Journal of Animal & Plant Sciences, 35(5): 2025, Page: 1387-1397
ISSN (print): 1018-7081; ISSN (online): 2309-8694
https://doi.org/10.36899/JAPS.2025.5.0119

EVALUATION OF FARMERS' PRACTICES AND KNOWLEDGE ON THE SAFE USE OF PESTICIDES IN ALGERIA: CASE OF THE REGION OF EL-OUED

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ABSTRACT

Modern agriculture's heavy reliance on pesticides presents serious health risks and adds to environmental deterioration. This study looked at farmers' sources of information about relevant risks and assessed their knowledge and actions regarding the safe use of pesticides. In the south-eastern Algerian district of El-Oued, which ranks third in the country for potato cultivation and is renowned for its extensive vegetable output, 136 farmers participated in a field survey. According to the report, 131 commercial pesticide products were used. 41% of respondents said they utilized generic substitutes, whilst 59% said they used branded international products. The primary objectives included weeds, fungal diseases, and insect pests like tomato leaf miner, aphids, and whiteflies. The most commonly utilized active ingredients were metribuzin, fosetyl-aluminum, and abamectin. The majority of farmers did not follow basic safety precautions, despite 71% of them acknowledging the dangers of pesticide exposure. The risk of environmental contamination increased since pesticide containers were frequently disposed of improperly and personal protective equipment was rarely used. Additionally, more than 60% of the farmers solicited guidance from unofficial sources like neighbors or nearby pesticide vendors. The results show a substantial discrepancy between safe practices and knowledge. In order to guarantee the safe and sustainable use of pesticides, these findings highlight the critical need for enhanced farmer training, efficient regulatory enforcement, and the creation of focused awareness campaigns.

Keywords: Agricultural extension, awareness, chemical exposure, farmer behavior, personal protective equipment, pest control, rural knowledge, safety compliance

Published first online August 16, 2025 Published final September 30, 2025

INTRODUCTION

Significant health and environmental problems are brought up by the global use of pesticides, which involve about 1,500 different chemical chemicals (Bolognesi and Merlo, 2011). Vegetable farmers mostly use chemical pest control to boost yields in order to satisfy market needs. Intensive application, however, can have negative effects on ecosystems, farmers, and consumers (Sanborn *et al*., 2004; Pazou *et al*., 2006a, b), with acute to chronic health effects (Mahmood *et al*., 2016). The main way that humans are exposed is through food, but they can also be exposed by water, inhalation, or skin contact (Belhadi *et al*., 2016). With 6.09% of the African market, Algeria uses pesticides in a comparatively low manner (UIPP, 2009; FAO, 2014). However, some crops, particularly those grown in greenhouses, need a lot of pesticide inputs (Nicot, 2008). According to a recent study conducted in the Ziban region (Cheiakh *et al*., 2024), the greenhouse microclimate promotes the growth of pests and fungi, which results in the overuse of pesticides that have negative effects on the environment and farmers.

With over 480 active ingredients registered and yearly consumption ranging from 6,000 to 10,000 tons, Algeria's use of pesticides increased by 139% between 2000 and 2021 (FAO, 2023). This rise coincides with the growth of vegetable farming in arid regions, which has been aided by national development initiatives. Currently, over 92,736 hectares are used for vegetable cultivation, of which 41% is dedicated to potatoes (*Solanum tuberosum*). More than 13 million quintals of potatoes are produced annually in the state of El Oued alone, accounting for more than 30% of the nation's total yield (DSA, 2021). Despite the region's significance in agriculture, many farmers are not properly trained in handling pesticides. Inadequate usage of personal protective equipment (Rahmoune *et al*., 2018; Sarkar *et al*., 2021), coupled with poor levels of education and training, leads to dangerous phytosanitary procedures, raising health hazards and environmental contamination (Vilain *et al*., 2008). Small-scale farmers in particular frequently ignore or misunderstand official pesticide bulletins published by the Ministry of Agriculture that offer crucial instructions on pest management, doses, and application frequency (Cissé *et al*., 2003; Akogbeto *et al*., 2005).

While earlier research have concentrated on northern Algeria, few data available on pesticide use in southern Saharan zones such as El Oued. The region's remarkable vegetable output and the explosive expansion of pesticide retail stores (DSA, 2021) underscore the need for comprehensive field study. By examining pesticide use trends, safety precautions, and information sources in the El Oued area, this study seeks to close this knowledge gap.

MATERIALS AND METHODS

Study area: One of the world's largest deserts (Benarba *et al*., 2015), the Algerian Sahara occupies around 84% of the country's land area and contains significant subterranean water resources (Sahali and Sahoune, 2019). Because of its relatively low elevation, El Oued is located in the middle of the Grand Erg Oriental in southeast Algeria, inside a sizable synclinal basin known as the Lower Sahara.

