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Phytosanitary practices and associated human health and environmental risks in vegetable cropping systems in Northeastern Côte d'Ivoire

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Abstract

The Bogofa commune is becoming a dynamic area for market-oriented vegetable production with farmers who use synthetic pesticides. However, synthetic pesticides threaten both the environment and consumer health. There is growing interest in assessing pesticide-use practices among local farmers to raise awareness and promote the safe, responsible, and appropriate use of pesticides in agricultural production. An exploratory survey was conducted from August 2023 to September 2023 to evaluate commercial garden systems in the Bogofa community and determine which commercial garden areas were most representative. The Bogofa community was selected as it drastically increased vegetable production due to significant barriers associated with safe pesticide usage. A sample of 58 farmers was selected based on the amount of production using hectares as a measurement to complete the analysis through Statistica Version 12.5. The plants produced most commonly were tomatoes, peppers, eggplant, cabbage, and cucumbers (94.83 %). Additionally, approximately 11 pesticides from the Directorate of Plant Protection, Control, and Quality (Class II) are available to vegetable farmers, which contain K-Optimal 35 EC (Lambda-cyhalothrin and Acetamiprid) and Decis Forte 100 EC (Deltamethrin) that put them at risk due to their lack of Personal Protective Equipment (94.83 %) and reliance on their regular clothing (91.38 %) and 91.38 % of purchasing pesticides from farmer vendors in local retail outlets. Storage methods vary little; they store them at home-46.55 %-in field shelters-27.59 %-or storage facilities-25.86 %. Moreover, 37.93 % dispose of their remaining pesticide mixes in farms or storage facilities. Of the rest, 27.59 % discarded any unused mixed pesticides along with their empty containers and other debris collected from their farms. Farmers commonly burned empty containers (44.83 %), leave them in the field (39.66 %), or reuse them somewhere else (3.45 %). All these practices combined will increase the amount of leftover pesticide residue on farms, making consumers may increase the risk of environmental contamination and dietary exposure. The findings demonstrate an urgent need for formal training in pesticide selection, application, personal protection, storage, and container disposal.

Key words: Empty containers, pesticides, farmers, phytosanitary products, management, poisoning

Introduction

The development of the agricultural sector has been a priority for Côte d'Ivoire since its independent in 1960. The agricultural sector has always been viewed as a pillar of Cote d'Ivoire's economy (FAO, 2021). Historically, agricultural investment has largely focused on cash crops for export such as cocoa, coffee, cotton, oil palm, rubber, and cashews. The creation of these cash crops has greatly contributed to Cote d'Ivoire's economic growth through the generation of foreign currency (Losch and Michaud, 2016; World Bank, 2023). However, in light of the various social groups that exist as well as Cote d'Ivoire's excellent fertility of land and favorable growing conditions, many have been transitioning to more diverse agricultural activities that are better suited to urban areas and peri-urban areas. This transition has occurred in response to urbanization and growth through the development of both full-time and part-time urban agriculture as well as peri-urban agriculture (Ouattara *et al.*, 2021; Soro *et al.*, 2023). Among these types of agriculture that have recently developed are market gardens, which are found in both urban and peri-urban areas. Market gardens are primarily characterized by the production of both local and imported vegetables to be sold for income or grown for subsistence (Hien *et al.,* 2023). Market gardening has a significant impact on food security and nutritional value for individuals living in Côte d'Ivoire. Many farmers use this method to generate various foods that have nutritional value to maintain health. Farmers and producers also obtain a large percentage of their income through market gardening, whether they live in rural or urban areas (FAO, 2017). Market gardening has recently become an important agricultural development area in the northeastern part of Côte d'Ivoire (specifically, the Bounkani region) due to its good soil conditions, favorable climate and growing demand for fresh produce from urban areas nearby. Therefore, this Region has become a significant area for research on agricultural practices, phytosanitary management, and their socio-economic and environmental effects. There are numerous major challenges that market gardeners face in this

area, including abiotic and biotic constraints (Samb, 2023). Therefore, these constraints have significantly reduced crop yields and farmers' incomes.

In order to manage biotic stresses and improve their productivity, many market gardeners have turned to intensive and, in many cases, systematic use of phytosanitary products (herbicides, insecticides, fungicides, and other biocides) for insect and weed management (Doumbia and Kwadjo, 2009; Diomande *et al.,* 2025). Excessive, inappropriate application of pesticides poses a significant risk to both human health and the environment. Many reports indicate that certain practices in market gardening in Côte d'Ivoire use non-registered or banned active materials (Diomandé *et al.,* 2025; Kouamé *et al.,* 2025). For example, farmers possess a limited understanding of the effects of pesticide exposure on human health, the environment, and pest management, which often leads to inappropriate use of PPE, improper disposal of containers, and overdosing when applying pesticides (Doumbia and Kwadjo, 2009; FAO and WHO, 2016). These negative behaviors increase the likelihood of farmer exposure to acute and chronic poisoning, environmental contamination, and the development of pesticide-resistant pests. To address these issues in accordance with the FAO recommendations regarding the sustainable management of pesticides, an agricultural study was conducted in the Bounkani region, focusing on the Nassian department and the villages of Têto, Farako and Gouméré within Bogofa commune, with the objective of evaluating the agricultural practices of market gardeners regarding phytosanitary practices to determine their training needs and assess the guidelines they use to choose pesticides. As part of the objective of conducting this study, researchers sought to examine how humans will be impacted by these types of gardening behaviors on an international basis and produce recommendations for risk reduction from gardening practices (FAO and WHO, 2021).

