*Cameroon Journal of Biological and Biochemical Sciences, 2024, 32, 82-109.*

CAMEROON JOURNAL OF BIOLOGICAL AND BIOCHEMICAL SCIENCES
Published by the Cameroon Biosciences Society (CBS)

*Review Article*

# Assessment of pesticide usage, phytosanitary practices and risks associated with pesticide use by farmers in Cameroon: A comprehensive literature review

***GAUTIER NERLUS SOPKOUTIE KENGNI [1*], JOSEPH FOVO DJEUGAP [1], ABUKARI WUMBEI [2], PIETER SPANOGHE [3] and JOSEPH HUBERT GALANI YAMDEU [4*]***

*[1] Plant pathology and agricultural zoology research unit (UR-PHYZA), Faculty of Agronomy and Agricultural Sciences, University of Dschang, PO Box 222, Dschang, Cameroon.*
*[2] Institute for Interdisciplinary Research, University for Development Studies, PO Box TL1350, Tamale, Ghana.*
*[3] Department of Plants and Crops, Faculty of Bioscience Engineering, Ghent University, Coupure Links 653, 9000 Ghent, Belgium.*
*[4] Section of Natural and Applied Sciences, School of Psychology and Life Sciences, Canterbury Christ Church University, Canterbury, CT1 1QU, United Kingdom.*
**Corresponding Authors: gautier.sopkoutie@univ-dschang.org; joseph.galaniyamdeu@canterbury.ac.uk*

*Received: 09 Sep 2024, Reviewed: 29 Oct 2024, Revised: 12 Nov 2024, Accepted: 23 Nov 2024, Published: 23 Dec 2024*

**ABSTRACT**

Studies have explored Cameroonian farmers' use of synthetic pesticides for pest and disease control during crop production and postharvest. Given reports of pesticide poisoning and high residue levels in Cameroonian food products, a comprehensive overview of pesticide practices among smallholders is essential. This review aims to assess current practices and factors influencing farmers' phytosanitary behaviors in Cameroon. Data were compiled and analyzed from 27 peer-reviewed articles found through online databases. Results indicate insufficient knowledge, lack of training, and non-compliance with recommended doses (81% on average), application frequency (93.4%), and manufacturer guidelines (87%). Additionally, 75% of farmers do not use personal protective equipment (PPE), with higher education levels linked to better PPE use. Between 11% and 60% of farmers engage in unsafe practices, such as talking, singing, or eating during pesticide application; 74% ignore preharvest intervals, and half store pesticides in the house where they live. Concerning disposal, 44% discard empty containers on fields, while 17% reuse them, sometimes for food or water. This review identified 24 acute toxicity symptoms, including cramps (71%), pruritus (66%), thirst (54%), abdominal pain (42%), and chronic issues like reproductive toxicity (19%) and cancer (5%). In conclusion, this review reveals significant gaps in phytosanitary practices, impacting health, environmental safety, and consumer exposure, emphasizing the need for better farmer training and stronger pesticide regulation in Cameroon.

**Keywords.** Toxicity, Environment, Pesticide application, Knowledge, Cameroon.

**RÉSUMÉ**

Des études ont examiné l'utilisation de pesticides de synthèse par les agriculteurs camerounais pour la gestion des ravageurs et des maladies durant la production et la post-récolte. Face aux rapports d'intoxication par pesticides et aux niveaux élevés de résidus dans les aliments au Cameroun, une vue d'ensemble des pratiques phytosanitaires des petits exploitants est essentielle. Cette revue vise à évaluer les pratiques actuelles et les facteurs influençant les comportements phytosanitaires des agriculteurs au Cameroun. Les données de 27 articles évalués par des pairs, obtenus via des bases de données en ligne, ont été compilées et analysées. Les résultats révèlent une connaissance insuffisante, un manque de formation et une non-conformité aux doses recommandées (81% en moyenne), à la fréquence d'application (93,4 %) et aux instructions des fabricants (87 %). En outre, 75 % des agriculteurs n'utilisent pas d'équipement de protection individuelle (EPI), bien que les niveaux d'éducation plus élevés favorisent son usage. Entre 11 % et 60 % des agriculteurs adoptent des pratiques dangereuses, comme parler, chanter ou manger lors de l'application des pesticides; 74 % ne respectent pas le délai avant récolte, et la moitié stocke les pesticides à domicile. Quant à l'élimination, 44 % jettent les contenants vides dans les champs, et 17 % les réutilisent, parfois pour des aliments ou de l'eau. Cette revue recense 24 symptômes d'intoxication aiguë, dont des crampes (71 %), prurit (66 %), la soif intense (54 %) et douleurs abdominales (42 %), ainsi que des effets chroniques tels que la toxicité reproductive (19 %) et les cancers (5 %). En conclusion, cette revue souligne des lacunes critiques dans les pratiques phytosanitaires, impactant la santé, la sécurité environnementale et l'exposition des consommateurs, et recommande une formation accrue et une réglementation renforcée des pesticides au Cameroun.

**Mots-clés :** Toxicité, Environnement, Application des pesticides, Connaissances, Cameroun.

## 1. INTRODUCTION

Agriculture is among the main occupations for over 70% of Cameroonians and contributes greatly to the country's economy, with an estimated 45% share of Cameroon's Gross Domestic Product (GDP). The agricultural sector is responsible for ensuring food security for both rural and urban populations in Cameroon, as well as within the Economic and Monetary Community of Central Africa (CEMAC) zone (Abia et al., 2016).

Cameroon produces 52% of agricultural products with a total gross agricultural production index equal to 107.16 (FAOSTAT, 2019). For this reason, the country is known as the food basket of the CEMAC zone (World Bank Group, 2024). In Cameroon, pesticides are intensively used by farmers and traders during production and postharvest storage by farmers and traders to protect their plants and crop products (Galani et al., 2018; Tarla et al., 2015; Ugboka et al., 2020), but few are adequately informed about the hazards associated with the agrochemicals(Tayoh et al., 2016). Generally, pesticide usage should be carried out following the good practices prescribed by the manufacturers, which include doses, frequency, time before harvest (TBH), restricted entry interval (REI), meteorological condition of application, and wearing of personal protection equipment (PPE), to avoid environmental pollution and human exposure. The utilization of pesticides can have many consequences on the environment, such as contamination and destruction of soil biodiversity, and pollution of surface water and groundwater. In humans, pesticides can cause acute toxicity resulting in cough, nausea, skin, irritation, watery eyes, vomiting, nausea, diarrhea, abdominal pain, and even death. Pesticides can also cause chronic toxicity in humans that may lead to cancer, reproductive toxicity, genotoxicity, deterioration of the immune system and hepatic diseases. Poor phytosanitary practices can also have consequences on consumers' health, through residues of pesticides that remain in the commodity. For instance, the consumption of fruits containing detectable pesticide residues raised various human health concerns, including endocrine disruption, cancer, and Parkinson's disease (Kenko et al., 2017).

Poor phytosanitary practices should not be overlooked in Cameroon because, from several studies carried out in the country, inappropriate use of pesticides has been reported in several parts of the country. The non-compliance with the recommendations of manufacturers and conditions of usage before, during and after the application by farmers has been reported (Gama et al., 2016; Kenko et al., 2017; Sopkoutie et al., 2021; Tarla et al., 2013; Tayoh et al., 2016). Additionally, a lack of training and assistance of farmers by agricultural extension officers were observed (Abdulai et al., 2019; Efuetlancha, 2020; Efuetlancha & Kuete, 2020; Kenko et al., 2017; Sonchieu et al., 2017; Tandi et al., 2014; Tarla et al., 2013). Other works reported that farmers don't have knowledge of good actions that must be taken in case of intoxication (Matthews et al., 2003) and farmers don't know anything about the legality of pesticides (Kenko et al., 2017; Manfo et al., 2020; Sonchieu et al., 2017; Tarla et al., 2013, 2015). Some studies show that during pesticide application, some farmers speak, drink (water and alcohol), smoke and sing. Other studies show that the time before harvest is not respected by many farmers in Cameroon (Efuetlancha, 2020; Efuetlancha & Kuete, 2020; Sonchieu et al., 2017; Tandi et al., 2014; Tarla et al., 2013). Spraying equipment in certain cases can be a very high source of pollution and exposure of farmers when they are faulty. The study by Matthews (2003) demonstrated that many farmers reported leakage of the products during pesticide application (Matthews et al., 2003). Knapsack sprayers and hand sprayers are more used by farmers in Cameroon, but some of them in rural areas use bucket containers to mix their pesticides, and then spray them with their hands (Kamga et al., 2013). Other farmers were found using branches of cypress to spray the products mixed in the same buckets that are used for other household chores. In some cases, farmers have no consideration of wind direction during pesticide application, and some of them spray against the wind direction, and when the speed of wind is high. Many farmers store pesticides on the field, but because of the possibility of theft, other farmers store their chemicals at home, especially in the kitchen or in the bedroom (Onguene et al., 2021). Regarding the disposal of pesticide containers after usage, many authors reported that they were reused by farmers at home to store salt, palm wine, palm oil, cereals and kerosene (Abdulai et al., 2019; Sonchieu et al., 2017; Tarla et al., 2015).

These poor phytosanitary practices of farmers in Cameroon can have many consequences on the safety of farmers, the environment, and consumers. Cases of chronic and acute intoxication of Cameroonian farmers and their families have been recorded in the country (Kenko et al., 2017; Sopkoutie et al., 2021; Tandi et al., 2014). Levels of pesticide residues above the safe limits have been found in foods from Cameroon, which have consequences on trade and the health of the consumer (Galani et al., 2018; Galani, Orfila, et al., 2020). Despite all of the above that indicates a serious concern about pesticide usage in Cameroon, to the best of our knowledge, no studies described and analyzed the general knowledge of the farmers on phytosanitary practices in the country. This review, therefore, aims to

examine and analyze the phytosanitary practices and health issues related to the utilization of pesticides by farmers and general households in different agroecological zones of Cameroon, and highlight the gaps and perspectives.

## 2. METHODOLOGY

This systematic review was conducted following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)® (Page et al., 2021).

### 2.1. Eligibility criteria

Eligibility criteria were established based on the PICOS methodology (Cochrane, 2020) to set precise inclusion and exclusion parameters. Studies qualified for inclusion if they met the following conditions: they focused on pesticide use, phytosanitary practices, and knowledge among Cameroonian farmers; were written in English or French; and were published between January 1, 2003, and December 31, 2021. Articles were included if they presented data on occupational exposure, pesticide usage, health effects, or farmers' knowledge regarding pesticides. Studies were excluded if they: did not involve Cameroonian agricultural workers; concentrated solely on environmental impacts without human health relevance; addressed general population health outside of agricultural contexts; exclusively reported pesticide residues, assessed exposures unrelated to pesticides; deviated from the core theme of pesticide risks and behaviors in agricultural settings; or were systematic reviews, narrative reviews, or meta-analyses.

### 2.2. Information sources, search strategy, and article selection

An extensive literature search was conducted using four major electronic databases: Google Scholar, PubMed, Scopus, and Science Direct, selected for their comprehensive coverage of scientific literature in agriculture, pesticide use, and health sciences. Keywords applied in the search included "Cameroonian farmers," "pesticide usage," "phytosanitary practices," "pesticide knowledge," and "health." Results were filtered to include only articles published between 2003 and 2021, in English or French, and available in full text, refining the search to studies directly relevant to the research objectives. All identified articles were imported into Zotero 7 reference management software to eliminate duplicates. The article selection process comprised two stages. In the initial screening, two independent reviewers (YGJH and DFJ ) Assessed titles and abstracts against pre-established inclusion and exclusion criteria to identify potentially relevant studies. In the subsequent phase, full-text reviews of selected articles were conducted, and relevant data were extracted. Any discrepancies between reviewers were resolved through discussion, ensuring consistency in selection.

### 2.3. Data Extraction and Analysis

Data were extracted and organized in a Microsoft Excel 2016 spreadsheet, capturing details such as authors' names, study year, agroecological zones, regions and divisions covered, season, crop groups, sample size, field area, gender, marital status, land ownership, education level, pesticide usage experience, training and assistance received, behaviors during pesticide handling, and farmers' symptoms of chronic and acute toxicity. Data analysis included calculations of means, maximums, minimums, percentages, and graphical representations for non-categorical variables, all performed using Microsoft Office Excel 2016. Relationships between variables were determined using chi-square tests for categorical variables and Pearson’s correlation tests for non-categorical variables in SPSS version 22. A 5% significance level was applied throughout the analysis.

## 3. Distribution of surveys on farmer’s phytosanitary practices in Cameroon

### 3.1. Geographical distribution

Cameroon is divided into 5 agroecological zones as follows: Zone I = Soudano–Sahelian zone, characterized by very short rainy seasons (3 to 5 months, 500-900 mm) with the common crops being cotton, yams, onion, sesame, and groundnuts. Zone II = Guinean high savannah zone, which has a tropical humid climate with 7 months of 1500-1800 mm precipitations, the common crops being maize, yam, cassava, sweet potatoes, rice, and cotton. Zone III = Western high plateau zone, characterized by important rainy seasons (7 to 8 months, 1800-2400 mm) and very fertile soil, with the main crops grown being maize, beans, potatoes, rice, sweet potatoes, vegetables, and coffee.

