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**Article — Published Version**

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Environment, Development and Sustainability

**Provided in Cooperation with:**

Springer Nature

*Suggested Citation:* Madaki, Mustapha Yakubu; Lehberger, Mira; Bavorova, Miroslava; Igbasan, Boluwatife Teniola; Kächele, Harald (2023) : Effectiveness of pesticide stakeholders' information on pesticide handling knowledge and behaviour of smallholder farmers in Ogun State, Nigeria, Environment, Development and Sustainability, ISSN 1573-2975, Springer Netherlands, Dordrecht, Vol. 26, Iss. 7, pp. 17185-17204, <https://doi.org/10.1007/s10668-023-03332-8>

This Version is available at:

<https://hdl.handle.net/10419/318037>

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# Effectiveness of pesticide stakeholders' information on pesticide handling knowledge and behaviour of smallholder farmers in Ogun State, Nigeria

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Received: 7 November 2022 / Accepted: 2 May 2023 / Published online: 14 May 2023  
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## Abstract

Although pesticides ensure the quality and quantity of agricultural produce, they have adverse effects on farmers, their families, and consumers. Therefore, in order to reduce the unpleasant effects of pesticide use, stakeholders would be well advised to extend guidance and precautions to end users. The objective of this study was to determine the pesticide handling behaviour and the effectiveness of pesticide information on pesticide handling knowledge and personal protective equipment (PPE) use among farmers in southwest Nigeria. One hundred and fifty-six farmers were interviewed using a structured questionnaire in December 2019 and January 2020. The results revealed that a one-third of the farmers dispose their pesticide residues on the field, only 3% of the farmers dispose the hazardous pesticide waste at a collection point, and 65% of them dispose the empty containers indiscriminately. The majority of farmers never use respirators (79%), hats (60%), and boots (57%) when applying pesticides. Knowledge of pesticide application and waste management is low (58% of respondents scored less than 10 on a knowledge scale of 0–14). The result of the regression model shows that information from pesticide labels and farmer-to-farmer exchanges significantly increase farmers' knowledge of pesticide handling and PPE use. Our results suggest that the effectiveness of current information provision to smallholder farmers on the correct use of pesticides is not sufficient. Therefore, we highlight the need for pesticide companies, distributors, and government agencies to intensify and further develop their efforts to empower smallholder farmers to improve their knowledge and use of pesticides.

**Keywords** Pesticide handling · Personal protective equipment · Pesticide information sources · Pesticide labels

## 1 Introduction

Pesticides play an important role in agricultural development as they reduce the losses of agricultural products and improve the affordable yield and quality of food (Strassemeyer et al., 2017). The use of pesticides contributes to food security and is one of the technologies projected to contribute to meeting the future food demand in 2050 (FAO, 2017). Without the use of pesticides, there would be a 78% loss in fruit production, a 54% loss in vegetable production, and a 32% loss in cereal production (Tudi et al., 2021). In terms of quality and quantity, the increase in agricultural production led to the unprecedented use of pesticides. Globally, three billion kilograms of pesticides are used every year to ensure crop protection for food security (Hayes et al., 2017).

The potential economic benefits of pesticides are evident for farmers in terms of substantial contribution to increasing yields and reducing post-harvest losses. An ongoing scientific and public debates are focusing on minimizing the negative side effects of the use of pesticides on human health and the environment (Bernardes et al., 2015; Tudi et al., 2021). In terms of the environment, pesticides have been linked to declines in birds and bees, among other things (Francisco, 2021; Goulson, 2014; Rajmohan et al., 2020; UNEP, 2021). Pesticide use leads to environmental pollution, including soil, water, and air pollution, as well as food contamination (EPA, 2021). Pesticides are among the leading causes of deaths by self-poisoning, particularly in low- and middle-income countries (WHO, 2021). Aniah et al. (2021) estimated that nearly 3 million farmers suffer from severe pesticide poisoning and 25 million from mild pesticide poisoning annually, resulting in approximately 180,000 deaths per year. Guertler et al. (2021) found that farmers are unaware of the occupational risks and underestimate the potential hazard.

Inappropriate handling and misuse of pesticides are among the factors that can lead to a negative effect that harms the environment and farmers (Bertrand, 2018; Struelens et al., 2022; Teklu et al., 2021). This leads the concerned organizations to develop guidelines for pesticides, including the appropriate dose, dosage, and clothing (EPA, 2021; FAO, 2008; WHO, 2021). Knowledge of pesticides and safety precautions can help reduce the negative effects of pesticides on farmers' health and the environment. Studies confirm the importance of using personal protective equipment (PPE) (Garrigou et al., 2020).

Pesticide companies are striving to reduce the negative side effects of their products through innovative inputs, new ways of farming, more precise applications to further reduce these effects, and the potential trade-offs of increased use of such pesticides (Bayer, 2022). Training materials on the responsible use of crop protection products, pesticide information, guidelines, training of trainers/extension workers, and various media campaigns were provided (CropLife International, 2022).

