Heliyon 10 (2024) e32917

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Small-scale market gardeners' knowledge, attitudes and practices regarding the use of chemical pesticides in the Kabare territory (South-Kivu) in Eastern D.R. Congo

Dieumerci R. Masumbuko [a,*], Audaxine N. Mwitangabo [a], Espoir B. Basengere [a,b,c], Patient M. Zamukulu [b,d], Leonard K. Mubalama [a], Gustave N. Mushagalusa [a,b]

[a] *Department of Environment and Sustainable Development, Institut Supérieur de Développement Rural (ISDR), P.O. Box 2849, Bukavu, South-Kivu, Congo*
[b] *Faculty of Agriculture and Environmental Sciences, Université Evangélique en Afrique (UEA), P.O. Box 3323, Bukavu, South-Kivu, Congo*
[c] *Faculty of Agronomy, Université Catholique de Bukavu (UCB), P.O. Box 285, Bukavu, South-Kivu, Congo*
[d] *Institut Supérieur D'Etudes Agronomiques et Vétérinaires (ISEAV), Walungu, South-Kivu, Congo*

A R T I C L E I N F O

Keywords:
Attitudes
Knowledge
Farming practices
Pesticides and small-scale market gardener

A B S T R A C T

Damage caused by pests and diseases is one of constraints on crop production for food security. Based on the use of questionnaire and interviews that were conducted in Kabare territory (South-Kivu), this study was carried out to (i) assess farmers practices, attitudes, and knowledge about pesticides use, and (ii) assess the human health and physical environment effects using pesticides. Data was collected from 300 small-scale farmers in study area. Results showed that majority of our respondents were men (59 %) rather than women (41 %) and local knowledge of pesticide use was low (60 %). Education level had a significant influence ($p < 0.01$) on level of knowledge about pesticide use, time and dose of treatment, method of control, and persistence time. In addition, education level influence significantly farmers' attitudes before and after pesticide treatment ($p < 0.05$). Pest management control, time of pesticide application, and packaging management method varied significantly with level of local knowledge ($p < 0.01$). Pesticides use by small-scale farmers has an effect on water, soil, and air quality. It also causes human pathologies such as vomiting, eye irritation, and even loss of life in event of heavy exposure. Inhalation and dermal exposure are main and most dangerous routes of pesticide exposure in our study area, which lacks protective strategies. Finally, use of pesticides disrupts biodiversity through the disappearance of pollinators, predators, parasitoids, and soil microorganisms. Therefore, broad continuity of this study with integration of other scientific aspects would effectively contribute to the improvement of environmental quality.

1. Introduction

Between 1920 and 1970, world's population almost doubled, from 1.811 billion to just over 3.6 billion [1]. In 2008, this population reached 6.7 billion [2]. By 2019, it will have reached 7.7 billion inhabitants. This demographic growth means increased vital needs for

* Corresponding author. Department of Environment and Sustainable Development, Institut Supérieur de Développement Rural, Bukavu, South-Kivu, Congo.

E-mail address: dieumercimasumbuko@gmail.com (D.R. Masumbuko).

https://doi.org/10.1016/j.heliyon.2024.e32917
Received 12 April 2024; Received in revised form 11 June 2024; Accepted 12 June 2024
Available online 13 June 2024
2405-8440/© 2024 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC license (http://creativecommons.org/licenses/by-nc/4.0/).

care, space, food and drinking water [3,4]. To meet this challenge, urban and peri-urban agriculture has gradually emerged, capable of meeting growing demand, particularly for vegetables, leading to the development of market gardening [5]. This type of farming is linked to excessive use of plant protection products [6] to produce beautiful vegetables that most consumers demand [4,7].

The use of plant protection products in agriculture has been seen as a necessary evil to guarantee farmers' effective protection of their crops against crop pests, thus ensuring productivity that meets their objectives [6,8]. Over last 50 years, pesticides (insecticides, fungicides, herbicides, etc.) have made it possible to increase agricultural production and fertility of the land and labor [9]. As a result, soil fertility is deteriorating, diseases and parasites are appearing, production costs are rising, water and soil are being polluted by the excessive use of chemicals and certain toxic products are accumulating in the fruit (harvested produce) [10]. Crop associations and organic fertilization in market gardening respond to challenges of crop quality, biodiversity conservation, pest pressure, sustainability of soil fertility management and production, but fundamentally also to efficiency of production factors [11].

Since its inception in the 1960s, the Integrated Pest Management (IPM) concept has aimed, among other things, to rationalize and reduce use of chemical products. It should be noted that without use of pesticides, there would be a 78 % loss in fruit production and a 54 % loss in vegetable production [12,13]. The quantity of pesticides used worldwide continues to increase, leading to soil, water, and air pollution, declining pollinator populations, health impacts on ecosystems and human populations, and the development of resistance in crop pests and plant pathogens [14,15]. Worldwide pesticide consumption continues to rise, and the few notable reductions remain modest and localized. According to FAO [5], global pesticide uses almost doubled between 1990, and 2018, rising from 1.7 to 2.7 million tons.