Sample size and research tool: the questionnaire: This study employed a mixed-methods approach, combining structured questionnaires with in-depth semi-structured interviews to gain a comprehensive understanding of farmers' pesticide practices. A total of 136 farms were randomly selected across the El-Oued region, covering over 14 municipalities in the four main geographical directions (Figure 1, Table 1). This methodological framework allowed for a nuanced understanding of farmers' behaviors, perceptions, and practices concerning pesticide use. A standardized questionnaire covering a variety of topics, such as pesticide exposure, knowledge levels, preventive practices, and perceived health effects, was prepared in the local language and took about 30 minutes to complete. A thorough explanation of the study's objectives and procedures was given to all respondents prior to their participation, and they were able to complete the survey between December 2021 and February 2023, excluding the summer months of May to August due to reduced agricultural activity and limited accessibility caused by unfavorable weather conditions. To ensure the validity of the responses, the data were cross-verified with credible sources, such as the World Health Organization (WHO), the 2017 edition of the Algerian Plant Health Index, and its revised version published in 2021.

Twelve well-chosen questions were used to evaluate knowledge and behavior related to pesticide use. Incorrect answers received a score of 0, while correct answers received a score of 1. A score of less than six was regarded as having inadequate knowledge, whereas a score of more than six was regarded as having strong knowledge (Table 2). The total knowledge score was a number between 0 and 12.

Table 1. Location of municipalities of survey.

Municipalities	Location	Number of farmers
Kouinine,Taghzout, Guemar and Reguiba	North	31
Nakhla, Robbah, El Ogla and Bayadha	South	32
Hassi Khalifa, Trifaoui, Magrane and Hassani Abdelkrim	East	42
Ourmes and Oued El Alenda	West	31

Table 2. Knowledge of farmers about pesticide (n = 136)

Variables	Correct (%)	Incorrect (%)
Crop damage caused by diseases and pests	47.8	52.8
Name of the pesticide you are using	31.6	68.4
Name of the active ingredient used	10.3	89.7
Pre-harvest interval	73.5	26.5
Deadline for pre-harvesting	90.4	9.6
Buy pesticides in a specified small quantity (repackaging)	54.4	45.6
Pesticides hazards	100	0
Must read the label before use	12.5	87.5
Expiry date	80.9	19.1
Screening of insect and disease samples prior to pesticide use	0.8	99.2
Fate of expired or un labelled products	66.2	33.8
Follow the recommended dose	69.8	30.2

