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RESEARCH

Effect of integrated pest management practices on the occurrence of pesticide residue in okra cultivated by farmers in Kwara state

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Abstract Integrated pest management (IPM) is a sustainable approach for minimizing the negative impacts of pests on crops while reducing reliance on synthetic pesticides. This study was conducted in Kwara State Nigeria in 2023, to investigate the effects of implementation of IPM practices on the occurrence of pesticide residues in okra cultivated by the farmers in Kwara State, Nigeria, and identify the factors affecting the use of IPM practices for pest control in okra production. A sample of 245 okra farmers was selected across 4 agricultural zones of Kwara State using a multistage sampling technique. Additionally, okra samples were collected from the farmers of each community of the local government areas. The data collected from the farmers were analyzed using descriptive and inferential statistics including frequency count, percentage, mean, standard deviation, and Pearson product moment correlation (PPMC). The collected okra samples were taken to the laboratory for pesticide residue extraction and analysis was performed using gas chromatography (GC)-mass spectrometer (MS). The results showed that most okra producers in Kwara State were smallholder farmers who, despite practicing IPM, had limited knowledge of the technology. Some pesticide residues were detected in okra, out of which two were present in quantities above the maximum residue limit, while others were below the maximum residue limit. Therefore, this study recommends that the government should improve extension services in the State by providing adequate funds and training extension agents who can provide comprehensive training to farmers on the types and application of IPM as an eco-friendly technology for preventing pesticide residue in okra.

Keywords Extension services · Herbicide · Insecticide · Pest control · Southern Guinea savanna

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Introduction

Okra (*Abelmoschusesculentus*(L.) Moench) is a widely grown crop in Nigeria whose fruits are highly

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valued. (Ofuya et al., 2023). It is grown in other parts of the world including, West Africa, India, Brazil, and the USA (Nath et al., 2020). It has been reported that India is the world's largest producer of okra, followed by Nigeria and Sudan, and approximately 2 million hectares of okra are cultivated annually in Nigeria (Idowu et al., 2022).

Okra is used in many ways in Nigeria. It is used as a soup thickener and to prepare relatively slimy soups and sauces. Dried okra seeds contain nutrients and are used to prepare vegetable curds. It can also be roasted and ground as a coffee additive or substitute (Khoso et al., 2017). Okra leaves serve as good fodder for cattle and their mucilage is used for both medicinal and industrial purposes as it has been reported to serve as a plasma replacer or blood volume expander, for the glazing of papers and confectionery uses (Mohankumar et al., 2016).

Pesticides have been reported to increase crop yields; however, the possibility of causing health hazards as a result of misuse has been a major subject of concern. Reports of both acute and chronic pesticide toxicity have been published (OMAF, 2004). This is further corroborated by the report of Best-Ordinohia and Ataga (2017) who reported that the indiscriminate application of pesticides at residual concentrations and their metabolites increased in harvested maize cobs due to inappropriate application of pesticides. Additionally, the higher levels of pesticide residues present in the imported Nigerian beans led to the ban of this commodity from the European Union (The Guardian Newspaper, 2016). According to Jensen et al. (2011), the continuous ingestion of toxic pesticides, though in trace amounts, could accumulate in body tissues with adverse health consequences.

