

Research Article

# Farmers' Perception on Pesticide Use and Pest Management of Vegetable Crops: In the Upper Blue Nile Basin, Ethiopia, in the Case of Fogera Plain

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## Abstract

This study examines the impact of training on smallholder farmers' pesticide handling practices, perceptions, and behaviors, with a focus on the correlation between training and several key factors, including pesticide storage, pest identification skills, pest management strategies, pesticide application frequency, information sources, protective equipment use, pesticide mixing habits, and disposal of empty pesticide containers. The research highlights that training plays a significant role in improving farmers' pesticide handling practices, although some areas still require additional education or interventions for further improvement. Significant associations were found between training and pest identification abilities. Farmers who received training were more adept at recognizing pests such as onion thrips ( $X^2 = 17.130$ ,  $p < .001$ ), downy mildew ( $X^2 = 10.221$ ,  $p = 0.001$ ), fruit borers ( $X^2 = 26.246$ ,  $p < .001$ ), and white flies ( $X^2 = 3.226$ ,  $p = 0.072$ ) compared to untrained farmers. Trained farmers were also more likely to seek reliable information from extension workers ( $X^2 = 13.18$ ,  $p < 0.001$ ), chemical dealers ( $X^2 = 15.44$ ,  $p < 0.001$ ), personal experience ( $X^2 = 8.03$ ,  $p = 0.005$ ), and product labels ( $X^2 = 14.36$ ,  $p < 0.001$ ), whereas untrained farmers were more inclined to guess or rely on informal sources ( $X^2 = 21.85$ ,  $p < 0.001$ ). Regarding pesticide storage, trained farmers were more likely to store pesticides safely, away from living areas, children, and animals, whereas untrained farmers often stored pesticides indoors. Training also affected mixing practices, with trained farmers less likely to mix pesticides near water sources ( $X^2 = 6.4$ ,  $p = 0.01$ ) and more likely to mix them in the field ( $X^2 = 51.38$ ,  $p < 0.001$ ). However, there were no significant differences in practices such as mixing pesticides according to the recommended doses ( $X^2 = 3.15$ ,  $p = 0.08$ ) or mixing different types of pesticides ( $X^2 = 0.31$ ,  $p = 0.58$ ). Trained farmers demonstrated better adherence to safety protocols, such as using personal protective equipment (PPE) and avoiding pesticide mixing at home. They were also more likely to triple-rinse spray tanks and avoid discharging pesticides into irrigation ditches. However, no significant differences were observed in reading pesticide instructions before spraying ( $X^2 = 0.24$ ,  $p = 0.63$ ), indicating a need for further emphasis on this aspect during training. Overall, the study confirms that training significantly improves safe pesticide handling but suggests areas for further education and intervention.

## Keywords

Miss-use of Pesticide, Pesticide Training, Smallholder Farmers, Pesticide Use Practices

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## 1. Background and Justification

Vegetables are essential for human nutrition, providing dietary fiber, vitamins, minerals, and non-nutritive phytochemicals like phenolic compounds and flavonoids. These components help reduce the risk of chronic diseases such as cardiovascular diseases, diabetes, certain cancers, and obesity. The Food and Agriculture Organization [13] recommends a vegetable consumption rate of 200 grams per day per person, equating to 73 kilograms per person annually. In Ethiopia, smallholder farmers predominantly rely on traditional agricultural practices to cultivate vegetables such as onions, potatoes, tomatoes, cabbages, garlic, shallots, and green peppers. Onions and potatoes, in particular, are popular among both small and large-scale farmers [10]. Farmers in wetland areas of Fogera district grow different products two to three times a year, and they have intensively and frequently utilized pesticides for their productivity of potatoes, onions, cabbages, and other vegetables, but there is a scarcity of information on pesticide use safety practices [15]. However, vegetable production faces numerous challenges, including biotic and abiotic factors, with pests being a major constraint [42].

Pesticides play a crucial role in preventing crop loss due to pests, but their improper handling and application pose significant environmental and human health risks [43]. Research has consistently shown that pesticides can degrade environmental quality and pose severe health hazards on local, national, and global scales. Pesticides are linked to biodiversity loss and ecosystem degradation, with only 1% of sprayed pesticides reaching target pests; the remainder causes pollution through drift, volatilization, leaching, and runoff [11]. The World Health Organization [44] reports approximately 18.2 acute pesticide poisoning cases per 100,000 agricultural workers, with PAN International estimating around 41 million farm laborers globally suffering from pesticide poisoning annually [36]. Although emerging countries use only 25% of the world's pesticides, they account for 99% of pesticide-related deaths due to more intense and hazardous use and weaker regulatory systems [44]. [9] In 2015, Crop Life International reported that 15% of crop protection products sold by its members were Highly Hazardous Pesticides (HHPs) as defined by the WHO. In developing nations, the lack of personal protective equipment (PPE) and limited instruction on safe pesticide application exacerbate health risks [18]. Pesticide exposure occurs through skin contact, inhalation, or ingestion, leading to a range of health effects, including ocular, dermal, cardiovascular, gastrointestinal, carcinogenic, endocrine, developmental, neurological, and respiratory issues [34].

This study aims to examine the effect of training on farmers' perceptions and practices regarding vegetable pest management and pesticide use in the Upper Blue Nile Basin, specifically in the Fogera Plain, Ethiopia. Previously conducted pesticide-related Knowledge Attitude Practice (KAP) studies in Ethiopia have indicated that farm workers had lim-

ited knowledge on pesticide hazards, inadequate awareness about safe pesticide management, and poor hygienic and sanitation practices [3, 25]. A study in Ethiopia [5] showed that the most likely reasons for unsafe use of pesticides is lack of formal training on pesticide-related occupational and environmental hazards; the absence of a responsible institution particularly in farm for training provision; and the continued illegitimate usages of organo-chlorides particularly DDT on food crops. Given that farmers often lack accurate knowledge about safe pesticide use, leading to unsafe behaviors such as under-dosing, frequent applications, and improper handling practices [38], there is a critical need for effective training and information campaigns. Prior studies indicate that technical training improves safety measures among farm workers in developing countries [8, 21, 37, 41].

Previous studies in Ethiopia have primarily focused on pesticide applicators and the Knowledge, Attitude, and Practices (KAP) of farmers in various farming systems [5], small-scale farmers in the Upper Rift Valley [42] and the attitudes and practices of farmers regarding pesticide use. Research has also examined pesticide use practices among smallholder vegetable farmers in the Ethiopian Central Rift [33]. These studies consistently found that the primary reasons for misconceptions and unsafe pesticide use were due to a lack of formal training and highlighted the importance of such training by NGO and Governments.