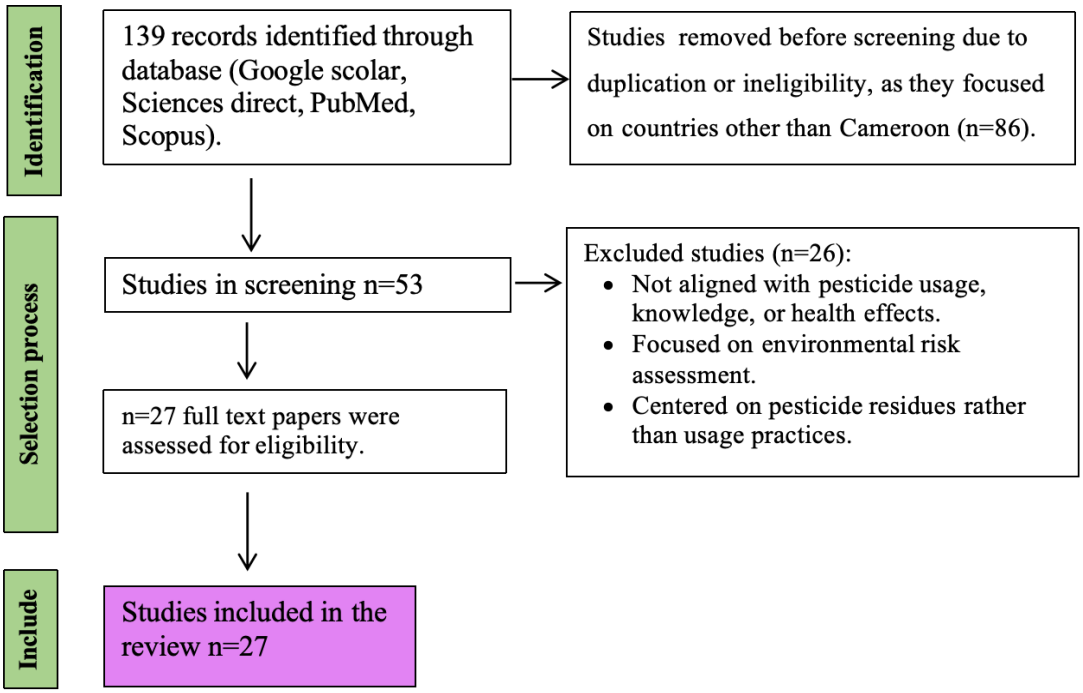


**Figure 1.** PRISMA 2020 flow diagram for updated systematic reviews, which included the search in databases.

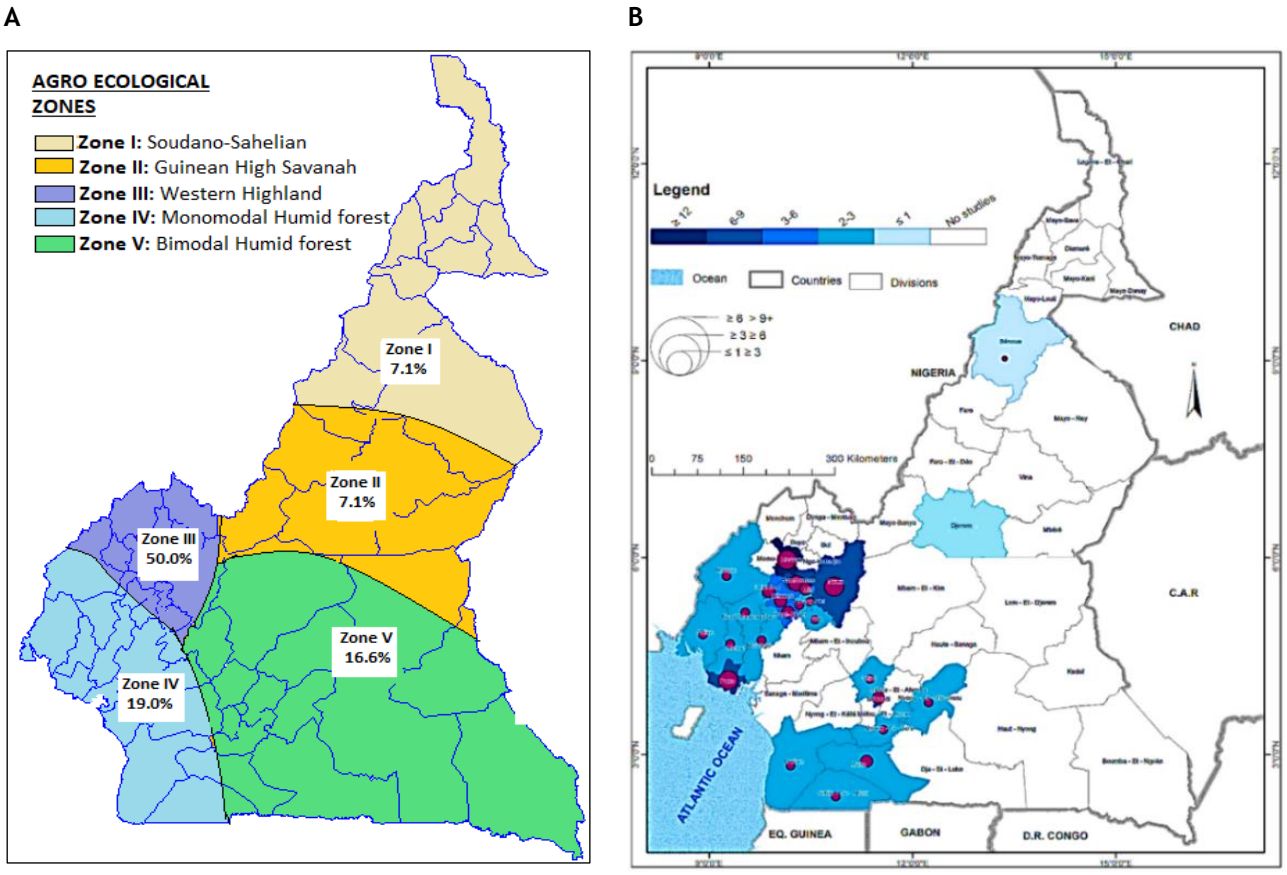


**Figure 2.** Map of Cameroon showing the distribution of surveys on phytosanitary practices of farmers in the agroecological zones (A) and in the administrative divisions (B).

Zone IV = Monomodal humid forest zone, which is characterized by two rainy seasons per year (9 to 10 months in total, 2000-11000 mm), with the main crops being banana, plantain, cassava, cocoyam, sweet potatoes, maize, vegetables, cocoa, coffee, oil palm, rubber, and fruits. Zone V = Bimodal humid forest zone, which is very similar to the western highland zone, (7 to 9 months, 1500–2000 mm), with the main crops being plantain, cassava, banana, maize, cocoyam, sweet potatoes, cocoa, oil palm, rubber, coffee, maize, cocoa, and fruits. Our data compiled in this review show that studies conducted in Cameroon on pesticide usage and phytosanitary practices by farmers are mostly in zone III (50.0%), followed by zone IV (19.0%) and zone V (16.6%); zones I and II have been targeted by only a few investigations (7.1%) (Figure 2A). Out of the 10 administrative regions of Cameroon, most of the studies are conducted in the West region (30.7%), followed by the Southwest (17.3%); Northwest (13.4%); Centre (11.5%) and Littoral (9.6%). Other regions like South (3.8%), Far North (3.8%), Adamaoua (1.9%) and Eastern region (1.9%) which produce considerable amounts of food, have been less surveyed. Regarding the administrative divisions, surveys on phytosanitary practices and the use of pesticides were performed in 43.0% of the divisions in Cameroon, i.e., Mezam (11.3%), Noun and Fako (9.0%). This shows a huge disparity in the distribution of the studies over the Cameroonian territory and highlights orphan areas where studies are needed (Figure 2B).

### 3.2. Seasonal distribution

Regarding the seasonal distribution, most of the studies were performed during the rainy season (74.0%). This review shows that 75.0% of crop groups, including that is vegetables, cereals, legumes, fruits, and tubers, are produced during raining season, and only 25.0% of crop groups are produced during the dry season. Many farmers prefer growing their crops during the rainy season because water, which is of utmost importance for crop growth is available. However, the inconvenience of growing crops in the rainy season has been highlighted by many authors in the country. For instance, the work by Sopkoutie et al.(2021); and Tarla et al. (2015) revealed that in Foumbot subdivision, raining season required more inputs to manage pests and diseases. Due to the high cost of input, some farmers cultivate in the dry season in lowlands with swamps or with irrigation water taken from surrounding streams using motor pumps. In Foumbot, 51% of tomato farmers preferred to cultivate in the dry season (off-season), because they will not require a large investment to purchase inputs to manage pests and diseases (Sopkoutie et al., 2021), thereby avoiding crop failure resulting from pests and diseases.

### 3.3. Crop distribution

On average, two crop groups are found in each of the studies conducted in Cameroon. Vegetables are more investigated (53.1%), followed by fruits (15.6%), and legumes (18.8%), while tubers and cereals (12.5%) are less scrutinized in Cameroon. Vegetables are mostly represented in the surveyed farms of agroecological zone III (31.2%), while cereals are the only concerned crop groups in the agroecological zone I. According to Nguemo et al.(2019), in the Mezam Division, North-west Cameroon, insecticides (92.2%) are used in vegetable crops, followed by beans (70%), fungicides are mostly used (33%) in maize cultivation, and rodenticides and herbicides (61.7% and 10.8% respectively) in groundnut cultivation. This review shows that only a few studies in Cameroon involve tubers, legumes, and cereals, which can be a big issue because residues of pesticides were found in these foods also. A report by Wumbei et al. (2019) in Ghana showed that yams are contaminated by 11 pesticides and 10% of the farmer's Estimated Daily Intake (EDI) is higher than their Acceptable Daily Intake (ADI) to fenpropimorph and fenitrothion. More importantly, many reports show concerning levels of pesticide residues in cereals and legumes from Cameroon. Therefore, there is a need to investigate the phytosanitary practices of farmers growing tubers, legumes, and cereals in Cameroon.

### 3.4. Farm size

According to the farm sizes of the surveyed areas in Cameroon, the mean percentage of farmers having a farm size less than 1 ha is 83.3% (Figure 3), showing that the great majority of these farmers are smallholders. A few reports examined land ownership and revealed that on average 30.8% of farmers in Cameroon rent land to grow their crops. A study conducted in Pakistan indicated that only 14.9% of farmers operate on rented land (Mubushar et al., 2019), whereas in Mauritius, land rental is prevalent, with 67% of farmers leasing their agricultural land (Le Bellec et al., 2017). Landholders minimize subjective (uncertainty) and objective (pest infestation, disease, weather variation etc.) risks to obtain the income necessary to pay the rent for the land. However, when farmers rent the land, they subject their crops to an intense spraying regime, both preventive and curative, in other to prevent disease and pests from

reaching an economic threshold where they can no longer earn an income to pay for inputs. Reports show that two third loan of Mauritian farmers realized opportunistic agriculture aiming to optimize their plots in time and space because they do not own the land (Le Bellec et al., 2017).

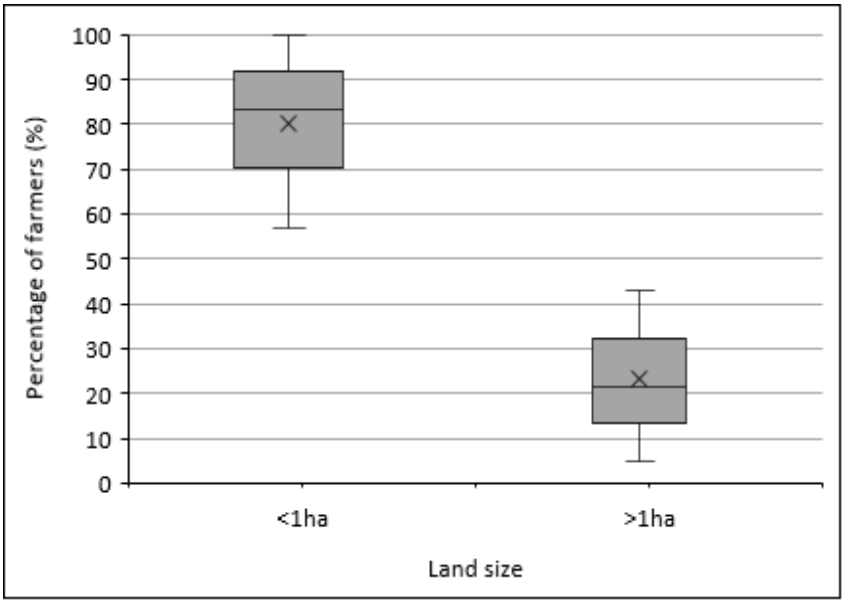


**Figure 3.** Land size distribution of Cameroonian farmers surveyed for phytosanitary practices.

### 3.5. Pesticide usage

In Cameroon, the pesticide indicator is 0.18 kg/ha, with 7,073 tons of pesticides used in 2018, among which 4,640 tons were fungicides and bactericides, 1,204 tons were herbicides, and 1,173 tons were insecticides (FAOSTAT, 2019). A review of the 2021 list of registered pesticides in Cameroon shows approximatively 700 pesticides 5 registered for pest and disease management, with insecticides, herbicides, and fungicides being the most represented. Our data show that 90.6% of surveyed farmers on average use pesticides in Cameroon to manage pests and diseases on their farms. This is less than in Togo where 100% of farmers use pesticides in market gardening (Diaité et al., 2020). In Pakistan, it is reported that 92.8% of farmers apply pesticides to control weeds or insects/pests, and 87.7% apply pesticides to control diseases (Mubushar et al., 2019).

This high utilization of pesticides by farmers could be due to the development of resistance by pests over time (Tetang & Foka, 2008). Concerning the WHO classification, our review of all studies in Cameroon showed that 58% on average of active ingredients found with farmers, belonged to class II (moderately hazardous), followed by class III (unlikely to cause hazards) (33.0%). No studies revealed the presence of classes IV and I in Cameroon. Class II pesticides have been considered to be the most hazardous to humans (Tandi et al., 2014). In fact, Cameroonian farmers can be more intoxicated if, they do not respect the prescription of manufacturers and good phytosanitary practices (GPP). Of all the approximately 700 registered agrochemicals in Cameroon, 269 could be identified in the farmers' place with 192 active ingredients reported in all studies undertaken in the country. Fungicides are the most represented (47.0%), followed by insecticides (42.0%) and herbicides (17.0%). This is not similar to the situation in Kenya (East Africa), where the major types of pesticides used by farmers were insecticides 53%, fungicides 28%, herbicides 16% and others 3% (Tolera, 2020). In Cameroon, the active ingredients revealed in the different studies include mancozeb found in two studies, chlorothalonil in one study, maneb in one study, lambda-cyhalothrin in three studies, cypermethrin in two studies, copper oxide in one study, and glyphosate in two studies. In terms of crops, pesticides in Cameroon are mainly registered for tomato production (19%), cocoa (17%), cotton (17%) and banana (10.3%). For other crops largely produced in Cameroon such as coffee, potato, soy, carrot, cassava, cabbage, tobacco, sorghum, and bean, pesticides are not often registered. When considering the pesticide groups, we computed that most herbicides are registered for palm oil production (29.4%), followed by sugarcane (20%) and maize production (18.3%). As for the insecticides, 29% are registered for tomato production, 28% for cocoa and 26% for cotton. Most fungicides are used for tomato production (36%) generally to control diseases such as late blight and early blight, and for cocoa production (33%) to control

brown pod rot. Nematicides are only registered for plantain production (92%) and sugarcane (8%). Acaricides are only registered for plantain production (MINADER, 2021). A Chi-squared statistical test showed that there was no relationship between active ingredients and crop groups ($X^2$=19.4, p=0.99). This suggests that many chemicals are not used on the crop for which they are registered. In Foumbot for example, high rates of cypermethrin, acetamiprid, spinetoram and chlorpyrifos-ethyl were used on vegetable crops, for which they are not registered (Galani et al., 2018). When pesticides are not used on the right crop, they can reduce the yield of crops because of their negative effect on photosynthesis activities, transpiration and functioning of stomata (Ahemad & Khan, 2012; Mustapha et al., 2017). As result, farmers can think that the products are not effective and ulterior change the chemical, or even increase the dose or frequency of application of a chemical, which does not agree with GPP.

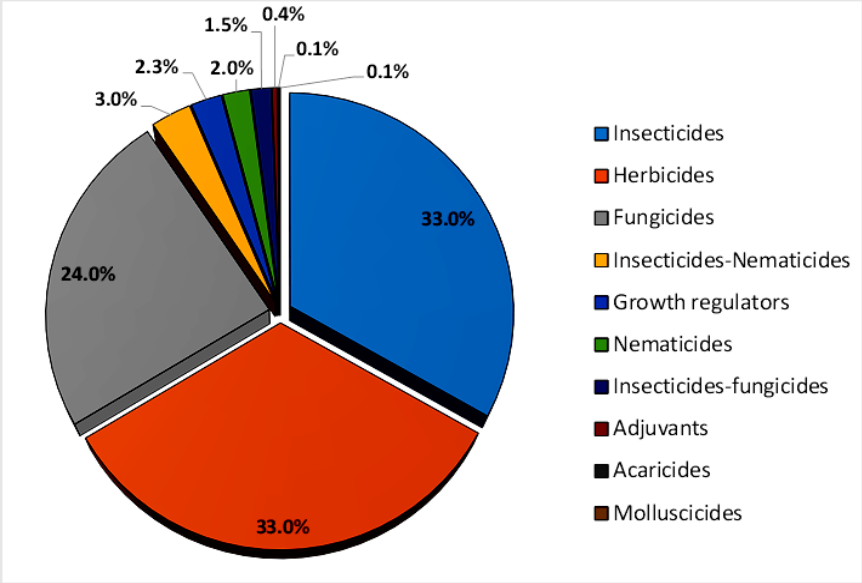


**Figure 4.** Distribution of pesticide types registered in Cameroon in 2021.

### 3.6. Case study: usage of obsolete pesticides in Cameroon High levels of pesticide residues have been found in foods from Cameroon.

