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Occupational Safety Knowledge, Attitude, and Practice among Farmers in Northern Nigeria during Pesticide Application—A Case Study

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Abstract: Pesticides are known human and environmental toxicants, with an estimated 3 million cases of pesticide poisoning happening every year globally, resulting in more than 250,000 deaths. According to the existing literature, different pesticides groups are readily used among farmers in Nigeria. With recent developments around commercial farming, crop damage from pests, etc., this has led to higher consumption of pesticides among the farming community. The lack of product knowledge and safety awareness among this group further exposes them to the effects of pesticides. The study aims to measure Northern Nigerian farmers' safety knowledge, awareness, and practices related to pesticide application. A cross-sectional study using an online survey questionnaire was adopted to generate responses from 524 farmers across the north-central and northeastern region of the country. Farmers' attitudes towards pesticide use were driven by high crop yield, as 35.4% strongly agree that pesticide use is indispensable for high crop yield. The frequent use of empty pesticide containers for other secondary uses on the farm or at home, as confirmed by 30.6% of the participants, also presents safety and health concerns. Farmers' age ($p > 0.038$) influenced pesticide containers use for other secondary purposes. In contrast, education attainment ($p < 0.001$) significantly influenced the use of pesticide containers for other farm or domestic uses. Farmers' safety behaviours are influenced by socioeconomic factors, including educational level, age, and years of farm practice experience. The study concludes on the need to develop an approach that will help strengthen capacity-building programmes and enhance knowledge base initiatives around the adoption of non-synthetic pesticides.

Keywords: agriculture; occupational exposure; health impact; low and middle-income countries; pesticides; pest management

1. Introduction

The frequent use of pesticides in agricultural practices and the impact of climate change that has further increased farm pest and disease resistance has presented several routes of human exposure. The outcome from prolonged exposure can present acute or chronic hazards to human health and the environment. Most pesticide poisonings occur in the developing world, where safe health standards are inadequate or non-existent [1].

With increased temperature due to climate change impact, pesticide residue exposure among farmers is expected to increase through various routes [2]. Causes of pesticide-related health problems can be grouped into occupational, accidental and intentional (suicidal) categories, and occupational exposure accounts for the greatest exposure route among farmers in low- and middle-income countries (LMICs), where a higher proportion of individuals are engaged in agriculture and pesticide use [3–6].

Consequently, highly hazardous pesticides banned in High-Income Countries (HICs) are readily available and in frequent use in agricultural practices in LMICs, to which factors such as the insufficient registration of products, farmers' perceptions, and limited knowledge around alternatives contribute the ongoing use of these harmful products [1,3,7]. Existing data from LMICs further indicate acute pesticide poisoning as a significant cause of morbidity and mortality among farmworkers, where long-term exposure to organophosphates and carbamates are associated with a wide range of chronic health effects, including respiratory effects, neurobehavioral function, miscarriages, infant deaths, allergies, and carcinogenic and endocrine-disrupting properties, especially among vulnerable groups [6,8–10]. In addition to their use in agricultural practices, pesticide exposure accounts for 14–20% of suicides globally, and most of these incidences are reported among LMICs populations who ingest these compounds when faced with personal life crises [1,11–13].

Most studies carried out in LMICs rely on self-reported pesticide exposure where poor knowledge and awareness around safe application methods and low-risk perceptions contribute to high exposure incidence [14–17]. Because of the lack of monitoring and reporting systems for both the health and environmental impacts of pesticides, most incidences related to pesticides exposure go undetected [1].

