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Research Article

Evaluation of Pesticide Contamination Levels in Pineapple Plantations Soils in Three Areas of the Sud-comoé Region (Côte D'Ivoire)

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Abstract

This study was conducted in Côte d'Ivoire, specifically in the Sud-Comoé region, encompassing the Assé, Toumanguié, and Samo zones. The aim was to identify and quantify pesticide residues in the soils of pineapple plantations in these areas. The study involved 60 soil samples, carefully collected at a rate of 20 samples per site. The samples were prepared and analysed using a SHIMADZU high-performance liquid chromatograph system. The analysis revealed the presence of pesticide residues, including glyphosate, aldicarb, profenofos, parathion-methyl, cypermethrin, permethrin, deltamethrin, chlorpropham, and lambda-cyhalothrin, in concentrations ranging from 0.022 to 0.088 mg/kg. The pesticide residues found belong to two major families of pesticides, namely insecticides and herbicides. Except for aldicarb and lambda-cyhalothrin, all detected residue levels were below the safety thresholds set by the Codex Alimentarius. This indicates that soils in these plantations could be capable of supporting the production of pineapples that meet quality standards for human consumption.

Keywords

Pesticide Residues, Soil, Pineapple Plantations, Sud-Comoé, Safety Thresholds, Codex Alimentarius

1. Introduction

Achieving diversification and food self-sufficiency has been at the heart of the Ivorian government's policy for the agricultural sector [1-10]. One of the axes of this policy concerns fruit crops, in particular pineapple cultivation. Pineapples, being perennial plants, are rich in enzymes like bromelain which aids in protein, citric acid, malic acid and vitamins digestion [2-11]. As well as being rich in vitamins, pineapples play a crucial role in the local economy. Its cultivation generates income for many farmers and creates jobs in rural areas. As a major export product, especially to Europe and other international markets, it helps to diversify the country's exports and generate foreign currency. Pine-

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apple production also enhances food security by providing nutritious food for the local population. Pineapple cultivation promotes rural development by improving local infrastructure, such as roads and markets, while stimulating other economic sectors linked to production and distribution. It also acts as a brake on rural exodus. Since June 1993, the Ivorian government has implemented a policy aimed at modernizing farming practices, which requires increasing use of agricultural inputs, particularly pesticides. While these inputs boost crop yields, excessive pesticide use poses serious risks. Pesticide accumulation can contaminate soils, endanger human health, and harm the environment [3-13]. It is in this context that we are endeavouring to assess the level of pesticide contamination in the soils of pineapple plantations in the coastal areas of Côte d'Ivoire, with a view to preventing possible contamination.

2. Material and Methods

2.1. Material

We collected 60 soil samples from the outskirts of Bonoua and Adiaké, focusing on areas like Samo, Assé, and Toumanguié. These samples were carefully analyzed in the laboratory using advanced equipment to ensure precise results. Key tools included an OHAUS electronic balance with a precision range of 1 mg to 0.1 g, a SEVERIN electric mixer, and a SIMUDZU HPLC system. Distilled water, methanol (purity 99.9%), sodium tetraborate (purity 99.5%), FMOC (9-fluorenylmethoxycarbonyl) (purity 98%) and dichloromethane (purity 99.8%) were used as solvents and reagents.

2.2. Methods

Following FAO (Food and Agriculture Organisation) guidelines, 60 soil samples were randomly collected from three distinct sites: Assé, Toumanguié, and Samo. Each site contributed an equal number of 20 samples, ensuring a balanced and representative sampling approach. Using a PVC pipe, a random sampling of soil was carried out, each sample weighing 500 g and taken at different depths: from 0 to 15 cm at the surface and from 15 to 30 cm at depth. Gloves were put on beforehand to avoid contamination. The samples were placed in polyethylene bags and labelled for identification. All the samples were then packed in a cool box and transported to the laboratory for analysis.

2.2.1. Molecules Dosage Procedure (Except Glyphosate)

The molecules were assayed in three stages.