Integrated pest management (IPM) is a technique involving a strategic combination of available pest control techniques including the use of minimum rates of synthetic pesticides to effectively control pests below economic threshold levels (Ofuya et al., 2023). This technique is considered to be the best approach for preventing pesticide residue in crops (Avav & Ayuba, 2006; Imoloame et al., 2021). According to (El-Shafie, 2018), IPM was originally developed for agricultural pest management, but its scope has now expanded to include diseases, weeds, and other pests. The aims of IPM are threefold, to sustain a safe ecosystem and environment through the reduced use of pesticides, to save money and increase profitability by reducing the application rates of chemicals, and to protect human and animal health through the provision of safe food devoid of pesticide residue (Dhawan & Penshin, 2009). In recent years, research has made it possible for the rise in the use artificial intelligence, remote sensing, and autonomous agricultural vehicles which has led to a sharp reduction or complete suspension of pesticide use (Filho et al., 2020). In Africa and Nigeria, achievements in IPM include the use of resistant cultivars, agroecological. biological, and biopesticides methods for pest control in major cropping systems. In the past 60 years of its existence, IPM has been successfully implemented in many places the world over. For example, in a review of Waddington and white (2014) and Norton et al.(2019), 13% and 19% increases in crop yields and farm profits respectively were recorded from 500 IPM programs across the globe. Despite the positive impact of IPM on farmers around the globe (Rejesus & Jones, 2020), IPM adoption is still low in developing countries due to lack of awareness and knowledge, perception of low profitability and risk uncertainties (Norton et al., 2019). These reasons could be responsible for the increase in the use of pesticides globally, especially in Europe under the directives on the sustainable use of pesticides (2009/128/EC) (Buckwell et al., 2020). Additionally, Guichard et al. (2017) reported 25% increased use of pesticides in spite of plans put in place to reduce the use of these agricultural pesticides in France. The same situation applies to the USA (Meehan & Gratton, 2016), China, India, and developing countries like Nigeria (Peshin & Zhang, 2014). The European Union legislation on pesticide maximum residue limits (MRLS) not mentioned in the regulation is automatically set at the default level of 0.01 mg/kg (Anonymous, 2024).

The amount of pesticides imported into Nigeria has increased over the years, suggesting their increased use by farmers for the control of pests. Most farmers prefer pesticides to other methods for controlling pests (insects and weeds), due to the ease of application and effectiveness of these methods (Sharifzadeh et al., 2018). However, pesticides are applied indiscriminately by Nigerian farmers, given their lack of relevant education (Imoloame, 2013). Therefore, the danger of excessive pesticide application may lead to pesticide contamination and residue in crops. To the best of our knowledge,

no study has been conducted in the southern Guinea savanna zone of Nigeria to investigate the extent of pesticide contamination in okra resulting from pesticide usage and the adoption of IPM among the farmers. This justified this study.

Therefore, the general objective of this study was to investigate the use of Integrated Pest Management (IPM) techniques among okra farmers in Kwara State, Nigeria, and to determine the presence of pesticide residues in okra samples. The specific objectives were to describe the socioeconomic characteristics of the respondents, determine the types of pesticides farmers use in the study area, determine to what extent okra crops grown by farmers are contaminated, examine the use of IPM practices for pest control among respondents, and identify factors affecting the use of IPM practices for pest control in okra production.

Methodology

Study area

The study area for this research was Kwara State, which is composed of 16 local government areas. The study is expected to cut across all the okra farmers in Kwara State as shown in Fig. 1.

Population, sampling technique, and sample size

The population of this study is composed of all the okra farmers in Kwara State. A total of 245 okra farmers were selected across the four zones of the Kwara Agricultural Development Project (KWADP), using a multi-stage sampling technique. The sample size was determined using Cochran's sample size formula. The first stage involved the random selection of 30% of the LGAs in each agricultural zone which yielded 6 selected LGAs, viz., *Baruten* from zone A; *Edu* from zone B; *Ilorin-south* and *Asa* from zone C; and lastly, *Ifelodun* and *Oyun* LGAs from zone D. At stage two, 30% of the districts were randomly chosen from the selected LGAs, making 7 districts as listed in Table 1. After that, 10 communities were proportionately selected from these districts. Finally, 24 and 25 respondents were selected per community, making a total of 245 respondents, sampled for the study.

$$n = \frac{Z^2.P(1-P)}{e^2}$$

n desire sample size.

z standard normal distribution = 95%



Fig. 1 Map of Kwara State

Table 1 Summary of respondent selection

Zone	LGAs	District	Communities	Respondents
A	Baruten	Ilesha	Shemga	25
B	Edu	Tsaragi	Saragi & Songa	48
C	Ilorin South	Gaa Akanbi	Tanke	25
	Asa	Owode	Budo Gambari, Bala,	72
		Omupo	Ayegunle, Ayekale	25
D	Ifelodun	Idofian	Ganmo	25
	Oyun	Okeogun	Ijagbo	25
	6	7	10	245

Source: Field Survey, 2023

p Estimated proportion of the population of interest = 155.

e desired margin of error = 0.05.

$$n = \frac{(1.96)^2(0.2*0.8)}{(0.05)2} = \frac{0.614656}{0.0025}$$
$$n = 245.86$$

Data collection and analysis

An interview schedule was used to collect primary data from the farmers. The data collected were analyzed with descriptive and inferential statistics. These include frequency count, percentage, mean, standard deviation, and Pearson product moment correlation (PPMC).

