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Review

Pesticide Application as a Risk Factor/Behaviour for Workers' Health: A Systematic Review

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Abstract: The main objective of this review was to determine the main risks that agricultural workers are exposed to during pesticide application, which may have a harmful effect on their health and on public health. This systematic review was based on the PRISMA guidelines. A search for articles was conducted in the Medline/PubMed, ScienceDirect, and Web of Science databases. Fifteen articles were selected considering their assessment of agricultural workers' knowledge, perceptions, attitudes, practices, and behaviours, identifying the main risks and risk factors for disease associated with the unsafe handling of pesticides. The main risk factors identified were age, education, pesticide safety training, farming experience, and contact with other farmers/intermediaries resulting in pesticide access. The most frequent risk behaviour was an application of pesticides without personal protective equipment (PPE), incorrect disposal of empty packaging and waste, and undervaluation of label information, as well as other unsafe practices. Multidisciplinary and more effective training must be delivered to enhance pesticide-safe usage. This will empower workers to adopt more conscious and safer behaviours while using pesticides.

Keywords: behaviour; pesticides; occupational exposure; food safety; agricultural workers

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1. Introduction

Population growth, as well as the increasing prevalence of pests and problems that affect crop productivity and enhance yield losses, has resulted in more intensive agriculture aimed at producing the necessary amounts of food; consequently, pesticide use has been increasing significantly worldwide, demanding further attention from the authorities through the implementation and supervision of laws and regulations that require their safe and environmentally-conscious use; for example, *Directive 2009/128/EC*, *Regulation (EC) no. 1907/2006* and *Regulation (EC) no. 1272/2008* [1–4].

Workers are daily exposed to many physical, chemical, biological, mechanical, and ergonomic risks [5]. In agricultural workers, exposure to pesticides, in some circumstances, can result in the contact of these substances with the human body in three common ways: via dermal (contact with skin), oral (ingestion through the mouth), or respiratory routes (inhalation) [6–9]. Reconsidering current agricultural practices and systems is essential to safeguard public health and the environment and protect farmers/agricultural workers, who are more exposed to these chemicals when good practices are not considered [10–13].

The adoption of good practices suggested by occupational health and safety (OHS) and public health entities, including the use of personal protective measures, allows workers to significantly reduce their occupational exposure to various known or potentially hazardous agrochemicals, such as pesticides, and thus diminish the risks of health damage [2,11,14–16]. In pesticide handling, these practices must be implemented throughout the process: in storage; during transport to/from farms; in mixture preparation, application, and after application; during re-entry into treated areas, and during disposal of waste and empty

packaging. It is therefore essential to conform to the guidelines at each stage to protect workers from increased occupational exposure that could potentially damage their health. It is important to note that the exposure depends on many factors, such as the nature of the active substance, the toxic properties of the substances, the exposure time, the vulnerability of the worker, or the technology of use, and for this reason, it is difficult and complex for OHS authorities to provide detailed information about the relationship between the use of various pesticides and the consequent exposure risks for the workers [4,6,17].

On the other hand, the presence of pesticide residues in food is expected when plant protection products are applied. However, excessive and unsafe use of pesticides is perceived, for instance, when the established maximum residue limits (MRLs) for a pesticide/crop combination are exceeded, or when a variety of residues is found in the same food sample, suggesting the possibility of adverse mixture effects endangering workers' health and affecting food safety, the environment (negative indirect effects on soil, air, and water quality), and public health through the consumption of pesticide-contaminated food [1,2,18–24].

The behavioural and educational factors that can lead to pesticide contamination and health issues in farmworkers include the use of banned or restricted pesticides; no use of personal protective equipment; unsafe behaviours and practices throughout the pesticide handling process; over-application; undervaluation of label information; inadequate spraying operations in farms; incorrect disposal of empty pesticide containers and residues; insufficient information on hazards, health, and environmental effects; and inadequate education and training on the safe use of pesticides [1,2,13,15–17,25,26].

Previous studies indicate that the study and evaluation of farmers' knowledge, attitudes, and practices regarding the use of pesticides is a key step to mitigate pesticide hazards that may contribute to high exposure, and consequently to a higher risk of health damage [6,14,27]. However, such studies, as well as their relationship and impact on safety behaviours, are limited. Evidence shows that occupational safety and health in agriculture is a little-debated topic, as few farmers receive training in occupational health [1,14,16,17,26,27]. Thus, more studies focused on the knowledge, attitudes, perceptions, practices, and behaviours of farmers and agricultural workers are essential to support the authorities who will shape policies and awareness-raising programs targeting workers to encourage the safe use of pesticides [1,2,17].

This systematic review aimed to determine the main risks that agricultural workers are exposed to and the risk behaviours they adopt while applying pesticides, which may have harmful effects on their health and the environment. At the same time, this study was conducted to identify the level of knowledge and attitudes of agricultural workers regarding the safe use of pesticides; the protective measures and practices taken during all steps of pesticide handling, as well as the inappropriate practices and behaviours of pesticide appliers; the main risk factors influencing the inappropriate use of these products; the health hazards of occupational exposure to pesticides; and the possible effects of contaminants (residues) on food safety, and consequently, on public health.

2. Materials and Methods

This systematic review was based on the guidelines of the *Preferred Reporting Items for Systematic Reviews and Meta-analyses* (PRISMA)® [28]. The research question was:

- *What are the main risks and behaviours identified among agricultural workers exposed to pesticides that can potentially trigger health problems and unsafe food?*

2.1. Eligibility Criteria

The eligibility criteria were defined according to the PICOS methodology guidelines, which assisted in the establishment of the inclusion and exclusion criteria [29]. All studies on farmers' occupational exposure to pesticides, written in Portuguese, Spanish, and English, and available in full form, were included. Their publication date was also considered: only articles published between 1 January 2018 and 31 July 2022 were included. Articles were excluded if they were in the following categories: (1) the study population

did not consist of agricultural workers or their families; (2) the results only referred to environmental implications resulting from the excessive use of pesticides; (3) the results were related only to health problems in the general population; (4) the results were related to occupational exposure to factors other than pesticide exposure; (5) the study objective was not in the realm of the research interest; and (6) if the study was a systematic review, narrative, or meta-analysis.

2.2. Sources of Information, Research, and Study Selection

The articles were searched in three electronic databases: Medline/PubMed, ScienceDirect, and Web of Science. The terms used for the search were: "behaviour", "practice", "pesticides", "food safety", "occupational* exposure*", "farmworkers", and "agricultural workers". The Boolean terms "AND" and "OR" were used to combine the various keywords, thus improving the search strategy and the results. Filters were applied during the search, such as the year of publication and idiom, to reach a given number of articles related to the research question.

After the search, the selected articles were put through the *Mendeley Reference Manager 2.79.0*® software to eliminate duplicates. Subsequently, two reviewers (AM and PC) proceeded with the selection process: in the first phase, the titles and abstracts of the articles were analysed by both and classified as potentially relevant or not, according to the inclusion and exclusion criteria; in the second phase, the articles considered relevant were fully and independently studied and data collection was conducted. Any possible disagreement was resolved through discussion between the reviewers.

2.3. Data Collection and Extraction

Data from the selected studies were collected after a full reading and then organised in a detailed table according to the author(s), year of publication, objectives, characteristics of the participants, country/location where the study was conducted, type of intervention, and main results (subdivided into identified knowledge/attitudes, referred behaviours/practices, determining risk factors, and reported side effects). This detailed information is presented in Appendix A.

2.4. Quality Assessment and Risk of Bias

The methodological quality of the selected studies was independently assessed by two reviewers (AM and PC) using the *Strengthening the Reporting of Observational Studies in Epidemiology* (STROBE) software [30] and a combination of STROBE and the *Cochrane Systematic Review Handbook* [31]. According to these tools, the higher the final score, the greater the number of compliant items in the study, thus indicating whether the study has a strong methodological quality [32,33].

