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Pesticide Use Practices by Chinese Cabbage Growers in Suburban Environment of Lubumbashi (DR Congo): Main Pests, Costs and Risks

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Abstract Market gardeners in Lubumbashi grow Chinese cabbage in monocropping system during the dry season for cash and livelihood. Crop attracts pests but little is known about farmers' pest management practices. This study was initiated to obtain comprehensive information on pesticide use practices and the risks faced by vegetable farmers while handling pesticides to control pests. Survey, simulated treatment with fluorescent tracer and field observations were used to collect data on farmers' knowledge of cabbage pests; pesticide use, costs and risks for both farmers and the environment. A high proportion of cabbage growers (66%) considered *Agrotis ipsilon* (Lepidoptera, Noctuidae) as the most destructive pest of cabbage crop. Most of the farmers (91%) spent between 0.5 and 4 US dollars to purchase insecticides, sprayed up to 4 times (10%) during the growing cycle of Chinese cabbage (45 days). The dose applied was twice lower than that recommended by the manufacturers of the Lambda-cyhalothrin and Diclorvos, two of the main active ingredients commonly used in the study area. Many farmers (72%) sprayed pesticides with inappropriate equipment (buckets and brooms) during the day while the targeted pests hide underground and damaged the crop at night when the pesticide has already volatilized. Destruction by insecticides of beneficial entomofauna was reported (bees 22%), earthworms (36%) and cabbage pest natural enemies (18%). Farmers got contaminated by pesticides and reported some discomforts such as nostril irritation accompanied with sneeze (94%), eyes irritation (76%) and headache (30%). These results may help vegetables farmers understand the urgent need to use existing alternative methods to control pests and may also contribute to the reformation of pesticide policies for safe and effective use of plant protection products in DR Congo. To relieve farmers from pesticide health risks, a program of awareness and information is also needed.

Keywords: *Lubumbashi, Chinese cabbage, pesticide, fluorescent tracer, risk assessment*

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1. Introduction

Urban food needs in African cities are growing due to rapid urbanization that has resulted in growing numbers of urban consumers [1,2]. In Lubumbashi (southeastern DR Congo), more than 7,800 households are involved in vegetables farming for cash and livelihood [3]. Chinese cabbage (*Brassica chinensis* L.) is one of the main crops grown in monocropping system during the peak season from March to September [4]. It occupies a surface of 67.5 ha but the yield has been reported very low compared to that recorded in South Africa because of the great issues of soil fertility and pest attacks [4,5,6]. Pests and diseases cause qualitative and quantitative damages which lead to enormous economic losses [7,8,9]. A study conducted by [10] estimated the losses caused by pests between 35% and 39%, respectively, for maize and potatoes. In 2000, [11] ranged the losses caused by the insects in cabbage crop in suburban areas of Bukavu in DR Congo from 3.5 to 55.8%. If pest's identification remains a challenging work for farmers, several studies in Africa have highlighted the indigenous traditional farmers' knowledge of a variety of pests and the damage they cause on crops [12,13]. Among insect pests affecting cruciferous vegetables, diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae), has been considered to be the most destructive throughout the world [14,15,16] whereas *Agrotis ipsilon* (Lepidoptera: Noctuidae) is described as a polyphagous pest and more active during the night [17]. In order to protect crops, farmers often use chemical pesticides because of their effectiveness and immediate action on pests [1,18]. However, besides their beneficial effects, pesticides are accepted as having negative impacts including resistance of targets, human intoxication and damage to the biodiversity [1,10,19]. Indirect economic losses related to the purchase and the application of pesticides have been also reported [9] as well as the high expenses related to medical treatment for people poisoned by pesticides [9,20]. Studies conducted in many regions in Africa and Asia underline the luck of full understanding from farmers of the effects of pesticides on their health. Farmers come into contact with pesticides while preparing mixtures, during pesticide application, weeding, pruning, harvesting, and re-entry to collect vegetables [20,21,22,23]. Concerns related to pesticides use have increased, particularly in developing countries like DR Congo where regulations are not strictly implemented and farmers' knowledge of safe handling procedures is often inadequate [24]. In Lubumbashi as anywhere in DR Congo, even if the use of pesticides by small farmers is still low (do not use much quantity) compared to other regions of the world, there are trends towards misuse [4,25,26,27]. Poor protective equipment, inappropriate spraying material and limited knowledge of pesticides as well as of targeted pests have exacerbated farmers' vulnerability to pesticides. Pesticide retailers who are considered as primary source of information for farmers have also limited knowledge of agricultural inputs such as pesticides. This study was initiated to obtain comprehensive information on pesticide use practices among vegetable farmers. It aims at identifying the type of pesticides used and the pest targeted. Analyzing farmers' practices and assessing the risks related to the use of pesticide by farmers growing cruciferous vegetables in urban and suburban area of Lubumbashi in DR Congo.

