

Influence of Soil Physicochemical Properties and Farmers' Pesticide Practices on Cypermethrin Residue Levels in Cowpea (*Vigna unguiculata*) in Keffi, Nigeria

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Abstract

This study assessed the influence of soil physicochemical properties and farmers' pesticide use practices on cypermethrin residue levels in cowpea (*Vigna unguiculata*) cultivated in Keffi, Nasarawa State. A field experiment was conducted using five treatment plots. Soil samples were analyzed for physicochemical properties using pH meter, Walkley-Black, Bray-1, and EDTA titration methods, while pesticide residues in cowpea were extracted by solvent extraction and analysed by Thin Layer Chromatography (TLC) for detection and UV-Vis spectroscopy for quantification. In addition, 45 cowpea farmers were surveyed to assess pesticide use behaviour, safety practices, and constraints. Soil analysis revealed a neutral pH (7.3), low cation exchange capacity (4.92 cmol/kg), moderate organic matter (4.47%), and a sandy loam texture dominated by sand (80%). These characteristics suggest low pesticide retention capacity and high mobility potential. Survey results indicated that 95.6% of farmers used pesticides, with cypermethrin being the most common (66.7%). Pesticide application was frequent, with 40% often exceeding recommended dosages (800mL/ha), and largely conducted using manual spraying methods (93.3%). Poor safety practices were observed, including low use of personal protective equipment (55.6%) and failure to observe pre-harvest intervals (60%). Cowpea samples were obtained from control, single-dose, recommended-dose, multiple-dose, and double-dose treatment plots and analyzed using TLC and spectrophotometric methods. Results showed no detectable residues in the control, single-dose, and recommended-dose groups, while high residue levels were recorded in the multiple-dose (2.42 ± 2.0 mg/kg) and double-dose (2.45 ± 1.0 mg/kg) groups, exceeding the WHO/FAO limit of 0.05 mg/kg. The study highlights potential food safety risks associated with pesticide misuse and emphasizes the need for improved farmer education, stricter regulatory enforcement, and promotion of sustainable pest management practices to reduce chemical contamination in food systems. The findings demonstrate that both environmental and human factors jointly influence cypermethrin residue levels in crops and calls for further studies and action.

Keywords: Cypermethrin, Cowpea, Soil Properties, Pesticide Practices, Residue, Food Safety.

Introduction

Cowpea (*Vigna unguiculata*) is one of the most important grain legumes cultivated across sub-Saharan Africa. Nigeria is the largest producer and consumer of cowpea globally, accounting for a significant proportion of total production in West Africa ((Food and Agriculture Organization [FAO], 2022). In Nigeria, cowpea serves as a major source of affordable protein, income, and food security for millions of households. Despite its economic and nutritional importance, cowpea production is severely constrained by insect pests, especially during the flowering and podding stages, leading to substantial yield losses if not adequately controlled. As a result, farmers rely heavily on synthetic pesticides, with pyrethroids such as cypermethrin being among the most commonly used due to their broad-spectrum efficacy and relatively low cost (Huang *et al.*, 2019).

The use of pesticide in agriculture in recent times is well documented, especially in enhancing agricultural yield, and ensuring food security in developing nations. However, poor handling of pesticides presents significant risks to the crop itself and the environment, making it imperative to enhance farmers' pesticide safety and health handling practices (Jallow *et al.*, 2017). Pesticides have become an indispensable chemical used among farmers to prevent pre- and post-harvest losses, ensuring sustainable food production by increasing yields and providing year-round food availability (Adom *et al.*, 2021) partly due to climate change impacts and increased pest resistance. Around 3.5 million tons of pesticides have been used globally in 2021 with a marginal increase in its use in Africa between 2020 and 2021 from 203 kt to 204 kt (FAO, 2023). Nigeria remains a major importer of pesticides in the continent by volume with a reported 147,477 tons imported in 2020 (Vanguard, 2023). Despite its increased use in farming activity, only around 1% of these products are effectively employed in the control of farm pests, leaving the remaining as residue in other secondary media, thereby resulting in harm to both humans and the environment (Tudi *et al.*, 2022)

While cypermethrin is effective in pest control, its widespread and often indiscriminate use has raised serious concerns regarding pesticide residues in food crops and their implications for human health. Studies have shown that improper application practices including over-dosage, frequent spraying, and failure to observe pre-harvest intervals can result in the accumulation of pesticide residues beyond permissible limits (Donkor *et al.*, 2017; Akoto *et al.*, 2021). In developing countries, these practices are frequently linked to limited farmer education, poor access to extension services, and weak enforcement of regulatory guidelines (Damalas & Koutroubas, 2016; Sule *et al.*, 2020). Consequently, consumers may be exposed to unsafe levels of pesticide residues through dietary intake, posing potential risks such as endocrine disruption, neurotoxicity, and carcinogenic effects (Kim *et al.*, 2019; WHO, 2020).