The risk of bias in the selected studies was assessed with the *Risk of Bias in Non-randomized Studies* (ROBINS) for observational studies, developed by Cochrane [34]. This instrument considers seven domains and categorises them according to five possible classifications: low risk of bias, moderate risk of bias, severe risk of bias, critical risk of bias, or no information to assess the risk of bias.

3. Results

The database search retrieved 1704 articles with the selected keywords. Figure 1 is a flow diagram describing the study selection. A total of 15 articles were included in the study for analysis.

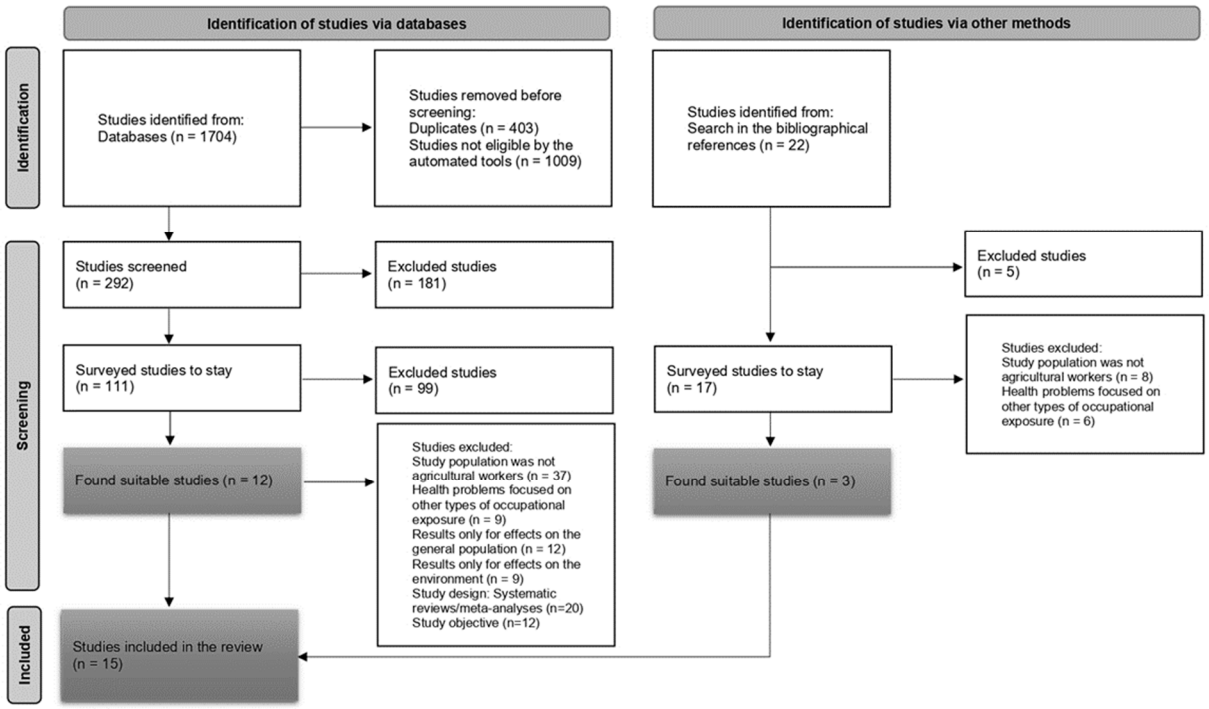

Figure 1. PRISMA 2020 flow diagram for updated systematic reviews, which included the search in databases and other sources.

3.1. General Characteristics of the Studies

The selected studies followed an observational methodology [1,2,10–12,14–16,35–38]. The duration of these studies ranged from 4 to 16 months. Their intervention involved the completion of a pre-tested and pre-defined questionnaire with several items for a face-to-face interview with farmers/agricultural workers [1,2,10–16,25,27,35–38]. The completion of this questionnaire was carried out either by the own farmers/workers or by the members/authors of each study, who in some cases were hired stuff. It should be noted that in all studies, consent to take part in the research was collected from all participants, and their rights were thoroughly explained to them.

The results of the selected studies (Appendix A) agreed with each other regarding the main risk factors and behaviours influencing the safe handling of pesticides in agriculture. Such studies were from non-European countries (Bangladesh, Iran, Pakistan, India, Cambodia, Laos, Vietnam, Nigeria, Ghana, and Lebanon), indicating that the issue under study is still relevant and current in underdeveloped and developing countries.

3.2. Quality Assessment and Risk of Bias

Given their results, these studies were regarded as having a good methodological quality, according to the STROBE criteria and the STROBE and *Cochrane Systematic Review Handbook* compilation. The results for the risk of bias according to the *Risk of Bias in Non-randomized Studies* (ROBINS) are presented in Table 1.

Table 1. Risk of bias of the included studies according to the *Risk of Bias in Non-randomized Studies* (ROBINS).

Study	D1	D2	D3	D4	D5	D6	D7	Total
Akter et al. (2018) [1]	⊖	⊕	⊕	⊕	⊕	⊖	⊕	Moderate risk
Bagheri et al. (2018) [14]	⊖	⊖	⊕	⊕	⊖	⊕	⊕	Moderate risk
Mehmood et al. (2019) [10]	⊕	⊕	⊕	⊕	⊕	⊕	⊕	Low risk

Table 1. *Cont.*

Study	D1	D2	D3	D4	D5	D6	D7	Total
Memon et al. (2019) [11]	⊖	⊕	⊕	⊕	⊖	⊕	⊕	Moderate risk
Schreinemachers et al. (2020) [13]	⊖	⊖	⊕	⊕	⊕	⊕	⊖	Moderate risk
Sharafi et al. (2018) [16]	⊕	⊕	⊕	⊕	⊕	⊕	⊕	Low risk
Bakhtawer (2021) [37]	⊖	⊗	⊗	⊕	⊕	⊕	⊕	Severe risk
Nwadike et al. (2021) [27]	⊕	⊕	⊕	⊕	⊕	⊕	⊕	Low risk
Bagheri et al. (2019) [36]	⊖	⊖	⊕	⊕	⊖	⊕	⊕	Moderate risk
Nath et al. (2022) [12]	⊖	⊕	⊕	⊕	⊖	⊕	⊕	Moderate risk
Masruri et al. (2020) [25]	⊕	⊕	⊕	⊕	⊖	⊕	⊕	Moderate risk
Aniah et al. (2021) [35]	⊖	⊕	⊕	⊕	⊕	⊖	⊕	Moderate risk
Mardigian et al. (2021) [15]	⊕	⊕	⊕	⊕	⊕	⊕	⊕	Low risk
Sookhtanlou et al. (2022) [38]	⊖	⊖	⊕	⊕	⊕	⊖	⊕	Moderate risk
Kumari et al. (2021) [2]	⊖	⊕	⊖	⊕	⊕	⊖	⊕	Moderate risk

⊖⊕⊗: Low risk of bias, moderate risk of bias, and severe risk of bias, respectively.

3.3. Socioeconomic Characteristics of the Studies

The participants were mainly male farmers (73.8%), farm workers, and/or their relatives, with an average age of 43 years old (implying that farmers are in middle age) (Table 2). Most participants were involved in the farming of apples, onions, turmeric, chillies, condiments, garlic, potatoes, coriander, cotton, mustard, beans, wheat, corn, barley, beet, rapeseeds, tomatoes, chickpeas, pistachios, soybeans, maize, cowpeas, groundnuts, among other vegetables and fruits. Their educational level ranged from illiterate to college graduates. The average length of education is 7.6 years, suggesting that most participants completed only their elementary education. The average experience in agriculture and the use of pesticides is 15.8 years, which points to a significant experience in this field [1,2,10–16,25,27,35–38].

Table 2. Summary of socioeconomic characteristics of 15 studies included in the systematic review.