Despite various studies indicating that Ethiopian farmers have a poor understanding of pesticide handling and often misuse these substances, the government has not focused on addressing this issue. There has been no specific government-led training on proper pesticide practices and perceptions. Currently, NGOs are stepping in to support farmers through capacity-building initiatives. One notable example is Crop Life Ethiopia, which, in collaboration with the SNV project, is recognized for its effective pesticide management training programs. CropLife Ethiopia is a non-governmental organization (NGO) that operates in various regions of Ethiopia. Its primary focus is on improving pesticide handling and management practices among farmers. The organization collaborates with other entities, such as the SNV project, to provide comprehensive training programs. These programs typically include both practical and theoretical instruction on the safe and effective use of pesticides. In addition to training, CropLife Ethiopia also supplies personal protective equipment to selected trainees to ensure safer pesticide application. The organization plays a crucial role in enhancing agricultural practices and promoting safer pesticide usage in Ethiopia ([croplifeafrica.org](http://croplifeafrica.org)).

A study conducted in Fogera, also suggest that, to improve the pesticide handling and storage practice, it is imperative to enhance the level of the farmer's knowledge through training, and information dissemination in workshop [7]. Previous studies in Ethiopia have focused on various aspects of pesti-

cide use, including the knowledge, attitudes, and practices (KAP) of farmers in different farming systems (Negatu *et al.*, 2016), small-scale farmers in the upper Rift Valley [42] attitudes towards pesticide use, and practices among smallholder vegetable farmers in the Central Rift Valley [33]. These studies consistently found that the primary reasons for misconceptions and unsafe pesticide use were due to a lack of formal training, and they emphasized the importance of providing such training. However, no studies have investigated the impact of formal training on farmers' pesticide handling and perceptions. A study in Fogera identified additional challenges such as insufficient training opportunities and materials, weak law enforcement, limited access to guidelines, and a shortage of media coverage [14].

This research aims to assess whether educational and training interventions can positively influence farmers' use of personal protective equipment (PPE), hygiene practices, understanding of pesticide instructions, and overall pesticide management. By addressing these gaps, the study seeks to reduce health risks and promote safer agricultural practices among smallholder farmers in Ethiopia. However, none have investigated the impact of formal training on farmers' pesticide handling and perception.

Therefore, the objective of the present study was to assess the effect of training on the farmers' exposure to pesticides,

perceptions, knowledge, current pesticide use practices on major vegetable pests in Fogera plain, Ethiopia.

## 2. Materials and Methods

### *Description of the Study area*

This experiment was conducted in the Amhara region, Fogera plain (Figure 1). Fogera Plain located in the Blue Nile Basin of Ethiopia, three districts from the South Gondar zone, serves as a major irrigated vegetable production area for smallholder farmers in the Amhara region. The area is specifically located 45 km from the city of Bahir Dar and it is surrounded by Gumara and Rib River. The study encompassed in South Gondar zone of three districts: Fogera (located at 11.058° latitude and 37.041° longitude), Dera (Latitude: 31°49'N, Longitude: 70°55'E), and Libokemkem (Latitude: 12°04'N, Longitude: 37°45'E), (Latitude and longitude of 11°10'N and 37°2'E to 11°25'N and 37°17'E) in Ethiopia. These districts were chosen due to the prevalent use of irrigated land for vegetable production, and the survey was conducted from October 2020 to March 2021. Water source of Vegetable production in this area is from ground water by using water pump and in some extent from Rib and Gumara River.

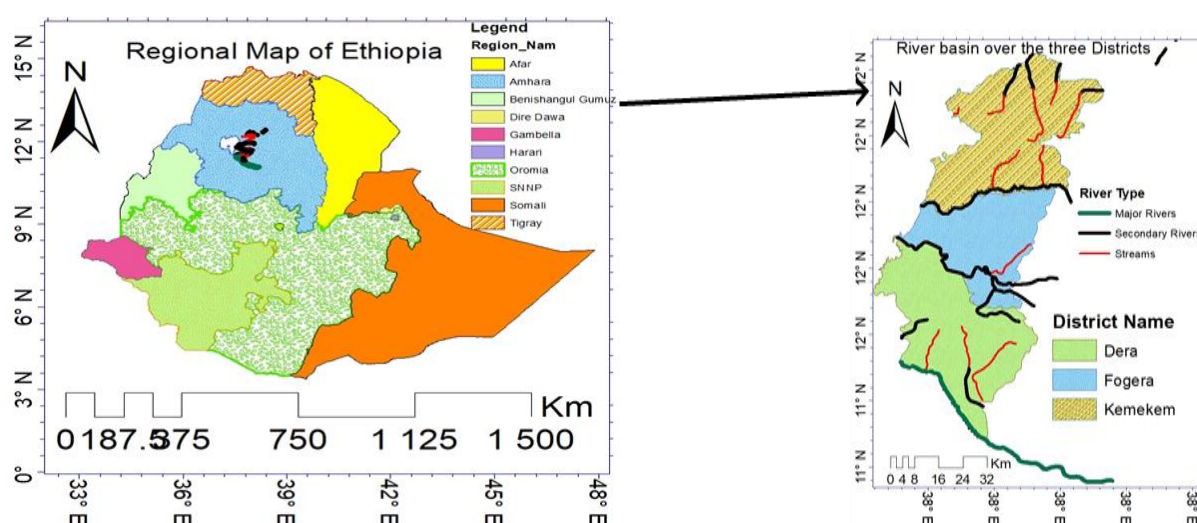


Figure 1. Represents the study area, Fogera plain.

### *Irrigation and Crop Production*

The irrigation season begins in mid-November, following the rice harvest, and continues until the end of April. During this period, vegetables are the predominant crops produced using irrigation.

### *Study Participants and Sampling Procedure*

The study participants were farmers engaged in pesticide use—those who buy, handle, and apply pesticides—among the Fogera Plain irrigation vegetable producers. Information about the types and number of irrigation kebeles (12) in the

study area was obtained from the district development office. The total sample size was determined based on the potential vegetable production within the study area.

A multi-stage sampling technique was used to select participants. Initially, the Fogera Plain, consisting of three districts (Dera, Fogera, and Libokemkem), was purposively chosen for its significant vegetable production in the South Gondar Zone, Amhara region, Ethiopia. The agricultural offices of these districts helped identify potential vegetable producers, resulting in the selection of 12 kebeles for inter-

views. Using the transect method (Dansi *et al.*, 2008), 8-12 vegetable producers were randomly selected from each kebele for individual interviews. Due to a shortfall of trained farmers in two kebeles, development agents were asked to include farmers who had completed a five-day training program on pesticide and pest management within the last six months to two years.