At the national level, the government is responsible and accountable for the protection of its citizens, including farmers, in Nigeria, our study area. The guidelines for the issuance of permits for the production and importation of pesticides are regulated by the National Agency for Food and Drugs Administration and Control (NAFDAC, 2016). Protection of human health and the environment from the harmful effects of hazardous pesticides and other agrochemicals is enforced by the National Environmental Standards and Regulations Enforcement Agency in cooperation with the Ministry of Agriculture (NESREA, 2019). These institutions oversee the dissemination of pesticide handling information from pesticide companies (pesticide labels and training), extension agents, and other concerned organizations to achieve proper use of pesticides by farmers. However, despite these efforts, the use of unapproved pesticides, indiscriminate overdose, poor handling knowledge and

use of PPE, as well as pesticide poisoning were observed in the country (Moda et al., 2022; Oludoye et al., 2021, 2022; Oyekale, 2022).

Previous studies have investigated various aspects of how farmers use pesticides and the consequences of inappropriate use on farmers' health and the environment (Bertrand, 2018; Struelens et al., 2022; Teklu et al., 2021; Tudi et al., 2021), but little is known about the effectiveness of the efforts made by pesticide stakeholders. Although producers, sellers, and governments have provided information on proper handling in the form of written materials, pesticide labels, or training, there is less evidence on the effectiveness of information provision in shaping and achieving proper use behaviour. To provide such evidence, a study area in a developing country, Nigeria, was selected as a case where less is known about smallholder farmers' knowledge and handling of pesticides, although pesticide stakeholders report to provide information. To measure and compare farmers' knowledge, we developed a pesticide handling knowledge index.

Information such as pesticide handling information is considered effective when both parties, the sender, e.g. pesticide producing or supplying companies, and the receiver, e.g. farmers, give the same or very similar meaning to the message being disseminated (CPD, 2021). For this to happen, the pesticide handling information has to be clear, consistent, transparent, accessible and inclusive. Difficulties in understanding the information provided are mostly due to of language barriers, limited literacy, or age (Oludoye et al., 2021; Scheufele, 2013; WHO, 2022). Derived from the knowledge gap theory, we expect that farmers who are illiterate or of low socio-economic status will have difficulty in understanding and following instructions from companies, government, or extension services on pesticide use (Tichenor et al., 1970).

The main sources of agricultural information are private or public extension services (Bavorova et al., 2020). In Nigeria, the Federal Ministry of Environment and other regulatory agencies organize periodic training workshops related on pesticide use and handling (Tijani, 2006). However, Asogwa and Dongo (2009) reported that there are quality problems in the Nigerian extension services, for example, because the extension workers themselves are trained more on which pesticides to use on which pests than on equipment, application techniques, and safety.

In this regard, the literature revealed that pesticide labels generally provide instructions on the amount to be used and the type of activities that should not be carried out while spraying pesticides (Damalas & Khan, 2017). In Nigeria, chemicals, including pesticides, are required by law to carry information on ingredients and appropriate use, which is supposed to be enforced by the government (NAFDAC, 2016; NESREA, 2019). However, the frequent use of non-native languages on labels hinders the effectiveness of knowledge transfer on safe pesticide handling practices (Oludoye et al., 2021). To obtain information on safe pesticide handling practices, pesticide dealers are usually consulted (Shammi et al., 2018) and other farmers (Damalas & Khan, 2017; Shammi et al., 2018).

There is still a gap in knowledge on the effectiveness of information provided to farmers, particularly by pesticide stakeholders (producers and dealers), in increasing farmers' knowledge and appropriate behaviour. To fill this gap, this study investigated the pesticide handling behaviour of farmers and the effectiveness of pesticide information sources on pesticide handling knowledge and use of PPE among farmers in southwest Nigeria. The study provides answers to the following main research questions: i. How knowledgeable are farmers about pesticide handling? and ii. How do sources of information used affect pesticide handling knowledge and PPE use?

The results may be beneficial to pesticide stakeholders, particularly regulators and companies, by highlighting the sources of information used by farmers, and their impact on

pesticide knowledge and handling. The results on the effect of socioeconomic and demographic factors of farmers will help to identify characteristics of less knowledgeable farmers who need more targeted information and training. The results will allow the adjustment of current policies and the design of new policies and programmes, where necessary, to reduce the negative health and environmental externalities of pesticide use.