Socioeconomic Characteristics	N	Age (Years)	Sex (%)	Education (Years)	Training Received [1]	Experience (Years) [2]
Akter et al. (2018) [1]	101	41.8	100 (M) 0 (F)	1.9	19.2 (Y) 80.8 (N)	11.2
Bagheri et al. (2018) [14]	200	52.9	100 (M) 0 (F)	10.9	27.0 (Y) 73.0 (N)	25.5
Mehmood et al. (2019) [10]	307	NE	NE	NE	NE	NE
Memon et al. (2019) [11]	260	32.6	0 (M) 100 (F)	1.5	NE	9.7
Schreinemachers et al. (2020) [13]	1000	NE	NE	NE	NE	NE
Sharafi et al. (2018) [16]	311	39.6	100 (M) 0 (F)	7.8	21.5 (Y) 78.5 (N)	17.6
Bakhtawer (2021) [37]	300	33.8	93.7 (M) 6.3 (F)	6.9	19.0 (Y) 81.0 (N)	6.8
Nwadike et al. (2021) [27]	513	40.6	80.6 (M) 19.4 (F)	9.9	91.2 (Y) 8.8 (N)	10.3
Bagheri et al. (2019) [36]	200	52.9	100 (M) 0 (F)	10.9	27.0 (Y) 73.0 (N)	25.5
Nath et al. (2022) [12]	90	NE	NE	NE	NE	NE
Masruri et al. (2020) [25]	380	49.0	100 (M) 0 (F)	7.1	27.9 (Y) 72.1 (N)	16.7

Table 2. *Cont.*

Socioeconomic Characteristics	N	Age (Years)	Sex (%)	Education (Years)	Training Received [1]	Experience (Years) [2]
Aniah et al. (2021) [35]	150	40	34.0 (M) 66.0 (F)	1.2	59.3 (Y) 40.7 (N)	6.2
Mardigian et al. (2021) [15]	104	47.7	100 (M) 0 (F)	10.9	NE	NE
Sookhtanlou et al. (2021) [38]	370	46.5	NE	9.4	NE	23.6
Kumari et al. (2021) [2]	96	46	84.4 (M) 15.6 (F)	NE	NE	18

[1] Training received in the use of pesticides that can include training about the side effects of pesticides, banned pesticides, use of recommended dose on labels, commercial names, pesticide storage location, use of PPE, and reentry period after application, among others. [2] Experience in agriculture and pesticides. N = Number of participants. *M* = Male and *F* = Female. *Y* = Yes and *N* = No. *NE*: *Not specified*—this data is not included in the study.

3.4. Knowledge, Attitudes, and Perceptions

Considering the results for knowledge, attitudes, and perceptions of farmers/agricultural workers on the safe use of pesticides, we could perceive, in most studies (60%), a poor knowledge of the toxic effects of pesticides and toxicity classifications [1,2,12,16,25,35–37]. A large number of the studies indicated a lack of knowledge on reading and interpreting labels/pictograms and on product selection considering the problem/pest detected [1,2,15,16,27,35,37]. Only 42.6% of farmers took training in the use of pesticides, with most of it focusing on the amount of pesticide to be applied rather than safety in pesticide use, suggesting that more than half have been applying pesticides for a few years without training [2,14,16,25,35,37]. In the selected studies, there was also a significant percentage of farmers who were unaware of the health and environmental risks of pesticide over-application and inappropriate disposal of pesticide waste [1,2,12,15,16,25,35–37]. Some agricultural workers were able to identify the routes of entry of pesticides into the human body and singled out reduction of the used dosage, the use of PPE, and the use of less toxic pesticides as active measures to reduce the risk associated with occupational exposure [27].

3.5. Practices and Behaviours

The practices and behaviours of agricultural workers during pesticide handling are identified in the selected studies [1,2,10–12,14–16,35–38].

- Thirty-three percent refer to over-application of products for more effective control or because their experience indicates so.
- Inadequate disposal of pesticide containers and waste was reported in 53.3% of the studies (e.g., burning, burying, washing them near water courses, use of containers for domestic and agricultural purposes, leaving them on farms, among other practices).
- Lack of information and signalling (a warning signboard or red flag) on the recently sprayed areas and conditions to re-enter the same.
- Storage of pesticides at their homes (46.7%).
- Preparation of pesticides or mixtures in houses, orchards, or near irrigation points with bare hands or sticks (26.7%).
- Preparing and spraying pesticides without considering/reading the information on the product's label (safety precautions, recommended dosage, disposal of empty containers, weather conditions, targeted pest problem, among other information) was a practice described in 40% of the studies.
- Almost 70% of the studies point to the fact that farmers do not yet wear appropriate PPE during pesticide use (masks, gloves, long-sleeved shirts, and boots).
- Eating, drinking, and/or smoking during or at the place of application/preparation of pesticides seems to be a common practice, according to 46.7% of the studies.

However, some studies reveal an increasing tendency toward abandoning these practices, which might lead to a change in behaviours [1,2,14–16,25,36,37].

3.6. Health Effects of Occupational Pesticide Exposure

Occupational pesticide exposure affects the health of workers, with the most reported symptoms being short-term effects, since the long-term health effects depend on more concrete and solid data, and these studies are based only on self-reports. Thus, the most frequent symptoms identified in 60% of the selected studies were: headache, nausea, vomiting, dizziness, excessive sweating, hypersalivation, blurred vision, and skin and eye irritation [1,2,10–12,14,16,27,35].

Most studies refer to the importance of developing intensive training programs on occupational safety specific to pesticides, to increase the workers' literacy and contribute to safer practices and behaviours, better food safety, and preservation of the environment and public health [1,2,10–16,25,35–39].

4. Discussion

The negative implications of the improper use of pesticides have been reported in several studies over time [10,11,13,16,17,40–55]. However, these implications do not result only from their use, but from a set of factors that include lack of knowledge and inappropriate attitudes, perceptions, beliefs, practices, and behaviours among agricultural workers, which a threat to their health, the safety of food items, the environment, and public health [1,35,36].

Some studies agree that the inappropriate use of pesticides occurs particularly at the stages of storage, spraying, and disposal of empty containers. This improper behaviour, reported in the selected literature, is due to factors such as limited education, awareness, and training that negatively influence the adoption of safe behaviours during this process [15,16,25,37]. Other studies report that inadequate or unsatisfactory training on pesticide safety essentially occurs because it is not provided by official entities [12,16,35,37]. Evidence shows that most of the information on pesticide safety is transmitted to farmers and agricultural workers by friends, relatives, pesticide sellers (not always qualified to do so) or through unreliable sources [12,16,35,37].

A lack of knowledge when choosing and buying pesticides is one of the risk factors most often associated with unsafe behaviours in pesticide use, as they allow agricultural workers to contact and trust intermediaries with scarce knowledge of the products (e.g., pesticide sellers without adequate training), and consequently, to have access to unlimited products without labels and instructions on the recommended dosage and appropriate use [5,8,9,15,25,35,38,56–59].

Bagheri et al. (2018) and other authors affirm that a lack of proper monitoring and regulations has led to more adverse effects of pesticides and their residues in developing countries when compared to developed countries. Although in developed countries the regulations and laws for selling and purchasing these products are significantly effective, there are still countries where such laws are unclear or not yet enforced, and this opens a window of opportunity to the free market (easily accessible these days) and more attractive prices that result in more risks to health and the environment [3,15,27,35,37,60–63]. For instance, in Portugal, *Law no. 26/2013 of 11 April* regulates the activities of distribution, sales, and application of plant protection products for professional use, intending to promote the sustainable use of pesticides while reducing their risks and effects on human health and the environment. Furthermore, this law establishes that all pesticide users must be qualified to do so, and when this is the case, they are given a card that is renewable every 10 years, and only those holding this card can apply such products. Sellers, as well as pesticide retailers, must also have the qualifications referred to in the legislation to be considered legally recognised technicians and sales operators [56,57,59].

