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Social and environmental impacts of pesticide use in mango cultivation

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ABSTRACT

Objective: to identify the social and environmental impacts derived from the inappropriate use and management of pesticides by mango producers in the municipality of San Marcos, Guerrero, Mexico, emphasizing the effects on the health of farmers and environmental contamination.

Design/Methodology/Approach: a cross-sectional study was applied to 40 mango producers using a questionnaire. In addition, focus groups were conducted to delve into pesticide management practices and farmer perceptions of risks. Data were analyzed through descriptive statistics with the GraphPad Prism 7 software.

Results: farmers interviewed (100%) use pesticides, although only 40% identified to what pests those are used. The most commonly used agrochemicals belong to the organophosphate and pyrethroid chemical groups. Ninety-one percent of farmers do mix two or more pesticides without using personal protective equipment; 50% have presented some symptoms of poisoning. Empty containers are left in the orchards and the remains are dumped directly into the soil, contaminating groundwater aquifers.

Limitations/Implications of the study: the design of appropriate pesticide management programs is needed; also the promotion of sustainable agriculture practices in the region.

Findings/Conclusions: almost all the producers (91%) use pesticides improperly, half of them have experienced some chemical intoxication. This study highlights the importance of developing awareness strategies that include training programs based on scientific evidence, in order to teach the proper handling of agrochemicals, with a focus on the prevention for human health and environmental risks.

Keywords: agrochemicals, agricultural practices, environmental contamination.

INTRODUCTION

Mango, usually considered the top of tropical fruits, is grown in different regions of the world. Mango fruit (Anacardiaceae) is native to India, and is known for more than 4000 years. It is grown in tropical and subtropical climate areas with 24 to 27 °C optimal temperatures for development. Mango prefers soils with 5.5 to 7.5 pH, at altitudes between 600 and 1200 m (Lebaka *et al.*, 2021). In 2019, mango production was 51 million tons

(Megagrams, Mg) in 85 countries around the world. India was the main producer and exporter with approximately 22 million Mg per year (Sial *et al.*, 2015). Different varieties of mango are grown in the world, the most common are Alfonso in India, Carabao in the Philippines, Ataulfo and Manila in Mexico and Tommy Atkins and Keitt in Florida.

In Mexico, the variety with the largest cultivation area is Ataulfo, whose production occurs in April and May, and it is marketed nationally for fresh or industrial use. Due to its low firmness and short shelf life, it is exported in small volumes. In Guerrero, the Costa Chica region stands out for a high production of this fruit. An estimation of approximately 7117.8 hectares are planted for a harvest around 103 055 Mg. Mango varieties highlighted in terms of production are Ataulfo, Manila, Tommy Atkins and Haden. However, producers face heavy economic losses because they do not have the necessary infrastructure for the post-harvest stage. Particularly, absence of packing facilities and necessary conditions for storage, phytosanitary problems, low prices and the absence of marketing channels (Luna-Esquivel *et al.*, 2006).

Indiscriminate use of pesticides is considered another major problem. Mainly because it is used intensively despite the restrictions. Previous studies have shown that exposure to these chemical compounds is associated not only with environmental pollution, but with effects on human health (Lyall *et al.*, 2017). It is considered that pesticides enter the human body by dermal, respiratory or oral route (Daley *et al.*, 2014). Prolonged exposure over the years increases risks to human health with several effects, such as renal, hepatic, or endocrine damage, among others (Peres *et al.*, 2006; Sagiv *et al.*, 2008; Mnif *et al.*, 2011). Therefore, it is necessary to implement studies to acknowledge the social and environmental problems derived from the use of pesticides; as well as to develop strategies to address them adequately.

In this context, this research aimed to answer What are the social and environmental impacts derived from the inappropriate use of pesticides in mango harvest operation in the Costa Chica region, Guerrero, Mexico? The objective was to assess the social and environmental impacts of the indiscriminate use and management of pesticides by mango producers in the municipality of San Marcos (Guerrero) Mexico.

MATERIALS AND METHODS

Characteristics of the study area

The study was carried out in the municipality of San Marcos, Guerrero, in the geographical coordinates (DD) 16.794444 N and −99.391111 W, at an average 50 m altitude (Figure 1). This municipality is characterized by the high production of mango of different varieties, the most outstanding are Ataulfo and Manila. The study area was tracked along several routes visiting the mango orchards, accompanied by local farmers. Fruitful dialogues were established with them, with the research project as framework. Meetings with the local producers were attended by the major (president of the municipality) of San Marcos, the president of the National Committee of the Mango Product-System A.C. and other leaders in the region.