It is expected that this will enable policymakers across the globe to develop agricultural policies that foster safe, sustainable, and socially responsible gardening systems and promote the use of environmentally sustainable alternatives to food production.

Materials and methods

Study area: The Bounkani region, located in the extreme northeast of Côte d'Ivoire, borders Burkina Faso and Ghana. It is subdivided into four (04) departments: Bouna (chief town), Doropo, Nassian, and Tehini (Fig. 1). The Region covers an area of 22,091 km², representing 6.90 % of the national surface area, half of which is occupied by the Comoé National Park (11,090 km²). According to the 2021 general population and housing census, the population is estimated to be 427,037, including 216,310 men and 210,727 women (RGPH, 2021). The population comprises approximately ten (10) ethnic groups, with the three (3) predominant groups being the Koulango, Malinké, and Lobi. Sudan predominates in climate and vegetation types, with a large overhang of tree canopies on a few grassy savannahs (Comoé National Park contains this type of area). The combination of both the climate and vegetation type has created conditions favoring the establishment of an agrarian/animal husbandry economy among almost all the Region's heterogeneous population through mixed agriculture and animal husbandry. However, this is due to low-yield farming (less than that typically seen) on traditional farm plots or lands with freehold ownership. Most of the rural economy, therefore, consists of private subsistence agriculture. According to MEMINADER (2024), this zone is recognized as being a market gardening zone with a considerable production of eggplant, okra, and tomatoes and an estimated total production of 1957 tonnes.

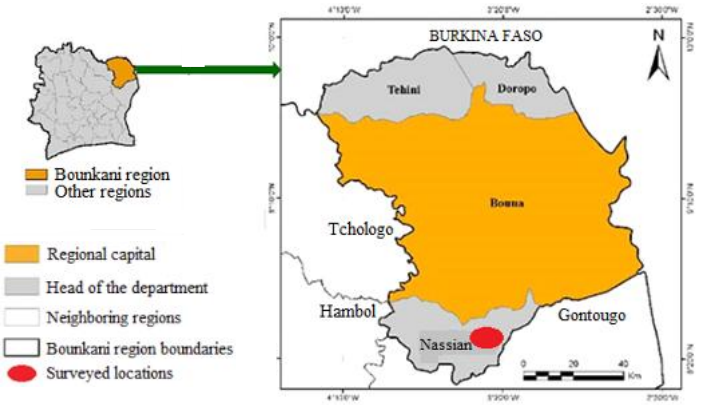


Fig. 1. Map of study area: Orange (Capital city), Grey (Head of Region), White (Neighboring regions and Bounkani region boundaries), and Red (Surveyed locations).

Data collection: A phytosanitary survey questionnaire was administered in parts of the Bounkani region in the Nassian department (Bogofa local government), specifically in the villages of Têto, Farako and Goumere. Several criteria guided the choice of this study area. These included the intensification of agricultural activities, particularly market gardening. However, dynamism of agriculture in the Region, which is often threatened by pests, weeds, and diseases, is leading growers to increase their use of pesticides. An exploratory survey was therefore conducted to identify the various market gardening sites in the Bogofa commune. At the end of this phase, the villages of Têto, Farako, and Gouméré with market gardening sites of at least 5 ha were selected. Data were collected using the individual survey method (Agnandji *et al.,* 2018) from 58 market gardening producers, supplemented in some cases by interviews. These producers were selected on the basis of the diversification of vegetable crops, pesticide use, willingness to participate voluntarily in the survey, and the areas allocated to vegetable crops. The survey was conducted during the months of August and September 2023, which corresponds to the period when market gardening is abundantly practiced. The survey questionnaire composed of open, semi-open, and closed questions. Some answers were verified by direct observation in the field. The data collected covered the sociodemographic characteristics of growers (gender, age groups, marital status, level of education, main activity, number of years of experience and secondary activity), the main market gardening crops grown, the main pesticides used by growers, means of protection used during pesticide applications, sources, and methods of pesticide supply, management of empty packaging and stocks, preparation of the phytosanitary spray mixture and destination of the remaining spray mixture, and growers' perceptions of the chemical risks of the use of the pesticide.

Statistical analysis of the data: Quantitative and qualitative datasets were recorded from field surveys, processed and analyzed using Statistica software (v12.5). Survey questionnaires had been screened for quality before being coded to allow entry into Microsoft Excel 2021 for calculations and to generate tables/figures. Descriptive statistics were used in the summarization of statistics in the form of frequency distribution tables and graphs. Relationships between categorical (qualitative) variables in our analysis were evaluated with Chi-square tests. To compare quantitative (numerical) variables, where possible we used parametric tests (Student's t-tests) to compare means when normality and equal variance were

satisfied; otherwise, we used non-parametric tests (Kruskal-Wallis tests) to compare medians when those same assumptions were violated. Active substances, their concentrations, pesticide categories, and FAO/WHO toxicity classes were identified based on recorded trade names using the national list of registered and authorized pesticides in Côte d'Ivoire (10 July 2024) issued by the Directorate of Plant Protection, Control, and Quality (DPVCQ) of the Ministry of Agriculture and Rural Development (MEMINADER, 2024), and the Footprint Pesticide Properties Database (Footprint, 2010).