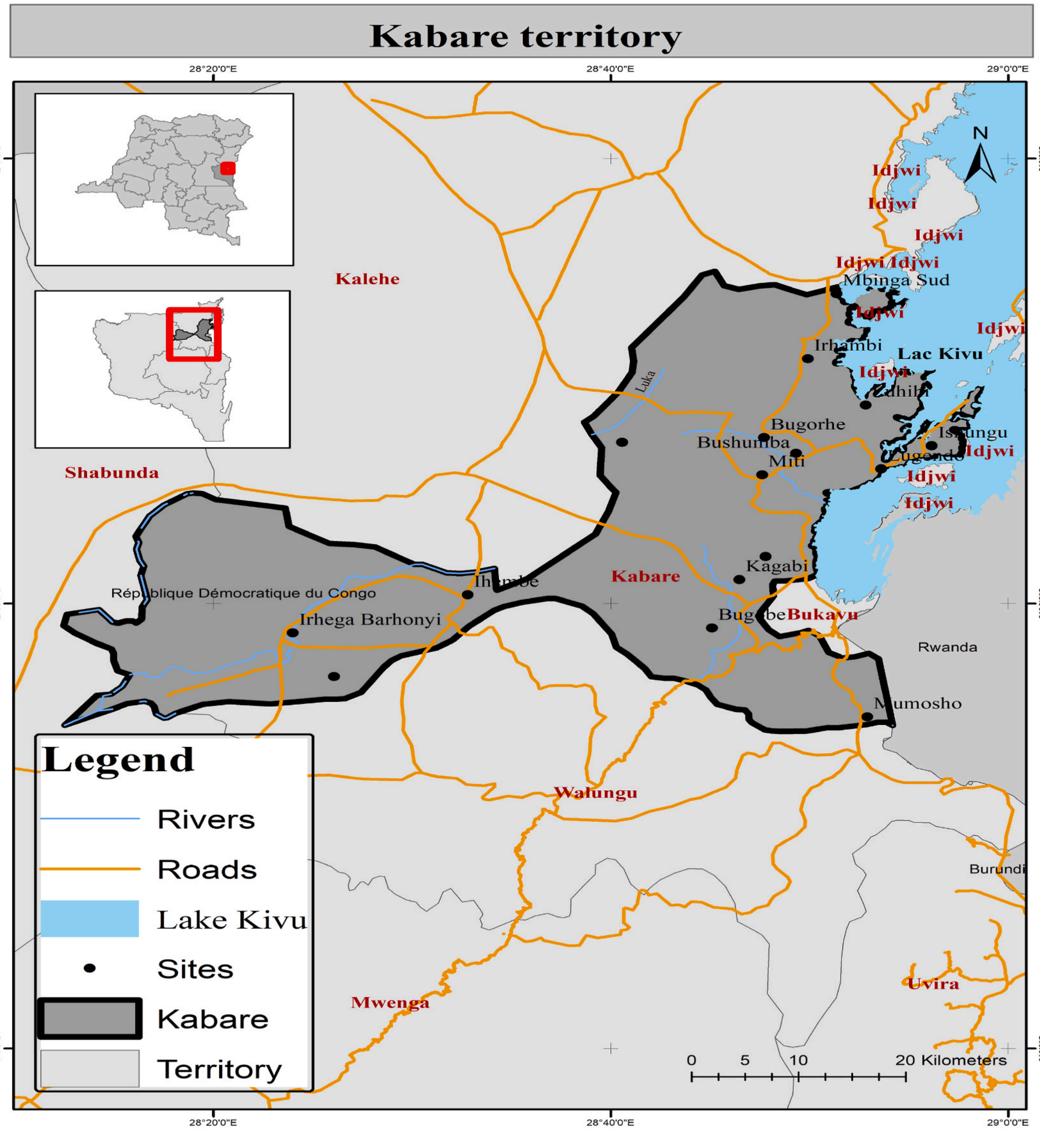

Fig. 1. Location of Kabare territory, Eastern D.R. Congo.

Africa still only accounts for 2 % of the world pesticide market [16]. However, their use, with little or no control, is giving rise to growing concern with the proliferation of non-communicable diseases such as cancer, congenital malformations, neurological disorders, and diabetes, for which these chemical substances may be one of causes [16]. According to many scholars, factors leading to morbidity and mortality from pesticide exposure include lack of knowledge, non-use or improper use of personal protective equipment (PPE), improper home storage, negative attitudes and inappropriate practices [17,18]. In addition, situation in the Democratic Republic of Congo (DRC) is worrying because of failure of Congolese authorities to regulate and control pesticide market has contributed to the distribution and sale of unauthorized and highly dangerous pesticides such as profenofos and dichlorvos [19]. The advantage of acting on a broad spectrum of pests and improving quantity and quality of harvests [20]. Repeated, poorly controlled use of pesticides leads to resistance from bio-aggressors and over-suppression of crop protection aids [21] environmental pollution, and serious health problems for farmers and consumers [22].

In South-Kivu province, due to a lack of awareness of safety and pre-harvest intervals for pesticides used, many farmers often remain working in treated plots and harvest produce that is unfit for consumption, with residues exceeding maximum limit [23]. In the same way, improper handling of pesticides (failure to respect dosage) [24], mixing pesticides with bare hands, minimal use of personal protective equipment (PPE) during application, inadequate disposal of empty pesticide containers after use, mixing pesticides near water sources and applying cocktails are main problems associated with poor knowledge and misuse of pesticides and lack of awareness of proper pesticide management practices among market gardeners posing a risk to human health and environment [21, 25–33].

However, all efforts made by government and development sectors to eliminate farmers' misconceptions about use of chemical pesticides are insufficient and almost ineffective. In addition, many users of chemical pesticides have a low level of education [34]. A recent study in town of Bukavu detected mancozeb residues in tomatoes produced by market gardeners in eastern DRC, above the maximum residue limit set by European food safety standards [35]. In Kabare territory surrounding Bukavu city, farmers use chemical pesticides to control damage caused by pests, diseases, and weeds to improve crops yield et profitability. Although chemical pesticides are widely used in many African agro-ecological zones (AEZs), such as farmers in our study area (Fig. 1). But, farmers have little knowledge of human health and environmental risks of pesticides use.

Objectives of this study were to assess small-scale market gardeners' knowledge, attitudes, and practices regarding use of chemical pesticides on market garden crops, as well as impact of these pesticides on human health, biodiversity, and physical environment in the Kabare territory in eastern of D.R. Congo.

2. Materials and methods

2.1. Study area

Kabare territory (29° west longitude, 2° south latitude) is located in province of South-Kivu in the D. R. Congo, covering an area of 1256 km^2. It is bordered to the north by territory of Kalehe, to the south by territory of Walungu, to the east by Lake Kivu and town of Bukavu, and to the west by chiefdoms of Kalonge (Kalehe). Kabare territory enjoys a humid tropical climate influenced by its mountainous terrain, with rainfall varying between 1300 mm, and 1800 mm per year and an average temperature of 20 °C. Its relief is dominated by mountains, the highest peaks of which are Kahuzi (3308 m above the sea level) and Biega (2790 m above the sea level) [36–38].

