Heliyon 7 (2021) e06118

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Pesticide usage practices as sources of occupational exposure and health impacts on horticultural farmers in Meru County, Kenya

Gabriel M. Marete [a], Joseph O. Lalah [b,*], Jane Mputhia [a], Vitalis W. Wekesa [c]

[a] Department of Geoscience and the Environment, School of Physics and Earth Sciences, Technical University of Kenya, P.O. Box 52428-00200, Nairobi, Kenya
[b] Department of Geochemistry and Environmental Chemistry, School of Chemistry and Material Science, Technical University of Kenya, P.O. Box 52428-00200, Nairobi, Kenya
[c] Department of Technical and Applied Biology, School of Biological and Life Sciences, Technical University of Kenya, P.O. Box 52428-00200, Nairobi, Kenya

ARTICLE INFO

Keywords:
Pesticide usage
Horticultural farmers
Agricultural extension workers
Health care workers
Health impacts
Meru county
Kenya

ABSTRACT

This study assessed pesticide usage practices, knowledge and health effects of pesticides through occupational exposure in randomly selected horticultural farmers in Imenti North, Imenti South and Buuri Sub-counties in Meru, Kenya, where horticultural crops are grown intensively for export and local consumption. The study was done through use of questionnaire distributed to farmers' households, agricultural extension workers and health care workers. The survey established that various classes of pesticides were used in horticultural crop farming and animal production in all the three sub-counties, with the most frequently used (>60 respondents out of 173) being parathion, diazinon, dimethoate, permethrin, pirimiphos methyl, endrin, deltamethrin, dieldrin, propoxur and endosulfan. It was found that there is a gap between the existing government regulations on pesticide use and safe handling and the implementation of these regulations by dealers, farmers and farm workers in the three sub-counties as some of the pesticides that were being used such as parathion, endrin, dieldrin and carbofuran had been banned by the government. Although most farmers had general information on pesticide usage through various social groups and contact with agricultural extension workers, only 32–43 % of the farmers had received training on pesticide handling and use. Most farmers (65%) had knowledge of safe pesticide handling procedures including reading labels on packages and wearing protective clothing; but many farmers (44% in Buuri, 57% in Imenti South and 60% in Imenti North) did not wear the requisite protective clothing when applying pesticides. The agricultural extension workers (52%) and health care workers (59%) were trained in their work and had at least a certificate level qualification from a tertiary institution. Most agricultural extension workers (95%) and health care workers (71%) had experience of dealing with pesticides and knew how to administer 1st AID against pesticide poisoning, respectively. Farmers (26%) reported experiencing health effects after using pesticides, with most effects being felt after using dimethoate, malathion, carbofuran, carbaryl and heptachlor. There was a statistically significant ($p < 0.05$) association between various factors (availability of protective clothing, hiring of labourers, farm land size, expenditure on pesticides and expenditure on treatment, respectively) on intoxication from pesticide exposure.

1. Introduction

1.1. Pesticide usage and human health impacts

Pesticide use and handling is a global issue because it affects human health. Estimates cited by the Food and Agriculture Organization (Wilson, 2005) showed that approximately 3 million people are poisoned and 200,000 die from pesticide poisoning every year. The largest number of poisonings and deaths occurred in developing countries, with an average projection of 220,000 fatalities per year in 2008 (Subashiny and Thiruchelvam, 2008). In Sri Lanka, studies showed that approximately 1000 fatalities occurred in 2008 due to unsafe handling of pesticides, while in Kenya, 350,000 cases of pesticide poisoning per year were estimated (Subashiny and Thiruchelvam, 2008). Frequent exposure to pesticides results in ill health, both in the short term and long term (Wilson, 2005). Rising numbers of cases of non-communicable diseases such as cancer

* Corresponding author.
E-mail addresses: joseph.lalah@tukenya.ac.ke, lalahjoseph@yahoo.com (J.O. Lalah).

https://doi.org/10.1016/j.heliyon.2021.e06118
Received 26 August 2020; Received in revised form 15 September 2020; Accepted 25 January 2021

have been linked to aerial pollution in large cities and pesticide exposure in commercial large scale farming rural areas (Alavanja et al., 2013). In global terms, therefore, in trying to find solutions to minimize incidences of ill health, it is important to determine whether farmers and farm workers, who are predisposed to pesticide exposure, take precautions in pesticide handling and adhere to pesticide use regulations. Proper use and handling of pesticides is also significant as it involves adopting good agricultural practices such as use of IPM, including, selection of pesticides which have less impact on the environment (Gómez-Ramíreza et al., 2019). It also has significant implications in global food trade, in which developing countries have to meet stringent regulations on residue limits in foods before their export produce is accepted into the international markets such as the EU (FAO/WHO, 2008; Marete et al., 2020). Therefore, there is a call for education and awareness on pesticide use and handling for agricultural extension workers, farmers and farm workers in the developing countries.

In Africa and other developing countries, pesticides are not used efficiently due various factors, including lack of knowledge, application equipment and qualified agricultural extension workers, in addition to, poor infrastructure for farming and regulation and pest resistance to pesticides (Wasilwa, 2008; Damalas and Eleftherohorinos, 2011; Lalah et al., 2018). The UN has recognized that the challenges of pesticide use and handling in developing countries include inadequate training of farm workers, extension workers and health care workers (WHO/UNEP, 2001). Such training would reduce exposure and prevent poisoning by inculcating use of protective devices such as clothing, hand gloves and eye goggles, when handling pesticides, and adherence to labelling and packaging instructions (FAO, 2015). In large scale commercial farming, where aircraft and tractors are used to apply the pesticides, occupational exposure is much lower, compared with small scale farming where knapsack or hand sprayers are used (Hanke and Jurewicz, 2004; Ojo, 2016). Limited availability of financial capital and therefore less intensity of pesticide usage in small holder family subsistence farming also results in less occupational exposure (Buiatti et al., 2013). The subsequent detrimental human and environmental impacts of pesticides are not only connected with agricultural production methods but also misuse and mishandling of pesticides by farmers and farm workers (Issa et al., 2010; Kithure, 2013; Kingola, 2015; Ngolo et al., 2019). For sustainable agriculture, proper use of pesticides requires not only knowledge of the pests, but also knowledge of pesticides and recommended handling procedures (Nguyen and Dang, 1999; Banjo et al., 2003; Murphy et al., 2004; Devi, 2009; Lalah et al., 2018). Exposure to pesticides can result in both acute and chronic health effects which include acute neurotoxicity, lung damage, respiratory failure, male infertility and cancer (Ohayo-Mitoko et al., 2000; Martin et al., 2002; Alavanja et al., 2004; UNEP/WHO, 2012; Gangemi et al., 2016).

Pesticide contamination and occupational exposure have been singled out as major environmental problems in agriculture globally (Helfrich et al., 2009; Leete, 2001); Akan et.al., 2013). The major health problems arising from usage of pesticides are the acute and sub-acute poisonings which result from repeated exposures during their application. Several previous studies have been conducted which illustrate reported cases of pesticide misuse and mishandling in horticultural farming and subsequent impacts of pesticides on human health through occupational exposure. A study conducted in Naivasha in Kenya through a survey involving 801 respondents, which included farm workers and non-farm workers, found high numbers of symptoms of pesticide exposure in farm workers and recommended training of planters, sprayers, weeders, and harvestors (Tsimbiri et al., 2015), as a remedy. In the same study, fewer numbers of symptoms were found among trained sprayers. Another study in Kenya which involved assessment of blood acetyl cholinesterase levels of farm workers, the knowledge, perceptions, and practices of farm workers were found to influence the extent of occupational exposure and poisoning (Ohayo-Mitoko et al., 2000). In Nigeria, Banjo et al. (2003) studied farmers' knowledge and perceptions towards pesticide usage in tomato farming and determined the types of pesticides used and application methods. They found that 86% of the farmers used pesticides without protective devices due to lack of education, awareness and involvement of agricultural extension workers, respectively (Banjo et al., 2003). In Tanzania, in a farm where small holder farmers grew vegetables including tomatoes, cabbages and onions, using pesticides, farmers' perceptions, practices and health effects were investigated, and various types of pesticides were found to be used including insecticides (59%), fungicides (29%) herbicides (10%), and rodenticides (2%) (Ngowi et al., 2007). In the same study, 68% of the workers reported that they felt sick with related health symptoms including skin problems and neurological problems such as dizziness and headaches, after routine applications, and spent a significant percentage of their incomes on treatment. Other more recent studies in Tanzania (Karianthi et al., 2016), Nepal (Khanal and Singh, 2016), Mali and Cote d'Ivoire (Abang et al., 2013; Ajayi et al., 2002; Ajayi et al., 2011) and Cameroon (Abang et al., 2013) and, earlier, in India (Bhanti et al., 2004), have also reported health impacts on farmers due to improper usage of pesticides. The occupational exposure of humans to pesticides has therefore been studied widely and a consistent pattern of adverse effects of pesticides on farmers including the impairment of farmers' health, has been reported (Wilson, 2005; Macharia, 2015; Tsimbiri et al., 2015); but the scenario in developing countries e.g. Africa, does not seem to have changed despite existence of government regulations on pesticide use. Exposure to pesticides can result in both acute and chronic health effects which include acute neurotoxicity, lung damage, respiratory failure, male infertility and cancer (Davies, 1990; Ohayo-Mitoko et al., 2000; Martin et al., 2002; Alavanja et al., 2004; UNEP/WHO, 2012; Gangemi et al., 2016).

