables (snow peas, French beans, cabbage carrots, onions, tomatoes) whereas the major cash crops are coffee, tea, horticulture and cut flowers. The average farm size is 1.75 hectares.

3.2 Study Design

The study was a cross-sectional study.

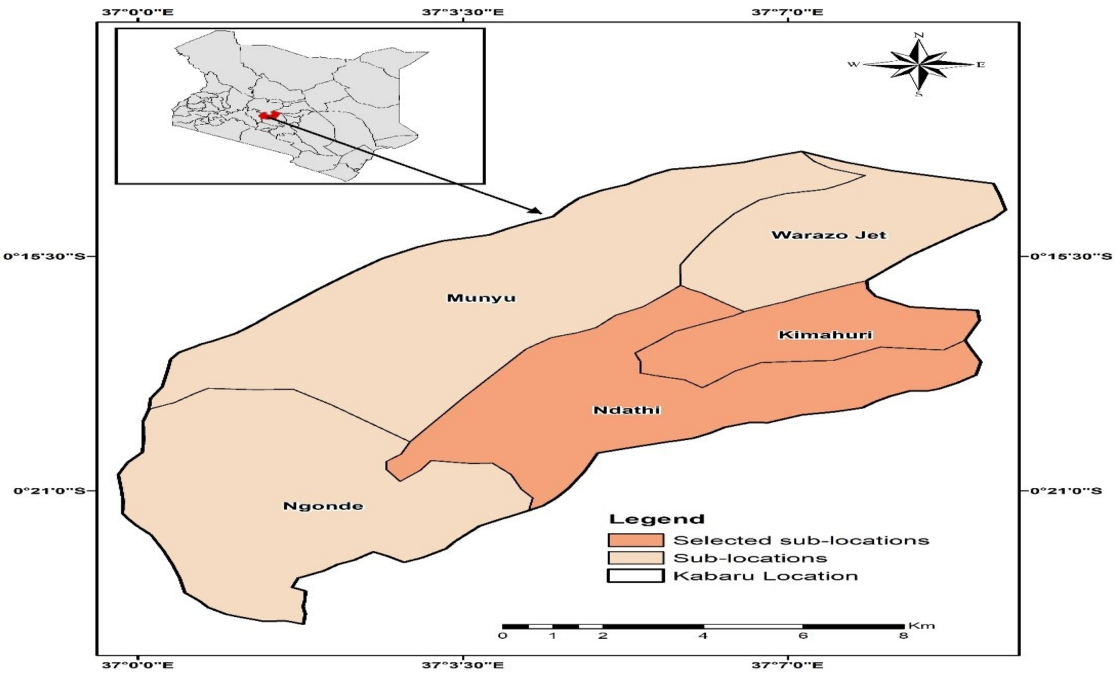

Figure 3.1: Map of Kabaru location in Nyeri County.

3.3 Study population

The study population comprised bean smallholder farmers who use pesticides against the bean fly on their farms in Kabaru location, Nyeri County in Kenya. The study targeted only Ndathi and Kimahuri sub-locations with a total of 385 respondents.

3.3.1 Inclusion criteria

The eligibility criteria included

(i) Farmers who had once planted bean plants in their farms.

(ii) A permanent resident in the study area

(iii) Farmers who consent to participate in the study and farmers who used pesticides in the farm.

3.3.2 Exclusion criteria

The exclusion criteria included (i) a non-farmer, (ii) non-permanent resident in the study area. (iii) Farmers who did not consent to the study and had never planted beans.

3.4 Study Variables

3.4.1 Main Determinants

The main determinants of interest include (i) knowledge on the effects of pesticides on human health and environment, (ii) hygiene practices and (iii) protection and safety practices. For knowledge of the effect of pesticide on human health and environment farmers answered questions on whether pesticide use/exposure has effect on human health, livestock and the environment and whether they are aware that there are other alternatives to pesticides. Hygiene practices inquired about how often they mix pesticide with bare hands, how often did they eat while spraying, and how often did they drink water while spraying. Questions on protection and safety inquired whether they wore PPE while spraying such as boots, hat, full face shield, chemically resistant gloves, overall and googles.

3.4.2 Dependent variable(s)

The main dependent variable is self-reported clinical effects following pesticide poisoning. Other variable includes: the ways of managing health effects following pesticide poisoning.

3.4.3 Confounders

Potential confounders include gender, age, farming experience, level of education and training on pesticide use. Selection of these variables was based on literature and their significant association with the parameters of interest, $p<0.05$ (Zyoud, 2010).

3.5 Sample size determination

Using the Cochran formula (Cochran 1977), $n= [z^2 p (1-p)]/\delta^2$ the sample size (n), was calculated, Where n was the required minimum sample size, Z was a standard score corresponding to 95% confidence level is 1.96, P was assumed equal to 50% which is the maximum variability in proportion of the bean fly infestation which is 50/100=0.5 and 1-p is 0.5 and δ is the margin of error, 5% (0.05)

$n= (1.96 \times 1.96 \times (1-0.5) \times 0.5)/0.05 \times 0.05$

n= 385

With this, an estimated population of 385 farmers was selected from Kabaru location.

3.6 Sampling technique

A list containing the number of households in each of the two sub-locations and their names was made. A semi-structured questionnaire was administered to the study respondents who were selected using systematic random sampling method. Sample members from a larger population were selected at fixed periodic interval in both Kimahuri and Ndathi Sub-locations. The sampling interval was calculated by dividing the population size by the desired sample size. For Kimahuri, 2475/165=15 m whereas for Ndathi=4400/220=20m interval.

3.7 Pre-test

A pre-test of the questionnaire was conducted on a sample of 38 selected bean smallholder farmers in one of the villages. This was important because it helped test the validity of questions and the reliability of the tool.

3.8 Data collection and analysis

Quantitative methods of data collection were used in the study. A structured questionnaire was administered to the randomly selected respondents in the selected Sub-locations. The questionnaire addressed the knowledge they have on pesticides used against the bean fly, the practices related to pesticides used against the bean fly, the self-reported clinical effects following pesticide use, the signs and symptoms and ways of managing them among common bean smallholders. The questionnaire was categorized as per the specific objectives of the study.