2.2. Soil

Apart from various swamps found in Kabare territory, most of the area is savannah with natural vegetation consisting of wild grasses. Mulume Munene plateau to the west are covered in the bamboo forest, with some forest species, shrubs, and grasses of primary forest. The marshy valleys are home to sedges, papyrus, and birds; there are also a few forest galleries on banks of Lake Kivu and some rivers [36]. Generally, soil of study area is developed on volcanic rocks and is dominated by a high clay activity and degraded by soil erosion and other human activity. This material is sometimes basaltic, sometimes schistose, sometimes heavy clay, and sometimes sandy clay. Ancient alluvial deposits, known as Kevers, are found in low-lying areas and are generally heavy and very clayey [37–41]. Kabare territory was chosen because market gardening is a major crop in this area and chemical pesticides are used to limit damage from pests, diseases, and weeds.

3. Methods

3.1. Sampling and data collection

To collect data for this study, a survey combined with observations was carried out from 15th August to September 20, 2023 during dry season. A survey questionnaire consisting of mixed questions (closed and open questions) was used. Questions relating to the characterization of respondents, such as age, level of education, main activity, marital status, and experience of pesticide use were asked. Actual questions concerned the knowledge, attitudes, and practices of market gardeners regarding the use of chemical pesticides in Miti, Katana, Cirunga, Bugobe, and Mumosho *groupement*. These five groups were chosen because of their high level of market garden production. Market gardeners were also asked questions about various chemical pesticides used in the region. As regards the impact of use of chemical pesticides, respondents were asked questions relating to the impact on physical environment, biodiversity, and human health. In addition, World Health Organization (WHO) toxicity guidelines were used to assess of pesticides [42]. Other information was gathered from pesticide vendors about the products sold. To do this, a random sample of selected 300 small-scale market gardeners was taken, with 60 small-scale market gardeners per *groupement*. Respondents were selected according to whether they were farmers growing market garden produce. They were also selected according to whether or not they used chemical pesticides.

3.2. Data processing and statistical analysis

Data collected, was processed using Microsoft Excel 16, followed by descriptive statistical analyses for quantitative data. Frequency analyses were carried out for qualitative data. An assessment of images taken in the field concerning use of pesticides was also carried out. Ki-squared test (χ^2) was carried out using Minitab® 19 to check whether there was a significant difference between different variables.

4. Results

4.1. Characteristics of respondents in study area

Results in Table 1 show that the level of education varies from one market gardener to another, with the majority having primary education (40.67 %) compared to market gardeners with no education (13.33 %). Market gardening is generally practiced by more men (59 %) than women (41 %). The majority of Kabare's market gardeners are married (57 %) or single (31 %), and farming is considered their main source of income (59 %), followed by trading (16 %) and livestock rearing (10 %). The average age of our respondents was 36.20 ± 13.00 years. Our respondents had 6.2 ± 2.9 years' experience of in using chemical pesticides.

4.2. Market garden crops grown and field occupancy status

Results in Table 2 show that amaranth, cabbage, and tomatoes are grown in the majority (54.2 %), compared with carrots, egg-plants, onions, and celery (30 %), and chili, peppers, spinach, and garlic (15 %), which are less grown in the study area. The majority of market gardeners acquired their land through purchase (50.3 %), compared with a smaller number who own their land through inheritance (0.7 %).

4.3. Small-scale market gardeners' knowledge of pesticide use

Results in Table 3 shows that small-scale market gardeners' knowledge of use of chemical pesticides in Kabare territory is low (60 %). Level of knowledge of pesticide use is significantly influenced ($p < 0.01$) by small-scale market gardeners' level of education. The lowest level was found among those who had attended primary school (22.7 %), followed by those who had attended secondary school (19.7 %). Moreover, the level of education had a significant influence on choice of treatment time ($p < 0.05$). The majority of market gardeners (72.7 %) applied pesticides during sunny weather. Results show that level of education had no influence on small-scale

Table 1
Characteristics of respondents in study area.

Variables	Frequency	%
Level of study	**300**	**100.0**
Primary	122	40.7
Secondary	89	29.7
University	49	16.3
Illiterate	40	13.3
Sex	**300**	**100.0**
Male	177	59.0
Female	123	41.0
Marital status	**300**	**100.0**
Single	93	31.0
Divorced	16	5.3
Married	170	57.0
Widowed	20	6.7
Main activity	**300**	**100.0**
Agriculture	177	59.0
Commerce	48	16.0
Private sector	9	3.0
Public official	18	6.0
Livestock	30	10.0
Technician	18	6.0
Age (years)	**36.2 ± 13**	—
Experience of pesticide use (years)	**6.20 ± 2.9**	—

Table 2
Small-scale market garden crops and field occupancy status.

Variables	Frequency	%
Cultivated market garden crops	**300**	**100.0**
Amaranth, cabbage, and tomatoes	163	54.2
Carrots, eggplants, onions and celery	90	30.0
Chili, pepper, spinach and garlic	47	15.8
Field occupation status	**300**	**100.0**
Donation	2	0.6
Heritage	17	5.6
Leaseholder	130	43.3
Proprietor	151	50.3

Table 3
Small-scale market gardeners' knowledge of pesticide in study area.

Knowledge of pesticides	Level of study (%)					χ^2	*P*-value
	None	Primary	Secondary	University	Total		
Good	2.0	6.0	6.3	2.0	16.3	51.1	*<0.01***
Low	3.6	22.7	19.7	14.0	60.0		
Moderate	7.7	12.0	3.7	0.3	23.7		
Time of treatment							
The day	7.3	7.3	0.3	0.3	15.3	89.7	*<0.05**
Morning	0.3	5.3	2.3	0.0	8.0		
Evening	0.0	3.0	1.0	0.0	4.0		
Sunny weather	5.7	25.0	26.0	16.0	72.7		
Protection during treatment							
No	1.7	6.7	4.3	2.3	15.0	0.4	$>0.05^{ns}$
Yes	11.7	34.0	25.3	14.0	85.0		
Protection mode							
No protection	4.7	10.3	1.0	0.0	16.0	110.4	*<0.01***
Wear mackintosh and hat	0.3	1.0	2.3	0.0	3.7		
Wear gloves, goggles and nose plug	0.0	12.7	6.7	7.0	26.3		
Wear appropriate mask	0.3	2.0	1.7	0.6	4.7		
Wear mask, overalls and boots	0.3	3.3	7.3	4.3	15.3		
Wearing overalls	5.0	11.0	10.3	4.0	30.3		
Wearing boots, cash nose and hat	2.7	0.3	0.3	0.3	3.7		
Respecting dose							
No	3.7	10.3	1.0	0.0	15.0	33.3	*<0.01***
Yes	9.7	30.3	28.7	16.3	85.0		
Packaging management							
No management	0.0	1.7	1.0	6.3	9.0	286.9	*<0.01***
Burning	4.3	11.7	10.3	4.0	30.3		
Landfill	0.0	7.0	0.0	0.0	7.0		
Flush down toilet	1.3	7.0	14.7	5.7	28.7		
Leave in the field	7.3	0.3	0.0	0.3	8.0		
Store them	0.3	3.0	2.7	0.0	6.0		
Use for domestic purposes	0.0	8.0	0.0	0.0	8.0		
Dry residues	0.0	2.0	1.0	0.0	3.0		