Agriculture remains the most important economic activity in Kenya, despite only 10.2% of the total land cover being arable (GoK, 2017). It contributes on average 27% of the country's GDP, and absorbs about 80% of the country's workforce that is engaged in farming and food processing. To achieve this production in the agricultural sector, pesticides have played a significant role. On average 12,983 tonnes of pesticides are imported in to the country annually, in various forms including insecticides (27%), fungicides (45%), herbicides (14%), and other products such as acaricides, fumigants, plant growth regulators, miticides and biocontrol agents (14%) (Figure 1), with a total value of KSh. 10.7 billion (approximately 100 million US$) (Birech et al., 2006; PCPB, 2012). The Pest Control Products Act CAP 346 of 1983 which came into law in 1983, regulates the manufacture, distribution, sale, safe use and disposal of pesticides in Kenya (PCPB, 2005). This regulation is implemented by the Pest Control Products Board (PCPB), which is responsible for informing the industry, the government and the general public on the authorized usage of crop protection products (PCPB, 2008). It has registered over 1000 pest control products for use in agriculture, animal health and public health (Leete, 2001; PCPB, 2010), with approximately 70–100 new products being registered annually (PCPB, 2008). More than eleven firms are involved in manufacturing and distribution of various pesticide products in the country (PCPB 2008). The PCPB regulations also cover microbial bio-pesticides which have recently found a ready market, especially in the horticultural sector (Ngaruiya, 2003; PCPB, 2008). The flow of such a large variety of pesticides in the economy is difficult to regulate. Pesticide use in Kenya therefore faces many drawbacks, ranging from reported cases of misuse, mishandling, illegal importation, occupational exposure, concerns of environmental and water quality and, sometimes, criticism from consumers for fear of human health impacts resulting from food contamination with pesticide residues Figure 1.

1.2. The study area and justification of the study

Meru County which is the site for this study is well known for agriculture, in particular, horticultural crop production (HCDA, 2009/2013). It produces various types of horticultural produce including tomatoes, French beans, tomatoes, kales and French peas, for large local markets like Nairobi as well as for export. The use of pesticides is therefore critical

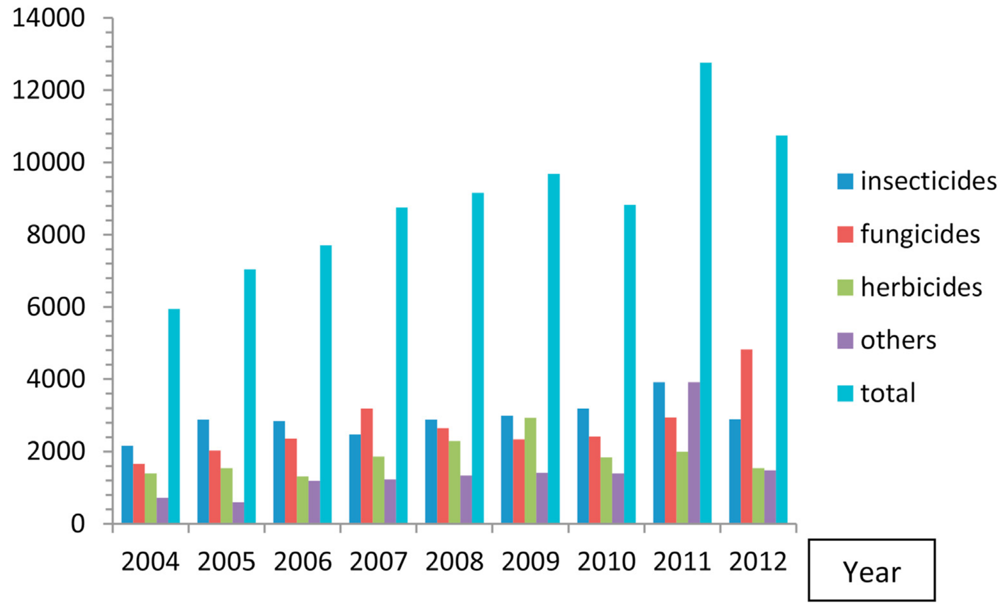

Figure 1. Annual (2004–2012) imports of pesticides (in tonnes). *Note: Others include acaricides, fumigants, plant growth regulators, mitigants, and other biocontrol agents.*

in this county, where various types of pesticides are applied in large scale and small scale farming ventures. Meru County is part of the Mount Kenya region that consumes more than 50% of all pesticides sold for agriculture in Kenya (PCPB, 2018). It has a population of 1,601,629 people (KNBS, 2013) and is among the fastest developing towns in Kenya (Jolicoeur, 2000). This growth is associated with rising number of vegetable and flower farming businesses, for example in the three sub-counties which have been selected for this study. However the status of pesticide usage and their impacts on farmers through occupational exposure which can result from lack of knowledge and education and awareness, and subsequently leading to misuse when handling, have not been studied. This research is therefore important because it has generated new information on pesticide usage and impacts on farmers in Imenti North, Imenti South and Buuri Sub-counties in Meru County in Kenya, and because pesticide use and handling has significant international implications on human health and world food trade. The objectives of the study were: to establish the types of pesticides used and handling practices by farmers; to assess the knowledge, perceptions and practices of the agricultural extension workers (AEW) and healthcare workers (HCW); and to document symptoms of pesticide poisoning caused through occupational exposure. Using the data, the authors wanted to document the prevalence of reported pesticide intoxication and demographic variables and show how the population demographic variables (including education level, financial borrowing potential, income, farm size, hired labour, and number of protective clothing) were associated either positively or negatively with the documented outcome of pesticide intoxication (HCDA, 2013)

2. Material and methods

2.1. Sampling area

The study was conducted in Meru County, which is found in the eastern region of Kenya, approximately 225 km northeast of Nairobi. Meru County has a total area of 6,936 km^2 (Chiramba et al., 2011). The county, which is located near the foot of Mount Kenya, lies within latitude 0.0515° N and longitude 37.6456° at an altitude of 5,300 feet above the sea level. Figure 2 shows the map of Meru County, with sampling sites, which represent clusters of farming households, in Buuri, Imenti South and Imenti North, indicated in red Figure 2.

2.2. Methods for field survey

2.2.1. Distribution of questionnaire

Information on the pesticides commonly used in the study area, pesticide usage practices, indicators of occupational exposure, and health impacts of pesticides on the users was obtained through questionnaire distributed to randomly selected farmers' households, area agricultural extension workers (AEW) and health care workers (HCW), respectively. The survey was done using a stratified random sampling technique where the three sub-counties were targeted by ensuring appropriate distribution, to get impartial and accurate data. Close-ended questions were used to elicit clear responses from the farmers according to the objectives of the study. A confidence interval of 95% (α = 0.05, margin of error) was considered giving a corresponding confidence level score of 1.96. A distribution of 80% (0.8) was used according to Ohayo-Mitoko (1997), Godden (2004) and Levy and Lemeshow (2008) to obtain a sample size using the formula,

$$ss = \frac{z^2 \text{x } p(1-p)}{c^2}$$

where: ss = sample size, z = z value (in this case 1.96 for 95% confidence interval level), p = percentage of selecting respondents expressed as decimal, i.e. 80% (0.8), c = confidence interval, expressed as decimal (0.05).

A sample size of 246 was determined but was increased to 316 to accommodate AEW and HCW (Levy and Lemeshow, 2008). Questionnaires were distributed to a total of 316 respondents, including 173 farmers' households, 70 HCW and 73 AEW. The survey on the status of the farmers, their perception, education and health effects from occupational exposure was achieved by distributing structured questionnaire to a total of 173 respondents chosen randomly in North Imenti, South Imenti and Buuri. The questionnaire consisted of targeted questions, divided into three (3) sections, representing farmers, AEW and HCW. Information was obtained on gender, age, main occupation, and level of education of the respondents. Other information collected was on the types of pesticides used and safety information, training on the use and mixing of pesticides, pesticides related accidents and their frequencies, any known effects of pesticides to the users, labeling of pesticides, sources of the pesticides and any technical assistance received from AEW. The questions also covered awareness on safe handling of pesticides and

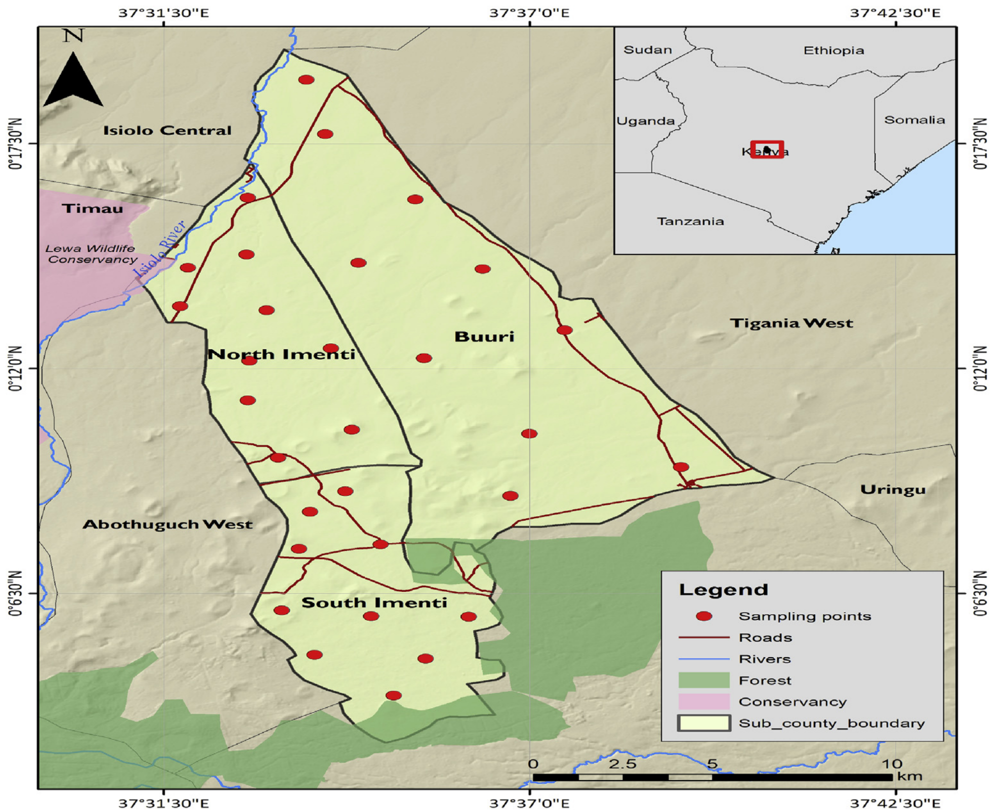

Figure 2. Meru County, Kenya, showing the sampling sites.

stocking of pesticides within the area. The copies of the questionnaire were submitted as supplemental material.