Other specific contributing factors for increased morbidity and mortality among farmers exposed to highly hazardous pesticides, especially in LMICs, include non-use or inappropriate personal protective equipment (PPE), non-adherence to manufacturers' safety guides, incorrect application techniques, poorly maintained or unsuitable spraying equipment, and improper storage practices [5,18–20]. In Africa, farmers' attitudes and behaviours have been found in several studies as precursors to highly hazardous pesticides poisoning [3,7,9]. There is a direct correlation between behaviour during pesticide handling in Nigeria, i.e., smoking, eating kola nuts, and pesticide poisoning [21]. Similarly, in South Africa, exposure risk practices were noted, especially during eating, break periods while wearing PPE, and servicing spray equipment [22]. In another study among farmers in Ethiopia, workers were observed eating, chewing, or drinking during or while on rest breaks in the pesticide-sprayed environment [10]. A review of global pesticide uses and human and environmental exposure revealed the socioeconomic role agriculture plays in the communities to which pesticide use is viewed among farmers as playing a vital role in meeting the family and community food security [23,24]. However, such practices present threats to human health and the environment. In Africa, where more than half of farm produce is cultivated by small scale farmers and their reliance on pesticide use to enhance the farm yield, pesticide poisoning crisis from these practices will continue to rise, especially where pesticide associated risk is not adequately assessed and appropriate measures considered to mitigate these risks [23–26]. Agriculture plays an essential role in the economy of Nigeria, where a substantial part of the population is employed within the agricultural sector; however, the over-reliance on agrochemicals to boost food security in the nation cannot be considered as sustainable, primarily where human health and environmental impact associated with such practice is high. This study's overall hypothesis is that several socioeconomic factors will influence farmers' existing occupational safety knowledge around pesticide use and their perceptions about pesticides' potential human and environmental effects. The study measured Northern Nigerian farmers' safety knowledge, awareness, and practices related to pesticide application on farmland.

2. Materials and Methods

2.1. Sample Size

Due to lack of official data in the public domain, a projection of over 14,000,000 active individuals engaged in farming actives as their primary source of livelihood in the study area comprising of six states (Bauchi, Benue, Gombe, Plateau, Nassarawa, and Kaduna) was made. To determine the sample size for the study, Fisher's formula [27] for estimating single proportions and estimation for minimum sample size was applied, and an estimated sample size of 385 was made.

Fisher's formula is calculated as follows:

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

where:

n = sample size;
Z = Standard deviation for 95% confidence level;
P = prevalence of the attribute (50%);
d = acceptable difference; if 5%, d = 0.05);
q = 1 − p.

2.2. Study Design, Population, and Sampling

As a result of the frequent use of pesticides among Northern Nigeria framers, a cross-sectional study was conducted from 15 February–30 June 2021 to determine their occupational safety knowledge and awareness during the application of pesticide on their farm. Three ecological zones define the vegetation of the study area, namely Guinea, Sudan, and Sahel Savannah, respectively. Participation in the survey was anonymous and voluntary and only completed where verbal consent was gained before other sections of the survey were introduced.

As part of the study inclusion criteria, individuals have to confirm handling and applying pesticides on the farm, be involved in the purchase and storage of pesticides, and be above 18 years of age. Recruitment of participants was achieved with the assistance of the local farmers association and farm extension officers. To help eliminate bias and avoid modification around pesticide application behaviour, participants were only informed of the study rationale before the collection of their responses. In addition, only individuals who indicated to have the role of applying pesticides among the farmers were invited to participate in the survey.

A convenient snowball sampling technique was adopted to select the participants. Participants were accessed by deliberate contact and sensitization exercises among the family community. At the end of the survey period, 531 participants responded to the survey, and 98.7% (524) were considered to have met the survey requirement and adopted in the study. The Federal College of Forestry ethics committee, Jos (FCFJ/MMU/001/02/2021), granted ethics approval on 9 February 2021.

2.3. Data Collection

To understand the types of pesticides used among the group, a desk-based study was conducted to identify the most common pesticides readily available to the farmers in Northern Nigeria. Moving forward, data were collected using a structured pretested questionnaire among a limited number of farmers on the highland of Jos Plateau to evaluate the reliability and validity of the survey instrument before the final distribution of the survey instrument.

Data gathered include farmers' sociodemographic characteristics, their awareness of pesticides frequently used/purchased, pesticide exposure routes, pesticide control methods, storage and disposal, use of PPE, attitudes about the hazardous effect of pesticides, practices of farmers during pesticides application, and health problems associated with pesticide use. Factors considered in the survey tool include farmers' safety knowledge during pesticide handling on the farm and possible health and environmental effects and common safety practices adopted during and after pesticide use on the farm. Farmers' attitudes about pesticide use and associated impact were measured using a 5-point Likert scale consisting of 8 items. Responses were set as strongly disagree = 1, disagree = 2, undecided = 3, agree = 4, and strongly agree = 5.

