



Assessment of Pesticides and Herbicides Risk on Yam (*Dioscorea rotundata*) Crop in Kwande Local Government Area of Benue State, Nigeria

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KEYWORDS

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ABSTRACT

Yam (*Dioscorea rotundata*) is a major staple crop in Nigeria, yet its production increasingly relies on herbicides and pesticides to control weeds and pests. This study assessed agrochemical use patterns, perceived health and environmental effects, and residue levels in yam tubers from Kwande Local Government Area. A stratified random sampling design was employed across three production zones (North, South, and West). Thirty farmers were interviewed, and thirty yam tuber samples were analyzed using the QuEChERS extraction method coupled with GC-MS/MS and LC-MS/MS. Method validation showed good linearity ($R^2 \geq 0.995$), recoveries of 80–110%, relative standard deviations below 15%, and limits of quantification of 0.01 mg/kg. Herbicide use was reported by 91.2% of farmers and pesticide use by 73.5%, with metazachlor, atrazine, cypermethrin, chlorpyrifos, glyphosate, and paraquat most frequently detected. Mean herbicide residues ranged from 0.042 ± 0.008 mg/kg (North) to 0.091 ± 0.012 mg/kg (West), while pesticide residues ranged from 0.035 ± 0.009 mg/kg (North) to 0.124 ± 0.018 mg/kg (West). Most values were below or close to international maximum residue limits, though higher concentrations in the West zone suggest more intensive chemical use. Farmers commonly associated agrochemical exposure with skin irritation, respiratory problems, and water and soil contamination. The findings indicate spatial variability in residue burden and highlight potential food-safety and environmental risks. Strengthened regulation, routine residue monitoring, and promotion of integrated pest management are recommended to ensure safer and more sustainable yam production.

CITATION

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INTRODUCTION

Yam (*Dioscorea rotundata*) occupies a central position in Nigeria's food system and cultural heritage. It is a staple crop that contributes substantially to household food security, rural livelihoods, and national agricultural output. Nigeria is the world's largest producer of yam, accounting

for over 60% of global production, with Benue State recognized as one of the major producing areas. Yam is nutritionally important as a major source of carbohydrates and provides essential micronutrients that support dietary energy requirements across socio-economic groups. However, yam production is constrained by agronomic

challenges such as weed infestation, pest attacks, and declining soil fertility. To manage these challenges, farmers increasingly depend on herbicides and pesticides. The widespread use of agrochemicals in tropical agriculture has raised concerns about their environmental fate and health impacts. In regions with heavy rainfall, such as Benue State, surface runoff and leaching increase the likelihood of herbicides and pesticides entering surface and groundwater systems, thereby contaminating rivers, streams, and wells used for domestic purposes. Agrochemical runoff has been associated with biodiversity loss, particularly among aquatic organisms, and with disruption of soil microbial communities, which compromises long-term soil productivity (Heywood, 2017; Morton, 2022). Several studies have also linked chronic exposure to agrochemicals with adverse human health outcomes, including respiratory disorders, neurological impairment, endocrine disruption, reproductive abnormalities, and increased cancer risk (Awotoye et al., 2012; Oladipo et al., 2023).

Beyond environmental contamination, the persistence of pesticide and herbicide residues in edible crops represents a direct food safety concern. The Codex Alimentarius Commission and other regulatory bodies have established maximum residue limits (MRLs) for many agrochemicals in food crops, typically in the $\mu\text{g}/\text{kg}$ (ppb) to low mg/kg (ppm) range, to minimize risks to consumers. Studies conducted in Nigeria and other West African countries have reported detectable residues of atrazine, chlorpyrifos, cypermethrin, and glyphosate in root and tuber crops, sometimes exceeding recommended MRLs. For example, investigations in southwestern Nigeria have documented pesticide residues in cassava and yam tubers linked to intensive herbicide and insecticide use, raising concerns about cumulative dietary exposure (Awoyinka et al., 2019; Akinola et al., 2021). Similar findings have been reported for cocoyam and sweet potato in Ghana and Benin Republic, where herbicide residues were detected in concentrations associated with inappropriate application practices and poor adherence to safety guidelines (Boateng et al., 2020; Kpanou et al., 2022).

