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Assessment of Pesticide Use against Tephritidae Fruit Fly and Other Pest among Small-scale Solanaceous Vegetable Farmers in Bugorhe-Kabare the Democratic Republic of Congo

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ABSTRACT

Ninety-six farmers interviewed in Kabare, east of the DR Congo during 2021. Farmers majority were males (79.17%), ranging 30 to 60 years, used different pesticides in vegetable farms and the main solanaceous crops cultivated is tomato. The use of insecticide and fungicide were high, with many different formulations of the different class types recorded in use, (20%) endocrine disruptors, (40%) cholinesterase inhibitors, (35%) carcinogen and potential carcinogens suspected to be. A lot of out of those pesticides are unregistered for general use. Farmers applied pesticide once a week and they didn't have specific instructions. The skin effects, headaches and dizziness are dominant. They do not have a good system of pesticide packaging management. For reducing pesticide application, we propose options of agro ecology. We suggest that the Congolese government must create a quarantine, control and surveillance service for phytosanitary products, fruits and vegetables within the DRC country and at these borders. Also, it needs urgent action from the federal and regional governments to formulate policy, design legislation, and enforcing for its implementation concerning the supply, transportation, storage, appropriateness, and application of harmful pesticides.

1. Introduction

Different types of insect pests afflict production in western Albertan Rift area ^[1,2]. Tephritid fruit flies such as *Dacus bivittatus* (Bigot), *D. punctatifrons* Karsch, *Ba-*

trocera dorsalis (Hendel), *B. latifrons* (Hendel), *Ceratitis cosyra* (Walker), *C. rosa* Karsch, *C. fasciventris* Bezzi, *C. capitata* (Wiedemann), *Zeugodacus cucurbitae* (Coquillett) and other pests such as *Anarsia lineatella* Zeller (Lepidoptera, Gelechiidae), *Comstockaspis perniciosus*

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(Comstock) (Hemiptera: Diaspididae) constitute a major constraint to increased production of fruits and vegetables in orchards and gardens^[3-7] and those small-scale farmers has a lack of fundamental horticultural knowledge^[8]. For example, the native species of tephritid fruit flies cause high damage and serious problems to growers. However, the invasion of *B. dorsalis* has exacerbated the situation, with damage frequency reaching 100% in the absence of effective control^[9,10]. This species is highly invasive than local fruit fly species in smallholder crops^[9]. Even today, Abang et al.^[11,12] show significantly losses through direct damage to fruits, vegetables and loss of market opportunities. According to Mengistie^[13,14], Fikadu^[15] pesticide refers to a wide range of compounds including insecticides, herbicides, fungicides, rodenticides, molluscicides and plant growth regulators. Promoting the sustainability, several authors^[11,16-20] demonstrated that agro-pesticide technologies (insecticides, fungicides and herbicides) were one of the driving forces for the development of agriculture. Moreover, requirement of pesticides is higher in Bugorhe area at Kabare, South Kivu province. Bugorhe area is one of the major suppliers of vegetables in the Bukavu town. However, the sharp increase in the urban population of Bukavu town poses several challenges, including food security (supplying these cities with food), job creation and income generation^[21,24]. In order to meet these challenges, poor families in cities resort to market gardening^[24,25]. These market garden centers generally exploit fruit vegetables (tomato, chili, pepper, eggplant, okra, and watermelon), tubers/bulb (carrot, onion) and some exotic leafy vegetables (scallions, leek). Indeed, Ekesi^[10] reported that. Again, market garden smallholders have a lot of difficult to get chemical pesticides, traps, lures and food baits, lack of IPM method and IPM experts, use and consequences chemical, lack of packaging management. Those market garden smallholders saw and knew fruit flies and other pest at solanaceous crop. In addition, the market garden smallholders do not know the good way to use chemical pesticides and traps such as lures as well as food bait are not sold in the east of the DRC in general and in South Kivu in particular. Relatively no pesticides on market garden such as solanaceous crop in study area. However, paper assesses farmers' smallholders chemical use in control of Solanaceous (tomato, eggplant, pepper, chili) pests Bugorhe-Kabare area at the western of Albertan Rift area.