2.4. Data Analysis

Data analysis was undertaken using a statistical package for social sciences (SPSS) 25.0 software for Windows. Raw collected data were inspected to remove cases with empty or more significant percentages of missing responses. Descriptive statistics results were presented as mean, standard deviations, percentage, and frequency tables for categorical data. Binary logistic regression was used to predict the relationship between sets of predictors (independent variables) and established variables (dependent variable). The Logit model was applied to analyse dichotomous data (1 = Yes and 0 = No) based on the model flexibility mathematically to present informed insight for the set of data considered [5]. A probability ($p < 0.05$) was regarded as a cut-off value for statistical significance in the final mode and summarised using odds ratio and 95% confidence interval.

3. Results

3.1. Farmer's Demographic Characteristics

The demographic characteristics of participants were summarised in Table 1. Based on the participant's response, 79.3% identified themselves as male, while another 19.1% confirmed their gender as female. Participants between 51–60 years age group accounted for 15.1% of the sampled population and were followed by the 31–40 years group (28.7%). Additionally, most participants had formal education, with 58.8% identified as having obtained tertiary education, and 29.2% were found to have received a secondary school certificate qualification. More than half of the participants (55.8%) said they have often used pesticides during farming activity in the last 6 to 15 years. Over half of the sampled population (52.2%) engage in wet and dry (irrigation) season farming. When asked if each farmer applies pesticides during the cropping season, 30.3% said they use pesticide more than three times per cropping season, while only 7.4% said they only apply a pesticide of their choice once per cropping season on their farmland (Table 1).

3.2. Farmers' Knowledge of Pesticide Use

As part of the survey, farmers were presented with a list of pesticides using their trade names to help identify the most common product. From their response, 16.3% said they had used paraquat for farm pest control, 15.6% have frequently used round-up (glyphosate), and 15.5% have used Lambda-cyhalothrin (Table 2). Based on sets of questions asked regarding ill-health symptoms experienced after the use of pesticide on the farm, headache (17.1%) was a common after-effect shared among the farmers and was followed by dizziness (13.4%), skin irritation (11%), itchy eyes (8%), coughing (6.7%), nausea (6.5%), and vomiting (5.4%) (Table 2). There was an above-average knowledge of pesticide residue entry routes into the human body among the respondents, with 58.8% identifying inhalation as the most likely route of the pesticide residue gaining entrance to the human body. Oral/mouth ingestion was identified as the second most possible route of exposure (54.5%). Within the sampled group, 60.3% said they are aware of secondary pesticide routes of exposure, including contaminated food ingestion and drinking water contaminated with pesticide, etc. According to the manufacturer's safety data sheet, health hazard classification revealed cocktails of health hazards associated with each product to which ill-health symptoms reported among the participants correspond with these hazards (Table 2).

3.3. Farmers' Pesticide Safety Knowledge

While most participants have limited knowledge of the WHO classification of each pesticide, 87.9% said they read the product safety data sheet (SDS)/container label before applying the product on their farmland (Table 3). In addition, there was high knowledge of safe pesticide application among the participants, with 91.2% affirming the question when asked. There was also high knowledge (94.5%) about safely using personal protective equipment among the farmers. Both questions on how to dispose of pesticide residue and expired product (85.1%) and knowledge around the safe storage of pesticides (86.9%) were scored slightly below other questions asked (Table 3).

Table 1. Farmer's demographic characteristics.

Variables		Frequency	%
Gender	Male	407	79.3
	Female	98	19.1
	Prefer not to state	8	1.6
Age	<20	17	3.3
	20–30	80	15.5
	31–40	148	28.7
	41–50	170	33
	51–60	78	15.1
	>60	22	4.3
Educational Status	No formal education	29	5.6
	Primary school	33	6.4
	Secondary	150	29.2
	Tertiary	302	58.8
Smoking habit	Smoker	45	8.8
	Never smoked	425	83.2
	Quit smoking	41	8
No of years working with pesticide on farm	0–5	123	23.8
	6–10	150	29.1
	11–15	138	26.7
	16–20	69	13.4
	>20	36	7
Work shift	Full day	167	32.8
	Half day	342	67.2
Do you practice wet and dry farming	Yes, both wet and dry season farming	269	52.2
	No, only wet season farming	238	46.2
	No, only dry season farming	8	1.6
Application of pesticide per cropping season	Once	38	7.4
	Twice	189	36.7
	Thrice	132	25.6
	>Three times	156	30.3
Land tenure system	Land owner	258	50.2
	Farm leasehold (private)	199	38.7
	Farm leasehold (government)	27	5.3
	Communal land tenure	30	5.8
Farm size	<1 hectare	256	49.9
	>1 hectare	257	50.1