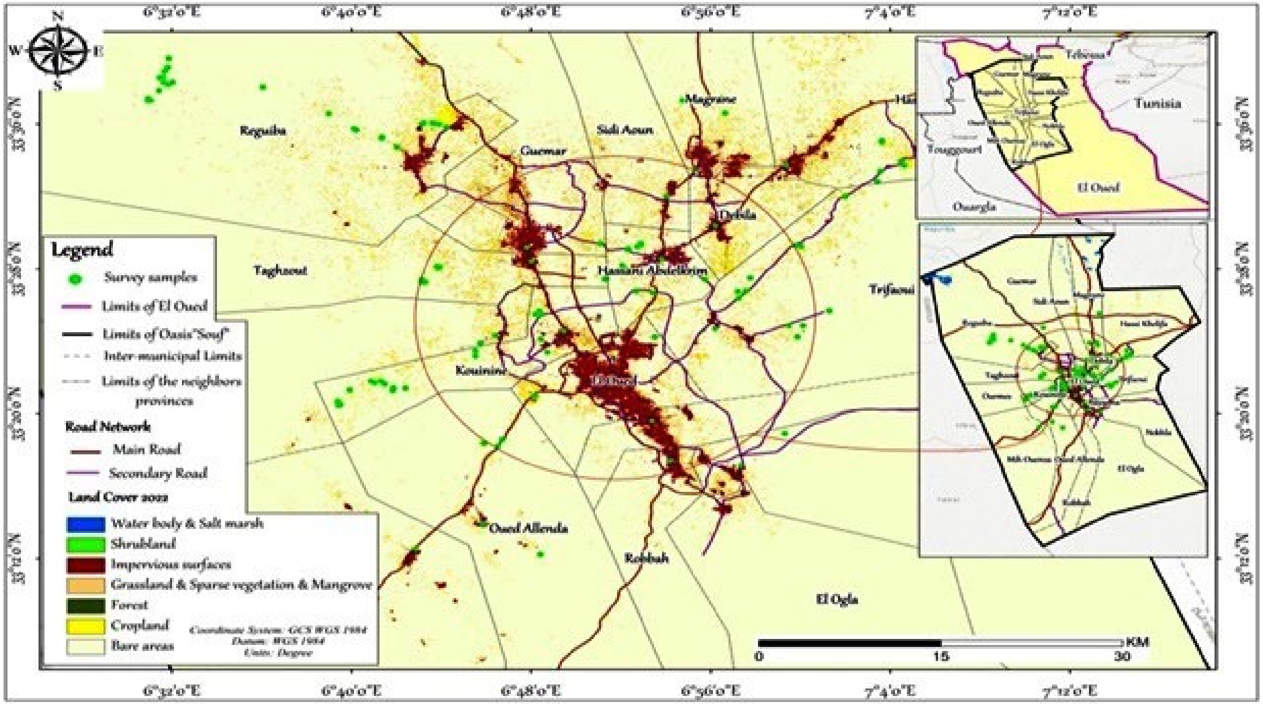

Figure.1 Land use map of El-Oued and location of survey samples

Statistical analysis: The Statistical Package for the Social Sciences (SPSS), version 23 (IBM Corp., USA), was used to enter and analyze the data. For continuous variables, descriptive statistics were presented as means ± standard deviation, and for categorical variables, as frequencies and percentages. To evaluate relationships between categorical variables, the chi-square test or, when applicable, Fisher's exact test were employed. Microsoft Excel was used to do a correlation study between the knowledge and pesticide use components (Microsoft Corp., USA). Statistical significance was defined at $p < 0.05$, and multiple logistic regression analysis was used to find significant predictors of adequate knowledge.

RESULTS

Profile of Farmers and Factors Influencing Pesticide Use: The characteristics of farmers and the many factors affecting their use of pesticides are examined in this document. We want to comprehend how factors like demography, educational attainment, and farming experience interact to influence crop management strategies. Promoting safe and sustainable farming methods requires a deeper comprehension of these connections.

A-Demographics of Participants: This study had 136 farmers in total. The majority of participants (99.3%) were male, and their average age was 44.9 ± 15.9 years (Table 3). Given that men are frequently more active in farm management decision-making, this gender distribution may have an impact on agricultural practices and the dissemination of knowledge.

B-Education Level: In terms of education, more than half of the participants (57.4%) had completed high school or college. Compared to farmers who were illiterate, this group showed a greater awareness of the negative impacts of pesticides on the environment and human health. On the other hand, almost half (42.6%) had only completed elementary or lower secondary school. This finding highlights how crucial education is to encouraging the responsible use of pesticides and reducing their abuse.

C-Agricultural Experience: Between 11 and 20 years of agricultural experience was indicated by a significant percentage of farmers. A small number of very large farms contributed to the significant diversity in the farms' average size of 5.9 hectares (standard deviation = 12.9 hectares). The fact that over 53% of the farmers polled farmed less than 4 hectares may also have an impact on how they use pesticides and crop management techniques.

D-Knowledge of Pesticides: When it came to pesticide knowledge, 29% of farmers had low knowledge (mean = 4.17, standard deviation = 1.02) and 71% had strong knowledge (mean = 7.2, standard deviation = 1.23). Good awareness of pesticides and education level were found to be significantly correlated ($p < 0.01$) (Table 3). This suggests that education is essential for learning about safe pesticide preparation techniques. These results emphasize how crucial demographic and educational characteristics are to comprehending and putting safe agriculture methods into reality. Improving farmer education and training may be crucial to encouraging proper pesticide usage and safeguarding the environment and public health.

Table 3. Demographics of the farm workers who participated in the study (n = 136).

Variable	Frequency (%)	Good knowledge n= 97 (71%)	Poor knowledge n = 39 (29%)	χ value p value
Age				
Less than 39 years	59 (43.4)	46	13	0,0002
From 40 to 59 years	48 (35.3)	39	9	<0.001
More than 60 years	29 (21.3)	12	17	
Education levels				
Illiterate	7 (5.1)	2	5	
Primary (Grades 1–6 years)	23 (16.9)	11	12	0,002
Middle school (Grades 7– 10years)	28 (20.6)	24	4	<0.01
Secondary (Grades11–13 years)				
University (Grades>13 years)	39 (28.7)	29	10	
	39 (28.7)	31	8	
Experience				
≤10 years	21 (15.5)	19	2	0,012
≥11- ≤ 20 years	74 (54.4)	55	19	<0.05
≥ 21 years	41 (30.1)	23	18	
Land size (ha)				
Less than 4	72 (53)	46	26	
≥ 4 - <8	49 (36)	37	12	NS
≥ 8 - <12	5 (3.7)	4	1	
≥ 12	10 (7.3)	10	0	

NS: non-significant

Farming system characteristics: There are two primary categories into which the farmers' cultivated areas can be divided: Vegetables occupy 88% of the area, with the remaining 12% set aside for other crops. 69% of the cultivated area is used for the production of potatoes (*Solanum tuberosum*), mostly with pivot irrigation systems, according to a thorough survey of vegetable crops (Figure 2). Other crops such as carrots (*Daucus carota*), garlic (*Allium sativum*), onions (*Allium cepa*), peanuts (*Arachis hypogaea*), and tomatoes (*Solanum lycopersicum*) occupy the remaining 31%. A statistically significant preference for potatoes over other vegetables was confirmed by a chi square test, with a score of χ^2 = 43.84, df = 1, $p < 0.01$. These findings emphasize how crucial potato farming is to the regional agricultural system and call for special consideration of management and cultural customs.