3.8.1 Measures and Analysis

For each of the surveyed members, various measures were created in order to assess their knowledge and practices regarding pesticides used to control the bean fly. This involved the importance of pesticides for pest control, the adverse impacts of pesticides on human health and the environment, the appropriate use of PPE, reading of pesticide labels, storage of pesticides prior to use, frequency of pesticide application, bathing/ hand washing, types of pesticide applicator, and the disposal of empty pesticide containers. Respondents were offered a choice of five pre-coded responses with the neutral point being neither agree nor disagree using a Likert Scale to allow the individual to express how much they agreed or disagreed with a particular statement. These responses were then scored quantitatively, the highest score being five with the positive response and lowest being one with the negative response for each variable.

Respondents whose questionnaire responses indicated a good understanding of the pesticide names, the importance of pesticide for pest control, the proper use of knapsack sprayers, the use of PPE, who read and understood pesticide labels, who safely disposed empty pesticide containers, who understood the adverse effects of pesticides on health and environment and had received pesticide use training in the past were considered to have good knowledge of safe pesticide use. Respondents who scored above 75% were considered to have good pesticide knowledge whereas those who scored above 80% were considered to have safe practices.

3.8.2 Quantitative data analysis

Descriptive statistics which is a set of brief descriptive coefficients that summarize a given data set representative of an entire or sample population was used in the study. Quantitative data were summarized as contingency tables or graphs using SPSS software. Differences between response categories within the sub-location as well as the overall sample were determined using the Chi-square test. All the statistical tests were performed using 95% CI as the level of significance. All the statistical tests were performed at 5% level of significance.

The magnitude and direction of relationships between variables were measured using the chi-square test. Statistical Package for the Social Science (SPSS, 2016) software was used for all data analysis.

3.9 Ethical considerations

The proposal for this study was submitted to KNH/UON Ethical Review Committee (ERC) for ethical approval (Ref no. P752/10/2016) as shown in Appendix 3. Approval was also sought from the county executive of health in the County. Written consent was obtained from all the respondents prior to the study.

CHAPTER FOUR

RESULTS

This study took place between March and May 2017.

4.1 Socio-demographic characteristics of the respondents

The socio-demographic characteristics of the 385 respondents of the two Sub-locations; Kimahuri (165) and Ndathi (220) are given in Table 4.1. Majority of the respondents were male (74%) farmers aged between 26 and 58 years. More than half of the respondents had completed secondary education (52%) while 38% had primary education. Most (90%) of the respondents had crop production and livestock as their only sources of income.

Table 4.1: Socio-demographic characteristics of the respondents

Variables	Kimahuri Sub-location (n=165)	Ndathi Sub-location (n=220)	Overall (n=385)
	N (frequency (%))	N (frequency (%))	N (frequency (%))
Age category			
18-25	7 (4.5%)	8 (3.6%)	15 (4.0%)
26-36	15 (9.1%)	94 (42.9%)	109 (28.0%)
37-47	68 (40.9%)	47 (21.4%)	115 (30.0%)
48-58	52 (31.8%)	55 (25.0%)	107 (28.0%)
59-69	23 (13.6%)	16 (7.1%)	39 (10.0%)
Sex			
Male	143 (86.4%)	142 (64.3%)	285 (74.0%)
Female	22 (13.6%)	78 (35.7%)	100 (26.0%)
Highest level of education completed			
Secondary	143 (86.7%)	204 (92.7%)	347 (90.1%)
College	22 (13.3%)	16 (7.3%)	38 (9.9%)
Sources of income			
Crop production	0 (0.0%)	8 (3.6%)	8 (2%)
Crop production and livestock	158 (95.5%)	189 (85.7%)	347 (90.0%)
Crop production, livestock and business	7 (4.5%)	23 (10.7%)	30 (8.0%)

*N refers to the total number of sample in the location

4.2 Knowledge on pesticide use

The pesticides used to control bean fly as shown in this study were from the organophosphates (18%), pyrethroids (55%), neonicotinoids (18%), and carbamate (9%) chemical families (Table 4.2). All the pesticides used belonged to WHO class II which are moderately hazardous chemicals.

Table 4.2: Commonly used pesticides to control bean fly in Kabaru location

Pesticides used	Chemical family	WHO class	Active ingredient	Total (n=385) *N (%)
Dimethoate	Organophosphate	Class II	Dimethoate	25(6.5)
Karate	Pyrethroid	Class II	Lambda cyhalothrin	83(21.6)
Actara	Neonicotinoids	Class II	Thiamethoxam	102(26.5)
Diazinon	Organophosphate	Class II	Diazinon	9(2.3)
Bulldock	Pyrethroid	Class II	Beta cyfluthrin	17(4.4)
Confidor	Neonicotinoids	Class II	Imidacloprid	2(0.5)
Pestox	Pyrethroid	Class II	Cypermethrin	48(12.5)
Brigade	Pyrethroid	Class II	Bifenthrin	9(2.3)
Cyclone	Pyrethroid	Class II	Paraquat-dichloride	25(6.5)
Pirimor	Carbamate	Class II	Pirimicarb	48(12.5)
Decis	Pyrethroid	Class II	Deltamethrin	17(4.4)

*N refers to the total number of sample in the location

The Likert Scale data on knowledge of pesticides showed that 96% scored 15 and above and only 4% scored <15 out of the highest-level attainable score which is 20 for the four questions each carrying five marks (Figure 4.1).