Table 2. Participants' knowledge of pesticides commonly sold in Nigeria and associated risk to health.

Pesticide Type (Trade Name)	Frequency	%	WHO Classification	Manufacturer Health Hazard Classification
Malathion (Malataf)	131	5.4	III	H302, H317, H410
Paraquat (Weed Crusher, Weedoff, Weedex, etc.)	395	16.3	II	H311, H330, H315, H410
Atrazine (Delzine, Atrataf, Atraforce, Xtrazine)	267	11	III	H317, H373, H410
Butachlor (Butaclear, Risene, Teer, Butaforce, Cleweed)	164	6.8	III	H302, H411
Glyphosate (Round-Up, Wipeout, Clearweed, Bushfire)	380	15.6	II	H312, H318, H411
Bentazone (Basagran)	51	2.1	II	H302, H319, H317, H412
Lambda-cyhalothrin (Karate Laraforce, Attack, Karto, Zap)	378	15.5	II	H304, H315+H320, H332, H371, H410
Propanil (Propacare, Propan, Rhonil, Orizo, Propaforce)	56	2.3	II	H302, H400, H411
Pendimethalin (Stomp, Pendilin)	129	5.3	II	H304, H317, H410
Oxidiaxone (Ronstar, Riceforce, Unicrown)	56	2.3	II	H304, H315, H336, H410
Mancozeb (Z-force, Hi-shield, Mancozeb, Mycotrin)	93	3.8	U	H317, H361d, H400
Dichlorvos (Smash, Wonder, Shooter, Nopest, DDforce, VIP)	49	2	I	H300, H330, H310, H317, H400
Cypermethrin (Suraksha, Superthrin, Best, Cymbush, Cypercot, etc.)	158	6.5	II	H301, H317, H332, H335, H410
2,4-D Amine (Aminoforce, Delmin-forte, 2,4-D-Amine, Select, etc.)	122	5	II	H302, H312, H332
Ill health symptoms associated with pesticide use.				
Headache	340	17.1		
Dizziness	266	13.4		
Skin irritation	218	11		
Vomiting	108	5.4		
Nausea	132	6.5		
Itchy eyes	159	8		
Coughing	134	6.7		
Stomach ache	98	4.9		
Poor vision	53	2.7		
Shortness of breath	68	3.4		
Excessive sweating	53	2.7		
Weakness/fatigue	73	3.7		
Diarrhea	38	1.9		
Restlessness	82	4.1		
Excessive salivation	43	2.2		
Chemical burns on the skin	41	2.1		
Mental confusion	7	0.4		
Muscular twitching	12	0.6		
Increased breathing rate	39	2		
Extra phlegm or mucous in the airways	22	1.1		

WHO classification: I = Highly hazardous II = Moderately hazardous; III = Slightly hazardous; U = unlikely to present acute hazard in normal use. Manufacturer Health Hazard classification: H300: Fatal if swallowed, H301: Toxic if swallowed, H302: Harmful if swallowed, H304: May be fatal if swallowed and enters airways, H310: Fatal in contact with skin, H311: Toxic in contact with skin, H315: Causes skin irritation, H317: May cause an allergic skin reaction, H318: Causes serious eye damage, H319: Causes serious eye irritation, H315 + H320: Cause skin and eye irritation, H330: Fatal if inhaled, H332: Harmful if inhaled, H336: May cause drowsiness or dizziness, H355: May cause respiratory irritation, H361d: Suspected of damaging the unborn child, H371: May cause damage to organs (Nervous system), H400: Very toxic to aquatic life, H410: Very toxic to aquatic life with long-lasting effects H411, H412.

