Journal of Applied Biosciences 202: 21493 – 21513
ISSN 1997-5902

Farmer's perception of pesticide use in the lower Bia basin (South-east of Côte d'Ivoire)

Amadou ASSOUMAN[1, 3*], Gibrilla ABASS[2], Charles GYAMFI[1], Yéi Marie Solange OGA[3], Geophrey ANORNU[1]
[1]Department of Civil Engineering, Kwame Nkrumah University of Science and Technology, Ghana
[2]Nuclear Chemistry and Environmental Research Centre, National Nuclear Research Institute, Legon, Ghana
[3]Laboratory of water, Soil and Geomaterials science, Training and Research Unit on Earth Science and Mineral Resources, Félix Houphouët-Boigny University, Côte d'Ivoire
***Corresponding author**: amadouassouman89@yahoo.fr , +2250757268661/+233 549995341

Submission 30th September 2024. Published online at https://www.m.elewa.org/Journals/ on 30th November 2024. https://doi.org/10.35759/JABs.202.8

ABSTRACT

Background: The heavy rainfall across south-east Côte d'Ivoire favours crop growth but also contributes to pest invasion. In order to improve harvest, pesticides are excessively used raising environmental concerns. This study identified the various pesticides applied on both cash and vegetable crops grown in the Bia basin and assessed the farmer's perception of the cultural practices involving the use of these chemicals.

Methodology and Results: Using a structured questionnaire, 96 farmers randomly selected from 7 localities of the study area were interviewed. Most of the farmers were male and young and all use pesticides. Overall, 67 formulations containing 33 active ingredients, mainly insecticides mostly applied on cocoa and vegetable farms were recorded. Of these formulations, 16.42% are unregistered in Côte d'Ivoire. The most active ingredients applied are lambda-cyhalothrin (35.4%) and Cypermethrin (31.3%) insecticides. 30.01% and 27.97% of farmers obtain their supplies from unauthorised channels such as the local market and travelling sellers respectively. Many farmers (58.3%) had no training on pesticide use including 67.9% of vegetable growers. Spraying is performed using motorised (32.3%) or manual (67.7%) knapsack sprayers, which sometimes leak. Assessment of PPE's use revealed that farmers do not completely wear them including those who have been trained. A cross-analysis shows that 71.4% of farmers wearing complete PPE did not experience any health complaints after application. The risk of intoxication is therefore reduced under normal conditions of utilisation. 67.1% of growers wash their equipment close to the river, which significantly contributes to the river pollution.

Conclusion and Application of results: This study highlighted concerns about pesticides potential negative effects on river Bia, on the fish and human health. Farmers' habits regarding the safe use and handling of pesticides need to be improved through education and training. There is also a need to sensitise them to the use of PPE when applying pesticides, to avoid direct intoxication.

Keywords: Pesticides, Active ingredients, environment pollution, Human health risk, Bia basin.

INTRODUCTION

Côte d'Ivoire's agricultural sector remains the main driver of the country's economic growth contributing to 22% of the Gross Domestic Product (GDP) and two-thirds of export products (Fleischer *et al.,* 1998). However, besides the challenges posed by non-mechanisation, small-scale farms also face crop diseases and pests' invasion similar to those encountered by industrial farms, leading to yield losses. Pest accounts for nearly 40% of the annual losses in global agriculture, representing over $220 billion for plant diseases and $70 billion for invasive insects (FAO, 2021). Therefore, over the last decades, most approaches to controlling these pests have been based on chemicals. However, the misuse of these products is becoming a growing concern, leading to environmental pollution and human intoxication (Zhang *et al.*, 2011). Although the United States Environmental Protection Agency (USEPA) and World Health Organisation (WHO) have established strict regulations on pesticide manufacturing and usage, farmers are often unaware of the recommended doses, timing and frequency of application, especially in developing countries. This not only contributes to the exposure of those farmers to direct intoxication but also the inefficiency of applications with less than 0.1% of the mixture reaching their target (Pimentel, 1995). As a result, nearly all the pesticides used are released into the environment polluting the soil, water and air. The agricultural context in the south-eastern Côte d'Ivoire is marked by the coexistence of staple crops and export crops. Although the region's climatic and ecological conditions are conducive to agricultural activities, they promote pests' proliferation, leading to excessive use of pesticides (ANO *et al.,* 2018; Irel *et al.,* 2020) which can raise numerous environmental concerns including water pollution. To limit the impact of pesticides on the environment and human health, farmer's knowledge of their use needs to be assessed in order to correct bad practices. Many studies conducted in Côte d'Ivoire highlight farmers' perceptions of pesticide use (Akesse *et al.,* 2015; Goran *et al.,* 2019; Kwadjo & Doumbia, 2009; Mambe-Ani *et al.,* 2020; Ouali-N'goran *et al.,* 2014; Soro *et al.,* 2018). However, these studies focused more on vegetable production although the contribution of cash crops exploitation to pesticide pollution is even greater. Therefore, it is important to identify the various pesticides applied on both cash crops and vegetables grown in the Bia basin and assess the farmer's perception of the cultural practices involving the use of these chemicals.

MATERIAL AND METHODS

Survey area: The localities of the survey were selected by overlaying the information collected from the local agricultural agencies to the Bia watershed map. These include the localities of Aboisso, Ouéssébo, Allékro, Ayamé, Akréssi, Ebikro and Bianouan (Figure1).

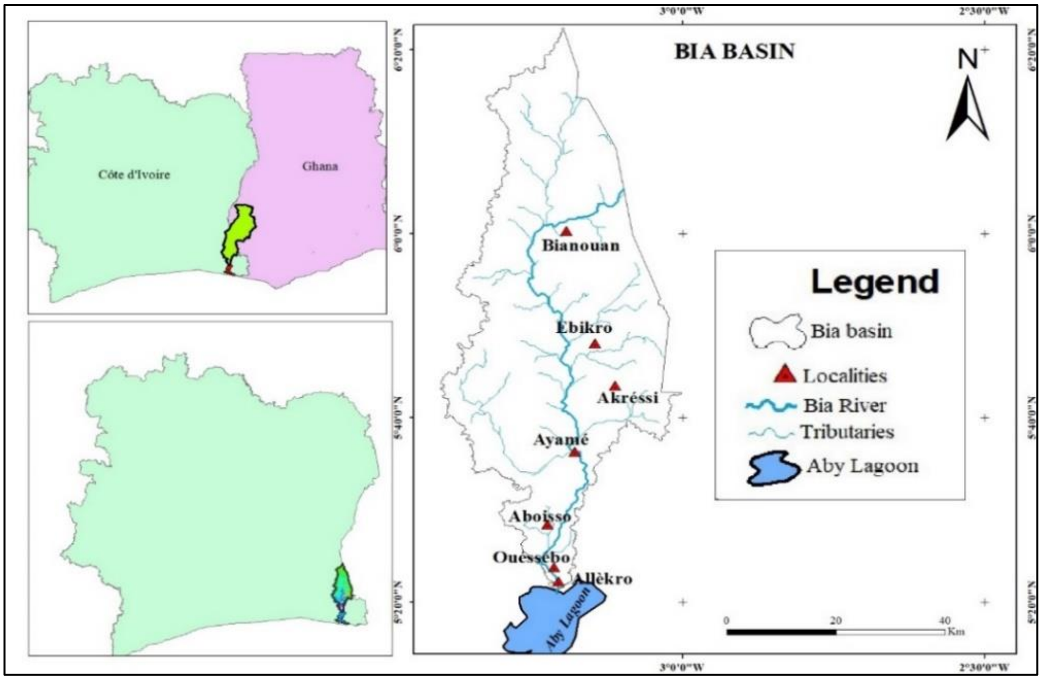

Figure 1: Location map

Sampling size: A total of ninety-six farmers (96) out of hundred randomly selected were interviewed. The other farmers (4) could not be interviewed due to the long distance involved and poor conditions of the roads leading to that area.