#### *Demographic and Socioeconomic Characteristics and Interview Sample*

Research has identified several demographic characteristics that influence farmers' perceptions of health risks associated with chemical pesticide use, including age, agricultural experience, education level, farm size, yield, average income, and membership in agricultural organizations [23]. To ensure a balanced representation, respondents were selected to be evenly distributed across both trained and untrained groups based on these characteristics.

The final interview sample included 113 participants from 12 kebeles. Initially, 61 trained and 61 untrained farmers were identified. However, 10 farmers were excluded from the trained group: five had only received a three-day training from the Agrobig project, two had completed a different five-day training unrelated to CropLife Ethiopia, and three had been trained by the Meda project and were no longer engaged in vegetable production. Thus, the sample comprised 52 farmers who had undergone specialized five-day training in pesticide handling in 2019-2020.

**Efforts to Minimize Differences;** Efforts were made to minimize differences in age, education level, and family size between trained and untrained farmers. Trained farmers received instruction on the proper use of personal protective equipment (PPE) and the disposal of empty pesticide containers. This comprehensive training spanned five consecutive days in both 2019 and 2020. Nearly all trained farmers reported having PPE and sprayer knapsacks during interviews. Development agents noted that most NGOs, particularly CropLife Ethiopia, provide training exclusively for males, operating under the assumption that females should not apply pesticides. Consequently, six females were included in the untrained group.

#### *Data Collection*

Face-to-face interviews were conducted on farms by four professionally trained interviewers in the local language. Data quality checks were performed by the principal investigator. The initial questionnaire items were reviewed by three plant protection specialists and pre-tested on a few participants to

ensure clarity. The questionnaire, consisting of 28 key questions, included open-ended and multiple-choice questions, and took about 25 minutes per interview. It gathered data on farmers' exposure to pesticides, current pesticide use practices, and perceptions of pesticides within their cultural context.

The data collected covered socioeconomic and lifestyle factors (age, sex, education, and land tenure), farmers' experiences with health risks related to pesticide use, pest management practices, sources of information on pest management, and the effectiveness of pesticide use. Additional data included details on pesticides (types, sources, and characteristics), storage, mixing methods, application frequencies and dosages, use of protective devices, and disposal of pesticide containers.

**Data Analysis;** Descriptive statistics, including frequency distributions, percentages, averages, and standard deviations, were computed using SPSS software version 20.0 and Microsoft Excel.

## 3. Results

### 3.1. Socio-demographic Characteristics of the Respondents

**Table 1** presents the socio-demographic characteristics influencing farmers' pesticide use. Education level showed no significant association with training ( $X^2 = 3.5$ ,  $p = 0.48$ ). Among illiterate respondents, 32.8% were untrained, and 1.9% trained. Those with grade 1-4 education included 39.3% untrained and 40.4% trained; grade 9-12 education had 8.2% untrained and 38.5% trained. All college graduates were trained (1.9%). In the 26-35 age group, 54.1% were untrained, and 57.7% trained; ages 36-55 showed 14.8% untrained and 15.4% trained. For farms of 0.5-1 hectare, 44.3% were untrained, and 38.5% trained; farms over 1 hectare had 21.3% untrained and 40.4% trained. Households with 1-3 members included 16.4% untrained and 21.2% trained; 4-6 members had 42.6% untrained and 44.2% trained. Gender showed a significant association with training ( $X^2 = 5.49$ ,  $p = 0.019$ ); 9.8% of females were untrained, and none trained, while 88.5% of males were untrained and 100% trained. Mobile access was also significant ( $X^2 = 8.87$ ,  $p = 0.003$ ); 19.7% without mobile access were untrained, and 1.9% trained, while 78.7% with mobile access were untrained, and 98.1% trained.

**Table 1.** Socio-economic characteristics of the respondents in the study area.

Variables	Do you get specific training about pesticide handling for more than 5 days? (N= Yes=52, No=61 and total N=113)					
	No (N)	%	Yes (N)	%	$X^2$	P
Age of the farmers (Years) <sup>ns</sup>					0.13	0.94

Variables	Do you get specific training about pesticide handling for more than 5 days? (N= Yes=52, No=61 and total N=113)				X <sup>2</sup>	P
	No (N)	%	Yes (N)	%		
(26-35)	33	54.1	30	57.7		
(36-55)	9	14.8	8	15.4		
(16-25)	18	29.5	14	26.9		
Farm size <sup>ns</sup>		0.0		0.0	4.99	0.08
0.5-1 ha	27	44.3	20	38.5		
<0.5 ha	20	32.8	11	21.2		
>1 ha	13	21.3	21	40.4		
Family number in a household (Numbers) <sup>ns</sup>		0.0		0.0	0.5	0.77
1-3	10	16.4	11	21.2		
4-6	26	42.6	23	44.2		
7-11	24	39.3	18	34.6		
Level of Education <sup>ns</sup>		0.0		0.0	3.5	0.48
Illiterate (unable to read and write)	20	32.8	1	1.9		
Grade 1-4	24	39.3	21	40.4		
Grade 5-8	11	18.0	9	17.3		
Grade 9-12	5	8.2	20	38.5		
Collage graduate	0	0.0	1	1.9		
Gender *		0.0		0.0	5.49	0.019
Female	6	9.8	0	0.0		
Male	54	88.5	52	100.0		
Mobile access*		0.0		0.0	8.87	0.003
Have No	12	19.7	1	1.9		
Have	48	78.7	51	98.1		

Ns: No significant difference ( $p > 0.05$ ), \*: Significantly higher percentage in the second category ( $p < 0.05$ )

### 3.2. Farmers' Responses to Questions Related to Pesticide Training and Practices Regarding Pesticide Handling and Use Practice

The table 2 presents data on farmers' responses to questions related to pesticide training and practices, with a total sample size of 113 respondents. Each row corresponds to a specific question, while the columns represent the number of respondents who answered "No" and "Yes" to that question. Farmers were asked, Do you get specific training about pesticides?, Out of the 113 respondents, 61 answered "No" and 52 answered "Yes" to receiving specific training about pesticides. They also asked Who provide the training?, Similarly, 61

respondents reported "No" while 52 respondents reported "Yes" to receiving training by Crop Life Ethiopia. Regarding the time of training, the data show that 61 respondents did not receive training in 2019/2020, while 52 did receive training during this period. Number of days of the training, how many days is the training? Is it for 5 days? 61 respondents did not receive training that lasted for 5 days, whereas 52 respondents did receive training of this duration. They were also asked about the scope of the training, is the training on safe use of pesticide and its handling? Here, 68 respondents indicated "No" and 45 respondents indicated "Yes" to receiving training specifically on the safe use of pesticides and their handling.