Legend: χ^2: Chi-squared statistical test, *: significant; **: very significant; ***: very highly significant, ns: not significant.

market gardeners' protection during treatment ($p > 0.05$). Level of education had a significant influence on method of protection during crop treatment ($p < 0.01$), compliance with the dose to be applied to crops ($p < 0.01$), and management of packaging after treatment ($p < 0.01$).

Concerning farmers' attitudes before and after using pesticides, aim was to understand farmers' behavior before using pesticides and their behavior after using pesticides. Results in Table 4 show that level of education has a significant influence ($p < 0.01$) on attitude of market gardeners before making decisions on pesticide use, as well as after pesticide use ($p < 0.05$). The majority of market gardeners (38.7 %) were reluctant to use chemical pesticides. Furthermore, level of education had a significant influence on compliance with the residual period ($p < 0.01$).

Results in Table 5 show that the level of small-scale market gardeners' knowledge of use of chemical pesticides has a significant influence on method of protection used by market gardeners', time of treatment, and management of packaging ($p < 0.01$). The majority of market gardeners (30.3 %) wore overalls when applying pesticides, while 26.3 % wore gloves, goggles and nose plugs for protection, but 16 % of these market gardeners did not use any protection at all. The majority of market gardeners (72.7 %) apply pesticides during sunny weather. When it comes to managing packaging, 30.3 % of market gardeners burn it, regardless of their level of knowledge. But 28.7 % of those with little knowledge flushed them down the toilet. It should be noted that 9 % of those with little knowledge do not manage their packaging at all.

Table 4
Small-scale market gardeners' attitudes before and after pesticide application in study area.

Attitude before use	Level of study					χ^2	*P*-value
	None	**Primary**	**Secondary**	**University**	**Total**		
No attitude	4.7	10.3	1.0	0.0	16.0	55.3	*<0.05**
Consult professionals	1.0	3.7	6.7	1.7	13.0		
Reluctance to use	3.0	14.0	11.0	10.7	38.7		
Tendency to use without information	4.7	12.7	11.0	4.0	32.3		
Attitude after use							
No attitude	4.7	10.3	1.0	0.0	16.0	79.7	*<0.05**
Drink milk, water and lemon juice	5.0	13.0	11.3	4.7	34.0		
Clean up, leave equipment in the field	3.0	11.7	2.7	6.0	23.3		
Take medication, drink milk	0.6	5.7	14.7	5.7	26.7		
Respect for residual time							
No	7.7	10.7	1.3	0.3	20.0	61.3	*<0.01***
Yes	5.7	30.0	28.3	16.0	80.0		

Legend: χ^2: Chi-squared statistical test, *: significant; **: very significant; ***: very highly significant, ns: not significant.

Table 5
The link between the level of small-scale market gardeners' knowledge and method of protection, treatment and management of packaging.

Protection mode	Level of market gardeners' knowledge of pesticides use				χ^2	*P*-value
	Good	Low	Moderate	Total		
No protection	0.0	0.0	16.0	16.0	426.4	*<0.01***
Wear a mackintosh and hat	0.0	0.0	3.7	3.7		
Wear gloves, goggles and nose plug	0.0	26.0	0.3	26.3		
Wear appropriate mask	4.7	0.0	0.0	4.7		
Wearing a mask, overalls and boots	0.0	15.3	0.0	15.3		
Wearing overalls	11.7	18.7	0.0	30.3		
Wearing boots, cash nose and hat	0.0	0.0	3.7	3.7		
Time of treatment						
The day	0.0	0.0	15.3	15.3	269.0	*<0.01***
Morning	0.0	3.7	4.3	8.0		
Evening	0.0	0.0	4.0	4.0		
Sunny weather	16.3	56.3	0.0	72.7		
Packaging management						
No management	0.0	9.0	0.0	9.0	405.5	*<0.01***
Burning them	16.3	14.0	0.0	30.3		
Landfill	0.0	7.0	0.0	7.0		
Flush down the toilet	0.0	28.7	0.0	28.7		
Leave them in the field	0.0	0.0	8.0	8.0		
Storing them	0.0	1.3	4.7	6.0		
Use for domestic purposes	0.0	0.0	8.0	8.0		
Dry them	0.0	0.0	3.0	3.0		

Legend: χ^2: Chi-squared statistical test, *: significant; **: very significant; ***: very highly significant, ns: not significant.

4.4. Existence of a state control service for chemical pesticides

Results in Table 6 show that there is no government quality control service for pesticides sold on markets (92.5 %), compared with 7.5 % who say that such a service exists.

Table 6
State control service for chemical pesticides.

Variables	Frequency	%
State quality control service	**300**	**100.0**
Yes	22	7.5
No	278	92.5
Quality control	**300**	**100.0**
Leave with empty packaging	9	3.3
They ask for the money	5	1.7
Checking packaging already in use	8	2.5
No service provided	278	92.5

4.5. Impact of pesticides on environment and human health

Results presented in Table 7 show that chemical pesticides have an impact on physical environment in the form of water (27.3 %), soil (26 %), and air (26.4 %) respectively. These same pesticides have an impact on biodiversity, particularly through loss of certain species and appearance of new species. As far as impacts on human health are concerned, it should be noted that use of pesticides by small-scale market gardeners' causes pneumonia and congenital malformations (27.3 %), and human death (19.4 %). Chemical pesticides also cause premature births, carcinogenic diseases, asphyxiation, and sexual weakness. Symptoms include headaches, skin rashes, and eye irritation (28.3 %), as well as abdominal pain, eye irritation, and redness (24.7 %). There are three (3) main routes of exposure to chemical pesticides: inhalation (40.7 %) of farmers, contact with products (33.3 %) and ingestion (26 %). Concerning the existence of pesticide residues in particles, it should be noted that these are found in fruit (26.3 %), vegetables (25.3 %), soil (23 %), water, and air.