Questionnaire design: Three audiences which include the Agriculture Ministry, Aboisso agricultural department and agencies involved in this sector (National Rural Development Agency: ANADER, National Centre for Agriculture Research: CNRA), pesticide traders and farmers were identified to complete a survey. Although the main target was farmers, the first two audiences helped to guide the survey and select the interviewees. A specific questionnaire was designed respectively for each audience.

Questionnaire for agricultural agencies: This questionnaire was designed to gather data on the various crops grown in the study area, the pesticide applied and the training content provided to farmers. A list of agricultural cooperatives in the area was also made.

Questionnaire for pesticide sellers: Interviews with pesticide distributors were based on whether or not they had accreditation on the various pesticides, they sell. Guidance given to farmers by the sellers was also investigated to assess their knowledge of the chemicals they offer.

Questionnaire for the farmers: To investigate farmers' practices regarding their behaviour and knowledge in handling pesticides, this questionnaire covered the different crops grown and the size of the farms, the different types of pesticides used, the use of Personal Protective Equipment (PPE) or not, the storage of pesticides and the pre-harvest interval after their application. Data was also sought on the health condition of farmers during and after the application.

Questionnaire process: A pre-questionnaire form was submitted to the technicians from the different agricultural agencies in the study area. After revision and correction, the questionnaire was pre-tested on a small sample of respondents in Aboisso to verify the validity of its content. Individual interviews followed by group discussions were used to obtain the information sought from the farmers. Based on the information collected from the agricultural agencies on the different farms in the Bia basin, seven communities were selected for the survey including Aboisso (12 farmers), Akréssi (13 farmers), Allékro (10 farmers), Ayamé (12 farmers), Bianouan (16 farmers), Ebikro (21 farmers), Ouéssébo (12 farmers).

Data analysis for the survey: The gathered survey data were analysed with the Statistical Package for Social Scientists (SPSS) version 19 software. The results from descriptive analysis were presented in tables and graphs (pie and bar charts). A cross-tabulation analysis was performed on the individual questions asked to assess whether there were differences in the answers given.

RESULTS

Profile of farmers: Among the farmers interviewed, female gender represented 28.1%. The farmers produce only cash crops (41.7%), vegetables (51%) or both crops (7.3%).

Table 1: Characteristics of farmers in the study area

Variable	Number	Percentage (%)
Sex		
Male	69	71.9
Female	27	28.1
Age		
< 20	3	3.1
]20;35]	39	40.6
]35;50]	43	44.8
>50	11	11.5
Education level		
None	61	63.5
Primary	29	30.2
Middle/JSH	5	5.2
Secondary/SHS	1	1.1
Years of experience		
< 5	11	11.5
]5;10]	23	24.0
]10;20]	37	38.5
]20;30]	25	26.0
Cash crops growers	**40**	**41.7**
Cocoa	42*	43.8**
Coffee	11*	11.5**
Palm tree	14*	14.7**
Rubber tree	17*	17.7**
Vegetable growers	**49**	**51**
Garden eggs	31*	32.3**
Pepper	20*	20.8**
Okra	23*	24**
Cucumber	6*	6.3**
Cash crops and vegetable growers	**7**	**7.3**

Vegetable farms irrigated	11	22.44
Bia river and tributaries as water source	89	92.7**
Hand dug well as a water source	5	5.2**
* **Farmers grow more than one crops of the same type** ** **Percentage within the total number of farmers**		

According to Table 1, cash crops consist of cocoa grown by 43.8% of the farmers, coffee grown by 11.5%, rubber trees grown by 17.7% and palm trees grown by 14.7%. The most vegetables grown in the area and covered by this study consist of garden eggs grown by 32.3% of the respondents, pepper grown by 20.8%, okra grown by 24% and cucumber grown by 6.3% of the farmers. With an average age of 37.27 the farmers are young and almost all of them are between] 20; 35] and] 35; 50]. The high number of illiterates among farmers has been recorded representing 63.54% of the farmers. Only 1.04% of the respondents have reached senior high school. The total number of working years is subdivided into 4 classes with the highest group belonging to [10; 20[representing 38.5%.

Use of pesticides and agricultural practice: The present study shows that all the farmers interviewed use chemicals to deal with pests that attack their crops. As indicated in Table 2, a total of 67 different formulations containing 33 active ingredients were recorded including insecticides (36), herbicides (15), fungicides (12) and boosters (4). Nine (9) formulations were unregistered in Côte d'Ivoire including 2 fungicides, 2 herbicides and 5 insecticides. Figure 2 illustrates the use rate of the different pesticides by type of crop grown. Applied by 94.8% of farmers, insecticide is the most used among the pesticides recorded. According to Figure 3, herbicides, insecticides, fungicides and boosters are respectively most used at Ebikro and Bianouan (22.6%), Ebikro (22%), Ayamé (24.2%) and Ebikro (50%).