**Table 2.** Summary of Farmers' Responses to Pesticide Training and Practices.

Farmers on Pesticide Training and Practices	No (N)	Yes (N)	X <sup>2</sup>	P-Value
Do you get specific training about pesticides?	61	52		
Is the training by Crop Life Ethiopia?	61	52	113.0	<0.001*
When do you get the training? Is it in 2019/2020?	61	52	109.04	<0.001*
How many days is the training? Is it for 5 days?	61	52	113.0	<0.001*
Is the training on safe use of pesticide and its handling	68	45	87.7	<0.001*

Ns: No significant difference ( $p > 0.05$ , \*: Significantly higher percentage in the second category ( $p < 0.05$ ).

### 3.3. Types of Pest Identified by the Respondents

Table 3 summarizes the types of pests identified by smallholder farmers in the study area across various crops and their training status in pesticide handling. A Chi-square test examined the relationship between pest identification and training. For onion crops, trained farmers were significantly more likely to identify onion thrips ( $X^2 = 17.130$ ,  $p < .001$ ) and

downy mildew ( $X^2 = 10.221$ ,  $p = 0.001$ ) than untrained farmers, but there was no significant association for basal rot ( $X^2 = 0.462$ ,  $p = 0.496$ ). For cabbage, no statistical analysis was provided for diamondback moth, and there was no significant association for aphids ( $X^2 = 1.365$ ,  $p = 0.243$ ). For tomatoes, trained farmers were more likely to identify fruit borer ( $X^2 = 26.246$ ,  $p < .001$ ) and whitefly infestations ( $X^2 = 3.226$ ,  $p = 0.072$ ), but there was no significant association for aphids ( $X^2 = 1.365$ ,  $p = 0.243$ ).

**Table 3.** Represents the major types of pests identified by small holder farmers in the study area, in irrigation vegetable.

Do you get specific training about pesticides? (N= Yes=52, No=61)				
	No N (%)	Yes N (%)	X <sup>2</sup>	P-Value
Pests identified on onion crops				
Onion thrips			17.130	<.001*
No	39 (63.9)	13 (25)		
Yes	22 (36.1)	39 (75)		
Downy mildew			10.221	0.001*
No	45 (73.8)	23 (44.2)		
Yes	16 (26.2)	29 (55.8)		
Basal rot			0.462	0.496 <sup>ns</sup>
No	49 (80.3)	39 (75)		
Yes	12 (19.7)	13 (25)		
Pests identified on cabbage				
Diamondback moth				
No	46 (75.4)	21 (40.4)		
Aphids				
No	15 (24.6)	18 (34.6)	1.365	0.243 <sup>ns</sup>
Yes	46 (75.4)	34 (65.4)		
Pests identified on Tomato				

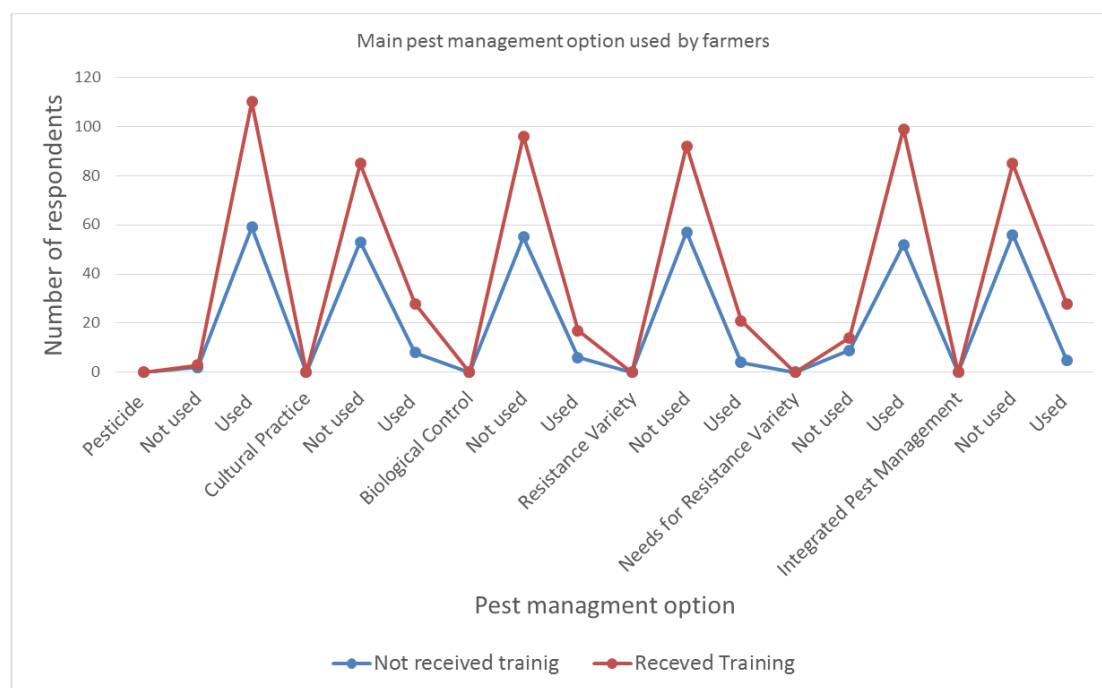
Do you get specific training about pesticides? (N= Yes=52, No=61)				
	No N (%)	Yes N (%)	X <sup>2</sup>	P-Value
Fruit borer			26.246	<.001*
No	48 (78.7)	16 (30.8)		
Yes	13 (21.3)	36 (69.2)		
White fly			3.226	0.072 <sup>ns</sup>
No	15 (24.6)	21 (40.4)		
Yes	46 (75.4)	31 (59.6)		
Aphids			1.365	0.243 <sup>ns</sup>
No	15 (24.6)	18 (34.6)		
Yes	46 (75.4)	34 (65.4)		

Ns: No significant difference ( $p > 0.05$ , \*: Significantly higher percentage in the second category ( $p < 0.05$ ).