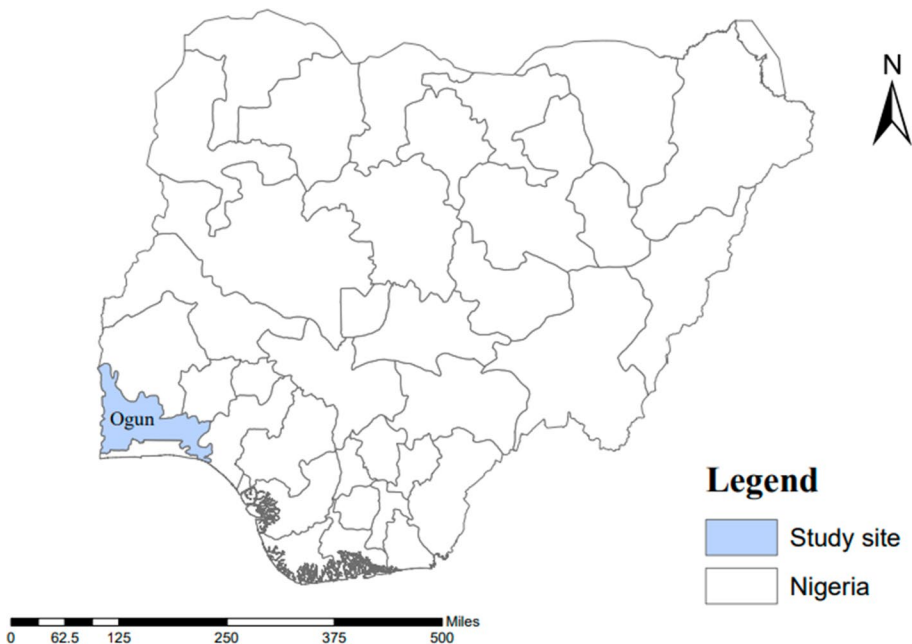
## 2 Methodology

### 2.1 Study area

The study was conducted in Ogun State in the southwest of Nigeria (Fig. 1). The state has a total area of 16,981 km<sup>2</sup> and a population of about 5 million (National Bureau of Statistics, 2016). The state is located in the tropical humid climate zone of Nigeria with high rainfall and high relative humidity. There are 42,000 farmers reported to be pesticide users in Ogun State (NBS, 2012). The tropical climate makes it suitable for the cultivation of rice, cassava, oil palm, cocoa, fruits, and vegetables.

### 2.2 Sampling procedure

A multistage sampling procedure was employed to select the sample. In the first stage, two major agricultural local government areas (Hubs) namely, Abeokuta North and Ifo local government (Fig. 2), were purposively selected with an estimated 4,200 pesticide users eligible for selection. The recommended sample size to achieve a representative sample for



**Fig. 1** Map of Nigeria highlighting Ogun State

**Fig. 2** The local governments in Ogun State selected for the survey



the area at a 95% confidence level and with a margin of error of 0.01 is about 160 respondents (Bavorova et al., 2021). In the second stage, in each of the two local governments, five communities were conveniently selected for accessibility. In each community, about 30 respondents were selected using snowball sampling, resulting in 156 farmers (heads of smallholder farms). All farmers interviewed for the study are plantation farmers, the plantation includes cocoa, plantain, and oil palm. The majority of farmers combined their plantations with food crops such as maize, cassava, and vegetables.

### 2.3 Data collection

Data were collected using face-to-face, pen-and-paper interviews by one of the co-authors between December 2019 and January 2020. Farmers were interviewed using a structured questionnaire. A pretest was conducted with 20 farmers prior to the survey, and the questionnaire was adopted accordingly; the pretest data were not included in the main analysis. The interviews were mostly conducted in Yoruba (95%), which is the native language of the respondents in the study area, and the answers were translated back into English on the spot. About 5% of interviews were conducted directly in English, and the interviews lasted between 30–45 min. The questionnaire consisted of four sections: i. Household head and farm characteristics such as age, gender, education, household size, and total hectares of land, ii. Farmers' knowledge of pesticide use, iii. Farmers' attitudes towards pesticide storage, and iv. Pesticide handling practices of farmers.

### 2.4 Data analysis and measurement

For our research objectives, i.e. to investigate the pesticide handling behaviour of farmers and the effectiveness of pesticide information on pesticide handling knowledge and PPE use among farmers, we used descriptive and two multiple linear regression models to achieve our objective. Variation inflation factor (VIF) was used to test for potential multicollinearity between the independent variables that derived from the knowledge gap theory. No multicollinearity was found as the variation inflation factor coefficients were less than 3 (Akinwande et al., 2015), except between two variables: attendance of “extension training” on pesticide handling and “extension officer as a source of pesticide information”. The two variables are correlated with  $r = -0.6247$ . Therefore, we decided to drop the variable

“extension officer as a source of pesticide information” to avoid problems of multicollinearity in the models. STATA statistical software (version 14) was used for the analysis.

Our models are specified as:

$$y = \beta_0 + \beta_1 X_1 + \dots + \beta_{13} X_{13} + \varepsilon \quad (1)$$

Where,  $y$  = dependent variable (Model 1: pesticides handling knowledge, Model 2: PPE use).  $\beta_0 - \beta_{13}$  = regression coefficients and  $X_1 - X_{13}$  = independent variables (socio-economic variables and pesticide handling information sources) are as shown in Table 1 and  $\varepsilon$  = error term. Our analysis approach is similar to other studies in the research context (e.g. Bagheri et al., 2018; Bondori et al., 2018; Damalas & Koutroubas, 2017).

