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EVALUATION OF FARMERS' PHYTOSANITARY PRACTICES IN THE PLAIN OF TRIFFA (EASTERN MOROCCO), IDENTIFICATION AND EVALUATION OF SANITARY AND ENVIRONMENTAL RISKS.

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Abstract

The use of pesticides in agriculture has certainly led to a dramatic increase in agricultural yields worldwide. Nevertheless, it is not without consequences for the environment and human health. In this context, we conducted a survey among 67 farmers in the Plain of Triffa of the Berkane region to analyze their phytosanitary practices and assess the risks to the environment and human health. 98% of the farmers have never received training on the use of pesticides. 181 different commercial specialty chemicals were inventoried. Insecticides (50%) are the most commonly used pesticides, followed by fungicides and herbicides with 28% and 10% respectively. The whole is divided into 19 chemical families, the most inventoried of which are organophosphorus (30%) and pyrethroids (29%). Organochlorines, despite their worldwide ban, are still in use. Of the 68 active ingredients listed, the most frequently used are imidacloprid, chlorpyrifos, lambda cyhalothrin, glyphosate, and deltamethrin. The doses used by farmers are in the majority of cases higher than those recommended. As for the pre-harvest interval, few farmers comply with the prescribed standards. Almost all farmers (85%) neglect the necessary protective measures. Empty packaging of plant protection products is either abandoned in the wild, incinerated or reused for domestic purposes. Thus, the phytosanitary practices of the farmers surveyed are described as poor. Faced with this frightening situation, there is an urgent need to intervene to support farmers and agricultural producers for better professional and environmental protection on the one hand and for healthy and safe production on the other.

Keywords: *agriculture, environment, human health, pesticides, phytosanitary practices.*

1.Introduction

The agricultural sector occupies a predominant place in Morocco's economy, participating in 14% of GDP and employing more than 40% of the active population [1]. Major projects, such as the Green Morocco plan implemented in 2008, have been launched with the aim of ensuring food security and promoting the country's economic development through the export of high value-added vegetable products (citrus fruits, tomatoes, potatoes) [2]. However, diseases, pests and weeds damage these crops and reduce yields, both in quantity and quality. To control these pests and reduce their impacts to an economically tolerable level, chemical control using plant protection products (commonly known as "pesticides") remains the method most commonly used by farmers [3]. The consumption of pesticides by Moroccan agriculture is still at a relatively low level compared to countries such as France, Germany, Spain or Belgium. However, it has been on an upward trend over the last ten years. According to estimates by CropLife Morocco [4], the local market is diversified and attractive because the value of plant protection product (PPP) imports has been growing by an average of 15% per year since 2005. Thus, a quantity of 22,000 tons of plant protection products were imported in 2019. The market is divided between insecticides (45%), fungicides (40%) and herbicides (15%) despite relatively small cultivated areas. Market gardening alone absorbs 44% of the imported volume, plantations (26%) and cereals (21%), the remainder (7%) being shared between the various industrial crops [5]. Because of their toxicity and ecotoxicity, the consequences of the use of plant protection products, still very poorly known due to a lack of studies, have become a permanent concern for the Moroccan population. This concern is legitimate in view of the numerous reports and studies demonstrating on the one hand the negative impacts on human health [6-8], such as neurological deficiencies, endocrine disruption and reproductive disorders, weakening of the immune system and even some cases of cancer after long-term exposure. On the other hand, it is now accepted that pesticides can have adverse effects on fauna (particularly earthworms and bees) and flora living in an environment contaminated by certain families of pesticides still widely used in Morocco such as carbamates, neonicotinoids, triazoles or organophosphates [9, 10]. In this context marked by the lack of exhaustive information and studies accompanying societal concern about the toxic and ecotoxic impact of pesticides, a survey was carried out in the Plain of Triffa to identify the plant protection products used, to assess the phytosanitary practices of farmers, market gardeners and citrus producers, and to attempt to evaluate their potential health and environmental risks. These data should provide the basis for useful recommendations to local decision-makers and managers to take appropriate measures to reduce the risk, firstly to users and secondly to the environment, through the adoption of best practices.