In a meeting with the producers, the research team presented the problems related to mango cultivation in the region, derived from a documentary analysis. An extended

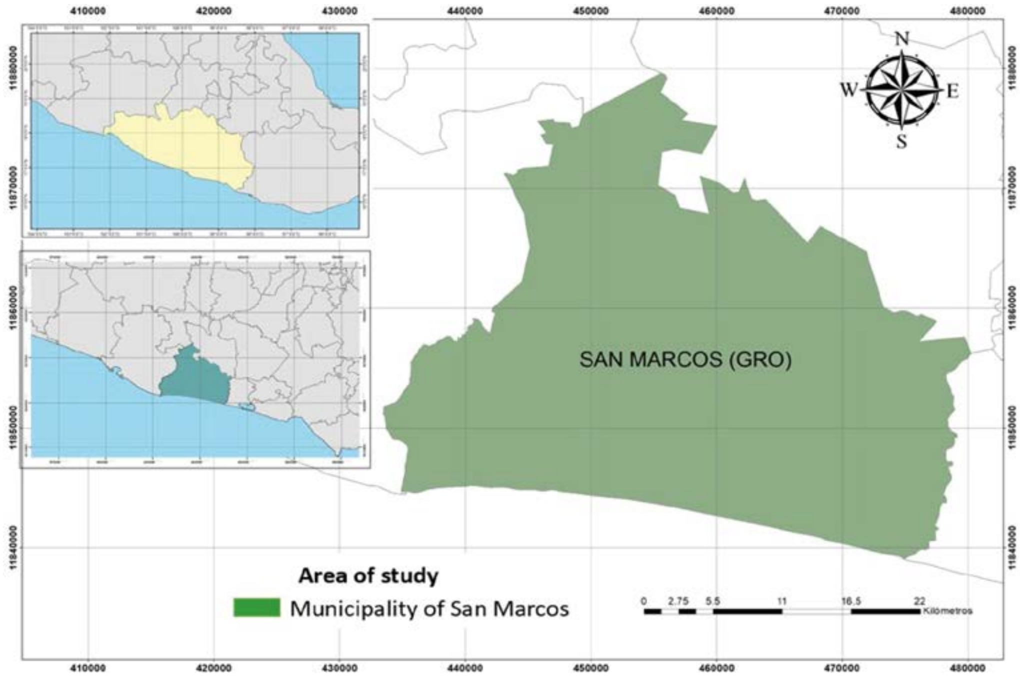

Figure 1. Location of the study area. Municipality of San Marcos (Guerrero) Mexico. lSystem/Datum: WGS 1984; Projection: UTM, zone 14N.

research proposal was also presented, which obtained a positive unanimous response. In addition, an exploratory talk was held that allowed to know the producers' ideas, opinions and expectations about the activities to be implemented.

Research techniques and procedure

We used a mixed methodology with a participative exploratory approach. A flexible, iterative design was used to collect data from a variety of sources, through interviews and focus groups. Producers from six localities in the municipality of San Marcos (Guerrero), Mexico participated in this research; San Marcos, Estero Verde, Alto de Ventura, Las Vigas, Nuevo Tecomulapa and El Palomar.

In the first discussion meeting, producers were asked to identify the main pests that affect their mango orchards. As well as the pesticides that farmers regularly use to combat pests and in what concentrations they use pesticides. In both activities, discussion groups were formed and bond paper was provided, allowing producers to respond to the questions: What are the main pests that affect mango cultivation? What pesticides do you use to combat pests? What concentrations of pesticide do you use to fumigate?

At the end, each team presented results and conclusions. The next activity consisted of conducting visits to the mango orchards, to verify the physical condition of the trees and to record whether an inappropriate disposal of empty pesticide containers existed. Also, if given the case, to verify the presence of agrochemical residues in the soil after fumigation. Data obtained were systematized and analyzed using the GraphPad Prism 7 statistical software to calculate averages and to generate graphic analyses. All the information was collected after informed and voluntary consultation to participate in the research. Also, all procedures were approved by the Bioethics Committee of the Research Directorate of the Autonomous University of Guerrero (Fol. Num. CB-004/23).

