RESEARCH ARTICLE

# Exposure to pesticides of North-Andean Peruvian farmers: environmental impact

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## *ABSTRACT*

The objective of the current study was to analyze feedback and experience of coastal farmers residing in northern Peru. For this, we performed a qualitative research, collecting information via a semi-structured survey; collected data was processed according by thematic analysis. Six categories were investigated pertaining the environmental load experience gained by farmers, with the purpose of mapping up sustainability knowledge of Peruvian cultivators.

It was found that farmers, who applied pesticides, were insufficiently trained on the risks derived from exposure to pesticides and they used unsatisfactory personal protection measures, they did lack a hygiene protocol, the storage of pesticides was done inside their homes, the reentry period was not respected, and the pesticide containers were disposed of in a disorganized manner, creating risks of exposure to the family members of the farmers and the environment, as well. Authors believe that environmental health interventions need to be conducted in this vulnerable group, which includes a large number of North-Andean Peruvian workers.

**Keywords:** Pesticides, occupational health, environmental experience, and Peruvian farmers.

## 1. Introduction

Agriculture is the main source of income for 2.3 million families in rural communities and is the main activity of 34% of Peruvian households (Escobal, 2015). Growing demand for food supplies, technological solutions, and the need to control new and diverse pests have advanced the production and use of pesticides (Cruz Escalon, 2017). Approximately one thousand chemical substances in over 50,000 formulations or trade names have been used worldwide as insecticides, fungicides, rodenticides herbicides, and antimicrobials (Karam, Ramírez, Montes, & Galván, 2004). Pesticides enhance agricultural production, but they are extremely toxic. The overall number of poisonings worldwide exceeds three million cases, and approximately 2% of them result in death (Altamirano, Franco, & Miltre, 2004).

Agricultural activities represent risk factors for global health, partly because of using pesticides. When they are used in an uncontrolled manner, without heeding the technical recommendations for the respective product, its allowed dose, and the timing of their application, pesticides may become harmful to the population and the environment (Zúñiga-Venegas et al., 2020). Therefore, farmers must receive sufficient information on the risks of using certain pesticides.

In Colombia, a vast majority (89.8%) of farmers lack knowledge about the risks posed by employed chemicals, consequently, they refrain from using protection measures, Also, 90% of agrochemicals are transported with other goods and food items, then the containers are discarded next to the crops, and some people reuse the pesticide containers to transport liquids aimed for consumption (Amador, Luna, & Puello, 2017). These practices encountered for farmers have also been observed for the Peruvian population, who consented that they used personal protection incorrectly (54.6%) (Yengle et al., 2008).

Agriculture is a major productive activity in the northern-coast areas of Peru, which has both social and cultural value. Commonly, farmers utilize pesticides (see supplementary table) while operating with precarious protection measures, in the preparation, use, and disposal of pesticides. Likewise, they do not comply with established norms of using and handling pesticides, such as wearing appropriate clothing and personal protective equipment (PPE). Therefore, it is necessary to investigate the use and applications of pesticides from the perspective of farmers; what is their related experience, what do they know about toxicity and possible risks, how do they protect themselves, and why they do it? Improper use and handling entail dangers not only to farmers, but their family, and their environment. Health problems and environmental pollution may arise from the harmful chemicals contained by pesticides. The objective of this study is to describe the farmers' experience with the use of and exposure to pesticides in Granja Sasap town, located in Tucume, Lambayeque, Peru. The investigation was conducted during the year 2018. We addressed six categories related to the environmental load experience gained by farmers, to map up sustainability knowledge of Peruvian cultivators.

## 2. Methods

Type of investigation and setting: Research was qualitative, the experience of farmers related to the use and management of pesticides was explored (Mays, N., & Pope, C). The investigation was done in the Granja Sasape hamlet, located on the north coast of Peru, 3 km away from the District of Tucume, Department of Lambayeque, Peru; it is a small agricultural settlement with 430 residents.

Population: The study participants were 10 farmers living in the Sasape-Túcume farmhouse. The sample size was determined by the saturation and redundancy criteria, and the semi-structured survey guide was no longer applied to the tenth survey, as it was completed with the total sample, according to protocol. We included in the survey all male farmers, 20 to 70 years of age, who have used pesticides for at least one year and own land for agricultural production but do not work in agro-industrial companies. Excluded were farmers, who use organic or natural fertilizers. After being informed of the scope of the study, all selected farmers agreed to participate.