Okra sample collection and pesticide residue extraction

Samples of okra fruits were procured from three farmers randomly selected from each of the communities in the six local government areas. All the okra samples from the three points within each Local Government Area were gathered together and taken to the laboratory for pesticide residue extraction and analysis. The pesticide residues were extracted using the quick, easy, cheap effective rugged, and safe (QuEChERS) method described by Anastassiades et al. (2003), with slight modification according to Srivastava et al., (2021). Approximately 100 g of the collected okra samples was homogenized with a blender and an aliquot of 5 g was then transferred to a 50 ml centrifuge tube, followed by the addition of 10 ml of acetonitrile and 5 ml of distilled water. The mixture was vortexed for 1 min and allowed to stand for 10 min. After that, 4 g of anhydrous $MgSO_4$ and 1 g of NaCl were added to the mixture and the mixture was centrifuged for 5 min at 5000 rpm. Thereafter, 6 ml of the supernatant (upper organic layer) was transferred into another centrifuge tube (Supel QuE ® dSPE) containing pre-weighed 900 mg of $MgSO_4$ and 150 mg of PSA and was centrifuged at 5000 rpm for 5 min. Approximately 5 ml of the supernatant was then acidified with 50 µl of 5% formic acid (10 µl/ml of extract) in acetonitrile to stabilize the extract and the extract was analyzed using GC–MS. All samples were analyzed in triplicate.

GC–MS analysis of pesticide residues in okra

The separation of target analytes was achieved on a DB-5MS fused capillary column containing 5% diphenyl and 95% dimethylpolysiloxane (30 m × 0.25 mm i.d. × 0.25 µm film thickness). The helium (carrier gas) was set to a constant flow rate of 1.3 ml/min with a linear velocity of 42 cm/s.

The GC column oven temperature program was set as follows. The temperature was initially set at 60 ℃ for 2 min, ramped at 30 ℃/min to 180 ℃, then ramped to 210 ℃ at 3 ℃/min, and finally ramped to 280 ℃ at 20 ℃/min held for 5 min, for a total runtime of 24.50 min. The MS operation conditions included a transfer line of 300 ℃, an ion source of 200 ℃, and an electron ionization (EI) of 70 eV. The pesticides were determined by matching the retention time of the standard and relative abundance and comparing the mass spectra of the standards and unknown with a mass spectra library (Ogah et al., 2011). The NIST library provided a list of the best matches based on the abundant mass-to-charge ratio.

Results and discussion

Socioeconomic characteristics of the respondents

Table 2 presents results on socioeconomic characteristics of the okra farmers including gender, age, farming status, and religion and qualification. The results showed that the majority (92.2%) of the respondents were males, 38.0% were young adults aged between 31 and 40 years, and 31.4% were aged between 41 and 50 years. The aged comprised the lowest percentage (26.9%) of the respondents. A greater percentage (75.9%) of the respondents were full-time farmers, 35.1% were degree holders, 31.4% were diploma holders, and 20.4% had first school leaving certificate (FSLC). These findings are consistent with the report by Adewole (2018) that okra farmers in Kwara State are mostly males and are married with formal education. Additionally, Imoloame et al. (2021) reported that the majority of farmers in Kwara State are young, aged between 31 and 40 years, and are employed in the agricultural sector due to the high unemployment rate in Nigeria. This finding is in line with the report of (NBS, 2020), in which 13.9 million youths were unemployed in Nigeria in 2020. Most of the farmers are still in their active and productive stages of life. They are also educated, a factor that inspires them to be more open to accepting innovations such as IPM. The findings of Uwagboe (2012) and Ejechi (2015) give credence to this because most of the farmers who were and adopted IPM were still in their prime age.