Beyond human factors, the behaviour and persistence of pesticides in agricultural systems are strongly influenced by soil physicochemical properties. Soil characteristics such as pH, organic matter content, texture, and cation exchange capacity (CEC) play critical roles in determining pesticide adsorption, mobility, degradation, and bioavailability (Huang *et al.*,

2019). For instance, sandy soils with low organic matter and low CEC tend to have reduced adsorption capacity, which enhances pesticide leaching and plant uptake (Vagi & Petsas, 2021). Conversely, soils rich in organic matter can bind pesticides more effectively, thereby reducing their mobility but potentially prolonging their persistence in the environment. Understanding these interactions is essential for predicting residue levels in crops and assessing environmental contamination risks.

In many parts of Nigeria, including Keffi in Nasarawa State, agricultural soils are predominantly sandy loam with variable fertility status, which may influence pesticide dynamics in ways that are not yet fully understood. At the same time, smallholder farmers in these regions often adopt pesticide use practices that deviate from recommended guidelines, thereby compounding the risk of residue accumulation in food crops. Although several studies have examined pesticide residues in vegetables and cereals in Nigeria, there is limited integrated research that simultaneously considers the combined effects of soil properties and farmer behaviour on pesticide residue levels in cowpea.

Therefore, this study aims to investigate the influence of soil physicochemical properties and farmers' pesticide use practices on cypermethrin residue levels in cowpea cultivated in Keffi, Nigeria. By linking environmental factors with human practices, the study provides a more comprehensive understanding of the drivers of pesticide contamination in food systems. The findings are expected to contribute to improved agricultural management strategies, strengthen regulatory frameworks, and promote safer food production practices in the region.

Statement of Problem

The increasing reliance on synthetic pesticides in cowpea production raises important concerns about food safety and public health in Nigeria. Although pesticides such as cypermethrin are effective in controlling pests and improving crop yield, improper application can result in the accumulation of harmful residues in food. Importantly, the environmental persistence and plant uptake of cypermethrin depend both on the farmer pesticide application practices, also the soil physiochemical properties (pH, organic matter, and soil texture) which regulate chemical degradation. Cowpea is widely consumed in Keffi, yet there is insufficient data on the levels of pesticide residues present in this staple crop.

In addition, many previous studies have used uncontrolled or market-based sampling approaches, failing to establish clear relationships between pesticide application practices and residue levels. Farmers often do not adhere strictly to recommended guidelines regarding dosage, frequency, and pre-harvest intervals, which increases the likelihood of unsafe residue levels ($<0.05\text{mg/kg}$). These gaps highlight the need for a more systematic investigation that links farming practices and soil physiochemical properties with residue accumulation and evaluates the potential health implications.

Research Questions

- i. What are the physicochemical and nutrient properties of soils used for cowpea cultivation in Keffi?

- ii. What pesticide application practices are currently adopted by farmers in Keffi?
- iii. Are cypermethrin residues detectable in cowpea cultivated under controlled field treatments?
- iv. How do cypermethrin residue concentrations vary among cowpea samples cultivated under the five treatment plots and do these concentrations comply with internationally established Maximum Residue Limits (MRLs)?

Objectives of the Study

- i. Characterize the physicochemical and nutrient properties of soils in experimental field.
- ii. Examine farmers' pesticide use practices and adherence to safety guidelines in Keffi.
- iii. Detect and quantify cypermethrin residues in harvested cowpea samples from five treatment plots using Thin Layer Chromatography (TLC), and Ultraviolet – Visible spectroscopy (UV-Vis).
- iv. Compare residue concentrations across different treatment levels and assess compliance with international MRLs.

Materials and Methods

Field and Experimental Materials

The field work made use of cowpea seeds of the same variety to ensure consistency across all plots. Basic farm tools such as cutlasses, hoes, measuring tape, tags, labels, pegs, and markers were used to set up and identify the experimental plots. Cypermethrin (Cypergreen® 50 g L⁻¹ EC, NAFDAC Reg. No.: A5-2052, Mfd. Date: 10-02-2024, Exp. Date: 10-02-2027, Batch No.: 0245 EC/23/24), a commonly used insecticide in Keffi, was applied during the experiment. To ensure accuracy, calibrated sprayers and measuring cylinders were used so that each plot received the correct amount. For safety, personal protective equipment (PPE) such as gloves, boots, and protective clothing were worn during pesticide application.

Study Area

The study was conducted in Keffi (latitude 8°50'N and longitude 7°52'E), Nasarawa State, Nigeria. The area lies within the Guinea savannah agro-ecological zone and is characterized by a tropical climate with distinct wet and dry seasons (Ishaya and Lawal, 2022). Soils in the region are predominantly sandy loam, supporting arable crop production, including cowpea.

