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Assessment of Phytosanitary Practices and Associated Risks Among Farmers in Khenchela, Northeastern Algeria.

Loubna Boudraa [a,b]*, Hassina Hafida Boukhalfa [a,c] and Mahdjouba Habbas [a,b]

[a] *Department of Agronomic Science, University of Biskra, Biskra, Algeria;* [b] *laboratory of Ecosystem Diversity and the Dynamics of Agricultural Production Systems in Arid Zones "DEDSPAZA", University of Biskra, Biskra, Algeria;* [C] *Laboratory of Promotion of Innovation in Agricultural in Arid Regions "PIARA", University of Biskra, Biskra, Algeria.*

Address: Mohamed Khider University, BP 145 RP, 07000 Biskra, Algeria

* E-mail: loubna.boudraa@univ-biskra.dz

* Telephone: (+213) 0657431991

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Abstract

This study examines the phytosanitary practices and associated challenges faced by farmers in the Wilaya of Khenchela, northeastern Algeria. A semi-structured survey, complemented by field observations, was conducted among 368 farmers engaged in tree and cereal cultivation. These farmers operate in diverse geographical areas, including mountainous regions within the communes of Bouhmama, M'sara, Chelia, Taouzient, and Yabous, as well as the Saharan zone of the Checher commune, and peripheral zones within the communes of Kais and Remila. Despite efforts to provide training, a significant proportion of farmers (22%) had never attended school, with only a minimal percentage (2.7%) having received training in the safe use of pesticides.

The survey revealed prevalent use of insecticides, including Chlorantraniliprole, Abamectin, Spirotetramat, Deltamethrin, Lambda-cyhalothrin, Chlorpyrifos-ethyl, Emamectin Benzoate, Thiamethoxam, and Tefluthrin, among other active substances, known for their toxic properties and potential adverse health effects. Alarmingly, a substantial portion of farmers (21%) reported not wearing any personal protective equipment during pesticide handling and application.

Observations further unveiled concerning practices regarding the disposal of empty pesticide containers, with instances of abandonment in fields (5% of cases) and, more distressingly, the repurposing of containers for collecting and storing drinking water (observed in 2% of cases). However, these on-site observations, translated into realistic scenarios, underscore the inadequacy of current practices in ensuring safe treatment operations for farmers in the study area.

Key words: survey, tree cultivation, cereal cultivation, phytosanitary practices, risk, Khenchela.

Introduction

Pesticides are considered essential components of modern agriculture, playing a major role in maintaining high agricultural productivity (Damalas et al., 2006). Their application reduces crop losses by protecting plants from pests (Ndao, 2008), regulating pest populations (Aïna et al., 2015), controlling weeds and crop diseases (Ramade, 2011), and ultimately improving crop yields (Diop, 2013; Jayashree et al., 2006). However, the indiscriminate use of these products often leads to environmental contamination (Briand et al., 2002; Sudhakar et al., 2001), posing significant risks to human health as well (Toumi et al., 2018; Toumi et al., 2022; Ahouangninou et al., 2019; Mehmood et al., 2021).

Consequently, areas with intense application of pesticides become vulnerable, with soil fertility declining and water resources worsening (Srivastav, 2020). This intensification also leads to biodiversity loss and disruption of fauna (Ano et al., 2018; Poulier, 2014), resistance of target pests (Sougnabe et al., 2009), and accumulation of residues in agricultural products affecting consumer health (Mebdoua, 2017). It is worth noting that more than 90% of pesticide inputs are wasted and fall off the target, dispersing into the air and becoming more toxic through their metabolites, posing various risks (Boukhalfa, 2016; Tsaboula et al., 2016; Boukhalfa et al., 2018; Hlihor et al., 2019; Tudi et al., 2021).

Algeria has been both an importer and large user of plant protection products, with an important increase since 2000. Some 400 phytosanitary products are registered, of which some forty varieties are widely used by farmers (Bouziani, 2007). However, worse phytosanitary practices (failure to adhere to recommended protection and hygiene rules during treatments, failure to comply with prescribed doses, improper management of empty pesticide containers, etc.) have been reported in Algeria, particularly in Biskra (Bettiche et al., 2017; Boukhalfa et al., 2018; Soudani et al., 2020a; Soudani et al., 2020b; Bettiche et al., 2021; Soudani, 2022; Soudani et al., 2022; Guehiliz et al., 2022).