76% of farmers grow their crops in open fields, 3% utilize greenhouses, and 21% use both cropping types (Figure 3). Farmers' preferences for cropping systems differed significantly (χ^2= 120.24, $p < 0.0001$), with a substantial preference for open-field farming, according to a statistical study (Chi-square test).

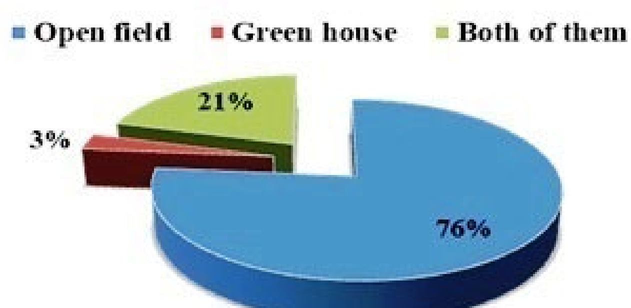

Figure 2. Vegetable cultivation areas according to crop type

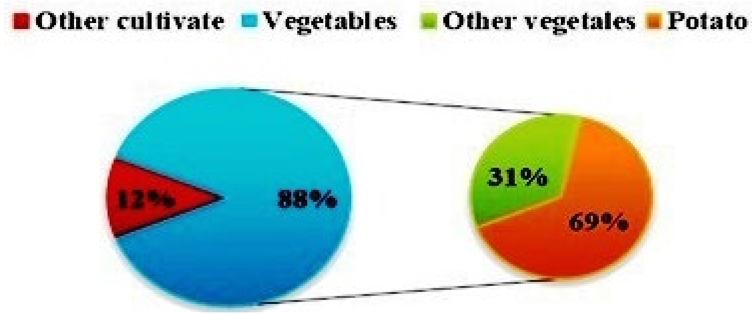

Figure 3. Cropping systems that farmers utilize include open fields, greenhouses, and both techniques

Pesticides used: Table 4 provides comprehensive details on the chemical families, uses, and danger classifications of the active components of pesticides often employed by farmers in El-Oued. The majority of pesticide applications (38%), followed by fungicides, insecticides, herbicides, insecticide-acaricide combos, acaricides, nematicides, and insecticides (28%, 18%), were made by fungicides. Significant variations in the frequency of pesticide usage across these groups were found using a chi-square test (χ^2 = 381.13, df = 5, p < 0.001), suggesting a strong preference for fungicides over other kinds.

Additionally, 131 commercial pesticide items were found in the survey; 41% were generics and 59% were original brands. While generic formulations accounted for 76% of herbicide usage, original products were employed mostly for fungicides (70%) and insecticides acaricides (73%).

Eleven primary categories were discovered in relation to chemical families (Figure 4). With 16% of applications, avermectins were the most commonly utilized, followed by phosphonates and triazinones (13% each), with triazoles and copper-based compounds making up 4% apiece. A variety of other families received the remaining 50%. The preponderance of avermectin-based drugs was highlighted by a chi-square analysis that demonstrated substantial differences in usage frequency among chemical families (χ^2 = 552.13, df = 5, p < 0.001).

The WHO hazard classification showed that 40.9% of the pesticides used by farmers in the El-Oued region were classified as moderately hazardous (Class II), 38.9% as unlikely to present an acute hazard under normal use (Class U), 10.4% as extremely hazardous (Class Ia), and 9.8% as unclassified compounds or Class III (Figure 5).

Significant changes in the distribution of hazard classifications were found using a chi-square test (χ^2 = 225.02, df = 3, p < 0.001), suggesting that farmers tend to prefer moderately and less risky pesticides.