2. Materials and Methods

The study was carried out in Bugorhe area, which is located at the Kabare territory (Latitude: 2° 30' and 2° 50'S, Longitude: 28° 45' and 28° 55'E, Southwestern of the

Kivu Lake) at the South Kivu province, eastern part of DR Congo. It is peripheral to the Kahuzi-Biéga National Park is located in the community Kabare chiefdom in South Kivu Province and inhabited by the Bashi ethnic group^[25]. The survey covered the period from January 01 to March 28; 2021. Simple random sampling was used. This least biased technique and also gives every element an equal chance for selection during the study^[26] and some criteria were followed by the quota method^[27,28]: being market gardeners (tomato, pepper, eggplant and pepper) and/or sellers of phytosanitary products and in one of the localities of the Bugorhe group, 12 market gardeners of these solanaceous and sellers of phytosanitary products of male and female sexes combined and chosen by locality, the freedom of choice left to the investigator. The sample size is 96 market gardeners. Research instrument includes reconnaissance survey interview questionnaire test, interview and field survey, smallholder vegetables and focus group discussions. Semi-structured type of questionnaire considering the purposed of study the farmer's practices, their knowledge and perceptions regarding the uses of pesticides. These include the socio professional characteristic of small-scale solanaceous vegetable farmers, crop production, main market gardeners' crops used, types of pesticides, pesticide application, pesticide mixtures used, trend in pesticide use, reasons given, system pesticide packaging management. Data were obtained from primary and secondary sources. Items were designed based on published literature on the subject as well as the authors' experiences in the field. Data were collected through survey face-to-face interviews with farmer's farm workers during activities. The questionnaire was designed and translated into Kiswahili (the national language) is understood by the majority of farmers and pre-tested small samples of farmers in the same areas before using it in this study. The data being encoded in Microsoft Excel 2010 (Microsoft Corporation, Redmond, WA, USA) and R (R Core Team, 2018) were analyzed. Two-way ANOVA was used at the significant level of 1%. The Tukey multiple comparison was being used too at the confidence level of 95%. Before the variance analyze application, normality verification of data distribution hypothesis was being done by the Bartlett's K-squared test and the descriptive result was expressed by percentage.

3. Results and Discussion

3.1 Socio Professional Characteristic

The majority of farmers were male (79.17%) with an average age of 30, ranging from 30 to 60, reported the use

of different pesticides in more vegetable farms in Bughore-Kabare zone. According to their level of education, 46.87% of these men attended primary school and 36.46% secondary school and 16% university, while 63.54% of them did not have agricultural training and 36.46% are trained in agriculture. Mawussi^[29] and Mondedji^[30] show a small percentage woman (8%~28%) are involved in market gardening in Togo too. The low involvement of women in the production of fruit vegetables (tomato, chili, eggplant and pepper) could be explained in the fact of that, women are generally not empowered to apply the phytosanitary treatment required by these crops^[21]. Acquiring product, preparing and using, and for uninitiated who constitute a large proportion of peasant women. Our result joined the results of Mawussi^[29] and Wade^[30], the market gardeners farm carried on through no employment and/or no decent salary with a level of primary and secondary school.

3.2 Solanaceous Output in Study Area during the Period of 2017 to 2021

The mean of tomato (5780 kg \pm 471.17) differed to the mean of eggplant (4700 kg \pm 158.11). The Table 1 presented the ANOVA summary of solanaceous output in study area during the period of 2017 to 2021.

The Table 1 shows a significant difference between the outputs of market garden crop. In case of years, there is no difference, *i.e.*, during the five years solanaceous products were the same with a high tomato output. This result is similarly to that of the South Kivu Agricultural Inspector^[32].

3.3 Main Market Gardeners' Crops Used

The main cultivated solanaceous crops grown in the Bughore area is tomato (*Lycopersicon esculantum*) at 47.92% followed by eggplant (*Solanum melongena*) at 36.46%, pepper (*Capsicum frutescens*) at 10% and pepper (*Capsicum annum*) at 5.21%. His reasons for choosing vegetable crops one of them for their short-cycle, easy-to-practice crops, another group for their short-term profitable investment and the last group for their crops with very

high market value per unit area. This may be explained the important income generation and job creation^[31,33] and in order to meet these challenges, poor families in cities resort to urban and peri-urban agriculture, in particular market gardening^[31,33]. Ngowi^[34] reported similar result.