To learn about the use and management of pesticides, symptoms of poisoning, social and environmental impacts generated by the use of pesticides, a semi-structured interview was applied. The interviews were conducted at the facilities of the City Council of San Marcos, Guerrero, where a total of 40 mango producers from the six localities attended. They were questioned about the preparation of agrochemicals, personal protection equipment or measures they use; also, about the existence of symptoms of poisoning, and their awareness of the social and environmental problems caused by an inadequate disposal of chemical remains of pesticides and containers (either empty or burned).

RESULTS AND DISCUSSION

Identification of pests and diseases in mango plantations

Information collected from interviewees showed that mango producers usually use agrochemicals to control pests and diseases, trying to avoid losses in mango production. However, even with this use farmers report average losses of 30%, and in some cases 50%. The toxic potential of those products, which allows to control diseases and destroy pests, also makes them potentially harmful to human health and the environment (Plenge-Tellechea *et al.*, 2007).

During the identification of pests that affect mango production, farmers informed problems in leaves, vegetative shoots, flowering and fruits. The most common pests include fungi of the genera *Colletotrichum*, *Fusarium*, *Oidium*, *Capnodium*, and *Erysiphe*. Other important pests are the fruit fly (*Anastrepha*) which damages the mesocarp; bacteria of the genus *Xanthomonas* which causes the black spot; and the snow mealybug, which feeds on the sap and causes a plant general weakening (Figura 2).

Over time, farmers have observed various pests in their orchards; they highlight the importance of identifying these pests correctly and in time to proceed with treatment and elimination.

Figure 2. Mango producers during identification of main pests that affect mango production.

Pesticide use and management

Once the producers identified the mango pests, our interest moved towards the knowledge of the process they implement to mitigate or eradicate the damage. To do this, six focus groups were organized, then we provided them a set of images of commercial pesticides, and we asked them to select which ones they used regularly. Then, producers explained what type of pests they fought and in what concentrations pesticides are used. A similar study implemented in a banana area in Colombia highlighted the importance of identifying the pesticides that producers use. Their purpose was to develop a Hazardous Waste Management Plan, and to ensure their proper management (Camargo *et al.*, 2021).

The conclusions of the focus groups revealed the lack of a standard measure and procedure for the preparation of pesticides. Some producers have 16-liter pumps, while others use 25-liters pumps. For liquid pesticides, they use the measuring cup included in the package. However, for powdered pesticides they use a soup spoon, which causes variability in the measurement. Some producers add two soup spoons for each 25-liter pump, while others add four to five spoons (Figure 3). Despite the differences in concentrations, producers know the group of pests to be controlled by each pesticide; whether it is an insecticide, fungicide, bactericide or herbicide. The latter are commonly known as "ultimate killers". Producers are also aware that beneficial pollinating insects die along with pests.

The presence of pests and diseases in orchards is one of the main phytosanitary problems. For this reason, the use of agrochemicals is an integral part of the production system, with the aim of improving crop yields. However, it is important to recognize the adverse impacts that agrochemicals have on the environment (Mena-Espino y Couoh-Uicab, 2015).

Evaluation of producer exposure to pesticides

The average age of the producers interviewed was 52 years old; 53% of them have used pesticides for more than ten years, while 46% have applied chemicals for less than ten years. Mango producers learned how to prepare pesticides on the recommendation of neighbors or acquaintances who are dedicated to the same type of crop; with the exception