The selected studies refer to a set of factors that negatively influence the adoption of safe practices/behaviours by agricultural workers during pesticide handling: advanced age, more work experience, lower educational level, and lack of training in [1,2,10–16,27,35,37,38]. The risk factors "education" and "training" identified in so many of the selected studies, as well as other studies, are two of the main enhancers of dangerous practices among farmers and agricultural workers, such as "using bare hands without gloves to mix pesticides". According to

the literature, this happens because they are unaware of the harmful effects of the products they are handling and the consequences of their attitude on their health [1–3,10–12,14,15,25,27,36].

Some studies on the effectiveness of interventions to promote pesticide safety state that education and training are also important precursors of safe behaviours. This is also proved by some of the selected studies, in which a positive association is found between a higher level of education and training and the implementation of safe pesticide behaviours and practices, such as the use of PPE, the correct storage of products, and proper disposal of pesticide waste and packaging [1,2,10–12,14,15,25,27,36,37]. On the other hand, the same studies indicate that age and farming experience are negatively associated with pesticide safety; i.e., older farmers adopt less appropriate practices and behaviours than younger farmers, and few of them are willing to adopt them in their day-to-day life [11,12,25,36]. This may be due, according to evidence, to a low level of education, lack of knowledge on the toxicity and risks of pesticides, beliefs that an increased use of these products will lead to greater productivity, and the fact that they have not yet experienced a real health implication after so many years of exposure (questioning safety concerns and continuing to rely on behaviours they have adopted so far) [1,10,15,36]. However, some studies point to a need to invest in multidisciplinary awareness and training programs featuring the experiences of other farmers, with videos and photographs, detailed focus, and discussion groups, which at the same time are adapted to the educational level of this population to facilitate learning; only then can the training and awareness programs have the desired effects and contribute to the knowledge of workers [2,14,16,27,36,37]. The importance of wearing PPE even in times of excessive heat is an example of something to be communicated at the educational level; this will be better understood if it is explained that by doing this, they will be reducing contact with one of the main routes of entry—the skin—of pesticide residues into the human body [1,12,14,15,37].

Studies have also suggested that it is of extreme importance and priority that these programs cover all phases of pesticide use, including the correct disposal of empty packaging and pesticide residues, according to the guidelines of the Food and Agriculture Organization of the United Nations (FAO) (e.g., triple washing and delivery to a waste management and recycling centre)—a rather uncommon practice in current studies, which, if implemented, will contribute to the reduction of risks to human and animal health and the environment [2,14]. In Portugal, there are regulations, for example, *Decree 187/2006*, which is aimed at controlling the conditions and safety procedures of pesticide waste management systems, dictating how the delivery of packaging waste or surplus waste to the reception centres should be carried out. This regulation also provides guidelines on the reporting of their collection for subsequent reuse or disposal [5,8,9,56–59,64].

In contrast, in the countries where the studies were conducted, for example in Iran, Pakistan, and Lebanon, this regulation still has significant gaps in their implementation and supervision [14,15,37]. This is evident since the most common packaging disposal practices still include burying, burning, leaving waste on farms, or throwing it out into waterways. Others use the packaging for domestic purposes, such as washing clothes, transporting food, storing water, or as toilet bowls. These practices reinforce the idea that it is important to explain the risks of food and water contamination with pesticides, as well as the dangers of contact with its residues [2,10,12,14,15,25,37,38].

It is also essential to discourage the storage of these types of products in houses—a practice mentioned by many farmers—since this puts not only the worker but also his/her entire family, especially children, at risk [25,27]. The unnecessary application of pesticides in treated areas and the application of a higher-than-recommended dosage is unfortunately common and a high-risk behaviour that may result in several reported problems. These include damage to quality products due to the presence of unwanted residues that may affect food safety, and consequently put businesses at risk; increased pest resistance; and the deposition of harmful substances into soil and water resources, which threatens human and animal health. Agricultural workers should be encouraged to respect good agricultural practices (GAP) recommended by the authorities, and, for

example, spray the recommended dosage and use residues to spray on untreated land, or proceed to more efficient management by defining the correct application rate before purchase and preparation [2,13,14,16,27,37,38].

Training programs on pest management have been associated, in several studies, with a positive influence on the safe use of pesticides, as they allow farmers to increase their knowledge of alternative methods to toxic chemical control and assist them in the identification of pests—knowledge that is lacking in most farmers. This should be encouraged, as it drives farmers to adopt more responsible and appropriate procedures for the use of chemicals, as well as more sustainable approaches to the economy, the community, and the environment. Hence the importance of addressing these topics in training [2,10,12,14,16,27,38].

Regarding the health implications of occupational exposure to pesticides, the most reported and evidence-based symptoms are headaches, nausea, vomiting, dizziness, and eye and skin irritation (self-reported data that only indicate health impacts) [2,10–12,14,27,65]. However, the studies report that only a small percentage ever went to the hospital after experiencing these short-term symptoms of intoxication—the literature justifies this by stating that workers regard these symptoms as "normal" and part of an episode that occurs after spraying, rather than an episode of intoxication, with symptoms corresponding to the adverse effects of pesticide use. Once again, the lack of information on the effects of unsafe spraying and the health risks of recurrent spraying endangers the safety and life of workers, who devalue these symptoms [2,10–12,14,27]. As for the long-term effects, it is essential to determine whether the diseases arise from occupational exposure to pesticides or other external factors. Therefore, more studies are needed to determine the root cause and cautiously expose the long-term health effects associated with pesticide use [2,10,12,66].

Regarding PPE, the studies found that contrary to what would be desired, this is still a significantly undervalued practice by agricultural workers, even among those who handle highly toxic products, which means that only a small percentage use adequate equipment during preparation and spraying with pesticides. The most used equipment consists of long-sleeved shirts, trousers, and some items to protect the face (e.g.: scarf)—not always a mask [2,10–12,14,16,25,27,37]. The selected studies, as well as others, suggest that this absence may be due to the high costs of this type of equipment, as well as the discomfort caused by the climatic conditions experienced in the studied locations (higher temperatures and humidity). These studies revealed that a higher educational level, access to training in the area, financing from local institutions, and a source of income aside from that derived from agriculture were positively associated with the use of PPE, as was encouraging farmers to adopt new protective measures and providing them with more tools to deal with risks, as well as increased financial freedom [1,11,12,14,25,27,37].

The research question also aimed to analyse the potential impact on food safety of risk behaviours adopted by agricultural workers in the use of pesticides. This aim was achieved indirectly through food residue analysis data and their relation to good agricultural practices. However, there was no direct information from the studies included in the review. Eating and drinking during the preparation/spraying of pesticides were referred to, in some studies, as practices that potentially affected the safety of foods consumed by agricultural workers in their job. Moreover, the harmful effects of consuming food contaminated with pesticide residues were often unknown [2,15,36]. It is necessary for more studies that show the relation between, for example, over-application in some areas (risk behaviour) and the presence of residues above MRLs in food-related areas.

There is also a need to rethink agricultural practices to encourage more sustainable farming and to strengthen farmers' knowledge of pest management, composting, resource conservation, and fertilisation. This will enable a change in farmers' attitudes, perceptions, and practices, and will certainly contribute to a more conscious and safer use of pesticides [1,2,27,35,38]. Determining the factors that influence safety in pesticide handling is the first step to making comprehensive policies that ensure safety for both health and the environment [2,10,38].

5. Limitations

This study has limitations that should be acknowledged for a better evaluation of the main findings. The selected studies are based on self-reported symptoms and safety practices that are limited, requiring studies with objective and quantitative measures to validate this information. Another limitation of this systematic review is the fact that it is based only on observational studies, due to the lack of experimental studies that meet the eligibility criteria and answer the research question. The selected studies were mostly conducted in developing countries in Asia and Africa (associated with a low level of literacy and precarious work conditions), preventing us from having a representative sample of the European and global reality on this topic—this may be due to their year of publication as well as their exclusion criteria. However, a search conducted by the authors on the European Agency for Safety and Health at Work database indicated the absence of recent studies from Europe and other continents on the knowledge and practices of farm workers regarding the use of pesticides, with works aimed only at providing information to workers on the safe use of pesticides. Another inherent limitation is the presence of a significant number of studies with a moderate risk of bias, and one having a severe risk of bias, requiring greater caution in the analysis of their results to improve the methodological aspects of further research.