3.4 Types of Pesticides

Farmers in the Bughore-Kabare region most often use insecticides (44.79%) and fungicides (43.75%) but also 4.17% herbicides and 7.29% rodenticides due to the production of tomatoes, eggplants, peppers and peppers and other vegetables. The type of pesticides used in different crops depended on the pest population and their potential damage to the crop as well as farmers' perception pest management practices. Pesticides were supplied in containers ranging from 0.5 liters to 5 liters or in ranging from 0.5 kilograms to 25 kilograms. In most cases, liter and kilogram were common, as well as of quantities by vendors. Beránková^[35], Sougnabe^[36] reported similar result in African countries and worrying risk values for the exposure of market gardeners to pirimicarb and Chlorpyrifos-methyl. Given large number pesticides used and the frequency of application (very high risk of bioaccumulation of pesticides). chemical pesticides cannot unless the methods of use are perfectly mastered^[37,38].

The Table 2 presents pesticides found in study area such as Cobox, Cypercal, Dimethoate, Dithane M45, Dursban, Dust, Dynamec, Funguran, Ivory 80WP, Mamba, Polytrin, RedCat, Ridomil, Rogor, Roundup, Selecron, Shumba dust, Sumithion, Thiodan and Thionex). In the Bughore-Kabare area, insecticides and fungicides registered of being endocrine disruptors (20%), 40% cholinesterase inhibitors and 35% were carcinogenic potentially carcinogenic. Many end-of-use pesticides were not registered for general use. However, the acelamectin (abamectin, abactin, acetamiprid) and dichlorvos, dimethoate and dithiocarbamates (Glucocorticoids), sulfate, metalaxyl-M, zinc, manganese, and mancozeb were also used. Gupta^[39] have found that and other authors^[40-44]. More of farmers applied pesticide once a week. The fact that pesticides are more expensive^[45,46]. Assogba-Komlan^[47] reported that too.

Table 1. ANOVA summary of solanaceous products

Source of variance	Df	Somme of square	Square of mean	F value	Pr (>F)
Years	1	144500	144500	1.199	0.30973
Market gardener's crop	1	2916000	2916000	24.199	0.00172 **
Residuals	7	843500	120500		
Tukey multiple comparison					
	Difference	lower	upper	p adj	
Tomato- eggplant	1080	560.8586	1599.141	0.0017151	

Codes of signification: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 2. Types of pesticides used in Bugorhe-Kabare area (2021), classified using the WHO Hazard Class and health effects (2005) ^[34,38]

Trade Name	Common Name	WHO Class ^a	Health Effects ^b	Target pests	Registration status ^c
Cobox	Copper oxychloride	III		Fungus	R
Cypercal	Cypermethrin	II	SE, PC	Larger-grain-borer	R
Dimethoate	Dimethoate	II		Insects	R
Dithane M45	Mancozeb	U	SE, C	Blight, downy-mildew, fruit fly, leaf-rust, wilting	R
Dursban	Chlorpyrifos	II	CI	Armyworm, cutworms, stem-borer	R
Dust	Methyl+permethrin	NK	PC	Stem-borer	R
Dynamec	Abamectin	II		insects	R
Funguran	Copper hydroxide	III		Leaf-rust	R
Ivory 80WP	Mancozeb	U	SE, C	Blight	R
Mamba	Glyphosate	U		Weeds	R
Polytrin	Cypermethrin	II		Insects, thrips,	R
RedCat	Zinc phosphide	Ib		Rats	U
Ridomil	Mancozeb+metalaxyl	NK	SE, C	Blight, spidermite	R
Rogor	Dimethoate	II		Stalkborer	U
Roundup	Glyphosate	U		Weeds	R
Selecron	Profenofos	II	CI	Aphids, fruit-borer, stemborer, spidermite, thrips, whitefly insects,	R
Shumba dust	Fenitrothion+deltamethrin	II	CI	Larger-grain-borer	R
Sumithion	Fenitrothion	II	CI	Stem-borer	U
Thiodan	Endosulfan	II	SE	Beetle, larger-grain-borer, leafminer, red-ants, stem-borer	R

Legend: ^a1a = Extremely hazardous; 1b = Highly hazardous; II = Moderately hazardous; III = Slightly hazardous; U = Unlikely to present acute hazard in normal use; NC = Not classified; NK = Not known. ^bCI = Cholinesterase Inhibitor, C = Carcinogen, PC = Possible Carcinogen, SE = Suspected Endocrine Disruptor (ILO, 2005) ^[38]. ^cR = Registered for General Use (Full, Provisional or Restricted); U = Not registered for General Use (not in the register, experimental use).