2. Materials and Methods

2.1. Description of the Study Area

The current study was conducted within five vegetable sites in Lubumbashi: Kimilolo (11° 43'007 " S, 27° 25'66"E); Kilobelobe (11 ° 40' 306 " S, 27 ° 30'974 " E) , Maendeleo(11° 42'615 " S, 27 ° 27' 976 " E), Naviundu (11 ° 37 '825' S, 27 ° 31' 266 " E) and Tingi-Tingi (11° 36'540 " S, 27 ° 28' 433 "E). According to [28], the mean annual temperature is 20 °C; the coolest month is July (15.6 °C), and the warmest month is October (23 °C). The mean annual rainfall is 1,270mm, with a rainy season that lasts 118 days, from November to March. Rainfall deficit (170mm) observed since 1999 in the study area has been reported as a limiting factor for urban and periurban agriculture [29,30,31]. There are more concerns about the quality of vegetables grown that accumulate trace metals [32] as well as unsafe pesticide handling that can result in serious health problems [4]. Lubumbashi has currently an estimated population of 2,097 thousands inhabitants and the projected statistics indicate 3,489 thousands inhabitants by 2030 [33]. Periurban agriculture is considered as a survival and entrepreneurial activity for many poor dwellers in the city where jobs opportunities are still limited [4,34,35,36]. The distribution of vegetable farmers surveyed between April and August 2016 as well as those monitored between April and June 2017 are presented in Table 1.

These sites were chosen on the basis of the following criteria: (i) Chinese cabbage was the main crop grown during the period of the study; (ii) almost of those sites were located in suburban area and were among the largest vegetable production sites in Lubumbashi; (iii) they were accessible and have experienced the Project for the Development of Urban and Peri-urban Horticulture (UPH) in Lubumbashi (DRC) 2002-2008 [3,37]. (iiii) the use of chemical inputs including pesticides was reported.

Table 1. Distribution of vegetable farmers surveyed in the study sites

N°	Production sites	Number of farmers in 2016	Number of farmers 2017
01	Kimilolo (Kisanga)	59	15
02	Katumbwi	17	-
03	Kilobelobe	43	15
04	Maendeleo	21	5
05	Naviundu	53	10
06	Tingitingi	53	5
Total		246	50

2.2. Data Collection

To assess pesticide use practices, data were collected in two rounds. First, 246 vegetable farmers were randomly interviewed during a large survey in 6 sites between April and June 2016, to describe the socioeconomic characteristics and collect general information on urban agriculture in Lubumbashi. Data collected at the first round were relative to the gender, education, and land access, farm size, farmers 'group (Association), and price of agricultural inputs, workforce and output (yield). Secondly, from March to June 2017, a random sample of 50 cabbage growers was drawn from the list of 246 vegetable farmers previously interviewed in order to obtain the practical information on the pest management.,. Field observations during pesticide application helped to understand farmers' practices and the challenges.

2.2.1. Assessment of Farmers Knowledge of Chinese Cabbage Pests and Damage

To assess farmers' knowledge of cabbage pests, we adapted the methodology used by [12] to characterize indigenous traditional knowledge of insect pests in Uganda. First, farmers were asked to name the main cabbage pests they knew. Secondly, insects were collected from underground and cabbage leaves. Collected insects were presented to a specialist for their identification. Finally, we asked the respondents to specify the Chinese cabbage organs damaged and determine the most destructive pest.

