RESEARCH ARTICLE
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Assessment of the contamination of *Lactuca sativa L.* (lettuce) and *Lycopersicon esculentum* (tomato) by pesticides: Case of market gardeners in Ouagadougou

Sibiri Sylvain Rouamba[1,2], François Tapsoba[2], Bazoin Sylvain Raoul Bazié[1], Ollo Youl[1], Saybou Savadogo[1], Elie Kabré[1,3], Lassana Sangaré[3,4] and Aly Savadogo[2]

1. Laboratoire National de Santé Publique, 09 BP: 24, Ouagadougou 09, Burkina Faso, West Africa; 2. Laboratoire de Biochimie et Immunologie Appliquée, Université Joseph KI-ZERBO, 03 BP: 7131, Ouagadougou, Burkina Faso, West Africa; 3. Unité de Formation et de Recherche/Sciences De la Santé, Université Joseph KI-ZERBO, 03 BP: 7021 Ouagadougou 03, Burkina Faso, West Africa; 4. Service de Bactériologie-Virologie, Centre Hospitalier Universitaire Yalgado Ouédraogo, 03 BP: 7022 Ouagadougou 03, Burkina Faso, West Africa.

Corresponding author: Sibiri Sylvain Rouamba, e-mail: rousib@yahoo.fr

Co-authors: FT: tapsobaf@gmail.com, BSRB: bazsylvain@yahoo.fr, OY: youl.ollo@yahoo.com, SS: ssaybou0204@gmail.com, EK: elie.kabre@gmail.com, LS: sangarelassana01@gmail.com, AS: alysavadogo@gmail.com

Received: 12-08-2021, **Accepted:** 27-10-2021, **Published online:** 11-12-2021

doi: www.doi.org/10.14202/IJOH.2021.251-256 **How to cite this article:** Rouamba SS, Tapsoba F, Bazié BSR, Youl O, Savadogo S, Kabré E, Sangaré L, Savadogo A (2021) Assessment of the contamination of *Lactuca sativa L.* (lettuce) and *Lycopersicon esculentum* (tomato) by pesticides: case of market gardeners in Ouagadougou, *Int. J. One Health*, 7(2): 251-256.

Abstract

Background and Aim: The use of pesticides in vegetable production can cause public health problems because these agrochemicals can leave residues in foodstuffs and disrupt the appropriate functioning of the organism. The aim of this study was to assess the level of contamination of lettuce and tomato by pesticide residues.

Materials and Methods: This study was conducted from February 12 to May 3, 2021, in concerned five market gardening sites in the city of Ouagadougou. A survey was conducted among 58 market gardeners selected at random from the sites of Boulmiougou, Tanghin No. 1 and 2, Bissigin, and the National School of Public Health. Simultaneously, 25 lettuce samples and 25 tomato samples were collected in a randomized manner for the examination and determination of pesticide residues using the quick, easy, cheap, effective, rugged, and safe method.

Results: The market gardening population was predominantly represented by women who had a low level of education. The cultivated species were a mixture of exotic cultures and traditional cultures. These crops were treated with various pesticides, the most common of which belonged to the organochlorine family. The tomato was the crop most contaminated by pesticide residues. However, no active ingredient from the synthetic pyrethroid family was found on lettuce or tomato.

Conclusion: Raising the awareness of market gardeners on good practices in the use of pesticides and on alternative methods to synthetic phytosanitary products is of paramount importance for the health of consumers.

Keywords: lettuce, market gardeners, Ouagadougou, pesticides, tomato.

Introduction

Today, agriculture, in general, and market gardening, in particular, must encounter several challenges such as not only increasing the food supply but also the requirement of agricultural production guaranteeing health security and quality, nutrition, and respect for the environment [1]. However, in several developing countries, regulations in terms of production techniques or the sanitary quality of agricultural production are either nonexistent or not accompanied by effective control of practices, inputs, and food products [1]. Therefore, market gardening in sub-Saharan Africa is often based on intensive, even abusive, use of inputs (mineral fertilizers, organic waste, phytosanitary products, and wastewater), with often harmful consequences for human, animal, and environmental health [2,3].