Instrument and data collection**:** A semi-structured survey was conducted. This is a technique of data collection, which consists of a rigorous construction of surveys aimed to measure the objectives of the study. Also, the surveys permit reciprocal interaction between the interviewer and the participant, allowing the interviewer to conduct further interviews to deepen the object of study (Kallio et al., 2016). Interviews were conducted by a research associate, who surveyed each farmer's home, over 25 to 30 min. Assessments were recorded utilizing a voice recorder after the farmer signed informed consent.

*Validation* of the instrument was carried out by expert judgment, which consisted of submitting it for review to two experts: a community nurse, practicing for over 20 years, and a nurse, expert in the case study method, with experience in teaching and research. To verify whether the questions were understood, a pilot test was carried out, in which 3 farmers were surveyed in the area. By this procedure, a quality instrument was obtained (Tavory I, 2020).

*Data analysis*: The analysis in this research was thematic, and was applied manually, following 3 stages. The first stage is the *pre-analysis*, data involving repeat

listening of each survey was organized; each voice recording was transcribed, ensuring that the material is complete and has the necessary quality to be analyzed exhaustively. The second stage is coding, which consists of transforming raw data into useful data, categorizing them to become helpful for conducting the research. We chose specific segments of the survey contents, called *unit of analysis* (topics). Their total number was 10 units. The third stage consisted of categorizing, organizing, and sorting the units obtained According to differentiation criteria. These criteria are semantic, i.e., the units were grouped by similarities in terms of their meaning. Here, the research associate contrasted real findings with literature data, establishing six categories.

*Ethical aspects*: The Research Ethics Committee of the Faculty of Medicine approved the project, and a similar authorization was requested from the Lieutenant Governor of the Farm Sasape-Tucume Village, Lambayeque, Peru. The bioethical principles of the participants were respected. All farmers participated freely and voluntarily by informed consent and were told that they can abandon the research at any time. Testimonies were confidential, protection was provided to people by keeping their identities anonymous *via* assigning pseudonyms, described as codes. Information was provided after collecting data on the risks to which they are exposed by handling pesticides, initiating willingness to use pesticides correctly, and, by this, to prevent harming themselves, their family, and their community.

## 3. Results and Discussion

The age range of 10 participants was from 29 years to 55 years. Details on participants are shown in Table 1.

**Table 1: Characteristics of the surveyed farmers from Tucume, Lambayeque, Peru**

| ID | Age (years) | Level of education | Marital status | Size of land (plots)* |
|---|---|---|---|---|
| 1 | 42 | High school | Cohabiting couple | 2 |
| 2 | 35 | None | Single | 1½ |
| 3 | 46 | Third-year of high school | Married | 2 |
| 4 | 55 | Second-year of high school | Married | 2 |
| 5 | 31 | Complete elementary school | Cohabiting couple | 1 |
| 6 | 40 | Third-year of high school | Married | 1½ |
| 7 | 29 | High school | Single | 1 |
| 8 | 45 | First-year of high school | Married | ¾ |
| 9 | 32 | High school | Cohabiting couple | 2 |
| 10 | 30 | Fourth-year of high school | Single | 1 |

* A hectare consists of 15 plots.

Six categories were found in the surveys, as shown in detail below.

**Category Nº 1. Protection and home clothing used by farmers over the preparation and fumigation of pesticides**

In Tucume - Peru, farmers of Granja Sasape do not possess personal protective equipment needed for the proper use and handling of pesticides. Therefore, they seek to protect themselves with "homemade" objects, being exposed to pesticides, as revealed by the following testimonies:

"To fumigate I use the same old clothes that I usually wear on the farm... I wear pants, T-shirt, sun hat and yanks... when the medicine smells very strong, I put on a T-shirt, which covers my nose and I tie it over my head... " – Farmer 03

"To fumigate I use simple clothes, like the ones I wear at home. I know there are special clothes, but instead, I wear clothes that are not too short, pants and long sleeve shirt, old shoes or sneakers, and a sun hat… nothing else…" – Farmer 07

"When I spray, I wear shorts, T-shirts, sneakers, and a cap. I don't protect myself with anything special, I just carry bags and cover my hands to prepare the pesticides,

and then I throw them away… when there is mud, I go barefoot to walk easily" – Farmer 06

"When I fumigate, I only put on a mask for not breathing the poison. I purchased one that is made of plastic, it covers my mouth and nose well, it lasts for several months, I change it when it gets old or the garters are stretched..." – Farmer 04

In their testimonies, farmers referred to their work clothes, where they agree that they all wear the oldest clothes they have, some try to cover their entire body with pants and shirts, others wear shorts or T-shirts. They also wear a hat or a cap, and T-shirts or rags as a mask, and they use bags on their hands to prepare pesticides. These garments are perceived as inappropriate clothing to protect against pesticides.