2.MATERIAL AND METHODS

2.1.*Selection of the area to be surveyed*

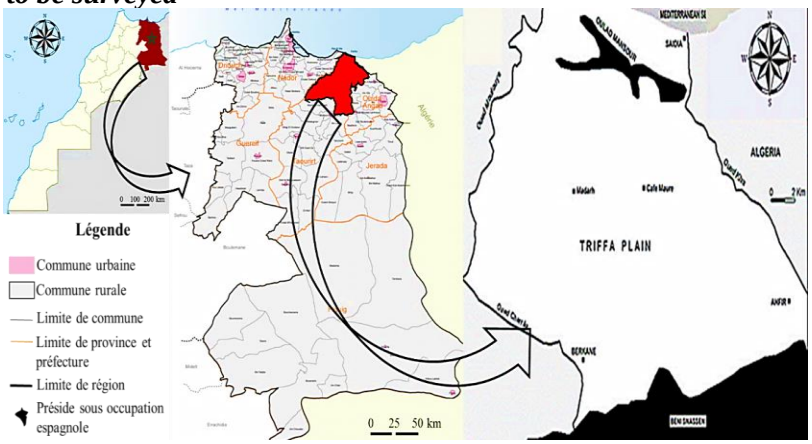

Figure 1. Area of investigation, Plain of Triffa.

A survey was conducted from 2017 to 2018 in five areas of the Plain of Triffa namely Madagh, Laatamna, Slimania, Aklim and Lamris, (Fig. 1). The survey covered 67 randomly selected farmers and producers. This study area, so far little prospected on this theme, was chosen for the importance of agricultural production, the massive use of plant protection products and the vulnerability of the water table. Furthermore, this choice was justified by the idea that epidemiological studies and diagnoses on the impact of phytosanitary treatment on human health and the environment in this area are rare or even nil.

2.2.*Methodology adopted for the survey*

The participatory approach was adopted by means of an individual semi-structured questionnaire lasting an average of one hour per farmer per season. Interviews with market gardeners and producers were conducted using a pre-established questionnaire with about thirty open and closed questions on: the level of education and training in pesticide use and plant protection, the plant protection products used, compliance with the recommended dosage and the pre-harvest period, the wearing of personal protective equipment, the management of empty packaging and their knowledge of the toxicity and ecotoxicity risk of the pesticides used.

2.3*Processing of collected results*

The survey forms were manually processed and the data collected were processed using the Excel data processing software. The determination of categories of plant protection products, the identification of active ingredients, families and chemical classes was established in relation to the names of the specialties listed using the phytosanitary index [11].

2.4.*Risk assessment*

The risk assessment involves determining the danger of a plant protection product and its exposure (Risk = Danger × Exposure). The methodology envisaged consists of the identification of the plant protection products used, the evaluation of farmers' plant protection practices and the analysis of the perception of risk among the farmers surveyed. The results of the survey make it possible to predict the health and environmental risks related to the use of plant protection products in the Plain of Triffa. Furthermore, the use of a very dangerous product can be safe if there is no exposure to it. On the contrary, a low risk product can be very risky if exposure is very prolonged. In addition, the exposure of surveyed farmers to plant protection products may occur during professional use in the field or in greenhouses.

3.RESULTS

3.1.*Socio-demographic characteristics of the farmers surveyed*

The vast majority of the market garden and citrus growers surveyed are men (90%), aged between 25 and 55.40% of them have received no education, and only 5% (citrus growers) have completed technical education. Of the 67 respondents, only 2% have received training in plant protection. In addition, of the seven (7) women interviewed, only two (2) have practiced phytosanitary treatment on plots.

3.2.*The main crops grown*

Almost the majority of the farmers surveyed practice intensive agriculture for crops with a high demand for phytosanitary products, namely: citrus fruits 40%, potatoes 35%, tomatoes (glasshouses) and sugar beet 20%.

The flow of production is linked to its nature. Citrus fruits, especially clementine, is destined for export (60%), the rest of the production is sold on the local and national market. Potatoes occupy the second position. Nevertheless, only a small part of the production is exported (20%) and the majority of the production is sold on the national and local market. As for the production of glasshouse tomatoes (cherry), a large part is destined for export. In addition, the level of production varies from year to year.

Table 1. Social status of market garden and citrus farmers and producers in the Plain of Triffa (surveys conducted in four zones: Madagh, Laatamna, slimania and Lamris) in 2017, 2018 and early 2019.