In the Aures region, where Khenchela is located, crop protection heavily relies on preventive and intensive chemical control methods. However, many farmers have not fully mastered this approach. Common problems include difficulty in adapting products to specific pests, as well as incorrect application of doses and timing due to a lack of understanding of the threshold treatment technique (Guettala, 2009).

Since agriculture is the main economic activity in the wilaya of Khenchela, encompassing a total agricultural area of 964,280 hectares and an irrigated area of 29,986 hectares, the agricultural workforce in the Wilaya of Khenchela represents 35.7% of the total working population (D.S.A., 2020). Mastery of techniques for applying plant protection products is crucial for minimizing their negative impact on the environment and public health. Therefore, it is essential to search for the best technical conditions adapted to local contexts to optimize and rationalize phytosanitary treatments.

In this context, a survey aims to establish the correlation between farmers' phytosanitary practices and the technical conditions necessary for optimal phytosanitary treatment, ensuring compliance with application criteria. The goal is to identify chemical control strategies tailored to the local context to mitigate risks associated with the use of phytopharmaceutical products.

Material and methods

Location of the study area

A questionnaire was distributed to farmers across the different communes within the study region. Surveys were conducted on farms situated in areas conducive to cereal and fruit cultivation, including apple orchards, in the Khenchela region of northeastern Algeria (**Figure 1**).

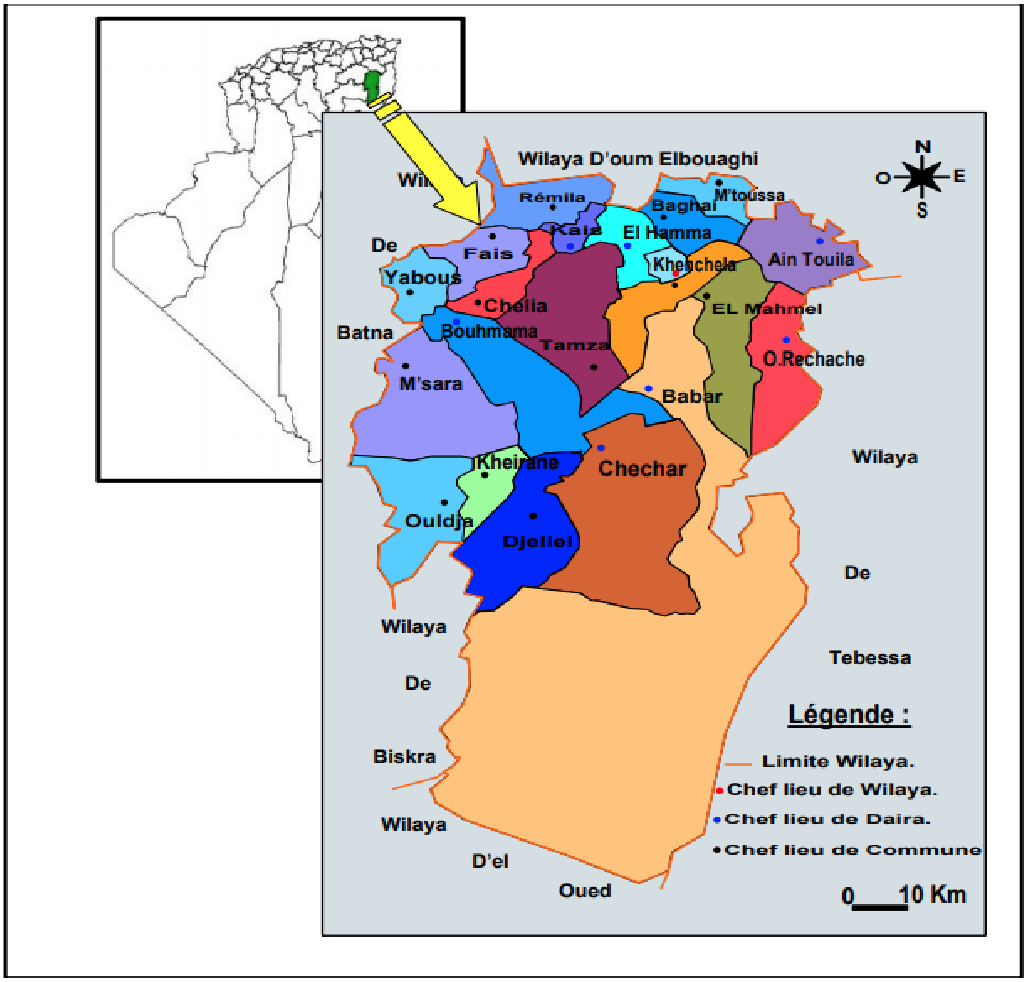

***Figure 1**. Geographical location of the Wilaya of Khenchela and its communes (Direction of Tourism and Handicrafts Khenchela)*