Pesticides are sold in Kabare area in the same shop along with other consumables. This really exposes users to the effects of dangerous pesticides. Products are easily inhaled and come into contact with anyone who goes into the shop (Fig. 2a). **Figure (2b)** show how pesticide users in Kabare territory do not protect themselves when handling products, which has consequences for their health. Image also shows that next to the field there is a stream and that by spraying product on the crops, water nearby is polluted.

5. Discussion

5.1. Small-scale market gardeners' knowledge of chemical pesticide use

Our results show that small-scale market gardeners in Kabare territory have a low level of knowledge about use of chemical pesticides (60 %) of respondents. Our results corroborate those of [43] which explains why farmers' who use chemical pesticides have little knowledge of these products. On other hand, results found by Ref. [44] in Malaysia explain that peasant farmers have a high level of knowledge of pesticide use. The low level found in Kabare can be explained by the fact that farming in developing countries, particularly in the DRC, is practiced by small-scale market gardeners with a very limited level of education. Our results show that sunny weather is the optimum time to apply pesticides. These results are similar to those obtained by Ref. [43], and by Ref. [45] which show

Table 7
Impact of pesticides on physical environment and human health.

Variables	Frequency	%
Impact on physical environment	**300**	**100.0**
No impact	61	20.3
Water pollution	82	27.3
Air pollution	78	26.0
Soil pollution	79	26.4
Impact on biodiversity	**300**	**100.0**
No impact	173	57.5
New species appear	45	15.0
Loss of certain species	82	27.5
Impact on human health	**300**	**100.0**
Asphyxia, water-borne diseases	15	5.0
Sexual weakness	19	6.3
Congenital malformation, carcinogenic diseases	22	7.3
Early birth	31	10.3
Death	58	19.4
Disturbance of the menstrual cycle	21	7.0
Pneumonia and congenital malformation	82	27.3
No impact	52	17.4
Symptoms observed	**300**	**100.0**
No symptom	48	16.0
Cramp, intense thirst, drowsiness, violent cough	14	4.7
Abdominal pain, eye irritation	74	24.7
Physical weakness and dermatological complaints	13	4.3
Headache, skin rash eye irritation	85	28.3
Nausea and vomiting, difficulty breathing	66	22.0
Voice of pesticide exposure	**300**	**100.0**
Contact	100	33.3
Ingestion	78	26.0
Inhalation	122	40.7
Existence of pesticides residues	**300**	**100.0**
Air	13	4.3
Water	17	5.7
Fruit	79	26.3
Vegetables	76	25.3
Soil	66	22.0
No existence	49	16.3

Fig. 2. (a) Sale of pesticides in bulk, (b) Pesticide application to crops.

that farmers prefer to spray when temperatures are average. Our results show that majority of market gardeners in the study area protect themselves when applying pesticides. These results are similar to those obtained by Refs. [44–46], which explain that market gardeners are aware of danger of chemicals to human health. There is a similarity between our results and those of ref. [45], and [46] who say that all farmers have a better understanding of labels on plant protection products and recommended dosage. However, results of ref. [24] diverge from ours because they found that majority of farmers do not understand the danger signs. Whereas those found by Ref. [29] show that 73 % of farmers using pesticides do not know labels. Good knowledge of the dose and label is linked to the fact that most small-scale market gardeners' in Kabare territory have primary or secondary education. This could influence their level of knowledge of the dose to be used and the label. As for management of packaging, our results show that most small-scale market gardeners' using pesticides on vegetable crops burn the packaging after treatment (30.3 %) and others store it. Similar results were found by Ref. [45] where 55.3 % of farmers burn waste and 41.7 % store it. Concerning residual period, our results show that small-scale market gardeners know and respect the residual period for each product (80 %).

5.2. Influence of level of education on knowledge of pesticide use

Concerning the influence of level of education on small-scale market gardeners' knowledge of the use of chemical pesticides, it should be noted that level of education had a significant influence on small-scale market gardeners' knowledge of pesticide use ($p < 0.01$), on time of treatment ($p < 0.05$), on method of protection ($p < 0.01$), on compliance with the dose ($p < 0.01$), on management of packaging ($p < 0.01$) and the duration of persistence ($p < 0.01$) (Table 4). For our results, most small-scale market gardeners' handling pesticides are at the primary level, followed by those at the secondary level. Our results are similar to those found by Ref. [14], ref. [33], and by Ref. [45], and ref. [41]. In contrast, results of ref. [47] show that most farmers using pesticides are illiterate, followed by those with a primary education. Level of education also has a significant influence on small-scale market gardeners' attitudes before treatment ($p<0.05$) and after treatment ($p < 0.05$) of crops with chemical pesticides. Before treatment, market gardeners showed a reluctance to use pesticides, whereas after use, small-scale market gardeners washed themselves and drank water or milk. There is a similarity between our results and those of [14] with ($p < 0.05$) as level of significant for attitudes before and after treatment with pesticides. On other hand, there was a discrepancy between our results and those of by Ref. [48] which show that most farmers do not adopt any attitude when pesticides are applied (61.1 %).

5.3. Influence of level of knowledge on method of protection, time of treatment, and method of managing packaging

Small-scale market gardeners' level of knowledge about pesticide use had a significant influence on method of protection, time of treatment, and method of packaging management ($p < 0.01$). This can be explained by the fact that all those who have a level of knowledge are those who have at least studied. Our results show that most small-scale market gardeners' have a primary or secondary education. This would influence level of knowledge, which in turn would influence mode of protection, timing of treatment, and mode of management.