Plant Material

The Cowpea seeds were bought in late May from the Aduga Farm Nig. Ltd, Keffi, Nasarawa State. It was identified by Prof. J.C. Onovo (Department of Plant Science and

Biotechnology, Nasarawa State University, Keffi) and a voucher specimen was deposited in the departmental herbarium under voucher number: NSUK/PSB/97.



Figure 1: Image showing Cowpea seeds used in the study.

Source: Aduga Farm Nig. Ltd, Keffi.

Laboratory Equipment and Chemicals

For pesticide residue analysis, Thin Layer Chromatography (TLC) materials were used, including silica gel plates, solvent mixtures (such as n-hexane and ethyl acetate), acetone, methanol, distilled water, analytical-grade cypermethrin standard, glassware, developing chambers, UV lamps (254 nm and 366 nm), and capillary tubes. UV–Visible spectrophotometry was also used, along with quartz cuvettes, standard pesticide solutions, and calibration records for quantification. General laboratory tools such as: an oven, a blender for sample preparation, centrifuge tubes, filter paper (Whatman No. 1), an analytical balance, and a fume hood for safe handling. All chemicals used were of analytical grade.

Soil Sampling and Analysis

Soil samples were collected from the experimental plots at a depth of 0–20 cm prior to planting. Samples were air-dried, crushed sieved (via 2-mm sieve), and analyzed for physicochemical properties and soil particle size distribution. Soil pH was determined in a soil water suspension using a glass electrode pH meter, while electrical conductivity was measured using electrical conductivity meter. Organic carbon was determined by the Walkley and Black wet oxidation method, and organic matter was calculated from it. Cation exchange capacity (CEC) and exchangeable acidity were determined by the ammonium acetate method and base saturation were determined using standard analytical procedures. Nutrient analysis was also conducted for nitrogen using Kjeldahl digestion method, available phosphorus was determined using the Bray-1 extraction method. Potassium and sodium were determined by flame photometry, calcium and magnesium

were determined using standard EDTA titration procedures following established soil analytical methods ((Black, 1965; Jackson, 1973). Particle size distribution was determined using the Bouyoucos hydrometer method, and the soil texture classification was assigned using the USDA textural triangle.

Survey of Farmers' Pesticide Practices

A survey conducted among forty-five (45) farmers randomly selected from the study area using a structured fully anonymous questionnaire. The questionnaire was administered electronically to cowpea farmers within the study area using the surveyheart.com to obtain information on socio-demographic characteristics, pesticide use patterns, application frequency, dosage, and adherence to safety guidelines. In accordance with the Nigerian National Code of Health Research Ethics (NCHRE), the study met the criteria for exemption from formal institutional review boards due to its completely non-identifiable, minimal-risk nature (National Health Research Ethics Committee [NHREC], 2007). Implied informed consent was established when participants voluntarily completed and submitted the anonymous survey forms. Data were collected through the surveyheart.com platform. This enabled real-time recording, storage and export of responses for analysis. The responses were analyzed using simple statistics such as frequencies, percentages, and averages.

Instrument Validity and Pre-testing.

The survey instrument underwent a structured validation and refinement process prior to deployment. To establish face and content validity, the questionnaire was initially reviewed by a panel of three experts in agricultural extension, phytomedicine & molecular genetics and environmental toxicology. based on their review, technical modifications were made to simplify technical terminology and clarify questions regarding pesticide chemical names, application frequencies and specific pre-harvest intervals. Following these adjustments, a field pre-test was conducted with a small cohort of local farmers sharing similar demographics to the target population. This pre-test ensured the questions were clear, culturally acceptable, and that local volumetric spray measurements were accurately captured. Data and feedback from the pre-test phase were used to finalize the survey structure, and pre-test participants were excluded from the final 45-farmers study sample.

Experimental Design and Field Treatment

A field experiment was carried out using a Randomized Complete Block Design (RCBD), with five different treatments applied across three replicates, giving a total of fifteen plots: T_0 = control (no pesticide), T_1 = single application, T_2 = recommended dose, T_3 = multiple application, and T_4 = double recommended dose of cypermethrin. The land was cleared manually and ridges were made for planting in August, 2025 at the experimental site in Keffi and harvested in November, 2025. Cowpea seeds were planted under uniform agronomic conditions, and pesticide treatments were applied at designated growth stages following standard farming practice and farmer's behaviors. Each plot covered an area of 5 m by 5 m

(25 m²) and was made up of six ridges. A spacing of 1.5 m was maintained between ridges and between the replicates to reduce any chances of overlap or interference between treatments.