Urban agriculture remains a key activity providing food, wealth, and jobs, in particular for the most vulnerable groups [4]. In Burkina Faso, market gardening represented 16.5% of agricultural production and 4.5% of the country's gross domestic product in 2002 [5]. Market garden products contribute to the food and nutritional security of populations by supplying vitamins and mineral salts with which they are abundant [4].

In Ouagadougou, the practice of market gardening has experienced a crucial boom since the 1990s [4]. Once only present around dams, it is now practiced around available water points in the city and its surroundings [6]. Ouagadougou has approximately 100 market gardening sites grouped into 28 zones and cultivated over an area of approximately 750 ha occupied by 5000 farmers and 15,000 seasonal workers [7]. Approximately 10 market gardening sites are recognized as the most important, including the

Boulmiougou and Tanghin sites. However, it appears that these sites are operated in poor sanitary conditions with regard to the unhealthy practices of the operators [4]. The use of wastewater in an uncontrolled manner and without treatment for watering market garden products, associated with the use of pesticides and chemical fertilizers intended for purposes other than market gardening, presents potential risks to human health and the environment [8]. In fact, peasant chemical control practices present real dangers at the following three levels: (i) Toxicity for producers, linked to exposure during the phases of preparation and application of the phytosanitary spray [8]; (ii) toxicity for the consumer, linked to the presence of toxic residues [9]; and (iii) environmental pollution and toxicity to non-target environmental organisms [10].

This study was conducted to evaluate the level of contamination of lettuce and tomato by pesticide residues from the market garden sites of Tanghin, Boulmiougou, Bissigin, and the National School of Public Health (ENSP) of Ouagadougou.

Materials and Methods

Ethical approval and informed consent

There was no need of ethical approval for this study. The verbal consent was obtained from each participant before the study.

Study period and sites

The study was conducted from February to May 2019. This descriptive and analytical study was carried out on urban market gardening sites in the city of Ouagadougou (Figure-1). It was carried out on the market gardening sites of dams n° 1 (12° 23’26”N 1° 31’25”E) and n° 2 (12° 23’14”N 1° 30’56 ‘ ‘E) from Tanghin, from Boulmiougou (12° 20’15”N 1° 35’12”E), from Bissigin (12 ° 23’56”N 1 ° 36’2”E), from the courtyard of the ENSP (12° 23’4”N 1° 30’31”E), and the canal behind the ENSP (12° 23’5”N 1° 30 ‘ 39”E).

Field investigation

A descriptive study was conducted on the market garden sites of interest. Sociological approaches such as semi-structured questionnaires, interviews, and direct observation were used to obtain information on cultivation practices from 58 randomly selected market gardeners. The primary information collected concerned socio-demography (age, sex, social status, education level, and primary activity), description of agricultural practices (types of vegetables grown, sources of water supply, irrigation systems, and types of pesticides and fertilizers used), and finally the perceptions of market gardeners on the quality of the vegetables produced.

Collection of lettuce and tomato samples

A total of 25 lettuces and 25 tomato samples were collected from several market gardeners at random from all sites and transferred into plastic bags (zip bags). All the collected samples were labeled and stored at +4°C in a cooler and then transported to the laboratory for analysis.

Determination of pesticide residues

Extraction and purification according to the quick, easy, cheap, effective, rugged, and safe (QuEChERS) method

The pesticide residues in the lettuce and tomato samples were quantified according to the QuEChERS method as described by Borowiak *et al*. [11]. This was performed in three primary stages, namely, extraction, purification, and storage in vials.