### 3.4. Types of Pest Management, Pesticides Used and Number of Spray Per Season

On pest management practice, there were significant differences between those who have received training and those who haven't. While both groups predominantly rely on pesticide use, trained farmers are notably more inclined to have knowledge about cultural practices (38% vs. 13%), biological control (21% vs. 10%), resistance varieties (33% vs. 7%), and integrated pest management (44% vs. 8%). Trained farmers

higher understanding proportions of using these methods compared to untrained farmers, indicating the effectiveness of training in promoting more sustainable pest management strategies. However, both groups express a high need for resistance varieties, with 90% of trained farmers and 85% of untrained farmers indicating such needs. Overall, even though there are difference knowledge and practice on trained and non-trained, still number of farmers who apply the biological and resistance variety is very low, due to unavailability of knowledge.

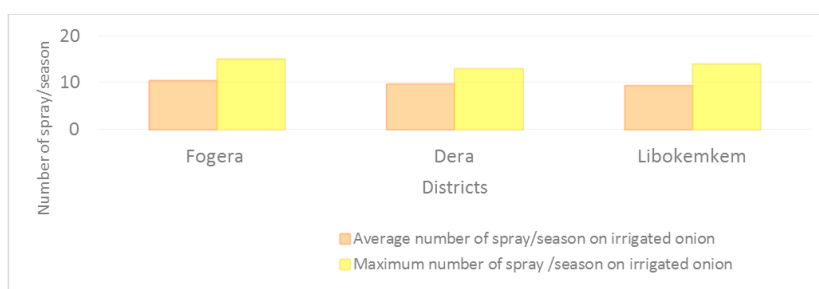


**Figure 2.** Represents the farmers' pest management practice in the study area.

### *Number of spray per season and Common pesticides used for vegetable pest control in irrigated vegetable*

The common pesticides used in the study area are, insecticides, Dimethoate, Karate, Profenofose, and fungicides are Mancozeb, Rodomil. Farmers in the Fogera district apply an average of approximately 10.222 sprays per season on irrigated onion fields, with a maximum of 15 sprays observed

during the season. In Dera district, farmers apply an average of about 9.519 sprays per season on irrigated onion crops, with the maximum number of sprays reaching 13 during the season. Farmers in Libokemkem district apply an average of around 9.325 sprays per season on irrigated onion fields, with the maximum number of sprays recorded at 14 during the season.



**Figure 3.** Represents the types of pest management used by respondents.

### 3.5. Source of Information about Pesticides Handling for Farmers

The results from the Chi-square test in Table 4 indicate notable connections between where farmers obtain information regarding pesticide application rates and spray volume and their participation in specific pesticide training. Farmers who received training showed a significant inclination towards obtaining information from extension workers compared to those without training ( $X^2 = 13.18$ ,  $p < 0.001$ ). Specifically, among untrained farmers, 15.38% reported receiving information from extension workers, while among trained farmers, this percentage increased substantially to 84.62%. Similarly, there was a significant relationship between acquiring information from chemical dealers and training receipt ( $X^2 = 15.44$ ,  $p < 0.001$ ). Trained farmers

were more likely to obtain information from chemical dealers compared to untrained farmers, with 73.08% of trained farmers relying on this source, as opposed to 26.92% of untrained farmers. Farmers who received training were significantly more inclined to rely on their own experience for pesticide information ( $X^2 = 8.03$ ,  $p = 0.005$ ). Specifically, 69.23% of trained farmers relied on their own experience, whereas only 30.77% of untrained farmers did so. Trained farmers were significantly more likely to read pesticide labels for information compared to untrained farmers ( $X^2 = 14.36$ ,  $p < 0.001$ ). Among trained farmers, 84.62% reported reading labels, while only 15.38% of untrained farmers did. There was a significant association between guessing and training receipt ( $X^2 = 21.85$ ,  $p < 0.001$ ). Untrained farmers were more prone to relying on guessing for pesticide information, with 82.69% reporting this method, compared to only 17.31% of trained farmers.

**Table 4.** Source of information for pesticide handling for smallholder farmers.

Do you get specific training about pesticides? (N= Yes=52, and N=No=61, Total N=113)				
Source of Information	No N (%)	Yes N (%)	$X^2$	P-value
From extension worker				
No	29 (47.5)	8 (15.4)		
Yes	32 (52.5)	44 (84.6)	13.18	<0.001*
Chemical dealers				
No	39 (63.9)	14 (26.9)		
Yes	22 (36.1)	38 (73.1)	15.44	<0.001*

Do you get specific training about pesticides? (N= Yes=52, and N=No=61, Total N=113)				
Source of Information	No N (%)	Yes N (%)	X <sup>2</sup>	P-value
Own experience				
No	35 (57.4)	16 (30.8)		
Yes	26 (42.6)	36 (69.2)	8.03	0.005*
By reading the label			14.36	<0.001*
No	30 (49.2)	8 (15.4)		
Yes	31 (50.8)	44 (84.6)		
By guess			21.85	<0.001*
No	24 (39.3)	43 (82.7)		
Yes	37 (60.7)	9 (17.3)		

Notes: Ns: No significant difference ( $p > 0.05$ ), \*: Significantly higher percentage in the second category ( $p < 0.05$ )

### 3.6. Respondents' Pesticide Storage Practice

Table 5 represents the respondents' pesticide storing practice, there is a notable link between storing pesticides within the house and receiving training ( $X^2 = 8.53$ ,  $p = 0.003$ ). Trained farmers tend to store pesticides outside the house more frequently compared to those without training. Specifically, among untrained farmers, 58.06% stored pesticides within the house, while among trained farmers, this figure dropped to 30.77%. Likewise, there is a significant correlation between storing pesticides on the farm and training receipt ( $X^2 = 29.8$ ,  $p < 0.001$ ). Trained farmers are more inclined to store pesticides on the farm than untrained farmers. Among those without training, only 6.45% stored pesticides on the farm, whereas this figure rose substantially to 92.31% among trained farmers. A significant relationship exists between storing pesticides in a separate place away from children and animals and training receipt ( $X^2 = 39.5$ ,  $p < 0.001$ ). Trained farmers demonstrate a higher tendency to store pesticides in a separate location compared to untrained farmers. Specifically, among those without training, 19.35% stored pesticides in a separate place, while among trained farmers, this percentage increased to 76.92%.