The Plot Treatment Structure:

T₀: Control (no cypermethrin application) – 0 mL

T₁: Single application at infestation stage (farmer's practice) – 2 mL

T₂: Multiple applications (vegetative and flowering stages), at 4-days intervals (farmer's practice) – 2 mL

T₃: Recommended dose according to manufacturer specifications – 2 mL

T₄: Twice the recommended dose (2× RD), at 7-days intervals (farmer's practice) – 4 mL

Determination and Application of Cypermethrin Dosage

The recommended application rate of cypermethrin is 800 ml per hectare (10,000 m²). The experimental plot used in this study measured 5 m × 5 m, giving a total surface area of 25 m². Cypermethrin (Cypergreen® 50 g L⁻¹ EC) was applied at the recommended dose (RD) specified on the product label (800 mL ha⁻¹). For each experimental plot measuring 25m² (5 m × 5 m), the corresponding recommended dose was calculated as 2.0 mL plot⁻¹. The required volume of cypermethrin was measured using a graduated syringe and diluted in 500mL of water before uniform application to the designated plots. All treatments were applied uniformly to the respective plots using a calibrated hand-held sprayer.

Residue Extraction and Analysis

Cowpea grains were harvested at full maturity from all the treatment plots after twelve (12) weeks of cultivation. About 500g of grains were collected from each plot, properly labeled, and left to air-dry at room temperature. Once dried, the samples were ground into a fine powder using a mortar and pestle. The powdered samples were then stored in amber glass containers at –20°C to preserve them and prevent any breakdown before analysis.

Cypermethrin residues were extracted using standard solvent extraction methods and analyzed using Thin Layer Chromatography (TLC) for detection and Ultraviolet–Visible (UV-Vis) spectroscopy for quantification following standard pesticide residue analytical procedures (AOAC, 2016).

Data Analysis

Data obtained from soil analysis and survey responses were subjected to descriptive statistical analysis using The IBM SPSS 23.0 Results were summarized using frequencies and percentages. Residue levels were evaluated for compliance by comparing detected levels against established maximum residue limits (MRLs = 0.05mg/kg).

Results and Discussion

Result

Soil Analysis Results

The soil analysis (Table 1) showed a neutral pH (7.3) and electrical conductivity of 145 ms/cm. Organic carbon (2.60%) and organic matter (4.47%) were moderate, with nitrogen at 0.56% and available phosphorus at 8.362 ppm. Exchangeable bases included K (0.21), Na (0.18), Ca (2.36), and Mg (1.89). Exchangeable acidity was 0.33, Cation Exchange Capacity (CEC) was low (4.92), and base saturation was high (93%).

The particle size distribution of the soil as presented in Table 2 reveals that the soil comprises of 80% sand, 5.4% silt, and 14.6% clay, and was classified as sandy loam.

Table 1: Soil Physicochemical and Nutrient Properties of the Soil

Parameter	Value
pH (H ₂ O)	7.3
Electrical Conductivity ((μS/cm)	145
Organic Carbon (%)	2.60
Organic Matter (%)	4.47
Nitrogen (%)	0.56
Available Phosphorus (ppm)	8.362
Potassium (K)	0.21
Sodium (Na)	0.18
Calcium (Ca)	2.36
Magnesium (Mg)	1.89
Exchangeable Acidity (E.A)	0.33
Cation Exchange Capacity (CEC)	4.92
Base Saturation (%)	93

Source: Laboratory Analysis, 2026

Table 2: Soil Particle Size Distribution

Parameter	Value
Sand (%)	80
Silt (%)	5.4
Clay (%)	14.6
Textural Class	Sandy loam

Source: Laboratory Analysis, 2026

Survey Results

Table 3-7 reveals the survey responses from respondents in the questionnaire distributed. Table 3 shows Socio-Demographic Characteristics of Respondents. The result showed that most farmers were within the active age group (31–40 years), predominantly male (75.6%) with over half having tertiary education (51.1%), though some still had limited formal education (20.0%).

Table 4 showed response on pesticide use among respondents. The table indicates widespread pesticide use (95.6%), with cypermethrin being the most common (66.7%). Application is frequent, mainly twice per season (44.4%) or weekly (40.0%), suggesting intensive use (100%).

Table 5 reveals the pesticide use and awareness result. It shows that pesticides were applied at all crop stages, including flowering (71.1%) and fruiting (44.4%). About 40% of farmers exceeded recommended doses, while manual spraying was dominant (93.3%).

Table 6 highlights poor safety practices. Over half of the farmers did not use Personal protective Equipment - PPE (55.6%), 35.6% never read labels, and 60% did not observe waiting periods, despite moderate awareness (62.2%).