6. Conclusions

The knowledge, attitudes, and perceptions of farmers, as well as their practices and behaviours, are influenced by several factors. This influence translates into different effects, both positive and negative. Education and training on pesticides allows farmers to better understand and interpret pesticide labels/instructions; informs them on the risks of pesticide use, and consequently, of exposure; equips them with knowledge on pesticide storage, preparation, and application; encourages better health protection behaviours, such as the use of proper PPE (mask, clothes, hat, and gloves); elucidates the correct way to dispose of pesticide waste and empty containers; and teaches new ways of fighting against pests. However, other factors are associated with the opposite effects for farmers. Examples are age, farming experience, and contact with other farmers and intermediaries, which have a negative influence on farmers' knowledge and attitudes regarding pesticide risk, thus increasing the adoption of unsafe behaviours while applying these products, with harmful effects on human and environmental health. The influence of personal background or previous episodes of pesticide poisoning is not unanimous, and therefore, needs further research.

There is a need to develop multidisciplinary and comprehensive programs to improve and increase literacy on pesticide safety, bearing in mind factors such as the educational level of farmers, and featuring content such as the correct methods for safe storage and application of pesticides, the importance of PPE, the relevance of personal hygiene during and after pesticide use (e.g., taking a shower after spraying, washing clothes separately and not eating, drinking, and/or smoking), an introduction to the health and environmental risks of pesticides, presenting other pest control strategies, and encouraging safe procedures for the disposal of pesticide residues and empty containers.

This will empower workers to adopt more conscious and safer behaviours while using pesticides, and consequently, contribute to a healthier life and the protection and safety of the produced food (products without harmful substances to health), as well as to the sustainability of agriculture, preservation of the environment, and promotion of public health.

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Appendix A

Table A1. Detailed data of the included studies.

Study	Objectives	Intervention	Main Outcomes			
			Knowledge Attitudes	Practices Behaviours	Risk Factors	Reported Side Effects
Akter et al. (2018) [1] **Bangladesh**	*Quantify the knowledge, personal background, and protective behaviours adopted by farmers; identify the factors influencing protective behaviours in pesticide use and recommend improvements in these practices.*	Application of a standard questionnaire (validated previously) to interview farmers (**with consent**) about their knowledge and practices related to pesticide use through face-to-face interviews with a demonstration of application practices, protective equipment used, and the storage place of the products, with site visits whenever possible (visual evidence). The questionnaire included 30 items on a farmer's knowledge of pesticide use (KNO; seven items); attitude (Atti; five items); past experiences of pesticide poisoning (PE; six items); perceived outcomes (PR; four items); and protective behaviours during pesticide selection, storage, and application (PB; eight items).	**Knowledge about pesticides:** Scores indicated a lack of knowledge about pesticide use (read and understand labels/pictograms/hazards of the product and choose the right product for the problem). The scores showed some knowledge of the issues related to linking pesticides to health. Most showed no knowledge that pesticides influence the acceptability and quality of products.	**Preparation and spraying: They** apply more product than the recommended quantity for fear of losing profits (they do not show a tendency to decrease). They do not believe that a reduction in pesticide application can minimise environmental pollution. The most adopted protective behaviour among farmers was the correct storage of pesticides, followed by showering after application as well as not eating or smoking during application. Additionally, it was uncommon to post recent treatment information on the sprayed area and to apply only the required dose of pesticide. **Protective equipment used and Disposal of empty containers and waste:** The least common practices were the use of adequate personal protective clothing and equipment as well as the correct disposal of waste and empty containers.	**Safe behaviour and practices:** Relation (+): Education; level of involvement in agriculture; training in the field. Relation (−): Older age; farm size; years of pesticide application. Safe practices associated with pesticide use are more influenced by the farmer's knowledge/attitudes and previous poisoning episodes.	Headaches, vomiting, dizziness (most frequent), eye irritation (60%), and skin irritation (50%).

Table A1. *Cont.*

Study	Objectives	Intervention	Main Outcomes			
			Knowledge Attitudes	Practices Behaviours	Risk Factors	Reported Side Effects
Bagheri et al. (2018) [14] **Ardabil, Irão**	*To study the use of pesticides as well as the associated health risks and determine the protective behaviours of apple producers.*	Application of a questionnaire (previously validated) completed face-to-face by the farmers (**with consent**) with questions related to socio-economic data, farming experience, household size, residence, marital status, level of education, function in agriculture, pesticide toxicity problems, safety and behaviours, use of PPE and pesticide handling practices. Farmers were asked to report only health complications caused by pesticide handling.	**Knowledge about pesticides:** Some agricultural workers presented training in the area; however, the training was more directed at the application quantity of products than at safety matters regarding the use of pesticides.	**Preparation and Spraying:** Some of the agricultural workers stored pesticides in warehouses; however, some still stored this type of product at home (8.5%). Due to the proximity of the farm, 8.0% of the agricultural workers indicated that they prepared the grouts for spraying in their kitchen. Most of the farmers (71.5%) stated that they prepared the sprays in the orchards or near water points. Washing hands with hot water and soap after spraying, not eating or drinking, not smoking during spraying, changing clothes, and taking a shower after spraying were considered by almost all farmers. Keeping pesticides in safe places and using eco-friendly/low-toxic pesticides were the least considered behaviours. **Disposal of empty containers and waste:** Almost one in three farmers (32.8%) reported that they "dumped" the empty containers in their orchards. Similarly, some farmers (30.2%) reported that they usually buried the empty containers, and others burned the empty containers (17%) or threw them into irrigation canals, regardless of their destination (10%). Others washed and used them to water domestic animals (10%).	**Influence on protective behaviours:** Relation (+): Education and training. Relation (−): Agricultural experience and age.	17% of farmers have been hospitalised for pesticide poisoning. **The most frequent symptoms:** irritated eyes and blurred vision.

Table A1. *Cont.*

Study	Objectives	Intervention	Main Outcomes			
			Knowledge Attitudes	Practices Behaviours	Risk Factors	Reported Side Effects
Mehmood et al. (2019) [10] **Pakistan**	*To analyse the factors determining the use of personal protective equipment by producers and to assess how pesticide residues and containers are disposed of.*	Application of a questionnaire (previously validated) to interview farmers (**with consent**) on information on socio-economic and farm issues, financial situation, access to finance for agriculture, costs for health protection as well as farmers' understanding of the use of toxic chemicals and taking safety measures in this regard.	Not specified	**Type of pesticides handled:** Various pesticides of categories Ib, II, and III (highly hazardous, moderately hazardous, and slightly hazardous, respectively) according to the WHO pesticide risk classification. **Preparation and Spraying:** While spraying, the protective equipment items that workers used the most were a hat/cover (33.2%), mask (28.7%), and socks/boots (12.7%). However, it was not common for them to use rubber gloves, goggles, and applicator suits. The study revealed that workers used at least one piece of personal protective equipment. **Protective equipment used: They** only used PPE during the spraying periods. Most farmers wore trousers, long-sleeved blouses/shirts, and gloves; however, they did not wear glasses or applicator suits. **Disposal of empty packaging and waste:** Fifty-three percent disposed of pesticide containers by throwing the containers into fields or bushes as solid waste, while 18% of respondents reused empty pesticide containers for domestic or agricultural purposes. A small percentage (7%) sold empty containers to street vendors. About a fifth (21.8%) of farmers set the empty containers on fire and/or buried them. There was no collection by the recycling system in place in any of the cases.	**Safe behaviour and practices (use of PPE):** Relation (+): Education; level of involvement in agriculture; training in the field; diversified income; access to finance. Relation (−): Age; health effects suffered; income; protective equipment costs.	Sweating, hypersalivation, dizziness, headache, skin and eye irritation, blurred vision (more frequent).