	Sociodemographic Characteristics	percentage %
Gender	Men	90
	Women	10
Instruction level	Primary	45
	Secondary	20
	Technically	05
	None	40
Phytosanitary formations	Yes	10
	No	90

3.3.*The main pests and diseases of crops in the Plain of Triffa*

The various crops grown in the region, particularly citrus and market gardening are subject to attack from a variety of enemies. According to the data collected from the respondents, the degree of attack differs from one crop to another and depends on the climatic and biological conditions and the pressure of phytosanitary treatments. Compared to the clementine tree, the most formidable pests which cause significant damage to citrus production are mites (*Panonychus citri*, *Tetranychus urticae*), ceratitis (*Ceratitis capitata*), several species of scale insects, in particular California lice (*Aonidiella aurantii*), citrus leaf miner (*Phyllocnistic citrella*), whitefly or whitefly and old citrus pests, aphids.

Potatoes are the second most important crop subject to attack; they are particularly affected by fungal diseases, in this case late blight, which is the most formidable enemy. Over the last few years, mole hogs have become a scourge for vegetable and industrial crops. Sugar beet, unlike other crops, suffers mainly from weeds such as *Convolvulus arvensis*, *Cynodon dactylon*, *Lepidium draba* and annuals infested with sugar beet such as (*Chenopodium album*, *beta macrocarpa*, *Polygonum aviculare*). In wet years, cersosporiasis can be a serious problem [12].

3.4. Categories of pesticides identified

Out of a total of 181 commercial specialties inventoried in the study area, insecticides occupy first place with 90% commercial specialties, i.e. 50% of the total inventoried, followed by fungicides with fifty specialties, representing 28% of the total, herbicides with eighteen specialties (10% of the total), acaricides with seventeen specialties, i.e. 9% of the total inventoried and finally, molluscicides and nematicides with one and three commercial specialties respectively (2% and 1% of the total inventoried). (Fig. 2). These results do not corroborate those reported by European and American studies which indicate that herbicides account for more than 50% of the pesticides used worldwide, followed by fungicides and insecticides [13].

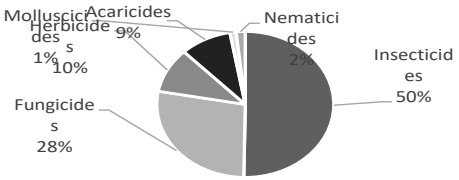

Figure 2. Proportion of pesticides used by farmers and producers in the triffa plain

3.5.*Identified Chemical Families*

In order to control pests and preserve agricultural production, the farmers and producers surveyed in the Plain of Triffa systematically practice chemical treatment with synthetic plant protection products. Sixty-eight active ingredients were identified and classified into nineteen chemical families following the census of all commercial specialties (Fig. 3). Among the chemical families identified in the survey area, organophosphates, pyrethroids, neonicotinoids and avermectins represent the most commonly used insecticides-acaricides, with 30, 29, 18 and 11 commercial specialties identified respectively. While triazoles, dithioarbamates and benzimidazole carbamates are mainly used in antifungal treatment with 17, 5 and 3 proprietary products respectively. In addition, the chemical families of Sulfonylureas with three commercial specialties, Amino acids with seven commercial specialties are the most widely used chemical families for effective control; this is explained by their ability to control weeds. The census of active ingredients of the chemical families also reveals the existence of the organochlorine family with five commercial specialties despite their prohibition worldwide.