Results

Sociodemographic characteristics of vegetable growers: The results shown in Table 1 relate to the sociodemographic characteristics of vegetable growers in the Bogofa commune. These results show that market gardening is predominantly practiced by men (94.83 %). Only 5.17% of women are involved in this activity. The age classification of the producers of the market gardening shows a diversity. Those aged 36 years had the highest frequency (51.72 %). This age group was followed by those aged between 25 and 35 (39.66 %). Individuals under the age of 25 represent 8.62 % of the market gardening surveyed. The analysis also reveals that the level of education of vegetable growers is relatively high (67.24 %: Primary education: 29.31 %, Secondary education: 34.48 % and More education: 3.45 %). Despite this educational background, safety practices remain poor, suggesting a gap between general literacy specific agricultural safety training. Only 34.48 % of growers had secondary education, compared with 29.31 % with primary education and 3.45 % with university education. However, 8.62 % of vegetable growers have not received any basic training. Market gardening is of interest to both married and single people.

Table 1. Demographic and socio-economic characteristics of vegetable growers

Variables	Modalities	Numbers (n = 58)	Frequency (%)
Gender	Men	55	94.83
	Women	3	5.17
Age groups (years)	Not more than 24	5	8.62
	Between 25 and 35	23	39.66
	36 or more	30	51.72
Matrimonial status	Married	6	10.34
	Single	52	89.66
Education level	None	19	32.76
	Primary	17	29.31
	Secondary	20	34.48
	More	2	3.45
Principal activity	Agriculture	49	84.48
	Market gardening	4	6.90
	Housekeeper	2	3.45
	Photograph	2	3.45
	Trade	1	1.72
Number of years' experience (years)	Less than 5	11	18.97
	From 5 to 10	22	37.93
	More than 10	25	43.10
Secondary activity	Market gardening	40	68.97
	Agriculture	15	25.86
	Trade	2	3.45
	None	1	1.72

≥ Greater than or equal to, ≤ Less than or equal to, < Greater than, > Less than, n = number of persons surveyed

The highest frequency of market gardening was found among single farmers (89.66 %) and the lowest among married farmers (10.34 %). Farming is the main activity for 84.48 % of market gardening, and market gardening is their secondary activity for 68.97 %. The majority of market gardening have more than 10 years of experience, with a frequency of 84.48 %. Producers with less than five years' experience in market gardening represented the smallest proportion (18.97 %).

Main difficulties of vegetable crops: At all market gardening sites surveyed, the dominant crops were tomatoes (93.10 %), peppers (22.41 %), eggplants (13.79 %), and okra (12.07 %). On the other hand, cabbage (6.90 %), lettuce (6.90 %), chili pepper (1.72 %), and cucumber (1.72 %) were the vegetable crops rarely found. The main reasons given by growers for choosing these vegetable crops were the ease of growing them, short cycle, short-term profitability of investments, and high market value per unit area. Eight vegetable crop species (tomato, bell pepper, eggplant, okra, cabbage, lettuce, chili and cucumber) belonging to five botanical families (Solanaceae, Brassicaceae, Malvaceae, Asteraceae and Cucurbitaceae) were inventoried during the survey (Table 2).

Table 2. Main vegetable crops grown by producers

Common names	Scientific names	Botanical families	Numbers (n = 58)	Proportions (%)
Tomato	*Solanum lycopersicum* L.	Solanaceae	54	93.10
Peppers	*Capsicum annuum* L.	Solanaceae	13	22.41
Eggplant	*Solanum melongena* L.	Solanaceae	8	13.79
Cabbage	*Brassica oleracea* L.	Brassicaceae	4	6.90
Okra	*Abelmoschus esculentus* L.	Malvaceae	7	12.07
Lettuce	*Lactuca sativa* L.	Asteraceae	4	6.90
Chili	*Capsicum annuum* L.	Solanaceae	1	1.72
Cucumber	*Cucumis sativus* L.	Cucurbitaceae	1	1.72

L.= Carl Von Linné, n = number of persons surveyed

Pesticides used by vegetable growers: Table 3 provides information on the main synthetic pesticides used by vegetable growers. Results analysis showed that, according to products commercial names, 11 synthetic pesticides formulations are commonly used by growers in Nassian department (Bounkani region). These synthetic pesticides consisted essentially of five insecticides, three fungicides, and three herbicides, with variations in their use. Indeed, insecticides were the most synthetic pesticides used by growers (60.34 %), followed by fungicides (32.75 %). Herbicides were the least used, with 6.89% rate. The three types of synthetic pesticides inventoried (insecticides, fungicides, and herbicides) had only two degrees of danger according to WHO classes. Nine (09) synthetic pesticides were classified as slightly hazardous (class III), whereas two (02) 16 were moderately hazardous (class II). Comparison of the synthetic pesticides used with the global list of pesticides registered and authorized in Côte d'Ivoire on July 10, 2024, by the Direction of Plant Protection, Inspection, and Quality (DPVCQ) of the Ministry of Agriculture and Rural Development shows that all pesticide formulations are registered.