Table 7 shows the challenges faced by farmers. Key challenges include high cost purchasing pesticides (26.7%), pest resistance (22.2%) and the least challenge being inadequate information on pesticide handling and alternative pest control methods (13.3%) which likely contributed to pesticide misuse

Survey Results

Table 3: Socio-Demographic Characteristics of Respondents (n = 45)

Variable	Category	Frequency	Percentage (%)
Age	Under 20	1	2.2
	21–30	10	22.2
	31–40	16	35.6
	41–50	10	22.2
	50 and above	8	17.8
Gender	Male	34	75.6
	Female	11	24.4
Education	No formal education	9	20.0
	Primary	3	6.7
	Secondary	10	22.2
	Tertiary	23	51.1

Source: Field Survey, 2025

Table 4: Pesticide Use Among Respondents

Variable	Category	Frequency	Percentage (%)
Use	Yes	43	95.6
	No	2	4.4
Type	Cypermethrin	30	66.7
	Dimethoate	8	17.8
	Lambda-cyhalothrin	7	15.5
Frequency	Weekly	18	40.0
	Twice season	20	44.4
	Once per season	7	15.6

Source: Field Survey, 2025

Table 5: Pesticide Application Practices

Variable	Category	Frequency	Percentage (%)
Stage	Vegetative	45	100
	Flowering	32	71.1
	Fruiting/Harvest	20	44.4
Quantity	Recommended dose	22	48.9
	Above recommended	18	40.0
	Below recommended	5	11.1
Method	Manual spraying	42	93.3
	Motorised spraying	3	6.7

Source: Field Survey, 2025

Table 6: Safety Practices and Awareness

Variable	Category	Frequency	Percentage (%)
Read label	Always	15	33.3
	Sometimes	14	31.1
	Never	16	35.6
PPE	Yes	20	44.4
	No	25	55.6
Awareness	Yes	28	62.2
	No	17	37.8
Waiting period	Yes	18	40.0
	No	27	60.0

Key: PPE = Personal Protective Equipment

Source: Field Survey, 2025

Table 7: Challenges Faced by Farmers

Challenge	Frequency	Percentage (%)
High cost of purchasing pesticides	12	26.7
Inadequate information on pesticide handling and alternative pest control methods	6	13.3
Toxicity concerns on farmers	8	17.8
Pest resistance	10	22.2
Others (NA)	9	20.0

Source: Field Survey, 2025

The chromatographic analysis revealed clear distinctions among treatment groups. Control (T_0): Only a single spot ($R_f = 0.16$) was observed, with no detectable cypermethrin (ND), confirming absence of contamination. Single Dose (T_1): Similar to control, only $R_f =$

0.16 was recorded, indicating that a single application did not result in detectable pesticide residue. Multiple Dose (T₂): Two distinct spots (R_f = 0.16 and 0.88) were observed, with the latter corresponding to the standard (R_f = 0.88), confirming residue accumulation. Recommended dose (T₃) and twice-recommended dose (T₄) Showed similar dual spots, supporting consistency of detection.

Table 8: TLC Analysis of Cowpea

Sample	Ref
T ₀ - Control	0.16
T ₁ - Single-dose	0.16
T ₂ - Multiple-dose	0.16, 0.88
T ₃ - Recommended-dose	0.16, 0.76
T ₄ - Double Recommended-dose	0.16, 0.88

Ref: Standard Cypermethrin = 0.88

Source: Laboratory Analysis, 2025

Cypermethrin Residue Composition in Cowpea

Table 9 shows the level of cypermethrin residues in cowpea samples across different treatments. The control, single-dose, and recommended-dose samples all recorded no detectable residues (ND), indicating no pesticide presence at those levels. However, residues were detected in the multiple-dose (2.42±2.0 mg/kg) and double recommended-dose (2.45±1.0 mg/kg) samples, showing that higher application rates led to significant pesticide accumulation in the cowpea grains. In comparison, the WHO/FDA permissible limit is very low (0.05 mg/kg), meaning that the detected levels in the multiple and double-dose treatments are far above the recommended safety threshold, which raises potential food safety concerns.

Table 9: Composition of Cypermethrin in Cowpea

Sample	Composition (mg/kg)
T ₀ - Control	ND
T ₁ - Single-dose	ND
T ₂ - Multiple-dose	2.42±2.0
T ₃ - Recommended-dose	ND
T ₄ - Double Recommended-dose	2.45±1.0

N.D = No detection

WHO/FDA = 0.05 mg/kg

Source: Laboratory Analysis, 2025

Discussion

The findings of this study provide important insights into how soil physicochemical properties and farmers' pesticide use practices influence cypermethrin residue levels in cowpea cultivated in Keffi, Nigeria. The results show a clear interaction between

environmental soil conditions and human agricultural behaviour, both of which jointly determine pesticide persistence and potential food safety risks.