Table 4. Classification of pesticides used by farmer

Type	Active ingredient	Chemical family	Originality (%)
Fungicide 38%	Fosetyl-Aluminium Thiophanate-methyl Hymexazol Propamocarb Difenoconazole Azoxystrobine Cymoxanil	Phosphonates Benzimidazoles Triazines Carbamates Triazoles Strobilurines Acétamides	O=70 G= 30
Insecticide 28%	Chloantraniliprole Lambda-Cyhalothrine Acetamipride Thiaméthoxame Chlorpyriphos Emamectin Benzoate thiocyclame hydrogene oxalate	Diamides Pyréthrinoïdes Néonicotinoïdes Néonicotinoïdes organophosphorés Avermectine Nereistoxin	O=62 G=38
Herbicide 18%	Metribuzine Oxyfluorfene Pendimethaline	Tryazinones Diphenylethers Dinitroanilines	O=24 G=76
Insecticide-Acaricide 10%	Abamectine Dimethoate	Avermectine Organophosphorés	O=73 G= 27
Acaricide 5%	Tebufenpyrad Hexythiazox	Pyrazoles Carboxamides	O=59 G=41
Nematicide 1%	Oxamyl Ethoprophos	Carbamates Organophosphorés	O=25 G=75

O : origin G : generic