The survey responses were divided into three categories based on questionnaire given to households, agricultural extension workers and health care workers, respectively, in the three study sites in Buuri, Imenti North and Imenti South sub-counties. The household questionnaire covered age, gender, marital status, education background, farming experience (number of years the respondent was involved in farming), off-farming activities (keeping and sale of animals, permanent employment, gross income and values of the animals), financial assets, credit facilities available, source of information on pesticides, prior training on pesticide usage, sickness from pesticide usage and the types of pesticides used at the time of sickness and which social groups the respondent belonged to, respectively. The same questions also applied to the AEW and the HCW, except that in each of these two categories of respondents, questions that targeted their specific experiences in their respective professions were also asked as presented in this section. For the AEW such questions targeted information on pesticide handling procedures including labelling, protective clothing, storage, mixing, application rates, disposal, specific pesticides dealt with, the corresponding poisoning incidences experienced from exposure, and education and awareness on pesticides and pesticide handling. For the HCW, the questions targeted responses including cases and symptoms of pesticide poisoning, types of pesticides involved and ability to offer first aid against poisoning, among others. The results are summarized and discussed in the following sections.

This research was part of a PhD research project and subsequently the methods adopted were vetted and passed by the post-graduate research committees of the university. Permission was given by NACOSTI (National Commission for Science, Technology and Innovation) Permit No. NACOSTI/P/18/0411/23769. Since no human specimens, such as blood and urine were taken, and no human specimen testing was involved, the proposal was not required to pass through a medical ethical committee. However, each participant (the interviewee) was inducted prior to the survey and each gave a consent indicating that he/she was willing to freely volunteer the information without being coerced. The researcher together with six research assistants were involved in the distribution and collection of the questionnaire. A pre-trial was conducted whereby the researcher and the research assistants visited the selected farmers' homes, the AEW and the HCW, to inform them of the nature of the research and types of responses required. The survey was conducted between March and May 2016, during the heavy rains season (KMD, 2013), when farming activities were at the peak.

2.2.2. Data analysis

For the farmers, the data were arranged into three sets, representing the three sub counties, respectively. SPSS statistical software was used to analyze the raw data. The responses from the AEW and HCW from each of the three sub counties were pooled and analyzed as two sets, respectively. Frequencies were conducted to determine the Descriptive statistics whereas Non Parametric Independent-Samples Mann-Whitney U Test and Kruskal-Wallis H tests were conducted to establish significant statistical questionnaire responses with $P \leq 0.05$. The statistical data obtained were submitted as supplemental material.

3. Results and discussion

3.1. Survey reports

For the household questionnaire, the sample distribution of responses received back, per sub-county was, Imenti South (49 respondents; 28%); Imenti North (65; 38%), Buuri (54; 31%) and unspecified (5; 3%).

3.1.1. Health effects and expenditure on chemicals

The survey established that overall 26% of households had experienced some level of intoxication from pesticides in the past 3 years.

Respondents from Imenti south were the least affected (8%) compared with Imenti North which had the highest level of intoxication at 57% (Table 1).

It was found that household heads and family members involved in pesticide application in all the three sub-counties who used mainly (with >12 respondents) dimethoate, malathion, heptachlor, endrin, dursban (chlorpyrifos), parathion and dieldrin, experienced higher levels of health effects, with less health effects reported when using plantvax 20 EC (oxycarboxin fungicide), dithane M45 (mancozeb, a fungicide), esfenvalerate, gramoxone (paraquat), lybacid (fenthion), methomyl and p,p'-DDT, in the three sub-counties (Table 2). The health effects and sicknesses experienced by pesticide applicators are recorded in Table 1 (Table 1). The farmers also reported applying certain formulations such as decis (deltamethrin), bullock (beta-cyfluthrin), fasta C (alpha-cypermethrin) and penncozeb (mancozeb) as well, but did not experience any poisoning symptoms. The results indicated that they experienced nearly the same level of poisoning in terms of percentages in all the three sub counties from usage of the pesticides in 2015 (Table 1).

The results indicated that they spent various amounts of money to purchase pesticides in 2015 as shown in Table 1. More than half (54%) of

Table 1. Varied responses related to pesticide use and exposure.

	Total		Imenti South		Imenti North		Buuri	
Average household expenditure on pesticides:								
<KSh. 2,000	93	54%	36	73%	23	35%	31	57%
KSh. 2,001–4,500	28	16%	7	14%	13	20%	8	15%
KSh. 4,501–9,000	22	13%	3	6%	12	18%	7	13%
KSh. 9,001–15,000	16	9%	3	6%	7	11%	5	9%
>Ksh. 15,000	14	8%	0	0%	10	15%	3	6%
Sources of information on pesticide usage:								
Extension service		59%		47%		72%		56%
Neighbours		24%		12%		28%		24%
Pesticide retailers		39%		45%		38%		37%
Salesmen from companies		24%		12%		35%		20%
Pesticide labels		38%		49%		37%		30%
TV/Radio		39%		22%		54%		41%
Experience		14%		14%		15%		11%
Other sources		1%		0%		3%		0%
Not specified		6%		6%		3%		9%
Types of symptoms of pesticide poisoning in affected farmers:								
Headache		95%		88%		96%		98%
Sneezing		98%		92%		100%		98%
Vomiting		95%		88%		94%		98%
Stomach ache		97%		92%		96%		100%
Back ache		95%		88%		94%		98%
Skin rash		96%		96%		96%		96%
Dizziness		96%		88%		98%		98%
Blurred vision		95%		88%		94%		98%
Diarrhoea		96%		88%		96%		100%
Eye irritation		98%		100%		98%		98%
other		91%		88%		89%		96%
Other methods used by farmers to protect crops:								
Total responding		86		20		39		23
Bio pesticides		12%		5%		13%		13%
Plant extracts		22%		15%		15%		43%
Concoctions		6%		0%		5%		4%
Hand picking		60%		30%		90%		43%
Physical killing		64%		55%		79%		43%
More than 1of these types		6%		10%		8%		0%
Others (specify)		24%		55%		8%		26%
Kinds of social groups households belonged to:								
Farmers' group				45%		56%		44%
Rotating credit association				32%		20%		25%
Burial society				3%		0%		3%
Village committees				5%		4%		0%
Clan family				0%		4%		3%
Trader association				0%		0%		0%
Religious group				0%		0%		0%
Water project				11%		12%		19%
other				5%		4%		6%

Note: 'Rotating credit association' is also known as 'Mary-go-Round'.

households (93) that responded spent less than KSh. 2,000 ($ 20) on purchase of pesticides. This data indicates that there were varying sizes of the farms and different categories of the farmers that were interviewed. This ranged from subsistence farms (with < Ksh. 2,000 expenditure on pesticides) up to large scale commercial farms (with expenditure on pesticides > Ksh. 15,000 KSh). More of the farmers in Imenti South (73% of respondents from Imenti South) were subsistence farmers, compared with 35% and 57% from Imenti North and Buuri, respectively. Compared to previous years, the expenditure on pesticides during the season 2015, had increased (83% of respondents). Other farmers reported that the expenditure on pesticides remained the same (10%) and decreased (4%), respectively.

The types of pesticides used and the health effects experienced by farmers following their application, as found in our study were similar to those reported in other studies that have been done in other countries, especially those done in Tanzania (Ngowi et al., 2007; Karianthi et al., 2016).

3.1.2. Training on pesticide use and use of protective clothing

Only 31% of the farmers had received training on application of pesticides (data not shown). However the proportion of those who had received training was higher (45%) in Imenti South than the other two sub-counties. In all households, it was the head of the household who made decisions about the use of pesticide at the household farm level. In most instances it was the field extension officers who provided information on the quality and quantity of pesticides to be used, as shown in Table 1. A greater proportion in Imenti South (49%) relied on pesticide labels, whereas 72% (Imenti North), 56% (Buuri) and 47% (Imenti South), respectively, relied on AEW extension service. Pesticide retailers were also significant as a source of information to farmers, 45% (Imenti South), 38% (Imenti North) and 37% (Buuri (Table 1)). Although the level of education of farmers and source of information was fair enough and the AEW were available, pesticide use regulations were still flouted and some applicators still did not own or use protective clothing, exposing themselves to high risks of pesticide poisoning. High costs of pesticides can also deter sufficient application of pesticides in farming by controlling the amounts purchased.

Households mainly preferred other non chemical methods because of risk evasion and high cost of pesticides (data not shown). Lack of enough knowledge about pesticide usage was also a contributing factor. All farmers using chemicals applied different crop protection practices in the dry and rainy seasons. Approximately 86 households (49%) out of 173 interviewed used other methods than pesticides, to protect their crops from pests and diseases (Table 1). Apart from pesticide application, the most commonly used other methods were physical killing and hand picking.