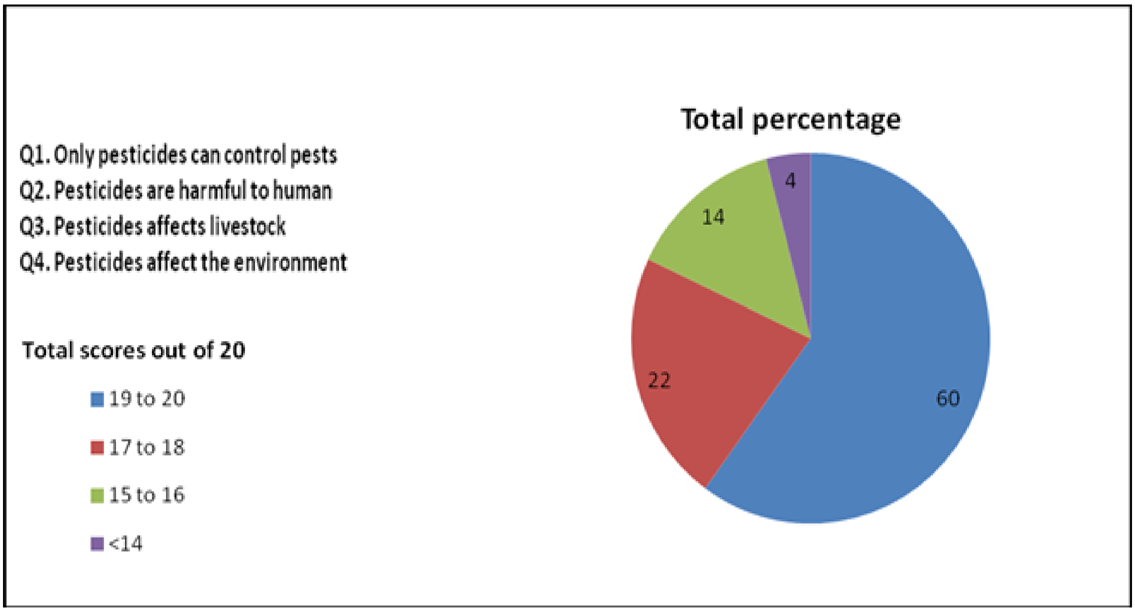

Figure 4.1: Level of knowledge on pesticides used against the bean fly

4.3 Practices on pesticide use

The Likert Scale data on practices showed that 76% of the respondents scored 12 and above while 24% scored <12 out of the highest-level attainable score which is 15 for the three questions each carrying five marks (Figure 4.2). All the surveyed farmers used personal protective equipment (PPE) to prevent pesticide exposure to the skin and inhalation and most of them read the pesticide labels (Table 4.3). Ninety-four percent of the farmers surveyed knew that pesticide containers have signs marking their toxicity levels but 60% did not know the signs marking the most dangerous pesticide. All the farmers did not eat or drink while handling chemicals. Also, of concern was the poor storage of the pesticides, as shown by the variation in storage facilities. Seventy two percent stored their pesticides in their store and small number in the group store. Moreover, majority of them (90%) had pesticide training in the past.

Ninety percent of the respondents had chemicals as the commonly used pest control measure and sprayed in the morning (Table 4.4).

Table 4.3: Pesticide safe practices and caution before use in Kabaru Location

Variables	Kimahuri Sub-location (n=165)	Ndathi Sub-location (n=220)	Total (n=385)
	Frequency (%)	Frequency (%)	Frequency (%)
Use Personal protective equipment (PPE)			
Yes	100.0a	100.0a	100.0a
No	0.0b	0.0b	0.0b
p –value			<0.0001
Read pesticide labels			
Yes	95.5a	96.2a	95.8a
No	4.5b	3.8b	4.2b
$\chi 2(1)$			83.90
p –value			<0.0001
Pesticide containers have signs marking their toxicity			
Yes	99.4a	89.0a	94.0a
No	0.6b	11.0b	6.0b
$\chi 2$ (1)			77.4
p –value			<0.0001
Signs marking the most dangerous pesticide			
I don't know	59.1a	59.8a	59.5a
Red colour	40.9b	40.2b	40.5b
$\chi 2$ (1)			3.67
p –value			0.06
Pesticide training in the past (Ministry of Agriculture)			
Yes	90.9a	89.5a	90.1a
No	9.1b	10.5b	9.9b
$\chi 2$ (1)			64.32
p-value			<0.0001

a & b denotes that there is a significant difference between the proportions

Table 4.4: Practices of bean smallholder farmers on pesticide use in Kabaru Location

Variables	Kimahuri Sub-location (n=165)	Ndathi Sub-location (n=220)	Total (n=385)
	Frequency (%)	Frequency (%)	Frequency (%)
Commonly used pest control measures			
Chemical	90.9a	89.3a	90.0a
Cultural & chemicals	9.1b	7.1b	8.0b
Chemical & hand picking	0.0c	3.6c	2.0c
Time of day			
Morning	81.8a	75.0a	78.0a
Evening	18.2b	25.0b	22.0b
Pesticide applicator			
Twigs	0.0b	0.0b	0.0b
Knapsack	100.0a	100.0a	100.0a
Places where chemicals are stored			
Store	90.9a	57.1a	72.0a
Group store	9.1b	35.7b	24.0b
House	0.0c	3.6c	2.0c
Outside	0.0c	3.6c	2.0c
Use of Personal protective equipment (gloves, overall, face masks, hat, boots, goggles)			
Yes	99.0a	99.0a	99.0a
No	1.0b	1.0b	1.0b
Eating while handling pesticides			
No	98.0a	98.0a	98.0a
Yes	2.0b	2.0b	2.0b
Drinking while handling pesticides			
Yes	0.0b	3.6b	2.0b
No	100.0a	96.4a	98.0a
Fate of empty pesticide containers			
Disposal pit	59.1a	75.0a	68.0a
Group disposal pit	13.6b	25.0b	20.0b
Pit latrine	9.1b	0.0c	4.0c
Destroying by burning	18.2b	0.0c	8.0c