Extraction

The lettuce and tomato samples were cut and then ground using a blender. Next, 5 g of the ground

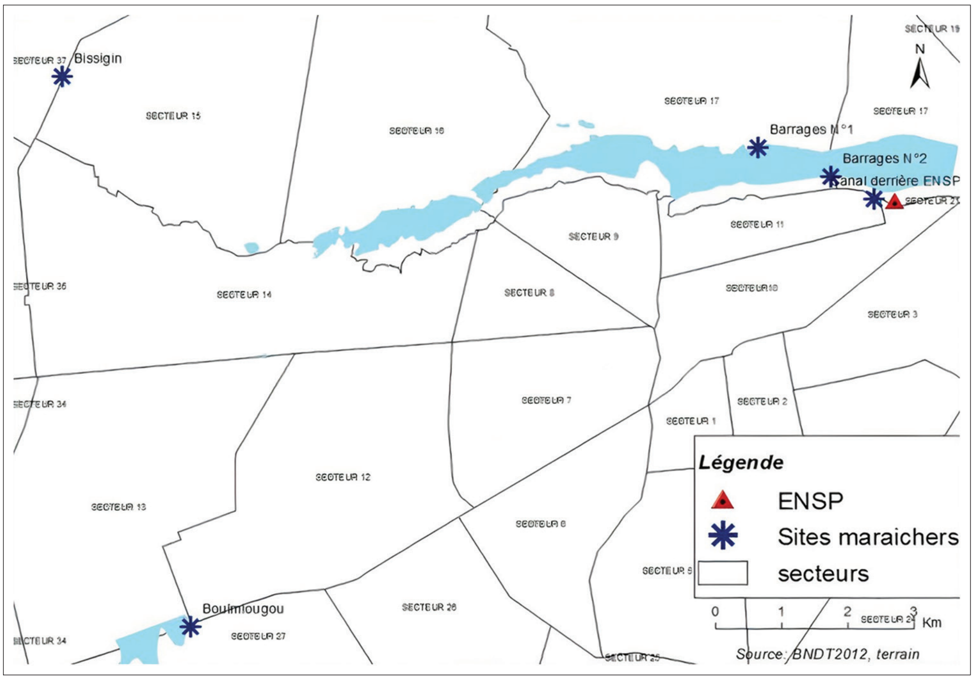

Figure-1: market gardening sites.

material was weighed and introduced into a 50-mL FALCON centrifuge tube. Then, a set of reagents consisting of 1 g of sodium chloride, 1 g of sodium citrate, 0.5 g of Na-citrate-anhydrous, and 4 g of magnesium sulfate ($MgSO_4$) were added to the contents of the tube. Acetonitrile was used as the extraction solvent. The tube was subjected to vigorous agitation for 1 min using a vortex. Finally, the tube containing the sample and the extraction reagents was centrifuged at 3000 rpm for 5 min.

Purification

After centrifugation of the sample, a 6-mL aliquot was taken and transferred into a 15-mL FALCON tube containing a purification reagent that was composed of 300 mg of Protein S A, 400 mg of activated carbon (C18), and 900 mg of $MgSO_4$. Acetonitrile was used as the purification solvent. The tube was vortexed for 1 min and then centrifuged at 3000 rpm for 5 min.

Storage in vials

In this step, 2 mL of the supernatant was taken and then transferred into vials, which will be used for analysis by chromatography.

The apparatus used to detect and quantify the pesticide residues is a pair comprising a Varian® 431-GC chromatograph (Agilent Technologies, Les Ulis, France) equipped with an automatic sample changer (Varian® CP-8410) and a Varian® 210-MS (Agilent Technologies) mass spectrometer operating with a charge trapping analyzer. The assembly is linked to a computer equipped with and controlled by the Varianworkstation® software (Agilent Technologies). The chromatograph uses a Zebron® ZB-5MS (Agilent Technologies) brand capillary column (5% diphenyl, 95% dimethylpolysiloxane), measuring 30 m in length, 0.25 mm inside diameter, and 0.25 μm in film thickness, obtained from Phenomenex (Le Pecq, France) and a carrier gas, namely, helium at 99.9% purity (Messer, Puteaux, France) with a flow rate of 1 mL/min.