The soil analysis revealed a neutral pH (7.3), moderate organic matter, and low cation exchange capacity, with a sandy loam texture dominated by sand. These characteristics are consistent with the Guinea savannah soils of central Nigeria, which are typically low in nutrient retention capacity and highly permeable (Ishaya and Lawal, 2022). The low CEC observed in this study suggests limited adsorption of pesticide molecules, thereby increasing their mobility and availability for plant uptake. Similar observations were reported by Silva *et al.* (2019), who reported that sandy soils with low organic matter could facilitate greater pesticide leaching and bioavailability compared to clay-rich soils.

The survey results showed that pesticide use among farmers was almost universal, with cypermethrin being the most frequently applied pesticide. This aligns with findings by Damalas and Koutroubas (2016), who observed that pyrethroids remain among the most widely used insecticides in smallholder farming systems due to their affordability and perceived effectiveness. However, the high frequency of application observed in this study (weekly or multiple times per season) reflects misuse and over-reliance on chemical control, a trend well documented in West African agricultural systems (Okoffo *et al.*, 2016; Sule *et al.*, 2020).

A particularly important observation is the widespread deviation from recommended pesticide application practices. About 40% of farmers applied cypermethrin above recommended doses, and pesticide application occurred across all growth stages, including flowering and fruiting. This observed trend agrees with the findings of Kapeleka (2024), who reported that smallholder farmers in Tanzania often exceed recommended pesticide dosages due to pest pressure and lack of technical guidance. Application during reproductive stages is especially critical, as it increases the likelihood of pesticide residues persisting in edible plant parts at harvest (Food and Agriculture Organization [FAO] & World Health Organization [WHO], 2023). The absence of adherence to pre-harvest intervals, as observed in this study, further exacerbates residue accumulation, a concern also highlighted by Donkor *et al.* (2017).

The absence of cypermethrin residues in the control, single-dose, and recommended-dose groups, as revealed by TLC and quantitative analysis, agrees with the findings of FAO/WHO (2021), who reported that adherence to Good Agricultural Practices (GAP) minimizes pesticide residues in food crops. However, the extremely high residue levels recorded in the multiple-dose (2.42 ± 2.0 mg/kg) and double-dose (2.45 ± 1.0 mg/kg) groups, which greatly exceeded the WHO/FAO limit of 0.05 mg/kg, confirm that repeated pesticide application promotes bioaccumulation. Similar trends were reported by Donkor *et al.* (2017), Kim *et al.*, 2019 and Tudi *et al.* (2022); they observed elevated pesticide residues in commonly consumed crops due to excessive field application and poor compliance with pre-harvest intervals.

Safety practices among the farmers were generally poor. More than half of the respondents did not use personal protective equipment (PPE), and a significant proportion did not read

pesticide labels or observe waiting periods. Similar behavioural patterns have been reported in developing countries, where limited training and inadequate extension services contribute to unsafe pesticide handling practices (Ngowi *et al.*, 2007; Madaki *et al.*, 2017). Although 62.2% of respondents indicated awareness of pesticide residues, this awareness did not translate into safe practices, reflecting a well-documented knowledge–practice gap in pesticide management systems (Sharma *et al.*, 2021; Moda *et al.*, 2022). The major challenges identified were high cost of pesticides, pest resistance, and limited access to relevant information which are in consonant with previous studies published across sub-Saharan Africa. For instance, Narmadha *et al.* (2025) reported that pest resistance drives farmers to increase pesticide dosage, while economic constraints often lead to improper application decisions.

Similarly, Kapeleka *et al.* (2020) noted that lack of extension support significantly contributes to pesticide misuse and poor compliance with safety standards. To encourage safe farm practices, educational background of farmers, training and appropriate orientation are relevant parameters as they shape safety practices and enhance critical thinking, alongside an increased tendency to apply required controls to help minimize associated risk and improve safety consideration (Oshingbade *et al.*, 2025).

However, it is important to emphasize that the major challenges identified — high cost of pesticides, pest resistance, and inadequate information usually create conditions that drive non-adherence to standardized guidelines. Also, economic pressure and pest pressure often lead farmers to increase dosage or frequency to achieve immediate pest control, even when it compromises residue safety. When combined with the low CEC and sandy texture of Keffi soils, these human factors create a high-risk scenario for cypermethrin accumulation in cowpea grains.

Conclusion

This study demonstrates that cypermethrin residue levels in cowpea are influenced by both soil physicochemical properties and farmers' pesticide application practices. The sandy loam soil with low cation exchange capacity enhances pesticide mobility and uptake, while widespread misuse of pesticides, including over-application and failure to observe safety intervals, increases residue accumulation in harvested cowpea. The combined effect of environmental conditions and poor agricultural practices presents a potential food safety risk and highlights the need for integrated management strategies.