Sampling and conducting the survey

Our study spanned 14 months, commencing in January 2020 and concluding around March 2021, encompassing three study Daïra (Bouhmama, Kais, and Baber) (**Table 1**). Stratified random sampling of respondents was conducted based on nominative lists obtained from the Directorate of agricultural services of the Wilaya of Khenchela (D.S.A., 2020).

The questionnaire was administered in three Daïra primarily engaged in tree and cereal cultivation (Bouhmama, Kais, and Baber), situated amidst mountainous terrain. Within these Daïra, are located the communes of Bouhmama, M'sara, Chelia, Taouzient, and Yabous, as well as in the Saharan zone of the Checher commune and a peripheral zone in the communes of Kais and Remila. The selection of these communes was based on specific criteria, including the intensification of apple and cereal cultivation, land accessibility, and the extensive use of phytosanitary treatments (**Table 1**).

Table 1. Study site roped lines (google earth).

Daïra	Sites	Rope line	Specific features of the habitat
Bouhmama	Bouhmama	35°19'13''N; 6°44'48''E	Cereal filds, orchards and mountainous areas
	Chelia	35°22'43''N; 6°46'58''E	
	M'sra	35°14'58''N; 6°34'46''E	
	Yabous	35°25'36''N; 6°40'36''E	
Kais	Kais	35°30'23''N; 6°55'31''E	Cereal fields and surrounding area
	Remila	35°34'19''N; 6°53'53''E	
	Taouzient	35°28'34''N; 6°39'03''E	
Baber	Ougla Baara	34°31'38''N; 6°53'54''E	Cereal fields and the Saharan zone
	El-Mayta	34°29'03''N; 7°03'01''E	

The sample size (n = 368 cereal and apple growers) for our study was determined using Steven's (2012) formula. Considering a prevalence (P=50%), a margin of sampling error (d=5%), the reduced deviation (Z=1.96) when the accepted confidence level is 95%. The sample size is calculated according to the following formula:

$$\left(n = \frac{\mathrm{N} \times \mathrm{p}\,(1-p)}{[[N - 1 \times (d^2 \div z^2)] + p\,(1-p)]}\right)$$

The total number of farmers (N=8702) registered according to the Directorate of agricultural services of the wilaya of Khenchela in 2020, is recorded in (**Table 2**).

Table 2. Distribution of farmers surveyed within the study site.

Sites	Total number of farmers per site (N)	Number of farmers to investigate (n)	Percentage of farmers investigated (%)
Bouhmama	736	31	8.4
Yabous	1029	44	12
Chelia	663	28	7.6
M'sara	505	21	5.7
Kais	352	15	4.1
Remila	1487	63	17.1
Taouzient	912	38	10.3
Babar	3018	128	34.8
Total	8702	368	100

The questionnaire is designed for farmers in the study area who have extensively utilized pesticides, aiming to evaluate the protective measures implemented in this region. This questionnaire, comprising various inquiries, was adopted for the purpose of this study. It focuses on the characterization of socio-professional factors for each farmer and their farm, as well as the characterization of phytosanitary practices, farm treatment equipment, and the types of phytosanitary products utilized.

Data collection and statistical analysis

The collected data comprised both quantitative and qualitative information, covering the following aspects:

- The growers' profile, including their educational level and training in pesticide application.
- The profile of phytosanitary treatments, which encompassed the frequency of pesticide use, the types of pesticides utilized, and their active ingredients.

Subsequently, the collected data were processed, coded, and entered for descriptive statistical analysis using Excel 2019 and IBM SPSS (Statistical Package for Social Science) version 21.

The active ingredients of products employed by farmers in the study area were identified utilizing the trade names of pesticides listed in the index of plant protection products for agricultural use (DPVCT, 2015 and DPVCT, 2017), as well as the IUPAC (2018) plant protection product database.