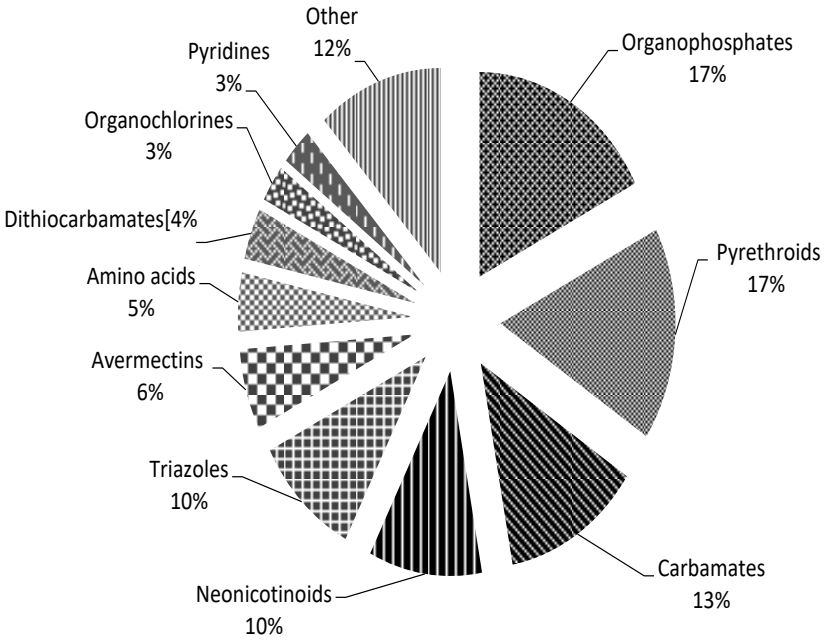

Figure 3. Chemical families surveyed among farmers and producers in the Plain of Triffa in percentage (survey conducted in four zones: Madagh, Laatamna, slimania, Aklim and Lamris) in 2017, 2018.

3.6.*Identified active substances and their toxicological classification*

As mentioned above, sixty-eight active ingredients have been identified (Tab. 1), of which half (thirty-four substances) belong to the insecticide/acaricide category, twenty-four substances belong to the fungicide group, and eight substances have herbicidal action. The active ingredients nematicides are represented by two active ingredients: Ethoprophos and cadusafos) finally, only one active ingredient belonging to the category of molluscides has been identified; it is acetaldehyde. Among these active ingredients, some are classified as extremely dangerous (Ib) for humans, such as Ethoprophos, and dangerous for the environment according to the WHO toxicological classification system, the Globally Harmonized System of Classification and Labelling of Chemicals (WHO-FAO), and others are classified as carcinogenic by the International Agency for Research on Cancer (Tab. 1).

3.7. ***Phytosanitary practices reviewed :***

a) Application Rate

The information collected and captured on application rates is often fragmentary and incomplete. However, it has been noted that the majority of market garden farmers, especially potato, beet and tomato (cherry) growers, do not respect the recommended doses indicated on the bottles. This is due to the farmers' preconceived idea that the effectiveness of the treatment depends on increasing the dose. Nevertheless, few farmers, particularly citrus growers, respect the prescribed and recommended doses; this is explained by the level of education and training of the technicians employed on the one hand and the need to respect the maximum residue limits on citrus fruits intended for export on the other hand.

b) Treatment equipment used

The phytosanitary treatment equipment used by the majority of farmers is characterized by a clear dominance of liquid pressure sprayers with spraying nozzles with 65%. The adoption of this type of material is explained by its versatility, low cost and easy technical adaptation. The sprayers called atomizers represent only 30% and are mainly used in the treatment of citrus fruits. The use of knapsack sprayers is very limited (5%). It has been noted that the majority of the liquid pressure sprayers encountered are equipped with a heavy tank that is sensitive to corrosion and have no gauge, which makes it difficult for the user to monitor the level of the spray liquid. According to Tielemans et al [14] the level of operator exposure risk is correlated with the type of equipment used. The majority of farmers and producers do not carry out the phytosanitary treatment themselves, they use external service providers. However, the use of sprayers by unqualified people often leads to a poor distribution of the product on the crops and consequently a low treatment efficiency.

c) Compliance with the safety or pre-harvest interval

The safety or pre-harvest interval is not always respected by farmers, especially potato producers. It varies from 2 to 5 days. Only 20% of them have respected the 15-day pre-harvest period. On the other hand, it is respected by 50% of citrus growers. This can be explained on the one hand by the satisfactory level of training of the employed citrus grower technicians and on the other hand by the requirements to respect the maximum residue limits on citrus fruits intended for export.

d) Protective means and equipment

Very little or no personal protective equipment is worn. Thus, the majority (75%) of farmers, producers and workers employed wore no means of protection during the surveys carried out, other than ordinary clothing from the

preparation of the spray mixture until the end of treatment, and declare that they are accustomed to the products. The rest of the farmers (20%) wore only one means of protection, either a glove, coveralls or shoes. Only 5% of the farmers used a full suit (Fig. 4). The arguments put forward to justify neglecting to wear protective equipment are, for farmers, the absence of risk for the applicator, the practical difficulty of changing clothes after spraying, the lack of comfort at work, and the high cost of protective equipment.