a, b & c denotes that there is a significant difference between the proportions

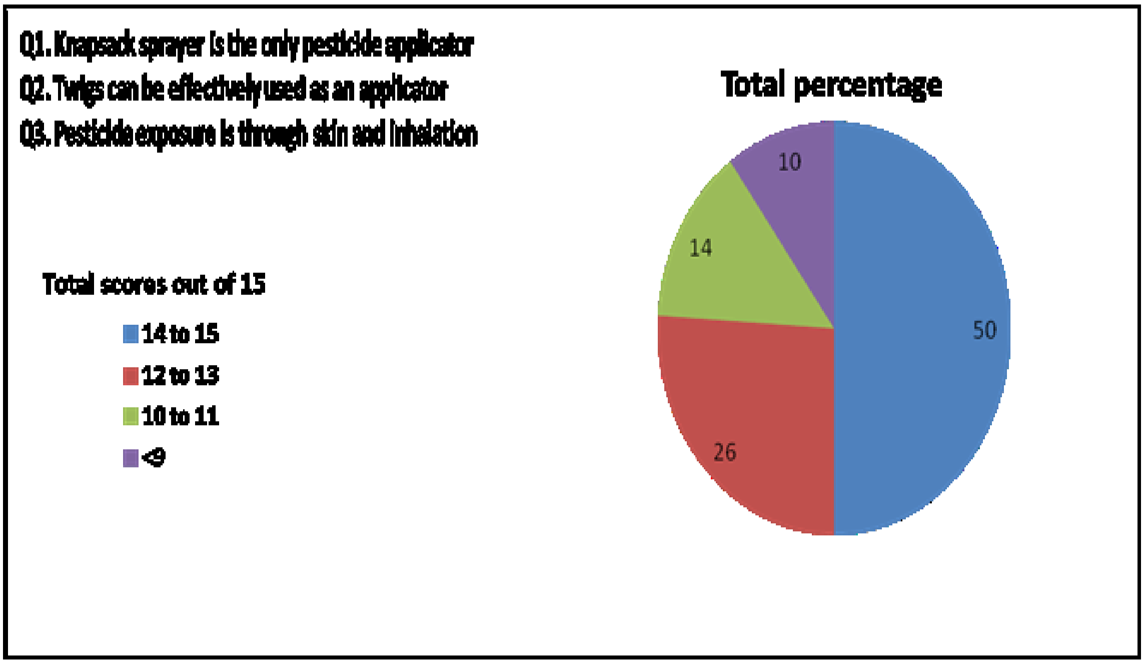

Figure 4.2: Practices on pesticide use in Kabaru location according to Likert Scale

4.4 Self-reported clinical effects following pesticide use

The major self-reported clinical effects experienced following pesticide use in this study included; headache, backache, dizziness, eye problems and sneezing (Figure 4.3).

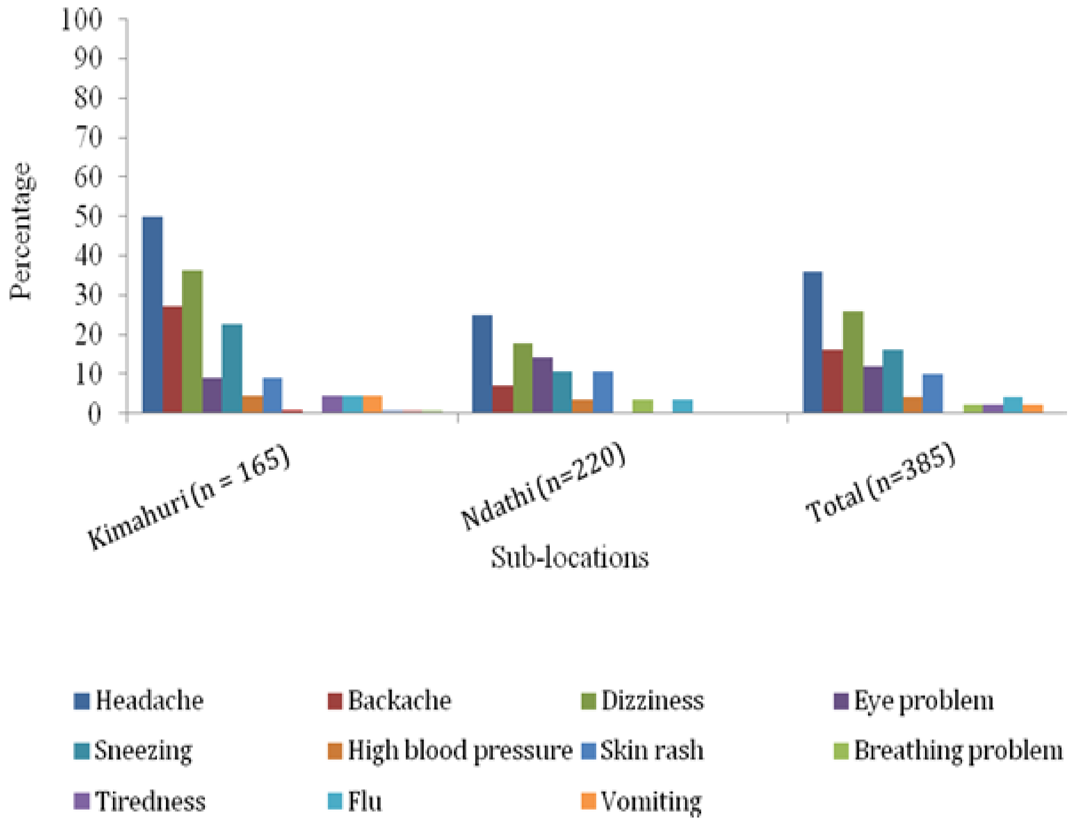

Figure 4.3: Self-reported clinical effects following pesticide use among bean smallholder farmers

4.5 Management of health effects following pesticide poisoning

In this study, most of the farmers did not go to hospital after experiencing signs and symptoms of pesticide poisoning and did not take medicine either but did wash their hands, took bath and removed PPE after experiencing the health effects of pesticide exposure as shown in Table 4.5.

Table 4.5: Management practices of health effects following pesticide poisoning among bean smallholder farmers in Kabaru location, Nyeri

Variables	Kimahuri Sub-location (n=165)	Ndathi Sub-location (n=220)	Total (n=385)
	Frequency (%)	Frequency (%)	Frequency (%)
Go to hospital after pesticide poisoning			
Yes	4.6b	6.7b	5.7b
No	95.4a	93.3a	94.3a
χ^2 (1)			78.5
p-value			<0.0001
Take medicine after experiencing symptoms of pesticide poisoning			
Yes	64.0a	32.4b	46.8a
No	36.0b	67.6a	53.2a
χ^2 (1)			38.7979
p-value			<0.0001
Wash hands after handling pesticides			
Yes	100.0a	100.0a	100.0a
No	0.0b	0.0b	0.0b
p-value			<0.0001
Take bath after handling pesticides			
Yes	32.0b	86.2a	61.6a
No	68.0a	13.8b	38.4b
χ^2 (1)			118.358
p-value			<0.0001
Remove PPE after handling pesticides			
Yes	100.0a	100.0a	100.0a
No	0.0b	0.0b	0.0b
p-value			<0.00001

a & b denotes that there is a significant difference between the proportions

CHAPTER FIVE

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

Majority of the respondents were male (74%) farmers aged between 26 and 58 years. The females were involved mostly in business and other engagements leaving the male to practice farming. The men due to masculine nature were able to do farming as compared to the women. Farmers in the age group of 26-47 years, are active, young males and females of reproductive age. The socio-demographic characteristics also showed that more than half of the respondents had completed secondary education (52%) while 38% had primary education. The level of education is important as farmers who knew to read English were able to read and understand pesticide labels. Most (90%) of the respondents had crop production and livestock as their only sources of income.