Table 2. Type of information collected on pesticide use practices during field survey

Type of information	Specific data collected in the questionnaire
Pesticide use practices	Type of pesticides used, purchase price, cost per production, type of spraying equipment, time and frequency of application, measurement of dose; protective equipment
Risk for farmer's health	Immediate effects of pesticide exposure (symptoms and discomfort reported by farmers after a spray event as well as the farmer's body parts contaminated by the pesticide)
Risk for environment	Management of empty containers of pesticide, immediate effects for biodiversity.(bees, earthworms, beneficial insects)

2.2.2. Identification of Pesticides and Assessment of Farmers' Exposure

To identify the pesticides used by cabbage growers, we visited the local agricultural shops closer to the sites and whereby we collected photos of pesticides commercialized and presented them to farmers in order to indicate the product usually bought and used. Data collected regarding the pesticide use practices and their effects for both farmers' health and environment are presented in Table 2. To assess the level of farmers' exposure to pesticides, we used a visual method proposed by [38]. Indeed, the farmer's body contamination assessment has been done in the following way: Among the fifty vegetable famers selected to assess the phytosanitary practices, 20% accepted to volunteer for performing the field trials. The choice of that number is explained by the limited quantity of gloves and coveralls (Tyvek®) available to perform the simulated treatment in each site. The volunteer farmers put on white cotton gloves, mask and coveralls (Tyvek®) and were asked to work according to their usual practices, as previously observed. Farmers used buckets and brooms because those were the equipment commonly used in the study area. The spray mixture was a solution of 6 grams of fluorescein mixed in 10 liters of clean water. The fluorescent tracer has been used previously in Nicaragua and Senegal for demonstrations as part of educational programs for agricultural workers and did not indicate any adverse health effects for applicators [39,40]. All the trials were conducted on 51m² plots of Chinese cabbage in every site. After mixture and sprayings, the applicator entered in a darkroom and a handheld UV lamp (LAMP04TBL) was used to visualize fluorescent depositions on their coveralls, gloves and masks. A camera was used to record pictures of the contaminated body's areas. The visual method presents an advantage to be easy to perform, affordable and help farmers understand the risk they face. However, the results provided are qualitative and just indicative [38,39,40]. This technique is also a powerful tool for showing pesticide contamination and for helping farmers evaluates their practices and protective equipment.

3. Results

3.1. Vegetable Farmers 'Socioeconomic Background

In the Table 3 are presented the socioeconomic characteristics of vegetable farmers surveyed and the results can be summarized as follows: 52% of farmers were male with mean age of 40 years; 62.6% attended the high school and 65.8% had an experience in periurban farming ranging from 1-10 years. Half of vegetable farmers (50%) cultivated small plots raging between 2 and 3 ares on which they produced between 406-975 kg of Chinese cabbage in 45 days.

3.2. Farmers' Knowledge of Main Pest and Damage in Chinese Cabbage Crop

Cabbage growers interviewed were facing a wide range of pests but the well-known were related to the damage they caused in cabbage crop (Table 4). The majority of farmers (66%) considered black cutworms (*Agrotis ipsilon)* as the most damaging because they cut the stems of the young plants underground during the night and farmers had to carry out repetitive transplanting. Twenty two (22%) of farmers pointed the diamondback moth caterpillars because they gnaw the leaves and mess them with their frass to the point of reducing the market value of the cabbage. As for the cabbage aphids (*Brevicoryne brassicae* L. Hemiptera, Aphididae), 6% of farmers quoted them as important pests because they cause the yellowing and withering of the plant. . Damage due to *Hellula undalis* (Lepidoptera, Pyralidae) was also reported(6%).

Table 3. Socioeconomic background of respondents (n=246)

Variables	Category	N^ber^ of farmers	Percentage
Gender	Male	128	52
	Female	118	48
Farmer's age	17-35	88	35.8
	36-54	92	37.4
	>55	66	26.8
Education level	Primary	54	22
	High school	154	62.6
	University	34	13.8
	Professional	4	1.6
Farmer's experience (years)	1-10	162	65.8
	10-20	84	34.2
Membership to a farmer's group		98	40
Training and farmer's field school		124	50.4
Land size	≥ 1are	85	34.6
	2-3 ares	123	50
	>3 ares	38	15.4
Tenant of farming plot		103	42
Main vegetable crops	Cabbage (Chinese c.)	246	100
Cabbage production	406-975 kg	-	-

Table 4. Main pests and damage reported by small vegetable farmers

Main pests	Scientific name	Damage	N*(%) of farmers
Black cutworms	*Agrotis ipsilon*	Cut plant shoots at the base in night.	33(66)
Diamondback moth Caterpillars	*Plutella xylostela*	Gnaw, consume the leaves and soil them with their frass.	11(22)
Cabbage webworm	*Hellula undalis*	Hole, lay on and consume young leaves	3(6)
Cabbage aphid	*Brevicoryne brassicae*	Stick on the leaves, cause yellowing and withering of the cabbage	3(6)

*N= number of farmers.