5.4. Impact of pesticides on physical environment, human health, and biodiversity

Our results show that use of pesticides has an impact on physical environment, particularly on water quality (water pollution), soil quality (soil degradation), and air pollution. Our results corroborate those of ref. [44], and ref. [49] who also found that use of pesticides harmed environment, soil and water quality, and human health. This affects life of soil microorganisms. On biodiversity, pesticides have negative effects on pollinators, predators, and parasitoids [50]. Pesticides have several negative impacts on human health, including asphyxiation, water-borne diseases, sexual weakness, congenital malformations, carcinogenic diseases, male deaths, disruption of menstrual cycle, pneumonia, etc. Symptoms include abdominal pain, eye irritation, headaches, skin rashes, nausea, vomiting and breathing difficulties. Symptoms include abdominal pain, eye irritation, headaches, skin rash, nausea, vomiting, and breathing difficulties. The same results were obtained by Refs. [30,50,51]. Our results show that most dangerous routes of exposure to pesticides are inhalation, followed by contact, and then ingestion (Table 7). However, similar results were obtained by Ref. [30], and ref. [50] that the most dangerous routes of exposure to pesticides are inhalation, contact, and ingestion. Small-scale market gardeners also point out that pesticide residues are present in air, water, fruit, vegetables, and soil [29,50] in their independent research, which found the same results as ours.

5.5. Pesticides encountered in which Kabare territory

Pesticides encountered in Kabare territory are insecticides, followed by fungicides, and then rongicides. Our results are similar to those of ref. [47], and ref. [52] which show that metalaxyl, cypermetrin, abametrin, mancozeb, endosulfan, profenofos, dichlorvos, malathion and zinc phosphide are the same pesticides that are mainly used in study area. According to the WHO classification [42], insecticides are the most dangerous pesticides encountered in Kabare territory. They are abametrin 1.8 % EC, Dichlorvos 77 % EC and a fungicide Zinc phosphide (10 %). They are all group *Ib* (very dangerous) (Table 8). This would explain the danger posed by these products to small-scale market gardening and the physical environment.

6. Conclusion and way forward

This study assessed small-scale market gardeners' knowledge, attitudes and practices regarding use of chemical pesticides in Kabare territory and their effects on human health and environmental quality. Results showed that small-scale market gardeners used more chemical pesticides on all crops bio-aggressors control. Education level is the main driver that significantly influences local knowledge, time and dose of pesticide application, practices, and attitudes of small-scale farmers of pesticide use for reduce theirs effects on human health and physical environment such as soil, water, and air, pollution. Pesticide use cause human pathologies such as carcinogenic diseases, respiratory difficulties, congenital problems, and so on. The way forward is to carry out research into the quantity of pesticides found in vegetables eaten in study area and to develop strategies to combat pollution of water, air, and soil by chemical pesticides. Providing much reliable recommendations is difficult from a qualitative research within a single location. We, therefore, recommend many studies based on soil, water, and plant analysis to evaluate their level pollution caused by pesticides et others chemical use for all crops control and production to provide strong recommendations to farmers in the target to reduce health and environment problems due to exposure of pesticide use before calling for adoption their large-scale use.

Data availability statement

Data will be made available on request.

Table 8
Typology and toxicological classification of pesticides encountered by ref. [39].

Product names	Type of pesticide	Danger class (WHO)	Status	Active substance
Ridomil	Fungicide	II et U	Not authorized	Metalaxyl 4 %+Mancozeb 64 %
Cyper star	Fungicide	II	Authorized	Cypermethrin 25 g/L
Dudu	Fungicide	Ib et II	Authorized	Abamectin 20 g/L + Acetamiprid 3 %
Dithane	Fungicide	U	Not authorized	Mancozeb 80 %
Thiodan	Insecticide	II	Not authorized	Endosulfan 400 g/L
Supa dudu	Insecticide	Ib	Authorized	Abametrin 1,8 % EC
Rocket	Insecticide	II	Not authorized	Profenofos 40 %
Lava	Insecticide	Ib	Not authorized	Dichlorvos 77 % EC
Guarantee	Insecticide	III	Authorized	Malathion 2 %
Fuko-kil	Rongicide	Ib	Authorized	Zinc phosphide 10 %

Legend: The WHO classification of the toxicity of active substances (2019) has identified 5 groups: Ia, Ib, II, III and U; Ia = extremely dangerous; Ib = very dangerous; II = moderately dangerous; III = slightly dangerous; U = unlikely to present an acute danger.

Additional information

No additional information is available for this paper.

Ethics and consent

Our study did not require ethical approval. The reasons why this study did not require ethical approval are as follows: we interviewed 300 respondents, and it was difficult to get written consent from all of them. But all the people who were affected by the study, because it was about pesticide use, agreed to give me the information. Their argument was: "We are going to give you this information so that you can find solutions for us regarding the use of pesticides in the environment. We don't know how to use them, so these products are causing us problems. They agreed with me because they told me that they expected me to come up with solutions (suggestions) for the proper use of chemicals. Participants will talk about other farmers who use pesticides on their farms. Write down all this information and bring us the book that contains it. They kept telling us: "You are researchers, you need to know what's going on in the field, and we can't hide information from you". Regarding the under-age children, they weren't part of this study because they don't do any agricultural activities in the area.