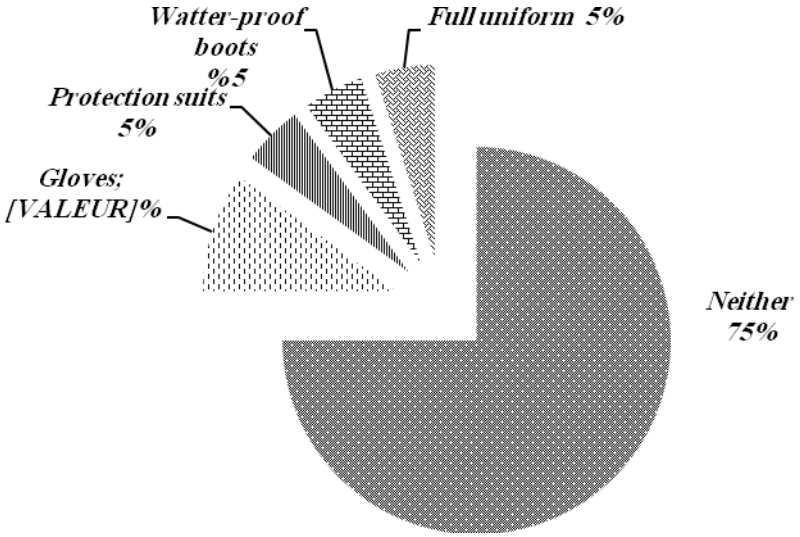

Figure 4. Percentage of farmers and producers handling plant protection products in the Plain of Triffa wearing personal protective equipment

e) Effects felt by the handlers of crop protection products

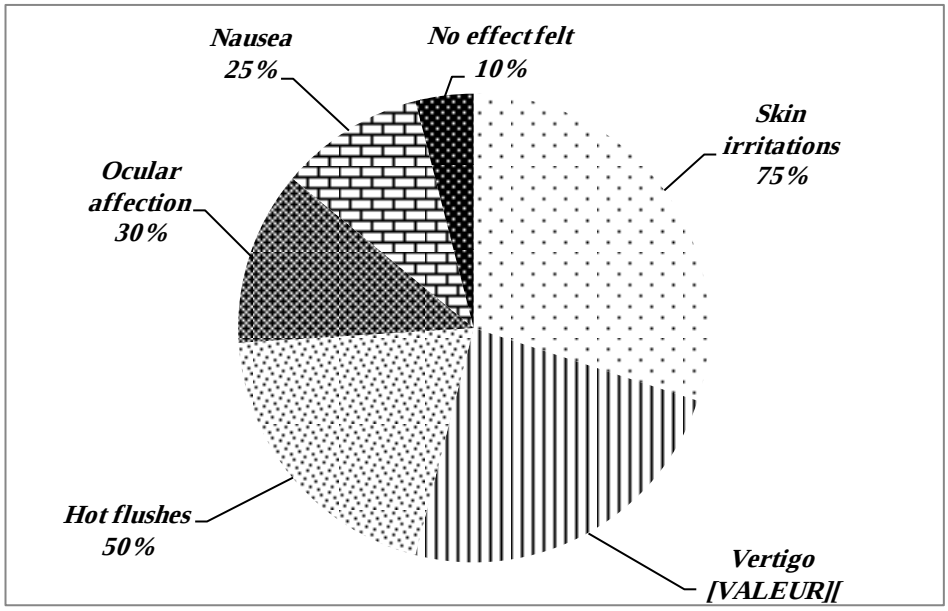

Figure 5. Effects felt by farmers and handlers of plant protection products in percent

Farmers felt various effects during and after crop protection treatment, such as hot flushes (50%), skin irritation (75%), fatigue (60%), nausea (25%) and eye infections (30%). On the other hand, 10% of the handling farmers reported feeling no effect (Fig. 5). These results show the harmful or toxic nature of the active ingredients used. The

farmers, in order to avoid side effects and to overcome possible cases of intoxication, declared to drink milk after completion of the treatments. Infections have been reported by Gomgnimbou et al [15] and Son et al [16] on vege**Table** producers in Burkina Faso.