Table 3. Safety knowledge during pesticide application.

Variable		Frequency (%)	M ± SD
Do you read pesticide safety data sheets/labels before use of pesticide?	Yes No Not sure	451 (87.9) 46 (9) 16 (3.1)	1.15 ± 0.438
Do you know how to safely apply/spray pesticide on the farm?	Yes No Not sure	465 (91.2) 26 (5.1) 19 (3.7)	1.13 ± 0.430
Do you know how to use personal safety equipment when handling pesticide?	Yes No Not sure	482(94.5) 16 (3.1) 12 (2.4)	1.08 ± 0.346
Do you know how to safely dispose of pesticide residue/expired pesticide?	Yes No Not sure	435 (85.1) 46 (9) 30 (5.9)	1.21 ± 0.531
Do you know how to safely store pesticides before and after application on the farm?	Yes No Not sure	446 (86.9) 47 (9.2) 20 (3.9)	1.17 ± 0.468
Do you know pesticides can affect human health?	Yes No Not sure	486 (94.6) 17 (3.3) 11 (2.1)	1.08 ± 0.336
Do you know pesticides can affect the environment?	Yes No Not sure	440 (85.6) 23 (4.5) 46 (8.9)	1.23 ± 0.599

3.4. Farmers' Attitudes to Pesticide Use

Farmers' attitudes towards pesticide use were necessitated by the drive for high crop yield, as 35.4% strongly agree that pesticide use is indispensable for increased crop yield (Table 4). In addition, 62.7% of the group strongly agree that personal protective equipment (PPE) will help prevent pesticide poisoning. Eating (kola nut, meal, etc.) and drinking while applying pesticide on the farm were strongly viewed by 52.7% of participants as a potential route of pesticide to gain entrance into the body. In addition, there was an overwhelming acceptance (80.7%) either agreeing or strongly agreeing that smoking while applying pesticide poses a high risk of exposure to pesticide residue (Table 4).

Table 4. Participant's attitude to pesticide use.

Variable	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	M ± SD
	Frequency (%)					
Pesticides are indispensable for high crop yield	46 (9.6)	50 (10.5)	26 (5.5)	186 (39)	169 (35.4)	3.8 ± 1.66
Smoking during use of pesticides increases chance of pesticides entering into the body	37 (7.9)	30 (6.4)	23 (4.9)	169 (36.3)	207 (44.4)	4.03 ± 1.21
Drinking and eating while handling pesticides increase potential entrance to the body	37 (8)	11 (2.4)	14 (3)	158 (34)	245 (52.7)	4.21 ±1.16
Use of personal protective equipment (PPE) is important to prevent the body from pesticide poisoning	40 (8.2)	12 (2.5)	9 (1.8)	121 (24.8)	306 (62.7)	4.31 ± 1.18
Using personal protective equipment (PPE) slows me down when I am applying pesticides on my farm	180 (38.5)	143 (30.6)	24 (5.1)	65 (13.9)	55 (11.8)	2.3 ± 1.4
Washing sprayer tanks in a river/pond/waterway will not pose danger to the environment	286 (61.9)	129 (27.9)	14 (3)	16 (3.5)	17 (3.7)	1.59 ± 0.98
Pesticides only have lethal effects on pests	224 (48.4)	153 (33)	34 (7.3)	27 (5.8)	25 (5.4)	1.87 ± 1.12
It is safe to mix pesticides with bare hand	309 (66)	111 (23.7)	16 (3.4)	22 (4.7)	10 (2.1)	1.53 ± 0.93

3.5. Safety Practices among Farmers

Overall, 96.1% said they regularly use mechanical sprayers consisting of a tank, a pump, a lance, and a nozzle during pesticide application on their farm. In addition, as part of their safety precautions, the use of gloves and masks (91.9%) and coverall/farm uniform (86.3%) was found to be highly utilized during pesticide application among the participants (Table 5). However, despite the high positive attitude displayed among the participants, what becomes problematic and presents negative safety practices as revealed among 30.6% of the participants relate to the use of empty pesticide containers for other farm or domestic use, thereby exposing the farmers to potential ill health associated with this practice. Another negative safety and health practices observed was that 32% of the respondents said that during pesticide application where the sprayer nozzle is blocked, they will use their mouth to blow out the clog. In addition, 10.1% affirmed not disposing of pesticide container according to the manufacturer's instruction, which is viewed as another likely exposure route of either the farmer or third parties to harmful chemical residues, especially where they have long half-life spans (Table 5).