CRediT authorship contribution statement

Audaxine N. Mwitangabo: Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Espoir B. Basengere:** Writing – review & editing. **Patient M. Zamukulu:** Writing – original draft, Methodology, Investigation. **Leonard K. Mubalama:** Writing – review & editing, Roosevelt R. Dieumerci Masumbuko, Writing – original draft, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Gustave N. Mushagalusa:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] G. Yeyret-Verner, L'évolution récente de la population mondiale. Les grandes tendances, Rev. Géogr. Alp. 60 (1) (1972) 25–42.
[2] S. Feld, Population et développement, De Boeck, Bruxelles, 2008, p. 111 (Mondes en développement).
[3] L. Macharia, D. Mithofer, H. Waibel, Potential environmental impacts of pesticides use in the vegetable sub-sector in Kenya, Afr. J. Hort. Sci. 2 (2009) 138–151.
[4] S. Sulaiman, Y. Ibrahim, M. Jeffree, Evaluating the perception of farmers towards pesticides and the health effect of pesticides: a cross-sectional study in the oil palm plantations of Papar, Malaysia, Interdiscipl. Toxicol. 12 (1) (2019) 15–25.
[5] M. Madaki, M. Lehgerger, M. Bavorova, B. Igbasan, H. Kächele, Effectiveness of pesticides stakeholders' information on pesticide handling kwnoledge and behaviour of smallholder farmers in Ogun State, Nigeria, Environ. Dev. Sustain. (2023).
[6] B. Wan, E. Zhou, P. Xiao, X. Sun, J. Yang, Pesticide overuse in vegetable production: a case study of urban agriculture in city x, China, Environ Res Commun 5 (8) (2023) 085012.
[7] A. Bagheri, N. Emami, C. Damalas, M. Allahyari, Farmers' knowledge, attitudes, and perceptions of pesticide use in apple farms of northern Iran: impact on safety behavior, Environ. Sci. Pollut. Res. 26 (9) (2019) 9343–9351.
[8] P. Manalu, H. Hulu, F. Samosir, B. Buenita, H. Hartono H, S. Siregar, M. Siagian, W. Sihotang, E. Harahap, Safe action in using pesticide among farmers : a scoping review, Public Health of Indonesia 9 (1) (2023) 31–41.
[9] C. Wilson, C. Tisdell, Why farmers continue to use pesticides despite environmental, health and sustainability costs, Ecol. Econ. 39 (3) (2011) 449–462.
[10] L. Bayendi, N. Ndoutoume, F. Francis, Le maraîchage périurbain à Libreville et Owendo (Gabon) : pratiques culturales et durabilité. Cah, Agric. For. 26 (4) (2017) 45002.
[11] C. Francis, P. Porter, Ecology in sustainable agriculture practices and systems, Crit. Rev. Plant Sci. 30 (1–2) (2011) 64–73.
[12] M. Tudi, D. Ruan, L. Wang, J. Lyu, R. Sadler, D. Connell, C. Chu, D. tri Phung, Agriculture Development, pesticide application and its impact on the environment, Int. J. Environ. Res. Publ. Health 18 (3) (2021) 1112.
[13] A. Mushagalusa, D. Mulume, S. Mwisha, S. Mukonde, J. Mugisho, Pesticide choice and use patterns among vegetable farmers on Idjwi Island, Eastern Democratic Republic of Congo, Sage Open 13 (4) (2023) 21582440231218099.
[14] I. Mahmood, S. Imadi, K. Shazadi, A. Gul, K. Hakeem, Effects of pesticides on environment, in: K.R. Hakeem, M.S. Akhtar, S.N.A. Abdullah (Eds.), Plant, Soil and Microbes, 2016, pp. 253–269.
[15] P. Nicolopoulou-Stamati, S. Maipas, C. Kotampasi, P. Stamatis, L. Hens, Chemical pesticides and human health: the urgent need for a new concept in agriculture, Front. Public Health 4 (2016).
[16] S. Lelamo, T. Ashenafi, A. Ejeso, N. Soboksa, B. Negassa, M. Aregu, Pesticide use practice and associated factors among rural community of Malga District, Sidama Regional State, South Ethiopia, Environ. Health Insights 17 (2023) 117863022311572.
[17] H. Gesesew, K. Woldemichael, D. Massa, L. Mwanri, Farmers knowledge, attitudes, practices and health problems associated with pesticide use in rural irrigation villages, Southwest Ethiopia, PLoS One 11 (9) (2016) e0162527.
[18] E. Lekei, A. Ngowi, L. London, Farmers' knowledge, practices and injuries associated with pesticide exposure in rural farming villages in Tanzania, BMC Publ. Health (i389) (2014) 1–13.
[19] A. Mushagalusa, F. Nkulu, Déterminants d'adoption des techniques de production et protection intégrées pour un maraîchage durable à Lubumbashi, République démocratique du Congo. Cah, Agric. For. 29 (2020) 13.
[20] J. Okolle, V. Afari-Sefa, J. Bidogeza, P. Tata, F. Ngome, An evaluation of smallholder farmers' knowledge, perceptions, choices and gender perspectives in vegetable pests and diseases control practices in the humid tropics of Cameroon, Int. J. Pest Manag. 62 (3) (2016) 165–174.
[21] A. Adesuyi, N. Longinus, A. Olatunde, N. Chinedu, Pesticides related knowledge, attitude and safety practices among small-scale vegetable farmers in lagoon wetlands, Lagos, Nigeria, Journal of Agriculture and Environment for International Development 112 (1) (2018).
[22] C. Damalas, S. Koutroubas, Farmers' exposure to pesticides: toxicity types and ways of prevention, Toxics 4 (1) (2016) 1.
[23] B. Schiffers, Sécurité des opérateurs et des bonnes pratiques phytosanitaires, Manuel de Formation, 2018, p. 225.