### 3.7. Washing the Spray Tank and Discharging Pesticides

Table 5 summarize that, there is a noteworthy association

between washing the spray tank after use with the triple rinsing method and training receipt ( $X^2 = 22.57$ ,  $p < 0.001$ ). Trained farmers are more likely to employ the triple rinsing method compared to untrained farmers. Among those without training, only 20.97% washed the spray tank with this method, while among trained farmers, 75% did so. But all of the respondents wash the sprayer when they want to spray herbicide. A significant connection was found between discharging pesticides in the irrigation ditch and training receipt ( $X^2 = 26.12$ ,  $p < 0.001$ ). Untrained farmers are more prone to discharging pesticides in the irrigation ditch compared to trained farmers. Among those without training, 64.52% discharged pesticides in the irrigation ditch, whereas only 23.08% of trained farmers did so. There is a significant correlation between discharging pesticides on the crop and training receipt ( $X^2 = 22.13$ ,  $p < 0.001$ ). Trained farmers are less likely to discharge pesticides on the crop compared to untrained farmers. Among those without training, 16.13% discharged pesticides on the crop, whereas among trained farmers, this figure increased notably to 80.77%.

### 3.8. Reading the Instructions on the Pesticide Carefully Before Spraying

There is no significant association between reading pesticide instructions carefully before spraying and training receipt ( $X^2 = 0.002$ ,  $p = 0.97$ ). Both trained and untrained farmers showed similar proportions in reading pesticide instructions carefully before spraying.

**Table 5.** Pesticide storage, wash the sprayer tank and discharge remaining tank water the by small holder farmers in the study area, in irrigation vegetable.

Variables	Do you get specific training about pesticides? (N= Yes=52, No=61)		X <sup>2</sup>	P-value
	N No (%)	N Yes (%)		
Store within the house			8.53	0.003*
No	25 (40.9)	36 (69.2)		
Yes	35 (59.1)	16 (30.8)		
Store pesticides on farm			29.8	< 0.001*
No	34 (55.7)	4 (7.7)		
Yes	26 (44.3)	48 (92.3)		
Store pesticide in a separate place (away from children and animals)			39.5	< 0.001*
No	49 (80.3)	12 (23.1)		
Yes	11 (19.7)	40 (76.9)		
Wash the spray tank after use with triple rinsing method			22.57	<0.001*
No	42 (68.9)	13 (25)		
Yes	18 (31.1)	39 (75)		
Discharge in irrigation ditch			26.12	<0.001*
No	17 (27.9)	40 (76.9)		
Yes	43 (72.1)	12 (23.1)		
Discharge on crop			22.13	<0.001*
No	38 (62.3)	10 (19.2)		
Yes	22 (37.7)	42 (80.8)		

Ns: No significant difference ( $p > 0.05$ , \*: Significantly higher percentage in the second category ( $p < 0.05$ ).

### 3.9. Place of Pesticide Mixing and Mix Different Pesticides

#### Place of Pesticide Mixing:

Table 6 showed that a notable There were significant differences in the location where farmers mixed pesticides based on whether they received specific training about pesticides or not ( $\chi^2 = 6.4$ ,  $p = 0.01$ ). Among those who received training, 32 (52.5%) farmers mixed pesticides near river or community water sources compared to 15 (28.8%) of those who did not receive training. Additionally, 47 (77%) of trained farmers mixed pesticides in the field (farm), while only 5 (9.6%) of untrained farmers did so ( $\chi^2 = 51.38$ ,  $p < 0.001$ ). Conversely, a higher proportion of untrained farmers (40 or 76.9%) mixed pesticides at home compared to trained farmers (33 or 54.1%) ( $\chi^2 = 11.27$ ,  $p < 0.001$ ).

#### Pesticide Handling Practices:

There was no significant difference between trained and

untrained farmers regarding mixing pesticides considering the indicated dose ( $\chi^2 = 3.15$ ,  $p = 0.08$ ), mixing different pesticides not recommended to be mixed ( $\chi^2 = 0.31$ ,  $p = 0.58$ ), and reading instructions on the pesticide carefully before spraying ( $\chi^2 = 0.002$ ,  $p = 0.97$ ).

### 3.10. Protective Equipment Used During Pesticide Application

The results in table 6 indicate significant associations between pesticide training and safer practices among small-holder farmers. Specifically, the practice of disposing of empty containers into irrigation canals or rivers shows a significant difference ( $X^2 = 6.97$ ,  $p = 0.008$ ), with a higher proportion of untrained farmers (68.9%) engaging in this practice compared to trained farmers (44.2%). Additionally, untrained farmers are significantly more likely to spray pesticides with bare feet (75% vs. 21%,  $X^2 = 33.06$ ,  $p < 0.001$ ) and less likely to use cotton overalls (95% vs. 25%,  $X^2 = 59.04$ ,  $p < 0.001$ ).

However, no significant differences were found in wearing normal clothes only, spraying with one piece of protective equipment, or bathing after application, indicating similar

proportions between trained and untrained groups in these aspects. Overall, training is effective in promoting safer pesticide use practices among farmers.

**Table 6.** Pesticide mixing, protective equipment the by small holder farmers in the study area, in irrigation vegetable.

Variables	Do you get specific training about pesticides? (N= Yes=52, No=61)			
Place of pesticide mixing			X <sup>2</sup>	P* value
Near river water/community water sources			6.4	0.01*
No	2 (47.5)	3 (71.2)		
Yes	3 (52.5)	1 (28.8)		
Mix in the field (farm)			51.38	<0.001*
No	4 (77)	(9.6)		
Yes	1 (23)	4 (90.4)		
Mix At home			11.27	<0.001*
No	2 (45.9)	4 (76.9)		
Yes	3 (54.1)	1 (23.1)		
Mix pesticide considering the indicated dose			3.15	0.08 <sup>ns</sup>
No	4 (67.2)	2 (51.9)		
Yes	1 (31.1)	2 (48.1)		
Do you mix different pesticides (non-recommended to be mixed?)			0.31	0.58 <sup>ns</sup>
No	2 (41)	1 (36.5)		
Yes	1 (31.1)	2 (48.1)		
Reading the instructions on the pesticide carefully before spraying			0.002	0.97 <sup>ns</sup>
No	3 (59.1)	3 (59.6)		
Yes	2 (39.3)	2 (40.4)		
Protective equipment used				
Wearing normal clothes only			1.8	0.18 <sup>ns</sup>
No	3 (59.1)	3 (71.2)		
Yes	2 (40.9)	1 (28.8)		
Spraying with bare feet			33.06	<0.001*
No	1 (24.6)	4 (78.8)		
Yes	4 (75.4)	1 (21.2)		
Spraying with one PPE (boot only, Hate only, or face mask only)			1.29	0.26 <sup>ns</sup>
No	4 (73.8)	4 (82.7)		
Yes	1 (26.2)	(17.3)		
Using cotton overalls (tuta)			59.04	<0.001*
No	5 (95.1)	1 (25)		
Yes				
Bath after application			1.86	0.17 <sup>ns</sup>

Variables	Do you get specific training about pesticides? (N= Yes=52, No=61)			
Place of pesticide mixing			X <sup>2</sup>	P* value
No	5 (83.6)	3 (73.1)		
Yes	1 (16.4)	1 (26.9)		

Ns: No significant difference ( $p > 0.05$ , \*: Significantly higher percentage in the second category ( $p < 0.05$ ).