**Category Nº 2. Hygiene carried out by farmers after getting in contact with pesticides**

Farmers of Granja Sasape reported, how they carry out personal hygiene and how they wash their protective equipment. Their hygiene habits depend significantly on the circumstances under which they find themselves. If they do not have supplies, such as soap, they only use water, hence, posing risking their health and exposing themselves to poisoning. Some of their testimonies are listed below:

"When I finish preparing the pesticides and "curing" them, I wash my hands well with just water, to get rid of things, and then, at home, I take a shower with soap and shampoo... my wife washes those clothes, sometimes I wash them myself. I put them in a bucket and scrub them well with detergent and bleach, then I spread them out. When I do not wash them right away, I leave it in the corral…" – Farmer 08

"After curing, I bathe and wash my clothes in the ditch with detergent or soap, the brush, and the rinsing water I let go through the ditch… I will eat at home and return, but rather as fruits from the farm like guavas or plum" – Farmer 02

"After spraying, I bathe in the canal with water and shampoo, then I change... I leave the work clothes outside the house to be washed, they are left in a tub and soaked in water, with plenty of detergents, the clothes… are washed separately in a tub, without other clothes. When my family bring me food, I clean my hands well with a flannel or I wash them with water from the canal" – Farmer 01

Most farmers prefer to wash in the ditch or canal, which represents a means of contamination for the water, the same being used by other people, livestock, or plants and may cause health damage. One can state that the common washing practices of farmers are ineffective.

**Category Nº 3. Storage at the home of equipment and materials used for fumigation**

Similarly, farmers of Granja Sasape voiced that they do not have a specific place to store pesticides and their application equipment. These are being stored at home, as they have no other safe place protected from theft. Faced with this reality, farmers stated the following:

"We leave things covered outside the house, covered, but the backpack, which takes inside the house for safety. Nobody takes it, but as I don't have small children, I don't worry" – Farmer 03

"I leave (my clothes) in the corral, there I put all the knobs, the cylinder, and my backpack, well covered with a large plastic; next to it there is an animal corral and next to it my kitchen" – Farmer 01

"Things always stay at my house or I pass them to the corral, we raise guinea pigs and chickens… my mother grows sabilas, tamarind, and lemon verbena in the corral…" – Farmer 07

Farmers of Granja Sasape are unaware of the dangers to which they are exposed when storing pesticides inside their home. Most revealed that they store pesticides and their application equipment inside the house, in places such as pens and rooms, being near to the kitchen and the bedrooms, so that the equipment and pesticide containers get in touch with poultry and some plants intended for consumption.

**Category Nº 4. Experiences in the time expected to enter the crops after having fumigated**

For safeguarding health during fumigation, a time interval must be kept before reentry in the cultivation land. During our investigation, it was discovered that farmers of Granja Sasape respect the period of reentry to the treated area only in part, as related below.

"We waited almost two days, we have to wait for the poison to take effect... unless it rains, that's the worst that can happen, everything is spoiled and you have to wait until it dries and then spray again; time and money are wasted. When they sell you the remedy, they explain to you how to apply it, how long to wait after spreading it, how much do you have to use, and how often. They may tell you to wait up to one week, as the knob says, but you must watch how it goes ..." – Farmer 07

"I wait for one day, neither more nor less. We must wait always to be able to enter, again, because the products that are applied are dangerous, and can poison us. Earlier I did not respect this, but they recommended that I wait; it is bad to enter so quickly to work after curing" – Farmer 09

"In half an hour or forty minutes I am already going back in the land, because we have to advance wedding... when there is nothing to do, I will leave it until next day…" – Farmer 08

Cases like this evidence that several farmers are unaware of the risks of not waiting before reentry; they believe that since they will not be in contact with the fumigated

plantations, they will not get exposed to any danger. They dedicate themselves to working in another area, which has not been fumigated, ignoring the effects of wind direction, rainfall, or intense heat, which can transport and deposit pesticides in other areas.