[24] A. Oesterlund, J. Thomsen, D. Sekimpi, J. Maziina, A. Racheal, E. Jørs, Pesticide knowledge, practice and attitude and how it affects the health of small-scale farmers in Uganda: a cross-sectional study, Afr. Health Sci. 14 (2) (2014) 420.
[25] K. Atreya, K. Kattel, S. Pandit, P. Chaudhary, P. Sipkhan, Understanding farmers' knowledge, attitudes and practices of pesticide use in Nepal: synthesis of a systematic literature review, Arch Agric Environ Sci. 7 (2) (2022) 278–287.
[26] K. Dad, F. Zhao, R. Hassan, K. Javed, H. Nawaz, M. Saleem, T. Fatima, M. Nawaz, Pesticides uses, impacts on environment and their possible remediation strategies- A Review, Pakistan J. Agric. Res. 35 (2) (2022) 274–284.
[27] M. Endalew, M. Gebrehiwot, A. Dessie, Pesticide use knowledge, attitude, practices and practices associated factors among floriculture workers in Bahirdar City, North West, Ethiopia, Environ. Health Insights 16 (2020) 117863022210762.
[28] Y. Mekonnen, Pesticide sprayers' knowledge, attitude and practice of pesticide use on agricultural farms of Ethiopia, Occup. Med. 52 (6) (2002) 311–315.
[29] M. Mergia, E. Weldemariam, O. Eklo, G. Yimer, Knowledge, attitude, and practice of farmers on pesticide use and their impacts on the environment and human health from small scale vegetable farming along the littoral of Lake Ziway. Ethiopia in Review, 2021.
[30] M. Mergia, E. Weldemariam, O. Eklo, G. Yimer, Small-scale farmer pesticide knowledge and practice and impacts on the environment and human health in Ethiopia, Journal of Health and Pollution 11 (30) (2021) 210607.
[31] B. Ndayambaje, H. Amuguni, J. Coffin-Schmitt, N. Sibo, M. Ntawubizi, E. VanWormer, Pesticide application practices and knowledge among small-scale local rice growers and communities in Rwanda: a Cross-Sectional Study, IJERPH 16 (23) (2019) 4770.
[32] D. Öztaş, B. Kurt, A. Koç, M. Akbaba, H. İlter, Knowledge level, attitude, and behaviors of farmers in Çukurova Region regarding the use of pesticides, BioMed Res. Int. (2018) 1–7.
[33] E. Rosanti, R. Rahma, M. Hamawi, D. Arifah, Farmers knowledge on pesticide safety management in Ponorogo, Advances in Health Sciences Research 33 (2021) 17–20.
[34] I. Ali, S. Rahman, A. Qamar, M. Khan, Knowledge, attitude and practices for safe use of insecticides in Aligarh district, Journal of Pharacovigilance and Drug Safety 19 (1) (2021) 1–5.
[35] S. Kavatsurwa, B. Kiremire, J. Wasswa, P. Mpiana, Dithiocarbamates residues level in selected vegetables from Bukavu, Democratic Republic of Congo, Journal of Physical and Chemical Sciences 1 (3) (2016) 1–7.
[36] Rapport Usaid, Comprendre l'imaginaire au cœur des dynamiques des conflits en territoire de Kabare, 2019.
[37] P. Zamukulu, E. Bagula, J. Mondo, G. Chuma, G. Bulonza, S. Mwaluke, Y. Mugumaarhahama, C. Mwimangire, E. Cinyabuguma, A. Lubobo, G. Mushagalusa, Assessment of the nitrogen fertilizer split-application on maize grain yield and profitability on Nitisols of South-Kivu, Eastern D.R. Congo, CABI Agric Biosci. 5 (22) (2024) 1–12.
[38] D. Masumbuko, J. Mugisho, G. Chuma, R. Ayagirwe, État de lieu de la Cercosporiose noire du bananier à l'Est de la République Démocratique du Congo, Afrique SCIENCE 15 (3) (2019) 23–33.
[39] P. Zamukulu, E. Bagula, J. Mondo, G. Chuma, F. Safina, T. Cishesa, A. Kavange, D. Masumbuko, J. Kazadi, G. Mushagalusa, A. Lubobo, Optimization of plant density and fertilizer application to improve biofortified common bean (Phaseolus vulgaris L.) yield on Nitisols of South-Kivu, Eastern D.R. Congo, Heliyon 9 (6) (2023) e17293.
[40] P. Cituli, L. Mubalama, Accès à la terre agricole et sécurité alimentaire : Un défi majeur dans la chefferie de Kabare en Province du Sud Kivu, RD Congo, 2020.
[41] G. Nachigera, A. Kashemwa, C. Sinza, L. Bigirimwami, K. Karume, A. Lubobo, Responses of biofortified common bean varieties to Di-ammonium phosphate fertilizer under climate variability conditions in South-Kivu, DR Congo, Afr. J. Agric. Res. 11 (38) (2016) 3569–3577.
[42] OMS, Classification OMS recommandée des pesticides en fonction des dangers qu'ils présentent et lignes directrices pour la classification, 2019.
[43] C. Nwadike, V. Joshua, P. Doka, R. Ajaj, H. Abubakar, S. Gwary-Moda S, M. Danjin, H. Moda, Occupational safety knowledge, attitude, and practice among farmers in Northern Nigeria during pesticide application—a Case Study, Sustainability 13 (18) (2021) 10107.
[44] S. Sabran, A. Abas, Knowledge and awareness on the risks of pesticide use among farmers at Pulau Pinang, Malaysia, Sage Open 11 (4) (2021) 215824402110648.
[45] E. Raimondo, S. Costa Gutierrez, S. Cabrera, C. Benimeli, Knowledge, Attitudes, and Practices on Pesticide Application Among Farmworkers from Communities in Western Catamarca Province, Argentina, NS, 2022.
[46] T. Nguyen, Le Ntt, J. Havukainen, D. Hannaway, Pesticide use in vegetable production: a survey of Vietnamese farmers' knowledge, Plant Protect. Sci. 54 (4) (2018) 203–214.
[47] Z. Ben Khadda, M. Fagroud, Y. El Karmoudi, S. Ezrari, I. Berni, M. De Broe, T. Behl, S. Bungau, T. Houssaini, Farmers' knowledge, attitudes, and perceptions regarding carcinogenic pesticides in fez meknes region (Morocco), Int. J. Environ. Res. Publ. Health 18 (20) (2021) 10879.
[48] N. Jambari, N. Samad, S. Anua, R. Ruslan, N. Hamzah, Knowledge, attitude and practice (KAP) on pesticide exposure among farmers in Kota Bharu, Kelantan. Malaysian Journal of Medecine and Health Sciences 16 (SUPP11) (2020) 56–62.
[49] M. Syafrudin, R. Kristanti, A. Yuniarto, T. Hadibarata, J. Rhee, W. Al-Onazi, T. Algarni, A. Almarri, A. Al-Mohaimeed, Pesticides in drinking water—a review, Int. J. Environ. Res. Publ. Health 18 (2) (2021) 468.
[50] P. Khatun, A. Islam, S. Sachi, M. Islam, P. Islam, Pesticides in vegetable production in Bangladesh: a systemic review of contamination levels and associated health risks in the last decade, Toxicol Rep 11 (2023) 199–211.
[51] K. Sharafi, M. Pirsaheb, S. Maleki, H. Arfaeinia, K. Karimyan, M. Moradi, Y. Safari, Knowledge, attitude and practices of farmers about pesticide use, risks, and wastes; a cross-sectional study (Kermanshah, Iran), Sci. Total Environ. 645 (2018) 509–517.
[52] M. Adeep, M. Kiran, N. Dorjee, D. Tshering, J. Sonam, W. Karma, J. Thinley, C. Vishal, Assessment of exposure to pesticides and the knowledge, attitude and practice among farmers of western Bhutan, PLoS One 18 (5) (2022) e0286348.