Statistical analysis

The survey data were processed and analyzed using the Sphinx Millenium 4.5 software, which enabled to generate the descriptive statistics. The mean values of the various study parameters were compared using the Addinsoft XLSTAT 2021.2 software (USA) at a significance threshold of 0.05%.

Results

Socio-demographic characteristics of market gardeners

The survey results showed that in the localities covered by the study, there are more women (55.2%) than men (44.8%) who practiced market gardening. The age of the producers ranged from 18 to >56 years, with 48.3% of them being aged between 18 and 35 years. The majority of the surveyed population had a low level of education, with 65.5% of market gardeners being illiterate and only 10.3% reaching post-primary education (Table-1).

Speculations produced on market garden sites

In all the sites, the survey results showed that lettuce (*Lactuca sativa* L.), amaranth (*Amaranthus hybridus*), tomato (*Solanum lycopersicum*), boulvanka (*Corchorus tri dens*), sorrel (*Hibiscus sab dar iffa*), kiennebdo (*Cleome gynandra* L.), and okra (*Hibiscus esculentus*) were the most frequent speculations during the study period. Cabbage (*Brassica oleracea*), carrot (*Daucus carota subsp. sativus*), parsley (*Petroselinum crispum*), leek (*Allium ampeloprasum*), bell pepper (*Capsicum ann uum*), mint (*Mentha spicata* L.), beet (*Beta vulgaris* L.), and strawberry (*Fragaria ananassa*) were also highly produced species.

Knowledge of producers on the health risks associated with the use of pesticides

The study results showed that less than half of the producers (41.4%) recognized the existence of health risks associated with the use of pesticides. Of those producers, 34.5% linked these health risks to the inhalation of chemicals.

Contamination of lettuce and tomato with pesticide residues

The results showed that 76.0% of tomato samples were contaminated with pesticide residues compared with 36% of lettuce samples.

Pesticide residue concentration

Based on the chromatographic profile of the lettuce samples collected from the market garden sites, 12 active ingredients were identified, which were divided into the following three families of pesticides: Carbamates, organochlorines, and organophosphates. The chromatographic profile of the tomato samples revealed 17 active ingredients that were also divided into the abovementioned three families of pesticides. Table-2 shows the distribution of the various compounds according to class. No active ingredient of the synthetic pyrethroid class was found.

Distribution of active ingredients by family

In lettuce, active organochlorines were the most frequent (43.8%), followed by carbamates (37.5%) and organophosphates (18.8%). Similar observations

Table-1 : Socio-demographic characteristics of the study population.

Variables	Categories	Number	Frequency (%)
Gender	Female	32	55.17
	Male	26	44.83
	Total	58	100
Age (years)	18-35	28	48.28
	36-55	22	37.93
	56 and over	8	13.79
	Total	58	100
Education	Without any education	38	65.52
	Primary	14	24.14
	Post primary	6	10.34
	Secondary	0	0
	Higher Education	0	0
	Total	58	100

were recorded in tomatoes, with organochlorines (43.4%) being the most frequent, followed by carbamates (40.9%) and organophosphates (15.7%).

Concentrations of active ingredients of pesticides present in lettuce and tomato compared to their maximum residue limits (MRL)

Concentration of different active ingredients per family found in lettuce compared to MRL

The results depicted in Figure-2 show that the concentrations of the quantified active ingredients are statistically higher than the toxicity thresholds, with the exception of diazinon and azoxystrobin whose concentrations were far less than the MRL.

Concentration of different active ingredients per family found in tomato compared to MRL

As shown in Figure-3, the concentrations of several active ingredients in tomato samples were statistically higher than the MRL.