Table 2 Socioeconomic characteristics of respondents ($n=245$)

Variables	Frequency	Percentage (%)
Gender		
Male	226	92.2
Female	19	7.8
Age (years)		
18–30	9	3.7
31–40	93	38.0
41–50	77	31.4
Above 50	66	26.9
Farming status		
Full time	186	75.9
Part-time	59	24.1
Qualifications		
Degree	86	35.1
Diploma	77	31.4
FSLC	50	20.4
Others	32	13.1

Source: Field Survey, 2023

Use, quantity, effectiveness, frequency, and stage of crop growth of insecticide application

Table 3 shows that a greater percentage of farmers (93.5%) applied insecticides to okra. According to a review by Ofuya et al. (2023), cypermethrin is the recommended insecticide for controlling insects on okra farms. However, it has been reported that synthetic chemicals are often indiscriminately used giving rise to health and environmental concerns (Stoll, 2001; Avav & Ayuba, 2006; Best–Ordinoha & Ataga, 2017). Similarly, 73.1% of the respondents applied 200 ml or less of insecticide/15 l capacity-knapsack sprayer. This dose is considered to be significantly greater than the recommended dose which is 1. 2 ml/l. A higher dosage of the insecticide used by farmers in Kwara State could have toxic effects on both target and non-target, especially when it is used at high concentrations (Agwu et al., 2016). Ekoja et al. (2023) suggest that application of cypermethrin to okra plants at a rate of 1.0 ml/l during both the vegetative and reproductive growth stages significantly decreases fruit damage by insects and consequently increases yields. The frequency of insecticide application by the respondents was mostly once (47.8%) or twice (42.5%). Furthermore, 60.0% of the respondents applied the insecticides at the early stage of growth and flowering. A great number of farmers in developing countries consider pesticide use as panacea to protect their crops from pest attacks; however, these pesticides are not utilized properly with the likelihood of causing pesticide residue or may increase insecticide resistance in the vectors as also reported by Matowo et al. (2020).

Use, types, quantity, and time of herbicide application among respondents

Table 4 shows that herbicides are highly used among okra farmers in the present study as 93.5% of them used the product, while 6.5% do not, for okra production. The brand of herbicide used by more than half of the respondents (56.1%) was Force Up

Table 3 The use, quantity, effectiveness, frequency, and stage of crop growth of insecticide application among respondents ($n=245$)

Variables	Frequency	Percentage
Use of insecticides		
Yes	229	93.5
No	16	6.5
Quantity of insecticide used (ml)/knapsack sprayer		
Not used	19	7.8
≤200	179	73.1
>200	47	19.2
Effectiveness of insecticide used for okra		
Yes	229	93.5
No	16	6.5
Number of times of insecticide application for okra		
Once	117	47.8
Twice	104	42.4
Thrice	11	4.5
Nil	13	5.3
Crop growth stage for insecticide application		
Early stage of growth only	37	15.1
Early stage of growth and flowering	147	60.0
Early stage of growth, flowing, and fruiting	48	19.6
Nil	13	5.3

Source: Field Survey, 2023

(glyphosate). Other herbicides include Champion (12.6) and Para Force (6.7%). Regarding the quantity of herbicides used, 90.2% of the farmers applied more than 200 ml of pre-emergence herbicides per 15-l knapsack sprayer (82.0%). It has been reported that most farmers in different ecological zones in Nigeria use herbicides more than they use other methods of weed control, and the most commonly used herbicide by farmers in Kwara and Niger States of Nigeria is Force Up, which is mostly applied pre-emergence (Imoloame, 2013; Imoloame et al., 2021; Kolo, 2004). The quantity of herbicide applied may be higher than the recommended rate. Furthermore, the herbicides may be poorly applied because farmers do not calibrate their sprayers before use, resulting in insufficient or excessive application of herbicides (Imoloame et al., 2021).

Farmers' knowledge and practice of IPM practices ($n=245$)

The responses of the okra farmers regarding their level of knowledge about the use of IPM in Table 5 indicated that in the majority of the farmers, 41.6% had limited knowledge while 35.1% had good knowledge. This finding implies that okra farmers in the study area had limited knowledge about the use of IPM. This could be due to the inability of the insufficiently trained extension agents (Agbamu, 2005), to provide up-to-date information on IPM to the farmers. This finding thus underscores the need for farmers to be trained on IPM.