User protection during pesticide application: The survey results in table 4 show that 94.83 % of vegetable growers did not have any personal protective equipment (PPE) or complete protective equipment (mask, dust cover, overalls, gloves, goggles, aprons, boots). Only 5.17 % of growers had PPE. The reasons given by growers for not having protective equipment where we

Table 3. Pesticides used by vegetable growers

Trading name	Active substances	Pesticide categories	Authorized crops / uses	FAO/ WHO classes	Frequency (%)
DECIS 12.5 EC	Deltamethrin: 12.5 $g.L^{-1}$	Insecticide	Avocado, citrus, banana, cocoa, coffee, vegetable and food crops	III	27.59
VETO 30 EC	Deltamethrin: 10 $g.L^{-1}$ + Acetamiprid: 20 $g.L^{-1}$	Insecticide	Vegetable crops	III	5.17
DECIS FORTE 100 EC	Deltamethrin: 100 $g.L^{-1}$	Insecticide	Vegetable crops, banana	II	22.41
CYPERCAL 50 EC	Cypermethrin: 50 $g.L^{-1}$	Insecticide	Cotton, vegetables and food crops	III	3.45
K-OPTIMAL 35 EC	Lambda-cyhalothrin: 15 $g.L^{-1}$ + Acetamiprid: 20 $g.L^{-1}$	Insecticide	Vegetable and food crops	II	1.72
BANKO PLUS 650 SC	Chlorothalonil: 550 $g.L^{-1}$ Carbendazim: 100 $g.L^{-1}$	Fungicide	Vegetable and food crops, palm seeds	III	10.34
IVORY 80% WP	Mancozeb: 800 $g.kg^{-1}$	Fungicide	Vegetable and food crops	III	15.52
MANCO 80 WP	Mancozeb: 800 $g.kg^{-1}$	Fungicide	Vegetable crops	III	6.89
LADABA 480 SL	Glyphosate isopropyl amine salt: 360 $g.L^{-1}$	Herbicide	All crops, fallow land and other uncultivated areas	III	1.72
LAMACHETTE 480 SL	Glyphosate: 360 $g.L^{-1}$	Herbicide	All crops, fallow land and other uncultivated areas	III	1.72
KILLER 360 SL	Glyphosate acid: 360 $g.L^{-1}$	Herbicide	Fallow land, plantations, and other uncultivated areas	III	3.45

FAO: Food and Agriculture Organization of the United Nations, WHO: World Health Organization, Class II: Moderately hazardous, Class III: Slightly hazardous, EC: Emulsifiable Concentrate, SC: Suspension Concentrate, WP: Wetable Powder, SL: Soluble Concentrate, g = gram, L = Liter.

lack of financial means (81.82 %), unavailability of protective equipment on the local market (14.54 %), and not needing to wear protective equipment for pesticide applications (3.64 %). Ordinary field clothing was used by 96.36 % of the growers for pesticide application, without gloves or masks. 3.64 % of growers used ordinary street clothes for pesticide applications (Table 4). However, some market gardening growers confessed to having equipped themselves with PPE following the recurrence of health problems observed and have fewer health concerns now that they are properly protected.

Table 4. Use of protective equipment by producers

Variables		Numbers (n=58)	Frequency (%)
Use of protective equipment	Yes	3	5.17
	No	55	94.83
Reason for lack of protective equipment	Lack of financial resources	45	81.82
	Unavailability of PPE on the local market	8	14.54
	No need to wear PPE	2	3.64
Outfits used	Ordinary field wear	49	84.48
	Ordinary street wear	6	10.34
	PPE	3	5.17

PPE= Personal Protective Equipment

Sources and methods of pesticide supply: The majority of Bogofa's vegetable growers buy their pesticides on the local market (91.38 %) from itinerant dealers or small retailers set up around local markets (Table 5).

Table 5. Acquisition and conditions of use of synthetic pesticides

Variables		Number (n=58)	Frequency (%)
Supply sources	Local market	53	91.38
	Approved seller	5	8.62
Methods of supply	Personal funds	53	91.38
	Credits	3	5.17
	Loans	2	3.45

However, only 8.62 % of growers obtain their supplies from approved crop protection product distributors with appropriate stores. Dealers of crop protection products on the local market have received no training in proper pesticide handling techniques. The most common method for acquiring pesticides used by growers is direct purchase with their own funds (91.38 %). While 5.17 % of growers buy pesticides on credit, 3.45 % use loans (Table 5).

Management of empty pesticide packaging and product stocks: In the Bounkani region, Nassian department, and Bogofa commune, the results of the survey revealed that vegetable growers have three (3) different ways of managing empty pesticide packaging (Fig. 2). Analysis of the results in table 6 shows that 44.83 % of growers burn (incinerate) empty pesticide packaging after use. In contrast, 39.66 % of growers discarded (abandoned) empty packaging on the plots and 12.07 % buried (buried) it in the ground. Empty pesticide packaging was reused (re-used) by 3.45 % of growers for domestic purposes as storage containers for water, beverages, and edible oil, or even as a medium for repackaging other pesticides (Fig. 2A). The survey results also (Fig. 2B) reveal that vegetable growers stored pesticides either in their homes (46.55 %), under shelters set up inside the fields (27.59 %), or in stores reserved for pesticides (25.86 %).