The pesticides used to control bean fly in this study were from the organophosphates (18%), pyrethroids (55%), neonicotinoids (18%), and carbamate (9%) chemical families. The WHO, (2010) classification of pesticide toxicity has been used by regulators to help determine which pesticides should be restricted into classes according to the pesticides' active ingredient. All the pesticides used belonged to WHO class II which are moderately hazardous chemicals. Nevertheless, these class II pesticides are still classified as Moderately hazardous but they are known to have severe negative effect on human health and the environment, and therefore other less dangerous alternatives should be promoted (Keifer, 2000). Farmers use these chemicals to control bean fly because they do not have adequate knowledge on the toxicity levels, and they are readily available in the market.

5.1.1 Farmers' knowledge on pesticide use

Data on Likert Scale showed that a respondent who scored 15 out of 20 (75%) was termed to have good pesticide knowledge. Such respondents knew that there are other pest control methods such as IPM and were aware of the adverse effects of pesticides to humans, livestock and the environment. Other pest control measures used apart from chemical pesticides reported in other studies include: cultural methods such as crop rotation and mulching and hand picking. (Mwanauta *et al.,* 2015) As found in this study, some farmers used them in combination with pesticides. Hand picking and mulching are very tedious while crop rotation can only be utilized in the next planting season and so it cannot control pests instantly (Mwanauta *et al.,* 2015). These pest control measures do not have adverse effects on human, livestock and the environment.

Majority of respondents strongly agreed that pesticides lead to adverse effects to human health, livestock and the environment. The same results were reported in other studies (Mekonnen & Agonafir, 2002; Ngowi *et al.,* 2001a; Ngowi *et al.,* 2001b; Oesterlund *et al.,* 2014). Human health and safety is threatened by the use of commercial pesticides with no mechanism to ensure food safety for consumers, and concern for the chronic effects of exposure. In addition, environmental impacts on wildlife, crop pollinators and natural enemies are also severe (WHO,1990). The adverse effects of pesticides include the killing of beneficial insects, polluting the air, pesticide resistance, death, vomiting, headache and nausea (Ngowi *et al.,* 2001a). According to the Likert Scale described above, most of the farmers had good knowledge about the adverse effects of pesticides on human health and the environment.

5.1.2 Practices surrounding pesticide use

Data on Likert Scale showed that a respondent who scored 12 out of 15 (80%) was termed to have safe pesticide practices. These respondents used the knapsack sprayer as the recommended pesticide applicator and did not use twigs for applying pesticides as they were not effective. In addition, they used PPE, sprayed in the morning and evening not to be exposed to pesticides through skin and inhalation.

Regarding methods of pesticide application, the majority (98%) reported that they used knapsack sprayers to apply chemicals. Knapsack sprayers are the recommended pesticide application device by WHO and are widely used in most smallholder settings. The use of an appropriate device minimizes exposure to and wastage of pesticides. The findings of this study showed that farmers in the study location did recognize the benefits of using the recommended equipment. Other studies also reported the benefits of using the recommended applicator (Zimba & Zimudzi, 2016). Some, 64%, disagreed that twigs can be effectively used to apply chemicals. The use of twigs leads to direct exposure and inhalation of chemicals as they are applied in a haphazard manner on the leaves of the plant. The inhalation of chemicals can result to pesticide poisoning or even death if in high doses.

All the respondents used personal protective equipment to prevent pesticide exposure to the skin and inhalation and most of them (95.8%) read pesticide labels (Table 4.3). The completeness of PPE was important as it minimizes the risk of pesticide poisoning. Other studies reported that the low provision of protective clothing was a major risk factor for pesticide poisoning among farm workers in Zimbabwe although most of them read pesticide labels (Magauzi *et al.,* 2011).

Majority (94%) of the farmers surveyed were aware that pesticide containers have signs marking their toxicity levels but 60% did not know the signs marking the most dangerous pesticide. Ntow *et al.,* (2006) & Oesterlund *et al.,* (2014) also reported a situation where farmers had limited knowledge about toxicity color codes. A study among farm workers in Zimbabwe by Magauzi *et al.,* (2011), showed that ignorance of colour codes was a major problem and a risk factor for pesticide exposure. Understanding colour coding on pesticide containers is therefore important for preventing pesticide poisoning. Labels carry these colour codes to indicate the toxicity level of pesticides and give instructions on use and first aid information in case of an emergency.

Moreover, majority (90%) of the respondents had been sensitized on pesticides in the past. This training is important as farmers thereby learn how to safely handle pesticides, read labels, dilution measures, use of PPE, first aid precautions, the fate of empty containers and they generally gain an understanding of the impacts of pesticides on humans, livestock, environment, birds, beneficial insects and other non-targeted organisms in the ecosystem. The minority (10%) were offered the same kind of sensitization by county health officers and agricultural extension officers at a later date.

Majority (90%) of the respondents used chemicals as their commonly used pest control measure and sprayed in the morning. There are various reasons why it is important to spray in the morning as plants absorb chemicals effectively and the air is more still than at other times of day. Still air is important for effective application and for personal protection. Spray directed at shrubs is scattered by the wind and may endanger people and animals in the wind path. Many insects are most active early in the morning and around dusk, making very early morning and early evening the most effective times for insecticide application. Pesticide sprays require between 1 and 24 hours of drying time to maximize benefits. Moreover, problems caused by spraying during high temperatures usually show up as burns on foliage.