### 2.4.1 Dependent variables

*Pesticide handling knowledge* was assessed through a 14-question quiz on basic safe pesticide handling practices. A correct answer was worth 1 point, and an incorrect answer or “don’t know” was worth 0 points. Consequently, the dependent variable, pesticide handling knowledge is a continuous variable with a potential range from 0 to 14 points. Four questions addressed knowledge of pesticide handling during the application process (spraying), another four addressed knowledge of pesticide waste handling, and the last six questions tested the pesticide toxicity knowledge of farmers. The questions were adapted from previous studies (Jallow et al., 2017; Okafoagu et al., 2017 and Mequanint et al., 2019) to our research context.

The use of personal protective equipment (PPE) was measured by asking farmers how often they used six different types of PPE: coveralls, respirators, nasal masks, gloves, hats, and boots. The answer “never” was worth 1 point, “sometimes” 2 points, and “always” 3 points. The dependent variable was calculated by adding all scores. Consequently, the dependent variable of PPE use ranged from 6 to 18.

### 2.4.2 Independent variables

Models 1 and 2 have identical independent variables, with the expectation that the dependent variable of Model 1 (*pesticide handling knowledge*), are used as an independent variable in Model 2. Evidence suggests that knowledge of safe pesticide handling practices is relevant to understanding the importance of PPE use (e.g. Damalas et al., 2019). The socio-economic and pesticide information sources considered in the model which derived from “the knowledge gap theory”.

*Socio-economic variables:* we used socio-economic variables that have been shown to be relevant for understanding levels of knowledge about pesticide and PPE use. Male farmers are likely to be more knowledgeable about the risks and unsafe use of pesticides (Hashemi et al., 2012; Wang et al., 2017a) and tend to use more PPE (Wang et al., 2017b). The effect of *age* appears to be context specific. On the one hand, evidence from Damalas et al. (2019) suggests that young farmers are more knowledgeable about pesticide handling than older farmers. A number of studies have also found that PPE use decreases with increasing farmer age (e.g. Boadi-Kusi et al., 2016; Memon et al., 2019; Oludoye et al., 2021; Oyekale, 2022; Wang et al., 2017b). On the other hand, evidence suggests a positive association between PPE use and farmers’ age (Diomedi & Nauges, 2016; Mehmood et al., 2021; Wang et al., 2017b). *Education* level is found to have a positive association with pesticide handling knowledge (Damalas et al., 2019; Mehmood et al., 2021; Mohanty et al.,

**Table 1** Description of the variables used in the two regression models (N = 156)

Variable	Description	Mean	Std. dev
<b>Dependent variables</b>			
Pesticides handling knowledge	Pesticide handling knowledge score (0–14)	9.34	2.86
Personal protective equipment	Frequency of using PPE (6–18)	12.63	3.80
<b>Independent variables</b>			
Pesticide label	Perceived importance of information received from pesticide label (1–4)	2.12	0.82
Pesticide distributors	Perceived importance of information received from pesticide distributors (1–4)	2.05	0.72
<b>Control variables</b>			
<i>Socio-economic characteristics</i>			
Gender	Male = 1, female = 0	0.23	0.42
Age	Age group category of farmer (<30 = 1, 31–40 = 2, 41–50 = 3, 51–60 = 4 and >60 = 5)	2.41	1.34
Formal education	Formal education = 1, non-formal = 0	0.35	0.48
Household size	Number of persons in the house	8.40	2.60
Farm size	Land size under cultivation (ha)	3.23	1.21
Ext. training on pesticide handling	Attending pesticide handling training from extension = 1 otherwise = 0	0.47	0.18
<i>Pesticide information sources</i>			
Government agencies	Perceived importance of information received from government agencies (1–4)	1.82	0.77
Farmers colleagues	Perceived importance of information received from farmers colleagues (1–4)	2.77	0.57
Mass media	Perceived importance of information received from mass media (1–4)	2.46	0.66
Prior knowledge	Perceived importance of prior knowledge (1–4)	2.82	0.45



2013) and PPE use (e.g. Memon et al., 2019; Mequanint et al., 2019; Oludoye et al., 2021; Oyekale, 2022; Sharifzadeh et al., 2019). Also, increasing *farm size* is positively associated with farmers' pesticide handling knowledge (Damalas et al., 2019) as well as PPE use (e.g. Okoffo et al., 2016; Okonya et al., 2019; Oyekale, 2018) while attending extension training is typically associated with improved knowledge of pesticide handling (Damalas & Khan, 2017) and PPE use.

As suggested by the knowledge gap theory, regarding pesticide information, previous evidence on the importance of different information sources of pesticide handling knowledge and PPE use is available. We considered six main sources of information: government agencies, pesticide distributors, other farmers, pesticide labels, mass media, and farmers' prior knowledge. Most evidence suggests that using one or more of these information sources is beneficial for pesticide knowledge (Mohanty et al., 2013; Sharifzadeh et al., 2019; Wang et al., 2017a) and PPE use (Damalas & Abdollahzadeh, 2016; Moradhaseli et al., 2017; Okoffo et al., 2016; Oyekale, 2022). All variables were measured on a scale of 1 (= not important) to 4 (= very important).