**Category Nº 5. Final disposal and disposal of empty pesticide containers**

During our investigation, farmers of Granja Sasape described how they empty pesticide containers.

"I bury them on the farm, so they do not bother (anyone). I do not take things home... and never reuse the containers except a few times to store the leftover (pesticides)." – Farmer 05

"I dispose of (containers) in the trash, (after) I make a hole in the bottom (of the container), so that (vendors) don't dump the (remainders of the) product and resell them... If I burn the product, I pollute (the air), a lot of smoke is released..." – Farmer 07

"When there are plastic bags, I throw them away, but when there are jars, I burn them... I never reuse the jars... I have never (destroyed) anything other than poison…" – Farmer 08

"I recycle the knobs in sacks and sell them as scrap metal; earlier I trashed them around the farm... I would not put something else inside… those things no longer work…" – Farmer 04

As these testimonies indicate, farmers of Granja Sasape do not have an established system for the final disposal of pesticide containers. This means that their disposal is chaotic; some farmers tend to dump containers on their land or in the trash, while others keep containers at home to sell them as scrap metal.

**Category Nº 6. Experience with poisoning caused by handling pesticides**

Chronic poisoning develops slowly, because of continuous or repeated exposure to small doses of a toxic substance, over a long time. Several farmers of Granja Sasape shared their experience with pesticide poisoning, although they tend to underestimate the importance of nonspecific symptoms (headache, dizziness, nausea, rhinitis, and others) and consider them as being related to routine work. This can be noted in the following testimonies:

"Once my hands, face, and back turned red, it burned and itched a lot, and the (red skin) couldn't be removed with anything... I think it happened because it was against the wind direction and (the pesticide) dropped onto my body" – Farmer 02

"After I finished spraying, I had a sensation of vomiting... it was probably because of the poison… at the end of the day, I felt better. I never learned how it happened" – Farmer 05

"When I was filling the backpack, the smell entered my nose, and I became nauseous. I felt dizzy…" – Farmer 09

"Many times, my head hurt, I felt like dizziness, but I have not been intoxicated. Dizziness was likely caused by hypertension I suffer... I bathed and it happened to me" – Farmer 08

Farmers report suffering from several main symptoms indicating pesticide poisoning. Nevertheless, farmers do not interpret them as such. Despite their direct knowledge of these damages, none of the farmers has stopped using pesticides, not even those who have suffered personal injuries. A summary of categories is listed in Table 2.

**Table 2**: Summary of categories on farmers' experience acquired while working with pesticides

| Category | Summary |
|---|---|
| Protection and clothing | Most farmers wear old clothes and do not use appropriate protective equipment |
| Hygiene after contact | Most farmers clean up in a ditch, and in many instances do not use soap |
| Storage of materials for fumigation | They store products inside their homes, mainly in corrals |
| Expected waiting time after fumigation | Farmers wait an average of one day, but some entered the area 30 min after fumigation |
| Final disposal and trashing pesticide containers | Farmers do not have a protocol for disposal (containers are trashed in the garbage, around households, etc.) |
| Experience of intoxication | They experienced symptoms of itching, nausea, dizziness, headache, etc. |

As highlighted by the study, all farmers of Granja Sasape are exposed to many risks, since they are not protected appropriately against exposure to pesticides; they either do not possess or do not use the recommended clothing to fumigate. All wear the oldest clothing for protecting their body, they utilize plastic bags as gloves, and a "rag" to replace the mask. Most farmers put on sneakers or yanks, only a very few wear shoes, while some spray barefoot. Some wear caps or hats, although it is perceived as sun protection, rather than safeguarding against pesticides. No farmers wear glasses, as they believe that maintaining proper distance protects from splashes and accidents.

Our results are similar to studies conducted in Colombia for evaluating the use of personal protection equipment on fumigation days. In Columbia it was found that only 37.8% of farmers used work clothes, 22.2% of them never used body protection tools, 11.1% utilized head

and respiratory protection, 26.7% protected their hands, and 37.8% safeguarded their eyes (Toro-Osorio, Rojas-Rodríguez, & Díaz-Zapata, 2017 ).