Practice of IPM for pest control

Furthermore, Table 5 indicates that the majority (98.4%) of respondents apply IPM for the management of pests on okra farms, despite their limited knowledge of the use of this technology (Table 5). Olasunkanmi et al. (2021) reported similar findings of IPM adoption among the majority of farmers. The type of IPM adopted in this study by a majority of the respondents (88.5%) was the combination of chemical and cultural methods (hoeing + insecticide + herbicide) while a few (4.5%) each adopted chemical methods only, herbicides and insecticides, cultural and chemical methods (hoeing + mulching + insecticide), or cultural + biological methods (hoeing + insect-resistant variety). This implies that the combination of chemical and cultural methods (hoeing + insecticide + herbicide) was the most common IPM practice adopted for the control of

Table 4 Use, types, quantity, and time of herbicide application among okra farmers ($n=245$)

Variables	Frequency	Percentage
Use herbicides		
Yes	229	93.5
No	16	6.5
Names of some herbicides used (*)		
Champion	45	12.6
Force Up (glyphosate)	201	56.1
Uproot	10	2.7
Gramazone	16	4.5
4D	11	3.1
ParaForce	32	8.9
Gobara	22	6.1
Atrazine	21	5.9
Quantity of herbicides used (ml)/knapsack sprayer		
Nil	16	6.5
< 200	8	3.3
> 200	221	90.2
Time of herbicide application		
Pre-emergence	201	82.0
Post-emergence	4	1.6
Pre- and post-emergence	24	9.8
Not applicable	16	6.5

Source: Field Survey, 2023

pests on okra farms in the study area, despite the limited knowledge about this technology. This high adoption of IPM among farmers in Kwara State departed from the findings of Afuoku et al. (2012) who reported that only 15.6% of the farmers in Central Agro-Ecology of Delta State Nigeria, adopted IPM and that there was a need to increase awareness of this technology and its benefits among the farmers. Similarly, Midingoyi et al. (2019) and Deguine et al. (2021) reported low adoption of IPM despite its economic and environmental benefits and that farmers still stick to synthetic pesticides as a major pest control technique. More than half of the population of farmers (55.9%) depend on extension workers for their source of information on agricultural innovation. However, such information may be inadequate, stale, and unreliable due to the limited knowledge of extension workers in Nigeria resulting from inadequate training and retraining (Ikuenobeet al., 2005; Imoloame et al., 2021).

Constraints to the use of IPM for okra production

The constraints to the utilization of IPM for okra production are presented in Table 6. The Findings showed that inadequate information on IPM

Table 5 Farmers' knowledge level and practice of IPM practices ($n=245$)

Farmers' knowledge IPM	Frequency	Percentage
No knowledge	23	9.4
Limited knowledge	102	41.6
Moderate knowledge	26	10.6
Good knowledge	86	35.1
Excellent knowledge	8	3.3
Use of IPM for pest control Do you apply IPM practices?		
Yes	241	98.4
No	4	1.6
Types of IPM applied		
Chemical method only: herbicide and insecticides	11	4.5
Chemical and cultural methods (hoeing + insecticide + herbicide)	212	88.5
Cultural and chemical (hoeing + mulching + insecticide)	11	4.5
Cultural + biological (hoeing + insect resistance variety)	11	4.5
Sources of information on IPM		
Researcher	58	23.7
Extension	137	55.9
Intuition	14	5.7
Friends	36	14.7

Source: Field Survey, 2023

Table 6 Constraints to the use of IPM for okra production

Constraints	SA (%)	*A* (%)	SD (%)	*D* (%)	*N* (%)	Mean	Rank
Inadequate information on IPM from extension agents	105 (42.9)	112 (45.7)	14 (5.7)	10 (4.1)	4 (1.6)	4.24 ± 0.874	1st
Inadequate demonstration of new technologies	72 (29.4)	152 (62.0)	8 (3.3)	3 (1.2)	10 (4.1)	4.11 ± 0.856	2nd
Lack of proper training	54 (22.0)	167 (68.2)	14 (5.7)	5 (2.0)	5 (2.0)	4.06 ± 0.736	3rd
Inadequate irrigation facilities	46 (18.8)	150 (61.2)	28 (11.4)	17 (6.9)	3 (1.2)	3.88 ± 0.858	4th
High cost of execution	25 (10.2)	127 (51.8)	66 (26.9)	20 (8.2)	7 (2.9)	3.58 ± 0.886	5th