3.3. Pest management practices

The main pest control methods used by small vegetable farmers in Lubumbashi are presented in the Table 5. Almost the farmers (86%) used pesticides to control the pests. They applied a diversity of insecticides belonging to different families of pesticides (Table 6). The organic pest management was practiced by 14% of farmers. They used natural products (ash, pepper) and crop maintenance (intercropping).

Table 5. Pest control in Chinese cabbage crop

Pest management	Number of farmers	Percentage (%)
Chemical control	43	86
Organic pest managment	7	14

3.3.1. Type of Pesticides Used by Farmers

The main pesticides commercialized and used by vegetable farmers are presented in the Table 6. Organophosphate products and pyrethroids were the dominant pesticides used by vegetable farmers to protect crops. The two families represented respectively 31 and 38% of crop protection products. Almost (94%) of pesticides were insecticidal substances among them the dichlorvos and lambda-cyhalothrin were two main active ingredients used.

3.3.2. Determinants of Pesticide application

Respondent farmers had different criteria to start the application of pesticide in Chinese cabbage crop (Table 7). The majority of Chinese cabbage growers (72%) applied insecticides once they have observed the holes on cabbage leaves and only 6% did so according to an advice from a fellow vegetable farmer. A high proportion (22%) sprayed once they noticed many insects in the field.

3.3.3 Cost of Pesticides Used by Farmers

The fact that small farmers could not afford the packaged product, generally 0.5-1 liter, pesticide retailers proposed different local measurement units among them; the commonly used was an empty can of tomato of 70 grams. Farmers purchased insecticides in agricultural shops closer to their vegetables production sites. The Figure 1 indicates that the price was almost the same in all the sites from Maendeleo where the lowest price (1660 ±230 CDF) was reported and the highest (1850 ±184 CDF) was recorded at Kimilolo with average price of 1700±200 CDF through all the sites.

Table 6. Crop protection products used by small vegetable farmers in the study area

N °	Trade local names	Actives substance	Family	Formulation*	%
01	Roach	Dichlorvos	organophosphate	EC	
02	Doom	Dichlorvos	organophosphate	EC	
03	Lava	Dichlorvos	organophosphate	EC	
04	Bloom	Dichlorvos	organophosphate	EC	31
05	Mo phos	Monorotophos	organophosphate	SL	
06	Kick boxer	Lambda cyhalothrin	Pyrethroid	EC	
07	Lambex	Lambda cyhalothrin	Pyrethroid	EC	
08	Judo	Lambda cyhalothrin	Pyrethroid	EC	
09	Ninja	Lambda cyhalothrin	Pyrethroid	EC	
10	Karatii	Lambda cyhalothrin	Pyrethroid	EC	38
11	Superforce	Cypermethrin	Pyrethroid	EC	
12	Akari	Clofentezine	Tetrazine	SC	6
13	Ascozeb	Manconzebe	Carbamate	WP	13
14	Methoforce	Methomyl	Carbamate	SP	
15	Agricrop	Fipronil	Pyrazole	SC	6
16	Agromectin	Abamectine	Avermectin	EC	6

* EC = Emulsifiable concentrate; WP = Wettable powder, SC= suspension concentrate , SP= soluble powder

Table 7. Criteria of application of pesticide on cabbage crop

Criteria of pest control	Number of farmers	Percentage (%)
Council received	3	6
Presence of many insects in the field	11	22
Observation of the holes on the leaves	36	72