Despite these growing concerns, research on pesticide and herbicide residues in yam tubers in Nigeria remains limited and geographically uneven. Most existing studies focus on cereals and vegetables, with comparatively fewer investigations addressing root and tuber crops, particularly in the North Central region. Furthermore, many published works emphasize farmers' knowledge and perception of pesticide risks without integrating residue

analysis in harvested produce. Where residue studies exist, they are often localized and do not adequately capture variations in agrochemical use across different production zones (Ekwoba et al., (2026).

Kwande Local Government Area (LGA) is one of the major yam-producing regions in Benue State, characterized by high weed pressure and pest incidence. Farmers in this area depend heavily on agrochemicals for weed and pest control, often with limited access to extension services and formal training on safe application practices. However, empirical data on the presence and concentration of herbicide and pesticide residues in yam tubers from Kwande LGA are scarce. The absence of such data creates uncertainty regarding consumer exposure, environmental sustainability, and regulatory compliance with established MRLs. Moreover, there is inadequate documentation of farmers' awareness of the long-term environmental and health implications of agrochemical use in this region.

This study therefore addresses a critical knowledge gap by providing a scientific assessment of chemical (herbicide and pesticide) risks associated with yam production in Kwande LGA of Benue State. By integrating information on agrochemical use with residue determination in yam tubers, the study contributes to food safety research and environmental risk assessment in root and tuber crops. The findings are expected to inform policymakers on the need for improved regulation and monitoring of agrochemical use, support agricultural extension services in promoting safer and more sustainable farming practices, and contribute to the academic literature on agrochemical residue dynamics in yam-based farming systems in Nigeria.

MATERIALS AND METHODS

Study Area

Kwande LGA is located in northeastern Benue State, Nigeria, between latitudes $6^{\circ}30'N$ and $7^{\circ}10'N$ and longitudes $9^{\circ}00'E$ and $9^{\circ}30'E$. It is characterized by a tropical savanna climate with rainy and dry seasons. The region is agriculturally productive, with yam, cassava, maize, and rice as major crops. The River Katsina-Ala supports irrigation and farming activities.

Kwande LGA comprises fifteen council wards, including Adikpo, Liev 1, Liev 2, Moon, Nanev, and Turan. Farming practices vary across upland and lowland zones, providing a suitable setting for comparative analysis of agrochemical use.