### 3.11. Respondents Empty Pesticide Container Disposal

The results indicate that specific training about pesticides significantly influences farmers' behaviors regarding the disposal of empty pesticide containers and their perceptions of certain pesticide hazards. Trained farmers are much less likely to engage in harmful disposal practices, such as throwing containers into irrigation canals or rivers (44.2% vs. 68.9%) and are more likely to adopt safer methods like collecting and burying or burning the containers (92.3% vs. 54.1%). The statistical significance of these differences ( $p$ -values  $< 0.001$  for most practices) underscores the effectiveness of training in promoting safer disposal methods. Additionally, trained farmers show a higher awareness of the health risks posed by pesticides (69.2% vs. 40.9%) and their impact on the environment (94.2%

vs. 65.6%), as reflected by significant chi-square values ( $X^2 = 9.016$  and  $X^2 = 17.78$ , respectively).

### 3.12. Respondents Perception on Pesticide Hazards

The training does not significantly alter farmers' perceptions of pesticides' effects on animal health, with similar percentages in both groups (trained: 26.9%, untrained: 23%). This lack of significant difference ( $X^2 = 0.24$ ,  $p = 0.63$ ) suggests that while training is effective in improving certain behaviors and awareness, it might need to be more comprehensive or targeted to address all aspects of pesticide hazard perception, especially concerning animal health. Overall, these findings highlight the need for more extensive and targeted training programs to ensure comprehensive improvements in pesticide handling and awareness among farmers.

**Table 7.** Represents the Fate of empty pesticide container.

Fate of empty pesticide container	Do you get specific training about pesticides? (N= Yes=52, No=61)			
	No (N) (%)	Yes (N) (%)	X <sup>2</sup>	P-value
Throw into irrigation canals or rivers (for this year)			6.97	0.008*
No	1 (31.1)	2 (55.8)		
Yes	4 (68.9)	2 (44.2)		
Collect and bury in ground or burn			20.19	<0.001*
No	2 (45.9)	(7.7)		
Yes	3 (54.1)	4 (92.3)		
Collect and burn on farm			15.95	<0.001*
No	4 (72.1)	1 (34.6)		
Yes	1 (27.9)	3 (65.4)		
Keep for domestic use			17.58	<0.001*
No	2 (44.3)	4 (82.7)		
Yes	3 (55.7)	(17.3)		
Collect and sell them			17.046	<.001*

Fate of empty pesticide container	Do you get specific training about pesticides? (N= Yes=52, No=61)		X <sup>2</sup>	P-value
	No (N) (%)	Yes (N) (%)		
No	3 (63.9)	4 (94.2)		
Yes	2 (36.1)	(3.8)		
Dump them by the field (throw away on farm)			12.043	<0.001*
No	2 (42.6)	3 (75)		
Yes	3 (57.4)	1 (25)		
Respondents perception of pesticide hazard				
Do you think that pesticides affect human health?			9.016	0.003*
No	3 (59.1)	1 (30.8)		
Yes	2 (40.9)	3 (69.2)		
Do you think that pesticides affect the environment (water bodies)?			17.78	<0.001*
No	2 (34.4)	(5.8)		
Yes	4 (65.6)	4 (94.2)		
Do you think as pesticides affect animal health?			0.24	0.63 <sup>ns</sup>
No	4 (77)	3 (73.1)		
Yes	1 (23)	1 (26.9)		

Ns: No significant difference ( $p > 0.05$ , \*: Significantly higher percentage in the second category ( $p < 0.05$ ).

## 4. Discussion

Pesticide safety practices are critical for minimizing health risks and environmental impact. Key practices include proper personal hygiene, effective laundering, separate pesticide storage at home, adherence to recommended concentrations and quantities on labels, refraining from eating and drinking during spraying, correct use of personal protective equipment (PPE), and appropriate disposal of empty containers [16].

### *Demographic characteristics of respondents*

Various demographic characteristics influence farmers' perceptions and practices regarding pesticide use. Factors such as age, agricultural experience, education level, farm size, yield, average income, and membership in agricultural organizations are significant [2]. However, our results show no significant association between trained and non-trained age groups, indicating that similar age found in both group. Similarly, no significant association was found between the educational levels of trained and non-trained farmers, suggesting comparable educational backgrounds in both groups. Additionally, family size did not show significant differences, indicating similar family sizes across the groups.

### *Pest identification skills*

Training significantly enhances farmers' ability to identify specific pests. Trained farmers were better at identifying onion

thrips ( $X^2 = 17.130$ ,  $p < .001$ ) and downy mildew ( $X^2 = 10.221$ ,  $p = 0.001$ ) on onion crops. However, no significant difference was observed for basal rot. For cabbage pests, such as diamondback moths and aphids, no significant difference was found. On tomato crops, trained farmers identified fruit borer infestations more effectively ( $X^2 = 26.246$ ,  $p < .001$ ) and showed a trend towards better identification of whitefly infestations ( $X^2 = 3.226$ ,  $p = 0.072$ ). The result in line with the research result which states, trained farmers were better equipped to integrate different pest control methods and make informed decisions based on ecological principles [22]. The current findings suggest that targeted training improves pest identification skills, which are crucial for effective pest management. However, a five-day training may not be sufficient for comprehensive skill development.

### *Pest management practices*

Trained farmers are more likely to understand diverse and sustainable pest management practices. They reported higher understanding and considering of cultural practices (38% vs. 13%), biological control (21% vs. 10%), resistant varieties (33% vs. 7%), and integrated pest management (44% vs. 8%). Both trained and untrained farmers showed a high demand for resistant varieties (90% vs. 85%). This indicates the effectiveness of training in promoting sustainable pest management practices. IPM integrates various pest control methods, including varietal resistances, cultural practices, mechanical and biological controls, and selective chemical use tailored to

specific field conditions [29, 4].

#### *Pesticide usage and application frequency*

Common pesticides used include Dimethoate, Karate, Profenofos (insecticides), and Mancozeb, Rodomil (fungicides). In the Fogera district, farmers applied an average of 10.2 sprays per season on irrigated onion fields, with a maximum of 15. In the Dera and Libokemkem districts, the averages were 9.5 and 9.3 sprays per season, respectively, with maximums of 13 and 14. The result supported by a findings which highlight the need for effective pest management strategies to reduce the frequency of pesticide applications [26]. Surveys indicate that some major vegetables are sprayed 12–17 times per season, often with overuse and misuse of pesticides, leading to pest resurgence and resistance [27].