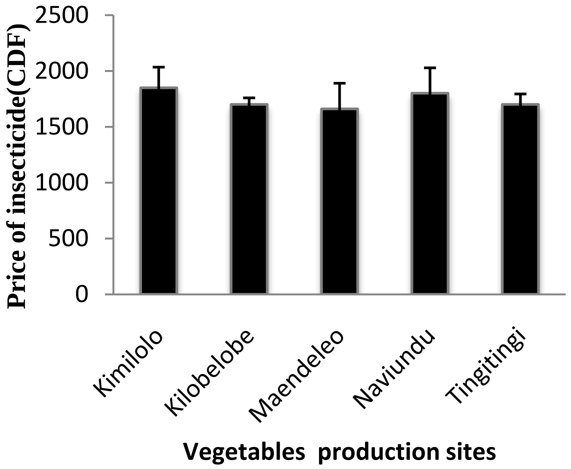

Figure 1. Purchase price 70ml(empty can of tomato) of insecticide in different sites (1 US dollar was 1440 Congolese francs (CDF) between April and May 2017 while collecting data)

Almost farmers (91%) spent between 0.5 and 4 US dollars to purchase insecticides sprayed to protect crops, whereas 1% of farmers reported incurring important cost for pesticides (Table 8). Farmers who spent 10 USD had likely large farms and used the same product bit by bit each time they renewed the plantation. Few farmers (3%) did not purchase the pesticides.

Table 8. Distribution of farmers according to the pesticide cost (USD)

Purchasing price	Number of farmers	Percentage
0.5 - 4	223	91
5 - 9	12	5
≥10	4	1
Did not purchase	7	3

3.3.4. Measurement of Dose and Pesticide Application by Small Farmers

The measurement units used by farmers to determine the dose are provided in the Table 9. All the respondent farmers kept insecticides in plastic containers of soft drinks and 94% used the container tops to determine the dose. Most of cabbage growers applied 14 ml or two tops in 10 liters of water. Despite the units of measurement used, the dose applied by farmers was lower than that recommended by the manufacturer of Lambda cyhalothrin and dichlorvos, two main active ingredients commonly used in the study area.

Table 9. Local dose measurement units used by small farmers in Lubumbashi

N* (%)	container	Measurement units	value (ml)	Dose(ml)/10 liters of water
47(94)	Bottle of soft drinks	Container top	7x2	14
3(6)		Syringe	5x2	10

The materials used by most of the farmers were not appropriated to spray crop protection products (Table 10). Most of the farmers observed (72%) used buckets and brooms or shrub branches to apply pesticides without protective equipment.. few (12%) used knapsack sprayers, but all of them were defective. Inappropriate equipment used promoted waste and poor distribution of the mixture on the treated crop.

Table 10. Materials used by small farmers while spraying pesticides

Materials	Number of farmers	Percentage (%)
Watering can	8	16
Backpark sprayer	6	12
Bucket and broom	36	72

3.3.5. Frequency of Pesticide Application

The frequency of pesticide application in Chinese cabbage crop for a cycle of ± 45 days is recorded in Table 11. More than half (52%) of farmers applied the pesticide once, 38% sprayed between two and three times while 10% went for up to four applications.

Table 11. Number of pesticide application in Chinese cabbage crop

Spraying frequency	Number of farmers	Percentage(%)
Once	26	52
Two- three times	19	38
Four times	5	10

3.3.6 Time of Pesticide Application

Farmers sprayed pesticides at different time during the day as shown in Table 12.

A high portion of the farmers (44%) applied the pesticide between 4- 6 pm whereas 34% of farmers could apply the pesticides any time of the day. Applying the pesticide during strong heat or windy time is not encouraged at all.

Table 12. Moment farmers sprayed pesticide

Time of application	Number of farmers	Percentage (%)
7-9 am	6	12
10-12 am	5	10
4-6 pm	22	44
Any time	17	34

3.4. Assessment of Farmers' Exposure to Pesticide by Using a Fluorescent Tracer

All farmers (100%) observed were greatly contaminated after spraying pesticide with poor equipement (Figure 2). The fluorescent tracer used for the simulated spraying highlighted that hands, thighs, legs and feet were the farmer's body parts most exposed and contaminated. Hands were first contaminated by the concentrated product during the measurement of the dose and preparation of mixture.

3.5. Vegetable Farmers' Report of Pesticide Poisoning Symptoms

Farmers exposed to pesticides during their regular application practices reported immediate poisoning symptoms as shown in Table 13. Most of the vegetable farmers reported having discomforts while and after spraying pesticides on cabbage crop. The most common symptoms reported by farmers are presented in Table 13. Nostril irritation accompanied with sneeze was mentioned by 94% of farmers, eyes irritation (76%) and headache (30%) was also reported.