f) Management of empty packaging

The results of our survey reveal that almost all farmers, particularly those in the market gardening sector, are unaware of the risks of accidental environmental contamination by the abandonment of empty packaging on agricultural land and near water resources, particularly in total contradiction with the laws on water and toxic waste management. After the use of phytosanitary products, packaging is either abandoned in the environment in 45% of cases or reused for domestic purposes (20% of cases), 10% of farmers burn it and 30% throw it in the landfill (Fig. 6). This can be explained by the lack of knowledge of the ecotoxicological risks incurred by the poor management of empty packaging. This ecotoxicological practice is also reported in the report on pesticide use in the Gharb area in Morocco (2015) and in the research work carried out by Belhadi et al [17] in Algeria. According to the International Code of Conduct for the Distribution and Use of Pesticides Rome [18], the walls of empty packaging are still contaminated by pesticide residues even after cleaning. Therefore, it is not recommended to accumulate empty packaging on farms, incinerate it or reuse it for domestic purposes. Among the recommendations proposed for the proper management of empty chemical packaging are the return of empty packaging after use to the manufacturer or distributor [19].

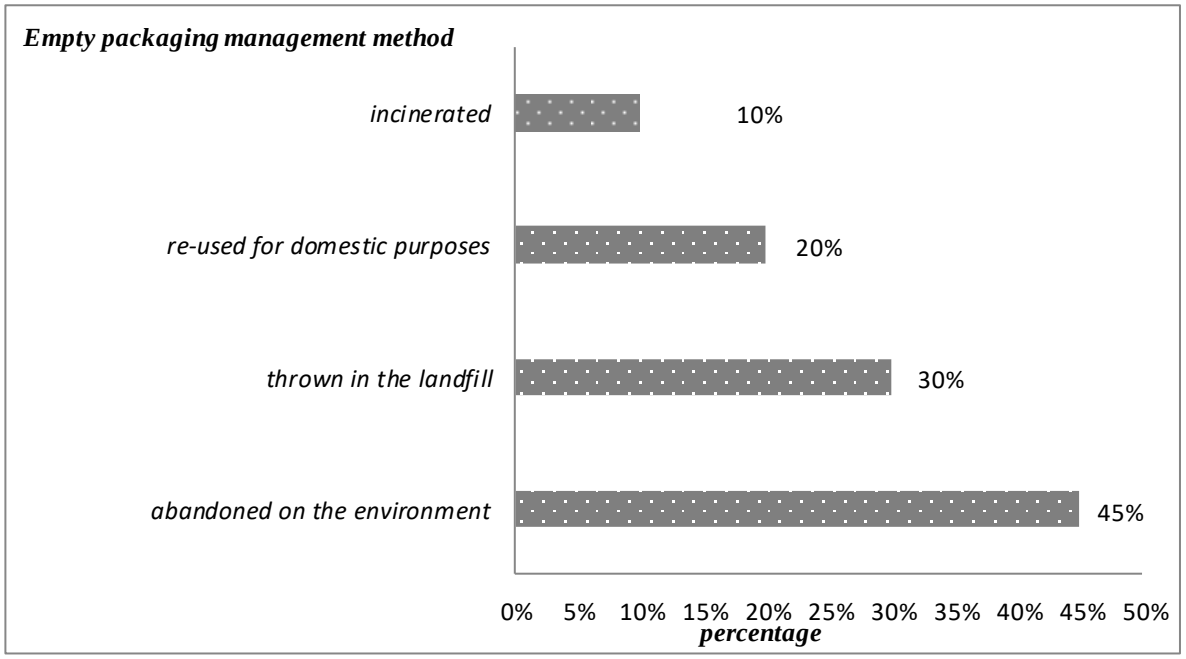

Figure 6. Management of empty packaging by farmers in the Plain of Triffa as a percentage of the total.

4.DISCUSSION

The results of the survey report that crop protection products are being used irrationally by farmers in the Plain of Triffa. However, misuse results in adverse effects on both human health and the environment. Therefore, the use of plant protection products requires a minimum of theoretical and practical knowledge to minimize the resulting toxic and ecotoxic risk. Farmers, particularly of market garden and citrus crops in the Plain of Triffa, treat the pests and diseases of their crops in a preventive manner. These practices do not take into account the real risk to the treated crops and therefore the use of pesticides is abusive. Almost all farmers purchase plant protection products from the retailers closest to their farms based on their experiences at the time of purchase, but also on the recommendations of