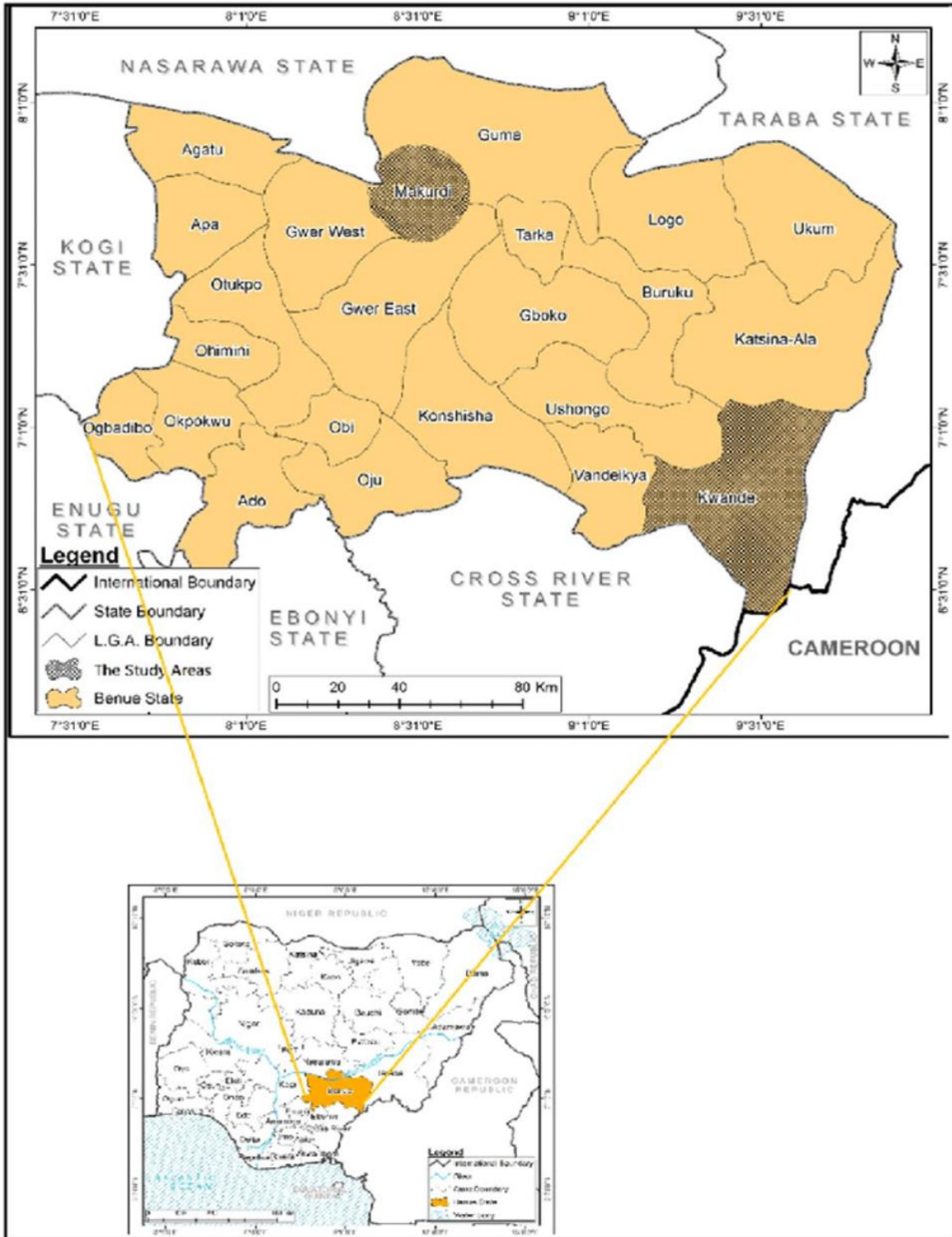


Figure 1: Showing Map of Kwande

Sampling Sites

A stratified random sampling technique was used. Twelve villages were purposively selected from three major zones: Kwande North, South, and West. Thirty yam farmers were

randomly interviewed (10 per zone). Thirty yam tuber samples were collected for laboratory analysis (10 per zone).

Table 1: Yam Productivity Communities in Kwande LGA

S/No.	Location	Villages	Frequency	Percentage (%)	Mean
1.	Kwande North	Adikpo	2	6.5	9(29.4)
		Liev 1	2	6.5	
		Liev 2	2	6.5	
		Ahile	3	10.5	
2.	Kwande South	Ikyurav	2	6.5	11(38.2)
		JatoAka	3	10.5	
		Adagi	2	6.5	
		Shangev-ya 1	3	10.4	
		Shangev ya 2	1	4.5	
3.	Kwande west	Nanev	4	15.5	10(32.4)
		Moon	2	6.5	
		Turan	4	15.5	
Total	3	12	30	100	30(100)

Agrochemical Use

Herbicide use was reported by 91.2% of farmers, while 73.5% used pesticides. Common brands included Force Up (25.0%) and Saro-sate (18.2%).