In some households especially in Imenti South and North, farmers did not own any protective clothing of any form. The mean ownership of protective clothing was 2 (per capita) in Imenti North and 3 each in Imenti South and Buuri, respectively. Maximum number of protective clothing in Buuri was high (7) compared to imenti south (5). All farmers in Buuri owned at least one protective clothing. Lack of adherence to protective clothing when handling and applying pesticides on the farm is a gross misconduct of pesticide safety protocols which emphasize use of protective clothing including hand gloves, goggles, overalls and boots.

The statistical analysis results indicated that there is a statistically significant association between the prices of protective clothing ($Z = 2.515$ $P \leq 0.012$), number of protective clothing ($Z = -4.225$, $p \leq 0.012$), respectively, and intoxication of the pesticide users; and the size of family and hired labour ($Z = -2.597$, $p \leq 0.009$) and intoxication of the pesticide

Table 2. List of pesticides reported by farmers to have caused poisoning.

Trade name/formulation reported	Common name/active ingredient-	No of respondents	%
Heptachlor	Heptachlor	15	7.7
Dieldrin	Dieldrin	15	7.7
Furadan; carbofuran	Carbofuran	13	6.7
Malathion	Malathion	13	6.7
Dimethoate; ogor	Dimethoate	13	6.7
Endrin	Endrin	12	6.2
Dursban; chlorpyrifos	Chlorpyrifos	12	6.2
Parathion	Parathion	12	6.2
Dithane M45; zencob	Mancozeb	11	5.7
Diazinon	Diazinon	10	5.2
Cypermethrin	Cypermethrin	8	4.1
Deltamethrin	Deltamethrin	8	4.1
Karate; thunder; Icon 62G	λ-cyhalothrin	8	4.1
Endosulfan; endosulfan sulphate	Endosulfan	6	3.1
Methoxychlor	Methoxychlor	5	2.6
Aldrin	Aldrin	5	2.6
Carbaryl	Carbaryl	5	2.6
Plantvax 20EC	oxycarboxin	4	2.1
Dithane M45	mancozeb	4	2.1
Propoxur	Propoxur	3	1.5
p,p'- DDT	p,p'- DDT	3	1.5
Round up	glyphosate	3	1.5
Omyl, methomyl	methomyl	3	1.5
Gramoxone	paraquat	2	1.0
Esfenvalerate	Esfenvalerate	1	1.0
Doom spray	phenothrin; pyrethroids	1	1.0
Lybacid	fenthion	1	1.0
Triatix	Amitraz/piperonyl butoxide/deltamethrin	1	1.0
Red cat	brodifacoum; zinc/aluminium phosphide	1	1.0

Note: The number of respondents (answered the question) was 45 out of 173.

users. The results similarly showed significant association between cost per package size of pesticides purchased ($Z = -2.404$, $p \leq 0.016$), expenditure on health during the last season ($Z = 3.060$, $p \leq 0.002$), the number of pumps sprayed in the farms ($Z = 3.579$, $p \leq 0.004$), respectively, and the intoxication of the pesticide users. It, therefore, means that a few of these areas that registered significant association need to be improved in order to safeguard the health of those persons handling pesticides from time to time. In particular, protective clothing, pumps and labour costs have implications on efficient pesticide use and reduction of level of intoxication from pesticide exposure in these sub-counties. The affordability of protective clothing, application pumps and hired labour needs to be addressed, e.g. by advising farmers to take loans for them after explaining the significance of safe use of pesticides.

Majority of respondents from Imenti South (71%) and Buuri (61%) had provision for separate storage for pesticides and the equipment (Figure 3). However, only 68% in Imenti North kept pesticides and equipments in the same houses they lived in. About 21% of the total respondents smoked regularly. The average years the farmers had smoked were 20 in Imenti south, 17 in Buuri and 8 in Imenti North (data not shown). Habits such as keeping chemicals inside residential houses expose farmers and their households to pesticide fumes or vapours and should be completely discouraged. In addition, smoking could exacerbate intoxication or poisoning effects on occupationally exposed farmers.

Although the majority of the farmers (65%) understood the labelling on pesticide packages (data not shown), most pesticide applicators (60%) did not use suitable protective gears in accordance with the labelling instructions when applying pesticides. Imenti South had the least farmers who did not understand labels on pesticide packaging. However, in terms of individual sub-counties, 57% in Imenti South and 44% of the respondents in Buuri were equipped with suitable protective gears when applying pesticides. The reasons given by all respondents for non usage of protective clothing ranged from, lack of money to buy (40%), feeling uncomfortable (38%), not suitable for local condition (27%), and unnecessary (20%) (data not shown). The farmers therefore reported 'lack of money and discomfort while wearing the clothes' as the main reasons for not using protective gears. This lack of adherence to protective clothing when applying pesticides was a gross violation of safe handling procedures and exposed farmers to hazardous compounds through contact, inhalation and/or ingestion. This is dangerous in cases of acute poisoning as well as long term exposure.

However, approximately 99% of the respondents had access to health services. Average distance to nearest health facility was 2.9 km in Imenti South, 3.3 km in Imenti North and 3.7 km in Buuri sub county. The furthest was 30 km in Buuri, 25 km in Imenti North and 18 Km in Imenti South. Most (79%) of the respondents had members who had visited health facilities for treatment of various ailments in the past season due to pesticide exposure, with mean expenditures for treatment ranging from KSh. 5,528 in Buuri, KSh. 7,041 in Imenti North and KSh. 7,770 in Imenti South. Although over 63% of the households lacked basic training in First Aids skills, they had easy access to health facilities and could afford to pay for treatment of pesticide-related symptoms.

Of all the respondents, pesticides were mainly applied by the household heads (57%) followed by spouses (26%) and male child (9%). Very few households (9%) sought the services of qualified technicians in the application of pesticides. However a significant proportion in Imenti South (18%) used services of technicians to apply pesticides, and therefore the concerns of occupational exposure affected not only farmers but also hired workers. Of all respondents, most farmers (67%) bought pesticides from the stockists (agrovet shops), 76% in Imenti South, 69% in Buuri and 57% in Imenti North. Another significant proportion (13%) recycled the old stocks, while 10% obtained from local open markets and 4% from friends. The incidences of leakages while spraying was rampant in Imenti North (52%) and lowest in Imenti South (9%) while usage of cocktail of chemicals was high in Imenti South (80%) and lowest in Imenti North (28%). Pesticides were mainly applied during the morning (60%), 39% during lunch and 11% in the afternoon. Usage in the morning was rated very high in Imenti South compared to the other areas. Most farmers preferred to apply pesticides during sunny weather (data not shown). Safety regulations recommend application in the morning when the weather is drier and cooler.

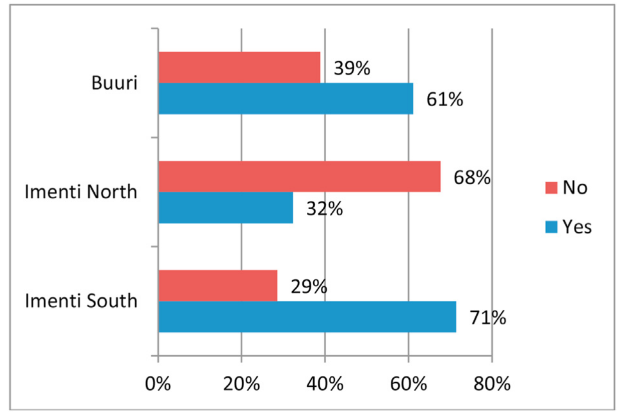

Figure 3. Separate storage for pesticides and the equipments.

The statistical analysis test showed that pesticide intoxication of a family member who sprayed was significantly affected by the extent of the land size in acres ($p \leq 0.001$), amount of money spent in pesticides ($p \leq 0.012$) leading to a significantly higher overall seasonal expenditure on health ($p \leq 0.000$). This relationship supports the fact that in large scale farms, pesticides were used more frequently as the farmers of such farms could afford to buy higher quantities of pesticides, compared with smaller subsistence farms. Subsequently there was more exposure and chances of intoxication in large farms which made them spend more on health. However, the test also showed that the source of water used did not significantly affect family member who sprayed since asymptotic values 0.229 and 0.173 were greater than the set $p < 0.05$.

In most cases it was the son who had been intoxicated more compared to any other member of the household, although most frequent applicators within the households were found to be farmers. This was manly evident in Imenti North and Buuri. Pesticide application in Imenti South was mainly done by the head of the household (fathers) and the spouses. Both types of applicators (father or mother) had been affected by exposure. The health effects of all respondents were evaluated and it was found that in the households, the respondents affected were fathers (36%), spouses (19%) and sons (44%), with 100% of the fathers and spouses who applied pesticides in Imenti South being affected. Those who used pesticides, 40% and 20% of the fathers in Imenti North and Buuri, respectively, were affected by pesticides. For the wives involved in pesticide application, 100% (Imenti South), 16% (Imenti North) and 20% (Buuri) were affected due to pesticide exposure.

Making a comparison with other studies, lack of adherence to pesticide use and handling regulations such as failure to wear protective clothing while applying pesticides was also found in a study done in Nigeria (Banjo et al., 2003) and this was reported to be due to lack of education and AEW. In our study, however, lack of wearing of protective clothing when using pesticides could not be explained by lack of education and awareness since the general level of education and awareness and availability of the AEW was significantly high in our study.

3.1.3. Household questionnaire

A total of 173 household questionnaires were administered in the three sub-counties. Most of the respondents were over 30 years of age with those up to 15 years (1%), 16–30 years (8%), 31–45 years (32%), 46–60 years (39%) and >60 years (21%) (data not shown). The marital status of the respondents was distributed, with 87 per cent of the respondents being married and others were divorced (4%), separated (4%), single (3 %) and widowed (2%).