Source: Field Survey, 2023

from extension agents (mean = 4.24) ranked 1st, inadequate demonstration of new technologies (mean = 4.11) ranked 2nd, lack of proper training (mean = 4.06) ranked 3rd, inadequate irrigation facilities (mean = 3.88) ranked 4th, while the high cost of execution (mean = 3.58) ranked the least constraint to the use of IPM for okra production in the study area. These findings show that inadequate information on IPM from extension agents, inadequate demonstration of new technologies, and lack of proper training were the leading constraints that the farmers were facing on the use of IPM for okra production in the study area. The extension services offered in Nigeria have been described as weak and ineffective, depriving the extension workers of adequate training (Agbamu, 2005). Since extension is the bedrock of agricultural development, Imoloame and Olanrewaju (2013) suggested the need for the government of Kwara State to inject adequate resources toward the training of extension agents for better service delivery.

Hypothesis of the study

HO_1: There is no significant relationship between sex or age and the use of IPM for okra production among the respondents. However, farming status ($r = 0.229$), qualification ($r = 0.235$), years of experience ($r = 0.132$), and okra farm size ($r = 0.228$) showed a significant positive correlations with the use of IPM among okra farmers (Table 7). These findings suggest that higher level of education, years of experience, and farm size will lead to greater use of IPM for okra production in the study area. The results for the farm size of okra are consistent with the findings of Olasunkanmi et al. (2021) who also reported a positive relationship between farm size and the adoption of IPM practices among farmers in Nigeria. The significant relationship between education and the adoption of IPM implies that highly educated people are more inspired and open-minded to learn about innovations that will help to improve their farming practices and productivity. This category of people can be appointed to act as contact farmers for the diffusion of IPM in Kwara State of Nigeria.

Table 7 Results of the relationship between socioeconomic characteristics and the use of IPM among respondents

Do you apply IPM (for usage)	Pearson correlation (*r*)	Sig. (*p*-value)
Gender	0.037	0.561
Age	−0.27	0.673
Farming status	0.229	0.000**
Qualification	0.235	0.000**
Years of experience	0.132	0.039**
Okra farm size	0.228	0.000**

Source: Field Survey, 2023; **significant

Pesticide residue analysis of okra

Table 8 presents the GC–MS okra analysis results. Pesticide residues were not detected in the okra samples obtained from Ilorin South, while in the Ifelodun local government area, only spiromesifen (0.38 mg/kg) was detected. In the case of Asa local government area, fipronil (0.02 mg/kg), propiconazole (0.006 mg/kg), phosmet (0.004 mg/kg), imidacloprid (0.29 mg/kg), and acetamiprid (0.21 mg/kg) residues were detected, while only imidacloprid (0.37 mg/kg) residue was detected in samples obtained from the Oyun local government area. Imidacloprid (0.24 mg/kg), phosmet (0.003 mg/kg), and propiconazole (0.04 mg/kg) residues were detected in samples from the Baruten local government, while diazinon (0.008 mg/kg), imidacloprid (0.34 mg/kg), and propiconazole (0.004 mg/kg) were also detected in samples

Table 8 Pesticides residue analysis of okra

Agricultural zones	Types of residue	Quantity of residue (mg/kg)
Ilorin South	None	0
Ifelodun	Spiromesifen	0.38
Asa local government	Fipronil	0.02
	Propiconazole	0.006
	Phosmet	0.004
Oyun	Imidacloprid	0.29
	Acetamiprid	0.21
	Imidacloprid	0.37
Baruteen	Imidacloprid	0.24
	Phosmet	0.003
	Propiconazole	0.04
Edu	Diazinon	0.008
	Imidacloprid	0.34
	Propiconazole	0.004