Table 5. Assessment of pesticide safety practices among the participants.

Variable	Yes	No
	Frequency (%)	
I regularly use a mechanical sprayer during pesticide spraying/application on my farm.	490 (96.1)	20 (3.9)
I use empty pesticide containers for other purposes/use in the house/farm.	156 (30.6)	354 (69.4)
I purchase pesticides sufficient for one cropping season.	455 (89.7)	52 (10.3)
I store pesticides at home in safe and secured location.	439 (86.6)	68 (13.4)
I wear gloves and masks to protect my face and hands when applying pesticides on farm.	468 (91.9)	41 (8.1)
I wear coveralls/farm uniform when applying pesticides on my farm.	442 (86.3)	70 (13.7)
I always read the safety instruction on the pesticide container before use.	446 (91.7)	42 (8.3)
If the nozzle gets blocked, I blow it with my mouth to get the clog out.	164 (32)	348 (68)
I wash contaminated farm clothes separately after using pesticides on the farm.	473 (92.7)	37 (7.3)
I dispose of empty containers according to the after-use instruction.	462 (89.9)	52 (10.1)

3.6. Factors Influencing Farmers' Safety Behaviour during and after Pesticide Application

Table 6 summaries the logit regression to estimate the factors influencing empty pesticide containers used for other farms/domestic purpose. Based on the outcome, farmers' age ($p > 0.038$) influenced pesticide containers for other secondary use. In contrast, education attainment ($p < 0.001$) had a significant positive influence on the usage of pesticide containers for other farm or domestics applications. Gender, year of farming experience, and farm practice (wet and dry season farming) negatively influenced the secondary use of pesticide containers the participants. The age of a farmer and education level ($p < 0.05$) significantly affected the probability of farmers using both masks and gloves during pesticide application on the farm. The results imply that older farmers with a limited level of education are more likely to not use gloves and masks while handling pesticides on the farm.

In addition, years of farming experience and practice of wet and dry season farming ($p > 0.05$) significantly and positively influenced farmers' habit of using their mouths to unblock sprayer nozzles. In contrast, age greatly influenced ($p > 0.001$) and negatively farmers' behavior around clearing the clogged nozzle using their mouth. The participant education level significantly ($p > 0.05$) and positively influenced the reading of safety information sheets (SDS) before handling the pesticides. This implies that farmers with higher educational levels are more than likely to access safety information regarding the chemical than those with limited education attainment (Table 6).

Table 6. Binary logit models for factors that influence farmers' safety behaviours during and after pesticide application.

Variables	Model 1: Use of Empty Container	Model 2: Pesticide Storage at Home	Model 3: Use of Masks/ Gloves	Model 4: Use of Coveralls	Model 5: Read Safety Information before Use	Model 6: Use Mouth to Unblock Nozzle	Model 7: Wash Farm Clothes Separately after Use	Model 8: Dispose Empty Containers Appropriately
Age	0.255 (0.038) *	−0.217 (0.152)	−0.371 (0.048) *	−0.209 (0.154)	−0.157 (0.384)	−0.175 (0.006) **	−0.235 (0.242)	−0.260 (0.110)
Gender	−0.089 (0.694)	−0.137 (0.655)	−0.209 (0.622)	−0.551 (0.159)	0.188 (0.585)	−0.391 (0.072)	0.326 (0.378)	0.576 (0.054) *
Educational level	0.419 (0.000) **	−0.436 (0.003) **	0.143 (0.035) *	0.331 (0.110)	−0.460 (0.010) *	0.051 (0.669)	−0.269 (0.181)	0.056 (0.769)
Farming experience (years)	−0.160 (0.153)	0.134 (0.380)	0.228 (0.205)	0.038 (0.793)	0.013 (0.941)	0.025 (0.010) *	−0.219 (0.311)	0.099 (0.535)
Practice wet and dry season farming	−0.101 (0.622)	0.259 (0.346)	0.545 (0.100)	−0.084 (0.752)	−0.368 (0.282)	0.388 (0.054) *	0.242 (0.497)	−0.339 (0.261)
Constant	−0.240 (0.787)	−0.955 (0.424)	−2.865 (0.070)	−4.712 (0.001) **	−2.431 (0.088)	1.128 (0.194)	−0.369 (0.810)	−3.693 (0.008) **
Log likelihood	595.521	361.243	264.036	373.471	268.819	604.267	235.397	318.766
Pseudo R^2	0.105	0.29	0.017	0.044	0.026	0.033	0.024	0.020
LR Chi^2	23.901	14.470	8.346	22.399	13.079	16.459	11.901	9.825
Prob > Chi^2	0.295	0.777	0.418	0.879	0.040	0.348	0.197	0.820