In 12 dry agricultural products from the West highland zone of Cameroon, it was reported that most foods contain at least one pesticide residue, and 21 pesticides (i.e., 34.4% of the tested compounds), including obsolete pesticides, exceeded their European Union Maximal Residues Limit (MRL) (Galani et al., 2018). A more recent study on the surveillance and the dietary risk of 81 pesticide residues in 11 local agricultural products from 3 large towns in Cameroon showed that 58 compounds were detected in the analyzed samples, and more than half of the positive samples contained residues above their EU MRL and 5 of the detected pesticides were not registered in the country (Galani et al., 2020). Another study on halogenated pesticides in Cameroon demonstrated that aldrin, p,p'-dichlorodiphenyltrichloroethane (DDT), and ß-hexachlorocyclohexane (ß-HCH) were found in 85.0%, 81.9% and 72.5% of samples, all the 20 tested 6 pesticides were above their MRLs, and the food samples contained 14 pesticides banned in Cameroon (Galani et al., 2021). Foods from Douala and Garoua were contaminated by organophosphate and pyrethroid pesticides (Ingenbleek et al., 2019). It was earlier found that 75% of maize, cowpea, and millet samples from northern Cameroon were contaminated by pesticide residues above the maximum residue limits (MRLs), and high amounts of organophosphorus pesticide residues in stored cowpea and two by-products (Sonchieu et al., 2013). Cowpea produced in northern Cameroon and sold in Nigeria and Gabon was found contaminated with 6 organophosphate pesticides (dichlorvos, methyl parathion, malathion, profenofos, diazinon and chlorpyrifos) (Sonchieu et al., 2013). Our data show that 79 obsolete agrochemicals were found in farmers' places in Cameroon. This could be linked to another report which revealed that 300,000 L and 200,000 kg of banned pesticides were inventoried in the country (Tarla et al., 2014). Numerous reports show that farmers use these obsolete pesticides. Cocoa production is most associated with banned pesticides in Cameroon (Mahob et al., 2014). In fact, cocoa from

Cameroon was rejected in the international market because of the presence of some banned pesticides above the European Union (EU) MRL (MINADER, 2016). In Balessing, West region of Cameroon, market gardeners used banned pesticides among others, on their crops (Ngameni et al., 2017). Similarly, in the Fako subdivision, farmers used banned pesticides such as dimethoate, malathion, carbofuran, oxamyl and lindane on their crops (Kenko et al., 2017). Dimethoate was also reported as being used by farmers in Fotouni (Kenko & Kamta, 2021). Expired pesticides not only present a hazard to popular health(Shah & Devkota, 2009) but can also defile natural resources and stand in the way of socio-economic development (Tarla et al., 2014). Obsolete pesticides can be a source of acute or chronic intoxication if there is no control and surveillance around the stock (Gimou et al., 2008) because they were suspiciously used (Kenko et al., 2017; Sonchieu et al., 2017). The consequence in Cameroon is that many food products are contaminated by residues of obsolete pesticides (Galani et al., 2018; Galani et al., 2020; Sonchieu et al., 2013), which could pose a health risk to consumers, and affect the market value of these agricultural produces. The study by Kenko et al. (2017) on pesticide pollution in the Benoe River in Cameroon revealed significant risks to the aquatic ecosystem. Pesticide assessment identified 44 active ingredients, categorized based on their environmental toxicity ratios. Seven pesticides pose a clear acute risk, while 28 pose no risk.

## 4. Sociodemographic characteristics of farmers and their phytosanitary practices in Cameroon

### 4.1. Gender of farmers

Our review shows that 4,470 farmers are implicated in phytosanitary practices studies in Cameroon, out of which 22.2% are in the West region, followed by the Northwest (19.2%), the Far north having a few representative farmers in studies in Cameroon (0.7%). Most of the farmers investigated in Cameroon were in agroecological zone III (43.5%) and men represented 72.9% of them (Figure 5). The highest presence of men could be justified by the fact that some farming activities require a lot of pesticide application and funding, which women cannot afford (Tarla et al., 2015). Women assisted their husbands in activities that did not require a lot of energy, such as transplanting and harvesting tomato fruits (Tambe et al., 2019). Smallholding requires strong physical efforts that women cannot sustain, the reason why they are more involved in selling farm products in Togo and Congo (Mawusi et al., 2014; Muliele et al., 2017).

### 4.2. Age of farmers

Farmer's age plays a role in the implementation of phytosanitary practices. For instance, younger farmers compared to older farmers are able and flexible to adopt new strategies in agricultural technology (Mengistie et al., 2017). Our data compilation on phytosanitary practices in Cameroon revealed that most of the farmer’s age was between 31-40 years (38.2%), followed by 21-30 years (25.8%) and 41-50 years (21.0%), farmers aged more than 60 years old are the lowest represented (2.8%) (Figure 6). These results are similar to the study on yam farmers in Ghana (Wumbei et al., 2019). Middle-aged farmers are mostly represented in Cameroon, this is because middle-aged farmers are more implicated in agriculture and farming than the youth (Mubushar et al., 2019). Moreover, smallholder agriculture is most mechanized; farming activities from land preparation, maintenance, and harvesting to packaging require a high amount of labor energy that only youths can bear (Tarla et al., 2015).

Pearson correlation statistical test from our compiled data revealed that in Cameroon, there is a positive significant relationship between farmers aged 31-40 years and compliance with manufacturer’s instructions, suggesting that farmers at that age level, pay more attention to manufacturers’ instructions. The data also show that there is a strong negative correlation between farmers aged between 21-30 years and pesticide storage on the farm, compliance with manufacturers’ instructions, and burning of empty pesticide containers. Likewise, we found a strong positive correlation between farmers aged between 41-50 years and pesticide storage on farms, and with burying of Empty Pesticides Containers (EPC) (Table 1).

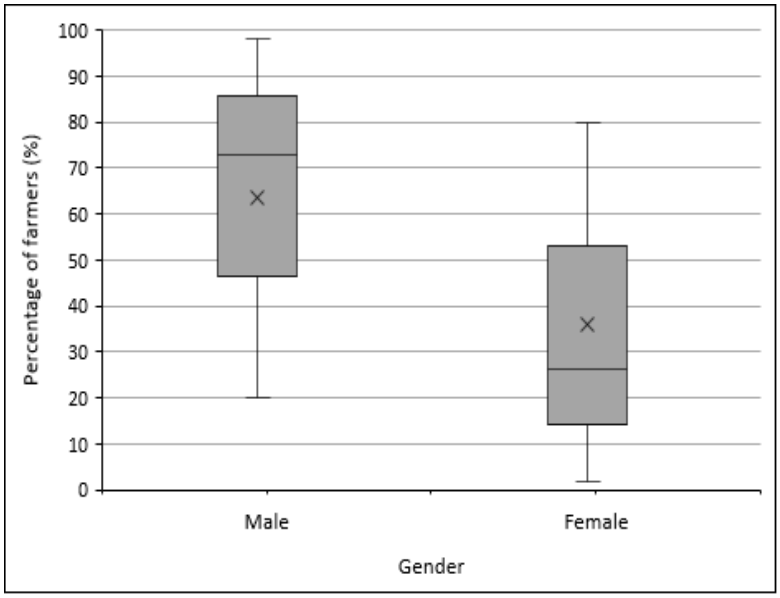


**Figure 5.** Gender distribution of Cameroonian farmers surveyed for phytosanitary practices.

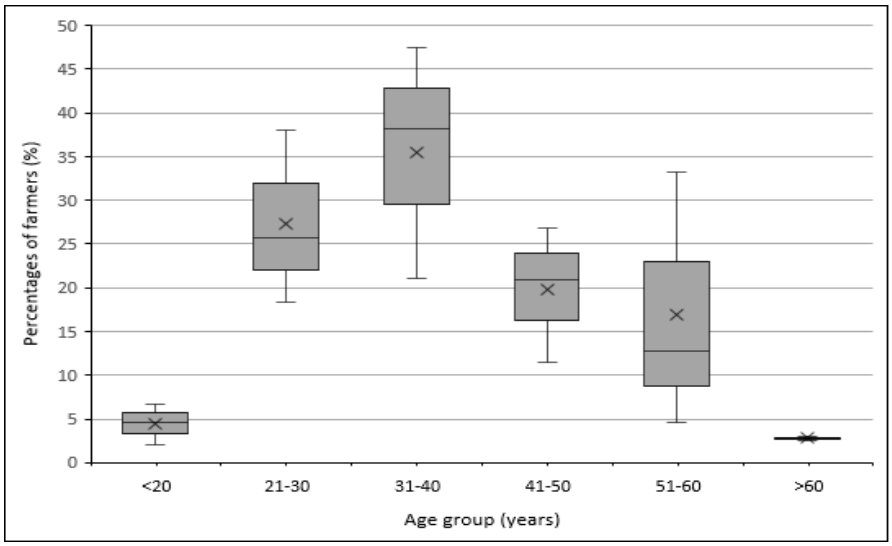


**Figure 6.** Age group distribution of farmers surveyed on phytosanitary practices in Cameroon.

**Table 1. Significant Pearson correlations between age of Cameroonian farmers and phytosanitary practices.**

| Cross variables | p-value | r | Confidence interval | n |
|---|---|---|---|---|
| Age 30-40 years × compliance with manufacturer instruction | 0.030 | 0.91 | 0.15;1.66 | 22 |
| Age 21-30 years × pesticides storage on the farm | 0.030 | -0.99 | -1.73; -0.25 | 24 |
| Age 21-30 years × burying empty pesticide containers | 0.003 | -0.98 | -1.33; -0.63 | 22 |
| Age 21-30 years × burning empty pesticide containers | 0.041 | -0.89 | -1.71; -0.06 | 22 |
| Age 41-50 years × pesticides storage in farm | 0.040 | 0.99 | 0.66;1.93 | 24 |
| Age 41-50 years × burying empty pesticide container | 0.010 | -0.95 | -1.50; -0.30 | 22 |

### 4.3. Number of years of experience in farming

In Cameroon, 53.2% of surveyed farmers on average, have farming experience of 16 years or more, followed by 6-10 years of experience (37.6%), and only 17.6% have farming experience between 0-5 years (Figure 7). Analysis of our data did not show any significant relationship between farmers' age and phytosanitary practices. This opposes other reports which demonstrate that farming experience (age) contributes positively to good phytosanitary practices (GPP). A study revealed that Chinese experienced farmers usually have more knowledge about pesticide utilization, and thus were less likely to overuse pesticides (Pan et al., 2020). Farmers that are experienced with pesticide poisoning are restricted to overuse them on their crops (Lui & Huang, 2013). The main weakness of experienced farmers is that some of them think they can use pesticides depending on the empirical knowledge of pesticides, and consequently, they reject the recommendations of manufacturers. This is the case of some reports in Cameroon, which show that pesticide handling methods, like target plant part, spraying time, frequency and doses may be incorrect, because 75% of farmers depend on other experienced farmers for advice on how to control pest and diseases (Abang et al., 2013). Similarly, a survey in Santa Northwest Cameroon shows that 95% of farmers using pesticides based on their personal experience did not protect themselves during pesticide application, and took poor safety measures leading to many cases of health problems being recorded among them (Sonchieu et al., 2017). A similar observation was recorded in Kuwait, where experienced farmers were not associated with PPE-wearing (Mustapha et al., 2017).

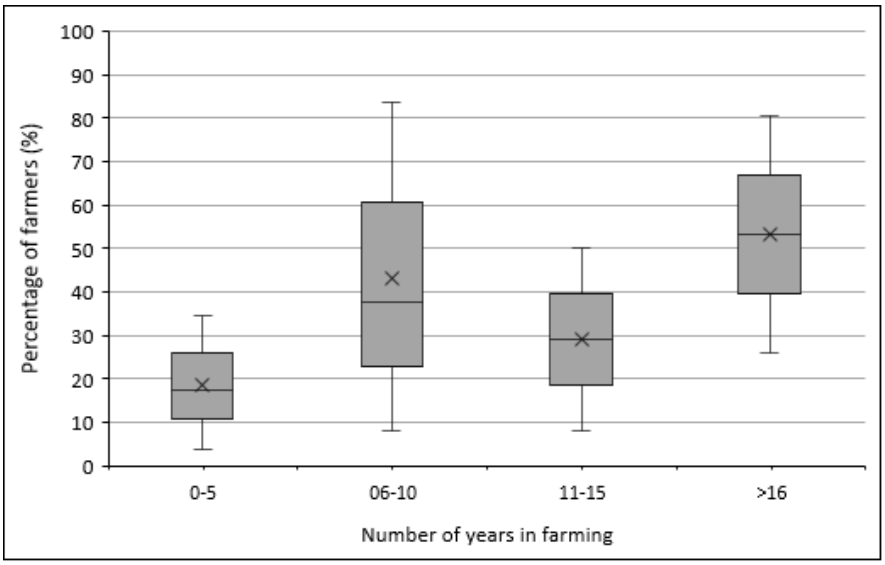


**Figure 7**. Experience level of farmers surveyed on phytosanitary practices in Cameroon.

### 4.4. Level of education of farmers

The level of compliance with manufacturers' instructions for farmers can be very low if they do not have a good education because they cannot read pesticide labels very well (Soro et al., 2019). Label reading and respect for prescribed guidelines are more favorable for farmers that are educated (Houbraken et al., 2016). The study by Lekei et al.(2014) revealed that when farmers have lower education levels, they have difficulty reading labels or understanding the negative effects of pesticides. Previous studies in China confirmed that education levels are positively related to proper compliance with pesticide application (Lekei et al., 2014; Sharma et al., 2015). Our compilation of studies in Cameroon revealed that the level of education of most farmers in the country is primary school (44.8%), followed by secondary school (36.1%), 14.1% of farmers are illiterate, and only 9.6% of 10 them received a higher level of education (Figure 8). In Pakistan, only 6% of farmers have received a university education (Mubushar et al., 2019).

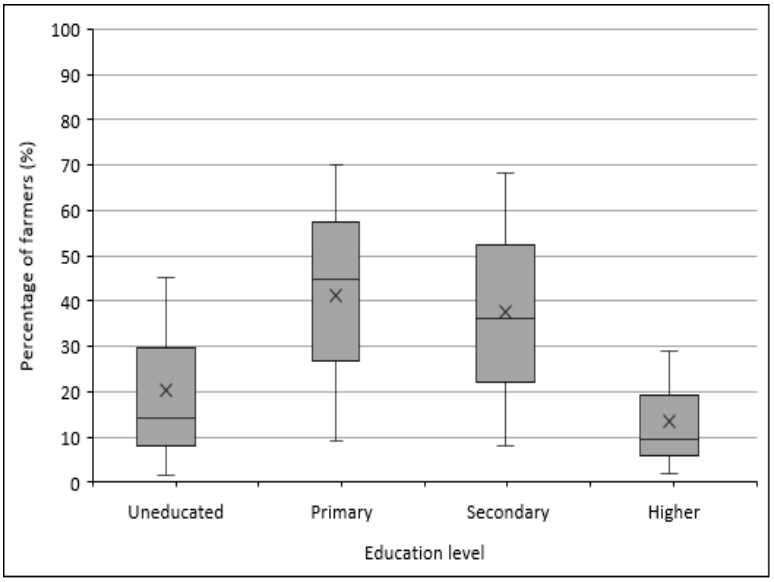


**Figure 8**. Education levels of farmers surveyed on phytosanitary practices in Cameroon.

Analysis of our data shows that there is a positive significant relationship between uneducated farmers and training (p=0.002, r=0.99, IC=0.07,0.11, n=23), bury empty container (p=0.031, r=0.90, IC=0.10,1.69, n=22), and farmers that throw empty pesticides containers in the environment (p=0.03, r=0.89, IC=0.08;1.71, n=22). Farmers who have a secondary level of education are most likely to use the recommended dose of pesticides (p=0.006, r=-0.74, IC=-1.2, -0.2, n=19); those with a university level of education are significantly associated with wearing PPE like nose mask and boots (p=0.030, r=0.99, IC=0.36,1.62, n=24). This suggests that training needs to be taken with high consideration for uneducated farmers to increase their knowledge and prevent the wrong utilization of pesticides in Cameroon. In fact, it was observed in the Democratic Republic of Congo, that farmers having secondary education levels have the ability to use pesticides properly only when they are assisted by civil servants of the National Institute for study and Agronomic Research (NISAR) (Muliele et al., 2017). Literate farmers have a good understanding of the effects of pesticides on health and the environment than illiterate ones (Mubushar et al., 2019). Son et al.(2017) showed that the low level of education, knowledge, and training of Chinese farmers increased the risk of pollution of the environment and low educated farmers did not comply with the recommended pesticide dose because they could not read pesticide labels. Because they are illiterate, Cameroonian farmers in Gallim did not follow manufacturers' instructions (Tarla et al., 2013) and most farmers of the Mezam subdivision, who are primary school dropouts, don't know the names of the pesticides they use, (Fon et al., 2019). Studies in humid tropics and Foumbot Western Highland of Cameroon showed that education level plays a major role in the adoption of new technologies of agricultural innovations (Okolle et al., 2016; Tarla et al., 2015). For the optimal application of alternative measures and implementation of integrated pest and disease management (IPDM) and new technological measures, education level is very necessary. Chinese investigation estimated that education level increased the probability of farmers choosing non-chemical pest control methods (Wang et al., 2018). Educated farmers were more willing to choose non-chemical pest control methods and adopt integrated pest management (Wang et al., 2018).

A previous study in Cameroon revealed that 78.0% of farmers attended primary school (Abang et al., 2013). More importantly, the health of pesticide users may also depend on their level of compliance to instruction: a study at Azaguié, south of Côte d'Ivoire, reported that the level of compliance to instruction must additionally be the reason for health symptoms developed by the farmers (Soro et al., 2019).