Source: Field Survey, 2023

obtained from the Edu local government area. Acetamiprid and fipronil were detected at concentrations higher than the maximum residue levels of 0.2 mg/kg and 0.01 mg/kg, respectively. Other pesticides were detected at concentrations lower than the MRLs (spiromesifen, 0.5 mg/kg; propiconazole, 0.01 mg/kg; phosmet, 0.05 mg/kg; imidacloprid, 0.5 mg/kg; and acetamiprid, 02 mg/kg) (EU, 2024; FAO/WHO, 2024). The above results demonstrated that only insecticide residues were present in okra produced in Kwara State and no herbicide residues were found. This could be because herbicides were applied pre-emergence, and so, all of the herbicides could have been metabolized in the plant system before the ripening stage. Previous research has shown that residues of herbicides in food are generally low and that human intake is normally below acceptable levels (Dewhurst, 2014). This finding is consistent with the report of Sondhia (2014), who reported that at harvest, herbicides in various commodities were found either below the maximum residue limit or below detectable limits. According to Liang et al. (2021), as soon as herbicides are applied, considerable processes such as rainfall, photodegradation, etc., immediately begin to impact the residue of those compounds in crops. The indiscriminate application and poor use of insecticides could have resulted in the above maximum residue limits of acetamiprid and fipronil insecticide in okra. This finding corroborates the findings of Ellion et al. (2000) and Mukherjee & Gopal (2003) that the indiscriminate use of pesticides leads to an undesirable load of pesticide residues in marketable vegetables; sometimes, these residues exceed their maximum limit and pose health hazards to consumers. Similarly, Bempah et al. (2011) reported the presence of gamma HCH, endrin, DDE, fenvalerate, deltamethrin, cyfluthrin, cypermethrin, and DDE in okra obtained from the local market of Kumasi, in Ghana at different concentrations. Pesticide residues, such as Lindane, HCB, HCH, aldrin, p,p′-DDE, and DDT, were also detected at different concentrations in okra obtained from Nigerian markets (Adeyeye & Osibanjo, 1999), although the levels were found below the maximum residue levels (MRLs). Although the other residues in okra in this study were present in trace quantities, which are below the acceptable maximum residue limits, the accumulation of these residues in the human body over time could be toxic and dangerous. It has been reported that many chemical residues, especially derivatives of chlorinated pesticides, exhibit bio-accumulation and can reach harmful levels in the body as well as in the environment (Jayaraj et al., 2016). Regardless of where the pesticide residue of okra was found to be high or low, farmers in Kwara State must be trained on IPM and its proper application as it is the best approach for preventing pesticide residue in crops. A strategy that integrates available pest control techniques including the minimum application of pesticides is needed to minimize risks to human health and the environment.

Conclusion

It can be concluded that the okra producers in the Kwara State were smallholder farmers who used both insecticides and herbicides for pest control. Glyphosate is the most commonly used herbicide for okra production. Although most of the farmers have adopted IPM practices consisting of the application of a combination of chemical and cultural methods (hoeing + insecticide + herbicide), their knowledge of this innovation was limited. This is because the okra farmers were not subjected to adequate training on IPM practices by extension agents, who in turn lacked sufficient training. A lack of training and field demonstrations on IPM were implicated as the leading

constraints facing okra farmers in adopting IPM practices. The GC–MS analysis detected two pesticide residues fipronil and acetamiprid which were above the acceptable maximum residue limits in the okra samples collected from the Asa agricultural zone but the okra samples from other zones recorded traces of pesticide residues less than the maximum residue limits. Therefore, there is an urgent need to educate and train farmers on the application of IPM which advocates the use of minimum quantities of pesticides in combination with cultural and biological methods. There were significant positive relationships between the adoption of IPM and farming status, educational qualification, years of experience, and farm size.

Recommendations

i. Researchers must develop IPM strategies that are adaptable and tailor-made to fit local requirements. This is because IPM differs based on crop type, area, and location.
ii. Extension agents should organize awareness, training, and demonstration programs on IPM practices for okra farmers. Such programs should focus on the minimal use of pesticides in combination with other pest control options.
iii. The extension agents who are the major source of information for farmers must be trained on the principles and practices of IPM. This can be achieved if the Kwara State Government adequately funds the Kwara State Agricultural Development Programme (KWADP). This approach will empower the latter to organize regular fortnightly and monthly meetings between the extension agents and researchers from the universities and research institutes for the transfer of technology and innovations.
iv. During the planning stage of an extension program on IPM, full-time vegetables/okra farmers with higher levels of formal education, years of experience, and large farm sizes should be selected as contact farmers who will facilitate and help in the diffusion of IPM technology.

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Declarations

Competing interests The authors declare no competing interests.

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