Discussion

Market gardening represents a financial opportunity and helps reduce food insecurity. In Ouagadougou, it is often practiced during the dry season around water points. In our study, the population of market gardeners was predominantly represented by women and a dominant age group between 18 and 35 years. Market gardening allows them to meet their needs and has the resources to finance their primary activities such as education and commerce [12].

The different crops grown correspond to those frequently consumed in Burkina Faso, in fact in the central region. These were exotic (lettuce, tomato, cabbage, carrots, etc.) and traditional vegetables (boulvanka, sorrel, kiennebdo, okra, etc.).

The lack of professional qualification combined with a high unemployment rate limits the possibilities of access to employment for the poorly educated population. Thus, this one comes to the market gardening sector, which does not require a high level of education [13].

The illiteracy of most market gardeners is an obstacle to the appropriate use of pesticides because the instructions for their use are most often written in French and English or sometimes in other languages. This situation could explain the high rate of their ignorance of the dangers related to abusive and uncontrolled use of pesticides. In fact, the lack of information and training on good pesticide use practices has been reported as a major problem by Samake *et al*. [14]. The low level of education severely limits the knowledge of pesticides, in particular on the application methods, persistence, compliance with withdrawal periods, as well as the precautions to be taken at the time of treatment [15].

According to our study results, 12 and 17 active ingredients were respectively detected in the lettuce and tomato samples with representativeness of the three major families of pesticides organochlorines, organophosphates, and carbamates. Hence, the tomato was the most contaminated speculation among the samples. These results are similar to those obtained by Tarnagda *et al*. [16], who detected a total of 13 active ingredients in the leafy vegetables examined in their study. These results are also consistent with those obtained by Farag *et al*. [17] in leafy vegetables sold in the Egyptian market. There was also a predominance of active substances belonging to the organochlorine family, unlike the results of Agnandji *et al*. [12] and Tarnagda *et al*. [16],

Table-2: Breakdown of active ingredients according to class.

Pesticide classes	Active ingredients	
	Lettuce	Tomato
Organochlorines	Lindane, HCB, Chlordimeform, Chlorothalonil, Méthazochlore	Lindane, Heptachlore, Alpha-endosulfan, HCB, Chlordimeform, Chlorothalonil, Méthazochlore
Organophosphates	Diazinon, Dimethoate	Dimethoate, Mevinphos, Monocrotophos, Heptenophos
Carbamates	Quintozene, Imazalil, Triadimeform, Azoxystrobine, Simazine,	Quintozene, Imazalil, Simazine, Methomyl, Propiconazol, Benalaxyl
Pyrethroids	Absence	Absence

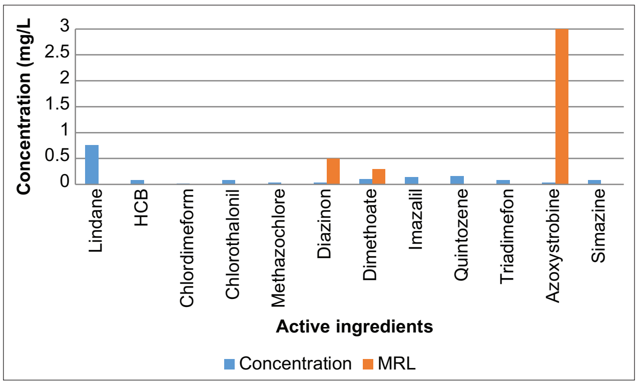

Figure-2: Concentrations of the active ingredients of pesticides present on the lettuce compared to their MRLs.