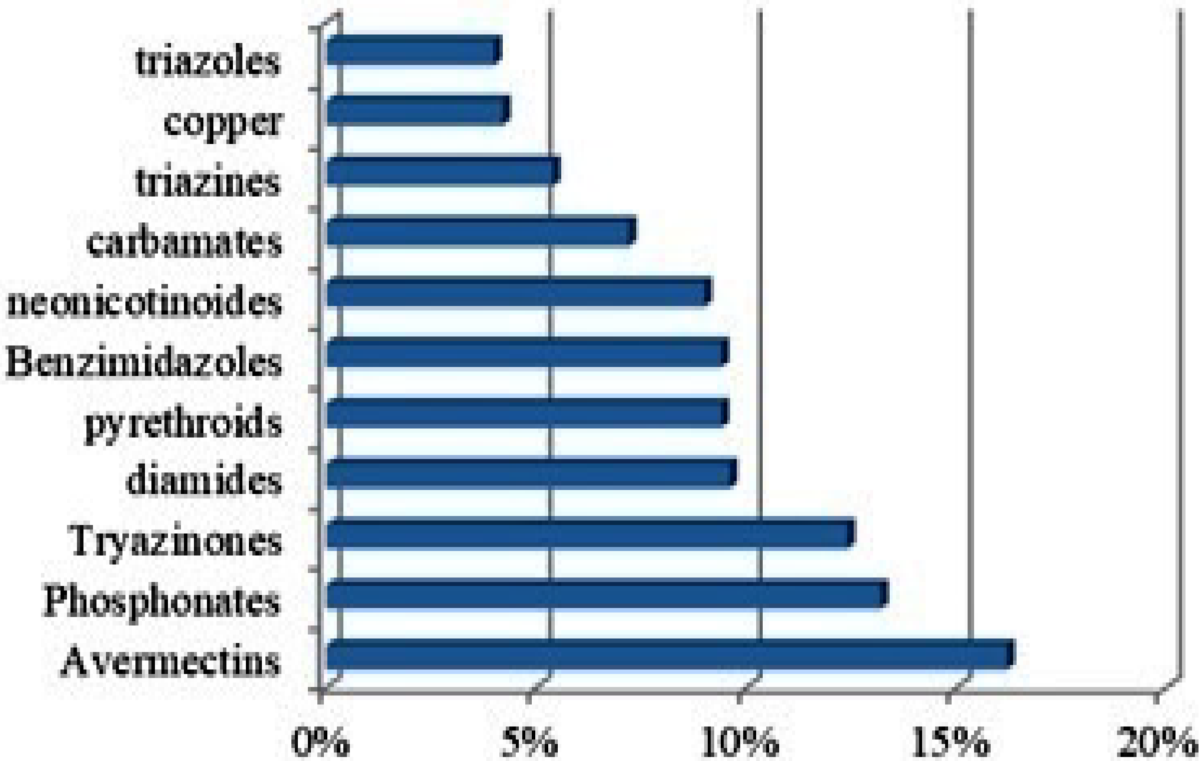

Figure 4. Proportional use of pesticide chemical families in El-Oued

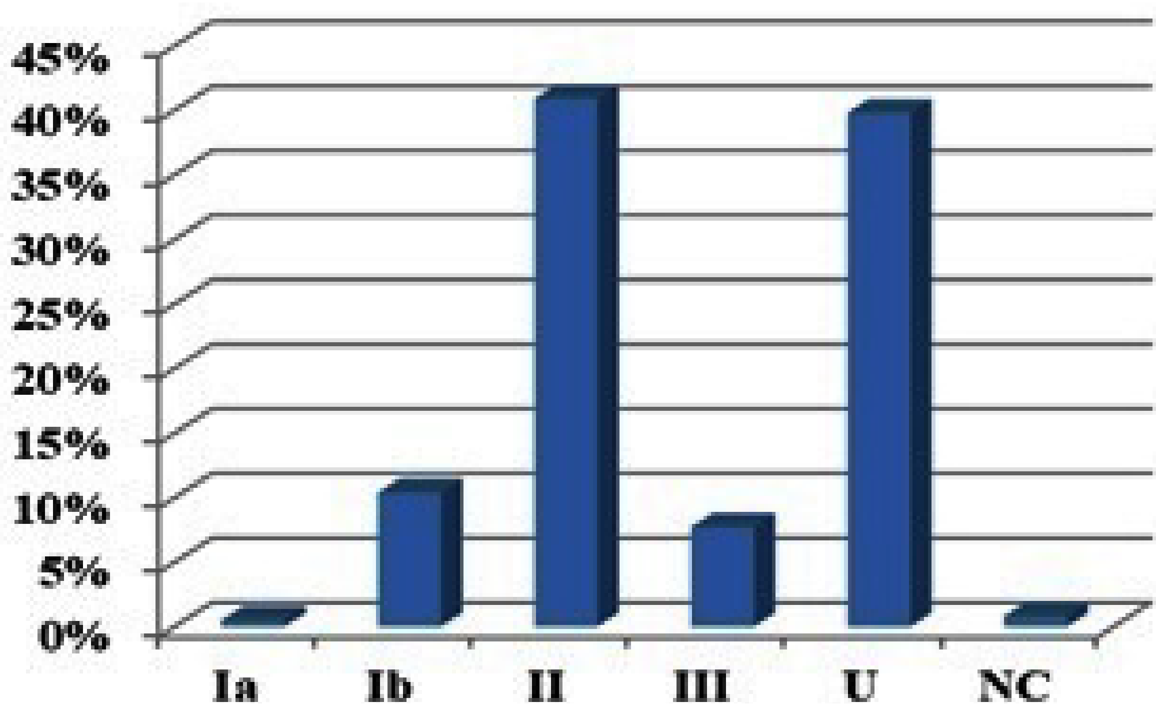

Figure 5. Toxicological classes of pesticides based on WHO classification

Factors predicting a good knowledge of pesticides: The study used multiple logistic regression analysis to find independent factors of farmers' good understanding of pesticide use. The ability to evaluate several explanatory factors simultaneously on a binary end variable—the existence or lack of good knowledge—

makes this analytical method especially suitable. The model improves the findings' internal validity by controlling for potential confounding variables and makes it possible to pinpoint the most important determinants. In order to promote safe and responsible pesticide practices, focused educational interventions and strategic awareness campaigns require a methodological framework of this kind.