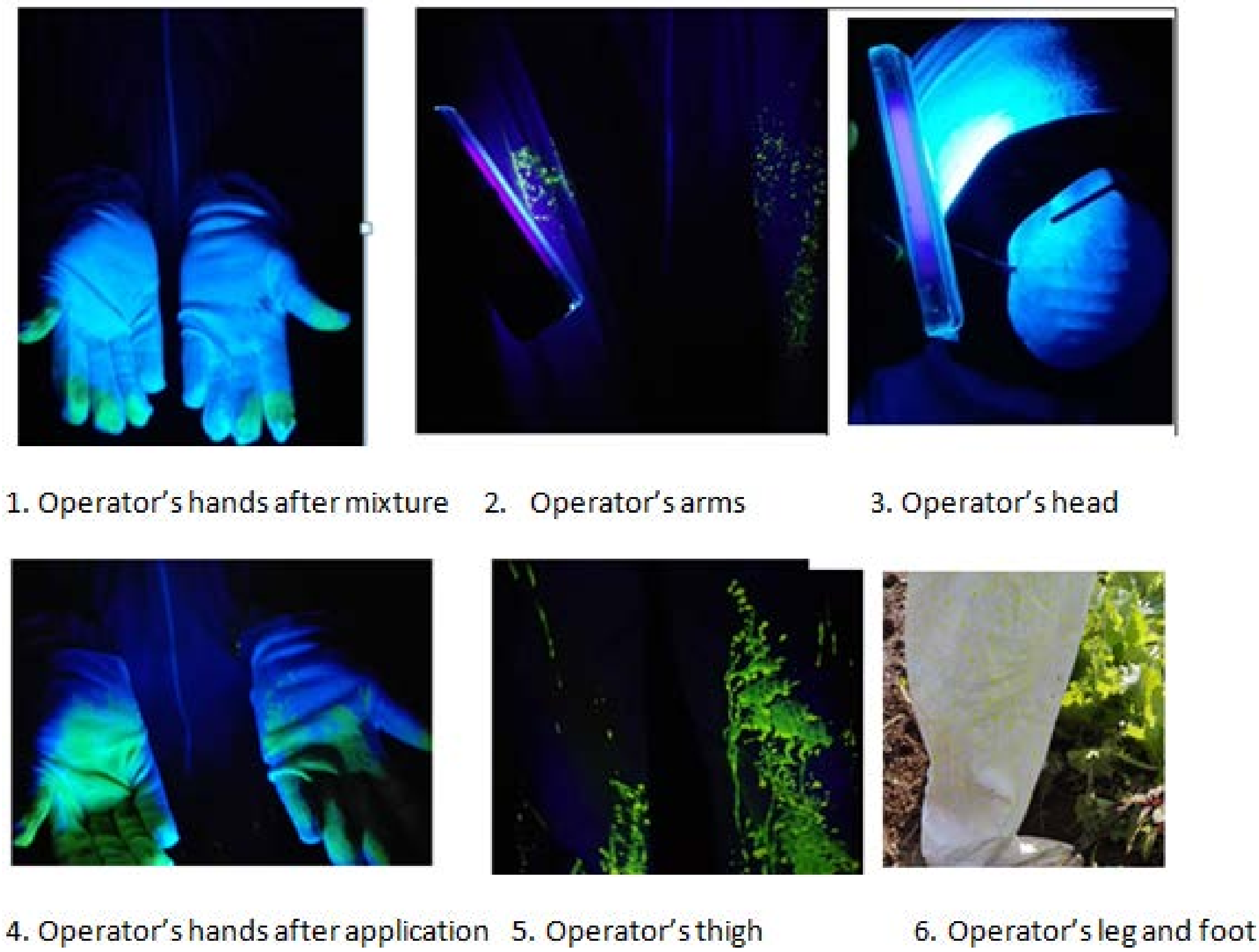

Figure 2. Farmer's body parts contaminated by the pesticides after mixture and application in simulated treatment with fluorescent tracer (green color)

Table 13. Poisoning symptoms reported by Chinese cabbage growers

Symptoms	Number of farmers	Percentage (%)
Nostril irritation and sneeze	47	94
Eyes' irritation	38	76
Skin irritation	26	52
Headche and fatigue	15	30