*, ** significant level at 5 and 1% probabilities, respectively, *p* values presented in parenthesis.

4. Discussion

The present study provides insight into Northern Nigerian farmers' safety attitudes and awareness of pesticide use on the farm. The study results reveal that several socioeconomic factors, including educational level, age, years of farm practice experience, etc., influence farmers' safety behaviours. For nations, especially in low- and middle-income countries (LMICs), to attain the Sustainable Development Goal 3, there is a need to advance safety awareness among vulnerable groups on how best to eliminate or minimise exposure to elements that can lead to the development of non-communicable diseases. The need for protection against farm pests has led to the unsafe handling of pesticides, which can cause both acute and chronic adverse health effects on humans and negatively impact wildlife and the natural environment [11,28,29].

Unsafe occupational exposure to pesticides among farmers in LMICs is linked to a lack of knowledge about the products and safety awareness among pesticide handlers, especially in developing countries where communication between producers and end-users (farmers) is almost nonexistent because of the over-reliance on intermediaries with limited knowledge on the product [30]. This trend has been enhanced because of the poor regulation of these products and the lack of education and awareness campaigns among the end-users, the majority of whom are the rural or urban poor [31–34].

The present study found gender and years of farming experience to negatively influence safety behaviour among the participants, especially around pesticide container secondary usage and adhering to manufacturers' safety guides when handling these chemicals. Based on our sampled group, 58.8% of the participants stated that they have acquired tertiary educations that include a national certificate in education (NCE), a national diploma (ND), a higher national diploma (HND), a degree, etc. Educational attainment was found to play a more significant influence on farmers' safety behaviours considering the direct relationship observed among those with higher educational levels and reading of the safety data sheet/label ($p > 0.024$), the use of coveralls/farm uniform ($p > 0.019$), and the secondary use of empty pesticide containers ($p > 0.001$). This outcome was earlier established in a previous study where farmers with a good level of education tend to have good safety awareness and behaviour toward pesticide handling [15,29,33]. Overall, all farmers affirmed the use pesticides at some point during each cropping season, with paraquat (16.3%), glyphosate (15.6%), and lambda-cyhalothrin (15.5%) as the most common pesticides used among the participants. More than half (55.9%) of the participants said they apply pesticides on their farms thrice or more during one cropping season. The reuse of empty pesticide containers for other domestic activities is a common practice among farmers, especially in LMICs, as reported in previous studies [5,35,36]. This practice can present severe non-occupational exposure to pesticide residue considering the persistent nature of these chemicals, which can remain in the containers over a long period.

The need to strengthen farmers' safety behaviour is ripe considering that 32% of the participants said they use their mouth to suck or blow blocked sprayer nozzles, while 86.6% said they store purchased pesticides at home. Such behaviour can lead to accidental poisoning of the farmers and threaten the health of their families, especially children. In addition, the improper disposal of pesticide containers and the indiscriminate disposal of empty containers can lead to the release of pesticide residues into the surrounding environmental media and increase farmers' exposure to pesticides [5,29].