Results

Socio-demographic characteristics of farmers

In terms of educational level, the majority of surveyed growers had an average level of study (38.1%). Additionally, 25.8% had completed high school, while 22% were farmers with no formal education (illiterate). Only 2.7% were university graduates and had received training in safe use of pesticides (**Table 3**). However, all interviewees stated that they had not received training in pesticide application.

Table 3. Operator's level of education and ability to characterize the crop protection product.

Level of study	Number of farmers (n)	Percentage of total (%)
Illiterate	81	22
Elementary	38	10,3
Middle	144	39,1
High school	95	25,8
Academic	10	2,7

Characterization of surveyed farms

Grown crops in surveyed farms

Cereal cultivation (52%) emerged as the predominant sector in the survey, reflecting its status as the primary agricultural activity in the region. It is closely followed by arboriculture (48%), which is highly prevalent in the mountainous areas of the region (**Figure 2**).

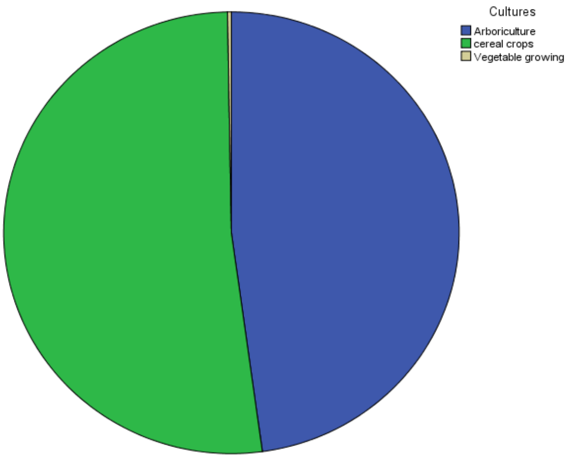

Figure 2. *Crops grown in surveyed farms.*

Surveyed farm size

Out of the 368 surveyed farms, 67% have a surface area of 1 to 10 hectares, 19% have a surface area of 10 to 20 hectares, 7% have a surface area of 20 to 30 hectares, and 7% have a surface area exceeding 30 hectares. In the southern part of the region, large farms primarily focus on arable farming, including cereals and flour production, while arboriculture is more prevalent in hilly areas. Unlike the large farms leased by the state (28.8%), the majority, 71.2%, are privately owned (**Figure 3**).

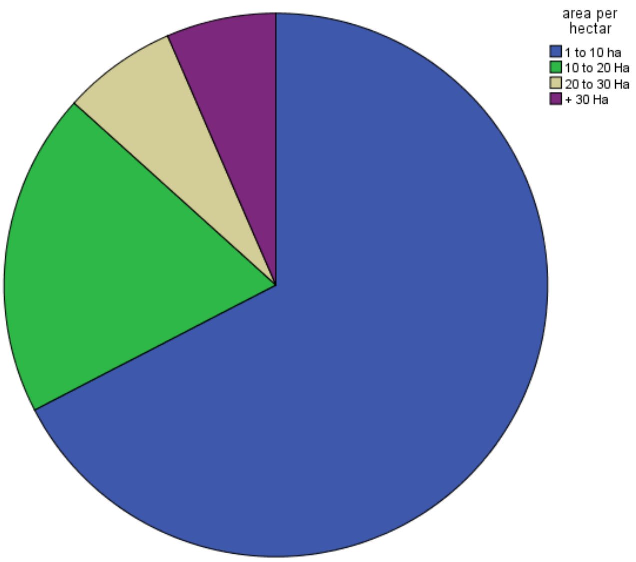

Figure 3. *Areas of surveyed farms.*

Agricultural equipment of surveyed farms

According to the results summarized in Table 4, farmers utilize manual sprayers (24.5%), consisting of 200-liter tanks (either metal or plastic) connected to a high-pressure pump and a gas hose attached to a spray gun. Additionally, mechanized crop protection equipment (75.5%) is employed, including tractor-mounted and tractor-coupled implements. Turbulence nozzles are utilized for spraying across all types of crops, including arboriculture and cereal crops (**Table 4**).

Table 4. Plant protection equipment used in surveyed farms.