Recommendations

Given that 40% of cowpea farmers applied cypermethrin above the recommended doses and 60% did not observe pre-harvested intervals, while 55.6% failed to use PPE, Agricultural Development Programs (ADPs) and extension workers should conduct regular training on correct dosage, application timing, and strict appliance to pre-harvest intervals using demonstration plots and local language materials.

Also, the residue levels exceeded NAFDAC Maximum Residue Limits (0.05mg/kg) in some samples, the National Agency for Food and Drug Administration and Control and Nasarawa

State Ministry of Agriculture should therefore intensify surveillance of cypermethrin residues in cowpea at farm gates and markets, as routine screening will enforce compliance deter indiscriminate pesticide use.

Furthermore, since the sandy loam soil with low cation exchange capacity of 4.92 cmol/kg and 80% sand showed high pesticide mobility, research institutions and NGOs should endeavour to promote Integrated Pest Management strategies that includes pest-resistant varieties. Farmers should also increase organic matter through residue retention and manure application to reduce pesticide uptake by cowpea.

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References

- Adom, J.A.; Dzidzienyo, D.K.; Ofori-Anim, J. (2021). Retailers' knowledge and practices on the storage and handling of certified vegetable seeds: A case study of the Ashanti Region Ghana. *Sustain. Futures*, 3, 100059. <https://www.sciencedirect.com/science/article/pii/S2666188821000186>
- Akoto, O., Gavor, S., Appah, M. K., & Apau, J. (2015). Estimation of human health risk associated with the consumption of pesticide-contaminated vegetables from Kumasi, Ghana. *Environmental Monitoring and Assessment*, 187(5), Article 244. [doi.org](https://doi.org/10.1007/s10661-015-4888-2)
- AOAC International. (2016). *Official methods of analysis of AOAC International* (G. W. Latimer, Jr., Ed.; 20th ed.). AOAC International. [aoac.org](https://www.aoc.org)
- Black, C. A. (Ed.). (1965). *Methods of soil analysis*. American Society of Agronomy.
- Damalas, C. A., & Koutroubas, S. D. (2016). Farmers' exposure to pesticides: Toxicity types and ways of prevention. *Toxics*, 4(1), Article 1. [doi.org](https://doi.org/10.3390/toxics4010001)
- Donkor, A., Osei-Fosu, P., Dubey, B., Essumang, D. K., Kouli, B., & Asante, K. A. (2017). Pesticide residues in fruits and vegetables in Ghana: a review. *Environmental Science and Pollution Research*, 24(28), 22119–22133. [doi.org](https://doi.org/10.1007/s11356-017-0000-0)
- Food and Agriculture Organization & World Health Organization. (2021). *Pesticide residues in food 2021: Joint FAO/WHO Meeting on Pesticide Residues*. FAO Plant Production and Protection Paper. [doi.org \[1\]](https://doi.org/10.2478/9789251095000)
- Food and Agriculture Organization, & World Health Organization. (2023). *International code of conduct on pesticide management: Guidance on monitoring the observance and implementation of the Code of Conduct*. FAO. <https://doi.org/10.4060/cc5124en>
- Food and Agriculture Organization. (2022). *FAOSTAT statistical database*. <https://www.fao.org/faostat/en/#data/RT>