(i). Extraction of Molecules Dosage Procedure

In the laboratory, we carried out the extraction of pesticide residues using a precise and methodical approach. From a uniformly ground sample, we measured out exactly 50 g. The resulting grind was placed in a clean, dry jar to ensure no contamination. The ground sample was thoroughly mixed with 100 mL of dichloromethane. The mixture was then agitated for 24 hours using an IKA orbital shaker, ensuring maximum interaction between the solvent and the sample. After agitation, the contents of the jar were carefully filtered through Wattman paper into a round-bottom flask. The filtrate was, then, subjected to evaporation using a BUCHI R-250 rotary evaporator. The process was conducted at a controlled temperature of 45 ℃ for 15 minutes, reducing the solvent to dryness and leaving behind the pesticide residues.

(ii). Purification of Molecules Dosage Procedure

To ensure accurate analyses, this stage focused on removing substances that could interfere with the target molecules. Using a vacuum pump equipped with a pre-activated C18 column, we filtered the recovered residues. The C18 column had been activated beforehand with a mixture of 3 mL methanol and 2 mL distilled water. After filtering the residues with methanol in a tube, the resulting contents were carefully decanted into a vial and then injected into the chromatography system for analysis.

(iii). Identification and Quantification of Molecules Dosage Procedure

Pesticide detection was performed using a SHIMADZU High-Performance Liquid Chromatography (HPLC) system equipped with an Ultra-Violet detector. The HPLC system was equipped with an SIL-20A automatic injector, a CTO-20A column heater, and an Interchrom column (250 x 4.6 mm) with a particle diameter of 5 µm. The mobile phase comprised water and acetonitrile in a 75: 25 (v/v) ratio. The stationary phase is a VP-ODS shimpack reverse phase column. The eluent flow rate inside the column is 1 $mL.min^{-1}$. The injection volume is 20 µL. Running time varies from 0 to 15 min. The pump used is a WATERS 600 gradient pump. The pressure is set at 13 MPa. The UV detector at a wavelength of 254 nm was used to read and record the peaks, the different surfaces (S) of which were produced using a microprocessor assisted by SHIMADZU software.

2.2.2. Glyphosate Dosing Method

Glyphosate dosage procedure was carried out in three stages.

(i). Extraction of Glyphosate Dosing Method

To extract glyphosate, 100 mL of distilled water was added to 15 g of finely crushed soil sample. This mixture was vigorously homogenized for 30 minutes using an IKA orbital shaker. The homogenized solution was then filtered through Whatman No. 114 filter paper into a round-bottomed flask.

The filtrate was evaporated to dryness using a BUCHI R-250 rotary evaporator at 45 ℃ for 15 minutes. The residues were recovered with 5 mL of distilled water.

(ii). Purification of Glyphosate Dosing Method

The purification step removed interfering substances to isolate the target molecule. In a 50 mL Falcon tube, 1 mL of the recovered residue was combined with 1 mL of FMOC (9-Fluorenylmethoxycarbonyl) and 1 mL of sodium tetraborate solution. The mixture was vortexed and shaken in the dark for 30 minutes. After centrifugation, the supernatant was collected and transferred into vials for HPLC analysis.

(iii). Identification and Quantification of Glyphosate Dosing Method

Identification and quantification of glyphosate followed the same HPLC procedure described above.

3. Results and Discussion

Molecule concentrations are generated by the chromatographic system as a function of detection surface values.

Analysis of soil samples from pineapple plantations in the various study areas revealed pesticide residues with different retention times. The findings are summarized in Table 1.

***Table 1**. Pesticide residues detected during the identification phase.*

Molecules detected	TR (min)	TR (min)		
	standards	Assé	Toumanguié	Samo
Glyphosate	4.2	4.3	4.2	4.2
Aldicarb	11.5	12	11.5	ND
Profenofos	3.2	3.2	3.2	3.2
Parathion-methyl	3.2	3.2	3.2	3.3
Cypermethrin	2.6	2.6	2.6	2.6
Permethrin	1.7	1.8	1.8	1.8
Deltamethrin	4.2	4.1	4.1	4.2
Lambda-cyhalothrin	2.6	2.7	2.6	2.6
Chlorpropham	3.7	ND	ND	3.7

ND= not found

3.1. Average Pesticide Residue Levels in the Soils of Pineapple Plantations in the Different Study Areas

Figure 1 illustrates the average concentrations of pesticide residues identified in the soils of three pineapple plantation locations: Assé, Toumanguié, and Samo.