	Agricultural equipment	**Number of farms to investigate (n)**	**Percentage of farms investigated (%)**
Sprayer type	Hand-held sprayer	90	24,5
	Boom or pistol sprayer	278	75,5
Tank capacity (l)	< 200 l	4	1,1
	200 l	74	20,1
	400 l	89	24,2
	800 l	1	0,3
	1000 l	131	35,6
	> 1000 l	69	18,8

Phytosanitary practices of surveyed farmers

Protection measures employed by surveyed farmers

According to the survey results, 57% of farmers were observed performing tasks such as preparing the spray mixture and spraying while wearing their regular work clothes without any additional protective equipment. The most commonly observed safety measure among farmers in the study region was the wearing of masks (23%) and boots (23%). Following closely behind was the use of disposable plastic gloves (22%). Another 22% of farmers exhibited partial protection by wearing overalls and gloves during all necessary phases of their work. Finally, 21% of farmers were observed without any protective measures at all, representing a total absence of protection (**Figure 4**).

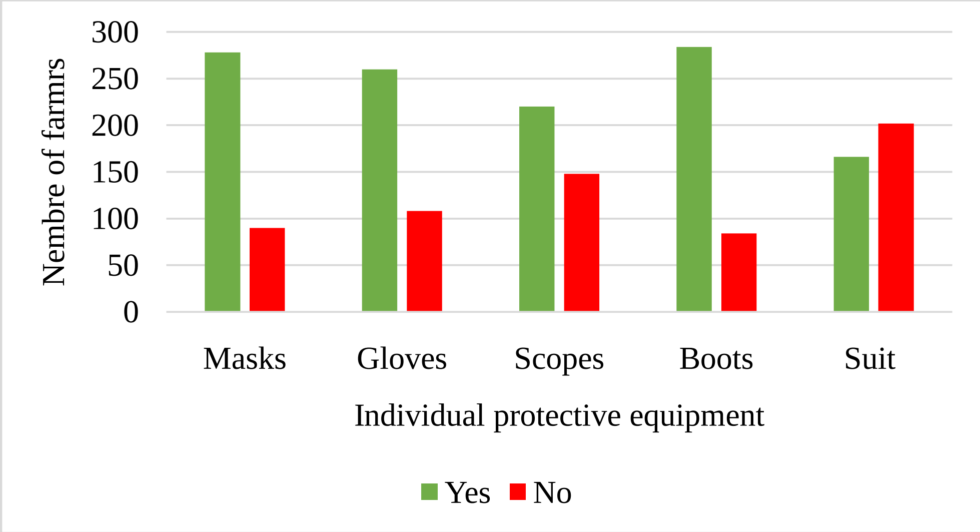

Figure 4. *Individual protective equipment used by surveyed farmers.*

Type of pesticides used in surveyed farms

A total of commercial specialties encompassing all plant protection products were inventoried in the Khenchela region. Among these, insecticides and herbicides emerged as the most widely used, accounting for 40% and 29% respectively, totaling 69% of all plant protection products. Fungicides followed closely behind at 25%. Growth regulators for cereal crops were utilized to a lesser extent, constituting only 6% of the inventory (**Figure 5**).

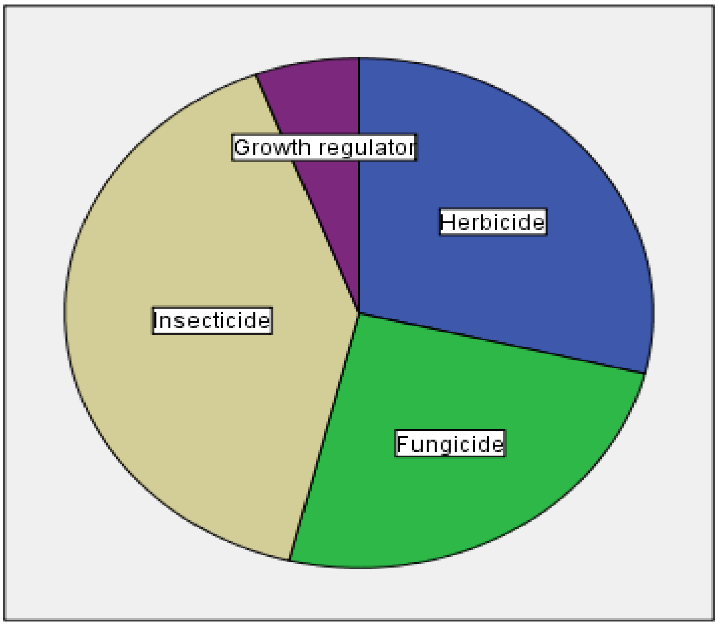

Figure 5. *Types of pesticides used in surveyed farms.*

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Active substance handled by surveyed farmers

The eight most commonly used insecticides by farmers in mountainous areas for apple cultivation, listed in order of importance, are: Voliam Flexi (33.3%), Movento (10.2%), Voliam Targo (9%), Décis (5.1%), Vertimec (5.1%), Actara (1.7%), Nomolt (1.1%), and Insegar (0.6%). Detailed information regarding their active substances and recommended doses can be found in **Table 5**.