Phytosanitary spray preparation and destination of the remaining spray liquid: For the application of phytosanitary products, vegetable growers in the Bogofa commune prepare the spray mixture in three different places (on the plot to be treated, at home or next to a watering place). Thus, 70.69 % of growers prepared their spray mixture on the plot to be treated, whereas 25.86 % prepared it at home before coming to the plot to be treated. On the other hand, only 3.45 % of growers prepare their spray next to a water source (Fig. 3). Sprays are used in the quantities necessary and sufficient for the phytosanitary treatments requested. However, growers who do not comply with this recommendation use various methods to manage the remaining spray liquid after application. Analysis of the results in Fig. 3 reveals a very worrying situation when it comes to managing leftover spray liquid. 37.93 % of market-garden growers surveyed, 37.93 % kept the leftover spray liquid at home

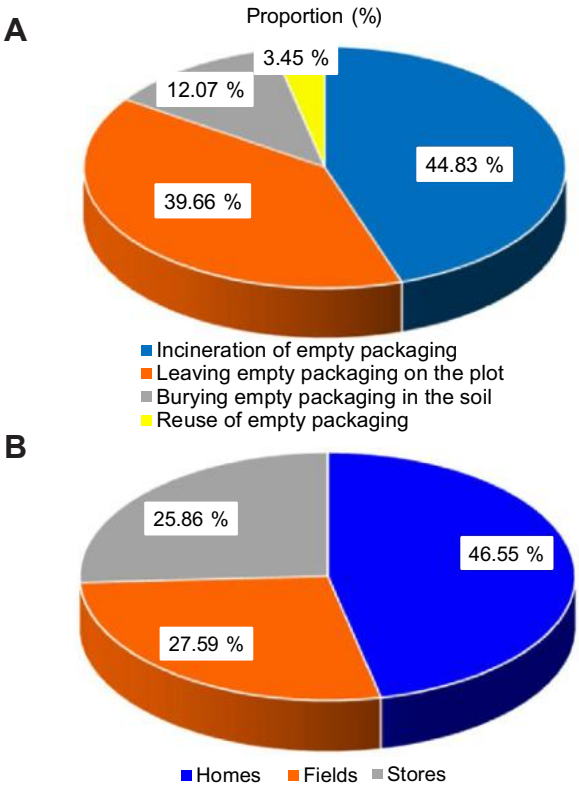


Fig. 2. Management of empty pesticide packaging and product stocks. A: Empty management; B: Products storage location

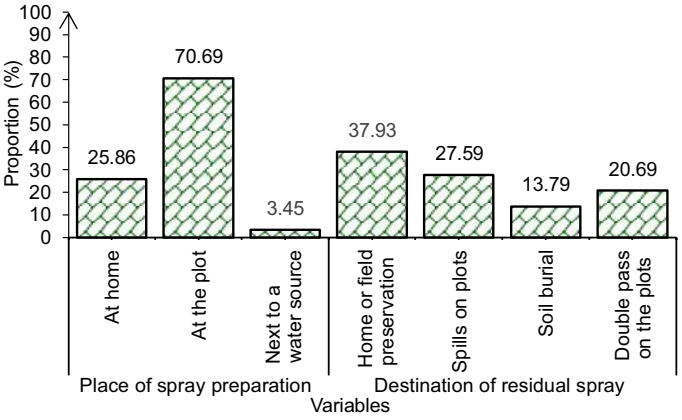


Fig. 3. Preparing and using leftover spray mixture.

or in the field for later use, and 27.59 % poured it directly onto the plots. On the other hand, 20.69 % of growers reported making a double pass over the plots, while 13.79 % buried it in the soil.

Growers' perception of the chemical risks of pesticide use: The vegetable growers we met during our surveys all justified the use of pesticides as the only alternative to effectively control crop pests (pests, fungi, and weeds). However, the results recorded in Figs. 4 and 5 show that growers are well aware that phytosanitary products can have harmful effects on their own health as well as that of consumers and generally have adverse consequences on the environment. Analysis of Fig. 4 shows that 48.27 % of growers experienced colds after applying a pesticide. Among growers, 20.69 % reported headaches following pesticide application, whereas 12.07 % reported skin irritation, 8.62 % weakness, 6.90 % coughing, and 3.45 % reported malaria-like symptoms (fever and chills) after pesticide use. With regard to the chemical risks of pesticide use on the environment, only 60.34

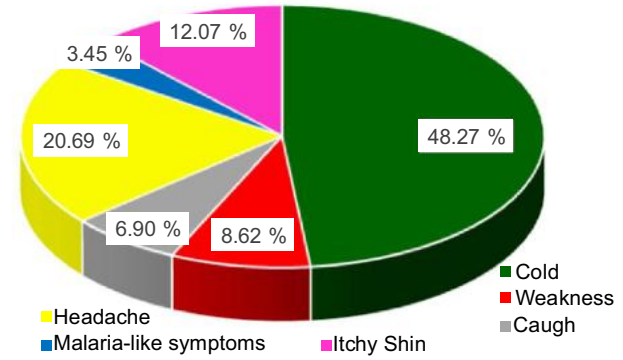


Fig. 4. Different types of discomfort experienced by growers after the application of a crop protection product.

% of vegetable growers in the study area acknowledged that chemical pesticides have a harmful effect on the environment. On the other hand, 39.66 % of growers said they had no idea of any harmful effect on the environment (Fig. 5A). For those growers who acknowledge a harmful effect of pesticide use on the environment, the answers given are diverse and vary from one grower to another. 67.24 % of growers point to the pollution of surface water by pesticides, while 25.86 % believe that pesticides kill aquatic life (Fig. 5B). For 6.90 % of growers, herbicides are mainly responsible for soil degradation in the area (Fig. 5B).