- Food and Agriculture Organization. (2023). *Pesticides use and trade, 1990–2021* (FAOSTAT Analytical Briefs Series No. 70). Available at: doi.org.
- Huang, Y., Xiao, L., Li, F., Xiao, M., Lin, D., Long, X., & Wu, Z. (2018). Microbial Degradation of Pesticide Residues and an Emphasis on the Degradation of Cypermethrin and 3-phenoxy Benzoic Acid: A Review. *Molecules (Basel, Switzerland)*, 23(9), 2313. <https://doi.org/10.3390/molecules23092313>
- Ishaya, S. K., & Lawal, D. M. (2022). Analysis of soil nutrients status under different cropping types in Karu Local Government Area of Nasarawa state Nigeria. *African Journal of Agricultural Science and Food Research*, 3(1), 51-53.
- Jackson, M. L. (1973). *Soil Chemical Analysis*. Prentice Hall of India, New Delhi.
- Jallow, M., Awadh, D., Albaho, M., Devi, V., & Thomas, B. (2017). Pesticide knowledge and safety practices among farm workers in Kuwait: Results of a survey. *International Journal of Environmental Research and Public Health*, 14(4), [Article340.doi.org](https://doi.org/10.3390/ijerph14040340)
- Kapeleka J. A. (2024). Quantification of pesticide dosage and determinants of excessive pesticide use in smallholder vegetable production systems in Tanzania. *Heliyon*, 10(24), e41070. <https://pmc.ncbi.nlm.nih.gov/articles/PMC11665471/>
- Kapeleka, J. A., Sauli, E., & Maeda, D. (2020). Understanding farmers' safety behavior regarding pesticide use in Tanzania: An integration of behavioral theories and soil science. *International Journal of Environmental Research and Public Health*, 17(18), [Article6479.doi.org](https://doi.org/10.3390/ijerph171806479)
- Kim, K. H., Kabir, E., & Jahan, S. A. (2017). Exposure to pesticides and the associated human health effects. *Science of the Total Environment*, 575, 525–535. [doi.org](https://doi.org/10.1016/j.scitotenv.2016.11.048)
- Madaki, M. Y., Lehberger, M., Bavorova, M., Igbanan, B. T., & Kächele, H. (2024). Effectiveness of pesticide stakeholders' information on pesticide handling knowledge and behaviour of smallholder farmers in Ogun State, Nigeria. *Environment, Development and Sustainability*, 26(7), 17185–17204. [doi.org](https://doi.org/10.1007/s10646-024-03000-0)
- Moda, H. M., Anang, D. M., Moses, N., Manjo, F. M., Joshua, V. I., Christopher, N., Doka, P., & Danjin, M. (2022). Pesticide Safety Awareness among Rural Farmers in Dadinkowa, Gombe State, Nigeria. *International journal of environmental research and public health*, 19(21), 13728. <https://pmc.ncbi.nlm.nih.gov/articles/PMC9657592/>
- Narmadha, N., Manimekalai, R., Janaki, R. A., Asokhan, M., Sumathi, E., & Padmarani, S. (2025). Do farmers overuse pesticides? A critical review from their perspective. *Plant Science Today*, 12(2). <https://doi.org/10.14719/pst.7376> (Original work published May 4, 2025)
- National Health Research Ethics Committee of Nigeria. (2007). *National code of health research ethics*. Federal Ministry of Health. <https://healthresearchwebafrica.org.za/files/NCHRECurrentVersion.pdf> [1, 2]
- Ngowi, A. V., Mbise, T. J., Ijani, A. S., London, L., & Ajayi, O. C. (2017). Smallholder vegetable farmers in Northern Tanzania: Pesticides use practices, perceptions and cost. *Crop Protection*, 26(11), 1617–1624.
- Okoffo, E. D., Mensah, M., & Fosu-Mensah, B. Y. (2016). Pesticide exposure and the use of personal protective equipment by cocoa farmers in Ghana. *Environmental Systems Research*, 5(1), [Article 9.doi.org](https://doi.org/10.1038/esr.2016.1)
- Oshingbade, O. S., Moda, H. M., Akinsete, S. J., Adejumo, M., & Hassan, N. (2025). Determinants of Safe Pesticide Handling and Application Among Rural Farmers. *International Journal of Environmental Research and Public Health*, 22(2), 211. <https://www.mdpi.com/1660-4601/22/2/211>
- Sharma, A., Kumar, V., Shahzad, B., & Tanveer, M. (2019). Worldwide pesticide usage and its impacts on ecosystem. *SN Applied Sciences*, 1, [Article1446.doi.org](https://doi.org/10.1007/s40201-019-00446-0)
- Silva, V., Mol, H. G. J., Zomer, P., Tienstra, M., Ritsema, C. J., & Geissen, V. (2019). Pesticide residues in European agricultural soils – A hidden reality unfolded. *Science of the Total Environment*, 653, 1532–1545.

- Sule, H., Haruna, Z. A., Halliru, M., Wudil, B. S., Sanda, N. B., & Abdullahi, G. (2020). Pesticide utilization and associated health hazards in Kano Metropolis. *Singapore Journal of Scientific Research*, 10(1), 52–58. <https://scialert.net/abstract/?doi=sjsres.2020.52.58>
- Tudi, M., Li, H., Li, H., Wang, L., Lyu, J., Yang, L., Tong, S., Yu, Q. J., Ruan, H. D., & Atabila, A. 2022. Exposure routes and health risks associated with pesticide application. *Toxics* 10(6): 335. <https://doi.org/10.3390/toxics10060335>
- Vagi, M. C., & Petsas, A. S. (2021). Sorption/desorption, leaching, and transport behavior of pesticides in soils: A review on recent advances and published scientific research. In M. S. Rodríguez-Cruz & M. J. Sánchez-Martín (Eds.), *Pesticides in Soils* (The Handbook of Environmental Chemistry, Vol. 113, pp. 137–195). Springer, Cham. https://doi.org/10.1007/698_2021_803 [1]
- Vanguard 2023, High Application of Pesticide Put Nigerian Consumers at Risk-Report. Available online: <https://www.vanguardngr.com/2023/04/high-applications-of-pesticides-nigerian-consumers-at-risk-report/> (accessed on 15 October 2024).
- World Health Organization. (2022, September 15). *Pesticide residues in food*. <https://www.who.int/news-room/fact-sheets/detail/pesticide-residues-in-food>