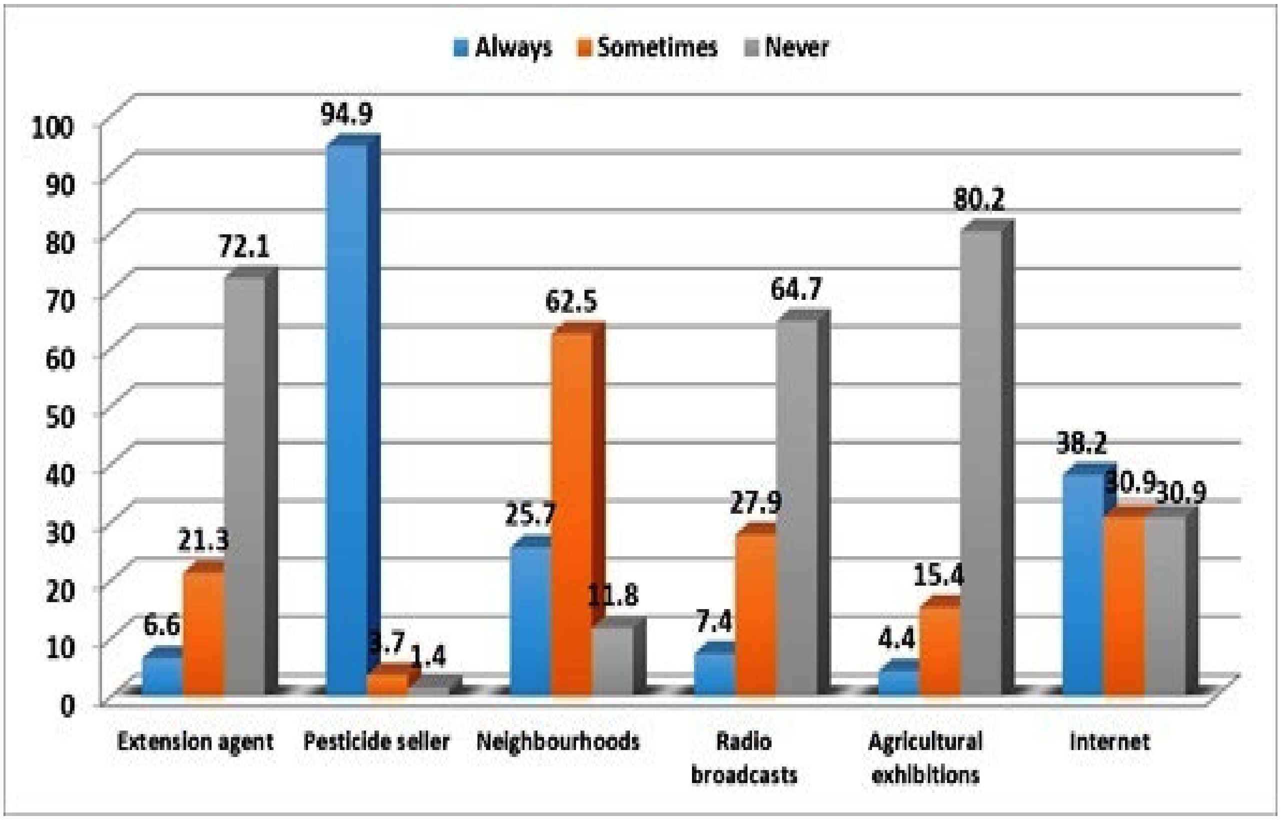

Figure 6. The percentage of farmers who use many sources to learn about the usage of pesticides.

A strong correlation between having a solid understanding of pesticides and two important variables—the municipality and farming experience—is shown by the regression model's results (Table 5). The related t-values and p-values demonstrated that these correlations were statistically notable. 20.8% of the variance in farmers' knowledge levels was also explained by the model's explanatory factors.

Farmers' sources of information on pesticide use: Farmers were asked to indicate the frequency with which they rely on different sources for information about proper pesticide use, using a nominal scale where 'always' = 3, 'sometimes' = 2, and 'never' = 1. According to the results (Figure 6), a vast majority of respondents (94.9%) reported either always or sometimes relying on pesticide sellers as their primary source of information. In contrast, only 1.4% of farmers indicated that they never consulted sellers for pesticide-related guidance. These proportions indicate a predominant dependence on pesticide sellers for pesticide knowledge, which may occur at the expense of more formal or scientifically regulated sources.

Preventive measures: A sizable portion of farmers do not handle pesticides in accordance with fundamental safety protocols, particularly when it comes to donning protective clothing and eye masks, according to the survey's findings. According to Table 6, 98.5% of respondents stated they do not wear these things. But a significant percentage of farmers reported following some safety measures, with 94.8% and 78.7% of them, respectively, saying they did not eat or smoke while using pesticides and then showered afterwards. These findings suggest that farmers may choose which preventive measures to implement.

Disposal of Packaging: A statistically significant correlation between farmers' level of awareness and the disposal of pesticide packaging close to agricultural fields was found when the approaches were analyzed. Regarding pesticide application, 66.7% of farmers who reported this disposal technique showed strong understanding, whereas 33.3% showed poor knowledge (Table 7).

Table 5. Predictive Factors of Pesticide Knowledge Using Multiple Linear Regression (Enter Method)[a]

Independent Variable	R	R²	F value	p-value (F-test)	b	t	p-value (T-test)	P value	VIF
Age	0.456	0.208	5.642	0.00	-0.57	-0.535	0.594	0.594	1.880
L. education					0.034	0.344	0.732	0.732	1.627
Municipality					0.185	2.293	0.023*	0.023	1.054
Experience					-0.289	-3.100	0.002**	0.002	1.412
Type of culture					0.047	0.585	0.559	0.559	1.050
Number of pesticide used					0.101	1.215	0.226	0.226	1.127

a: Enter method means that all variables entered the analysis at the same step; b: the coefficient of the predictor variables; VIF: variance inflation factor; * $p < 0.05$ (statistically significant); ** $p < 0.01$ (highly significant).

Table 6. Prevention practiced by agricultural workers with direct contact with pesticides

Variable	Safe practice (%)	Unsafe practice (%)
Wears special clothes	1.5	98.5
Wears a special face mask	3	97
Wears an eye mask	1.5	98.5
Gloves and shoes	11	89
Wears a scarf	44.1	55.9
Use specific mixing tools	98.5	1.5
Consuming food and smoke during the spraying	94.8	5.2
Take a shower after spraying	78.7	21.3

Table 7. Methods of disposing of empty pesticide packaging identified by respondents

Mode of disposal	Use	Good knowledge n= 97	Poor knowledge n=39	x value p value
Incinerated	Yes 35.2	38.2	28.2	NS
	No 64.8	61.8	71.8	
Abandonment next to the fields	Yes 72.8	68.1	84.6	0.04
	No 27.2	31.9	15.4	<0.05
Burial	Yes 2.2	3.1	0	NS
	No 97.8	96.9	100	
Sell	Yes 4.4	4.1	5.1	NS
	No 95.6	95.9	94.9	

NS: non-significant

DISCUSSION

This study offers a thorough examination of farmers' knowledge and practices on pesticide use in the El-Oued region of Algeria, taking into account the region's unique sociodemographic and agronomic circumstances.