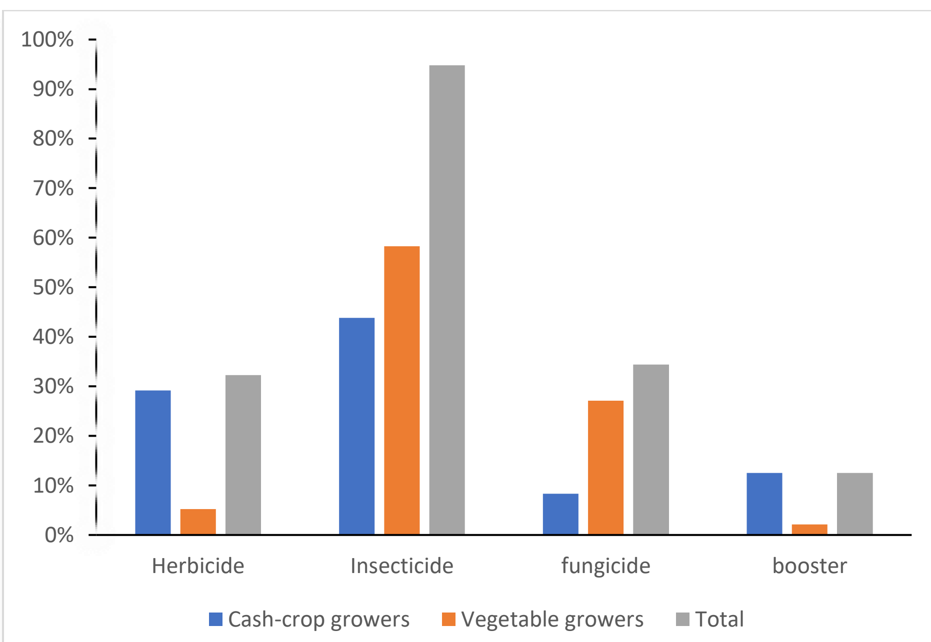

Figure 2: Pesticides types used by farmers

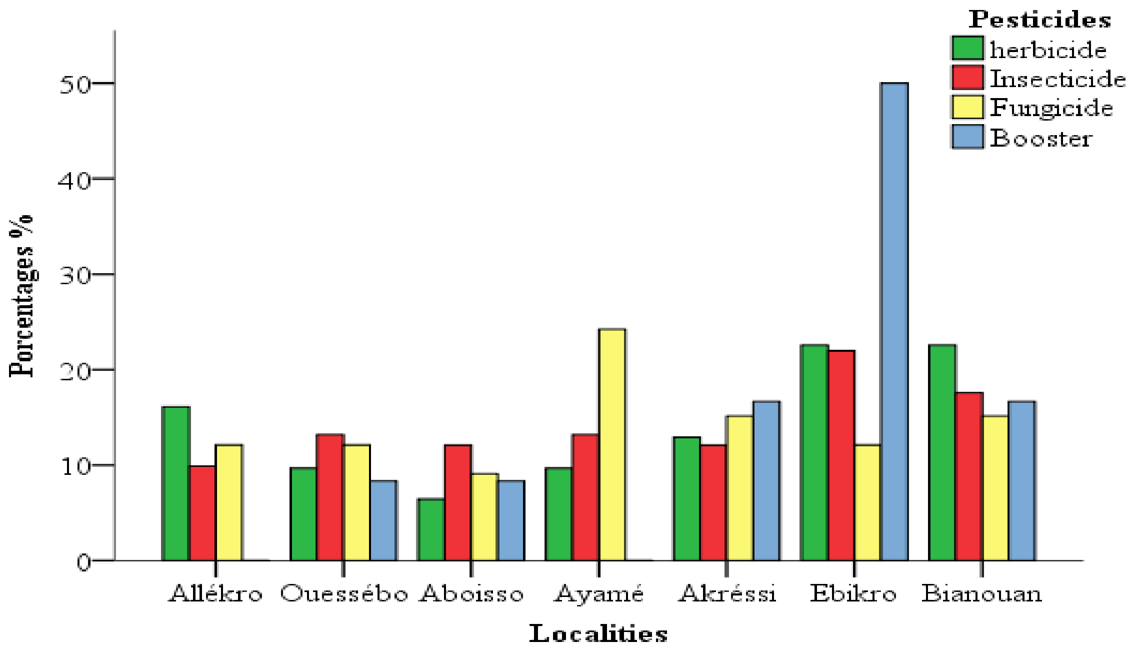

Figure 3: Pesticides used by localities

Table 2: Pesticides used in Bia basin

Type	Trade name	Active Ingredient	Chemical Group	Crops	WHO Class	Registration
B	BOOSTER 5 %	Ethephon	Phosphonic acid	Rubber tree	III	Yes
	Callel 5 % PA	Ethephon	Phosphonic acid	Rubber tree	III	Yes
	HEVEX 50 PA	Ethephon	Phosphonic acid	Rubber tree	III	Yes
	PLUTEX 50 PA	Ethephon	Phosphonic acid	Rubber tree	II	Yes
F	Banko plus	Chlorothalonil/Carbendazim	Organochlorine/Carbamate	Vegetable; palm tree	III	Yes
	CALTHIO C 50 WS	Thiram/Chlorpyrifos	Dithiocarbamate/Organophosphate	Cotton; Palm tree	II	No
	CHAMPION 800 WP	Mancozeb	Dithiocarbamate	Vegetable	III	Yes
	HEVEAFENDAIS 300 EC	TCMTB	Benzothiazole	Rubber tree	III	Yes
	HEVEAPANGA 1 GR	Triadimenol	Triazole	Rubber tree	III	Yes
	HEVIDAN 300 EC	TCMTB	Benzothiazole	Rubber tree	II	Yes
	Ivory 80 WP	Mancozeb	Dithiocarbamate	Vegetable	III	Yes
	K O FOMES 10 GR	Triadimenol	Triazole	Rubber tree	III	Yes
	LABILITE 70% WP	Maneb/Thiophanate	Dithiocarbamate/Carbamate	Vegetable	III	Yes
	PROCOT 40 WS	Carbendazim/Carbosulfan Metalaxyl-M	Carbamate/Bendamizole/ Phenylamide	Cotton	II	No
	Stop plus 690ml	Dimethomorph/Mancozeb	Morpholine/Dithiocarbamate	Cocoa	III	Yes
	TROPIC 66 WP	Metalaxyl-M /Cooper oxide	Phenylamide/Inorganic	Cocoa	III	Yes
H H	Abana	Glyphosate	Organophosphate	Total	III	No
	Atrazap 500	Atrazine	Triazine	Selective Control	III	No
	Atrazine 80 WP	Atrazine	Triazine	Selective Control	III	No
	CALLIFOR 858 WG	Glyphosate/Prometryn	Organophosphate/Triazine	Cotton	III	Yes
	COTOMAX EXTRA 412 EC	Metolachlor/Prometryn	Organochlorine/Triazine	Cotton	III	Yes
	DOUO 800 WP	Diuron	Substituted urea	Yam	III	Yes
	Focus ultra 100 EC	Cycloxydim	Cyclohexanedione	Pineapple; Cotton	III	Yes
	Glyphader super 35SC	Glyphosate	Organophosphate	Total	III	Yes

	Gramopat super	Paraquat	Bipyridinium	Total	II	No
	Herbastop 720 SL	2,4D-Amine	Phenoxy	Rice; Palm tree	III	Yes
	Herbextra 720SL	2,4D-Amine	Phenoxy	Rice; Palm tree	II	Yes
	Kalach 360 SL	Glyphosate	Organophosphate	Total	III	Yes
	La machette	Glyphosate	Organophosphate	Total	III	Yes
	Ladaba 75 SG	Glyphosate	Organophosphate	Total	III	Yes
	Rangro 480 SL	Glyphosate - Isopropyl amine-salt	Organophosphate	fallow land		Yes
I	Actara 240 SC	Thiamethoxam	Neonicotinoid	Cocoa; palm tree	III	Yes
	AKATE WURA 50SG	Bifenthrin	Pyrethroid	Cocoa	III	Yes
	BORADYNE SUPER 45 ZC	Thiamethoxam λ-cyhalothrin	Neonicotinoid/Pyrethroid	Cocoa	III	Yes
	BOREX 50 SC	Bifenthrin Imidacloprid	Pyrethroid/Neonicotinoid	Cocoa	III	Yes
	CACAO ALA DJE 50 EC	Imidacloprid/Bifenthrin	Neonicotinoid/Pyrethroid	Cocoa	III	Yes
	CACAO GOLD 45 EC	Acetamiprid/ Bifenthrin/ Imidacloprid	Neonicotinoid/Pyrethroid/ Neonicotinoid	Cocoa	III	Yes
	Cacao Lafi 20 EC	Acetamiprid/λ-cyhalothrin	Neonicotinoid/Pyrethroid	Cocoa	III	Yes
	Calfos-500 EC	Profenofos	Organophosphate	Cocoa	III	Yes
	Callifan super	Acetamiprid/Bifenthrin	Neonicotinoid/Pyrethroid	Cocoa	II	Yes
	Caofine super 50 EC	Imidacloprid/Bifenthrin	Neonicotinoid/Pyrethroid	Cocoa	III	Yes
	CAPORAL 500 EC	Profenofos	Organophosphate	Cotton	II	Yes
	Cothrine 50 EC	Cypermethrin	Pyrethroid	Vegetable	II	Yes
	Cypercal 250 EC	Cypermethrin Dimethoate	Pyrethroid/Organophosphate	Cotton	III	Yes
	Cypercot 186 EC	Profenofos Cypermethrin	Organophosphate/Pyrethroid	Cotton	III	Yes
	Decis FORTE 100 EC	Deltamethrin	Pyrethroid	Vegetable	II	Yes
	DUEL 186 EC	Cypermethrin Profenofos	Pyrethroid/Organophosphate	Cotton	II	Yes
	FARIMA SUPER 550 EC	Chlorpyriphos-ethyl/Cypermethrin	Organophosphate/Pyrethroid	Cocoa; vegetable	III	Yes
	FELITHRINE 50 EC	λ-cyhalothrin	Pyrethroid	Vegetable	II	Yes
	Gawa pro 80 SC	Bifenthrin/Imidacloprid	Pyrethroid/Neonicotinoid	Cocoa	III	Yes
	Grosudine Super 50	Imidacloprid/Bifenthrin	Neonicotinoid/Pyrethroid	Cocoa	III	Yes