Table A1. *Cont.*

Study	Objectives	Intervention	Main Outcomes			
			Knowledge Attitudes	Practices Behaviours	Risk Factors	Reported Side Effects
Memon et al. (2019) [11] **Southern Pakistan**	*To assess the health problems and associated costs arising from exposure to pesticides and to analyze the use of protective equipment by female workers.*	Application of a pre-tested questionnaire to interview the workers with questions related to the socio-economic status of cotton pickers, source of income, awareness of pesticide hazards, health problems occurring in cotton harvesting (considered by respondents to be a result of exposure to pesticides during harvesting), and personal protection practices adopted during harvesting and health facilities.	Not specified	**Type of pesticides handled:** Various pesticides of category II (moderately hazardous) according to the WHO pesticide risk classification. **Protective equipment used:** the majority did not use any type of PPE. Some workers indicated that they protected their face with some material (e.g., towel or scarf), used gloves and wore shoes during harvesting.	**Use of protective measures:** Relation (+): Younger age; higher level of education/training. Relation (−) Illiteracy and greater experience in harvesting and health treatments.	**Short-term:** skin and eye injuries, headaches, stomach aches and fever (more frequent)
Schreinemachers et al. (2020) [13] **Cambodia, Laos, and Vietnam**	*Quantify the excessive use of pesticides in production systems.*	Application of a pre-tested questionnaire to interview workers (**with consent**) with questions related to crop production, pesticide use, the distinction between beneficial and harmful arthropods to crops, and questions related to spraying practices and pesticide handling.	Not specified	**Preparation and Spraying:** In Vietnam, 100% of agricultural workers over-applied (above the optimal amount for profit) pesticides; in Cambodia, about 73%, and in Laos, the percentage of over-application was 75%. This reflects unnecessary costs for agricultural workers.	**Appropriate use of pesticides:** Relation (+):Pest management carried out by female workers; previous training in the area; contact with official entities. Relation (−): Advice from pesticide sellers; belief in (over)effectiveness of pesticides; more recent experience in agriculture.	Not specified

Table A1. *Cont.*

Study	Objectives	Intervention	Main Outcomes			
			Knowledge Attitudes	Practices Behaviours	Risk Factors	Reported Side Effects
Sharafi et al. (2018) [16] **Kermanshah, Iran**	*To assess the knowledge/attitudes of farmers and determine the risk factors affecting the use of pesticides and consequently causing effects on their health.*	Application of a pre-tested questionnaire adapted from two previous ones for face-to-face completion by farmers with questions on socio-economic characteristics and farming practices, including age, gender, education level, types of crops and products, type and amount of pesticide used and income; farmers' knowledge, attitudes and practices on pesticide use and risks and practices used for pesticide/residue disposal.	**Knowledge about pesticides:** Most did not have certified training in the area. Most farmers were aware that several pesticides have been banned in recent years, however, only about 18% of them knew that this was due to their high toxicity. Few had the information that pesticides had residues. Only about 15% and 29% of farmers were aware of the risks of pesticides to human health and the environment respectively. While the majority believed that pesticides do not have any adverse effect on human health, environment, or agricultural produce. Most of the respondents did not know (24.4%) or had no idea (24.8%) how to deal with the risks of pesticides. However, they indicated that reducing the dose (42.4%), using personal protection (30.5%), and using low-risk products (14.8%) can reduce the risk associated with pesticides.	**Type of pesticides handled:** various pesticides of categories Ib, II and III (highly hazardous, moderately hazardous, and slightly hazardous respectively) according to the WHO pesticide risk classification. Sixty-one percent of farmers used pesticides based on their own experience without reading the instructions. **Preparation and Spraying:** Most farmers (62.7%) washed their hands and face after application. **Protective equipment used:** Only about 18% of farmers used personal protective equipment for the body (face and hands). **Disposal of empty packaging and waste:** Most of the farmers (52.7%) claimed that they stored the surplus pesticides for another use. About 16% of the farmers employed the surplus pesticide/wash residues on the treated land or on uncultivated land, which amounts to unnecessary use of pesticides. About 10% of the farmers were dumping the waste into rivers and other waterways. Most of them (41.2%) disposed of the packaging with other waste. None of them disposed of the empty containers properly, using a specific program for their collection and recycling.	**Prevalence of health implications:** Relation (+): Training in the area or higher level of education. Relation (−): Age over 65 years; untrained farmers applying highly toxic pesticides.	Skin irritation and dizziness (most frequent symptoms).

Table A1. *Cont.*

Study	Objectives	Intervention	Main Outcomes			
			Knowledge Attitudes	Practices Behaviours	Risk Factors	Reported Side Effects
Bakhtawer (2021) [37] **Punjab, Pakistan**	*To assess farmers' knowledge/attitudes and practices in the use of insecticides against pests.*	Application of a pre-tested questionnaire to interview workers face-to-face (with consent). The first part was related to the socio-demographic characteristics of respondents, such as gender, marital status, age, level of education, agricultural area, irrigation method, agricultural experience, and working hours spent on the crops. The second part was related to farmers' perceptions about which insecticides were more effective and which they used more, which crop and pest were most frequently mentioned, methods of preparing the dose to apply considering the pests encountered, knowledge about alternative pest control methods, biological agents, and natural enemies. The third part referred to the respondents' attitudes and practices regarding their protection during spraying, use of personal protective equipment, and participation in training in the area.	**Knowledge of pesticides:** Only 7% had some qualification acquired in the area, and 12% had training on the use of insecticides. Most of them obtained the name of the products and used them for pests only following the indications of the agricultural technician. Little knowledge was revealed about integrated pest management and the biological pest control method. **Preparation and Spraying:** Forty-two percent of respondents understood the label instructions when preparing for spraying. **Alternative to insecticides:** Of the respondents, 63% did not know of the existence of an alternative, while 37% were aware of it. Among the respondents, 68.6% did not know integrated pest management, and 65.3% of the respondents did not know any information about the biological pest control method.	**Type of pesticides handled:** Various pesticides of category II (moderately hazardous) according to the WHO pesticide risk classification. **Preparation and Spraying:** Forty-two percent of respondents understand the label instructions while preparing for spraying. Twenty-two percent of respondents were able to prepare an adequate dose, while fifteen percent of respondents followed the pesticide application plan. **Protective equipment used:** The most used measures were rubber gloves (44%), mask (41%), and/or covering the face with some material (e.g.: cloth). **Disposal of empty containers and waste:** Of the respondents, 50.33% buried the empty containers, and 14% burned them, while 31.67% threw them in the rubbish without any processing. Only 3.67% of the respondents proceeded to collection centres for the disposal of empty insecticide containers.	**Safe practices in the use of insecticides:** Relation (+): A level of education and consequently knowledge about pest control procedures; interpretation of product labels; frequency and quantity of product to be applied; use of personal protective equipment; appropriate disposal of empty containers and waste.	Not specified