Table 5. Commonly used active substances in apple cultivation on season 2020/2021.

Type	Product	Active Substance	Concentration	Formulation	Dose
Insecticide	Insegar	*Fenoxycarbe*	25%	WG	0,3 kg/ha
	Voliam Flexi	*Chlorantraniliprole*	100 g/l	SC	0,3 L/ha
		Thiamothoxam	200 g/l		
	Voliam Targo	*Chlorantraniliprole*	45 g/l	SC	0.5 L/ha
		Abamectine	18 g/l		
	Movento	*Spirotetramat*	150 g/l	SC	1.9 L/ha
	Actara	*Thiamethoxam*	25%	WG	0,2 kg/ha
	Décis	*Deltaméthrine*	25 g/l	EC	0,4 L/ha
	Nomolt	*Teflubenzuron*	12 g/l	SC	1 L/ha
	Vertimec	*Abamectine*	18 g/l	CS	0,5 L/ha
Fungicide	Bayfidan	*Triadiménol*	312 g/l	SC	0,15 L/ha
	Score	*Difenoconazole*	250 g/l	EC	0,2 L/ha
	Aliette Flash	*Fosetyl- Aluminium*	800 g/kg	WG	2.5 kg/ha
	Flint	*Trifloxystrobine*	500 g/kg	WG	0,15 kh/ha

The five insecticide products commonly used for cereal crops are: Pyrical (7.3%), PrpAct (3.1%), Engeo (2.6%), Force (2.1%), and Actara (1%). The active ingredients of these products are detailed in **Table 6**.

Table 6. Commonly used active substances in cereal crops on season 2020/2021.

Type	Product	Active substance	Concentration	Formulation	Dose
Insecticide	Actara 25	*Thiamethoxam*	25%	WG	0,2 kg/ha
	Engeo	*Thiaméthoxam*	141g/l	SC	50 to 200 ml/ha
		Lambda Cyhalothrin	106 g/l		
	Force	*Tefluthrine*	0,50%	GR	40 kg/ha
	ProAct	*emamectine benzoate*	50 g/l	EC	1 l/ha
	Pyrical	*chlorpyriphos-ethyl*	480 g/L	EC	0,5 l/ha
Herbicide	Zoom	*dicamba*	65,90%	WG	120 g/ha
		Triasulfuron	4,10%		
	Désormone Lourd D	*2,4-D-ester S/F of butylglycol*	872 g/l 600 g/l acid	EC	0,7 à 1 l/ha
	Pallas 45	*Pyroxsulam*	45 g	OD	0,5 l/ha
		Cloquintocet-mexyl	90 g		
	Mustang	*Florasulam*	6,25 gr/l	SE	0,6 l/ha
		Ester 2,4 D	300 gr/l		
	Traxos One	*Pinoxaden*	30 g/l	EC	1 l/ha
		Clodinafop-propargyl	30 g/l		
		Florasulam	7,5 g/l		
		Cloquitocet-mexyl	7,5 g/l		
	Axial	*Pinoxaden*	4,50%	EC	1 l/ha
		Cloquintocet-Mexyl	1,13%		
	Delfan Plus	*Acides aminés libres*	24%	SL	1 l/ha
		Azote organique	9%		
Fungicide	Artea	*Cyproconazole*	80 g/l	EC	0,3 à 0,5 l/ha
		Propiconazole	250 g/l		
	Amistar Xtra	*Azoxystrobine*	200 g/l	SC	1 l/ha
		Cyproconazole	80 g/l		

Management of empty packaging by surveyed farmers

Empty packaging of phytosanitary products is commonly disposed of by burning (90%). Additionally, it is often abandoned in nature, with most cases occurring in fields (5%), or used to draw and store drinking water (2%). Some farmers bury empty packaging in the ground (2%), while 1% of farmers repurpose it for other uses, such as storage of other products. These results are presented in **Figure 6**.