The education background of the farmers was tabulated and it was found that most farmers (62%) had attained secondary or post-secondary education level while 29% had primary education (data not shown). Illiterate respondents were only 9%. More than half (56%) of the total respondents hired/employed farm workers to assist them; this varied by each sub-county i.e. 67% in Imenti North, 57% in Buuri and 46% in Imenti South. The workers were hired depending on the nature of work to be done either on a piece-work, daily or monthly basis. Of the hired farm workers, 3 % were casual labourers and 2% were artisans involved in off –farm activities.

About 52% of the farmers were involved in food crops production while those involved in cash crop production and livestock were 29% and 12%, respectively. Most respondents (74 %) had farming experience below 30 years, distributed as, up to 5 years farming experience (10%), 6–10 years (16%), 11–15 years (13%), 16–20 years (17%), 26–30 years (11%) and >30 years (8%). There was nearly an equal distribution of respondents in terms of years of experience in farming. The study was thus not biased in terms of experience since both extremes i.e. it covered experienced farmers and noviciates. Majority (60 %) relied on rain-fed agriculture while 10% relied on irrigation. About 29% applied both rain-fed technology and irrigation in the production system.

The responses were significantly important because they clearly indicated that even though the farmers had a fair education level and knowledge of safe use of pesticides such as use of protective clothing, reading the labels and following the protocols, regulations on safe use, in particular, wearing protective clothing, hand gloves and eye goggles, were not followed during application. A large proportion of farmers (46–67%) had hired labourers to help them on the farms but, this could indicate that they had failed to provide for or enforce use of protective clothing to them. The survey also established that farmers involved in crop farming were more likely to be exposed to pesticides and get intoxicated or poisoned than those involved in livestock production. The proportion of members involved in farming in the past 12 months in each household were 66% (1–2 people in the house hold), 19% (3- people in the household), while 14% did not specify how many people were involved in farming in their households in the past 12 months (data not shown).

Among those involved in work on household's land, 29% worked as full time farmers, 22 % (partly farming, but were professionals involved in other employment), 27% (as skilled labourers), and 22% (as unskilled labourers). They were mainly engaged as contract workers (46%), permanent employees (31%) and daily workers (23%), and therefore a significant number (79%) were less likely to experience continued long term exposure to pesticides even if they might not have been as careful in handling pesticides compared to the permanent employees (31%). Skilled labourers were mainly permanent employees on the farms while off-farm workers were mainly engaged in other activities on a daily basis. The main employers of unskilled farm workers were small scale farmers (46%), government employees involved in farming as well (14%) and commercial or large estate farms (12%). Urban dwellers and NGOs involved in farming were 8% and 3%, respectively. Industrial crops such as coffee, tea, and cotton as well as horticulture (fruits and vegetables) were the main enterprises where small scale farmers were involved. These were the farming activities where pesticides were intensively used.

Access to the market was also evaluated (data not shown). The median time it took farmers in Buuri was 23 min and 30 min in Imenti north and Imenti south to deliver their produce to a market point. Overall, it took farmers a maximum of 150 min and a minimum of 10 min to access the market points from the farms. The average walking time was just 27 min in Buuri, 30 min in Imenti south and 38 min in Imenti North, to reach the market. Most farmers in Imenti south used an average of 15 min to access nearby towns or markets.

3.1.4. Contact with agricultural extension officers, social groups and social assets of respondents

Table 1 shows that most farmers had contacts with agricultural extension workers (AEW) to get advice in the past 12 months in all the areas, i.e. 74% (Buuri), 74% (Imenti North) and 84% (Imenti South). This easy access to AEW could have contributed in adoption of proper procedures of pesticide application, but this contribution was not reflected as there was lack of adherence to rules of safe pesticide use generally. Other farmers got information from neighbours, pesticide retailers (vet shops), company salesmen, labels and TV or radio. Farmers also belonged to various social groups from which they could obtain information on pesticides. Overall, nearly 60% of the farmers belonged to a social group (i.e. excluding family/clan association) (Table 1), with 92% belonging to social groups in Imenti North, 85% in Imenti South and 83% in Buuri. The table (Table 1) shows that most households belonged to the most common social groups, i.e. Farmers group, Rotating (merry-go-round) savings and credit associations and water project group, respectively. These social groups could play a role in education and awareness as well as financial ability of the farmers. A few also belonged to burial society, village committees and family clan associations.

In addition, most farmers (data not shown) in the three sub-counties also belonged to credit organizations i.e. Sacco (38% Imenti South; 50% Imenti North; and 38% Buuri), Commercial banks (13% in Imenti South; 10% Buuri; 0% in Imenti North), microfinance institution (22% Imenti South; 5% Imenti North; 7% Buuri), and credit services groups (28% Imenti South; 45% Imenti North; 45% Buuri) and therefore had access to credit facilities. Approximately 49% of the total respondents had received credit services during the past 2 years. This indicated that most farmers had access to information through social contacts and a good number of them also saved and had access to credit facilities to enable them buy pesticides and related products or visit health facilities whenever necessary.

The farmers responded to questions on where they had received information on pesticide use, with responses being extension workers, other farmers, stockists, NGOs, media neighbours, pesticide retailers, health care workers, newspapers, radio, internet, as well as specific organizations such as KEPHIS, AAK and PCPB (Table 1). About 61% of the small scale farmers knew when to apply pesticides and 57% responded that pesticide poisoning is a problem in the community. Most AEW (84%) reported that they had advised the farmers on dangers associated with pesticides.

3.2. Health care workers (HCW) and agricultural extension workers (AEW)

Seventy (70) HCW, 32 female and 38 male and seventy three (73) AEW, 32 female and 41 male, were covered by the survey. The HCW had an average age of 42 for female and 45 for male and the AEW had an average age of 41 for female and 45 for male, with age ranging from 28-52 for female and 29–59 for males. Most of the 70 HCW (70%) had either certificate (13%), diploma (24%) or degree (7%) level of tertiary education in public health. Of the 73 AEW, 71% had attained either, a certificate (16%), a diploma (38%), or a degree (16%) level of tertiary education, and the rest were form four leavers (29%). In terms of specialization, the AEW had either a certificate in agriculture (16%), a diploma in agricultural education/agriculture/horticulture (38%), or a degree in horticulture/agriculture (16%). These AEW worked as animal health officers (22%) and agricultural extension officers (78%), with working experience ranging from 4- 26 years. They were mostly trained in agriculture and horticulture, and had dealt with pesticides (95%) in their work, with 84% reporting having offered advice on pesticide usage to farmers. The number and the qualifications of the AEW and HCW in the three sub counties were therefore reasonably sufficient to provide services to the farmers, including information and demonstrations on pesticide use as well as interpretation of regulations and government policies on pesticides. Eighty three 83% of them were able to provide a list of pesticides they had dealt with during their extension work. The list included acaricides, dewormers, insecticides, miticides, rodenticides, and herbicides (Table 3). The recorded number of pesticides that the AEW dealt with during their service to farmers corroborated with information on pesticides used by farmers (Table 5), except that the AEW reported having advised on or dealt with other formulations which were not reported by farmers, including actara (thiamethoxam), bullock/bulldock (β-cyfluthrin), sumicidin (fenvalerate), confidor (imidacloprid), aldrin, p,p'-DDT, chlordane, lindane, grammoxone (paraquat), copper oxychloride fungicide and abamectin.

The AEW explained their roles in their responses which included; advising on handling of pesticides and/or application rates; advising on wearing personal protective clothing; giving demonstrations on how to spray; giving information on pre-harvest intervals; advising on where to buy the pesticides and how to store them. Other roles were: giving information on de-worming, pesticide labels, mixing protocols, banned pesticides; poisoning and disposal of pesticides.

The HCW provided information on pesticides involved in poisoning (Table 4) through occupational exposure based on records of those cases they had handled previously. The list of pesticides generated from the HCW information corroborated the types of pesticides reported by farmers to have caused poisoning (Table 2). About 71% of HCW reported that they knew first procedures for handling poisoning involving pesticides.

Table 3. List of pesticides that AEW dealt with during service to farmers.

Trade name/formulation reported	Common name/active ingredient	No of respondents	%
Fungicides	Not specified	14	23.0
Dewormers	Not specified	14	23.0
Insecticides	Not specified	13	21.3
Acaricides	Not specified	13	21.3
Herbicides	Not specified	12	19.7
Miticides	Not specified	10	16.4
Nematicides	Not specified	8	13.1
Rodenticides	Not specified	1	1.6
Karate; thunder; Duduthrin	λ-cyhalothrin	24	39.3
Dursban; chlorpyrifos	chlorpyrifos	14	23.0
Victory; dithane; ridomyl	mancozeb/metalaxyl	12	19.7
Methomax; omyl; agrinate	methomyl	10	16.4
Decis; vectocid; deltamethrin	deltamethrin	9	14.8
Dimethoate; ogor	dimethoate	9	14.8
Malathion	malathion	8	13.1
Round up	glyphosate	6	9.8
Bullock; bulldock	β-cyfluthrin	5	8.2
Gramoxone	paraquat	5	8.2
Actelic	pirimiphos methyl	4	6.6
Diazinon	diazinon	4	6.6
Dieldrin	dieldrin	4	6.6
Heptachlor	heptachlor	4	6.6
Bestox; cypermethrin	cypermethrin	3	4.9
Parathion	parathion	3	4.9
Methoxychlor	methoxychlor	3	4.9
Ectopal	dogalact (steroid)	3	4.9
Esfenvalerate	esfenvalerate	3	4.9
Copper fungicide	copper oxychloride	3	4.9
Actara	Thiamethoxam	2	3.3
Aldrin	aldrin	2	3.3
Endrin	endrin	2	3.3
Lindane	lindane	2	3.3
Confidor	imidacloprid	2	3.3
Sumicidine	fenvalerate	1	1.6
Chlordane	chlordane	1	1.6
Endosulfan	endosulfan	1	1.6
Abemectin	abemectin	1	1.6
p,p'-DDT	p,p'-DDT	1	1.6
Summithion	fenitrothion/esfenvalerate	1	1.6

Note: 61 respondents (answered the question) out of 73.