All the respondents did not take any soft drinks, milk or water while only 2 % ate while handling chemicals. Eating with bear and unclean hands and drinking while handling increases the chances of pesticides entry in the body through the skin and ingestion. There is an association between poor handwashing and ingestion of pesticides through contaminated food. In Zimbabwe, studies on the occupational hazards of pesticide use and handling have shown that more than 50% of farm workers were exposed to organophosphates during spraying (Loewenson and Nhachi, 1996) through the skin and ingestion.

Further, of concern was the poor storage of the pesticides, as shown by the variation in storage facilities. Some, 72% stored their pesticides in their store and a small number in the group store. The Food and Agriculture Organization of the United

Nations (FAO, 2008), has highlighted the importance of rules for the proper storage of pesticides in order to maintain product efficacy and to prevent contamination of the surroundings. Farmers should follow all disposal instructions on the pesticide labels. Most of them disposed the empty pesticide containers in the disposal pit in their homes and a few in their group disposal pit. The safe disposal of pesticide waste, including used containers, is an important aspect of pesticide management in order to minimize risk to human health and the environment (FAO 2008; Karunamoorthi *et al.,*2011) which is a policy of the Ministry of Health. Empty pesticide containers should not be re-used. On the storage of and safe disposal of pesticide containers as indicated above had an implication that not all the farmers were able to follow the rules on safe practices which exposed them to various risks on their health and the environment.

5.1.3 Self-reported occurrences of health effects

Accidental exposure or overexposure to pesticides can have serious consequences. The major self-reported clinical effects following pesticide use in this study included; headache, backache, dizziness, eye problems and sneezing. Other reported health effects include skin rash, skin irritation, breathing problems and flu. According to the number of self-reported symptoms in our study, the farmers in these sub-locations were exposed to pesticides either through the skin or ingestion. Knowledge of these signs and symptoms will allow for prompt treatment and help prevent serious injury. Other studies also reported similar signs and symptoms (Antle & Pingali, 1994; Asfaw, 2008; Farquhar *et al.,* 2009; Harris *et al.,* 2001; Lekei *et al.,* 2014; Macharia *et al.,* 2009; Maumbe & Swinton, 2003; Ohayo-Mitoko *et al.,* 2000).

5.1.4 Management practices of health effects

In this study, most of the farmers did not go to hospital after experiencing signs and symptoms of pesticide poisoning and did not take medicine. The key to surviving and recovering from pesticide poisoning is to seek treatment immediately. This emergency action should be taken immediately when you suspect and experience signs and symptoms of pesticide poisoning. It is recommended that once one is exposed to a pesticide, to always wash the skin with soap or detergent with plenty of water and remove all the protective clothing after experiencing the health effects of pesticide exposure. Similar findings were reported by Reigart (2009), where for instance a pesticide applicator may not perceive the incident as being significant enough to seek care, particularly if he or she has been accustomed to low-level exposure scenarios on the job. According to these findings, farmers in Kabaru location need to be educated on the emergency measures to take when they experience the signs and symptoms of pesticide poisoning.

5.2 Conclusions

The findings of the present study suggest that the farmers had substantial knowledge about the hazards of pesticides oh humans, livestock and the environment. This is because there are two self-help groups in the region that educate and sensitize farmers on pesticide use.

Bean small-scale farmers in Kabaru location did not use the most hazardous pesticides of WHO class 1a and 1b. However, the use of WHO class II pesticides together with inadequate knowledge and undesirable practices such as incompleteness of PPE, ignorance and carelessness. among the farmers may lead to acute pesticide poisoning.

According to the number of self-reported symptoms in our study, the farmers in Kabaru location were exposed to pesticides either through the skin or ingestion. There is need for training on PPE.

There is need to educate them on the emergency measures to take such as seek treatment when they experience the signs and symptoms of pesticide poisoning.

5.3 Recommendations

The authorities should initiate active health education campaigns and appropriate training programs to promote the safe use of pesticides and to eliminate or minimize the use of the most hazardous pesticides.

Therefore, training of farmers in Integrated Pest Management methods as other safer alternatives should be promoted. These includes the use of bio-pesticides is affordable for the farmers and reduces the risk to humans and the environment while still yielding the expected outcome.

The sensitization on the time of spraying, safe pesticide storage, disposal of empty containers and the completeness of personal protective equipment when handling pesticides should also be promoted.

There should be health awareness campaigns to make farmers aware of the signs and symptoms of pesticide poisoning and emergency actions to take such as seeking medical treatment.

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APPENDICES

Appendix I: Informed Consent Form for Respondents

My name is Beritah Mumbi Mutune a Post Graduate Student in Jomo Kenyatta University of Agriculture and Technology (JKUAT). I intend to conduct a research proposal entitled "knowledge and practices of pesticides used against the bean fly (*Ophyiomyia phaseoli*) and associated health effects among bean (*Phaseolus vulgaris*) smallholder farmers in Kabaru location, Nyeri County".

I kindly request you to participate in this study that will be part of the requirement for award of degree of MSc. in Public Health of Jomo Kenyatta University of Agriculture and Technology (JKUAT). Your participation is voluntary and your choice to withdraw from the study at any time will be accepted. This study has no foreseeable risks associated with it. Anonymity will be ensured, as names will not be indicated in the questionnaire. The information provided will be confidential and used for the purpose of the study only. The results expected from the survey can be of benefit by helping reduce pesticide use by understanding the magnitude of the impacts of continued use of pesticides, reduce bean losses, increased farmer income, improving research and education capabilities. You may ask questions before consenting.

Participant / Respondent

I have read the above information and have had the opportunity to ask questions and all of my questions have been answered satisfactorily. I consent to participate in the field survey as it has been explained and as I have understood it. I have been given a copy of this consent form for my records and future references.

Tick if you **accept/do not accept t**o be part of the study.