Table 14. Environmental issues of pesticide use in the study area

Environmental issues	Numbers of farmers	Percentage (%)
Abandonment of pesticide packaging	42	84
Ignoring the threats to the environment	33	65
Loss of earthworms in the soil	18	36
Death of bees	11	22
Loss of pest natural enemies	9	18

3.6. Risk of Pesticides in the Market Gardening Ecosystem

Pesticides use practices by cabbage growers in peri-urban agriculture cause enormous environmental issues. The Table 14 presents the problems reported by farmers and observed ourselves in the sites. First, many farmers (65%) were not aware of pesticides threats to the environment. 84% of farmers left the empty pesticide containers in the fields. The destruction by pesticides of non-harmful organisms (useful entomofauna) was reported specifically for bees (22%), earthworms (36%) and cabbage pest natural enemies (18%).

4. Discussion

4.1. Diminution of Female among Vegetable Farmers and Its Impact on Pest Management

The number of female is gradually decreasing among vegetable farmers in Lubumbashi compared to 2000-2008 while the urban and periurban horticulture project was at its peak. The same trend has been mentioned by two studies carried out in the same area showing that the number of female in urban agriculture passed from 55% in 2010 [36] to 44% (4,17,41). This is because of land scarcity, lack of support and probably the dislocation of several local farmers' groups after the Urban and Peri urban Horticulture project (UPH). This situation has contributed to the abandonment of the integrated pest management practices promoted by UPH project which had a focus on the use of natural products, intercropping and rotation of crops [37]. The young male who represent 52% of the actual vegetable farmers in Lubumbashi have fully integrated pesticides in their agricultural practices. This is because they believe that spraying pesticides presents the easy and quick solution to pests problems in vegetable production [1,2,20,21] and help to optimize economically vegetable yield [42,43,44].

4.2. Farmers' Knowledge of Cabbage Pests

Vegetable farmers surveyed in Lubumbashi seemed to have knowledge of the main pests of crop and damage they caused. The same observation has been done in Uganda where 95% of the farmers knew the most conspicious insect damaging the pigeonpea at the flowering stage [12]. The majority of cabbage growers (66%) considered black cutworms (*Agrotis ipsilon)* as the most damaging in cabbage crop. All the pests known by farmers specifically cutworms (*Agrotis spp*.), *Plutella xylostella*, and *Brevicoryne brassicae* have been reported also as the major pests of tomatoes and cruciferous vegetables in Zambia and Malawi [45], in Ghana [16], in Cameroon [2] and Bukavu where [11]) reported a loss of cabbage plantlets up to 53.8% due to pests. Infestation of young cabbage leads also farmers to carry out repetitive transplanting and increase the production cost. Many researches conducted in Africa show that if the pests infestation is important, this can be considered as a major limiting factor of production [2,14,45].

4.3. Use of Pesticides by Vegetable Farmers

The competition, the damage and losses caused by pests (lead) push farmers to spray pesticides [46,47]. Most of the cabbage growers (86%) relied on pesticides as the major and often exclusive crop protection strategy. The same observation has been noticed in many developing countries among vegetable farmers who apply synthetic pesticides to improve the quality of the production and to attract the market [42,45,48,49]. Farmers sprayed pesticide because of its high perceived efficacy and less labor required compared to other crop protection practices [2,18]. Insecticides represented 94% of the pesticide used by cabbage growers in the study area. The same observation has been reported in Tanzania, Burkina Faso ,Niger where respectively 59%, 73% and 84% of plant protection products used by vegetable farmers were insecticides [20,27,50]. Most insecticides used by cabbage growers in the study area belong to two chemical families of pesticides respectively the pyretroids (38%) and organophosphate (31%). The main active ingredients used were lambda-cyhalothrin and dichlorvos . Farmers relied on local pesticide retailers for information about pesticide use whereas their background had nothing related to crop protection and had never been trained neither licensed to handle and sale agricultural chemical inputs. Another big challenge for both pesticide retailers and farmers is to read and understand the pesticide labels written in foreign languages (English, Chinese) while the main languages spoken in the study area are Kiswahili and French. According to [51] since pesticide retailers are farmers' primary source of information about pesticides, training people involved in pesticide trade can increase their knowledge of pesticides and that will help to avoid pesticide mishandling observed among farmers and sale agent[4,51,52,23]. A study conducted by [50] in Burkina Faso indicated that the lambda-cyhalothrin accounted for 67% of pesticide ingredients used among tomato growers because it is available on local markets. Experience from several countries proves that the choice of a pesticide by farmers is more influenced by pesticide selling agents and fellow farmers [1,20,47]. Results showed that 10% of farmers have sprayed insecticides up to four times before cabbage harvesting. This is probably because the active ingredient applied was not effective to control the pest targeted. A study conducted in India and Kenya showed not using insecticides adequately(wrong insecticide product to a target pest, poor application methods) can result in an unsuccessful pest control [14]. Farmers met in the study area applied the dose twice lower than that recommended by the manufacturer of diclorvos and the lambda-cyhalothrin. Diclorvos is volatile and inhalation is the most common route of exposure for farmers [54]. Although the diclorvos is volatile, farmers sprayed the pesticide during the day whereas at that moment, the main pest targeted (*Agrotis ipsilon*) hides underground and come out late at night to ravage the crop [17,55]. Pesticide use practices carried out by small vegetable farmers in were not effective neither safe. Results showed also that most of the farmers were not aware of the negative effects of pesticides to the environment. However, few farmers highlighted the loss of beneficial insects and earthworms in farming ecosystem. A study conducted by [15] showed that beside the benefits from insecticide of increased yields, this may be outweighed by killing of beneficial natural enemies in cabbage crop. In other hand, the lack of appropriate knowledge on safe handling and use of pesticides can increase the risk up to irreversible issues in the long-term both for biodiversity and farmers [20,19,56].