### 4.5. Knowledge of farmers on pesticide use and associated health and environmental risks

A deficit of knowledge on pesticides is interrelated with inappropriate pesticide handling (Pan et al., 2020). When the knowledge of pesticide residues build-up, the likelihood of willingness to downgrade pesticide use increases as well (Zhang et al., 2015). Minimal theoretical and practical knowledge is necessary and efficient to avoid risks to human health and the environment (Cissé et al., 2006; Wognin et al., 2013). In fact, farmers with more knowledge of

pesticides conducted better applications to decrease pesticide residues (Wang et al., 2018). Only two studies on the knowledge of farmers about pesticides were found in Cameroon, all in agroecological zone III (Sonchieu et al., 2019; Sopkoutie et al., 2021). They revealed that 17% and 9% of Cameroonian farmers have knowledge of pesticide residues in fruits, 4% have knowledge of the effect of pesticide residues on health (Sopkoutie et al., 2021), and 24.9% have knowledge about the recommended dose (Figure 8). This could be the reason why many studies have revealed contamination of foods from Cameroon by pesticide residues and health risks linked to their consumption (Galani et al., 2018, 2020, 2021; Sonchieu et al., 2013; Sopkoutie et al., 2021).

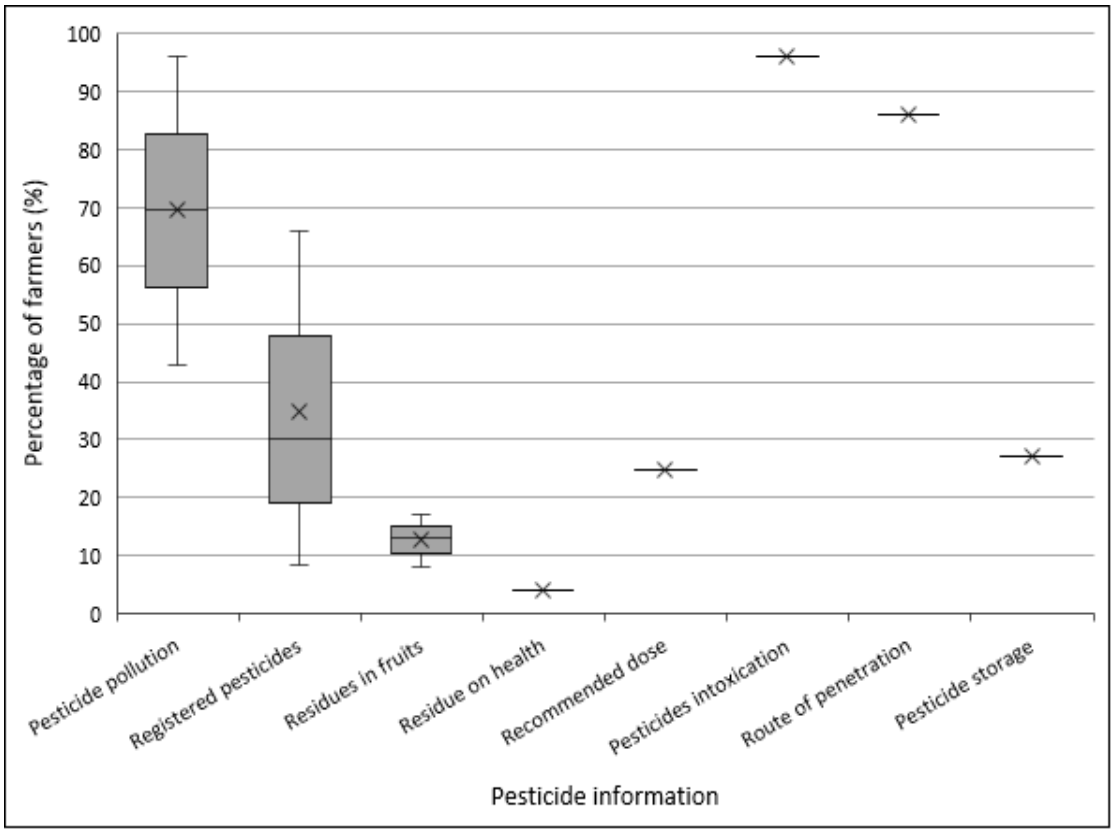


**Figure 9**. Distribution of Cameroonian farmers according to their knowledge of pesticide information.

Three studies revealed that on average, 30% of Cameroonian farmers know pesticide registration (Figure 9). More than half of the farmers used banned pesticides in Cameroon because they did not have information on them (Tarla et al., 2014). Residue analyses revealed the presence of non-registered pesticides in foods in Cameroon (Galani et al., 2018, 2020, 2021; Sonchieu et al., 2017) and their utilization by farmers during production activities (Kenko et al., 2017; Kenko & Kamta, 2021; Ngameni et al., 2017; Sopkoutie et al., 2021; Tarla et al., 2015). The current review found a single study, which showed that 96% of farmers have knowledge of pesticide intoxication and 86% of them know about the penetration route of pesticides in living organisms (Sonchieu et al., 2019).

Despite the high knowledge of farmers, many cases of intoxication of farmers have been reported in Cameroon, because farmers depended on their experiences and did not respect the prescription of manufacturers (Abang et al., 2013; Abdulai et al., 2019). One study from the West region of Cameroon, agroecological zone III, showed that 27% of farmers know pesticide storage (Sonchieu et al., 2019). Cases of accidental poisoning with pesticides, because of poor storage conditions were reported in the country (CPAC, 2010). Generally, pesticides are a very high source of pollution to the environment by bioaccumulation and bio amplification processes, in different environmental compartments such as soil, water, and air. For example, terrestrial ecosystems in the north of Benin have been polluted by the presence of pesticide residues linked to intensive utilization in agriculture (Gouda et al., 2018). Only one study was undertaken in Cameroon in this regard and showed that 69.5% of farmers on average know about pesticide pollution (Figure 9).

As a result, 57.1% on average of Cameroonian farmers have no consideration of wind direction because they don't have any knowledge of it. The pesticide drift following application in windy conditions can also contribute to pesticide pollution of the atmosphere in the surrounding of the spraying zone. In Santa, Northwest region of Cameroon, 10.7% of farmers were living in the sprayed farm, 40% were living closer to the farm, while only 49.3% of them were living far from the sprayed farm. The living conditions can contribute to the intoxication of these populations that are closer to the sprayed farm (Sonchieu et al., 2017).

It was found that in the 5 agroecological zones of Cameroon, only 2% of farmers know that pesticides can be hazardous to the environment (Pouokam et al., 2017). No investigation has been conducted in Cameroon to report the knowledge levels of farmers about the preharvest time and restricted entry time. Our data from this review show that 87.0% of farmers did not respect the separating time between the last application and harvest. No study in Cameroon assessed the knowledge level of farmers on the decontamination process after pesticide spraying operations. Studies showed that farmers had bad habits after pesticide application, such as carrying children, drinking, eating, do not take a bath, smoking, and keeping cloth of spraying with other clothes (Abayomi, 2018; Efuetlancha, 2020; Kamga et al., 2013; Sonchieu et al., 2017; Tandi et al., 2014). A single study in Cameroon on the knowledge of farmers on the attitudes to adopt in case of pesticide intoxication reported that only 3% of farmers identified the intervention hospital in case of pesticide poisoning (Matthews et al., 2003).

**4.6. Agricultural training and assistance**

The present review shows that 42.1% of farmers on average have received assistance and 35.6% received training on pesticide handling in Cameroon (Figure 10). But when considering crops and years, there can be some disparities: in 2003, it was found that many farmers spray pesticides without training of agricultural extension services on pesticides utilization (Tarla et al., 2015); during this last decade, lack and insufficient training and assistance have been reported in Cameroon (Gama et al., 2016; Kenko et al., 2017; Sonchieu et al., 2019; Tarla et al., 2015; Tayoh et al., 2016). In Cuba, only 28.3% of farmers have received specific training on pesticides (López-dávila et al., 2020).

This lack of training may explain the suboptimal practices observed among Cameroonian farmers in crop production. In this review, we found a significant relationship between training and uneducated farmers ($p=0.002$, $r=0.99$, IC=0.07,0.11, n=23), which highlights the need for training from the extension services by the less educated farmers. Australian farmers use PPE because they have received training (MacFarlane et al., 2008). In Pakistan, farmers have information on safety measures because of training (Mubushar et al., 2019). Training and assistance can contribute to increasing the knowledge of farmers on alternative methods to control pests and diseases and therefore reduce the utilization of pesticides. Several studies conducted in Gallim, Foumbot (West region) and Santa (North-West region) of Cameroon revealed that farmers do not have any pieces of knowledge of Integrated pest management (IPM), while it was shown that knowledge of IPM by farmers reduces crop losses and improves the income of farmers (Nie et al., 2018; Wang et al., 2017, 2018). A Chinese study showed that farmers think that reducing or working without pesticides can reduce crop yields (Wang et al., 2017). A study in Gallim showed that farmers applied pesticides based on the severity of the pest attack because they received advice from specialists (Tarla et al., 2013). The lack of farmers' training in Cameroon can be due to the non-accessibility of the agricultural civil servants to some remote production zones, because of lack of financial and logistic means. A study carried out in Bamenda, North-west region of Cameroon, revealed that rural farmers used their hands to spray pesticides that they mixed in buckets previously used for kitchen activity.

Farmers from peri-urban and urban zones did not practice this, because of their better exposure to training and assistance (Kamga et al., 2013). In remote areas in Cameroon, farmers have little or no contact with the village extension workers; instead, they seek advice from neighboring farmers (Abang et al., 2013). Accessibility of the production zones can be the reason for poor training and assistance to farmers because comparable to other accessible zones and their far agricultural assistance and training agencies or NGOs cannot reach there due to many factors such as the non-accessibility by the quality of the roads, the absence of hosting facilities for trainers.

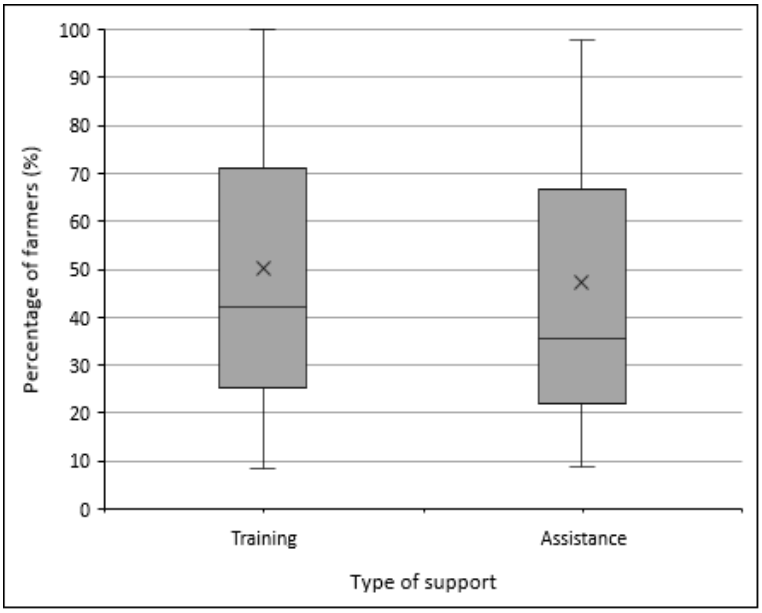


**Figure 10**. Distribution of Cameroonian farmers who receive training and assistance on phytosanitary practices.

## 5. Usage of pesticides by Cameroonian farmers

### 5.1. Farmers' behavior during pesticide preparation

Pesticide preparations have been considered to be the main source of intoxication for farmers and the risk is greater than during application (Damalas & Eleftherohorinos, 2011). The compiled data of the current review shows that on average 87.0% of Cameroonian farmers did not respect the recommendations of the manufacturers, 81% of farmers usually use a spoon and pesticide lid in measuring the pesticide, and the water used for diluting the pesticides generally comes from rivers that are near the farm. In the Far North region of Cameroon, farmers did not respect the dose because the measurements of the chemical are estimated by using tin or bottle caps Ahmadou et al., 2016). No study on the protective measures used during pesticide preparation in Cameroon was found in the literature. However, a study in Ghana revealed that 78.7% of farmers do not use oral or nose masks and 70.0% of the respondents indicated not wearing coveralls before pesticide application (Miyittah et al., 2020). No study in Cameroon investigated the situation of the containers that farmers use to mix chemicals and the conservation and utilization of remaining formulations by farmers.

#### 5.1.1. Spraying equipment

Our review data show that knapsack sprayers are mostly used by Cameroonian farmers during pesticide application (70.4%), followed by atomizers (18.5%), hand sprayers (11.1%), and buckets (11.1%). Sprayers are necessary for the good distribution of the chemical on the plant and to prevent exposition. A survey conducted amongst market gardeners in Bamenda showed that ownership of sprayers decreases in the rural areas compared to urban areas: 96% of farmers in rural and peri-urban areas use their hands to spray against 8% of the producers of the urban area (Kamga et al., 2013). Such differences refer mainly to the people who prepare the mixtures in the field, farmers that use buckets usually use leaves or their hands for application (Anoumaa et al., 2023). A study in Togo reported that farmers use a broom to apply pesticides, which can contribute to farmers' exposure to pesticides because they are directly in contact with the chemical (Diallo. Dalanda. et al., 2019).

#### 5.1.2. Farmers' behaviour during pesticides application

Farmer's behaviour can contribute to their exposure to pesticides through different routes of penetration, due to their low level of knowledge about routes of contamination of pesticides. Few studies have assessed the habits farmers exhibit during application activities. In Cameroon, most farmers (87.0%) drink alcohol during pesticide application,

drink water (59.5%), sing (46.0%), smoke (36.0%), speak (33.5%), and eat (11.1%) during pesticides handling (Figure 11). Smoking could exacerbate intoxication or poisoning effects on occupationally exposed farmers.

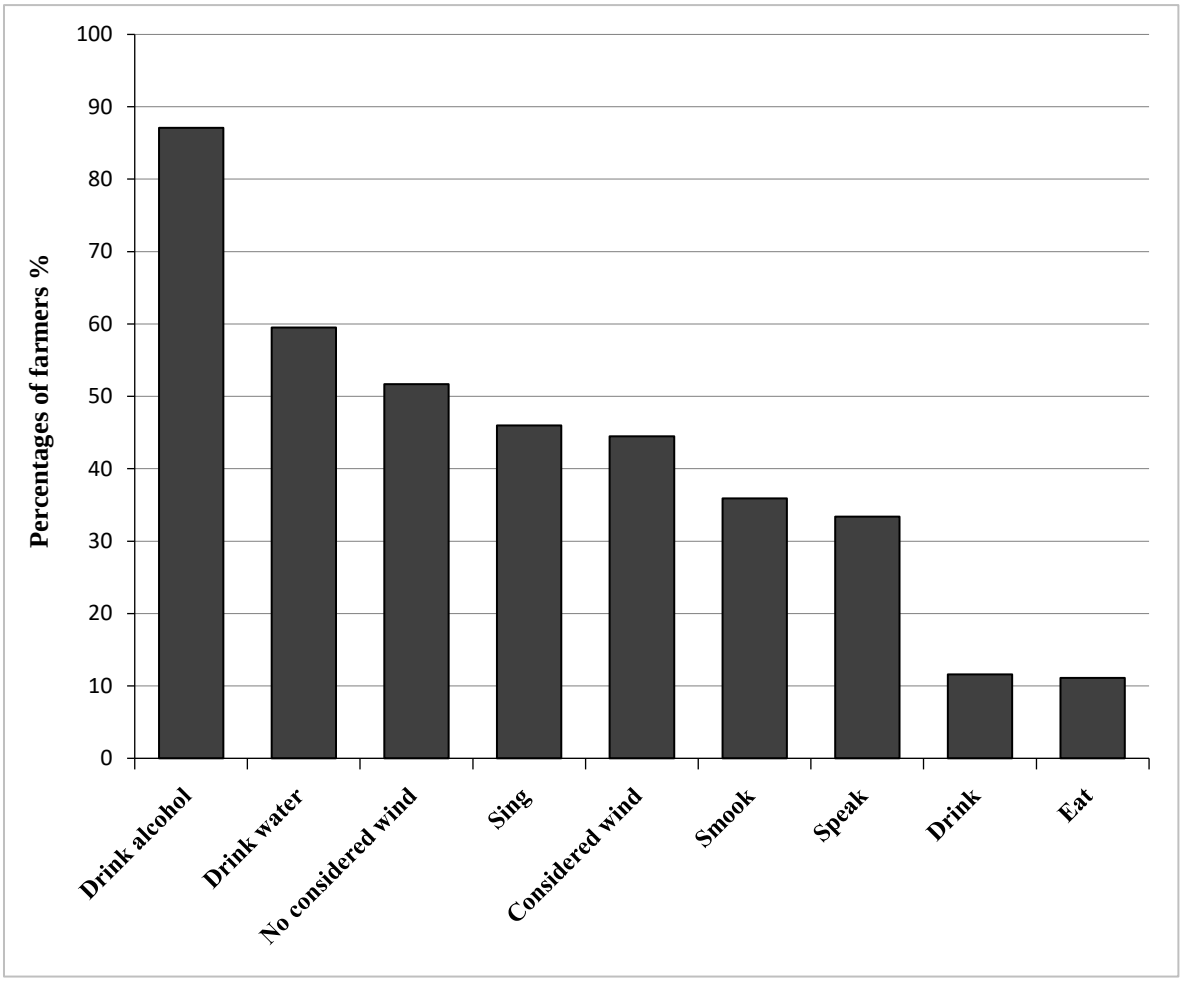


**Figure 11**. Behaviors of Cameroonian farmers during pesticide handling.

### 5.1.3. Environmental conditions during pesticide handling

Wind increases considerably spray drift and resultant exposure to the applicator (Damalas & Eleftherohorinos, 2011). This review reveals that on average, 52.0% of farmers spray with no consideration of wind direction and 45.0% take it into account when spraying. This can expose the farmers to pesticides, especially when they do not have PPE and when their PPE is not in good condition. Another main factor of intoxication can be the proximity of residential areas to farming areas (Swagata, 2021). Only one study in Santa, North-west region of Cameroon assessed the position of adjacent residential areas of spraying zones and showed that 10.7% of farmers were living in the sprayed farm, 40.0% were living closer to the farm, and 49.3% of them were living far from it. A South African investigation revealed that spray drift contributes to the intoxication of people living adjacent to agricultural farms (Swagata, 2021). A similar risk has been reported in Brazil (Bombardi, 2017).