Farmers confess that they are not customarily using individual protection. This indicates that their risky conduct is not exclusively the consequence of a lack of information. Among their justifications, we find: (i) excessive cost of protective equipment, and (ii) discomfort generated by protective equipment (because of weather and the difficulty of carrying out tasks, while wearing PPE, including limited eyesight, lack of touch by hands, etc. Various excuses for not using PPE generate new risk situations (Silva de Oliveira, Vinícius Cardoso Souza Resende, & Oliveira, 2017).

The ideal personal protective equipment consists of: (i) overalls for body protection, made of waterproof material, including plastics or treated polyester, (ii) hood or overalls covering the head, neck, and shoulders, (iii) a mask to protect the nose and mouth from inhaling gases, (iv) goggles or face mask to avoid splashing in the eyes, and (v) long rubber or rubber gloves and high rubber boots (Organization, 2020). It can be stated that many of the standards for fumigation clothing are disregarded, for various reasons, including economic causes (high cost of protective equipment), ignorance of the toxicity, or comfort (high temperature over working hours and difficulty of moving). Another reason is tradition: clothing they wear is like that used by their ancestors.

Likewise, farmers do not stick to an established hygiene protocol after fumigation, some bath in the ditch with soap and water, others wait until getting home, and take a bath only after 1.5 h. Some farmers consume food that is brought to them from home or eat fruits in the field, during the fumigation. Most farmers or their wives wash clothes used while spraying insecticides without much protection. These results are different from the study conducted in Colombia (López, Pinedo, & Zambrano, 2015) on occupational health practices and levels of serum biomarkers in pesticide applicators for rice crops. Research performed in Colombia pointed out that 89% of farmers take a shower at the end of the application process and wash their work clothes at home, only 6% consume food during the fumigation, and 22% of them drink various beverages.

Farmers' hygiene after being exposed to pesticides is insufficient and mostly incorrect. They delay taking a shower after fumigating; hence, they increase the toxic effect of pesticides. Several authors recommend that it is better to take a bath or shower with soap at the end of the workday, rather than allowing a longer time to pass after finishing the application of pesticides. The longer this is delayed, the greater the contact time with the toxic substances becomes and the greater the risk of intoxication by absorption through the skin (López et al., 2015; Toro-Osorio et al., 2017).

On the other hand, farmers addressed in the study are storing their equipment and fumigation materials inside their home. Indeed, they should be looking for a space outside their house, which can be built-in locations, where pesticides cannot contaminate biotic beings and resources of drinking water. These storage spaces should have natural lighting and good ventilation. These data are similar to the study conducted in Lima (Marañon Calderon, 2015), in which it was found that 39% of farmers do not store products, as they purchase pesticides only for immediate use, 38.9% store the products in their own house, while 22.1% of farmers own a warehouse in the field. Farmers in our study prefer to keep pesticides inside their homes or in the corral, given that they are afraid of theft. They do not know about the risks to which they expose themselves and their families, their domestic animals, and the plants in their garden.

Farmers in the area dispose of the empty pesticide containers inappropriately, they do not proceed to triple washing of the empty pesticide containers, and instead, they just perform common rinsing. No other cleaning procedure is applied; containers are typically incinerated, or trashed or buried. In some cases, containers are being recycled or stored at the farmers' homes. These insufficient safety measures originate from multiple causes. Some farmers simply avoid greater effort toward proper disposal, while they do not worry about the fate of used containers; they do not ponder or recognize the dangers involved (Lopez et al., 2015; Yengle et al., 2008).

There are recommended physicochemical methods for eliminating pesticide residues, which also include measures for expired pesticides. Recommended is incineration at elevated temperature, in special ovens (O'Farrill, 2004). Unfortunately, this type of treatment produces environmental contamination, and is not viable for developing countries, because of high costs and infrastructure requirements. One should mention that in rural areas of Peru, there is no container collection system; no large collection centers with special ovens, incinerators, and shredders are available to Peruvian farmers.

Most farmers in this study have suffered poisoning over their professional life. None of them requested treatment in a health center, as poisonings were typically mild and remitted when taking a shower or leaving the field. Experienced symptoms included skin irritation, itching, vomiting, dizziness, and headaches; these symptoms showed up in less than 24 h after applying the pesticides. Some of the farmers claimed that they had never been intoxicated, as they considered headaches to be caused by other factors. Most farmers exhibiting mild symptoms opted for home remedies. For this reason, little is known about the impact of pesticide use on

public health, since a relatively scarce number of pesticide poisoning cases have been reported and treated in a health center (Gómez-Arroyo et al., 2013).