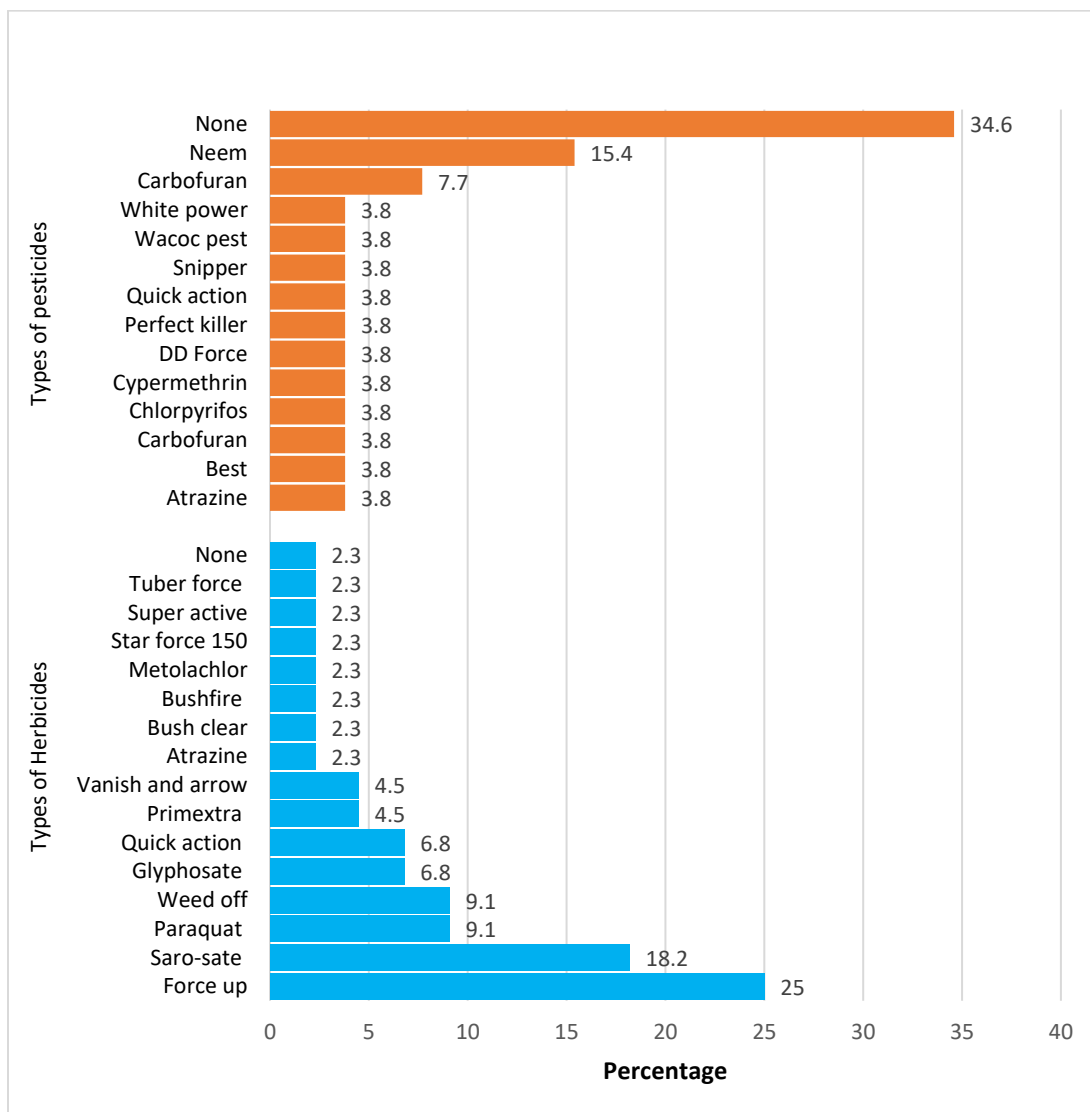


Figure 2: Types of Herbicides and Pesticides used by Yam Farmers

Perceived Environmental and Health Effects

Soil pollution (58.8%) and water contamination (55.6%) were the most frequently reported environmental effects.

Health problems included skin irritation (82.4%), respiratory issues (64.7%), nausea (50%), and headaches (38.2%).

Table 2: Perceived Effect of Herbicides and Pesticides on the Environment and Farmers' Health

Perception	F	%
Environmental effect		
Soil pollution	20	58.8
Water contamination	19	55.6
Death of animals	16	47.1
Others	8	23.6
Effect on human		
Skin Irritation, Rashes, and Blisters.	28	82.4
Respiratory Issues	22	64.7
Nausea	17	50
Vomiting	15	44.1
Headaches	13	38.2
Dizziness	15	44.1
Miscarriage	11	38.2
Birth Defects	13	38.2
Death	11	32.4

Sample Preparation

Fresh yam tubers were washed with distilled water, peeled, sliced, air-dried at ambient temperature, and homogenized into fine powder using a stainless-steel grinder. Representative subsamples (10 g) were weighed into 50 mL centrifuge tubes for residue extraction.