Signature……………………………….Date…………………………

Appendix II: Survey Questionnaire

SECTION 1: HOUSEHOLD CHARACTERISTICS	
001.Respondent's code	002a. Age of the farm head ______/ (in years) 002b. Phone No:_________________
003. Gender of respondent : 1 = Male /___/ 0 = Female /___/	004. What is the highest level of education of the farm head? (0)None /___/ (1)Standard (Primary) /___/ (2)High school (Secondary) /___/ (3) College/University) /___/ (4) Others(specify) /___/
005. What are the main sources of income of the farm head? (1) Farming (crop production) /___/ (2) Livestock keeping /___/ (3) Employment /___/ (4) Business/commerce /___/ (5) Other (specify) /___/	

SECTION 2: KNOWLEDGE ON PESTICIDE USED AGAINST BEAN FLY	
006. What are the names of the pesticides used to control the bean fly? (a) (b) (c) (d)	007. Pesticides are the only way of controlling pests (a) Strongly disagree (1) (b) Disagree (2) (c) Neutral (3) (d) Agree (4) (e) Strongly agree (5)
008. Knapsack sprayer should be the commonly used way to apply pesticides (a) Strongly agree (5) (b) Agree (4) (c) Neutral (3) (d) Disagree (2) (e) Strongly disagree (1)	009. Twigs can be effectively used to apply pesticides (a) Strongly agree (1) (b) Agree (2) (c) Neutral (3) (d) Disagree (4) (e) Strongly disagree (5)
010. Pesticides are harmful to human health (a) Strongly agree (5) (b) Agree (4) (c) Neutral (3) (d) Disagree (2) (e) Strongly disagree (1)	011. Pesticides enter the body through skin contact and inhalation (a) Strongly agree (5) (b) Agree (4) (c) Neutral (3) (d) Disagree (2) (e) Strongly disagree (1)

012. Pesticides use affects livestock (a) Strongly agree (5) (b) Agree (4) (c) Neutral (3) (d) Disagree (2) (e) Strongly disagree (1)	013. Pesticides affects the environment (a) Strongly agree (5) (b) Agree (4) (c) Neutral (3) (d) Disagree (2) (e) Strongly disagree (1)
014. Do you wear personal protective equipment? (a) Yes (1) (b) No (0)	015. Do you read label instructions of the chemicals? (a) Yes (1) (b) No (0)
016. Do the pesticide containers have any signs marking their toxicity? (a) Yes (1) (b) No (0)	017. Which sign marks the most dangerous pesticide? (a) I don't know (0) (b) Red colour coding (1) (c) Other colour (0)
018. Have you had any pesticide use training in the past? (a) Yes (1) (b) No (0)	
SECTION 3: PRACTICES OF COMMON BEAN SMALLHOLDERS ABOUT PESTICIDES USE	
019. What are the commonly used pest control measures?	020. What time of day do you apply pesticides? (a) Morning (b) Mid-day (c) Evening
021. What is the type of pesticide	022. Where do you store pesticides before using them?

applicator?	
023. Do you use any protective gear (PPE) while handling pesticides?	024. Do you eat while handling pesticides?
025. Do you drink while handling pesticides?	026. What is the fate of empty pesticide containers?
SECTION 4: SELF-REPORTED CLINICAL EFFECTS FOLLOWING PESTICIDE USE	
4.1 Signs and symptoms	
027. What signs and symptoms do you experience once you spray early in the morning? (a) (b) (c) (d) (e)	028. What signs and symptoms do you experience once you spray late in the evening? (a) (b) (c) (d) (e)
029. What signs and symptoms do you experience once you spray on a windy day? (a) (b) (c) (d) (e)	030. What signs and symptoms do you experience once you stay one week without spraying? (a) (b) (c) (d) (e)

4.2 Type of problem

031. What is your experience once you spray early in the morning? (a) (b) (c) (d) (e)	032. What is your experience once you spray late in the evening? (a) (b) (c) (d) (e)
033. What is your experience once you stay one week without spraying? (a) (b) (c) (d) (e)	034. Do you have a condition you suspect could be due to prolonged use of pesticides? (a) (b) (c) (d) (e)
SECTION 5: MANAGEMENT PRACTICES OF HEALTH EFFECTS AFTER PESTICIDE USE	
035. Do you go to the hospital once you experience the signs and symptoms of pesticide poisoning?	036. Do you take medicine once you experience the signs and symptoms of pesticide poisoning?
037. Do you wash hands with soap ling pesticides?	038. Do you take bath after handling pesticides?
039. Do you forget or remove the personal protective clothing once you experience signs and symptoms of pesticide poisoning?	

Appendix III: ethical approval

UNIVERSITY OF NAIROBI
COLLEGE OF HEALTH SCIENCES
P O BOX 19676 Code 00202
Telegrams: varsity
Tel:(254-020) 2726300 Ext 44355

KENYATTA NATIONAL HOSPITAL
APPROVED
08 FEB 2017
KNH/UoN-ERC
P.O. Box 20723-00202

KNH-UON ERC
Email: uonknh_erc@uonbi.ac.ke
Website: http://www.erc.uonbi.ac.ke
Facebook: https://www.facebook.com/uonknh.erc
Twitter: @UONKNH_ERC https://twitter.com/UONKNH_ERC

KENYATTA NATIONAL HOSPITAL
P O BOX 20723 Code 00202
Tel: 726300-9
Fax: 725272
Telegrams: MEDSUP, Nairobi

Ref: KNH-ERC/A/44

8th February 2017

Beritah Mumbi Mutune
Reg. No.TM310-1079/2013
JKUAT

Dear Beritah

Revised research proposal: "Knowledge and Practices of Pesticides used against the Bean fly(*Ophyiomyia phaseoli)* and associated health effects among Bean(*Phaseolous vulgaris*) small holder Farmers in Kabaru Locaiton, Nyeri county (P752/10/2016)

This is to inform you that the KNH- UoN Ethics & Research Committee (KNH- UoN ERC) has reviewed and **approved** your above revised proposal. The approval period is from 8th February 2017 – 7th February 2018.

This approval is subject to compliance with the following requirements:

a) Only approved documents (informed consents, study instruments, advertising materials etc) will be used.
b) All changes (amendments, deviations, violations etc) are submitted for review and approval by KNH-UoN ERC before implementation.
c) Death and life threatening problems and serious adverse events (SAEs) or unexpected adverse events whether related or unrelated to the study must be reported to the KNH-UoN ERC within 72 hours of notification.
d) Any changes, anticipated or otherwise that may increase the risks or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to KNH- UoN ERC within 72 hours.
e) Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. (*Attach a comprehensive progress report to support the renewal*).
f) Clearance for export of biological specimens must be obtained from KNH- UoN ERC for each batch of shipment.
g) Submission of an *executive summary* report within 90 days upon completion of the study. This information will form part of the data base that will be consulted in future when processing related research studies so as to minimize chances of study duplication and/ or plagiarism.