Table A1. *Cont.*

Study	Objectives	Intervention	Main Outcomes			
			Knowledge Attitudes	Practices Behaviours	Risk Factors	Reported Side Effects
Nwadike et al. (2021) [27] **Northern Nigeria**	*Assess farmers' knowledge/attitudes and safe practices in pesticide use.*	Application of a pre-tested questionnaire to face-to-face interviews with workers (with consent). Data collected included socio-demographic characteristics, knowledge about frequently used/purchased pesticides, pesticide exposure routes, pesticide control methods, storage and disposal, use of PPE, attitudes towards the hazardous effect of pesticides, farmers' practices during pesticide application, and health problems associated with pesticide use. The factors considered included farmers' knowledge of safety during pesticide application, on-farm handling, and possible health/environmental and safety effects of the most adopted practices during and after pesticide use on farms. Farmers' attitudes about pesticide use and associated impact were measured using a 5-point Likert scale.	**Knowledge about pesticides:** *Of the respondents*, 58.8% were able to identify inhalation as the most likely route of entry of pesticide residues into the human body. The oral route (ingestion) was identified as the second most likely route of exposure (54.5%). Among the respondents, 60.3% said they were aware of secondary routes of pesticide exposure, including ingestion of contaminated food and drinking water contaminated with pesticides, etc. There was limited knowledge of the risk classification of each pesticide according to WHO classification, but extensive knowledge of the safe application of pesticides as well as extensive knowledge of the safe use of personal protective equipment. Knowledge of how to dispose of pesticide residues and expired products and on the safe storage of pesticides received slightly lower scores. Extensive knowledge was found regarding practices to avoid during pesticide preparation and application (e.g., eating and/or drinking and smoking).	**Preparation and Spraying:** Of the respondents, 87.9% said they read the product safety data sheet/packaging label before applying the product on their plots. An unsafe practice for worker safety and health was observed: 32% of respondents stated that during pesticide application, when one of the nozzles of the sprayer was clogged, they used their mouth to unblock it. **Protective equipment used:** The most used measures were rubber gloves, masks, and applicator suits. **Disposal of empty packaging and waste:** Of the participants, 30.6% used empty pesticide containers for other agricultural or domestic uses, thus exposing farmers to potential health problems associated with this practice.	**Safe practices in the use of pesticides:** Relation (+): Gender, experience, and agricultural practice do not influence the use of empty containers for other household purposes. A higher educational level positively influences reading product labels before use as well as other safety practices. Relation (−): Older age and low educational level influence the use of empty containers for other domestic purposes as well as the use of protective equipment and the use of the mouth to unclog sprayer nozzles.	Headaches, dizziness, skin, and eye irritation, coughing, nausea, and vomiting.

Table A1. *Cont.*

Study	Objectives	Intervention	Main Outcomes			
			Knowledge Attitudes	Practices Behaviours	Risk Factors	Reported Side Effects
Bagheri et al. (2019) [36] **Ardabil, Iran**	*To assess the knowledge/attitudes and perceptions of apple producers regarding the use of pesticides.*	Application of a pre-tested questionnaire to interview workers face-to-face (**with consent**). Data collected included basic demographic characteristics of farmers; main pests in apple plantations; trust; use of information sources on pesticides, knowledge, attitudes, and perceptions related to pesticide use; and adoption of safety practices by farmers in the use of these products. Data were collected using a 5-point Likert scale.	**Knowledge of pesticides:** Low level of knowledge regarding pest control management. The score reveals a moderate level of knowledge of pesticides among the respondents regarding environmental problems arising from over-application as well as the effects on existing "healthy" crops. Most of the respondents perceived that spraying was harmful to the health of applicators who did not protect themselves during spraying, and that spraying should be carried out only by skilled personnel. The scores indicated a positive perception of the overall implications of pesticide use (e.g., they did not agree that decreasing spraying meant decreasing profits).	**Type of pesticides handled:** Fungicides, herbicides, insecticides, and acaricides. **Preparation and spraying:** Most relied on pesticide dealers as a trusted source of information for correct product application. Most farmers stated that they washed their hands with soap and water after spraying, while a large proportion reported eating and drinking during spraying. Additionally, many of the farmers stated that they did not smoke during spraying. Seventy-five percent indicated that they did not read pesticide labels.	**Correct knowledge, attitudes, and perceptions about pesticide use:** Relation (+): Credible and official information sources as well as younger age and naturally acquired professional experience. The level of personal and family literacy also positively influences knowledge, attitudes, and perceptions. Relation (−): Previous experience of poisoning.	Not specified

Table A1. *Cont.*

Study	Objectives	Intervention	Main Outcomes			
			Knowledge Attitudes	Practices Behaviours	Risk Factors	Reported Side Effects
Nath et al. (2022) [12] **India**	*To assess the knowledge/attitudes and practices of people regarding pesticide use and the occurrence of acute toxicity symptoms.*	Application of a pre-tested questionnaire to interview farmers face-to-face.	**Knowledge about pesticides:** *Of the respondents*, 82.2% used chemical pesticides and most recognised them as harmful.	**Type of pesticides handled:** Fifty-two percent belonged to WHO class II (moderately hazardous), 8% belonged to class III (slightly hazardous) and 4% belonged to class Ib (highly hazardous). **Protective equipment used:** Of the respondents, 75.7% reported not using any individual protection measures, while 13.51% stated that they did not use differentiated work clothes or wash them separately, despite applying pesticides.	**Knowledge, attitudes, and correct practices on the use of pesticides:** Relation (−): Lack of adequate knowledge; risky behaviour during handling; inappropriate storage and disposal of pesticides.	**Episodes of acute poisoning from pesticide use:** headache, nausea, irritated eyes, vomiting, decreased breathing, disturbed vision, and excessive sweating.

Table A1. *Cont.*

Study	Objectives	Intervention	Main Outcomes			
			Knowledge Attitudes	Practices Behaviours	Risk Factors	Reported Side Effects
Masruri et al. (2020) [25] **Iran**	*To determine the knowledge and practices of farmers towards the use of pesticide insurance.*	Application of a pre-tested questionnaire to interview workers face-to-face (**with consent**). The questions included topics on farmers' knowledge of pesticide safety as well as their practices in this regard. The topics were rated using a 5-point Likert scale.	**Knowledge about pesticides:** Of the respondents, 92.1% reported that they had not participated in any training on pesticide safety, while 41.6% of the farmers had a low level of knowledge, and 58.4% had a moderate level of knowledge about pesticide side effects, storage, transport, and disposal conditions as well as precautions when handling toxic products. Most of the farmers studied had good knowledge about the prohibition of eating and drinking at the application site, as well as the use of personal protective equipment, such as masks. On the other hand, only about 40% of the workers knew about the prohibition of the reuse of empty containers for other purposes and about the prohibition of burning them.	**Precautionary measures in the storage, transport, and disposal of pesticides:** *Of the participants*, 62.6% had a moderate practice, and 37.4% of them had a good practice in this regard. **Protective equipment used:** Only 58.2% of the farmers always washed their clothes after spraying, 29.5% always wore gloves and 1.6% boots, 7% always wore safety glasses, and 17.6% wore protective masks. Only 1.6% of the farmers always used appropriate clothing. Others indicated that it was not a common practice to use the protection equipment listed.	**Knowledge and safe practices in the use of pesticides:** Relation (+): Age; experience; level of education/training.	Not specified

Table A1. *Cont.*

Study	Objectives	Intervention	Main Outcomes			
			Knowledge Attitudes	Practices Behaviours	Risk Factors	Reported Side Effects
Aniah et al. (2021) [35] **Ghana**	*To assess farmers' actual knowledge and practices regarding the use of pesticides and evaluate how they are obtained.*	Application of a pre-tested questionnaire to interview workers face-to-face (**with consent**). Questions include individual characteristics such as age, gender, educational level, farm size, duration of pesticide application, and knowledge and understanding of the safe use of pesticides.	**Knowledge about pesticides:** About 95% of the farmers did not have adequate knowledge of the environmental and health implications of pesticide use, while 59.3% were trained in the use of personal protective equipment. However, 53% of the farmers were unable to adequately understand the correct meaning of pictograms. Farmers showed low levels of knowledge regarding the toxic effects of pesticides.	**Type of pesticides handled:** The pesticides identified belonged to WHO class II (moderately hazardous) and class Ib (highly hazardous). **Preparation and Spraying:** Most farmers (91.5%) reported that they did not read the label of pesticides before use. Seventy-seven percent revealed that some of the pesticides they bought did not even have labels or instructions. Farmers usually used much more than the recommended dose of the various pesticides they handled. **Protective equipment used**: Of the farmers, 3.3% wore gloves and masks, and fewer than 2% wore boots, while most of the farmers (90.2%) wore jackets and long sleeve shirts. **Storage:** Sixty-three percent of farmers stored their pesticides inside their own homes, while the rest (37%) stored their pesticides in a warehouse or a no-food zone. **Disposal of empty packaging and waste:** Most farmers (over 90%) indicated that they disposed of empty packaging by burying it in the soil or burning it.	**Health effects:** Relation (+) between pesticide use and eye irritation as well as between pesticide use and headache, vomiting, and nausea.	*Generalised discomfort, vomiting, headaches, nausea, and eye irritation. 96.7% of respondents reported having suffered pesticide poisoning at least once.*