3.5 Pesticide Application and Mixtures Used

Farmer applies once a week depending on the type of vegetable crop. Twenty-eight point zero four percent of farmers reported two pesticide applications and five times (10.42%) and six times (7.29%) per week, *i.e.* routine pesticide applications. The majority of farmers applied pesticides once a week. The fact that pesticides are more expensive and use cultural control methods and occasionally botanical pesticides. More farmers surveyed applied mixtures of pesticides (Table 3).

Reported pesticide mixtures included fungicide + insecticide (Dithane M45 and Ascozeb 80 WP) reapplied to pepper and tomatoes, Maneb and Rocket EC to tomatoes, eggplants and pepper. In addition, other pesticide mixtures are two fungicides + insecticide (Dithane M45, Ascozeb 80 WP and Ivory 80 WP) applied on chili and tomatoes,

two insecticides (Thiodan and Rocket EC) used on tomatoes and eggplant, insecticide + fungicide (Thiodan and Dithane M45) applied to pepper, chili, eggplant and tomatoes. These two mix. Either had no tanks mixes. Ghorbel ^[48] in Benin, Lwin ^[49] in Tunisia and Smit ^[50] in Birmania (Myanmar) reported the similar results. They observed that there was an interaction between fungicides, insecticides and water mineral content that influenced the efficacy of individual pesticide against fungal pathogens and insect mortality and some tank mixtures induced phytotoxicity on tomato. There is limited information on the reaction and effects of the mixtures observed in this study. According Antonella ^[51], WHO/UNEP ^[43] Epstein ^[52], the total exposure to the chemical is the sum of exposure during pesticide storing, mixing, applying and disposing of the chemicals.

Table 3. Pesticide mixtures used by small-scale vegetable farmers

Pesticides combination	Types of pesticides	Target crops
Dithane M45, Ascozeb 80 WP	Fungicide + insecticide	Pepper, tomatoes
Maneb, Rocket EC	Fungicide + insecticide	Eggplants, pepper, tomatoes
Dithane M45, Ascozeb 80 WP, Ivory 80WP	Two Fungicides + insecticide	Chili, tomatoes
Thiodan, Rocket EC	Two insecticides	Eggplants, tomatoes
Thiodan, Dithane M45	Insecticide + fungicide	Chili, eggplants, tomatoes, pepper

3.6 Trend and Reasons Given

62.5% of farmers who responded to the trend in over 3 years 20.83% thought and 16.67% in decreasing. In Bughore-Kabare region is on the rise as they farm in relatively similar environments and international organizations have started assisting them with agricultural inputs such as vegetable seeds. With the increase in the use of pesticides, there is also a decrease in bees observed by farmers in the environment of the study area. Our results joined results of Abate^[53], Belzunces and Colin^[54], Borneck and Bricout^[55], Tasei^[56].

According Melaku^[57], Desalegn^[58], Melisie^[59], Krystyna^[60], Guesh^[61] insecticides and herbicides had been reported as significant causes of the death of the colonies and absconding. Indeed, Chauzat^[62], MOWR^[63] show that improper use of insecticide leads to the honeybee's death and Melisie^[59] reported the decline of honeybee products and crop yield are among the significant constraints of the beekeeping sector.

The reasons for increasing trends in pesticide use are increasing insect damage, agricultural area, insect pests, plants and number of pests. The constant ones are that the area, less pests, even everywhere and pesticides used. Ngowi^[34], Gizachew^[64], Mengistu and Beyene^[65], Mengistie^[13,14] reported their research's the trend of chemical utilization, including usage by smallholders, has been increasing. The reasons for the tendency to the downside are heavy rains, unavailability of pesticides, price increase, less harvest, drought, good farm preparation and reduced agricultural area. With the increase in the use of pesticides, there is also a decrease in bees observed by farmers in the environment of the study area. This result is the same to the result of Ngowi^[34].