Relationship between educational level and pesticide use:

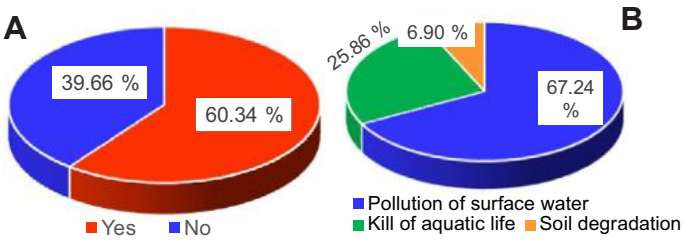


Fig. 5. Proportions of growers' perception of the chemical risk of pesticide use on the environment. A: Producers' knowledge of the harmful effects of pesticide use, and B: Adverse effects of pesticide use on the environment

Figs. 6 and 7 illustrate the distribution of synthetic pesticide use practices among producers according to their level of education. Analysis of Fig. 6 highlights a very low adoption of personal protective equipment (PPE) during pesticide application operations. Indeed, only 5.18 % of producers reported using adequate protective measures. Among these, 1.72 % had a primary level of education, while 3.45 % had attained secondary or higher education. Compared to educated producers who wore personal protective equipment (PPE), none of the non-educated producers reported wearing PPE while using pesticides. The majority (62.07 %) of educated producers did not use the recommended PPEs, exposing them to potential health risks through the improper use of pesticides (Fig. 6). Although the Chi-Square Test resulted in no statistically significant association between the producers' educational levels and their use of PPE, Chi-Square tests yielded no statistically significant association ($P > 0.05$) between educational level and PPE usage. While considering the diversity of pesticide usage (Fig. 7), it was noted that approximately 75.86 % of producers used multiple pesticide products, while 24.14 % of producers used only one type of pesticide. The data were averaged for each groups' educational level compared to the number of pesticide products used, between these groups,

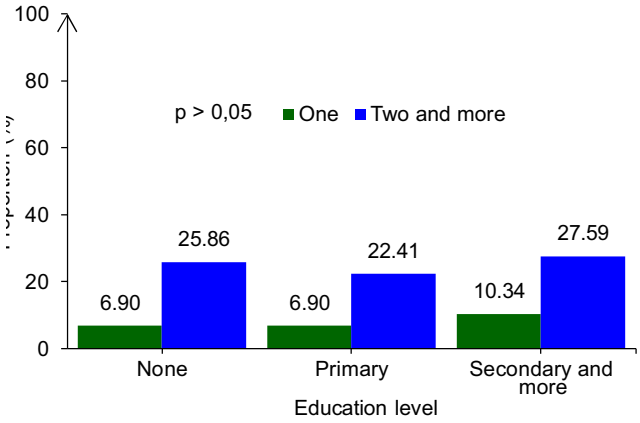


Fig. 6. Distribution of respondents by educational level and use of personal protective equipment (PPE).

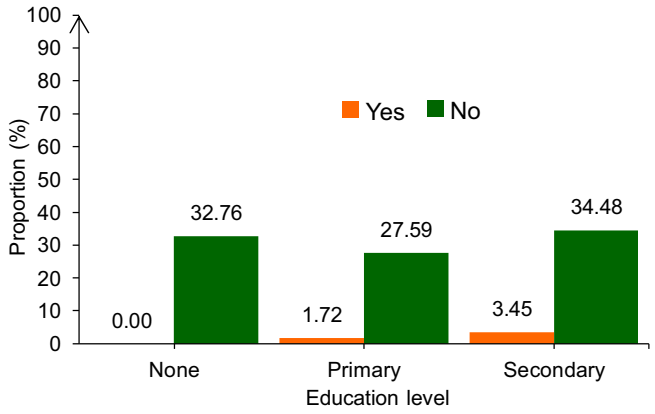


Fig. 7. Proportion of respondents according to their level of education and the number of products used.

indicating no differences between groups. Further evidence to support this finding was obtained through the Chi-Square Test, which revealed no statistically significant association between educational and pesticide usage ($P > 0.05$).