3.3. Types of pesticides used by farmers

Table 5 shows the list of pesticides used by farmers in three sub counties of Meru County, as established from the survey of 173 farmers. Their frequencies of use by respondents/farmers, and their WHO toxicity ranking data are also shown in the table. Nine of these pesticides, including parathion, methomyl, endosulfan, endrin, dieldrin, methoxychlor, heptachlor epoxide, carbofuran and endosulfan sulphate are very toxic (WHO class I) and require adherence to procedures of pesticide safe handling, while 12 are toxic (WHO class II) and 5 are moderately toxic (WHO class III). Fifteen (15) of them are very lipophilic (Log $K_{ow} > 4$) and therefore have great potential to bio-accumulate in the food chain as well as persist in the environment (Extoxnet, 1995).

There were other types of unspecified pesticides that were reported by farmers and agricultural extension workers as being used in Meru County including biopesticides, dewormers for cattle, and plant extracts. The more frequently (>60 respondents) used pesticides by farmers in the three sub counties included parathion, diazinon, dimethoate, permethrin, actelic (pirimiphos methyl), carbaryl, endrin, dieldrin, deltamethrin, propoxur and endosulfan. From the list of pesticides used by farmers (Table 5), organochlorines (×7), pyrethroids (×7) and organophosphate (×6) pesticides were the main classes of pesticides used, followed by carbamates (×4), and fungicides (×2). Other frequently used pesticides were ortho (a.i. bifenthrin), furadan (a.i. carbofuran), endosulfan sulphate, delta mectnin (a.i. zeta-cypermethrin), methoxychlor and cypermethrin. Some organochlorines (endrin, dieldrin, heptachlor), organophosphate (parathion) and carbamate (carbofuran/furadan) reported to be frequently pesticides by farmers, have been banned in Kenya (PCPB, 2010; Otieno et al., 2010) and globally in response to UN convention on POPs (UNEP, 2017). This implies that these banned organochlorines were either still being sold to farmers or recycled as old stock and/or were being used illegally by farmers in the three sub counties. The finding therefore shows that there was a gap between current government pesticide regulation policies and enforcement of policies and implementation authorities, agrochemical dealers and farmers. The toxicity ranges for the pesticides reported by farmers, showed that they were very toxic (most in the WHO Class I and II) to mammals and therefore their use would call for strict adherence to recommended pesticide handling procedures. Some of them including, dimethoate, malathion, carbaryl, carbofuran and heptachlor, were also reported as being responsible for some symptoms of poisoning that were recorded by farmers in Table 2.

3.4. Survey - main findings

From the household questionnaire, most farmers were between 46-60 years (39% of 173 respondents), 31–45 years old (32%), above 60 years (21%), and below 15 years only 2 responded. Eighty seven (87%) of the

Table 4. List of pesticides reported by Health Care Workers to have caused poisoning symptoms.

Trade name/formulation reported	Common name/active ingredient	No of respondents	%
Dimethoate; ogor	Dimethoate	33	54.1
Diazinon	Diazinon	30	49.2
Malathion	Malathion	29	47.5
Deltamethrin; decis	Deltamethrin	27	44.3
Karate; thunder; icon	λ-cyhalothrin	25	41.0
Heptachlor (+epoxide)	Heptachlor	24	39.3
Chlorpyrifos; Dursban	Chlorpyrifos	24	39.3
Parathion	Parathion	23	37.7
Endrin; (+aldehyde)	Endrin	23	37.7
Furadan; carbofuran	Carbofuran	21	34.4
Endosulfan; (+sulphate)	Endosulfan	18	29.5
Dieldrin	Dieldrin	17	27.9
Dithane; zencob; ridomyl	Mancozeb/metalaxyl	17	27.9
Permethrin	Permethrin	14	23.0
Cypermethrin	cypermethrin	13	21.3
Round up; touchdown; weedall	Glyphosate	13	31.3
Gramoxone	paraquat	10	16.4
Bulldock	β-cyfluthrin	9	14.8
Methoxychlor	Methoxychlor	9	14.8
Aldrin	Aldrin	8	13.1
Carbaryl; sevin	Carbaryl	7	11.5
Methomyl; agrinate	Methomyl	7	11.5
Esfenvalerate	Esfenvalerate	7	11.5
Red cat; rat rat	brodifacoum; zinc/aluminium phosphide	5	8.2
p,p'- DDT	p,p'- DDT	4	6.6
Propoxur	Propoxur	4	6.6
Doom spray	phenothrin/imiprothrin/ esbiothrin	3	4.9
Actelic	Pirimiphos methyl	2	3.3
Lindane	Lindane	1	1.6
Lybacid	Fenthion	1	1.6
Triatix	Amitraz/piperonyl butoxide/deltamethrin	1	1.6

Note: 61 respondents (answered the question) out of 70.

Table 5. List of pesticides and their frequency of use as reported by farmers in Imenti South, Imenti North, and Buuri.

Formulation name as reported	No. respondents	Active Ingredient	Pesticide Class	WHO Toxicity Rank	Regulation status
Dursban; Chlorpyrifos	36	Chlorpyrifos	Organophosphate	Class II	allowed
Parathion	62	Parathion	Organophosphate	Class I	banned
Malathion	31	Malathion	Organophosphate	Class III	allowed
Diazinon	79	Diazinon	Organophosphate	Class II	allowed
Ogor; Dimethoate	68	Dimethoate	Organophosphate	Class II	allowed
Permethrin	61	Permethrin	Pyrethroid	Class II	allowed
Actelic; Actelic Super	77	Perimiphos Methyl	Organophosphate	Class III	allowed
Ortho	54	bifenthrin	Pyrethroid	Class II	allowed
Delta-Mectnin	57	Zeta-cypermethrin	Pyrethroid	Class II	allowed
Agrinate	17	Methomyl	Carbamate	Class I	allowed
Karate; thunder; icon	13	λ-cyhalothrin	Pyrethroid	Class II	allowed
Cattle Dip	20	ns	-	-	-
Sevin Dudu Dust	45	Carbaryl	Carbamate	Class III	allowed
Heptachlor	25	heptachlor	Organochlorine	Class II	banned
Endosulfan	8	Endosulfan	Organochlorine	Class I	allowed
Endrin	9	Endrin	Organochlorine	Class I	banned
Dieldrin	76	Dieldrin	Organochlorine	Class I	banned
Methoxychlor	48	Methoxychlor	Organochlorine	Class I	allowed
Endrin Aldehyde	69	Endrin aldehyde	Organochlorine	Class II	banned
Esfenvalerate	29	Esfenvalerate	Pyrethroid	Class II	allowed
Cypermethrin	51	Cypermethrin	Pyrethroid	Class II	allowed
Decis; Deltamethrin	62	Deltamethrin	Pyrethroid	Class II	allowed
Heptachlor Epoxide	32	Heptachlor epoxide	Organochlorine	Class I	banned
Propoxur	69	Propoxur	Carbamete	Class II	allowed
Furadan; Carbofuran	52	Carbofuran	Carbamate	Class I	banned
Endosulfan Sulphate	64	Endosulfan sulphate	Organochlorine	Class I	allowed
Plantvax	2	oxycarboxin	fungicide	Class III	allowed
Dithane; ridomyl; zencob	18	mancozeb	fungicide	Class III	allowed

ns: active/technical name of the compound not specified by respondents in the questionnaire, the total number of respondents-173.
Source: Extoxnet (1995) and Yu (2008).

famers were married. The education background was 62% (at least secondary school level and above), 29% (primary school level) and 9% (illiterate). A large percentage of farmers (67% in Imenti North, 57% in Buuri and 46% in Imenti South) hired or employed additional farm workers for piece work, on daily or monthly employment basis. Therefore this could have effects on proper use of pesticides because such casual workers might not have had any training on pesticide usage.

Farming experience was very varied, ranging from 6-30 years, with only 10% having less than 5 years farming experience. This could have a positive impact with respect to occupational exposure, as first, they would be able to use pesticides more efficiently and secondly, they could have been exposed to pesticides for an extended period which could have a long term impact on their health. However, as established in the survey, lack of adherence to safe pesticide use and handling was still very rampant in the three sub counties.

Fifty two (52%) of the farmers were involved in food crop production while 29% and 12% in cash crop and livestock production, respectively. The majority relied on rainfall agriculture (60%), 29% (both irrigation and rain fed) and 10% (irrigation only). However, neither rain fed nor irrigation methods had any significant influence on pesticide use and intoxication during application. Various livestock were kept including cattle (mostly), followed by chicken and beehives. This therefore also influenced pesticides used as established by the survey. Indeed, acaricides were reported, apart from the main agricultural pesticides that were the focus of the study.

Most farmers had contact with agricultural extension workers and engaged in various social groupings that would have enabled them to get access to information including information on pesticide usage. They also had access to credit, mostly through Saccos and therefore could afford to apply pesticides in the farming. However, only 31%–43% of the farmers had received training on pesticide application even though they all had information from various sources. The analysis of the questionnaire showed that the majority of the farmers in Imenti North, Imenti South and Buuri Sub County, were male and in the age bracket of youth. Also the respondents in Imenti North, Imenti South and Buuri Sub County had different levels of literacy but most of them were not specifically trained on safe handling of pesticides. This corroborated the reported non utilization of protective gear by the small scale farmers.