Table A1. *Cont.*

Study	Objectives	Intervention	Main Outcomes			
			Knowledge Attitudes	Practices Behaviours	Risk Factors	Reported Side Effects
Mardigian et al. (2021) [15] **Lebanon**	*Assessing farmers' practices and determining risk factors that incorrectly affect pesticide use*	Application of a pre-tested questionnaire to interview workers face-to-face (**with consent**). The questions include socio-demographic characteristics, of the farm and questions related to usual practices in pesticide application.	**Knowledge about pesticides:** Most farmers indicated that they did not know the active substances of the pesticides they use. However, they relied on their education, research, and experience to obtain information on the safe use of pesticides. Among the farmers, 59.6% agreed that exposure to pesticides could result in short-term and long-term health effects. When asked about possible long-term health effects of pesticide exposure, almost half of the respondents (49%) mentioned at least one associated disease (cancer, depression and neurological deficits, respiratory diseases, gastrointestinal disorders, reproductive disorders, skin problems, eye problems, and kidney failure). Only 58.7% of respondents believed that pesticides could have negative effects on the environment; the rest were unaware of the issue.	**Type of pesticides handled:** The choice of pesticides as well as the indications for the safe use of pesticides was made by the suppliers (family/friends). **Preparation and Spraying:** Of the respondents, 87.5% said that they respected the recommended dose on the package label during the application, both by themselves and by their workers. It was indicated by 74.6% of farmers that they had increased the use of pesticides because of environmental issues or because of issues related to the loss of effectiveness of a certain amount of product, pest resistance to the product, and/or beliefs that higher doses had more effectiveness). Among the participants, 85.4% said they monitored wind direction before spraying. Most reported not eating/drinking (95.8%), or smoking (87.5%) during spraying activities. In addition, 93.7% said they showered and changed clothes immediately after spraying. **Protective equipment used**: Of the respondents, 41.4% reported mixing the different pesticides using their hands without protection or using a stick, and only 36.5% reported wearing gloves during mixing. **Willingness to use fewer toxic products:** When asked about the possibility of using a less toxic product with equal efficacy, 87% of respondents were willing to switch, motivated mainly by the price difference. The remaining indicated that they did not want to switch, as they were satisfied with the product and would only do so on the advice of the current supplier.	**Safe practices in the use of pesticides:** Relation (−): Costs of products influence the choice of products; a belief that pesticides are currently ineffective and therefore do not cause problems due to dermal contact (devaluation of toxicity). **Willingness to use a safe pesticide:** Relation (+): Younger age and education.	*Death of one of the workers due to poisoning caused by exposure to pesticides.*

Table A1. *Cont.*

Study	Objectives	Intervention	Main Outcomes			
			Knowledge Attitudes	Practices Behaviours	Risk Factors	Reported Side Effects
Sookhtanlou et al. (2022) [38] **Ardabil, Iran**	Analyse the health risks for farmers arising from the use of pesticides.	Application of a pre-tested questionnaire to interview workers face-to-face (**with consent**). The questions include sociodemographic and occupational characteristics of potato growers, questions related to the rate of pesticide use per area, and questions regarding protective measures and behaviours adopted throughout all stages of pesticide use. The topics were evaluated using a 5-point Likert scale.	Not specified	**Type of pesticides handled:** Pesticides used were mostly in WHO class II (moderately hazardous). Most of the respondents (39.4%) belonged to the group of potato growers who were exposed to high health risks, while 30.8% and 29.8% of the groups were exposed to moderate and low health risks respectively. **Preparation and Spraying:** Of the farmers, 74.6% used pesticides in excess, and only 24.6% used them within the allowed levels or below the recommended levels. The main protection measures adopted by farmers included determining the type of pesticide appropriate for the pest/disease, "checking their production and expiry dates", "preparing pesticides outside the house", "wearing boots" and "changing the suit after pesticide application". **Dangerous behaviours:** buying pesticides from unreliable outlets, not carefully reading instructions on pesticide labels, not paying attention to selecting an appropriate sprayer that is compatible with the pesticide/crop, and unsafe disposal of pesticide packaging and waste (burying, burning, etc.).	**Safe pesticide use behaviours and practices:** Relation (−): Age. Education, farm income, knowledge/perception of seriousness, and awareness of adopting safe behaviours as well as perceived benefits and beliefs influence (in both directions) the adoption of safe behaviours during pesticide use and contribute to the increase in the list of health risks for agricultural workers.	Not specified

Table A1. *Cont.*

Study	Objectives	Intervention	Main Outcomes			
			Knowledge Attitudes	Practices Behaviours	Risk Factors	Reported Side Effects
Kumari et al. (2021) [2] **North India**	*To assess farmers' knowledge and safety practices regarding pesticide use and the health effects associated with this exposure.*	Application of a questionnaire based on the WHO standard protocol (1982) for pesticide exposure surveys to face-to-face interviews with workers (**with consent**). Questions included socio-demographic characteristics; types, amount, frequency of pesticide application, knowledge/information, practices in pesticide use; familiarity with WHO label risk classification, and self-reports on experiences of health effects from pesticide application.	**Knowledge about pesticides:** Most farmers (97%) showed knowledge of the harmful effects of pesticides. Almost all farmers agreed that direct ingestion of pesticides was toxic; however, only 31% expressed an understanding of the risk of poisoning by consuming food (e.g., vegetables and fruits) with pesticide residues. Fifty-seven percent of respondents believed that empty pesticide containers could be reused after washing. Only 24% of applicators had certified training in pesticide spraying. **Interpretation of the risk classification defined by the WHO:** The data indicate that 59% of respondents identified the WHO classifications on pesticide containers, but only very few respondents knew what the information meant. Of the four categories (excluding the most recent U), only 18% of respondents knew the meaning of the red category, and 6% knew the meaning of the green colour category. However, no one could explain the meaning of the yellow and blue colour categories on pesticide containers. About 76% of the participants were not aware of these classifications. Only the red colour classification was interpreted as dangerous.	**Type of pesticides handled:** The most used pesticides were fungicides and insecticides in class II (moderately hazardous) and Ib (highly hazardous). **Preparation and Spraying:** Most pesticide applicators (92%) always washed their hands, and 96% always changed their clothes after use. Eating during and at the spraying site was practiced by 17% of respondents, while 51% always drank water on site. Most respondents (>65%) stored pesticides and related products in their own homes. Pictures taken confirmed this fact and indicated that products were handled with bare hands without gloves (15%). Only 32% followed the proper mixing procedure. **Protective equipment used**: Fifty-three percent of respondents always wore long-sleeved shirts, 37% always wore hats, and 48% always wore masks while handling pesticides. **Disposal of empty packaging and waste:** Most respondents burned (65%) and about 12% were seen burying the empty packaging. No one used the practice of handing over the packaging to an entity responsible for waste management and recycling recommended by FAO/WHO.	Lack of knowledge about the effects of pesticides and lack of understanding of the WHO-defined pesticide toxicity classification is associated with an increased likelihood of unsafe practices in pesticide use.	Eye and skin irritation.

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