Discussion

Market gardening in the commune of Bogofa, Nassian department, Bounkani region, Côte d'Ivoire, is predominantly male activity (94.83 %). Only a small percentage of women (5.17 %) engage in this activity. In fact, men are considered the heads of farms where market gardening is practiced. The low level of involvement of women in market gardening in this Region could be explained by the fact that women are generally not qualified to apply the phytosanitary products required by these crops. In addition, women living with their husbands or married in these localities constitute a labor force for their husbands, making it difficult for them to perform an activity on their own account. This result is in line with the work of Muliele *et al.* (2017) and Kpan *et al.* (2019), who established that the market gardening sector in the Democratic Republic of Congo's Nkolo zone and Côte d'Ivoire demonstrates pronounced gender differences regarding access to land, resources, and technical practices as well as phytosanitary governance. These studies were done in relation to market gardening areas such as Port-Bouët and Yopougon in Abidjan; these areas were characterized by substantially higher input usage and more stringent regulation. In some instances, male farmers are favored over female farmers due to greater amounts of male participation and increased levels of technological sophistication found in certain market gardening areas. In addition, gendered divisions of labor exist throughout the market gardening system, where women's involvement in production was lower in some urban systems but had greater levels of participation in downstream activities, particularly related to the marketing of horticultural products (Muliele *et al.,* 2017; Kpan *et al.,* 2019). Women are most producers (56 %) operating on small rented or squatted plots with high reliance on chemical inputs in Yopougon. This means that women face a gendered burden of labor and are exposed to a greater risk of health issues in peri-urban settings, where support from extension services is limited (Kouamé *et al.,* 2025). By contrast, the northern and northeastern regions (Korhogo and Solomougou irrigated basins) have a very large percentage of women in the production of crops (up to 95 % of producers at the Korhogo dam; Soro *et al.,* 2018). The relationship has been observed between men's preferring to put their resources into producing high-value cash crops like cotton and cashew and the lack of institutional regulation, poor access to formal training, and closeness to the international borders that promote informal pesticide markets and cross-border trade. In these circumstances, most market gardening occurs at smaller, household-based subsistence farming systems, which women have historically managed. Women producers in northern Côte d'Ivoire are encountering long-lasting problems stemming from the micro-parceling of their land (Adiko, 2020), an effect of inadequate land tenure systems (Adiko, 2025). As more women implement agro-ecological methods and have less access to training programs, workloads are expected to constantly rise (Balle and Kouakou, 2025). Consequently, it is possible for women to be disempowered despite having increased productivity as a result of implementing agro-ecological practices. Women's market gardening practices vary by region and include several plant protection practices. Still, they are often practiced in insecure conditions of land tenure, lack institutional support for their operations, and are increasingly exposed to health and environmental risks (Adiko, 2025; Kouamé *et al.,* 2025). The lack of secure land tenure disproportionately affects women's participation in market gardening; therefore, these regional differences have similar characteristics in how gender gaps persist along agricultural value chains throughout Côte d'Ivoire due to crop type and the institutional/governance barriers women face, consistent with current evidence that gender(s) gaps in agricultural value chains are consistently mediated by access to land and formal resources (Karakara *et al.,* 2024). Although the Bogofa commune has 51.72 % of market gardeners surveyed older than 36, there remains a large number of growers younger than 36, so the agricultural workforce cannot be considered aged. Therefore, age does not seem to influence or drive pesticide applications to the same extent as factors such as productivity on a restricted labor force and the use of herbicides as a strategy to save labor (due to time pressure) and maintain production levels. Consequently, pesticide use in this system should be interpreted as a response to structural and operational farming conditions rather than a direct outcome of farmers' age (Aké *et al.,* 2023). In fact, the use of herbicides by this age group can be explained by the lack of appropriate and efficient labor for weed control, which requires good physical condition. In terms of level of education, the analysis revealed that the majority of vegetable growers in Bogofa commune had attended school (67.24 %). This high level of education could be explained by the fact that young people in the region have dropped out of school because of the numerous sociopolitical crises that Côte d'Ivoire has experienced since the 2000s. This has prompted them to take up farming as a source of income. On the other hand, some young people practice market gardening on a temporary basis with a view to having