The farmers (26%) reported health effects after using pesticides, with most effects (>12 respondents) reported when dimethoate, malathion, heptachlor, endrin, dursban (chlorpyrifos), parathion and dieldrin, were used. Less health effects were reported when using plantvax 20 EC (oxycarboxin fungicide), dithane M45 (mancozeb), a dithiocarbamate fungicide, esfenvalerate, gramoxone (paraquat), lybacid (fenthion), methomyl and p,p’-DDT, in the three sub-counties. The symptoms of poisoning reported were headaches, sneezing, stomach aches, diarrhea, dizziness, skin rashes and eye irritations, among others (Table 1). Most (99%) had easy access to health services (at least 2.9 km away). Mostly men (household heads and their sons) were involved in spraying using pesticides which they obtained from agrovet shops/retailers (67%), old stock (13%) and open markets (10%), and which they sprayed mostly during sunny and cloudy (86%) as opposed to during rainfall (14%). Therefore men, mostly, reported health effects from pesticide usage in three sub counties. A significant finding was use of banned OC's (p,p’-DDT, endrin, dieldrin, heptachlor and aldrin) which were reported in the survey (Table 5). Only 24% of the farmers were smokers. Smoking could exacerbate intoxication when farmers were subjected to occupational exposure to pesticides.

Expenditure on pesticides was high and rose from 73% (of total farming cost) to 83% in 2015, implying that pesticide demand and usage in the three sub counties had increased. Most farmers (65%) reported that they understood the recommended safe handling protocols such as reading labels and wearing protective clothing during application. However, most farmers (44% in Buuri, 57% in Imenti South, and 60% in Imenti North) did not have protective clothing, which they blamed on lack of money and discomfort whenever they wore them, respectively.

In the pesticide use survey, farmers reported that several types of pesticides including organophosphates, organochlorines, carbamates, pyrethroids and fungicides were used in farming in the three sub-counties (Table 5). The most frequently used pesticides (more than 60 respondents out of 173) were parathion, diazinon, dimethoate, permethrin, pirimiphos methyl, carbaryl, deltamethrin, dieldrin, methoxychlor, cypermethrin, propoxur, and carbofuran. Some of these (i.e. dieldrin, parathion and carbofuran) were being used illegally because they had been banned. Most farmers (95%) also reported use of non synthetic chemical pesticides such as plant extracts and bio-pesticides, for crop production and animal production in addition to synthetic pesticides. Hand picking was also reported as a method for weed control in small scale farming.

When analysing the effects of training in chemical handling on intoxication related outcomes (amount of protective clothing, family size and hired labour, price per package of pesticide, expenditure on health, number of pumps used and price to get materials for use, respectively); the results indicated that there was statistically significant difference between the training of household in handling of chemicals and the number of pumps sprayed in the farms that is associated with intoxication ($Z = -3.579$ $P \leq 0.001$). The same applies to the cost of protective materials used ($Z = 2.515$, $P \leq 0.012$), number of protective clothing in place ($Z = -4.225$, $P \leq 0.012$), size of family and hired labour involved in application ($Z = -2.597$, $P \leq 0.009$), overall cost per package size of pesticides purchased ($Z = -2.404$, $P \leq 0.016$) and seasonal expenditure on chemicals ($Z = -2.404$, $P \leq 0.016$). Therefore as a counter measure, training in chemical handling should be emphasized as an urgent mitigative measure.

When analysing pesticide intoxication related parameters (size of acreage of farm, amount of money spent on pesticides, expenditure on health in the last season, prevalence of symptoms in days and treatment cost including transport), the test showed that intoxication of family member who sprays is significantly affected by the extent of the land size in acres ($P \leq 0.001$), amount of money spent on pesticides ($P \leq 0.012$) leading to a significantly overall seasonal expenditure on health ($P \leq 0.000$).

The findings from this study, which were similar, in some apsects, to previous findings reported from other developing countries, call for an urgent need to bridge the gap between existing national regulations on safe pesticide use and handling and their implementation by authorities, dealers and farmers in these countries in order to foster good agricultural practices for the safety of farmers.

4. Conclusions

The survey established that various classes of pesticides were used in horticultural crop farming and animal production in all the three sub-counties, with the most frequently used (>60 respondents out of 173) being parathion, diazinon, dimethoate, permethrin, pirimiphos methyl, endrin, deltamethrin, dieldrin, propoxur and endosulfan. It was found that there is a gap between the existing government regulations on pesticide use and safe handling and the implementation of these regulations by dealers, farmers and farm workers in the three sub-counties as some of the pesticides that were being used such as parathion, endrin, dieldrin and carbofuran had been banned by the government. The lack of adherence to pesticide use and handling procedures by farmers and farm workers such as failure to wear protective clothing when applying pesticides was prevalent despite the availability of agricultural extension workers in the areas and the levels of education and awareness of the farmers being generally high. This lack of adherence to regulations was shown to be due to lack of training on pesticide use and handling and availability of comfortable protective wear, respectively. Therefore, training on pesticide use and handling for farmers and farm workers in the three sub-counties should be emphasized as a mitigation measure. Most AEW (95%) and most HCW (71%) had experience of dealing with pesticides and knew how to administer 1st AID against pesticide poisoning, respectively. Farmers (26%) reported experiencing health effects after using pesticides, with most effects being felt after using dimethoate, malathion, carbofuran, carbaryl and heptachlor. There was a statistically significant ($p < 0.05$) association between various factors (availability of protective clothing, hiring of labourers, farm land size, expenditure on pesticides and expenditure on treatment, respectively) on intoxication from pesticide exposure.

Declarations

Author contribution statement

Gabriel M. Marete: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Joseph O. Lalah: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Jane Mputhia; Vitalis W. Wekesa: Conceived and designed the experiments.

Funding statement

This work was supported by the National Research Fund (NRF), Kenya, through the TUK/Maseno/MMUST/UoE/PCPB 2017–2020 Multidisciplinary project. The authors also wish to acknowledge the valuable financial contribution of Mr. Gabriel M. Marete.

Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

References

Abang, A., Kouame, C., Abang, M., Hannah, R., Fotso, A., 2013. Vegetable growers' perception of pesticide use practices, cost, and health effects in the tropical region of Cameroon. Int. J. Agron. Plant Prod. 4 (5), 873–883.
Ajayi, O.C., Camara, M., Fleischer, G., et al., 2002. Socio-economic Assessment of Pesticide Use in Mali, Pesticide Policy Project Publication Series No. 6. University of Hanover, Hanover, Germany, p. 2002.
Ajayi, O.C., Akinnifesi, F.K., Sileshi, G., 2011. Human health and occupational exposure to pesticides among smallholder farmers in cotton zones of Cote d'Ivoire. Sci. Res. 3 (10), 631–637.
Akan, J.C., Jafiya, L., Mohammed, Z., Abdulrahman, F.I., 2013. Organophosphorus pesticide residues in vegetables and soil samples from Alau dam and Gongulong agricultural areas, Borno State, Nigeria. Int. J. Environ. Monit. Anal. 1 (2), 58–64.
Alavanja, M.C., Ross, M.K., Hoppin, J.A., Kamel, F., 2004. Health effects of chronic pesticide exposure: cancer and neurotoxicity. Annu. Rev. Publ. Health 25, 155–197.
Alavanja, M.C., Ross, M.K., Bonner, M.R., 2013. Increased cancer burden among pesticide applicators and others due to pesticide exposure. CA A Cancer J. Clin. 63 (5), 120–142.

Banjo, A.D., Lawal, O.A., Fapojuwo, O.E., Songonuga, E.A., 2003. Farmers' knowledge and perception of horticultural insect pest problems in southwestern Nigeria. Afr. J. Biotechnol. 2 (11), 434–437. http://www.academicjournals.org/AJB.

Bhanti, M., Shukla, G., Taneja, A., 2004. Contamination levels of organochlorine pesticides and farmers' knowledge, perception, practices in rural India: a case study. Bull. Environ. Contam. Toxicol. 73, 787–793.

Birech, R., Bernhard, F., Macharia, F., 2006. Towards reducing synthetic pesticides imports in favour of locally available botanicals in Kenya. In: Conference on International Agricultural Research for Development, Bonn, Germany.

Buiatti, M., Christou, V., Pastore, G., 2013. The application of GMOs in agriculture and in food production for a better nutrition: two different scientific points of view. Genes Nutr. 8 (3), 255–270.

Chiramba, T., Mugoi, S., Martinez, I., Jones, T., 2011. Payment for Environmental Services pilot project in Lake Naivasha Basin – a viable mechanism for watershed services that delivers sustainable natural resource management and improved livelihoods. In: UN-water International Conference on Water in the green Economy in Practice: towards Rio 20. Zaragoza, Spain, 3–5 Oct 2011.

Damalas, C.A., Eleftherohorinos, I.G., 2011. Pesticide exposure, safety issues and risk. assessment indicators. Int. J. Environ. Res. Publ. Health 8, 1402–1419.

Davies, E.J., 1990. Neurotoxic concerns of human pesticide exposures. Am. J. Ind. Med. 18, 327–331.

Devi, P.I., 2009. Health risk perceptions, awareness and handling behaviour of pesticides by farm workers. Agric. Econ. Res. Rev. 22, 263–268.

Extoxnet, 1995. Extension Toxicology Network. Acephate: a Review by the Manufacturer. Pesticide Information Project. Cornell University.