### 5.1.4. Doses and frequency of pesticide usage by farmers

The current analysis of published data demonstrates that 81.0% of Cameroonian farmers on average did not respect the recommended dose prescribed by the manufacturers, labelled on the containers of the chemicals (Figure 12). The majority (96.8%) of Abidjan farmers in the Ivory Coast did not respect the dose of pesticide (Doumbia & KWADJO, 2009). Pearson correlation statistical test reveals that there is a significant relationship between dose and farmers' ownership of land (rented land or own land) ($p=0.041$, $r=-0.95$, IC=-1.89; -0.001, n=19) and reusing EPC ($p<0.010$, $r=-0.95$, IC=-1.26, -0.64, n=19).

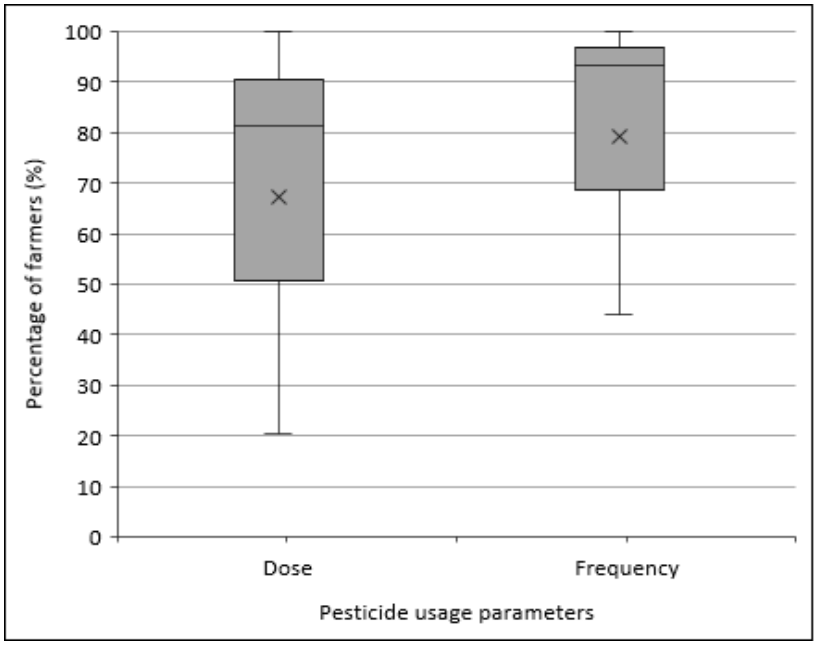


**Figure 12.** Distribution of Cameroonian farmers according to their non-compliance with dose and frequency of pesticide application.

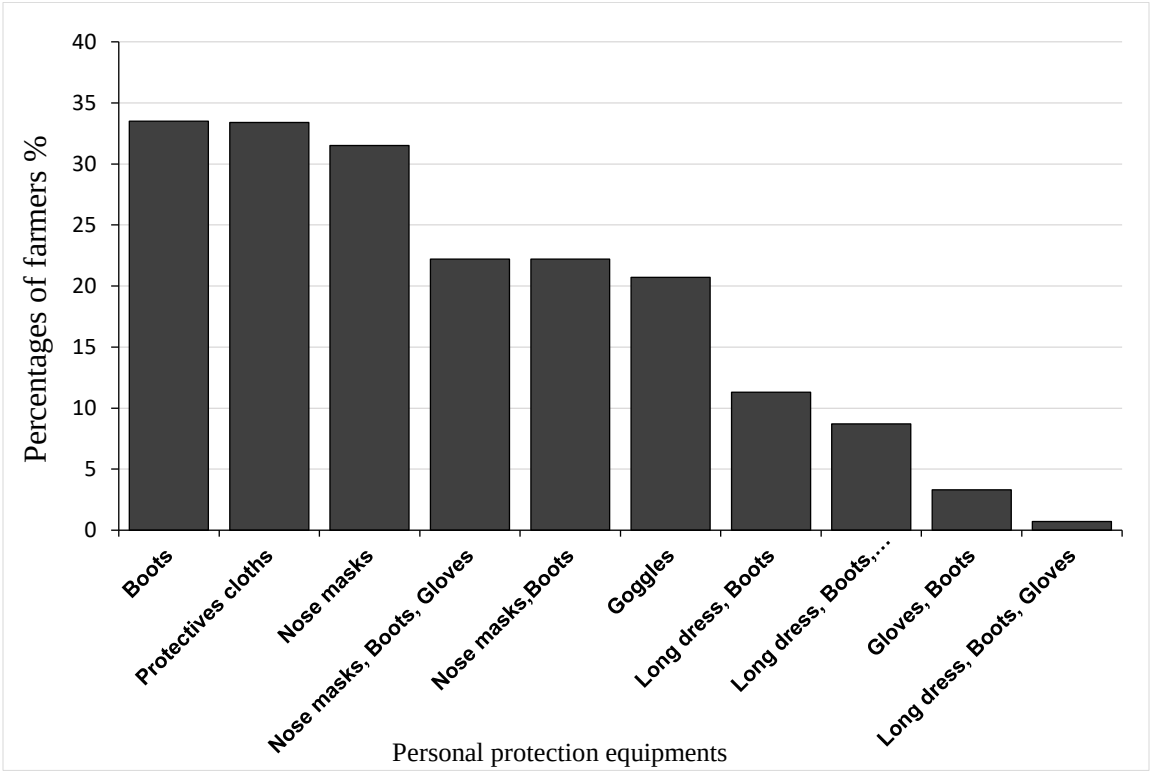


**Figure 13**. Distribution of Cameroonian farmers according to the types of personal protection equipment they use.

Farmers use PPE that could not directly prevent pesticide intoxication, but protect them from mosquitoes, snake bites, and environmental constraints like rain, wind, and sun. Farmers attributed the non-wearing of PPEs to their poverty situation, high cost of PPEs, ignorance, and discomfort (Kenko & Kamta, 2021; Sopkoutie et al., 2021; Tarla et al., 2013, 2015). Similarly, in Kuwait, farmers revealed that they did not wear PPEs because of their non-availability when they need them (35%), discomfort (90%), cost (65%) and slowing them down (29%) (Mustapha et al., 2017). Yam farmers in Ghana reported that they did not wear PPEs because of the discomfort and the cost (Wumbei et al., 2019).

The high cost of PPEs is generally the reason why some farmers did not provide them for laborers during spraying activities (Swagata, 2021). This situation could also be because farmers did not know the penetration route of pesticides in the body, as a study conducted in West Cameroon revealed that 86% of farmers don't know the route of penetration of pesticides into the body (Sonchieu et al., 2019). The high lack of PPEs during pesticide handling can contribute to acute pesticide poisoning (Oesterlund et al., 2014) and contribute to a high risk to farmers (Ahouangninou et al., 2011). A study in Ivory Coast revealed that 94% of farmers are generally victims of health problems such as headaches (11,76 %), sneezing (35,29 %), dizziness (17,65%) and dermatosis (52,94 %) (Soro et al., 2019). Reports show that Ghanaian farmers in the central region have been most exposed to health problems because of their inappropriate use of basic PPEs during pesticide application (Miyittah et al., 2020).

### 5.2. Post-application activities

After the application of pesticides, it is necessary to implement some decontamination strategies to reduce possible pesticide residues deposited on the body or PPE used for handling pesticides. Pesticide exposure increases when farmers do not implement or ignore fundamental sanitation practices such as the washing of hands after pesticide handling or before eating. The post-application activities also determine the amount of pesticide residues that can be found in the harvested foods and 19 the exposure risk for consumers. Only 6 surveys revealed a decontamination strategy implemented by Cameroonian farmers.

#### 5.2.1. Time before harvest (TBH) and restricted entry interval (REI)

The non-respect of time before harvest (TBH), that is, the time allocated between the last pesticide treatment and the harvest, constitutes a high risk for consumers (Bayendi et al., 2017). Our review of the 3 studies undertaken in Cameroon shows that on average, 74.0% of Cameroonian farmers did not respect the TBH (Figure 14). A study in Cuba shows that 22% of farmers only adhere to the preharvest interval with a significant positive correlation with trained farmers (López-dávila et al., 2020). The main reasons for non-compliance to TBH were that farmers harvest earlier to prevent additional lost that can decrease their financial revenue (Kouakou et al., 2019), because of the availability of buyers (Sonchieu et al., 2017), or because they don't have any knowledge on TBH in West Cameroon, 10.0% of farmers did not know about it (Sonchieu et al., 2019). However, A study in Gabon showed that the majority of farmers who acknowledge the importance of TBH did not respect it (Bayendi et al., 2017). Farmers using non-adapted pesticides on some crops can also be the reason for the non-respect of time before harvest and dose (Bayendi et al., 2017). At some level, the non-respect of TBH is triggered by the perception of buyers and consumers. In Foumbot, West Cameroon, it was found that farmers did not respect TBH because when buyers of vegetables saw traces of chemicals, they assumed that the vegetables could have a longer shelf life (Sopkoutie et al., 2021). In Gabon, a study reported that farmers use chemical treatments right up to the day before harvest, so as not to have any insects on the market product, disregarding the risk of harming their health and that of the consumers (Bayendi et al., 2017). Only 3 studies conducted in Cameroon assessed farmers' re-entry time, and our data compilation shows that on average, 74.1% of farmers did not follow re-entry time, depending on the last application time (Figure 13). Moreover, only one study done in Cameroon highlights that for 21% of farmers, the re-entry time is between 48-72h, and for 59% of them, it was superior to 72h. The majority of farmers (70%) have never heard about REI in Fotouni, West Cameroon (Kenko & Kamta, 2021).

#### 5.2.2. Hygiene behavior of farmers after pesticide usage

This review shows that on average, 59% of Cameroonian farmers do not take a bath and 51% do not wash their hands after the application of pesticides. To remove all residues that are deposited on the skin, Jaga in 2003, reported that exposure to pesticides is quite significant when workers bring contaminated items home (Jaga & Dharmani, 2003). On average, 14% of farmers don't wash their cloth and wear them during another activity after pesticide usage. Further studies need to be conducted in Cameroon, to know how clothes are washed by farmers, i.e., whether the dirty clothes are washed separately, or are washed with other family clothes. About 18% of farmers in Cameroon carry children directly after pesticide usage activities, which can lead to exposure of family members (**Figure 15**).

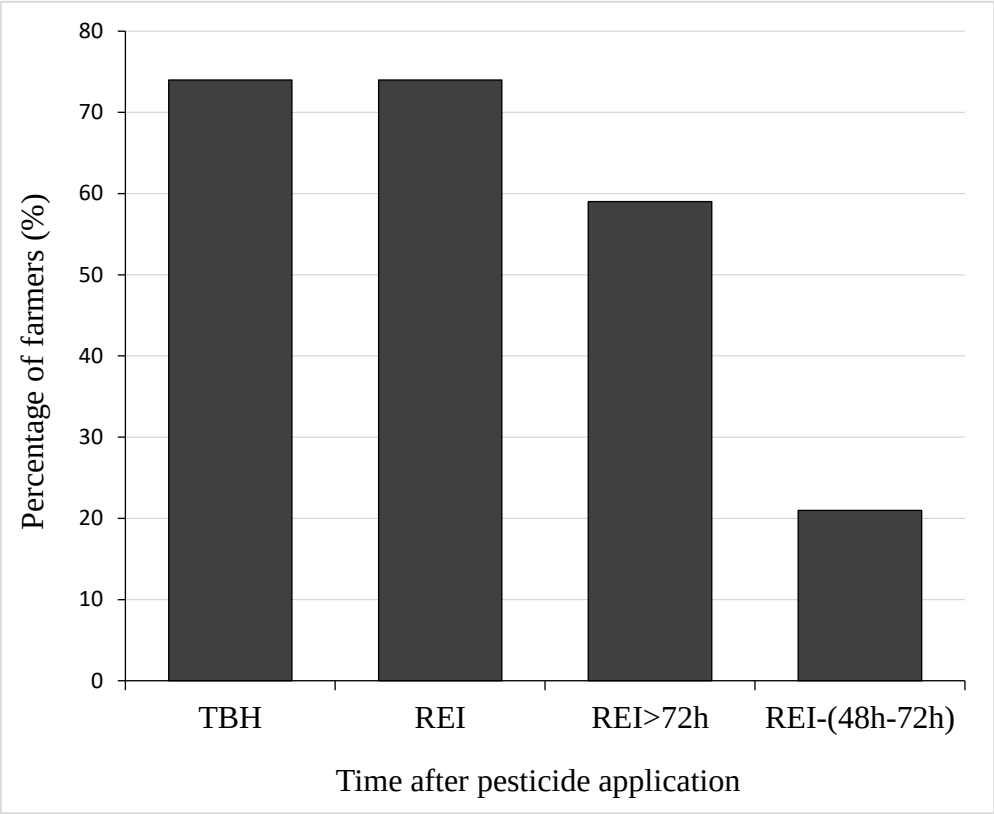


**Figure 14.** Distribution of Cameroonian farmers according to their compliance with time before harvest (TBH) and restricted entry interval (REI).

### 5.3. Storage of pesticides

Our reviewed data show that on average, 49.7% of Cameroonian farmers store pesticides at home, generally in the kitchen with other farming equipment or in the living room, while 29.9% of farmers store pesticides on the farm (**Figure 16**). Pesticides are stored without respecting the conventional standards of the United Nations Organization for Industrial Development (UNOID). How pesticides are stored may lead to exposure and adverse health consequences (Abang et al., 2013).

In Kenya, behaviour such as keeping chemicals inside residential houses exposed farmers and their households to pesticide fumes or vapours and should be completely discouraged (Marete et al., 2021). In Cameroon, many cases of death and severe poisoning are attributed to the storage of pesticides, because they are usually mistaken for salt and spice, and added to foods, leading to poisoning. Farmers in Foumbot store pesticides in the kitchen near other accessories of food like salt, spices, and pepper. Three cases of suicide and 02 cases of accidental poisoning of children were recorded in a village in Foumbot, one of which a grandmother used herbicide in the place of spices, leading to her death and 21 of her three grandchildren (Tarla et al., 2013). Similarly, 03 persons were reported dead in West Cameroon after eating food accidentally contaminated with pesticides (CPAC, 2020).