	Karaté 5 EC	λ-cyhalothrin	Pyrethroid	Vegetable; palm tree	II	Yes
	King Lambda	λ-cyhalothrin	Pyrethroid	ND	ND	No
	Kombat	λ-cyhalothrin	Pyrethroid	ND	ND	No
	Lambda power	λ -cyhalothrin	Pyrethroid	ND	ND	No
	Lambda super	λ -cyhalothrin	Pyrethroid	ND	ND	No
	LEGUMAX SUPER 25 EC	Deltamethrin	Pyrethroid	Vegetable	II	Yes
	MESSI 45 SC	λ - cyhalothrin/Thiamethoxam	Pyrethroid/Neonicotinoid	Cocoa	III	Yes
	Onexsuper 40EC	Acetamiprid/Cypermethrin	Neonicotinoid/Pyrethroid	Cocoa	II	Yes
	Onexunik 45EC	Acetamiprid/Imidacloprid/ Bifenthrin	Neonicotinoid/Pyrethroid/ Pyrethroid	Cocoa	III	Yes
	Polytrin C330 EC	Profenofos	Organophosphate	Cotton	II	Yes
	Profex Super	Profenofos/Cypermethrin	Organophosphate/Pyrethroid	Cotton	II	No
	REZO 50 EC	Cypermethrin	Pyrethroid	Vegetable	II	Yes
	Stop 25 EC	Acetamiprid/λ-cyhalothrin	Neonicotinoid/Pyrethroid	Cocoa	II	Yes
	Thiosulfan 60EC	Imidacloprid	Pyrethroid	Cocoa	III	Yes
	TOUMOU FLA 88 EC	Cypermethrin Acetamiprid	Pyrethroid/Neonicotinoid	Cotton; Palm tree	III	Yes
	Toumoux 25 SC	Acetamiprid/λ-cyhalothrin	Neonicotinoid/Pyrethroid	Cocoa	III	Yes
B: Booster; F: Fungicide; H: Herbicide; I: Insecticide						

Active ingredient used on Bia basin: Figure 4 shows that the 33 active ingredients recorded in this study belong to 16 different families of which the most represented are pyrethroid (18.2%). According to the graph displayed in Figure 5, the most active ingredients used by the farmers interviewed are lambda-cyhalothrin and cypermethrin, which are respectively used by 35.4% and 31.3% of the farmers.

Farmer's knowledge of pesticide usage: As far as the training of farmers is concerned, the majority lean towards those who have not received any training (58.3% of the farmers). The untrained farmers are more represented among vegetable growers (67.9%) (Table 4). Farmers are supplied from different sources (Figure 6) with the highest numbers (22.4%) who are supplied by different cooperatives. Only 19.6% of the interviewees get their chemicals from pesticide retailers' accredited stores.

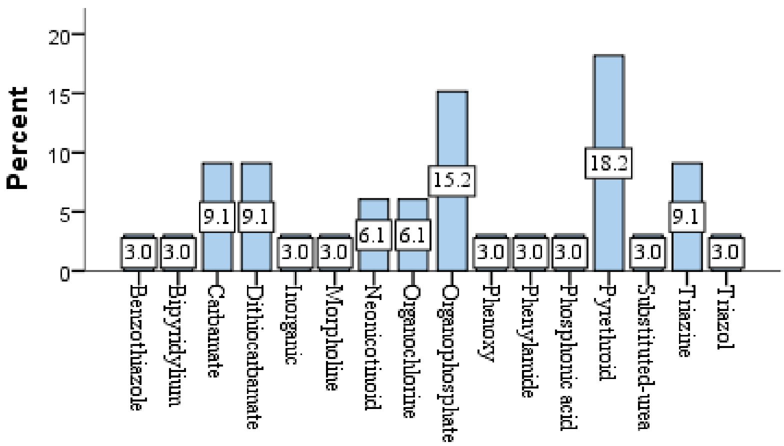

Figure 4: Distribution of different chemical groups of pesticides used in the Bia basin

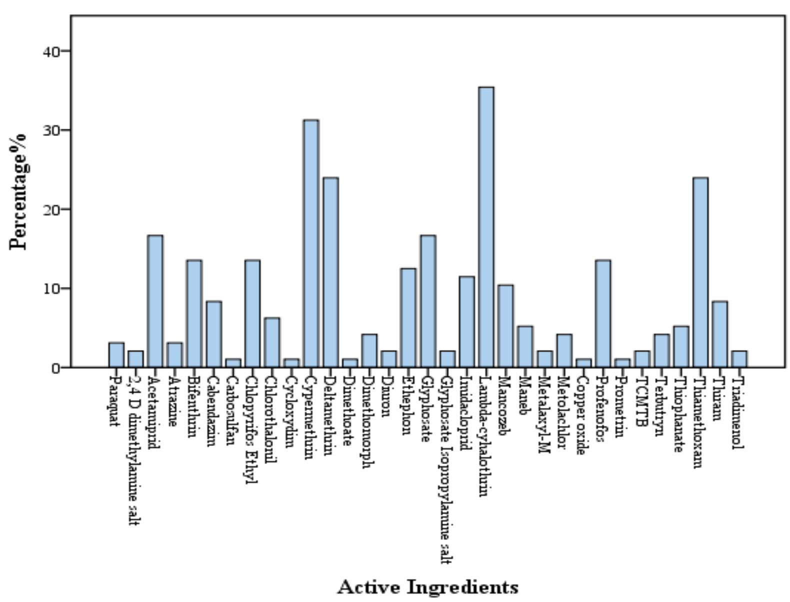

Figure 5: Distribution of active ingredient used in Bia basin

Table 4: Training status of farmers

	Type of crops		
	Cash crops	**Vegetable**	**Total**
Farmers trained	24 (51.1%)	18 (32.1%)	40 (41.7%)
Farmers untrained	23 (48.9%)	38 (67.9%)	56 (58.3%)

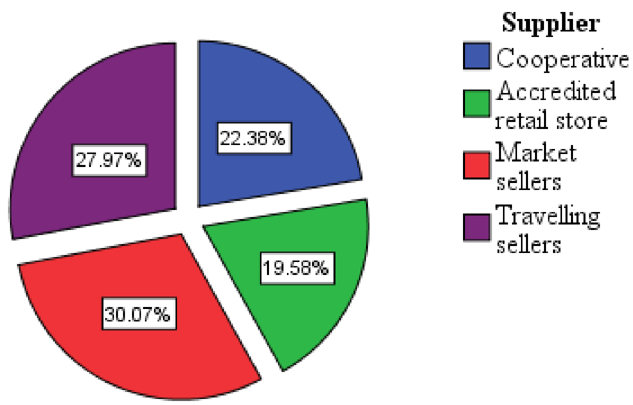

Figure 6: Percentage of farmers by source of pesticide supply

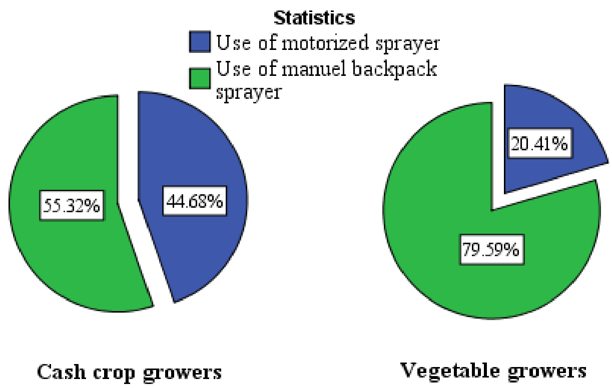

Figure 7: Type of sprayers used by farmers

Table 2: Use of PPE by the farmers

PPE	**Cash crops growers**	**Vegetable growers**	**Total**
Glove	15 (31.9%)	9 (16.1%)	22 (22.9%)
Boot	43 (91.5%)	37 (66.1%)	73 (76%)
Goggle	4 (8.5%)	1 (1.8%)	4 (4.2%)
Overalls	7 (14.9%)	2 (3.6%)	8 (8.3%)
Nose mask	23 (48.9%)	26 (46.4%)	46 (47.9%)
No PPE	3 (6.4%)	15 (26.8%)	18 (15.8%)
Complete PPE	6 (12.8%)	2 (3.6%)	7 (7.3%)
Total	**47 (49%)**	**56 (58.3%)**	**96 (100%)**

Motorized (32.3%) and manual (67.7%) backpack sprayers are used for pesticide application. The motorized sprayer is more used among cash-crop growers (44.7%) than vegetable growers (23.2%) (Figure 7). The use of personal protection equipment (PPE) has also been assessed (Table 5). Five different equipment which consist of goggles, nose masks, overalls, gloves and boots were used by the growers. It has been considered in this survey that a set of PPE which consists of a nose mask, combination, gloves and boots is a complete PPE. Table 5 shows that only 7.3% of the farmers are correctly protected when they spray pesticides. These farmers are more represented among cash crop growers (12.8%) than vegetable growers (3.6%). After the application of the chemicals, the empty containers are managed in different ways by the farmers (Table 6). Many farmers (47.9%) throw away the empty containers of pesticides. Among this group, 84.8% have not received training. Some farmers that reuse empty containers (4.2%) have been recorded in this survey. All of these particular farmers have not received training on pesticide handling. Concerning the storage of pesticides (Table 7), three different habits have been recorded among the farmers. Most of the farmers keep their chemicals on the site (51% in the bush and 18.8% in a Phyto-room design for this purpose). However, the rest of the interviewees who keep it at home are still important (30.2%).