the retailer. In general, price and product efficacy are the two main criteria adopted by farmers and agricultural producers in the choice and purchase of their products. In the absence of training and technical supervision, particularly in the market gardening sector, farmers tend to use inappropriate products and apply incorrect doses. However, few growers and employees in the citrus sector reported a more or less adequate level of training in pesticide treatment techniques and use. This is due to the requirement to comply with maximum residue limits on citrus fruit intended for export. Most farmers cannot understand labels in foreign languages, follow instructions for use or even interpret safety pictograms. This increases the risk of occupational and environmental poisoning. As a preamble, high pest pressure combined with low levels of education and lack of training are the main factors leading to poor practice in the use of plant protection products and consequently an increased risk of intoxication and pollution of the local environment. According to the survey, 68 active substances have been identified and classified into six categories of pesticides and nineteen chemical families, including ethoprophos, a persistent organic pollutant qualified as extremely dangerous (Ia), and other pollutants qualified as dangerous (Ib) for health according to WHO, such as cadusafos, glyphosate, methomyl, carbofuran and oxamyl. These active ingredients are grouped into five chemical families, namely: organophosphates, pyrethroids, carbamates, neonicotinoids and triazoles, which represent the most widely used chemical families against pests and diseases. However, according to Testud et al [20], all these chemical families, especially those with the effect of insecticides, have toxic repercussions on human health but also ecotoxic repercussions on the environment. According to Wood et al [21], the predominance of organophosphates and pyrethroids is mainly due to their wide range of modes of action and the multiple possibilities in their applications. Organophosphorus products are rapidly degradable and therefore provide an alternative to persistent organochlorines. They are, however, highly toxic for the users of these substances. Thus, several organophosphorus molecules have been banned in European countries, and others are being monitored, in particular parathion and parathion-methyl. The family of pyrethroids is second only to organophosphates. Their massive use is mainly due to their characteristic of photo-stability, their low cost and their effectiveness by being used at low doses [22]. On the other hand, they are very toxic for bees, beneficial insects and fish, RICHOU et al [23]. Carbamates are less used by farmers compared to organophosphates and pyrethroids because of their low selectivity and their multiple activities. Methomyl, can be used as a contact insecticide, fumigant and sometimes as a systemic insecticide. The chemical family of organochlorines and despite its international ban due to their persistence in the environment and bioaccumulation in organisms, it is still used by farmers in the Plain of Triffa. Organochlorines are very stable, fat-soluble and can accumulate and persist for a long time in soil, plant tissue and fat. They are neurotoxic. According to Corinne [24], several epidemiological studies are in favour of an influence of organochlorine pesticides on the incidence of hormonodic pathologies. This survey also reported that farmers in the Plain of Triffa use certain phytosanitary products not registered by the National Office of Sanitary and Food Safety (ONSSA), namely: (*Bazooka 200, Forward, Warrior, Deminar 200EC, Romectin, Agrizole 250*). This is due to lack of information and weak control leading to non-compliance with legislation. Strict enforcement of the regulations through the establishment of adequate control measures will make it possible to put unregistered products and persistent organic pollutants out of the commercial circuit. According to Benaboud et al [25], the eastern region to which the Plain of Triffa belongs is flooded with unsuitable pesticides from smuggling that do not meet quality standards and are banned. However, the official channels of pesticide distribution are not well controlled, hence the proliferation of the informal sector in this area. Thus, the issue of control is crucial when reviewing legislation and regulations concerning the use of pesticides. The results of our survey showed that almost a majority of farmers do not use adequate protective measures when using plant protection products. This shows a lack of awareness of the harmful and delayed effects of pesticides on human health, particularly that of professionals. Indeed, during exposure, the operator only feels minor disorders, but in the long term, more significant