According to earlier research, the majority of responders were under 40 (Zyoud *et al*., 2010; Dadamoussa, 2017; Alam and Wolff, 2016). Additionally, the majority of farmers had a comparatively high level of education, which has been linked to safer usage methods and a better comprehension of pesticide labels (Damalas *et al*., 2019; Mubushar *et al*., 2019). Overall, it was discovered that 75% of farmers knew a fair amount about pesticides. According to Paudel *et al*. (2024), there was a strong correlation between age and knowledge level ($p < 0.05$), with older farmers (≥45 years) exhibiting higher knowledge scores. In agreement with other findings, a significant connection ($p < 0.05$) was also discovered between knowledge and education level (Zyoud *et al*., 2010; Nazari *et al*., 2011; Gaber and Abdel-Latif, 2012; Taghdisi *et al*., 2019). These results provide credence to the idea that increased literacy enhances knowledge of the health concerns associated with pesticides (Oliveira *et al*., 2001; Atreya, 2007). In line with Damalas and Khan

(2016), there was no discernible correlation between farm size and expertise.

Income diversification is facilitated by the fact that more than half of the farms assessed grow vegetables and fodder crops outside of palm plantations. The use of pivot irrigation systems raises the frequency of fungal diseases, particularly *Fusarium oxysporum*, which results in increased fungicide use, yet open-field farming (76%) may lessen direct exposure to chemicals.

Even though branded insecticides are more expensive, knowledgeable farmers frequently favor them. There have been reports of this behavior in Biskra and other Saharan locales (Rahmoune *et al*., 2018; Bettich, 2017). For pesticides, however, many farmers continue touse manual weeding or generic chemicals since they are more affordable. A common insecticide-acaricide, abamectin, is concerning because the WHO has categorized it as extremely dangerous (Category Ib).

In line with research from Pakistan and Kuwait, farmers' primary knowledge source was found to be pesticide vendors (Jallow *et al*., 2017a; Damalas and Khan, 2016). According to our survey of 136 farmers, the main reason for their dependence on sellers is their accessibility and real-world expertise. However, 72.1% of respondents said they avoid agricultural extension agents because they are thought to be less useful. Sellers are frequently driven by business objectives and do not highlight the health or environmental hazards of pesticides (Alam and Wolff, 2016)).

One possible tactic is to distribute personal protection equipment (PPE) to pesticide vendors; this concept is already being explored in Bangladesh (Alam and Wolff, 2016). A large number of farmers do not have proper PPE, which raises their exposure risk. In order to encourage safer pesticide usage, incentive-based extension services have been developed in China in response to comparable problems (Liu and Huang, 2013).

PPE use is still restricted. Because of the high temperatures and short application times, gloves, masks, and overalls are rarely utilized; scarves are the most popular type of protection. As seen in other areas, actual preventative measures are still insufficient despite some understanding of the risks associated with pesticides (Al Zadjali *et al*., 2015; Khanal *et al*., 2016; Jallow *et al*., 2017b; Belhadi *et al*., 2016; Rahmoune *et al*., 2018).

Because there are no official collecting procedures in place, improper disposal of pesticide containers continues (Adechian *et al*., 2015). Commonly, farmers bury, destroy, or resell containers—practices linked to ignorance or insufficient training (Al Zadjali *et al*., 2013; Mohanty *et al*., 2013; Belhadi *et al*., 2016). In order to encourage environmentally friendly disposal practices, this emphasizes the necessity of focused awareness initiatives.

This is the first study that we are aware of that documents farmers' awareness and usage of pesticides in the El-Oued region. The results shed important light on the relationship between socioeconomic characteristics and pesticide management, particularly in relation to the region's contribution to the nation's agricultural output, particularly in the areas of greenhouse crops and potatoes.

Conclusion: Despite farmers' adequate level of knowledge, this study reveals a lack of awareness of personal protective measures in the El-Oued region, which is known for intense agriculture and frequent use of pesticides. It takes more than literacy to ensure safe practices. Therefore, it is essential to put practical measures in place to reduce health hazards. Controlling the advice provided by pesticide vendors is essential among these, as many farmers depend on them more than on agricultural extension agents. Wider access to these safety devices would also be guaranteed by the distribution of personal protective equipment (PPE) through agricultural cooperatives. Last but not least, promoting safer pesticide usage and safeguarding farmers and the environment require improving ongoing training and putting in place more efficient monitoring mechanisms.

Authors' Contributions: **SI** was responsible for the study's conception, technique design, data collection and analysis, and manuscript writing. **DML** oversaw the study, helped with the statistical analysis, and gave the findings a critical evaluation. As co-supervisor, **BMEH** helped write, edit, and interpret the findings of the manuscript. **BA** assisted with data administration and oversaw project logistics. **IIH** helped with the literature review and data collecting. The final manuscript was read and approved by all writers.

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