Table 3: Pesticide empty containers disposal by farmers

	Trained on pesticide use		**Total**
Disposal practice	Yes	No	
Burying	23 (79.3%)	6 (20.7%)	29
Burning	10 (58.8%)	7 (41.2%)	17
Throw	7 (15.2%)	39 (84.8%)	46
Reuse	0 (0%)	4 (100%)	4
Total	40 (41.7%)	56 (58.3%)	96

Table 4: Storage of pesticides by farmers

	Farmers trained		**Total**
Storage place	Yes	No	
Phyto-Room	15 (83.3%)	3 (16.7%)	18 (100%)
Bush	21 (42.9%)	28 (57.1%)	49 (100%)
Home	4 (13.8%)	25 (86.20%)	29 (100%)
Total	40 (41.7%)	56 (58.3%)	96 (100%)

Table 5: Health status of farmers during the application

Health status during the application	**Frequency**	**%**
Fine	23	24.0
Nausea	32	33.3
Eye Irritation	19	19.8
Dizziness	22	22.9
Health status after application		
Fine	42	43.8
Coughing	21	21.9
Itching	10	10.4
Stomach ache	13	13.5
Cold	10	10.4

The health status of the farmers during and after the spraying of pesticides has been also assessed. According to Table 8, only 24% of the farmers are fine during the application. few days after pesticide application, 56.2% have some discomfort. These can be coughing (21.9%), Itching (10.4%), stomach ache (13.5%) or cold (10.4%). As shown in Figure 8, a higher proportion of farmers using complete PPE reported feeling well during application (71.43%) opposite to those who don't wear complete PPE (21.35%). Table 9, shows that 55.5% of the farmers clean the sprayer on the banks of the river Bia. Cleaning was done either with soap (24%) or only with water (58.3%).

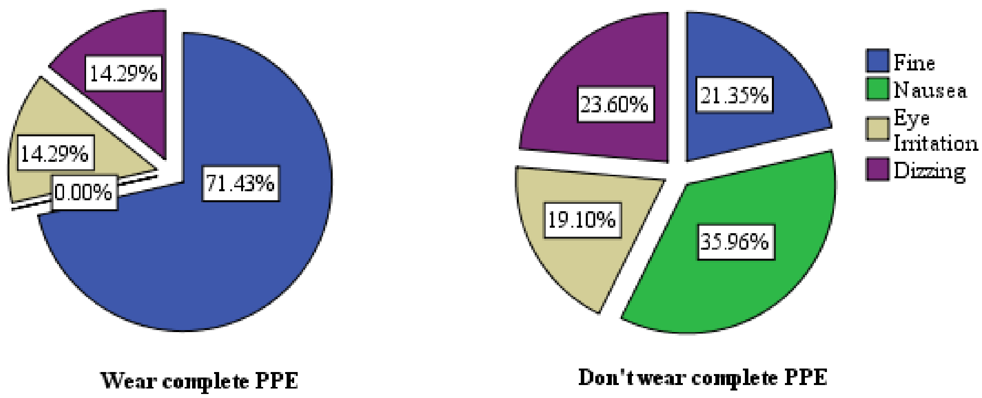

Figure 8: Relationship between the health status of farmers and their level of protection during the application of pesticide

Table 6: Cleaning method of sprayer

	Cleaning method			Total
Cleaning point	Water + Soap	Only water	Unclean	
River Bia	9	44	0	53 (55.2%)
Water point	3	10	0	13 (13.5%)
Home	11	2	0	13 (13.5%
Unclean	0	0	17	17 (17.70%)
Total	23 (24%)	56 (58.3%)	17 (17.7%)	96

DISCUSSION

Profile of farmers: This study shows that the male gender (71.9%) was more represented among cash crops and vegetable farmers. The fewer female gender among farmers interviewed can be explained by the fact that the females have a limited access to arable land. Four different age groups were identified with only 11.5% of the farmers being over 50 years old (Table 1). This work confirms studies by Gokou *et al.*,(2021) Among farmers in Guesabo (Central west of Côte d'Ivoire) which found that 73.64% of these farmers were under 50 years old. Among cash crops identified in the study area, cocoa is the most cultivated (43.8%), which is in line with the country's agricultural status as the world's leading producer with over 40% of the world's cocoa production. Referring to vegetable production, it is done at a large scale with sizes that can reach 3 acres, usually owned by the same farmer. To meet the continuous need of the market for vegetables, some of the interviewees (11.5%) practice manual irrigation especially in the dry season. As a result, the majority (92.7%), especially the vegetable farms are close to the Bia river and its tributaries. In the central west of Côte d'Ivoire, the use of the Sassandra riverbed during the dry season for vegetable growing has been reported by Gokou *et al.,* (2021). This promotes chemical contamination of the river and the aquatic organisms. The high number of illiterate farmers (63.54%) recorded in the study area reflects the reality of farmers' education level in rural areas of sub-Saharan Africa. Indeed, most of them have poor reading skills because they could not read questions on the survey forms correctly. This result is very disappointing in line with Okoffo *et al.*, (2016) study among cocoa farmers in Ghana because it shows that only a few farmers are able to read the label on different packages of the pesticide they apply. According to Mekonnen & Agonafir, (2002) studies in Ethiopia, no matter their reading skill level, farmers don't read the label on the pesticide packaging. This is alarming because it leads to misuse of pesticides which can cause intoxication and environmental pollution.

Pesticide use: More than 74% of the farmers interviewed have been working in the agricultural sector which involved the use of pesticides for more than ten years. Unfortunately, 58.3% reported that they had never received training on pesticide use, especially among vegetable growers (67.9%). This low rate of trained farmers could be explained by a lack of interest in the training, especially among illiterate farmers. Indeed, the National Agency for Rural Development (ANADER) staff that are in charge of supervising farmers in the rural communities mostly do not speak the local languages of the study area, and, given the poor educational level of the farmers, some of them reported during group discussions that they do not clearly understand the processes mentioned in the few training sessions they have received. To solve this problem, the agency trained agricultural extensionists in each locality who can properly apply the mixture. Unfortunately, few of the farmers used the services of the latter, due to their cost (2,000 FCFA i.e. 3.3 USD per hectare treated) which they consider high. The same observation was made in Nigeria, where only a few vegetable growers from Oyo state reported having hired experts to apply pesticides (Ugwu *et al.*, 2015). Whether they use applicator services or not, farmers are exposed to pesticide contamination when they don't use PPE during the spreading.