## 3 Results and discussion

### 3.1 Sample description

The majority (76.9%) of farm heads in our sample are male (Table 2), which is consistent with other evidence suggesting low female representation in Nigerian agriculture (Mukasa & Salami, 2015). About one-third of the sample was less than 30 years old and had no formal education. Around 43.6% of farmers had less than 10 years of farming experience, with most households having between 5 and 10 members and a farm size of 2–4 ha.

#### 3.1.1 Pesticides handling behaviour and use of information on pesticides

The results (Table 3) show that a significant proportion of farmers do not use pesticides appropriately or are not aware of the risk. Forty-six per cent of the surveyed farmers store pesticides in refrigerators with other food, and 48% store their pesticides in an open shed, which is also inappropriate. This is consistent with previous evidence reporting that inappropriate storage of pesticides is a common problem in the global south (Jallow et al., 2017; Mequanint et al., 2019; Okafoagu et al., 2017). The result further revealed that 62% of farmers do not know that some pesticides are banned for use in the country, and 44.2% of them do not read and understand the instructions written on the pesticide labels. Around half of the farmers never attend extension training on pesticide use, although 41.7% of them think that training on pesticide hazards is important. This indicates that the aim of providing pesticide handling information might be defeated if a large number of farmers do not read and understand the pesticide labels and never attend pesticide handling training. However, this can be corrected and overcome as they believe it is important to attend training that will enable them to handle pesticides properly.

Table 4 shows the relative importance of pesticide information sources among farmers. Farmers indicate that by far the most important sources of pesticide information are their own prior knowledge and other farmers. This is a serious problem because

**Table 2** Socio-economic characteristics of the farmers ( $N=156$ )

Variable	Description	Percentage
Sex	Male	76.9
	Female	23.1
Age (years)	$\geq 30$	35.9
	31–40	21.2
	41–50	17.3
	51–60	17.3
	$> 60$	8.3
Educational level	No formal education	35.9
	Primary	21.2
	Secondary	17.2
	Tertiary	25.7
Household size (person)	$< 5$	8.9
	5–10	70.6
	$> 10$	20.5
Farm size (ha)	$< 2$	1.3
	2–4	85.9
	5–6	12.2
	$> 6$	0.6
Farming experience (years)	$< 10$	43.6
	10–20	39.0
	21–30	15.4
	$> 3$	2.0

**Table 3** Information on pesticides ( $N=156$ )

Variable	Item	Percentage
Are you aware that some pesticides are banned for use?	Yes	37.4
	No	62.6
Do you read and understand the instruction written on labels?	Yes	9.6
	No	44.2
	Sometimes	46.2
Have the instructions written on the label been helpful?	Yes	13.4
	No	46.2
	Sometimes	40.4
Do extension workers train you on pesticide usage?	Often	26.3
	Rarely	18.6
	Never	55.1
Do you think training on the danger of pesticides is important?	Yes	41.7
	No	58.3

knowledge about pesticides is not static. As the knowledge is constantly developing with new scientific knowledge about the efficacy of pesticides, and the fatal effects on humans and the environment, which is based on past experience and other farmers

**Table 4** Pesticide information sources and their relative importance to farmers ( $N=156$ )

Variable	Not important (%)	Less important (%)	Important (%)	Very important (%)
Extension agent	5.1	10.3	34.6	50.0
Pesticide distributors	3.8	12.2	59	25.0
Government agencies	3.2	30.8	46.8	19.2
Other farmers	1.9	1.9	12.8	83.3
Pesticide label	3.2	19.2	39.7	37.8
The media	1.9	3.8	40.4	53.8
Prior knowledge	3.2	10.9	0.0	85.9

knowledge may be outdated. Government agencies and pesticide distributors are perceived as the least important sources. This indicates the root of the problem, as reliable sources of pesticide information, such as government agencies that are professional and responsible for enforcing guidelines and standards, were not considered important by the farmers. Consultation with fellow farmers (83.3%) appeared to be among the most important sources of pesticide information. Oludoye et al. (2021) reported that cocoa farmers in Nigeria complained about a lack of information on pesticide use from relevant stakeholders, except from pesticide retailers and farmers' colleagues, whose priority is profit and not health and the environment. This can be another source of misleading pesticide information if farmers do not have adequate pesticide knowledge to share.

Table 5 indicates that approximately one-third of respondents dispose of residues in the field, and evidence suggests that this practice can cause significant harm to the aquatic organisms (Ghayyur et al., 2021; Schäfer et al., 2011). Only 3% of farmers dispose the hazardous pesticide waste at the collection point. The majority of surveyed farmers (65%) reported disposing of empty containers in the field. In addition, 18% of respondents dispose of empty containers in the trash, which is also inappropriate.