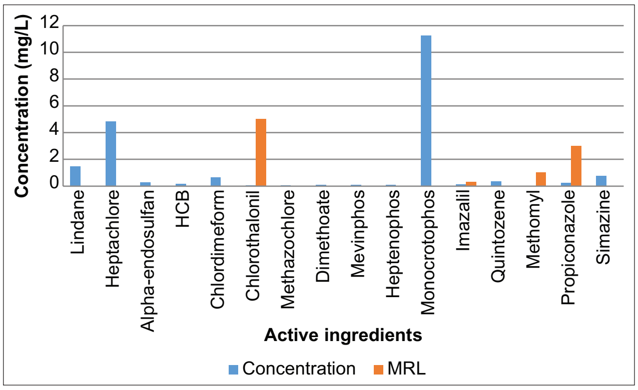

Figure-3: Concentrations of the active ingredients of pesticides present on the tomato compared to their MRLs.

who, respectively, reported that synthetic pyrethroids and organophosphorus were the most widely used pesticides. Our results reveal a greater persistence of organochlorines in lettuce and carbamates in tomatoes than in other families. This variability in the predominance of active ingredients is attributed to the use of a wide range of pesticides at random, depending on the site and the availability of products.

A comparison of the results obtained using the MRL of Codex Alimentarius, the Sahelian Pesticides Committee, and the European Union revealed the presence of a sample with a toxicity level greater than the standard. In fact, the levels of all the active ingredients were analyzed, with the exception of diazinon and azoxystrobin in lettuce and chlorothalonil, imazalil, methomyl, and propiconazole in tomato, were quantified to be greater than the MRL set. Similar observations were made in other countries in the subregion. For instance, in Kenya, Karanja *et al*. [18] found excessive levels of diazinon, profenofos, and cypermethrin in leafy vegetables. However, in Benin, similar concentrations of dichlorodiphényltrichloroéthane and lindane were found in samples by Diop *et al*. [13]. This situation would also infer the use of pesticides not recommended for the treatment of vegetables, such as cotton pesticides, which have a high concentration of active substances and high persistence in the vegetables, or the disregard of the recommended doses and a delay before the harvest [19]. In Ivory Coast, dimethoate and lambdacyhalothrin are the pesticides that are most commonly conveyed by lettuce to consumers [20]. Hence, 90.2% of these consumers are exposed to the chronic effects of dimethoate, and 97.4% of them are susceptible to chronic cyhalothrin exposure [20].

Moreover, a concentration of pesticide residues detected in a food sample, even if it is lower than the recommended MRL, should be of major importance. In fact, the presence of pesticide residues in the food chain is a troublesome issue for human health even if their consumption does not immediately present major health risks. Indeed, recent research on the effects of very-low-dose pesticides suggests that current safety levels should be much stricter to properly protect human health, especially that of children and other vulnerable groups as the major health problems related to the daily ingestion of pesticide residues can be neurological and hormonal imbalances and increased cancer risk [21]. Moreover, repeated exposure, reinforced by the accumulative nature of certain substances could present long-term risks and result in pathologies such as immunodeficiency, neurological deficits, reproductive disorders, behavioral abnormalities, and carcinogenesis [22,23]. In addition, there are uncertainties about the effects of mixtures of different pesticide residues, which can interact in the body and exacerbate the damage.

Conclusion

Market gardening contributes to food security and the reduction of the unemployment rate. It generally employs producers with low levels of education. Several categories of exotic and traditional speculations are produced. To optimize yield, growers use pesticides to control pests. This pest control is not without consequences on the quality of the market garden products. Therefore, it is extremely important to educate market gardeners on good practices for the use of pesticides and on alternative methods to synthetic phytosanitary products to protect both their health and that of vegetable consumers against the harmful effects induced by pesticide residues for the sustainability of this activity.

Authors' Contributions

SSR: Conceptualization, investigation, formal analysis, result analysis, review, and editing of the manuscript. FT and BSRB: Investigation and review of the manuscript. OY: Formal analysis, result analysis, and writing-review. SS: Result analysis and writing-review. EK: Conceptualization, supervision, and review. LS: Conceptualization, supervision, and review. AS: Conceptualization and supervision All authors read and approved the final manuscript.

Acknowledgments

The study was supported by University Joseph KI-ZERBO and Laboratoire National de Santé Publique (LNSP), Burkina Faso.

Competing Interests

The authors declare that they have no competing interests.

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