Commonly used pesticides in Peru belong to the group of organophosphorus and carbamates, which can affect neurobehavior and cause fatigue, dizziness, blurred vision, gastrointestinal effects, e.g., nausea, respiratory effects, such as dry throat and shortness of breath, effects that involve the skin and mucous membranes, such as ocular burning, painful skin, and red nose, muscle symptoms, including muscle stiffness and weakness. These may cause death over a few weeks, depending on product characteristics, as well as duration and dose of exposure (Gómez-Arroyo et al., 2013).

Hence, acute poisonings can be very dangerous, so continuous testing should be performed on this population, mainly to measure their level of cholinesterase (Karam et al., 2004; Toro-Osorio et al., 2017). Use of pesticides can not only cause acute diseases, but prolonged exposure has been associated with neurodegenerative diseases (Calvo-Trujillo, Mendoza-Goez, García-Espiñeira, and Ramos-Clason, 2019), and it affects neurodevelopment in environments, where people are exposed to pesticides (Molina, Zarate, González, & Núñez, 2019).

Finally, government institutions such as the National Agrarian Health Service (SENASA), the Ministry of Agriculture and Irrigation (MINAGRI), and the Ministry of Health (MINSA) should create strategic alliances so that farmers get informed about good practices in handling pesticides, making them aware of dangers caused by the indiscriminate use of pesticides. In the context of the study, there are still no initiatives or proposals to solve this health problem, despite the existence of Legislative Decree No. 1387 (Ministerio del Ambiente, 2019), which strengthens the powers, supervision, oversight, and sanctioning functions, and the Steering Committee of the National Agricultural Health Service (SENASA). It is intended that the regional authorities prioritize the use of pesticides and their effects as a policy, because it is a problem that not only affects the health of farmers, their families, communities and consumers of products, but also contaminates food and the environment.

Some limitations of our investigation consist of the lack of our ability to generalize this study, since farmers surveyed belong to a specific population, and there may be a memory bias of participants on the use and management of pesticides. The latter may limit recalling past symptoms or the use of personal protection equipment. The authors tried to minimize biases by training the personnel, which conducted the surveys.

## 4. Conclusions

In their testimonies, farmers state that they adopt home protection methods to fumigate, wearing old clothes and covering their hands with plastic bags to substitute for gloves. When the product releases an unpleasant smell, rather than putting on a mask, they use a handkerchief or a cloth instead. It has also been noticed that farmers do not stick to a protection protocol, but instead, they decide to use one or the other method depending on the type of product applied or weather conditions. Similarly, they do not have an established place for keeping fumigation materials, such as containers and equipment with pesticides in their living rooms, corrals, dining rooms, or kitchens. This habit originates from the fear of theft, and weather conditions: lightnings or high temperature. Farmers are biased by economic, cultural, and ideological considerations. Many of them declared that they cannot afford to buy special clothes or make a deposit dedicated to the equipment and fumigation materials. This attitude is also combined with ignorance on the risks to which they are exposed.

Hygiene measures employed after exposure to fumigation were inadequate, typically they waited an exceedingly long time before taking a bath. More alarming is that some farmers consumed food in the fumigated land. Although there are regulations for the washing of personal protective equipment used for pesticide management, these are mostly unknown to the farmers and their families. The waiting period before reentry to the cultivation field was not respected, half of the farmers waited two to three days, some waited one day only, while a few waited as little as half an hour. Farmers improperly disposed of their containers, trashed them around the crops, buried, burned, or recycled them by selling containers as metal scrap. Half of the interviewed farmers have suffered mild poisonings, which were treated at home, while the other farmers have not yet suffered any poisoning.

We recommend reorganizing the system for controlling the use of pesticides in agriculture in order to protect the health of farmers, taking into account: hygiene, adequate use of personal protective equipment, safe storage, responsible management of remnants and empty containers; as well as massively disseminating "Integrated Pest Management" practices, starting with cultural, ethological, biological and finally chemical control, reducing dependence on chemical pesticides and, therefore, reducing the farmer's exposure to toxic substances.

## Supporting material

Please note: The publisher is not responsible for the content or functionality of any supporting information supplied by the authors. Any queries (other than missing

content) should be directed to the corresponding author for the article.

Supplementary table: Pesticides most used in the North of Peru



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