### 5.4. Disposal of empty pesticide containers

Pesticide containers in Cameroon are usually made of plastic of 0.5 to 200 L containers and plastic sachets of a wide range, from 40 g to 45 kg (MINADER, 2021). This review shows that 44.0% of farmers on average, dispose of their empty pesticide containers (EPC) on the farm, 26.0% in the environment such as in the soil and river, 21.0% burn after utilization and collecting, and 16.0% bury the containers to prevent contact with people, and supposedly, to reduce environmental pollution. Our data also show that 17.0% of the farmers on average, reuse EPCs (**Figure 17**).

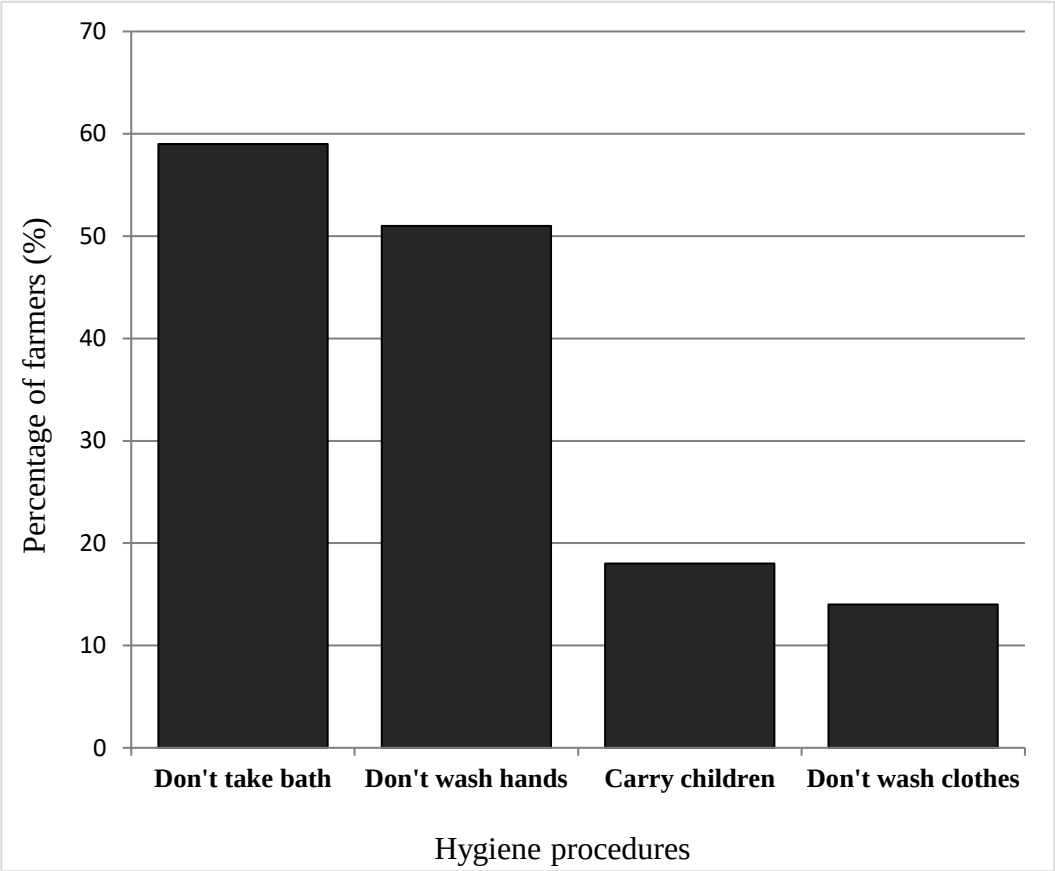


**Figure 15**. Distribution of Cameroonian farmers according to their non-compliance with hygiene procedures after pesticide handling.

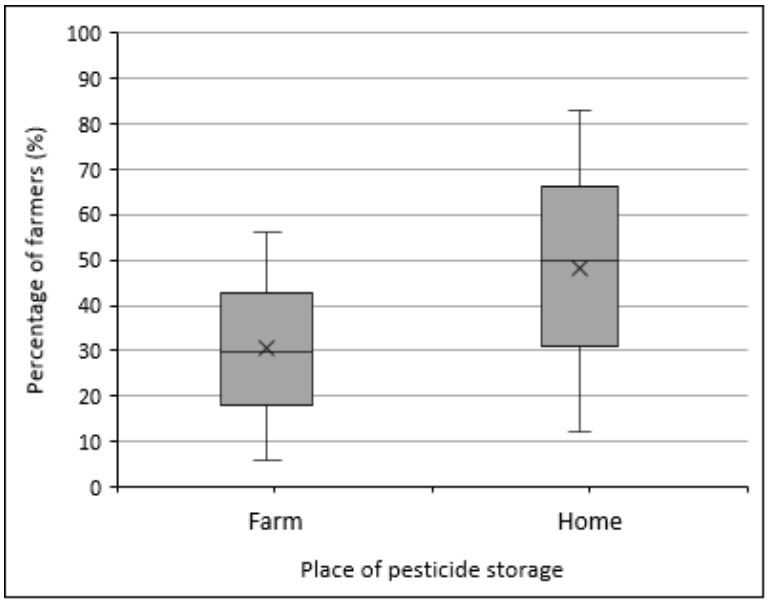


**Figure 16.** Distribution of Cameroonian farmers based on where they store pesticides.

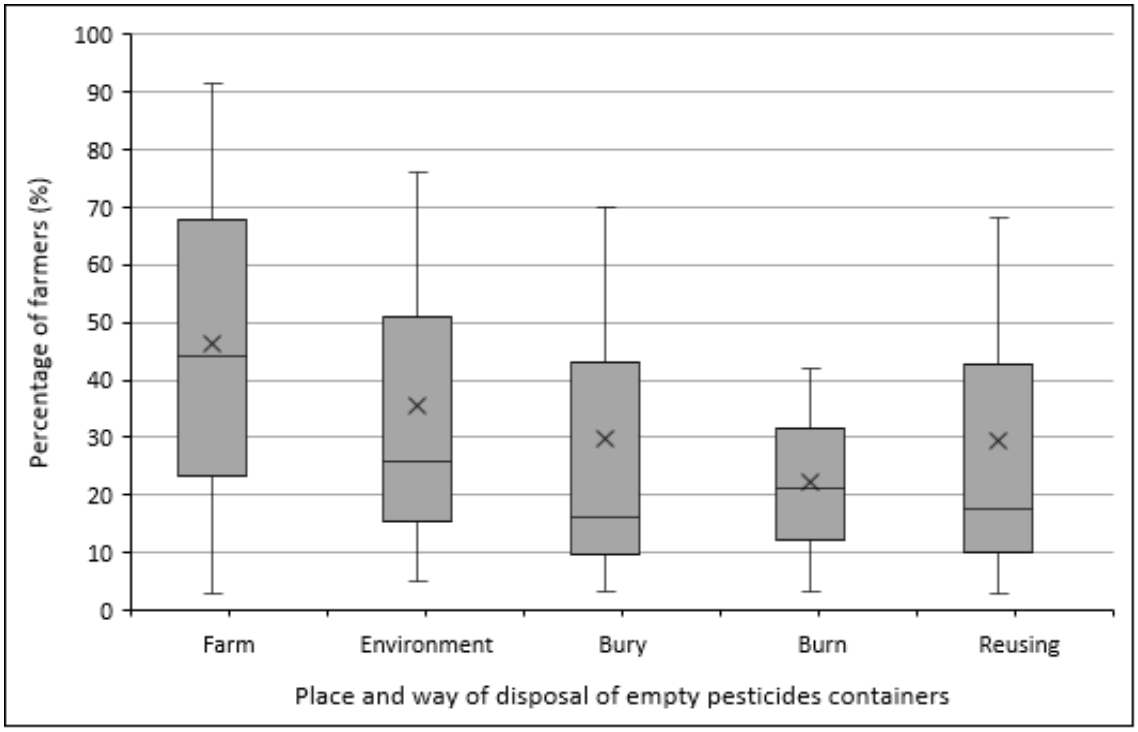


**Figure 17.** Disposal and fate of empty pesticide containers by Cameroonian farmers.

As many as 23,926 empty pesticide sachets and 32,431 empty plastic bottles were inventoried in Cameroon (Tarla et al., 2014). Generally, after application, pesticide containers are discarded in the fields and rivers, which could cause the accumulation of pesticide residues in the water or soil depending on their persistence. Approximately 10.9% of farmers in the Fako Division, South-west Cameroon, throw EPC in water (Kenko et al., 2017). This can disturb the natural ecological balance in the soil (Skevas et al., 2012). For instance, diuron showed the highest mobility potential in water and significant toxicity to the alga Scenedesmus. Chlorpyrifos-ethyl and lambda-cyhalothrin showed high toxicity to crustaceans and for fish, the highest risks were related to beta-cyfluthrin and lambda-cyhalothrin(Bayili et al., 2021). After 06 months of pesticide application, the behaviour of animals in the immediate surrounding production sites in Rwanda became abnormal (Ndayambaje et al., 2019).

A study in Cameroon revealed that empty sachets of pesticides are burnt by farmers, and empty pesticide containers are kept for reuse (Kenko et al., 2017). When pesticides are burned, the residues left in the containers can release toxic fumes or contaminate the environment (Kenko & Kamta, 2021). Contaminated EPCs constitute a serious hazard when they are reused for domestic purposes like carrying drinking water or storing table salt (Tarla et al., 2014). The empty pesticides containers are generally used for grain storage, water consumption, cooking oil and paraffin after washing the plastic containers (Kenko & Kamta, 2021; Ngameni et al., 2017; Sopkoutie et al., 2021), they are sold to pesticide vendors (Abdulai et al., 2019; Kenko & Kamta, 2021; Tarla et al., 2015) dumped in municipal rubbish and neighborhood fields, or used as drinking and eating bowls (Abdulai et al., 2019).

Empty containers are beneficial to the manufacturers who could recycle them, but children who engage in collecting them are exposed to the remnants of pesticide products they may contain (Tarla et al., 2014). Moreover, repurposing EPC for storing foods can lead to accidental poisoning: in 2010, six children died in Yagoua, Far-North Region of Cameroon, after consuming grains that were stored with insecticides purposely for planting (Tarla et al., 2013). On the other hand, the reuse of EPC can also encourage wrong pesticide usage. When farmers use labours for pesticide application, the latter mostly apply pesticides inappropriately, because they focus on the EPC for their own usage or for sale to earn some money. Our data show that reusing is significantly associated with dose ($p=0.010$, $r=-0.95$, IC=-1.26; -0.64, $n=19$) and frequency ($p=0.001$, $r=-0.98$, IC=-1.26; -0.70, $n=22$) of pesticide application in Cameroon.

Effect of agrochemical pesticides on the health of Cameroonian farmers in developing countries, there have been increasing concerns about health hazards resulting from agricultural activities (Manfo et al., 2020). As poisons that kill or warm unwanted living organisms, it is not surprising that pesticides generate adverse health consequences for

humans. There have been reported symptoms such as muscle fatigue, dizziness, headaches, vomiting and burning of the urinary tract in farmers who have handled pesticides (KHAN et al., 2009). Sometimes, the effectiveness of pesticides in protecting their crops makes farmers forget about the sanitary risks associated with their utilization. In Cameroon, 78% of pesticide intoxications were accidental, 12% were suicide attempts, while 4% were criminal (Pouokam et al., 2017). The main reason why many cases of diseases have been reported among pesticide users lack of training and assistance (Sonchieu et al., 2017) as well as a lack of knowledge of the effects on human health.

### 6.1. Acute toxicity

Generally, acute toxicity is a type of toxicity characterized by the rapid duration of manifestation of symptoms after being subjected to high doses of pesticides. This produces many adverse effects on human health. Our reviewed data show that 24 symptoms of acute toxicity after pesticide handling have been recorded in Cameroon. The most common symptoms include cramps (71.3%), pruritus (65.8%), intense thirst (53.4%), abdominal pain (41.9%), and dehydration (39.0%) (Figure 18). In Ngaoundere hospital, Adamaoua Region of Cameroon, health personnel reported 51 cases of intoxication and two cases of death due to pesticide poisoning in 27 months (Tarla et al., 2013).

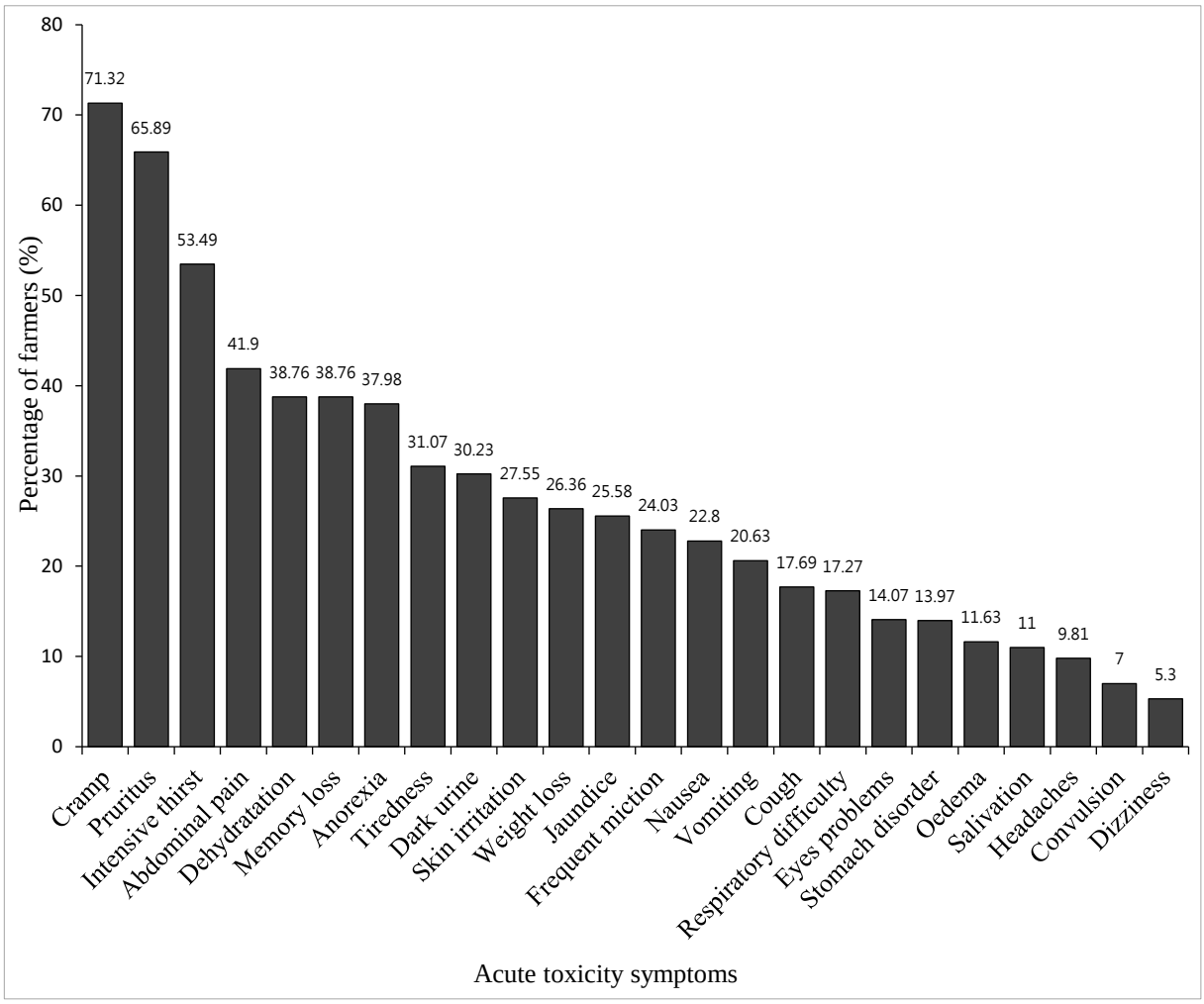


**Figure 18.** Distribution of symptoms of acute toxicity linked to pesticide poisoning among Cameroonian farmers.

This situation can be because farmers did not respect the recommendations of manufacturers. A study in Nigeria, the second importer of pesticides in Africa, revealed that 65% of farmers did not read the pesticide label, and as a result, 92% were exposed and fell sick after exposure to pesticides (Tolera, 2020). Pesticide exposure leading to acute toxicity can occur from leakages of chemicals, accidental spills, or faulty spraying equipment (Damalas & Eleftherohorinos, 2011). Non-wearing of good and complete PPE and bad attitudes during pesticide application can increase the exposure (Damalas & Eleftherohorinos, 2011). In cocoa farming in Cameroon, spray leaks were reported by the majority of farmers and the leaked liquid caused skin irritation (Matthews et al., 2003). The lack of funding and training and non-

compliance with REI has been found to be a reason for the exposure of farmers in Fako, Cameroon (Kenko et al., 2017). Lack of knowledge of the dangers of pesticides was also correlated with health problems: in Bamboutos, West Cameroon, many farmers present symptoms and signs of pesticide toxicity, because they are ignorant of the fact that safety measures are very important and knowledge on health, and penetration route are very ambiguous (Sonchieu et al., 2019); similarly, a Tanzania investigation found that farmers have health problems because 65% did not believe that pesticides could have any consequential effects on human health or other organisms than the targeted pests (Tolera, 2020). Studies show that the number of symptoms of pesticide acute poisoning is related to age and gender, where men mostly suffer more than women (Kenko et al., 2017), and young farmers suffer more than old farmers (Tandi et al., 2014). The type of pesticides used based on WHO classification can be the source of acute poisoning of farmers. Fifty-eight per cent of active ingredients on average, found with farmers in Cameroon belonged to class II (moderately hazardous). In the last 7 years, 50% of pesticides registered in Morocco were 25 classes I (extremely or highly hazardous) and II (moderately hazardous) and these are considered to be the cause of acute pesticide poisoning in the country (Swagata, 2021). Cases of intoxication of Cameroonian farmers and/or their family members have been reported (Kenko et al., 2017; Onguene et al., 2021; Sonchieu et al., 2017; Tandi et al., 2014). Because of inappropriate storage of pesticides, cases of accidental poisoning are common in Cameroon. In 2008, three children died in Bafang, West Region of Cameroon, after consuming a meal where a crystal-like pesticide was put into food in the place of salt (CPAC, 2010). Three cases of suicide due to direct consumption and 02 cases of accidental poisoning of children were recorded in a village near Foumbot, one of which a grandmother used herbicides in the place of spices, leading to her death and that of her three grandchildren (Tarla et al., 2013).