**Table 5** Pesticide handling behaviour of farmers ( $N=156$ )

Variable	Item	Respondents (%)
Pesticide storing place of farmers	Refrigerator with other food items	46
	Open shed just with pesticide	48
	Living area within the reach of children	6
Unused leftover (diluted) pesticide	Bring to the hazardous waste collection site	3
	Dispose in sewer	4
	Apply on another crop	61
	Dispose in the field	32
Pesticide empty container handling	Incineration on farm	8
	Re-use for other purposes	10
	Dispose in trash	17
	Discard in field	65

Indeed, pesticide containers require special treatment for destruction or sequestration as described in the International Code of Conduct on the Distribution and Use of Pesticides (FAO, 2008). Overall, our evidence suggests that there is a significant mishandling of pesticide containers in our study area, which is consistent with other evidence from the global south (Aniah et al., 2021; Bagheri et al., 2018; Bondori et al., 2018; Okafoagu et al., 2017).

### 3.1.2 Use of personal protective equipment

The results on the use of personal protective equipment (Table 6) show that respirators are the least used, with 79% of respondents reporting that they “never” use them. Nasal masks and gloves are most commonly used; but only 17% of farmers say they “always” use them. The overall low rate of PPE use is consistent with previous findings from developing countries (Aniah et al., 2021; Gesesew et al., 2016; Mengistie et al., 2017; Mequanint et al., 2019; Oludoye et al., 2022). This indicates that farmers are not adhering to the precautions of pesticide handling, which creates a space where pesticide companies and distributors, in collaboration with the government, can help as part of their ethical responsibility by educating the farmers on the lethal and toxic nature of the pesticide that PPE must be used for their safety.

### 3.1.3 Knowledge of safe pesticide handling practice

The results of farmers' knowledge about pesticide use are shown in Table 7. On the one hand, the vast majority of farmers know about the importance of washing hands after spraying (94.2%), that inhaling pesticides can lead to illness (89.1%), and that eating while spraying pesticides is a problem (85.9%). On the other hand, farmers have a relatively low knowledge of the importance of showering immediately after spraying (34.0%), that pesticides should not be stored on the rooftop of the bedroom (34.6%), and that excessive use of pesticides can cause damage to the soil (44.2%). This indicates that farmers need to know more about the aspect of which they are unaware, which may lead to unintended harm to their health and the environment. This indicates that the pesticide information disseminated to farmers is not very effective, although it may have some effect.

Farmers' pesticide knowledge score ranged between 0 and 14 points. In general, farmers have low pesticide knowledge regarding banned pesticides and low attention to pesticide labels and understanding of the information, as well as inadequate participation in pesticide handling training. This may be the reason why they rely heavily on their colleagues for pesticide information instead of considering reliable sources such as government agencies

**Table 6** Frequency of use of personal protective equipment ( $N = 156$ )

PPE	Never (%)	Sometimes (%)	Always (%)
Coverall	48	40	12
Respirator	79	16	5
Nose mask	25	59	17
Gloves	27	57	17
Hats	60	29	11
Boots	57	36	7

**Table 7** Pesticide handling knowledge ( $N=156$ )

Question <sup>1</sup>	% of farmers with correct answer
<i>Pesticides handling knowledge during spray</i>	
Eating while spraying pesticides is not a problem	85.9
There is no problem with children spraying pesticides	70.5
The direction of the wind while spraying is not important	46.2
The dosage of pesticides must be precisely calculated	44.9
<i>Pesticide waste handling knowledge</i>	
Empty bottles of pesticides can be used for storage of drinking water	48.7
Some pesticides are extremely dangerous to health	73.7
Pesticides may be stored in the rooftop of the bedroom	34.6
Following the instruction written on labels is important	55.8
<i>Pesticide toxicity knowledge</i>	
Inhaling pesticides could lead to sickness	89.1
Blowing sprayer nozzle with the mouth is not a problem	72.4
Excessive use of pesticides can cause damage to the soil	44.2
Stirring of pesticides with bare hands could lead to skin irritation	80.1
Showering immediately after spraying pesticide is necessary	34.0
Washing hands after spraying is important	94.2

<sup>1</sup>Answer options: Yes, No, I do not know

as less important. This results in improper pesticide storage, indiscriminate handling of leftover pesticides and empty containers, and failure to use PPE.

### 3.2 Determinants of pesticide handling knowledge

The results of multiple linear regression on the effect of pesticide information on pesticide handling knowledge are presented in Table 8. The adjusted  $R^2$  indicates that almost 60% of the variation in our measure of pesticide handling knowledge is explained by the independent variables in the model. Regarding the effects of the *socio-economic variables*, we find that age, extension attendance, and having formal education have a statistically significant positive influence on farmers' pesticide handling knowledge. On the one hand, this is in accordance with Damalas and Khan (2017) as well as Mohanty et al. (2013), who found that attending extension training and education have a positive association with pesticide handling knowledge. On the other hand, Damalas et al. (2019) reported that young farmers are more knowledgeable on the importance of personal safety during pesticide handling than older farmers. Thus, the effect of age appears to be context specific.