#### *Information Sources on pesticide handling and selecting*

Trained farmers are more likely to seek information from reliable sources. They consult extension workers (84.62% vs. 15.38%,  $X^2 = 13.18$ ,  $p < 0.001$ ) and chemical dealers (73.08% vs. 26.92%,  $X^2 = 15.44$ ,  $p < 0.001$ ) more frequently. They also rely on personal experience (69.23% vs. 30.77%,  $X^2 = 8.03$ ,  $p = 0.005$ ) and reading labels (84.62% vs. 15.38%,  $X^2 = 14.36$ ,  $p < 0.001$ ), whereas untrained farmers are more prone to guessing (82.69% vs. 17.31%,  $X^2 = 21.85$ ,  $p < 0.001$ ). This result in line with the research, [20] found that farmers who received training were significantly more likely to consult agricultural extension services for pesticide-related information. The other research result magnify the impact of training on pesticide purchase, [30] indicated that trained farmers are more likely to purchase pesticides from reputable dealers who provide guidance on proper usage, as opposed to untrained farmers who might rely on less reliable sources.

This underscores the impact of training on farmers' information-seeking behavior and the importance of structured education in pesticide handling.

#### *Pesticide Storage Practices*

Training significantly improves pesticide storage practices. Trained farmers are more likely to store pesticides outdoors (30.77% vs. 58.06% of untrained farmers) and on the farm (92.31% vs. 6.45% of untrained farmers). They also tend to store pesticides in separate areas away from children and animals (76.92% vs. 19.35%). These practices align with findings from previous studies, [6] found that training programs effectively encouraged farmers to store pesticides in safer locations, such as designated storage areas away from living spaces and children. A study also highlighted that trained farmers were more likely to adopt these safer storage practices compared to untrained farmers. [28] Reported that farmers with higher levels of education and training were less likely to store pesticides at home, opting instead for more secure and appropriate storage solutions.

#### *Pesticide mixing practices*

Trained farmers prefer mixing pesticides away from water sources and in the field ( $X^2 = 6.4$ ,  $p = 0.01$ ;  $X^2 = 51.38$ ,  $p < 0.001$ ). Untrained farmers are more likely to mix pesticides at

home ( $X^2 = 11.27$ ,  $p < 0.001$ ). No significant difference was found in mixing pesticides according to indicated doses or mixing different pesticides ( $X^2 = 3.15$ ,  $p = 0.08$ ;  $X^2 = 0.31$ ,  $p = 0.58$ ). Training impacts certain safety protocols but may not fully address all mixing practices. Research supports, [31] reported that training programs led to a higher adoption rate of mixing pesticides in the field, away from residential areas and water sources. Similar finding which support our result, [39] Demonstrated that Brazilian farmers who participated in training programs were more likely to mix pesticides directly in the field, adhering to safer practices and reducing the risk of contaminating their home environments.

#### *Protective equipment use*

Untrained farmers are more likely to spray pesticides without footwear (75% vs. 21%,  $X^2 = 33.06$ ,  $p < 0.001$ ) and less likely to use cotton overalls (95% vs. 25%,  $X^2 = 59.04$ ,  $p < 0.001$ ). However, no significant differences were found in wearing regular clothes, using just one piece of protective gear, or bathing after application. Training proves effective in encouraging safer pesticide use practices, aligning with findings, [40] found that training programs significantly increased the use of PPE among farmers. Trained farmers were more likely to wear appropriate protective clothing, gloves, and masks during pesticide application, reducing their exposure to harmful chemicals. And also the other result which support current finding, Perry and Layde [37] reported that educational interventions led to higher adoption rates of PPE among farmers. [27] found that educational initiatives increased farmers' awareness of the dangers of pesticide exposure and the benefits of PPE. As a result, trained farmers showed a higher compliance rate with PPE usage guidelines. This study highlighted that trained farmers were more consistent in using PPE compared to their untrained counterparts.

#### *Pesticide instructions, tank washing, and disposal*

Training impacts certain pesticide handling practices. Trained farmers are more likely to use the triple rinsing method for washing the spray tank and less likely to discharge pesticides in irrigation ditches or on crops. No significant difference was found in reading pesticide instructions before spraying, suggesting this aspect may not be influenced by training [20]. Education programs can directly influence and improve practice habits, providing an effective solution for preventing pesticide poisoning [27]. The result also align with the [30], finding highlighted that training programs significantly influenced farmers' disposal practices. Trained farmers were less likely to dispose of pesticide containers inappropriately, such as in irrigation ditches or on crops. Instead, they adopted safer disposal methods, reducing environmental hazards.

#### *Empty pesticide container disposal and perception of pesticide hazards*

Training significantly influences practices related to pesticide container disposal and understanding of pesticide hazards. Trained farmers are less likely to use improper disposal methods and show greater awareness of risks to

human health and the environment. Untrained individuals are more likely to recognize the harmful effects of pesticides on human health ( $X^2 = 9.016$ ,  $p = 0.003$ ) and the environment, especially water bodies ( $X^2 = 17.78$ ,  $p < 0.001$ ). This results supported by studies emphasizing the importance of educational initiatives [31, 17]. Similarly, this study likely underscores the importance of providing farmers with information based on scientific evidence to raise awareness about environmental measures and promote safer pesticide handling practices.

## 5. Conclusion

Training significantly enhances many aspects of pesticide handling and safety practices among farmers. However, certain areas, such as following recommended doses and avoiding the mixing of unendorsed pesticides, remain unchanged. Additional efforts, including longer training durations and follow-up sessions, are necessary for comprehensive improvement. Challenges in pest identification highlight the need for extended training to address all facets of pesticide handling effectively. Overall, education plays a crucial role in shaping safer and more sustainable farming practices.

## 6. Recommendations

To improve the effectiveness of training programs, the following recommendations are suggested:

- 1) Extended Training Duration: Increase the duration of training programs to ensure comprehensive skill development, particularly in pest identification and safe pesticide handling practices.
- 2) Follow-Up Sessions: Implement periodic follow-up sessions to reinforce training and address any gaps in knowledge or practice.
- 3) Customized Training Modules: Develop tailored training modules that address specific needs based on regional pest challenges and farming practices.

## Abbreviations

PPE	Personal Protective Equipment
CSA	Central Statistical Agency of Ethiopia
WHO	World Health Organization

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## Conflicts of Interest

The authors declare no conflicts of interest.

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