4.4. Assessment of Farmers' Exposure to Pesticides

Simulated treatment with fluorescent tracer showed that farmer's hands, legs and feet were the body parts most contaminated by the pesticide (Figure 2). The same observation has been done among small farmers in North of Benin where [38] stated that applicator's body can be fully contaminated and exposed ten times to pesticide if the applicator prepares and sprays without protective equipment. According to [24], the deposition of pesticide on legs can be even 31 times higher than on arms. Many cabbage farmers in the study area experienced discomforts during mixture preparation and after spraying pesticides. This is because pesticides were not correctly handled by farmers and did not put on the personal protective equipment [1,57]. Respondent farmers used baskets and shrub branches to apply pesticide. That working condition has led to the waste of mixture and increased farmers' exposure to pesticides. This is in agreement with several studies showing that the failure to wear personal protective equipment and use of poor material when spraying pesticide can increase contamination and risk exposure for the applicator [19,38,58]. The symptoms expressed by Chinese cabbage growers (eye and skin irritation, sneezing, headache) have been reported among vegetable farmers in other developing countries [1,2,20,22,38,44,50]. In Northern Tanzania, farmers spent a lot of money for health care due to pesticide poisoning. Yet, many farmers in developing countries always assume the symptoms and the contamination as the common phenomena after working in the fields [20]. The possible strategy of relieving farmers from the health risks associated with pesticide exposure is to deploy a program of awareness and information [35,59].

5. Conclusion

This study provides useful information on the pesticide use practices, the insect pests targeted the cost and the risk faced by vegetable farmers in Lubumbashi. Findings state that the progressive diminution of female among vegetable farmers in Lubumbashi is accompanied by the abandonment of integrated pest management techniques promoted by the Urban and Periurban Horticulture project. Even if farmers use very low dose of pesticides, however, it is the way they handle those toxic substances without the appropriate equipment (personal protective equipment, spraying materials) that arises many concerns. Farmers met still lack appropriate knowledge on safe handling, storing. They relied on pesticide sale agents who had also limited knowledge of pesticides. Poor spraying materials, inappropriate pesticide, bad weather during pesticide application and little dose used by small farmers have contributed to an ineffectiveness of pesticides to control pests in the study area. The health issues were not limited to the contamination of hands, legs and feet, but also discomforts like sneezing; skin irritation and fatigue were reported by the farmers. It is urgent to deploy a program of awareness to relieve farmers from pesticide hazards. We suggest that in short term, efforts to reduce pesticides issues for both farmers and environment could pass through an integrated training of farmers and pesticide sale agents on handling and use of pesticides safely. In long term, the appropriation by vegetable farmers of the integrated pest management techniques promoted by Urban and Periurban Horticulture project remains a sustainable solution for both farmer and market gardening ecosystems in Lubumbashi.

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