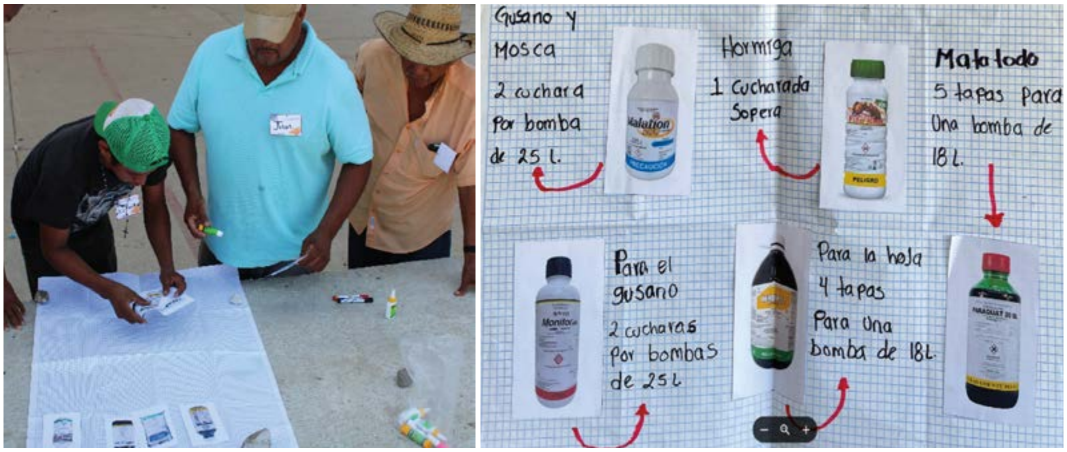

Figure 3. Mango producers during identification of pesticides used for pest control in their orchards.

of four producers who follow the indications of the labels on the packaging. A factor to consider about the levels of exposure to chemicals is the low level of education of the producers. Because this could be associated with the lack of reading comprehension of the instructions for use of each product. In addition to the very small letters on the containers, which include complex mathematical formulas and a technical language that is difficult to understand.

This exponentially increases the risk of poisoning due to improper handling of active substances. In the study by López-Dávila *et al.* (2019), the degree of training of farmers in the use of pesticides was low; only 28.3% had received specialized courses for that use. On the other hand, similar data were reported in the state of Durango, where only 40% of producers had received training on the appropriate use and management of pesticides (Esquivel-Valenzuela *et al.*, 2019). To achieve effective pest control, 92% of producers mix two or more pesticides. Common combinations include Foley® Rey/Manzate Mancozeb®, Foley® Rey/Captan®, Foley® Rey/Benomyl®, Velcron®/Manzate Mancozeb® and Malathion®/Amistar®. The goal of mixing these active compounds from pesticides is the allegedly faster control of fungi and insects.

Sometimes, at the end of the fumigation days, the remains of pesticide are poured directly onto the ground at the edges of the orchards. Whereas empty containers are thrown away or burned; since there is no Agency or public policy that regulates this action, farmers have normalized this situation, without paying attention to the social and environmental consequences that this entails. Yáñez and Camarena (2019) also reported in Sinaloa, that 61% of farmers leave containers in the field or burn them after use. Interviews recorded that 40% of producers wear masks, boots and sometimes, gloves. However, the protection is not complete, so there is a direct exposure to agrochemicals during the handling and application process. The lack of protection during pesticide application is also a common practice in the state of Coahuila, where it was reported that 75% of producers lack personal protective equipment; while in the state of Chihuahua that percentage is 73% (Esquivel-Valenzuela *et al.*, 2019; Ordoñez-Beltrán *et al.*, 2019).

According to Khan *et al.* (2015), in the process of preparing the solution or in the application by spraying, producers are exposed to pesticides spillage and contact, because they use defective sprayers. Adverse weather conditions or inadequate preventive measures are other factors to consider (Tsimbiri *et al.*, 2015). Pesticides can remain in the environment for much longer than intended, because of some specific characteristics that include toxicity, persistence, and organic effects. For this reason, people who work in agricultural fields are exposed to these risks, without awareness (Bejarano, 2017).

During the preparation and application of agrochemicals, it is essential to wear personal protective equipment, as this protects from possible adverse consequences (Houbraken *et al.*, 2016). Jiménez-Quintero *et al.* (2016) mentioned that despite producers know the importance of protective equipment, they do not use it during the labor. According to Negatu *et al.* (2016), pictograms on pesticide labels help to inform about risks to human health and advise the use of personal protective equipment. In contrast, the interviewed producers stated that labels are not understandable, because their size is too small. Of producers, 30% are unaware of the long-term health effects of pesticide exposure; whereas 50% stated that they had experienced some symptoms of poisoning at least once; such as, blurred vision, vomiting, headache or dizziness (Figure 3).