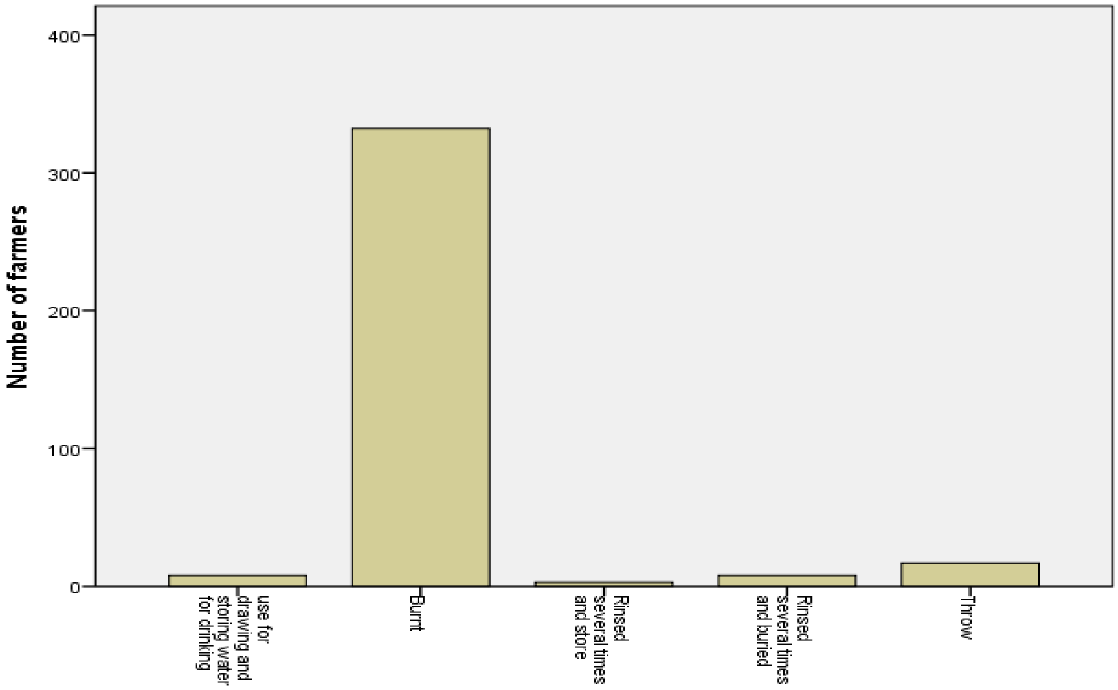

Figure 6. *Management of empty packaging on the surveyed farms.*

Discussion

This study aims to characterize the phytosanitary practices employed by farmers in the Khenchela region, including identifying the active substances used and the protective measures taken during phytosanitary treatments, such as wearing personal protective equipment.

An examination of the socio-demographic characteristics of those surveyed farmers reveals that the majority of them have an average level of education. To address this, distribution companies, the Agriculture Room (CAW), the Directory of Agricultural Services (DSA), the Cooperative of Cereals and Vegetables (CCLS), along with other farmers and sellers of phytosanitary product, provide training in pesticide application. However, farmers with lower levels of education are more likely to encounter difficulties in correctly reading and adhering to pesticide application rules and understanding the risk instructions on product labels as registred by Jallow et al. (2017), Bettiche et al. (2017), Toumi et al. (2018), Boukhalfa et al. (2018), Soudani et al. (2020a), Soudani et al. (2020b), Bettiche et al. (2021), Toumi et al. (2021), Soudani (2022), Soudani et al. (2022) and Guehiliz et al. (2022). Therefore, it's crucial for every farmer to be aware of the hazardous nature of pesticides and to receive adequate training to apply these products safely on crops, reducing the risk of poisoning and environmental pollution as much as possible. The same observation was made by Kanda et al. (2013), Wognin et al. (2013), Bettiche et al. (2017), Boukhalfa et al. (2018), Soudani et al. (2020a), Bettiche et al. (2021), Soudani (2022,) Soudani et al. (2022) and Guehiliz et al. (2022).