Use of Equipment*:* Exposure to pesticides occurs mainly during two handling stages: the mixing and application phase. It is therefore not only important that farmers are well protected during these two stages but also that they use adequate spraying equipment. In this study, PPE that consists of Boots, nose masks, gloves, overalls and goggles are not completely worn by the farmers. Boots are the most used among PPE because farmers declared that it mostly protects them against bites from some venomous reptiles. Only a few farmers (7.3%) wear a complete set of PPEs (a combination of a nose mask, overalls, gloves and boots). Despite the fact that 90% of farmer's exposure to pesticides is due to handling without body protection (Tudi *et al.*, 2022), this study revealed that 91.2% of farmers do not wear overalls. In fact, farmers reported feeling discomfort with these PPEs, especially in hot and humid climates (Adjrah *et al.*, 2013). Sprayers which can be either manual or motorised (Agricultural atomizer used by 32.3% of farmers) are used by farmers to apply the mixture. The motorised sprayer is mostly used by cash crop growers due to the extended size of their farms. This equipment which is more secure in terms of leakage is unfortunately less used because even though it makes application easier, it requires additional cost for the fuel. A similar observation has been reported by ANO *et al.*, (2018) who support that manual sprayers are not appropriate for pesticide application on certain crops such as cocoa. This can obviously result in poor dosing and distribution of the mixture. Unlike the latter, most of the manual knapsack users have complained about leakage during operation. According to Matthews *et al.,* (2003), these leakages could be associated with defects in the hose and its connection to the pump mechanism and in the activation valve to which unprotected hands could be directly exposed. Besides spilling the mixture on the operator's body, the defective knapsacks also cause a significant spill on the ground which can lead to surface and groundwater pollution.

Pesticides supply channels: Most of the farmers get their products from informal supply channels which can provide fraudulent and fake products. This is in line with a study by Kanda *et al.,* (2009) in Togo which found that small travelling redistributors are very common in the pesticide supply channel. In this study, almost all the farmers who rely on the normal distribution channel (Cooperative and accredited stores) for pesticide supply are cocoa growers. This can be explained by the fact that the cocoa sector is the most well-structured in Côte d'Ivoire agricultural sectors. These channels usually provide the chemicals imposed by the Coffee and Cocoa Council (CCC). Almost all the accredited stores are located in the main cities (Aboisso) and big communities (Bianouan and Ayamé). It is clear that most of the farmers from the other communities don't have easy access to them. Therefore, they rely on illegal sources of supply for their pesticide needs, increasing the risk of using fraudulent and banned products. Mengistie *et al.,* (2017) also revealed vegetable farmers from Ethiopian Central Rift Valley used fraudulent pesticides from neighbouring countries. All these, reflect difficulties faced by the implementation of legislation on agrochemicals in the country.

Different formulations and active ingredients used in the study area: The 67 different pesticide formulations recorded in this study include 16.42% of unregistered chemicals. The use of fraudulent pesticides is very common in Côte d'Ivoire (Doumbia & Kwadjo, 2009) and in other countries in Africa (Lekei *et al.,* 2014; William Joseph Ntow, 2008)**.** All the chemicals applied to cocoa are registered which is consistent with the findings of ANO *et al.,* (2018). According to these authors, this is because, since its creation in 2011, the CCC has been distributing annually some insecticides free of charge to the farmers. Also, all cocoa cooperatives in the study area that the Ministry of Agriculture accredits provide pesticides on loan to their subscribers and the amount due is deducted when the harvests are sold. In addition, although they are typically indicated for cotton and cocoa, some insecticides are applied on vegetables. These contraindicated products used in vegetable farming are generally supplied by travelling sellers who are widespread in the study area. In opposition to cocoa farming, the lack of control in this sector allows all sorts of practices to take place. This phenomenon is observed even in main cities like Abidjan where studies by Doumbia & Kwadjo, (2009) shows a misuse of cotton pesticides for vegetable spraying. All the formulations recorded in this study include a total of 33 active ingredients belonging to different families or chemical groups as presented in Table 3. The high number of insecticide formulations identified in this survey is because they are alternated each year with the introduction of new chemicals especially for cocoa farms under the control of the CCC, in order to prevent insects' resistance. In addition, in vegetable growing, insects constitute a greater threat to crops and herbicide application is often more complex carrying a greater risk of crop damage. Other studies also revealed that insecticides dominate chemical pest control in Central-West of Côte d'Ivoire (ANO *et al.,* 2018) and in Ghana (Afari-Sefa *et al.,* 2015). The active ingredients recorded in this study are usually found in combination with the different formulations reported. By taking fungicides and herbicides into account, 28 formulations of combined active ingredients representing 41.8% have been recorded (table 3). These enhance the number of active ingredients, which can be released into the different compartments of the environment especially in water bodies making difficult the monitoring of pesticides. Found in several pesticide formulations recorded in this study, λ-cyhalothrin and cypermethrin are the most used among all active ingredients identified (respectively applied by 35.4% and 31.3% of the farmers). These two insecticides are recommended for both vegetable and cash crop applications. Also, λ-cyhalothrin and cypermethrin are some of the most recent pyrethroid insecticides synthesised, providing immediate and persistent activity against a wide variety of arthropods that are harmful to plant, livestock and human health (Elhalwagy *et al.*, 2015; Yadav, 2018). Although most of the chemicals recorded in this study are moderately (19 belong to WHO class II) or slightly hazardous (43 belong to WHO class III), long-term exposure may result in chronic toxicity or adverse impacts on the environment. Initially considered as having a low risk to non-target species, new research by WHO concluded that glyphosate is probably carcinogenic to humans (Myers *et al.*, 2016). According to Houndji *et al.*, (2020) λ-cyhalothrin which is widely used in this study can easily get into the water bodies and then become highly toxic to African catfish.

Empty container disposal and storage of the chemicals: The storage of pesticides was also assessed in this study. For this variable, the best practice has been observed among some trained farmers who designed a particular place called a phyto-room in their farm for chemical storage. Study in Cameroon by Matthews *et al.*, (2003), has also highlighted this good agricultural practice implemented by some farmers in the Bia basin which should be promoted. However, some bad practices have been detected mostly among untrained farmers (83.3%), in terms of pesticide storage, which involves keeping the chemicals at home. In fact, for these farmers, it is the best way to secure the product against theft. Unfortunately, these practices can expose farmers and their family members especially children who can accidentally come in touch with the chemical. Burning empty containers seems to be the best way of managing them by the farmers in this survey. However, when it is done in open air, this practice can pollute the environment (air) and due to the high toxicity of smoke given off, the inhalation can be very harmful to people and animals in the area (Chen *et al.*, 2012). This method should not be used for pesticide empty container management according to Damalas *et al.*, (2008). The action of throwing the containers directly into the farms, which are mostly bordered by the main river of the basin, presents a serious risk of pollution not only for the soil but also for the water of the river. Indeed, given the fact that those containers are not rinsed beforehand, the pesticide residues inside can be washed into the main river by runoff during a rain event. This finding has been observed in Côte d'Ivoire (Kwadjo & Doumbia, 2009; Soro *et al.*, 2019), in Burkina Faso (Son *et al.*, 2017) and in Ghana (Okoffo *et al.*, 2016). According to Soro *et al.*, (2019), 82% of Azaguié (South of Côte d'Ivoire) farmers abandon these empty packaging which ends up in wetlands where they pollute the water and become not only harmful for fishes but also for the consumers. According to Ntow *et al.*, (2006), where farms are close to drinking water sources and streams, as in the case of many plantations in the study area, the disposal of leftover mixtures in sprayers and empty containers on the fields is a major source of pollution for those who drink from these water sources as well as for the aquatic ecosystems that are sources of livelihood for communities. Cases of fish contaminated by pesticides have been reported from the market in Côte d'Ivoire (Biego *et al.*, 2010) and from Lake Bosomtwi in Ghana

(Darko *et al.,* 2008). Contrary to the adoption of PPE, empty container management is very strongly influenced by the level of education and training on Good Agricultural Practice (GAP). Indeed, almost all the farmers that have bad practices in terms of empty container management (such as reuse of empty containers), have low education levels and did not attend any training section (table 6).