A study conducted in Tanzania showed that 93% of farmers have suffered poisoning from pesticide exposure, mainly from organophosphate pesticides (Lekei *et al.*, 2014). According to Eskenazi *et al.* (2007) these symptoms can be avoided when farmers wear full personal protective equipment (coveralls, masks, gloves and boots) and they have water available for hand washing. In agreement, farmers in Cuba and India expressed that the instructions for use and safety procedures on labels are difficult to understand. Mainly because most of labels, in addition to appear in small print, use technical vocabulary in a foreign language (Kumari and Reddy, 2013). Producers also believe that a lack of knowledge can lead to situations such as an incorrect election of products, inappropriate dosage, and misuse of pesticides, which jointly lead to a failed pest control.

The pesticides most commonly used by producers are fungicides and insecticides of the chemical group of organophosphates, carbamates and pyrethroids. The most commonly used pesticides belong to grade II toxicity, which according to the World Health Organization corresponds to moderately toxic (Table 1).

The interviews conducted with the producers made it visible the social and environmental problems related to the use of pesticides. First of which is the loss of biodiversity, mainly pollinating insects. Also, farmers consider that dumping the remaining pesticide on the orchards and adjacent lands contaminates the subsoil, while burning the empty containers causes air pollution. The inadequate disposal of empty pesticide containers was confirmed, thus the low awareness of farmers about the risk to which they are exposed (Negatu *et al.*, 2016). Because these pesticides are dispersed in the air and become pollutants for biotic systems (animals and plants), and for abiotic systems (soil, air and water). As well as,

Table 1. Types of pesticides and frequency of use by mango producers.

Trade name	Chemical group	Active ingredient	Product type	Toxicity*
Foley Rey	Organophosphate/ pyrethroid	Chlorpyrifos ethyl/ permethrin	Insecticide	II
Malathion	Organophosphates	Malathion	Insecticide	II
Velcron	Organophosphates	Monocrotophos	Insecticide and acaricide	II
Sultron		Elemental sulfur	Fungicide and acaricide	II
Benomyl	Benzimidazoles	Benomyl	Fungicide	II
Captan	Carboximides	Captan	Fungicide	II
Manzate	Carbamates	Mancozeb	Fungicide	II
Amistar	Methoxyacrylates	Azoxystrobin	Fungicide	II
Dimethoate	Organophosphate	Dimethoate	Insecticide	II
Permethrin	Pyrethroids	Permethrin	Insecticide and acaricide	II
Pervel	Pyrethroids	Permethrin	Insecticide and acaricide	II

*Toxicity classification by the World Health Organization. AI: extremely toxic; BI: highly toxic; II: moderately toxic; III: slightly toxic.

pesticides are a risk to environmental stability, which potentially can lead to a public health problem. Other aspects on which farmers reflected were the frequency with which they present symptoms of poisoning, as well as the harvest of contaminated fruits. Similarly, producers have detected that the early fall of fruits while growing is becoming more and more frequent.

According to Bustamante-Villarroel *et al.* (2014) and López-Dávila *et al.* (2020), the indiscriminate use of pesticides, as well as their application at inappropriate times, becomes a potential hazard to the environment with impacts on soil fertility, beneficial organisms, wildlife, water reservoirs, and even on human health.

This research with mango producers in the Costa Chica region allowed us to learn directly about their agricultural practices and their experience in pesticide management. Moreover, on their perceptions of the damage to pollinators, which are key elements in the production chain of their crops. This study highlighted the importance of developing awareness strategies that include scientific evidence-based training programs. Such programs should teach the correct handling of agrochemicals, with a focus on the prevention of health and environmental risks. It is critical that these programs involve agricultural authorities, public health experts, and local communities.

CONCLUSIONS

The lack of use of personal protective equipment, the inability to properly interpret product labels, and low risk perception are critical factors that increase pesticide exposure and, therefore, health risks. A 91% of farmers mix two or more pesticides without full knowledge, and 50% have suffered symptoms of poisoning. These findings highlight the urgent need to implement effective interventions.

Mango production generates considerable economic and social benefit for the region; this relevance justifies the proper intervention of Science academy and the Government to work together with the producers. Academy should supply data and experiences that support the development of sustainable agricultural practices; and governmental entities should strengthen regulation and control of pesticide use. While, producers should make efforts towards adopting safer and more sustainable practices.

Future research should focus on measuring the long-term effects of pesticide use on local ecosystems; also, in developing alternative and less toxic methods and technologies for pests control in agriculture production. In addition, there is a need to evaluate the effectiveness of educational interventions in reducing the risk of exposure to pesticides.

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