In terms of the composition of the surveyed farms, we interviewed farms from various sectors across the region, including cereal growing, market gardening, and arboriculture. Cereal growing emerged as the most represented sector, serving as the backbone of agriculture in the region. Arboriculture ranked second in representation, particularly prevalent in the mountainous areas. However, our survey results do not align with the findings of Guehiliz et al. (2023), who suggest that most farmers in Saharan regions engage in both agriculture and livestock farming. This discrepancy may be attributed to the unique characteristics of the region.

The risk of poisoning increases when doses are high and protection is inadequate. According to the survey results, the majority of farmers wore their protective equipment while preparing and spraying the mixture, despite also wearing their daily work clothes. Additionally, these farmers had received training in phytosanitary treatments. These findings are consistent with previous studies by Dümmler (1993) and Guissou et al. (1996), which indicate that farmers' exposure to phytosanitary products during spraying, especially over prolonged periods and without proper protective equipment, poses significant health risks. The risk of exposure could be greatly reduced if farmers used full personal protective equipment, as suggested by Dümmler (1993) and Guissou (1996). Personal protective equipment plays a crucial role in minimizing operator exposure to plant protection products, as emphasized by Ouedraogo et al. (2014) and Toé et al. (2013).

A comprehensive inventory of commercial phytosanitary products in the Khenchela region revealed a predominant use of insecticides and herbicides, followed by fungicides, with limited utilization of growth regulators beneficial for cereal crops. These findings are consistent with studies by Kanda et al. (2013) and Déla et al. (2014), which attest to the increasing prevalence of insecticides and other phytosanitary products in tandem with agricultural development and efforts to control harmful vectors. Pest pressure emerges as a significant challenge for crop cultivation, driving the widespread use of pesticides. However, the specific types of pesticides employed are strongly influenced by crop varieties and local farming practices. For instance, in the United States, where field crops like corn, wheat, and soybeans predominate, herbicides constitute the primary category of pesticides. Conversely, in France, fungicides represent approximately half of the total tonnage sold (Aubertot et al., 2005). While Guehiliz et al. (2022) suggest reduced use of insecticides and fungicides in arid regions due to climatic conditions, cereal crops in such areas experience comparatively lower activity from bio-aggressors, particularly fungal diseases, attributed to the arid region's low humidity levels.

A total of 26 commercial products, including 12 for arboriculture and 15 for cereal crops, are registered in Algeria according to DPVCT (2017). This study identified a diverse range of active ingredients, with notable compounds such as Chlorantraniliprole, Thiamothoxam, Abamectin, and Spirotetramat being significant in the pesticides used for arboriculture. Additionally, cereal growers predominantly utilize four active ingredients: Emamectin Benzoate, Chlorpyriphos-Ethyl, Thiamothoxam, and Lambda-Cyhalothrines. It's important to note that these active substances are classified as hazardous and toxic to both humans and the environment according to the CLP (Classification, Labelling, and Packaging of Substances and Mixtures) regulation under Regulation (EC) No. 1272/2008. This classification warns that almost all active substances listed on the packaging pose risks if swallowed or in contact with the skin. Previous studies have also highlighted the prevalence of poor pesticide use practices (Adechian et al., 2015; Son et al., 2017; Bettiche et al., 2017; Boukhalfa et al., 2018; Soudani et al., 2020a; Soudani et al., 2020b; Bettiche et al., 2021; Soudani, 2022; Soudani et al., 2022; Guehiliz et al., 2022).

According to the survey results, the majority of farmers resort to burning empty packaging, and their storage practices for phytosanitary products do not adhere to the conventional standards outlined by the United Nations Industrial Development Organization (UNIDO). These findings align with similar observations made by Gouda et al. (2018) in Benin, Son et al. (2017) in Burkina Faso, and Kanda et al. (2013) in Togo, all of whom have documented instances of poor management of stocks and empty packaging of plant protection products.

Conclusion

In conclusion, the survey conducted among farmers in the Wilaya of Khenchela sheds light on significant challenges in the management and use of phytosanitary products. The findings underscore the urgent need for comprehensive interventions to improve agricultural practices and mitigate risks to human health and the environment. Effective measures should include enhanced training programs for farmers on proper pesticide handling, the promotion of safe storage and disposal practices for empty packaging, and the provision of adequate personal protective equipment. Collaborative efforts among agricultural authorities, extension services, and local communities are essential to implement sustainable solutions and safeguard the well-being of farmers and the ecosystem.

Acknowledgments

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