Health assessment: Health issues related to pesticides can be acute or chronic for farmers, people around the farms during the application and the consumers. In this study, only the acute toxicities have been highlighted. The discomforts reported by the farmers match obviously with the toxic and irritating nature of the pesticides but also with the unsafe practices of pesticide handling such as the poor use of PPE during the application of the mixture (Balasha *et al.*, 2023). Similar to this study, horticulturists in Azaguié (South of Côte d'Ivoire) have experienced the same health issues linked to pesticide application but with high cases of skin disorders like itching (Soro *et al.*, 2019). Even though some farmers consider them to be benign and not too severe, other health issues can also appear a few days following the application and may persist for some time. The high number of farmers affected by health issues even some days after pesticide handling clearly shows that they don't respect the safety measures relating to the use of these chemicals. As mentioned above, almost all the farmers use incorrectly or not a PPE during the application which reduce considerably their protection. Cases of health disorders have been observed in Abidjan and its suburbs affecting not only vegetable growers applying pesticides but also children found on the farms during the application (Kwadjo & Doumbia, 2009). Istriningsih *et al.*, (2022) have categorised health disorders related to pesticide exposure as: mild acute poisoning for dizziness, headache, skin irritation or itching, body aches, diarrhoea; severe acute poisoning for nausea, chills, stomach cramps, shortness of breath salivation, shrinking of pupils, and increased pulse and chronic poisoning for loss of consciousness, convulsions and death. In this study, only mild and severe acute poisoning have been reported. A cross-tabulation analysis between wearing a complete PPE or not and farmers' health status shows that among the farmers who wear a complete PPE, 71.4 % did not experience health disorders after the application of the mixture. This confirms the fact that pesticides present neither a health nor environmental hazard under normal conditions of use (Mambe-Ani *et al.*, 2020).

CONCLUSION AND APPLICATION OF RESULTS

Both women and men cash crop and vegetable growers from the Bia basin interviewed in this survey use pesticides intensively. Despite the young age of the majority, these farmers have been working for significant years in the agricultural sector. Their low education level, which leads to their demotivation for the training on the use of pesticides and to their inability to read the product label is the main factor of the misuse of the chemical on Bia basin. These would justify the use of unauthorised pesticides by many farmers and their application on crops for which they would not be recommended. The large number of pesticide formulations recorded in the study area, combined with their improper use, particularly for vegetable growing have been observed. In addition, frequent use of faulty spraying equipment, which can lead to significant spillage of the mixture, combined with poor container disposal, has been noted. All the above observations can lead to the accumulation of a chemical cocktail on the soil that can easily find its way into water bodies through run-off. Regarding the health of farmers, this study showed that it is strongly linked to the use of PPE or not, which is most often limited to a simple nose mask, goggles, gloves or a boot. This could be the main cause of the many health problems recorded during and after the application. This extensive survey of how farmers use pesticides provided a detailed view of their practices and attitudes. It is clear that pesticides play a crucial role in protecting crops and ensuring optimum yields. However, the study highlighted legitimate concerns about the potential negative effects on the environment and human health.

ACKNOWLEDGMENT

This study was supported by the Kumasi Regional Water and Sanitation Centre of the Kwame Nkrumah University of Science and Technology under the African Centre of Excellence project of the World Bank

REFERENCE

Adje, K., Djidji, A., Fondio, L., N'Zi, J., & Kouame, C. (2010). Efficacité des traitements phytosanitaires contre les ravageurs et maladies de quatre variétés de tomate au Centre de la Côte d'Ivoire. Agronomie Africaine, 21(2), 165–172. https://doi.org/10.4314/aga.v21i2.49806

Adjrah, Y., Dovlo, A., Karou, S. D., Eklu-Gadegbeku, K., Agbonon, A., de Souza, C., & Gbeassor, M. (2013). Survey of pesticide application on vegetables in the Littoral area of Togo. Annals of Agricultural and Environmental Medicine, 20(4), 715–720.

Afari-Sefa, V., Asare-Bediako, E., Kenyon, L., & Micah, A. J. (2015). Pesticide Use Practices and Perceptions of Vegetable Farmers in the Cocoa Belts of the Ashanti and Western Regions of Ghana. Advances in Crop Science and Technology, 03(03). https://doi.org/10.4172/2329-8863.1000174

Ajayi, O. C., & Akinnifesi, F. K. (2007). Farmers ' understanding of pesticide safety labels and field spraying practices : a case study of cotton farmers in northern Côte d ' Ivoire. Scientific Research and Essay, 2(June), 204–210.

Akesse, E., Ouali-N'Doran, S., & Tano, Y. (2015). Insectes ravageurs du piment Capsicum chinense Jacq. (Solanaceae) à Port-Bouët (Abidjan-Côte d'Ivoire) : Pratiques de lutte par les pesticides chimiques. Journal of Applied Biosciences, 93(1), 8667. https://doi.org/10.4314/jab.v93i1.1

ANO, E. J., TAHIRI, A., Diby, Y. K. S., & SIAPO, Y. M. (2018). Évaluation des pratiques phytosanitaires paysannes dans les cacaoyères : Cas du département d ' Abengourou (Est , Côte d ' Ivoire). Journal of Animal & Plant Sciences, 38(1), 6159–6174.

Balasha, A. M., Mulume, D. A., Mwisha, S. W., Nkulu, J., Fyama, M., & Kalumbu, T. (2023). Utilisation des pesticides en cultures maraîchères sur l' île d ' Idjwi à l ' est de la République démocratique du Congo : connaissances et pratiques des agriculteurs. Cahiers Agricultures.

Biego, Henry;, Yao, K., & Kouadio, L. (2010). Assessment of organochlorine pesticide residues in fish sold in Abidjan markets and fishing sites. African Journal of Food Agriculture Nutrition and Development (AJFAND), 10(3).

Biego, HM, Coulibaly, A., Koffi, M., Chatire, O., & Kouadio, L. (2009). Niveaux de résidus de pesticides organochlorés dans les produits du cacao en Côte d'Ivoire. International Journal of Biological and Chemical Sciences, 3(2), 297–303.

https://doi.org/10.4314/ijbcs.v3i2.44509

Chen, K., MacKie, J. C., Kennedy, E. M., & Dlugogorski, B. Z. (2012). Determination of toxic products released in combustion of pesticides. Progress in Energy and Combustion Science, 38(3), 400–418. https://doi.org/10.1016/j.pecs.2012.01.002

Damalas, C. A., & Koutroubas, S. D. (2016). Farmers' exposure to pesticides: Toxicity types and ways of prevention. Toxics, 4(1), 1–10. https://doi.org/10.3390/toxics4010001

Damalas, C. A., Telidis, G. K., & Thanos, S. D. (2008). Assessing farmers' practices on disposal of pesticide waste after use. Science of the Total Environment, 390(2–3), 341–345. https://doi.org/10.1016/j.scitotenv.2007.10.028

Darko, G., Akoto, O., & Oppong, C. (2008). Persistent organochlorine pesticide residues in fish, sediments and water from Lake Bosomtwi, Ghana. Chemosphere, 72(1), 21–24. https://doi.org/10.1016/j.chemosphere.2008.02.052

Doumbia, M., & Kwadjo, E. (2009). Pratiques d ' utilisation et de gestion des pesticides par les maraîchers en Côte d ' Ivoire : Cas de la ville d ' Abidjan et deux de ses banlieues (Dabou et Anyama). Journal of Applied Biosciences, 18(June 2014), 992–1002.

Elhalwagy, M. E. A., Abd-Alrahman, S. H., Nahas, A. A., Ziada, R. M., & Mohamady, A. H. (2015). Hepatopancreatic intoxication of lambda-cyhalothrin insecticide on albino rats. International Journal of Clinical and Experimental Medicine, 8(5), 7297–7305.

FAO. (2021). Scientific review of the impact of climate change on plant pests. In FAO. https://doi.org/10.4060/cb4769en

Fleischer, G., Andoli, V., Coulibaly, M., & Randolph, T. (1998). Analyse socio-économique de la filière des pesticides en Côte d ' Ivoire.