Extraction and Clean-up (QuEChERS Method)

Pesticide and herbicide residues were extracted using the QuEChERS (Quick, Easy, Cheap, Effective, Rugged, and Safe) method. Ten milliliters of acetonitrile were added to each sample and shaken vigorously for 1 min. A salt mixture (4 g MgSO₄ and 1 g NaCl) was added, followed by centrifugation at 4,000 rpm for 5 min.

An aliquot of the supernatant was subjected to dispersive solid-phase extraction (d-SPE) clean-up using primary secondary amine (PSA), C18 sorbent, and MgSO₄ to remove organic acids, sugars, and pigments. The cleaned extract was filtered through a 0.22 µm membrane filter prior to instrumental analysis.

Instrumental Analysis

Residue determination was carried out using GC-MS/MS for cypermethrin, chlorpyrifos, atrazine, and metazachlor, and LC-MS/MS for glyphosate and paraquat, due to their high polarity and thermal instability.

Quantification was achieved using external calibration with certified analytical standards prepared in matrix-matched solutions. Identification was based on retention time matching and confirmation by at least two diagnostic ion transitions per compound.

Validation

The analytical method was validated according to international guidelines (e.g., SANTE/12682/2019). The following parameters were evaluated:

Linearity: Calibration curves showed coefficients of determination (R^2) ≥ 0.995 for all analytes.

Recovery: Mean recoveries ranged between 80–110% at three fortification levels (0.01, 0.05, and 0.1 mg/kg).

Precision: Intra-day and inter-day relative standard deviations (RSDs) were $< 15\%$.

Limit of Detection (LOD): 0.001–0.005 mg/kg.

Limit of Quantification (LOQ): 0.01 mg/kg.

Matrix effects: Signal suppression/enhancement was $\leq \pm 20\%$ and corrected using matrix-matched calibration.

These validation results demonstrate that the method is suitable for reliable determination of pesticide and herbicide residues in yam tubers.

Quantitative Determination of Herbicide Residues in Yam Tubers

Residue concentrations were expressed in mg/kg (ppm). The mean concentrations of detected herbicides are presented below:

Concentration (mg/kg) of Herbicide Residues in Yam Tubers

Kwande North: 0.042 \pm 0.008

Kwande West: 0.091 \pm 0.012

Kwande South: 0.087 \pm 0.010

Metazachlor and atrazine were the most frequently detected herbicides. Residue levels were highest in Kwande West and Kwande South and lowest in Kwande North. Although detectable, most residues were below or

close to established international Maximum Residue Limits (MRLs).

Quantitative Determination of Pesticide Residues in Yam Tubers

Concentration (mg/kg) of Pesticide Residues in Yam Tubers

Kwande North: 0.035 ± 0.009

Kwande West: 0.124 ± 0.018

Kwande South: 0.109 ± 0.014

Cypermethrin and chlorpyrifos were the dominant insecticides detected. Kwande West recorded the highest pesticide burden, suggesting more intensive pesticide application in that region.

Interpretation of Results

The observed variation in pesticide and herbicide residue levels among Kwande North, West, and South may be attributed to differences in agrochemical usage patterns, frequency of application, and environmental conditions affecting pesticide persistence and uptake.

Residue identification was confirmed by chromatographic retention times and MS/MS ion transitions rather than by Rf values, thereby eliminating ambiguity associated with TLC-based identification.

The relatively low standard deviations indicate uniform contamination within sampling locations, while inter-regional differences suggest spatial variability in pesticide use.

Reliability

The replacement of ethanol extraction, TLC identification, and UV-Vis colorimetry with QuEChERS extraction coupled with GC-MS/MS and LC-MS/MS provides:

Reliable compound-specific identification

Accurate quantification at trace ($\mu\text{g}/\text{kg}$) levels

Scientifically defensible comparison with MRLs

Validated analytical performance

This validated multi residue approach ensures that the reported pesticide and herbicide concentrations in yam tubers are robust, reproducible, and suitable for regulatory and public health interpretation.