FAO, 2015. International Code of Conduct on Pesticide Management Guidelines on Pesticide Legislation. Viale delle Terme di Caracalla, Rome, Italy.

FAO/WHO, 2008. Codex Alimentarius. Pesticide Residues in Food. Maximum Residue limits.9 April Rome Italy.

Gangemi, S., Miozzi, E., Teodoro, M., Briguglio, G., De Luca, A., Alibrando, C., Polito, C., Libra, M., 2016. Occupational exposure to pesticides as a possible risk factor for the development of chronic diseases in humans. Mol. Med. Rep. 14 (5), 4475–4488.

Godden, B., 2004. Sample size formulas. Retrieved from. http://www.sample-size-formulas-williamgodden-com.pdf. Retrieved 31st December 2020. at 2.09 pm.

GoK, 2017. Ministry of Agriculture, Livestock and Fisheries. Capacity Building Strategy for Agruclture Sector, November, p. 2017.

Gómez-Ramíreza, P., Pérez-García, J.M., León-Ortegae, M., Martínez, J.E., Calvoe, J.F., Sánchez- Zapata, J.A., Botella, F., María-Mojica, P., Martínez-Lópeza, E., García-Fernándeza, A.J., 2019. Spatiotemporal variations of organochlorine pesticides in an apex predator: influence of government regulations and farming practices. Environ. Res. 176, 108543.

Hanke, W., Jurewicz, J., 2004. The risk of adverse reproductive and developmental disorders due to occupational pesticide exposure: an overview of current epidemiological evidence. Int. J. Occup. Med. Environ. Health 17, 223–243.

HCDA, 2009. Horticultural Crops Development Authority, Strategic Plan, 2009-2013, Nairobi, Kenya.

HCDA, 2013. Horticultural Crops Development Authority. Horticulture Validated Report, Nairobi, Kenya.

Helfrich, L.A., Weigmann, D.L., Hipkins, P., Stinson, E.R., 2009. Pesticides and aquatic animals: a guide to reducing impacts on aquatic systems. In: Virginia Polytechnic Institute and State University. Available from. https://pubs.ext.vt.edu/420/420-013/420-013.html. (Accessed 17 January 2019).

Issa, Y., Sham'a, F., Nijem, K., Bjertness, E., Kristensen, P., 2010. Pesticide use and opportunities of exposure among farmers and their families: cross-sectional studies 1998-2006 from hebron governorate, Occupied Palestinian Territory. Environ. Health 9, 63.

Jolicoeur, J.L.C., 2000. Groundwater Contamination Potential of Agriculture Around Lake Naivasha: Comparison of Five Different Unsaturated Soil Zones. International Institute for Aerospace Survey and Earth Sciences (ITC) Enschede, The Netherlands. MSc. Thesis.

Karianthi, V., Kassim, N., Kimanya, M., 2016. Pesticide exposure from fresh tomatoes and its relationship with pesticide application practices in Meru district. Cogent Food Sci. Technol.

Khanal, G., Singh, A., 2016. Patterns of pesticide use and associated factors among the commercial farmers of chitwan, Nepal. Environ. Health Insights 10 (Suppl 1), 1–7, 2016.

Kingola, A.M., 2015. Determination of Dimethoate and Chlorpyrifos Residue Levels in French Beans and Snowpeas in Nairobi, Kenya. Master Thesis, Department of Chemistry, University of Nairobi, Nairobi, Kenya.

Kithure, J.G.N., 2013. The Distribution of Chlorpyrifos and Some Organochlorine Pesticide Residues in Tana River in the Upper Tana Catchment between 2008 and 2010. PhD Thesis. Department of Chemistry, University of Nairobi.

KMD, 2013. Kenya Meteorological Department Annual Report, p. 2013.

KNBS, 2013. Statistical Abstract. Kenya National Bureau of Statistics. Retrieved from. https://www.google.co.ke/#q=KNBS+(2013)+.Statistical+abstract.+Kenya+National+Bureau+of+Statistics.1:2Kenya.

Lalah, J.O., Omwoma, S., Osano, F.O., Omukunda, E., Wafubwa, G., Muyekho, D., Schramm, K.-W., 2018. Assessment of potential risks and effectiveness of agrochemical usage in a catchment: a case study of the Nzoia Nucleus Estate sugarcane farms in western Kenya. In: Maestroni, Britt, Cannavan, Andrew (Eds.), Chapter 16 in: Integrated Analytical Approaches for Pesticide Management. Academic Press Publishers, Elsevier, Paperback, p. 338 eBook: 9780128161562.

Leete, L., 2001. Whither the nonprofit wage differential? Estimates from the 1990 census. J. Labor Econ. 19 (1), 136–170.

Levy, P.S., Lemeshow, S., 2008. Sampling of Populations: Methods and Applications. John Wiley and Sons, New York, pp. 456–467.

Macharia, I., 2015. Pesticides and health in vegetable production in Kenya. BioMed Res. Int. 2015.

Marete, G.M., Shikuku, V.O., Lalah, J.O., Mputhia, J., Wekesa, V.W., 2020. Occurrence of pesticides residues in French beans, tomatoes, and kale in Kenya, and their human health risk indicators. Environ. Monit. Assess. 192, 692, 2020.

Martin Jr., S.A., Sandler, D.P., Harlow, S.D., Shore, D.L., Rowland, A.S., Alavanja, M.C.R., 2002. Pesticide use and pesticide-related symptoms among black farmers in the Agricultural Health study. Am. J. Ind. Med. 41 (3), 202–209.

Murphy, H.H., Sanusi, A., Dilts, R., Djajadisastra, M., Hirschhorn, N., Yuliatingsih, S., 2004. Health effects of pesticide use among Indonesian women farmers: Part I: exposure and acute health effects. J. Agromed. 9 (2), 349–373.

Ngaruiya, P.N., 2003. Overview of registration of pesticides in Kenya. In: Wabule, M.N., Ngaruiya, P.N., Kimmins, F.K., Silverside, P.J. (Eds.), Registration for Biocontrol Agents in Kenya: Proceedings of the PCPB/KARI/DFID CPP Workshop, Nakuru, Kenya, 14 – 16 May 2003, pp. 79–85, 2003.

Ngolo, P., Nawiri, M., Machocho, A., Oyieke, H., 2019. Pesticide residue levels in soil, water, kales and tomatoes in ewaso, narok wetland, laikipia, county, Kenya. J. Sci. Res. Rep. 24 (5), 1–11.

Ngowi, V.F., Mbise, T.J., Ijani, A.S.M., London, L., Ajayi, O.C., 2007. Pesticides use by smallholder farmers in vegetable production in Northern Tanzania. Crop Protect. 26 (11), 1617–1624.

Nguyen, A., Dang, Q., 1999. A safety and sound use of pesticides in agricultural production. Asian Pac. Newsl. Occup. Health 6, 64–65.

Ohayo-Mitoko, G.J.A., 1997. Occupational Pesticide Exposure Among Kenyan Agricultural Workers: an Epidemiological and Public Health Perspective. Wageningen University. PhD Thesis.

Ohayo-Mitoko, G.J.A., Kromhout, H., Simwa, J.M., Boleij, J.S.M., Heederik, D., 2000. Self reported symptoms and inhibition of acetylcholinesterase activity among Kenyan agricultural workers. Occup. Environ. Med. 57, 195–200.

Ojo, J., 2016. Pesticides use and health in Nigeria. IFE J. Sci. 18 (4), 981–991.

Otieno, P.O., Lalah, J.O., Virani, M., Jondiko, I.O., Schramm, K.-W., 2010. Carbofuran and its toxic metabolites provide forensic evidence for Furadan exposure in Vultures (*Gyps africanus*) in Kenya. Bull. Environ. Contam. Toxicol. 84 (5), 536–544.

PCPB, 2005. Annual Report, July 2004/June 2005. Pest Control Products Board, Nairobi, Kenya.

PCPB, 2008. Annual Report, July 2007/June 2008. Pest Control Products Board, Nairobi, Kenya.

PCPB, 2010. Pest Control Products Registered for Use in Kenya, ninth ed. Pest Control Products Board, Nairobi, Kenya.

PCPB, 2012. Annual Report, July 2011/June 2012. Pest Control Products Board, Nairobi, Kenya.

PCPB, 2018. Annual Report, July 2011/June 2018. Pest Control Products Board, Nairobi, Kenya.

Subashiny, N., Thiruchelvam, S., 2008. Knowledge of farmers about pest management practices in pambaimadu, vavuniya district: an ordered probit model approach. Sabaramuwa Univ. J. 8, 79–89.

Tsimbiri, P.F., Moturi, W.N., Sawe, J., Henley, P., Bend, J.R., 2015. Health impact of pesticides on residents and horticultural workers in the lake Naivasha region, Kenya. Occup. Dis. Environ. Med. 3, 24–34.

UNEP/WHO, 2012. State of the Science of Endocrine Disrupting Chemicals—2012. United Nations Environment Programme/World Health Organization, Geneva, Switzerland.

UNEP, 2017. Stockholm Convention on Persistent Organic Pollutants: Report of the Conference of the Parties to the Stockholm Convention on Persistent Organic Pollutants on the Work of its Eighth Meeting. Geneva.

Wasilwa, L., 2008. Horticulture for Food. Report. Kenya Agricultural Research Institute.

Wilson, C., 2005. Exposure to pesticides, ill-health and averting behaviour: costs and determining the relationships. Int. J. Soc. Econ.

WHO/UNEP, 2001. World Health Organization (WHO) United Nations Environmental Program. Public Health Impact of Pesticides used in Agriculture, Geneva.

Yu, S.J., 2008. The Toxicology and Biochemistry of Insecticides. CRC Press, New York, pp. 25–84.