Regarding the influence of the *importance of information source*, pesticide label has a statistical effect on the pesticide handling knowledge of farmers. This implies that as the perceived importance of receiving pesticide information from pesticide labels of farmers increases the pesticide handling knowledge of farmers increases. This suggests that pesticide companies have an important role to play in making farmers understand the important information on labels and in making the information easy for farmers to absorb. Comparing our results with other findings, a number of studies from the global south indicated

**Table 8** Determinants of pesticide handling knowledge and PPE use

Variable	Pesticide knowledge (N = 156)		PPE use (N = 152)	
	Coefficient	SE	Coefficient	SE
Control variables				
<i>Socio-economic variables</i>				
Gender	-0.5082	0.3665	0.1923	0.552
Age	1.4905***	0.2079	-0.6472*	.3565
Formal education	1.0451*	0.5303	0.9124	0.7938
Household size	-0.0140	0.0644	0.3406***	0.0942
Farm size	-0.0833	0.1323	-0.4434**	0.1980
Ext. training on pesticide handling	0.5771***	0.1955	0.5173*	0.298*
Knowledge of safe pesticide handling			0.3385***	0.1220
<i>Sources of pesticide handling information</i>				
Pesticide label	0.5717***	0.1984	0.3924**	0.2010
Pesticide distributors	0.2697	0.2397	-0.3267	0.3567
Government agencies	0.2262	0.2240	0.2794	0.3298
Farmers colleagues	0.7266**	0.3038	0.6796**	0.3752
Mass media	0.0525	0.2677	0.3008	0.3938
Prior knowledge	-1.1740***	0.3716	-0.1257	0.5846
Constant	5.7194***	1.632	13.3874***	2.733
$R^2$	0.6201		0.5441	
Adjusted $R^2$	0.5883		0.5012	
F-value	0.000		0.000	

\* =  $P < 0.10$ , \*\* =  $P < 0.05$  and \*\*\* =  $P < 0.01$

the importance of pesticide labels (Damalas & Khan, 2017). Pesticide information from distributors seemed to have a positive effect on the pesticide handling knowledge of farmers, however, is not significant. Relying on other farmers have a positive statistically significant effect. Comparing our results with other findings, a number of studies from the global south indicate the importance of consulting colleagues on proper pesticide handling (Macharia et al., 2013; Mengistie et al., 2017). Regarding the influence of prior knowledge, results suggest that the more farmers perceive their prior knowledge as an important source of information, the lower their pesticide handling knowledge. From a behavioural economics perspective, this can be interpreted it as a problem of farmers' overconfidence in their own competence (e.g. Kruger & Dunning, 1999).

### 3.3 Determinants of personal protective equipment use

Table 8 also shows the result of multiple linear regression, explaining the frequency of use of personal protective equipment by farmers. The adjusted  $R^2$  indicates that around 50% of the variation in our measure of PPE use is explained by the independent variables in the model.

Regarding the *socio-economic variables as control*, we find that age, household size, farm size, attending extension service as well as pesticide handling knowledge have a statistically significant effect on PPE use. Consistent with previous findings by Oyekale

(2022); Memon et al. (2019) and Wang et al. (2017b), our results suggest that as farmers' age increases, PPE use decreases, as reported by Oludoye et al. (2021) and Oyekale (2022) in Nigeria. Regarding the effect of farm size, we find that it reduces PPE use, which is contrary to many other studies on PPE use (e.g. Okonya et al., 2019; Oyekale, 2018). We find that household size has positive statistically significant impact on the use of PPE. One possible reason may be that large households may have different sources of income that will help them to purchase PPE. As expected, we find that pesticide handling knowledge as well as attending extension training on pesticide use have a statistically significant positive impact on PPE use.

In terms of *information source*, relying on other farmers and pesticide labels have a statistically significant and positive effect on PPE use. Overall, this supports earlier evidence on the positive influence of pesticide label information sources (Mengistie et al., 2017; Levesque et al., 2012; Sapbamrer and Thammachai, 2020; Oyekale, 2022). This indicates that pesticide companies can reduce the impact of pesticides on farmers' health by providing and promoting readings and understanding of pesticide labels. Pesticide information from distributors seemed to have a large negative effect on PPE use, but it is not significant.

### 3.4 Comparing the key results of Model 1 and Model 2

Overall, there are many similarities in the results of models 1 and 2 that indicate the crucial role of pesticide labelling from the pesticide companies on both the pesticide handling knowledge and PPE use of farmers while the pesticide information of distributors does not seem to have a significant effect on the pesticide handling knowledge and the use of PPE. Regarding the effect of socio-economic control variables, we find evidence that age and attending extension training have a statistically significant and positive effect on both dependent variables. Regarding the importance of information sources, our evidence suggests that pesticide information from fellow farmers is valuable for understanding pesticide handling knowledge and PPE use. Prior knowledge has a negative effect in both models but is only statistically significant in explaining pesticide handling knowledge. Differences are also found in the statistical significance of a number of socio-economic variables, such as farm and household size, which are only significant in model 2 (PPE use).