Paraquat, lambda-cyhalothrin, and glyphosate, classed as moderately hazardous ingredients in pesticides (class II) by the WHO [37], are among the most commonly used products by the participants. From each product's toxicological evidence, they present significant human and environmental impact. As such, the need for enhanced training and awareness to help farmers make informed decisions in the selection, timing, and rate of application of pesticides on the farm should be considered. Ntow et al. [24] identified lapses around pesticide application among cocoa farmers in Ghana where different products are combined without having any significant effect on control of pest on the farm. Where such practices are encouraged, the combination of other pesticides with possible carcinogenic or endocrine-disrupting impacts is more than likely to produce adverse health effects in humans and develop further pest resistance [24,38,39]. In addition, Jallow et al. [40] acknowledged several factors contributing to the misuse of pesticides among the farmers engaged in their study, which include the farmers' lack of knowledge and their lack of awareness of the pesticides' long-term impacts, the influence from pesticide retailers, as well as a lack of non-synthetic pest control methods.

From the present study, there was a high dependence on family and friends and pesticide vendors for information pertaining to the pesticide types used among the farmers, which further affirms the earlier position made by previous authors [40,41]. Whereas the decision to use pesticides should be made based on thorough risk assessment of the product and where farmers' knowledge is limited, experts can help guide individuals on the right approach to apply the product and help limit its impact on humans and the environment. Pesticide-associated health risks identified among the participants ranged from headache (17.1%) to dizziness (13.4%) and skin irritation (11%) alongside other identified ill health effects. Similar outcomes were found among cocoa farmers in southwestern Nigeria [15], cotton farmers in Pakistan [42], sugarcane farmers in Malawi [43], Moroccan farmers [29], and Ethiopian farmers [33]. Part of the reason around the ill-health outcome mentioned in the present study, despite adequate pesticide safety attitudes identified among the participants, might be associated with a lack of proper use of personal protective equipment (PPE), eating and drinking while handling pesticides, etc. Other studies have established neurobehavioral defects and neurological symptoms, reflecting cognitive and psychomotor dysfunction with high to moderate pesticide exposure among several farming communities [44–46]. With the existence of inadequate regulatory systems in most LMICs, the proliferation of banned and substandard pesticide products into these countries that does not meet the international standards is likely to increase safety risk to human health and the environment [47], hence the need for farmers to consider integrated pest management (IPM) and organic agricultural practices as alternatives.

While there was high use of coveralls/uniforms (86.3%) and gloves/masks (91.9%) among the farmers, one quarter (25.7%) of the participants consider the use of PPE as a barrier to their work, where the discomfort experienced is associated with restricted movement and excessive heat associated hot climatic condition in a tropical climate such as the northern region of Nigeria. There is a need for further assessment around the effectiveness of PPE usage under extreme working conditions and consideration of effective pesticide risk management as control measures that include lifelong education programmes and training to help change the perceptions and behaviours beyond the use of PPE among farmers [48,49]. This approach will help modify farmers' behaviour towards the safe use of pesticides and limit the health hazard impacts and environmental impacts associated with the application of pesticides. It is almost impossible to ban pesticides among farmers, especially among rural farmers in LMICs, due to several factors that include beliefs and behaviour. To help make an inroad, there is the need for government and related stakeholders to consider approaches that will help strengthen capacity-building programmes and the enhancement of knowledge base initiatives and education around the adoption of non-synthetic pest control methods.

5. Conclusions

The study has further highlighted farmers' safety behaviours and awareness around pesticide application in the northern region of Nigeria. Considering the health and environmental effects associated with chemical pesticides, there is additional room for introducing a new concept in farming activities. Where extension workers and other stakeholders considering education and training, there is the need to factor in different secondary exposure routes to ensure greater awareness beyond farm application. In addition, as the impact of climate change is intensely felt in the tropics, there is also the need to develop integrated pesticide risk management beyond the use of PPE. With the role agriculture plays in the economic development of the Northern Nigeria region, stakeholders are encouraged to advance of good safety and health communication strategy among farming communities and ensure that adequate safety practices are adopted by the farmers to help in the prevention of adverse health effects from pesticide exposure and the promotion of sustainable development in the economy of the region.

While the paper presents certain limitations in terms of sample size and does not reflect the safety behaviour of overall farmers in the 19 northern states of Nigeria, there are still lessons there to be gained, which can be applied in future studies.

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