Figure 1 illustrates the pesticide residues detected in the soils of three pineapple plantations: Assé, Toumanguié, and Samo. The residues identified primarily consist of insecticides and herbicides, with most insecticides belonging to the pyrethroid family. In the Assé plantation soils, aldicarb was found at the highest concentration (0.088 mg/kg), while parathion-methyl recorded the lowest concentration (0.002 mg/kg). In the Toumanguié soils, we found identical concentrations for lambda-cyhalothrin and parathion-methyl (0.05 mg.kg-1). Profenofos (0.009 mg.kg-1) had the lowest concentration. For the Samo plantation, the soil exhibited the highest concentration of cypermethrin (0.054 mg/kg), followed by lambda-cyhalothrin (0.05 mg/kg), while profenofos had the lowest concentration (0.007 mg/kg). The presence of these pesticide residues is likely due to their use in pest control to enhance fruit and vegetable productivity. Additionally, improper agricultural practices and a lack of awareness among some farmers could contribute to residue accumulation in the soil [4]. A study carried out in market gardening, revealed the presence of the same chemical families of pesticides in cabbages and tomatoes, albeit in varying proportions [5]. Similarly, a study carried out in the Nkolo area of Kongo Central, Democratic Republic of Congo, identified insecticides and fungicides as the predominant pesticide types used in vegetable cultivation [6]. Aldicarb, commonly sold under the trade name TEMIK, is extensively used as an insecticide, miticide, and nematicide, which could explain its high soil concentration. Likewise, MATADOR (lambda-cyhalothrin) is another widely used pesticide for pest management. Pesticides are used extensively throughout the world, due to their affordable cost, wide range of effectiveness and low persistence in the environment [7-14].