### 6.2. Chronic toxicity

While acute effects are observed quickly and can be swiftly contained and remedied, chronic effects are difficult to recognize. Hundreds of thousands of people could therefore have suffered irreparable damages before these insidious effects went unnoticed. Chronic exposure to pesticides could cause disease across three generations. The chronic effects of pesticide poisoning are mainly neurological, reproductive, developmental, carcinogenic, and immunological. Long-term exposure to pesticides can lead to cardiovascular disease, diverse types of cancer, muscle, and retinal degeneration (Graziano et al., 2006). Studies on the chronic effects of pesticides on farmers in Cameroon are very few. A study in the South-west region found that 18.6% of Cameroonian farmers are suffering from reproductive toxicity and cannot procreate children, and 4.6% are victims of cancers, signs of alteration of liver function marked by the increase of serum alanine aminotransferase activity were also found among the farmers (Manfo et al., 2020).

## 7. Conclusion and perspectives

This review highlights the high occurrence of non-compliance with good phytosanitary practices among Cameroonian farmers, mostly due to a lack of knowledge on pesticide usage and risks associated with pesticides, but also insufficient training, assistance, and funding for acquiring proper equipment for spraying and personal protection. This suggests a high exposure of farmers and a high environmental impact of pesticides in the country. This could justify the high prevalence of symptoms of pesticide acute toxicity and poisoning presented in this review. It appears that to improve human and environmental safety, agricultural sustainability, and economic viability of Cameroonian smallholders, education, training, and financial support must be strengthened. Further research should consider filling the identified gaps in this review, including the occurrence of chronic toxicity associated with pesticide usage among farmers, studies on phytosanitary practices in different zones of the country, and studies on many more crops produced in Cameroon.

**DECLARATIONS OF ETHICS APPROVAL AND CONSENT TO PARTICIPATE.** Not applicable.

**AVAILABILITY OF DATA AND MATERIALS.** The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

**COMPETING INTERESTS.** Co-author Joseph Hubert Galani Yamdeu is the Deputy Editor-in-Chief of the Journal; to ovoid any conflict of interest, he was excluded from every stages of the publication of this article.

**FUNDING.** This research received no funding.

**AUTHORS' CONTRIBUTIONS.** GNSK, JDF, and YJHG conceived the study and designed the structure of the manuscript. NGSK collected the data and analyzed it together with YJHG. NGSK wrote the manuscript draft. JFD, AW, PS, and JHGY reviewed the manuscript. All authors approved the final manuscript.

**ACKNOWLEDGEMENTS.** The authors are grateful to lecturers of the Faculty of Agronomy and Agricultural Sciences, University of Dschang, Cameroon, particularly to Tarla Divine Nfor, Yaouba Aoudou, Dzokou Victor Joly, Djomaha Edwige Sidoine and Bedine Boat Marie Amperes, Koulagna Issa Honoré for my training in research activities.

**REFERENCES**

Abang, A. F., Kouame, C. M., Abang, M., Hannah, R., & Fotso, A. K. (2013). Vegetable growers perception of pesticide use practices, cost, and health effects in the tropical region of Cameroon Article. *International Journal of Agronomy and Plant Production*, *4*(5), 873–883. https://doi.org/10.1089/jwh.2018.7274

Abayomi, O. S. (2018). Cocoa farmers' compliance with safety precautions in spraying agrochemicals and use of personal protective equipment (PPE) in Cameroon. *International Journal of Environmental Research and Public Health*, *15*. https://doi.org/10.3390/ijerph15020327

Abdulai, A. N., Konje, C. N., Achiri, T. D., Tarla, D. N., & Nsobinenyui, D. (2019). Pesticide Use Practices by Market Gardeners in the Santa Area of the North West Region of Cameroon. *International Journal of Plant & Soil Science*, *26*(6), 1–11. https://doi.org/10.9734/ijpss/2018/v26i630060

Abia, W. A., Shum, C. E., Fomboh, R. N., Ntungwe, E. N., & Ageh, M. T. (2016). Agriculture in Cameroon: Proposed Strategies to Sustain Productivity Environmental Health View project Plectranthus spp. Biological screening View project. *International Journal for Research in Agricultural Research*, *2*(2), 1.

Ahemad, M., & Khan, M. S. (2012). Chemosphere Effect of fungicides on plant growth promoting activities of phosphate solubilizing Pseudomonas putida isolated from mustard (*Brassica compestris*) rhizosphere. *Chemosphere*, *86*(9), 945–950. https://doi.org/10.1016/j.chemosphere.2011.11.013

Ahmadou, Y., Kouebou, C., Malaa, D., Bourou, S., Olina, J. P., & Mbiandoun, M. (2016). Les engrais et les pesticides dans la riziculture périurbaine de la ville de Garoua , au Nord- Cameroun: Cas de Nassarao et Boklé. *International Journal of Innovation and Applied Studies*, *18*(1), 26–35.

Ahouangninou, C., Fayomi, B. E., & Martin, T. (2011). Évaluation des risques sanitaires et environnementaux des pratiques phytosanitaires des producteurs maraîchers dans la commune rurale de Tori-Bossito (Sud-Bénin) Claude. *Cah Agric*, *20*(3), 216–222.

Anoumaa, M., Kouam, E. B., Kanmegne, G., Kamga, Y. B., Sime, H. D., Nkombo, L. L. C., & Fonkou, T. (2023). Phenotypic variation and genetic divergence studies in Cameroonian potato (Solanum tuberosum L.) genotypes. *Journal of Applied Biology & Biotechnology*, *11*(01), 220–221. https://doi.org/DOI: 10.7324/JABB.2023.110130

Bayendi, L. S. M., Ndoutoume, N. A., & Francis, F. (2017). Le maraîchage périurbain à Libreville et Owendo (Gabon): Pratiques culturales et durabilité. *Cahiers Agricultures*, *26*. https://doi.org/10.1051/cagri/2017026

Bayili, B., Ouedraogo, R., Sidibe, H., Ilboudo, S., & Ouedraogo, G. A. (2021). Pesticides Ecotoxicological Risk Assessment for Surface Waters in the Cotton Growing Area Around the Bala's Hippopotamus Pond Biosphere Using PIRI Method. *European Scientific Journal ESJ*, *17*(14), 167–182. https://doi.org/10.19044/esj.2021.v17n14p167

Bombardi, L. (2017). Atlas: Geografia do Uso de Agrotóxicos no Brasil e Conexões com a União Européia,. In *First edition, FFLCH- USP, São Paulo*.

Cissé, I., Fall, S. T., Badiane, M., Diop, Y. M., & Diouf, A. (2006). Horticulture et usage des pesticides dans la zone des Niayes au Sénégal. *Ecocité*, 14.

CPAC (Director). (2010). Intoxication alimentaire: Des pesticides font des morts au Cameroun [Broadcast]. In *CPAC Info Pesticide0010: 15*.

CPAC. (2020). Homologation Des Pesticides En Zone Cemac, Le CPAC Renforce Les Capacités Des Acteurs De La Filière. In *C AC INFOS Trimestriel d'information phytosanitaire en zone CEMAC, No 28. Pesticides* (Issue 28).

Cochrane. (2020). Cochrane Handbook for Systematic Reviews of Interventions (version 6.1, updated September 2020). Retrieved from https://training.cochrane.org/handbook

Damalas, C. A., & Eleftherohorinos, I. G. (2011). Pesticide Exposure, Safety Issues, and Risk Assessment Indicators. *Int. J. Environ. Res. Public Health*, *8*, 1409–1419.

Diaité, B., Dalanda Diallo, M., Goalbaye, T., Diédhiou, S., Diallo, A., Talla, R., Diop, A., & Guissé, A. (2020). Effet de l'application de différentes doses de fertilisants organiques sur la croissance et le rendement de la tomate (Solanum lycopersicum L.) en conditions semi-contrôlées. *Journal of Animal & Plant Sciences*, *44.1*(April), 7553–7566. https://doi.org/10.35759/janmplsci.v44-1.2

Diallo. Dalanda., Mariama., Diaité., B., Diédhiou., P. M., Diédhiou., S., Goalbaye., T., Doelsch., E., Diop., A., & Guissé., A. (2019). Effets de l'application de différents fertilisants sur la fertilité des sols, la croissance et le rendement du mil (Pennisetum glaucum (L.) R. Br. Dans la Commune de Gandon au Sénégal. *Revue Africaine d ' Environnement et d ' Agriculture*, *2*(2), 7–15.

Doumbia, M., & Kwadjo, K. E. (2009). Abstracts-Posters. *Journal of Applied Biosciences*, *18*, 992–1002. https://doi.org/10.1111/acer.13084

Efuetlancha, E. N. (2020). Assessing Small-Scale Farmers' Attitudes, Practices and Vulnerability to Pesticides Use in Market Gardening Crops in M'muockngie (South Western Cameroon). *Journal of Advances in Education and Philosophy*, *4*(6), 295–305. https://doi.org/10.36348/jaep.2020.v04i06.010

Efuetlancha, N. E., & Kuete, M. (2020). An Assessment of School Going Population Exposure Pathways to Agropesticide in the Mungo Corridor of Cameroon. *European Scientific Journal ESJ*, *16*(26), 123–144. https://doi.org/10.19044/esj.2020.v16n26p123

FAOSTAT. (2019). *Http://www.fao.org/faostat/fr/#data/QC*. Http://Www.Fao.Org/Faostat/Fr/#data/QC. https://doi.org/10.4236/as.2019.108079

Fon, D. E., Ntong, T. M., & Tarla, D. N. (2019). Contribution of Phytosanitary Products to the Revenue of Market Garden Farmers in Mezam Division, North West Region of Cameroon. *EC Agriculture*, *5.5*, 236–247.

Galani, Y. J. H., Houbraken, M., Wumbei, A., Djeugap, J. F., Fotio, D., Gong, Y. Y., & Spanoghe, P. (2020). Monitoring and dietary risk assessment of 81 pesticide residues in 11 local agricultural products from the 3 largest cities of Cameroon. *Food Control*, *118*, 107416. https://doi.org/10.1016/j.foodcont.2020.107416

Galani, Y. J. H., Houbraken, M., Wumbei, A., Djeugap, J. F., Fotio, D., Gong, Y. Y., & Spanoghe, P. (2021). Contamination of Foods from Cameroon with Residues of 20 Halogenated Pesticides , and Health Risk of Adult Human Dietary Exposure. *International Journal of Environmental Research and Public Health*, *18*, 5043.

Galani, Y. J. H., Houbraken, M., Wumbei, A., Djeugap, J., Fotio, D., & Spanoghe, P. (2018). Evaluation of 99 Pesticide Residues in Major Agricultural Products from the Western Highlands Zone of Cameroon Using QuEChERS Method Extraction and LC-MS/MS and GC-ECD Analyses. *Foods*, *7*, 184. https://doi.org/10.3390/foods7110184

Galani, Y. J. H., Orfila, C., & Gong, Y. (2020). A review of micronutrient deficiencies and analysis of maize contribution to nutrient requirements of women and children in Eastern and Southern Africa. *Critical Reviews in Food Science and Nutrition*, *0*(0), 1–24. https://doi.org/10.1080/10408398.2020.1844636

Gama, E. N., Folorunso, S. T., & Adeola, S. S. (2016). Analysis of factors affecting the technical efficiency of cocoa producers in the south-west region of Cameroon. *Journal of Agricultural Research and Development*, *14*(2), 89–96. https://doi.org/10.4314/jard.v14i2.9

Gimou, M. M., Charrondiere, U. R., Leblanc, J. C., & Pouillot, R. (2008). Dietary exposure to pesticide residues in Yaoundé: The Cameroonian total diet study. *Food Additives and Contaminants - Part A Chemistry, Analysis, Control, Exposure and Risk Assessment*, *25*(4), 458–471. https://doi.org/10.1080/02652030701567475

Gouda, A.-I., Toko, I. I., Salami, S.-D., Richert, M., Scippo, M.-L., Kestemont, P., & Schiffers, B. (2018). Pratiques phytosanitaires et niveau d'exposition aux pesticides des producteurs de coton du nord du Bénin. *Cah. Agric.*, *27*, 65002.

Graziano, N., Mcguire, M. J., Roberson, A., Adams, C., Jiang, H., & Blute, N. (2006). 2004 National Atrazine Occurrence Monitoring Program using the Abraxis ELISA method. *Environ. Sci. Technol*, *40*, 1163–1171.

Houbraken, M., Bauweraerts, I., Fevery, D., Van Labeke, M.-C., & Spanoghe, P. (2016). Pesticide knowledge and practice among horticultural workers in the Lâm Đồng region, Vietnam: A case study of chrysanthemum and strawberries. *Science of the Total Environment*, *550*, 1001–1009.

Ingenbleek, L., Hu, R., Lopes, L., Paineau, A., Colet, I., Zié, A., Adegboye, A., Epiphane, S., Dembélé, Y., Dada, A., Sika, C., Kisito, K. J., Eyangoh, S., & Verger, P. (2019). Food Chemistry: X Sub-Saharan Africa total diet study in Benin , Cameroon , Mali and Nigeria: Pesticides occurrence in foods. *Food Chemistry: X*, *2*(December 2018), 100034. https://doi.org/10.1016/j.fochx.2019.100034

Jaga, K., & Dharmani, C. (2003). Sources of exposure to and public health implications of organophosphate pesticides. *Pan. Am. J. Public Health*, *14*, 171–185.

Kamga, A., Kouame, C., Tchindjang, M., Chagomoka, T., & Drescher, A. W. (2013). Environmental impacts from overuse of chemical fertilizers and pesticides amongst market gardening in Bamenda , Cameroon. *Revue Scientifique et Technique Forêt et Environnement Du Bassin Du Congo*, *1*, 8–24.

Kenko, N. D. B., Fai, A., Ngameni, T., & Mbida, M. (2017). Environmental and Human Health Assessment in Relation to Pesticide Use by Local Farmers and the Cameroon Development Corporation (CDC), Fako Division, South-West Cameroon. *European Scientific Journal, ESJ*, *13*(21), 454. https://doi.org/10.19044/esj.2017.v13n21p454

Kenko, N. D. B., & Kamta, N. (2021). Human and Environmental Health Implications of Pesticide Utilization by Market Gardeners in the Western Highlands of Cameroon. *Asian Journal of Environment & Ecology*, *14*(3), 44–56. https://doi.org/10.9734/ajee/2021/v14i330210

Kenko, D. B. N., Asanga, P. B., Tasse, G. C., Ngameni, N. T., Ngealekeleoh, F., & Mpoame, M. (2017). Assessment of chemical pollution with routine pesticides using PRIMET, a pesticide risk model in the Benoe Stream in the South-West Region of Cameroon. European Scientific Journal, 13(30), 153. https://doi.org/10.19044/esj.2017.v13n30p153

Khan, D., Shabbir, S., Majid, M., Naqvi, T., & Khan, F. (2009). Farmers risk assessment of pesticide exposure on health of Pakistani tobacco. *J. Expo. Sci. Env. Epid*, *20*, 196–204.