pathologies may appear [26]. Several international research studies have demonstrated strong correlations between the use of pesticides in the context of an agricultural professional activity and the appearance of dermatoses, allergies and certain cancers, particularly haematopoietic cancers of the brain, kidneys or prostate [27-29]. According to the work of Jakubowski and Trzcinka-Ochocka [30], the absorption of pesticides through the skin is revealed as the most significant route of exposure in the absence of personal protective equipment in agricultural environments. More relevant, research by Lander et al [31] indicates that the risk of dermal exposure is very high even when gloves are worn. A study carried out in France on the degree of health protection has shown that the effectiveness of personal protective equipment is insufficient [32]. The infections most frequently reported by farmers in the Plain of Triffa during and after pesticide use, such as skin irritations, fatigue and other ailments mentioned above, are very significant and show that the absence of personal protective equipment increases the risk of acute and chronic exposure. For this reason, and in order to considerably reduce the risk of exposure to pesticides and to ensure better protection, it is strongly recommended that the farmer should start his day by wearing full, clean and undamaged personal protective equipment during the performance of the various work tasks. According to our survey, the use of pesticide doses higher than those recommended and the failure of the majority of farmers in the Plain of Triffa to respect the pre-harvest interval can most likely lead to the accumulation of very high concentrations of pesticide residues in agricultural products intended for consumption, thus increasing the inherent toxic risk. Pesticide residues are the ongoing concern of the scientific community and the Public Health Organizations around the world. Thus, in view of the adverse effects of pesticides on human health, maximum residue limits (MRLs) for pesticides in various consumer products have been legislated by the Codex Alimentarius Commission [33] (established by the FAO and WHO) based on both toxicological and agronomic data. On this point, several studies have shown that MRLs have been exceeded and that good agricultural practices have not been respected, in particular the pre-harvest intervals and the quantities of active ingredients used. Exposure to pesticides does not only concern the occupational environment, but also the general population through the contamination of food by pesticide residues. According to several global toxicological studies, it is difficult to find a direct link between chronic disease and pesticide exposure. Nevertheless, the ingestion of small amounts of residues in food and their accumulation in the human body over a long period can induce disturbances of the reproductive, endocrine, immune and nervous systems, but also have carcinogenic effects [34-35].
World Health Organization statistics indicate that contamination of food with pesticide residues is by far the most important route of exposure. Similarly, its Figure s attribute a 90% risk to dietary exposure compared to 10% to water exposure. According to research by the International Pesticide Action Network [36] it is estimated that out of a total of 1.3 billion agricultural workers worldwide, 41 million suffer from pesticide poisoning each year. Several epidemiological studies have established more or less important links between occupational exposure to pesticides and certain forms of cancer [37]. Indeed, according to Inserm [38], farmers use these products at relatively high doses and repeatedly during their working life. Wearing personal protective equipment is therefore supposed to protect the user by forming a barrier between pesticides and the human body. Among the key tools to ensure healthy and compliant production and to control compliance with good agricultural practices, monitoring of pesticide residues on agricultural products is essential [39]. According to Geahchan et al [40], the decrease in food protection can be dramatic in the absence of effective means of control in developing countries.

5.CONCLUSION

In the light of the results of this survey, we deduce that farmers and agricultural producers in the Plain of Triffa do not respect good practices through the abusive and systemic use of pesticides, exceeding the recommended dose, neglecting the pre-harvest period, not wearing personal protective equipment, poor management of empty packaging

and ignorance of the chemical risk of the substances used. In the Plain of Triffa, the toxic and ecotoxicological effects of pesticide use are, above all, a reality. Farmers and agricultural producers systematically use products to protect their crops against pests and thus stabilise their yields. Nevertheless, their low level of education and lack of training in pesticide use and plant protection techniques result in poor phytosanitary practices. Indeed, the use of toxic chemicals combined with the failure to respect good plant protection practices has adverse consequences for the health of farmers themselves, for the environment and for consumer health in general. Faced with this frightening situation, it is recommended that several actions be promoted, on the one hand to encourage rational management of pesticides and on the other hand to minimise their impact on human health and the environment. First of all, and to quench this thirst for knowledge and information on such a topic, it is imperative to encourage epidemiological and toxicological studies to diagnose the health status of farmers and consumers on the one hand, and to strengthen research on the fate of pesticides in the environment on the other. This must be undertaken in parallel with the monitoring of pesticide residues in agricultural products intended for local consumption and in the various environmental compartments, i.e. water, soil and air. Secondly, there is a great urgency for public initiatives to be taken by local and national officials, consumer and environmental protection bodies, researchers and specialists in the field of pesticide registration and use, to carry out awareness-raising and training activities for the benefit of farmers and agricultural producers in the Plain of Triffa on plant protection techniques and good phytosanitary practices such as the rational use of pesticides, basic safety instructions and the importance of wearing personal protective equipment, the proper management of empty packaging and compliance with prescribed doses and pre-harvest intervals. Finally, it is imperative to work on strategic plans to reduce the use of plant protection products by promoting integrated crop protection practices.

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