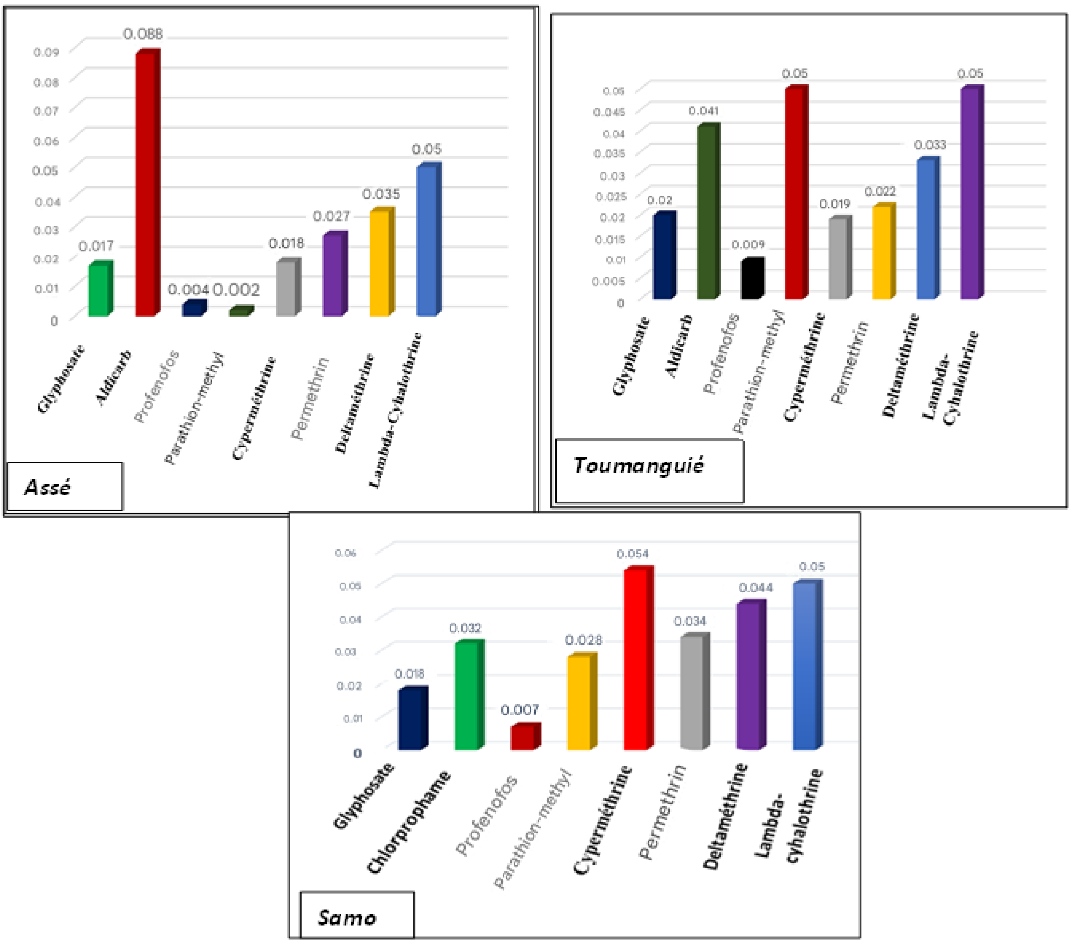

Figure 1. *Average concentrations of pesticide residues detected in the soils of the Assé, Toumanguié and Samo pineapple plantations respectively.*

3.2. Comparison of Pesticide Residue Levels with Codex Alimentarius Standards

Table 2. *Compares the average concentrations of pesticide residues in the soils of the Assé, Toumanguié and Samo pineapple plantations with Codex Alimentarius standards.*

Molecules detected	**Average levels**			**FAO/WHO**		
	Assé (mg/kg)	**Toumanguié (mg/kg)**	**Samo (mg/kg)**	**MRL (mg/kg)**	**Organizations**	**Years**
Glyphosate	0.017	0.02	0.018	0.05	Codex Alimentarius	2016
Aldicarb	0.088	0.041	ND	0.07	Codex Alimentarius	2011
Profenofos	0.004	0.009	0.007	0.07	Codex Alimentarius	2016
Parathion-methyl	0.002	0.05	0.028	5	Codex Alimentarius	2005
Cypermethrin	0.018	0.019	0.054	0.7	Codex Alimentarius	2009
Permethrin	0.027	0.022	0.034	2	ND	ND
Deltamethrin	0.035	0.035	0.044	0.03	Codex Alimentarius	2016

Molecules detected	Average levels			FAO/WHO		
	Assé (mg/kg)	Toumanguié (mg/kg)	Samo (mg/kg)	MRL (mg/kg)	Organizations	Years
Lambda-Cyhalothrine	0.05	0.05	0.05	0.03	Codex Alimentarius	2016
Chlorpropham	ND	ND	0.032	0.07	Codex Alimentarius	2011

ND=not found

Analysis of Table 2 shows that aldicarb has the highest concentration in Assé soil at 0.088 mg/kg. Notably, this level exceeds the maximum residue limit (MRL) established by the Codex Alimentarius, indicating potential overuse of this pesticide. Similarly, lambda-cyhalothrin, with a concentration of 0.05 mg/kg, surpasses the permissible limits across all three study regions. In contrast, the concentrations of other detected substances remain within the safe thresholds defined by the Codex Alimentarius standards. This could suggests that farmers may have received adequate training in proper cultivation techniques, such as appropriate frequency of application, correct dosage, and optimal timing for harvesting. However, exceeding authorized limits is often linked to over-application during spraying [8]. Additionally, certain environmental factors can hinder the complete degradation of some pesticide molecules, leading to their accumulation in the soil or on crops over time [9-15]. These findings highlight the importance of promoting sustainable agricultural practices and monitoring pesticide usage to minimize potential risks.

4. Conclusion

The chromatographic analysis carried out on the soils of the pineapple plantations from Assé, Toumanguié and Samo revealed nine pesticide residues. These include glyphosate, aldicarb, profenofos, parathion-methyl, cypermethrin, permethrin, deltamethrin, chlorpropham, and lambda-cyhalothrin. The residues found primarily fall into two categories: insecticides and herbicides. Most of the insecticides belong to the pyrethroid family. In addition to the insecticides, two herbicide, chlorpropham and glyphosate, were also detected. Aldicarb and lambda-cyhalothrin had the highest concentrations and exceeded the maximum residue limit set by Codex Alimentarius [7]. On the other hand, the other substances identified comply with the standards set by the Codex Alimentarius. The soils in these pineapple plantations are suitable for producing good quality fruit for human consumption.

Abbreviations

FAO	Food and Agriculture Organisation
FMOC	9-fluorenylmethoxycarbonyl
HPLC	Chromatographie Liquide à Haute Performance
MRL	Maximum Residue Limit
TR	Retention Time

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Author Contributions

Gouli Bi Irié Marc: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing

Konan Kouadio Franck: Conceptualization, Funding acquisition, Supervision, Validation, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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