3.7 Perception of Pesticide Poisoning Symptoms

Hundred farmers use chemical in study area. However, the most common symptoms reported and included skin effects (37.5%), neurological system disorders

(headache, dizziness) were (20.83%). Additionally, farmers reported suffering from sneezing (6.25%), excessive sweating (5.21%), coughing and poor vision (3.12%), nausea (2.08%) and stomach pain (1.04%). Therefore, skin effects, headaches and dizziness are dominant in the Bughore-Kabare region. The three routes of exposure to pesticides: dermal, respiratory and oral^[66]. Almost 750,000 people contract a chronic disease such as cancer each year because of exposure to pesticides, nerve damage, infertility and deformities, etc. In addition, although developing countries only employ 20% of all chemicals used in agriculture globally, they still account for more than 99% of deaths worldwide because of human poisoning pesticides^[36]. The studies are carried out in Indonesia^[67] and in Ivory Coast^[68] reported.

3.8 System of Pesticide Packaging Management

Sixty-two point five percent of the farmers answered that the management system for pesticide containers is to leave them and keep them on the stakes and/or sticks in the field, while 20.83% buried them and 16.67% burned them. The management of packaging and packaging waste has a very pronounced ecological, social and economic significance. Pesticide packaging management system used by farmers is stake and/or stick in field in Bughore-Kabare area as they have no training in pesticide use, water pollution water, air, soil and living beings hence the problem of poisoning in the environment. Our result is similarly to result of Ahouangninou^[69]. The abandonment of packaging in the field poses a great danger to children and the uninitiated who may use it as second-use packaging and containers. Incineration of packaging (including pesticide waste and contaminated materials) is also not a good practice because during combustion, some pesticides produce highly toxic fumes which inhalation and / or contact are harmful to the human body and animals^[69]. Likewise, 6% farmers burie packaging, residues and waste of pesticides. It presents the risk of contamination of groundwater. Pesticide packaging is generally abandoned in the field or incinerated as initially observed in other African countries^[36,69]. According to Muliele^[23], Nkolo area in west of DR Congo and its surroundings, the market garden fields being mainly installed along waterways for watering facilities, part of the packaging abandoned in the field ends up in the course of water carried by strong winds or runoff. The same is true for pesticides accumulated in the soil, which, after heavy rains, carried in the runoff to the rivers and volatile particles during the treatment, some of which are deposited directly in the rivers. At the end of the treatment, the market gardeners wash and wash their

clothes in the streams. Contamination of waterways with pesticides is therefore not excluded in the study area, even though most market gardeners claim to maintain sprayers in the field so as not to pollute the waterways. Our result is in the same way to result of Muliele ^[23], WHO ^[70], Jeyanthi and Kombairaju ^[71] reported that.

4. Conclusions

Investigations were made with market gardeners on the evaluation of the use of chemical pesticides in the fight against solanaceae pests (tomato, eggplant, pepper, pepper) in the Bugorhe-Kabare region in the west of the region of the Alberta Rift. Smallholder farmers use them poorly due to lack of training, hence the poisoning. Also to contribute to the reform policy in the Bughore-Kabare region in the east of the DR. Congo, we need strict control over all the sale of chemical pesticides. The Congolese government must create a quarantine, control and surveillance service for phytosanitary products, fruits and vegetables within the DRC country and at these borders. Additionally, it needs urgent action from the federal and regional governments to formulate policy, design legislation, and enforcing for its implementation concerning the supply, transportation, storage, appropriateness, and application of harmful pesticides.

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Author Contributions

Jean Augustin Rubabura Kituta had the idea and designed the research. Jean Augustin Rubabura Kituta, Jean Berckmans Muhigwa Bahananga, Alex Lina Aleke and François Ndatbaye Lagrissi prepared the manuscript. Jean Augustin Rubabura Kituta and François Ndatbaye Lagrissi led the survey and data processing. Jean Augustin Rubabura Kituta, Jean Berckmans Muhigwa Bahananga and Alex Lina Aleke contributed to interpretation of the results and revision of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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