resources to finance their main activities, such as studies and trade (Agnandji *et al.,* 2018). This high level of education among growers should be an asset for the proper use of phytosanitary products, which was not the case in this study. Son *et al.* (2017) and Naamane *et al.* (2020) support the conclusion of this study of the high rates of uneducated people involved in growing vegetables. Results from Son *et al.* (2017) suggest that people who were unable to read or write had inadequate knowledge on how to correctly apply plant protection chemicals, largely because they were unfamiliar with pest management in agriculture and therefore used a pheromone based on the pest they were using in their application. Furthermore, Naamane *et al.* (2020) stated that a high illiteracy rate among farmers and an overall lack of awareness surrounding agricultural pest management may also be reasons for not adhering to the precautionary measures recommended when using phytosanitary products. Furthermore, Agnandji *et al.* (2018) stated that illiteracy among market gardeners creates an additional obstacle to their ability to read or understand the use instructions for pesticides, as these instructions are frequently written in a language they cannot read (i.e., French or English) or may contain a combination of the two languages; as such, market gardeners cannot appreciate any potential harm from improper and uncontrolled use of pesticides. Other than the many crops produced at each of the market garden sites sampled, tomatoes (93.1 % of total crops); bell peppers (22.4 %); eggplant (13.8 %); and okra (12.1 %) were the primary crops produced at each of the sites. However, tomatoes are one of the vegetable crops subjected to heavy pest pressure (pests, fungal diseases, bacterial diseases, nematodes, etc.). According to James *et al.* (2010), tomatoes and cabbage are crops at high risk of infestation by *Helicoverpa armigera* and *P. xylostella* caterpillars in West Africa. According to Son *et al.* (2017), poor farming practices by growers encourage the outbreak of certain pests and the spread of diseases. These authors cite crop associations, such as tomato or cabbage with okra, and tomato and bell pepper crop rotation. The use of uncomposed poultry manure by growers, combined with high doses of nitrogen and excessive irrigation, is particularly conducive to the development of fungal and bacterial diseases in most vegetable crops, such as tomatoes (Schiffers, 2011). Attacks by these pests are so often severe that most growers systematically use synthetic pesticides to control them. However, repeated use of molecules from the same family of synthetic pesticides can lead to the development of resistance to fungal pathogens (Assogba-Komlan *et al.,* 2007), as well as the destruction of auxiliary insects and, in turn, a pest outbreak (Boyer *et al.,* 2017). Analysis of the results reveals that, according to the trade names of the products, 11 formulations of synthetic pesticides are commonly used by growers in the Nassian department (Bounkani region). However, during application, growers use these phytosanitary products without any personal protective equipment (PPE). According to Gouda *et al.* (2018), growers' health is threatened by the lack of personal protective equipment worn during the preparation and execution of phytosanitary treatments. This may be at the root of some of the ailments recorded in this study among growers, including cases of colds (48.27 %), headaches (20.69 %), itchy skin (12.07 %), weakness, cough (6.90 %), and malaria-like symptoms (fever, chills; 3.45 %). Indeed, according to Balasha *et al.* (2023), these various ailments could be explained by the irritant and toxic nature of the products used and the producers' poor protection. The long experience of more than 10 years of most growers (43.10 %) in the use of pesticides could be a significant factor in the successful management of phytosanitary products. However, it could also constitute a toxicological risk factor for applicators because they are always in contact with synthetic pesticides. Indeed, the number of years of experience should play an important role in the use of phytosanitary products by contributing to producers' compliance with pesticide management standards. However, the results of this survey reveal that most growers with long experience in vegetable crop production make very poor use of phytosanitary products. Growers were found to wear incomplete protective equipment (ordinary, often dilapidated outfits, equipment not associated with masks) as a means of protection, and some growers even carried out treatments barefoot. In this study, only 5.17 % of growers used personal protective equipment (PPE) or complete protective equipment (mask, dust cover, overalls, gloves, goggles, aprons, boots), which are suitable for good protection. This low rate of use of personal protective equipment by growers suggests that good practices in the use of plant protection products are far from being linked to the number of years of experience. The reasons given by growers for the absence of protective equipment were lack of financial means (81.82 %), unavailability of protective equipment on the local market (14.54 %), and the fact that it was not necessary to wear protective equipment when applying pesticides (3.64 %). According to Gouda *et al.* (2018); FAO and WHO (2020), mandatory wearing of personal protective equipment (PPE) when applying plant protection products is recommended. However, some growers of vegetable crops feel that the use of personal protective equipment or coveralls when applying plant protection products ventilates their bodies, which sometimes suffocates them. This result is in line with the work of Tyagi *et al.* (2015), who showed that growers do not regularly protect themselves when using pesticides because of the high cost of equipment and, above all, a lack of awareness of the dangers to which they are exposed. Regarding the management of leftover plant protection product spray liquid, 37.93 % of market gardening growers surveyed kept the remaining spray liquid at home or in the field for later use, while 27.59 % poured it directly onto the plots. On the other hand, 20.69 % of growers reported making a double pass over the plots, while 13.79 % buried it in the soil. Note that storing leftover plant protection products at home exposes family members to the harmful effects of these products. Dumping or burying leftover pesticide sprays in the soil can lead to soil and water health risks. The results are consistent with those of Balasha *et al.* (2023). As stated by Balasha *et al.* (2023), double passes can be employed as an agricultural best management practice to avoid excessive amounts of spray being wasted during sprayer rinsing and cleaning operations. In addition, many growers are not able to properly determine the quantity of spray needed to apply to their crops, resulting in increased potential for phytotoxicity and high levels of pesticide residues consumed by consumers (Koffi *et al.,* 2022; Thakur *et al.,* 2025). To ensure that the level of pesticide residues is kept to a minimum, Balasha *et al.* (2023); FAO and WHO (2021) recommend that growers adhere to preharvest intervals and use integrated pest management strategies when growing their crops. With regard to the management of empty packaging, its reuse could increase health risks (the complete elimination of pesticide residues by simple washing), and its abandonment would expose the environment. According to Muliele *et al.* (2017) and Balasha *et al.* (2023), abandoning, incinerating, and burying empty packaging is a source of pollution to soil, water, and air and is therefore dangerous for living beings. For these authors, the incineration of packaging is not a good practice because during combustion, certain pesticides produce highly toxic fumes that are harmful to

humans and animals when inhaled. However, burying packaging presents the risk of contamination of groundwater. Users and distributors therefore need to be made aware of the need to properly dispose of such packaging. Similarly, the storage of nonempty pesticide cans in courtyards or dormitories could lead to health problems for family members, especially children who like to play with whatever is lying around. As far as the management of empty packaging is concerned, its reuse is common. In fact, after the application of pesticides, growers have reported health problems such as headaches, itchy skin, weakness, coughing, and malaria. These symptoms confirm the harmful nature of the pesticides used. These results corroborate those of Balasha *et al.* (2023).

The use of pesticides in agriculture remains a necessity to improve productivity and increase producers' incomes. At the end of this study, it emerged that vegetable growers in the Bogofa commune in the Nassian department are predominantly male. The study also showed that most producers grow tomatoes (93.10 %). To control crop pests, diseases and weeds, growers use insecticides, fungicides and herbicides. However, insecticides were the most used pesticides (60.34 %) by growers. Market gardening growers obtain most of their phytosanitary products from the local market (91.38 %), mainly from itinerant retailers or from retailers set up around local markets. Vegetable growers in the Bogofa commune are not very familiar with pesticides and do not generally comply with the recommendations on product labels, particularly with regard to the dose to be applied, the wearing of protective clothing, and the management of packaging. The results reveal the potential risk of pesticide poisoning for producers and consumers alike and the urgent need for training in the judicious use of synthetic chemical pesticides.

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