For more details consult the KNH- UoN ERC website **http://www.erc.uonbi.ac.ke**

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Appendix IV: Board of Postgraduate Proposal Approval Letter

JKUAT
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P.O. Box 62000-00200, NAIROBI
24 MAR 2017
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RECEIVED

JOMO KENYATTA UNIVERSITY
OF
AGRICULTURE AND TECHNOLOGY
DIRECTOR, BOARD OF POSTGRADUATE STUDIES

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KENYA
Email: director@bps.jkuat.ac.ke

TEL: 254-067-52711/52181-4
FAX: 254-067-52164/52030

REF: JKU/2/11/ TM310-1079/2013

17TH MARCH, 2017

MUTUNE BERITAH MUMBI
C/O SPH
JKUAT

Dear, Ms. Mumbi,

RE: APPROVAL OF RESEARCH PROPOSAL AND OF SUPERVISORS

Kindly note that your MSc. research proposal entitled: **"KNOWLEDGE AND PRACTICES OF PESTICIDES USED AGAINST THE BEAN FLY (*Ophyiomyia phaseoli*) AND ASSOCIATED HEALTH EFECTS AMONG BEAN (*Phaseolus vulgaris*) SMALLHOLDER FARMERS IN KABARU LOCATION, NYERI COUNTY."** has been approved. The following are your approved supervisors:-

1. Dr. John Gachohi
2. Prof. Gideon Kikuvi

Yours sincerely

PROF. MATHEW KINYANJUI
DIRECTOR, BOARD OF POSTGRADUATE STUDIES

Copy to: Dean, SPH

/cm

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Appendix V: Thesis Approval Letter

File

JOMO KENYATTA UNIVERSITY
OF
AGRICULTURE AND TECHNOLOGY
DIRECTOR, BOARD OF POSTGRADUATE STUDIES

29 MAY 2018

P.O. BOX 62000
NAIROBI – 00200
KENYA
Email: director@bps.jkuat.ac.ke

TEL: 254-067-52711/52181-4
FAX: 254-067-52164/52030

REF: JKU/2/11/TM310-1079/2013

22ND MAY, 2018

MUNENE BERITAH MUMBI
C/o SoPH
JKUAT

Dear Ms. Mumbi,

RE: APPROVAL OF YOUR INTENT TO SUBMIT MSc. THESIS FOR EXAMINATION

We are in receipt of your letter of intent to submit your MSc. thesis for examination.

This is to inform you that your request **has been approved**. It is a requirement that you clear with all the relevant departments/ sections of the University and forward the duly completed Clearance Form to the BPS office to enable us processes your thesis for examination.

The Clearance Form is obtainable from the Office of the Director, Board of Postgraduate Studies.

Yours sincerely

PROF. MATHEW KINYANJUI
DIRECTOR, BOARD OF POSTGRAUDATE STUDIES
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Appendix VI: Publication

International Journal of Health Sciences
March 2018, Vol. 6, No. 1, pp. 1-11
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Knowledge and Practices of Pesticides Used Against the Bean Fly (*Ophiomyia phaseoli*) and Associated Health Effects among Bean (*Phaseolus vulgaris*) Smallholder Farmers in Kabaru Location, Nyeri County

Beritah Mutune[1,2], John Gachohi[1], Gideon Kikuvi[1], Saliou Niassy[2] & Christine Bii[3]

Abstract

Farmers' knowledge and practices regarding pesticides used against the bean fly, (*Ophiomyia phaseoli*) and the associated health effects is of great public health importance. This information is lacking among smallholder bean farmers in many sub-Saharan countries. A structured questionnaire was administered to 385 study participants. Systematic random sampling using a point transect method was performed and both qualitative and quantitative methods were used. A Likert Scale was used to scale responses. Data were analyzed using SPSS software. Differences between response categories were determined using the Chi-square test. The pesticides used in this study belonged to the pyrethroids (55%), organophosphates (18%), neonicotinoids (18%), and carbamate (9%) chemical families all of which belong to the WHO class II. Data from the Likert Scale on knowledge of pesticides showed that 96% scored above15 out of highest score of 20. Similarly on practices, 76% scored above 12 out of the highest score 15. The major self-reported clinical effects following pesticide use were headache, backache, dizziness, eye problems and sneezing. Although the farmers had a reasonable knowledge of the hazards of pesticides, they utilized undesirable practices such as incomplete use of Personal Protective Equipment (PPE). Therefore, more training is recommended to promote pesticide knowledge and safer practices for all the farmers.

Keywords: Organophosphates, pyrethroids, neonicotinoids, toxicity, self-reported data.

Introduction

Agriculture is the leading user of pesticides followed by vector control (Karunamoorthi, Mohammed, & Jemal, 2011). Over the past years there has been an increase in the use of pesticides in developing countries (Oesterlund et al., 2014). According to the World Health Organization, (WHO, 2011), the level of safe pesticide management in developing countries is low.

Insect pests such as the bean fly, *Ophiomyia spp.* (Diptera: Agromyzidae), are the most important field and storage pests, respectively (Abate, 1991) which can cause up to 100% loss (Ochilo & Nyamasyo, 2011; Wickramasinghe & Fernando, 1962). The management of bean fly is difficult because of the cryptic behavior of the pest. Most farmers do not believe that they can successfully cultivate the bean crop without using pesticides. Farmers get less profits and low field harvests because of bean fly damage which results in the great risk of failing to contribute as expected towards the GDP and achievement of Millennium Development Goal (MDG) number one which is to eradicate extreme hunger and poverty.

[1] Jomo Kenyatta University of Agriculture and Technology P.O Box 62000-00200, Nairobi, Kenya
[2] International Center of Insect Physiology and Ecology P.O Box 30772-00100 Nairobi, Kenya
[3] Kenya Medical Research Institute (KEMRI) P.O Box 54840-00200 Nairobi, Kenya

Correspondence :beritamutune@yahoo.com or beritamumbi@gmail.com