Kouakou, K. J., Gogbeu, S. J., Sika, A. E., Yao, K. B., Bounakhla, M., Zahry, F., Tahri, M., Dogbo, D. O., & Bekro, Y.-A. (2019). Caractérisation physico-chimique des horizons de surface de sols à maraîchers dans la ville d'Abidjan (Côte d'Ivoire). *International Journal of Biological and Chemical Sciences*, *13*(2), 1193. https://doi.org/10.4314/ijbcs.v13i2.47

Le Bellec, F., Scorbiac, M., & Sauzier, J. (2017). Les pratiques phytosanitaires des producteurs de légumes de l'île Maurice: Impacts et perspectives de changement. *Cahiers Agricultures*, *26*, 55001. https://doi.org/10.1051/cagri/2017038

Lekei, E. E., Ngowi, A. V., & London, L. (2014). Farmers' knowledge, practices and injuries associated with pesticide exposure in rural farming villages in Tanzania. *BMC Public Health*, *14*, 1–13. https://doi.org/10.1186/1471-2458-14-389

López-dávila, E., Torres, L., Houbraken, M., & Laing, G. (2020). Knowledge and practical use of pesticides in Cuba Conocimiento y uso práctico de plaguicidas en Cuba. *Environmental Management and Sustainability*, *21*(1). https://doi.org/10.1186/s40550-018-0066-1

Lui, M. E., & Huang, G. (2013). Risk Preferences and Pesticide Use By Cotton Farmers in China E. *Journal of Development Economics*, *66*, 37–39.

MacFarlane, E., Chapman, A., Benke, G., Meaklim, J., Sim, M., & McNeil, J. (2008). Training and other predictors of personal protective equipment use in Australian grain farmers using pesticides. *Occupational and Environmental Medicine*, *65*(2), 141–146.

Mahob, R. J., Ndoumbe-Nkeng, M., Ten Hoopen, G. M., Dibog, L., Nyasse, S., Rutherford, M., Mbenoun, M., Babin, R., Amang A Mbang, J., Yede, Y., & Bilong Bilong, C. F. (2014). Pesticides use in cocoa sector in Cameroon:

Characterization of supply source, nature of actives ingredients, fashion and reasons for their utilization. *International Journal of Biological and Chemical Sciences*, *8*(5), 1976–1989. https://doi.org/10.4314/ijbcs.v8i5.3

Manfo, F. P. T., Mboe, S. A., Nantia, E. A., Ngoula, F., Telefo, P. B., Moundipa, P. F., & Cho-Ngwa, F. (2020). Evaluation of the Effects of Agro Pesticides Use on Liver and Kidney Function in Farmers from Buea, Cameroon. *Journal of Toxicology*. https://doi.org/10.1155/2020/2305764

Marete, G., Lalah, J., Mputhia, J., & Wekesa, V. (2021). Heliyon Pesticide usage practices as sources of occupational exposure and health impacts on horticultural farmers in Meru County , Kenya. *Heliyon*, *7*(January), e06118. https://doi.org/10.1016/j.heliyon.2021.e06118

Matthews, G., Wiles, T., & Baleguel, P. (2003). A survey of pesticide application in Cameroon. *Crop Protection*, *22*, 707–714. https://doi.org/10.1016/s0261-2194(03)00008-5

Mawusi, G., Kolani, I., & Devault, D. (2014). Use of chemical pesticides in vegetable production systems in West Africa and impacts on soil and water resources: The case of Togo. *44th Congress of the French Group of Pesticides*, 46–53.

Mengistie, B. T., Mol, A. P. J., & Oosterveer, P. (2017). Pesticide use practices among smallholder vegetable farmers in Ethiopian Central Rift Valley. *Environment, Development and Sustainability*, *19*, 301–324. https://doi.org/10.1007/s10668-015-9728-9

MINADER. (2016). Décision N°01326/16/D/MINADER/SG/DRCQ/SDRP/SRP portant interdiction de l'importation et de l'homologation des formulations de pesticide à base de métalaxyl au Cameroun. In *Ministère de l'Agriculture et du Développement Rural (MINADER)*.

MINADER. (2021). Liste Des Pesticides Homologues Au Cameroun Au 04 Mars 2021 Liste réservée au Grand Public. In *Commission Nationale d'Homologation des Pesticides à Usage Agricole; Ministère de l'Agriculture et du Développement Rural (MINADER)*.

Miyittah, K. M., Kwadzo, M., Gyamfua, A. P., & Dodor, D. E. (2020). Health risk factors associated with pesticide use by watermelon farmers in Central region, Ghana. *Environmental Systems Research*, *9*(10). https://doi.org/10.1186/s40068-020-00170-9

Mubushar, M., Aldosari, F. O., Baig, M. B., Alotaibi, B. M., & Khan, A. (2019). Saudi Journal of Biological Sciences Assessment of farmers on their knowledge regarding pesticide usage and biosafety. *Saudi Journal of Biological Sciences*, *26*(7), 1903–1910. https://doi.org/10.1016/j.sjbs.2019.03.001

Muliele, T. M., Manzenza, C. M., Ekuke, L. W., Diaka, C. P., Dieudonné, M., Kapalay, O. M., & Mundele, A. N. (2017). *Utilisation et gestion des pesticides en cultures maraîchères: Cas de la zone de Nkolo dans la province du Kongo Central , République démocratique du Congo*. 11954–11972.

Mustapha, A. J., Awadh, D. G., Albaho, M. S., Devi, V. Y., & Thomas, B. M. (2017). Pesticide knowledge and safety practices among farm workers in Kuwait: Results of a survey. *International Journal of Environmental Research and Public Health*, *14*, 340. https://doi.org/10.3390/ijerph14040340

Ndayambaje, B., Amuguni, H., Coffin-Schmitt, J., Sibo, N., Ntawubizi, M., & VanWormer, E. (2019). Pesticide Application Practices and Knowledge among Small-Scale Local Rice Growers and Communities in Rwanda: A Cross-Sectional Study. *Int. J. Environ. Res. Public Health*, *16*, 4770. https://doi.org/doi:10.3390/ijerph16234770

Ngameni, T. N., Kenko, N., & Djomo, E. N. (2017). Évaluation des facteurs de risques environnementaux liés à la mauvaise utilisation des pesticides par les maraîchers au Cameroun: Le cas de Balessing à l'Ouest Cameroun. *Afrique SCIENCE*, *13*(1), 91–100.

Nguemo, C. C., Tita, M., & Abdel-Wahhab, A. M. (2019). Preliminary screening of pesticides used by farmers in North West Cameroon. *International Journal of Halal Research*, *1*(1), 48–55. https://doi.org/10.18517/ijhr.1.1.48-55.2019

Nie, Z., Heerink, N., Tu, Q., & Jin, S. (2018). Does certified food production reduce agro chemical use in China? *China Agricultural Economic Review*, *10*(3), 386–405. https://doi.org/10.1108/CAER-11-2016-0190

Oesterlund, A. H., Thomsen, J. F., Sekimpi, D. K., Maziina, J., Racheal, A., & Jørs, E. (2014). Pesticide knowledge, practice and attitude and how it affects the health of small-scale farmers in Uganda: A cross-sectional study. *African Health Sciences*, *14*(2), 420–433.

Okolle, N. J., Afari-Sefa, V., Bidogeza, J. C., Tata, P. I., & Ngome, F. A. (2016). An evaluation of smallholder farmers' knowledge, perceptions, choices and gender perspectives in vegetable pests and diseases control practices in the humid tropics of Cameroon. *International Journal of Pest Management*, *62*(3), 165–174. https://doi.org/10.1080/09670874.2016.1184772

Onguene, D., Nguefack, J., Dongmo L, B. J., Daboy, C. D., Azah, R. U., & Ndonkeu, M. G. (2021). *The Cultivation of Sweet Pepper ( Capsicum Annuum ) in Foumbot Agricultural Area , West Region , Cameroon*. *8*(1), 54–66. https://doi.org/10.21467/ajss.8.1.54-66 SURVEY

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ, 372, n71.

Pan, Y., Ren, Y., & Luning, P. A. (2020). Factors influencing Chinese farmers' proper pesticide application in agricultural products – a review. *Food Control*, *122*(Novembre 2020), 107788. https://doi.org/10.1016/j.foodcont.2020.107788

Pouokam, G. B., Album, W. L., Ndikontar, A. S., & Sidatt, M. E. H. (2017). A pilot study in cameroon to understand safe uses of pesticides in agriculture, risk factors for farmers' exposure and management of accidental cases. *Toxics*, *5*(30), 1–15. https://doi.org/10.3390/toxics5040030

Shah, B., & Devkota, B. (2009). Obsolete pesticides: Their environmental and human health hazards. *J. Agric. Environ.*, *10*, 51–56.

Sharma, R., Peshin, R., Shankar, U., Kaul, V., & Sharma, S. (2015). Impact evaluation indicators of an Integrated Pest Management program in vegetable crops in the subtropical region of Jammu and Kashmir, India. *Crop Protection*, *67*, 191–199. https://doi.org/10.1016/j.cropro.2014.10.014

Skevas, T., Stefanou, S. E., & Lansink, A. O. (2012). Do Farmers internalise environmental spillovers of pesticides in Production? *J. Agric. Econ.*

Son, D., Somda, I., Legreve, A., & Schiffers, B. (2017). Pratiques phytosanitaires des producteurs de tomates du Burkina Faso et risques pour la santé et l'environnement. *Cahiers Agricultures*, *26*, 25005. https://doi.org/10.1051/cagri/2017010

Sonchieu, J., Fointama, E., Akono, N., & Serri, B. (2019). Farmers' Knowledge, Attitude and Practices on Pesticide Safety: A Case Study of Vegetable Farmers in Mount-Bamboutos Agricultural Area, Cameroon. *Agricultural Sciences*, *10*, 1039–1055. https://doi.org/10.4236/as.2019.108079

Sonchieu, J., Ngassoum, B. M., Akono, E. N., & Laxman, P. S. (2017). Pesticide Applications on Some Vegetables Cultivated and Health Implications in Santa, North West-Cameroon. *International Journal of Agriculture & Environmental Science*, *4*(2). https://doi.org/10.14445/23942568/ijaes-v4i2p108

Sonchieu, J., Ngassoum, M., Tchatchueng, J., Ashutosh, K., & Laxman, P. (2013). Contamination of cowpea and by-products by organophosphorous pesticide residues in Ngaoundere markets: Dietary risk estimation and degradation study. *African Journal of Food Science*, *7*(5), 92–102. https://doi.org/10.5897/ajfs2013.1013

Sopkoutie, N. G. K., Abdulai, A. N., Tarla, D. N., Djeugap, F., Galani, Y. J. H., Ekengoue, C., Tabang, W., Nya, E., & Payne, V. (2021). Phytosanitary Practices And Evaluation Of 17 Pesticides Residues In Tomatoes Fruits Produced In Foumbot District Western Highland-Cameroon. *European Scientific Journal ESJ*, *17*(3), 30–50. https://doi.org/10.19044/esj.2021.v17n3p30

Soro, G., Amao, W. S., Adjiri, A. O., & Soro, N. (2019). Risques sanitaires et environnementaux liés à l'usage des produits phytosanitaires dans l'horticulture à Azaguié (Sud Côte d'Ivoire). *Journal of Applied Biosciences*, *138*, 14072–14081. https://doi.org/10.4314/jab.v138i1.7

Swagata, S. (2021). *The use of pesticides in developing countries and their impact on health and the right to food* (Issue January). poldep-expo@europarl.europa.eu

Tambe, A. B., Mbanga, B. M. R., Nzefa, D. L., & Nama, M. G. (2019). Pesticide usage and occupational hazards among farmers working in small-scale tomato farms in Cameroon. *Journal of the Egyptian Public Health Association*, *94*. https://doi.org/10.1186/s42506-019-0021-x

Tandi, T. E., Wook, C. J., Shendeh, T. T., Eko, E. A., & Afoh, C. O. (2014). Small-Scale Tomato Cultivators' Perception on Pesticides Usage and Practices in Buea Cameroon. *Health*, *06*, 2945–2958. https://doi.org/10.4236/health.2014.621333

Tarla, D. N., Manu, I. N., Tamedjouong, Z. T., Kamga, A., & Fontem, D. A. (2015). Plight of Pesticide Applicators in Cameroon: Case of Tomato ( Lycopersiconesculentum Mill .) Farmers in Foumbot Plight of Pesticide Applicators in Cameroon: Case of Tomato ( Lycopersiconesculentum Mill .) Farmers in Foumbot. *Journal of Agriculture and Environmental Sciences*, *4*(2), 87–98. https://doi.org/10.15640/jaes.v4n2a10

Tarla, D. N., Meutchieye, F., Assako, V. A., Fontem, D. A., & Kome, J. J. A. (2013). Exposure of market gardeners during pesticide application in the western highlands of Cameroon. *Scholarly Journal of Agricultural Science*, *3*(5), 172–177.

Tarla, D. N., Tchamba, N. M., Baleguel, N. P., Fontem, D. A., Baleguel, P. D., & Hans, D. (2014). Inventory of obsolete pesticide stockpiles in Cameroon. *Scholarly Journal of Agricultural Science*, *4*(1), 43–50.

Tayoh, L. N., Kiyo, M. L. I., & Nkemnyi, M. F. (2016). Chemical fertilizer application and farmers perception on food safety in Buea, Cameroon. *Agricultural Science Research Journal*, *6*(12), 287–295.

Tetang, T. J., & Foka, G. (2008). Utilisation des pesticides dans la zone agricole du MOUNGO - évaluation de l'impact sur l'environnement, la santé des populations, et solutions envisageables: Cas de la localité de NJOMBE dans l'arrondissement de NJOMBE-PENJA TETANG. *Pesticide Bull*, *2*, 12–16.

Tolera, S. (2020). Systematic Review on Adverse Effect of Pesticide on Top Ten Importers of African Countries. *J. Appl. Sci. Environ*, *24*(9), 1607–1616.

Ugboka, U. G., Ihedioha, J. N., Ekere, N. R., & Okechukwu, F. O. (2020). Human health risk assessment of bisphenol A released from polycarbonate drinking water bottles and carbonated drinks exposed to sunlight in Nigeria. *International Journal of Environmental Analytical Chemistry*. https://doi.org/10.1080/03067319.2020.1759572

Wang, J., Chu, M., Yuan, Deng. Y., Lam, H., & Tang, J. (2018). Determinants of pesticide application: An empirical analysis with theory of planned behaviour. *China Agricultural Economic Review*, *10*(4), 608–625.

Wang, J., Tao, J., Yang, C., Chu, M., & Lam, H. (2017). A general framework incorporating knowledge, risk perception and practices to eliminate pesticide residues in food: A Structural Equation Modelling analysis based on survey data of 986 Chinese farmers. *Food Control*, *80*, 143–150. https://doi.org/10.1016/j.foodcont.2017.05.003

Wognin, A., Ouffoue, S., Assemand, E., Tano, K., & Koffi-Nevry, R. (2013). Perception des risques sanitaires dans le maraîchage à Abidjan, Côte d'Ivoire. *International Journal of Biological and Chemical Sciences*, *7*(5), 1829. https://doi.org/10.4314/ijbcs.v7i5.4

World Bank Group. (2024). *Economic Barometer. CEMAC Update: Recent Economic Development, Outlook and Key Development Challenges in the Region* (Vol. 6). May 2024.

Wumbei, A., Houbraken, M., & Spanoghe, P. (2019). Pesticides use and exposure among yam farmers in the Nanumba traditional area of Ghana. *Environmental Monitoring and Assessment*, *191*(5). https://doi.org/10.1007/s10661-019-7449-5

Zhang, C., Hu, R., Shi, G., Jin, Y., Robson, M. G., & Huang, X. (2015). Overuse or underuse? An observation of pesticide use in China. *The Science of the Total Environment*, *538*, 1–6.