Discussion

This study confirms extensive use of herbicides and insecticides in yam production across Kwande North, West, and South, as evidenced by the detection of metazachlor, atrazine, cypermethrin, chlorpyrifos, glyphosate, and paraquat in yam tubers. Similar findings of multiple pesticide residues in root and tuber crops have been reported in southwestern Nigeria (Awoyinka et al., 2019; Akinola et al., 2021) and Ghana (Boateng et al., 2020), indicating that intensive agrochemical use is widespread in tuber-based farming systems in West Africa. Residue analysis using QuEChERS extraction with

GC-MS/MS and LC-MS/MS revealed marked spatial variation, with Kwande West recording the highest mean concentrations, followed by Kwande South, while Kwande North showed the lowest levels. These differences likely reflect variations in agrochemical use intensity and local agronomic conditions such as weed pressure and pest incidence, consistent with earlier observations (Awotoye et al., 2012; Morton, 2022).

The analytical approach employed in this study overcomes limitations associated with thin-layer chromatography (TLC) and Rf-based identification, which are prone to ambiguity (Adesiyun & Odihirin, 2021). The use of compound-specific retention times, diagnostic MS/MS transitions, matrix-matched calibration, and acceptable recovery rates (80–110%) supports the reliability of the results and aligns with recommended residue analysis protocols (FAO, 2021). However, the restriction of sampling to a single production season and the lack of assessment of post-harvest degradation represent limitations that warrant consideration in future multi-season studies, given the influence of environmental factors on pesticide persistence (Vegher, 2018).

Comparison with established Maximum Residue Limits (MRLs) indicates that most residues were within or close to Codex and EU thresholds (CAC, 2019; European Commission, 2020). Nevertheless, the relatively higher concentrations observed in Kwande West approach levels of concern, particularly because yam is consumed frequently and in large quantities. The detection of compounds such as chlorpyrifos, atrazine, and paraquat, which are highly regulated or restricted in many jurisdictions, raises concerns regarding cumulative dietary exposure and environmental persistence (Heywood, 2017; Oladipo et al., 2023). The co-occurrence of multiple residues further suggests the potential for additive toxicological effects (Ekwoba et al., (2026).

Farmers' perceptions corroborate these findings, with respondents linking agrochemical use to reduced crop quality, environmental contamination, and adverse health effects. Although farmers demonstrated awareness of these risks, continued reliance on chemical control reflects limited access to effective alternatives and inadequate extension support (FAO, 2021; World Bank, 1999). This highlights the need for improved risk communication and practical interventions.

The adoption of Integrated Pest Management (IPM) offers a viable pathway for reducing pesticide dependence while maintaining productivity (Omoleke et al., 2021). Strategies such as crop rotation, mulching, mechanical weed control, botanical pesticides, and judicious chemical use could substantially reduce residue accumulation. Overall, the findings underscore the need for routine residue monitoring, stronger regulatory enforcement, and wider promotion of IPM-based production systems. Future research should incorporate multi-season sampling and

confirmatory analyses using certified reference standards to improve assessment of long-term exposure risks and inform sustainable yam production policies.

CONCLUSION

This study provides evidence of widespread herbicide and pesticide use in yam production across Kwande North, West, and South, as indicated by the detection of metazachlor, atrazine, cypermethrin, chlorpyrifos, glyphosate, and paraquat in yam tubers. Residue analysis using validated QuEChERS extraction with GC-MS/MS and LC-MS/MS revealed significant spatial variation, with Kwande West recording the highest concentrations, followed by Kwande South, while Kwande North showed the lowest levels. These differences reflect variation in agrochemical use intensity and local agronomic conditions. Although most residues were within or close to established Maximum Residue Limits, their occurrence in a staple food crop raises concerns about cumulative dietary exposure and potential long-term health risks, particularly for vulnerable populations. The presence of highly regulated or restricted compounds further highlights environmental and sustainability concerns. Continued reliance on chemical control methods, despite awareness of associated risks, suggests limited access to effective alternatives and inadequate extension support. Strengthened regulatory oversight, routine residue monitoring, farmer education, and wider adoption of Integrated Pest Management strategies are therefore essential. Further multi-season studies using certified reference standards are recommended to better assess long-term exposure risks and support evidence-based policy for safer and more sustainable yam production systems.

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