Gokou, D., Marie, J., Victor, K. K., Dopé, Y., & Cyrille, A. (2021). Phytosanitary Risks and Practices of Farmers around the Sassandra River in Guessabo (Central West, Côte D'ivoire). Journal of Chemical, Biological and Physical Sciences, 11(3), 201–209. https://doi.org/10.24214/jcbps.d.11.3.20109

Goran, M. S. O. N., Kouadio, M. N., Guettia, A. M. C. N., Yeboue, N. L., & Tano, Y. (2019). Effets des pratiques phytosanitaires sur l'entomofaune et le rendement du concombre Cucumis sativus (Cucurbitaceae) Linnaeus, 1753 en milieu paysan à BONOUA (Sud-Est de la Côte d'Ivoire). Agronomie Africaine, 31(1), 1–14.

Gunby, P. (1979). Toxicity of pesticides. Journal of the American Medical Association, 242(7), 596–597. https://doi.org/10.1001/jama.242.7.596

Houndji, M. A. B., Imorou Toko, I., Guedegba, L., Yacouto, E., Agbohessi, P. T., Mandiki, S. N. M., Scippo, M. L., & Kestemont, P. (2020). Joint toxicity of two phytosanitary molecules, lambda-cyhalothrin and acetamiprid, on African catfish (Clarias gariepinus) juveniles. Journal of Environmental Science and Health - Part B, 55(7), 669–676. https://doi.org/10.1080/03601234.2020.1763712

Irel, A., Arnaud, N., Anny, K., Chantal, A., & Madina, O. Y. (2020). Évaluation de l ' exposition aux organophosphorés et aux carbamates chez les travailleurs d ' une entreprise de palmiers à huile en Côte d ' Ivoire. CAMIP. Info, 1, 1–14.

Istriningsih, Dewi, Y. A., Yulianti, A., Hanifah, V. W., Jamal, E., Dadang, Sarwani, M., Mardiharini, M., Anugrah, I. S., Darwis, V., Suib, E., Herteddy, D., Sutriadi, M. T., Kurnia, A., & Harsanti, E. S. (2022). Farmers' knowledge and practice regarding good agricultural practices (GAP) on safe pesticide usage in Indonesia. Heliyon, 8(1), e08708. https://doi.org/10.1016/j.heliyon.2021.e08708

Kanda, M., Wala, K., Batawila, K., Djaneye-Boundjou, G., Ahanchede, A., & Akpagana, K. (2009). Le maraîchage périurbain à Lomé : Pratiques culturales, risques sanitaires et dynamiques spatiales. Cahiers Agricultures, 18(4), 356–363. https://doi.org/10.1684/agr.2009.0319

Kwadjo, & Doumbia. (2009). Pratiques d' utilisation et de gestion des pesticides par les maraîchers en Côte d ' Ivoire : Cas de la ville d ' Abidjan et deux de ses banlieues (Dabou et Anyama). Journal of Applied Biosciences, 18(January), 992–1002.

Lekei, E., Aiwerasia, V. N., & Leslie, L. (2014). Farmers' knowledge, practices and injuries associated with pesticide exposure in rural farming villages in Tanzania. BMC Public Health, 14(i389), 1–13.

Mambe-Ani, P., Ouattara, K. N., Elleingand, F. E., & Kadjo, V. (2020). Assessment of the impact of pesticide use in urban and periurban agriculture in Abidjan, Côte d'Ivoire. International Journal of Biological and Chemical Sciences, 13(6), 2824. https://doi.org/10.4314/ijbcs.v13i6.32

Martin, S. Y., Annick, T., Joachim, A. E., & Séraphin, D. Y. K. (2018). Évaluation Des Pratiques Phytosanitaires Paysannes Dans Les Vergers De Cacao Dans Le Departement De Daloa, Côte d'Ivoire. European Scientific Journal, ESJ, 14(33), 267. https://doi.org/10.19044/esj.2018.v14n33p267

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

Mekonnen, Y., & Agonafir, T. (2002). Pesticide sprayers' knowledge, attitude and practice of pesticide use on agricultural farms of Ethiopia. Occupational Medicine, 52(6), 311–315. https://doi.org/10.1093/occmed/52.6.311

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(1), 301–324. https://doi.org/10.1007/s10668-015-9728-9

Myers, J. P., Antoniou, M. N., Blumberg, B., Carroll, L., Colborn, T., Everett, L. G., Hansen, M., Landrigan, P. J., Lanphear, B. P., Mesnage, R., Vandenberg, L. N., Vom Saal, F. S., Welshons, W. V., & Benbrook, C. M. (2016). Concerns over use of glyphosate-based herbicides and risks associated with exposures: A consensus statement. Environmental Health: A Global Access Science Source, 15(1), 1–13. https://doi.org/10.1186/s12940-016-0117-0

Ntow, William J., Gijzen, H. J., Kelderman, P., & Drechsel, P. (2006). Farmer perceptions and pesticide use practices in vegetable production in Ghana. Pest Management Science, 62(4), 356–365. https://doi.org/10.1002/ps.1178

Ntow, William Joseph. (2008). The use and fate of pesticides in vegetable-based agro-ecosystems in Ghana [Wageningen University]. In J. Agric. Food Chem (Issue January). https://doi.org/10.1201/b15743

Okoffo, E. D., Mensah, M., & Fosu-Mensah, B. Y. (2016). Pesticides exposure and the use of personal protective equipment by cocoa farmers in Ghana. Environmental Systems Research, 5(1). https://doi.org/10.1186/s40068-016-0068-z

Ouali-N'goran, S.-W. M., Yao, K. P., Kra, K. D., Kouassi, K. P., & Tano, Y. (2014). Évaluation de l'efficacité de l'insecticide Tricel 480 EC comparée à la Deltamétrine et à la Cyperméthrine contre les ravageurs du chou (Brassicacae L. sp.) en milieu paysan dans la région de Yamoussoukro, en Côte d'Ivoire. Afrique Science, 10(1), 194–207. http://www.afriquescience.info/document.php?id=3210

Pimentel, D. (1995). Amounts of pesticides reaching target pests: Environmental impacts and ethics. Journal of Agricultural and Environmental Ethics, 8(1), 17–29. https://doi.org/10.1007/BF02286399

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(2). https://doi.org/10.1051/cagri/2017010

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(1), 14072. https://doi.org/10.4314/jab.v138i1.7

Soro, G., Koffi, N. M., Kone, B., Kouakou, Y. E., M'bra, K. R., Soro, P. D., & Soro, N. (2018). Utilisation de produits phytosanitaires dans le maraîchage autour du barrage d' alimentation en eau potable de la ville de Korhogo (nord de la Côte d ' Ivoire) : risques pour la santé publique. Environ Risque Sante, 17, 155–163.

Tudi, M., Li, H., Li, H., Wang, L., Lyu, J., Yang, L., Tong, S., Yu, Q. J., Ruan, H. D., Atabila, A., Phung, D. T., Sadler, R., & Connell, D. (2022). Exposure Routes and Health Risks Associated with Pesticide Application. Toxics, 10(6), 1–23. https://doi.org/10.3390/toxics10060335

Ugwu, J. A., Omoloye, A. A., Asogwa, E. U., & Aduloju, A. R. (2015). Pesticide-handling practices among smallholder Vegetable farmers in Oyo state, Nigeria. Scientific Research Journal, 3(4), 40–47.

Yadav, B. (2018). Cypermethrin Toxicity: A Review. Journal of Forensic Sciences & Criminal Investigation, 9(4), 9–11. https://doi.org/10.19080/jfsci.2018.09.555767

Zhang, W., Jiang, F., & Ou, J. (2011). Global pesticide consumption and pollution: with China as a focus. International Academy of Ecology and Environmental Sciences (IAEES), 1(2), 125–144. www.iaees.org