### 3.5 Implications and limitations

Our results have both practical implications and implications for further research. In terms of implications for further research, contrary to most previous evidence, we find that farm size has a negative effect on PPE use. This suggests that the relationship between these two variables may be context specific and further research could identify and compare these context specific factors, in order to better understand the relationship between PPE use and farm size. In addition, the negative effect of farmers' previous knowledge on pesticide handling knowledge requires further investigation.

In terms of practical implications, our results suggest that enforcement of environmental and public health laws should be strengthened, for example, through regular inspections to ensure that farmers but also pesticide distributors, comply with existing laws. We find evidence that the purchase and use of banned pesticides are common in our study area. In addition to stronger enforcement, we find that farmers need more support from pesticide companies and distributors, as well as from the government, to avoid risks to human health and the environment. In addition to providing education and training, governments must

work with pesticide manufacturers and distributors to provide and organize the safe and effective collection and treatment of these hazardous wastes as part of their environmental, ethical, and social responsibilities. This is because we find evidence that the inappropriate handling of empty pesticide containers and leftover pesticides is very common in our study area. Furthermore, our results indicate a need for further and improved extension training. We find that extension training has a positive effect on increasing pesticide handling knowledge and PPE use. This holds true even though approximately half of the surveyed farmers indicate that extension workers do not train them on pesticide use. According to our results, training that allows for knowledge transfer from farmer to farmer could be particularly beneficial, as other farmers are a key information source for pesticide handling knowledge and PPE use. To improve knowledge of safe handling practices, our results also suggest that the pesticide companies and distributors in collaboration with extension and farmer organizations, should place emphasis on involving young farmers and those with non-formal education, as we found that these farmers are particularly prone to have a lower levels of pesticide handling knowledge. This is especially important as an increasing knowledge of safe handling practices has a direct positive effect on the use of PPE. In terms of interventions, for example, pesticide labels should focus more on communicating information through pictograms.

Our study results are limited in their generalizability due to our non-probability sampling technique as well as the rather small sample size. In addition, we conducted face-to-face interviews, which raised concerns about social desirability bias. Studies typically suggest that social desirability bias is higher when the survey is interviewed rather than self-administered (Krumpal, 2013). However, chose this method of data collection to ensure that all questions were well understood, as over a third of our participants had no formal education. Interviews with key informants from a wide range of sectors in further studies would allow for broader perspectives and understanding of underlying issues and problems.

## 4 Conclusion

The aim of this study was to investigate farmer' pesticide handling behaviour and the effectiveness of pesticide information on pesticide handling knowledge and use of personal protective equipment among farmers in southwestern Nigeria. To do so, we surveyed 156 farmers via face-to-face interviews with a structured questionnaire.

Our results revealed that the overall knowledge of safe pesticide handling and the use of personal protective equipment are low. Using a self-developed pesticide handling knowledge index, further we found out that almost one-third of the surveyed farmers were unable to correctly answer more than half of our 14 questions on basic safe pesticide handling practices. Moreover, inappropriate pesticide handling and storage behaviour were identified in the responses of the majority of participants. Regarding the frequency of personal protective equipment use, we found low usage of basic protective equipment, such as nasal masks or gloves. The identified behaviours of surveyed farmers stipulate risks to human health as well as to the environment that pesticide companies and distributors must address as part of their corporate social responsibility. For example, to reduce the mishandling of pesticide containers in our study area, pesticide stakeholders (companies, distributors, and the government) should take responsibility for the construction of pesticide waste



collection centres and provision of training on how to handle pesticide waste according to the International Code of Conduct on the Distribution and Use of Pesticides (FAO, 2008).

Our results indicate that the majority of the respondents considered information from pesticide distributors and government agencies as important or very important, this perceived importance did not have a statistically significant effect on pesticide handling knowledge and PPE use. On the contrary, the majority of farmers do not consider pesticide labels to be a very important source of handling information. Overall, our research suggests that the effectiveness of current information provision to Nigerian smallholder farmers on proper use of pesticides is unsatisfactory. We therefore recommend that pesticide companies, distributors, and government agencies intensify their efforts to empower Nigerian smallholder farmers to improve their knowledge as well as handling of pesticides in order to reduce the negative environmental and health externalities caused by the inappropriate use of pesticides.

**Acknowledgements** This study was supported by the Internal grant agency of the Faculty of Tropical AgriSciences, the Czech University of Life Sciences, Prague, Project Number 20223113.

**Funding** Open access publishing supported by the National Technical Library in Prague.

**Data availability** The data sets generated during and/or analysed during the current study are available from the corresponding author upon reasonable request.

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