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PESTICIDE MANAGEMENT AND FARMERS PERCEPTION OF ENVIRONMENTAL AND HEALTH ISSUES DUE TO PESTICIDE USE IN THE STATE OF YUCATÁN, MEXICO: A STUDY CASE

Manejo de plaguicidas y percepción de los agricultores sobre los problemas ambientales y de salud por el uso de plaguicidas en el estado de Yucatán, México: estudio de caso

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Key words: agrochemicals, crop production, personal protection, pesticide handling issues, risk.

ABSTRACT

Agriculture in the Yucatán Peninsula, Mexico, grew last year, and pesticide use problems have been reported; however, there is no information about the use and management of pesticides in farms. In this study, the main pesticides used by farmers were identified in two types of agriculture: open-air (milpa) (OA) and enclosed area (shade house and greenhouse) (EA), in order to evaluate their use and management and the related environmental and health perceptions of users. Surveys (38 questions) were applied to 39 farmers in the study area, which consisted of 14 localities in Yucatán State. The most cultivated products were habanero pepper (*Capsicum chinense*) for enclosed-areas and maize (*Zea mays*) for open-air agriculture. The use of 33 active ingredients was reported. Some of them have restrictions in México (i.e., dicofol and methamidophos). Paraquat was the most used of all pesticides reported. Organophosphorus pesticides (OP) were the most used. Farmers know about the environmental and health risks related to pesticide use; however, a lack of knowledge about the misuse of these products was evident. The surveys showed deficiencies in personal protection during application and incorrect disposal of empty containers and wastes. The analysis showed that the behavior of farmers about pesticide management and their perception of damage to health and the environment were multifactorial. The results conclude that farmers' personal aspects (i.e., language, education) are the leading cause of problems associated with pesticide misuse and the lack of information and training, representing a risk for human health and the environment.

Palabras clave: agroquímicos, producción de cultivos, protección personal, manejo de plaguicidas, riesgo.

RESUMEN

La agricultura en la Península de Yucatán, México, creció en los últimos años, reportando problemas con el uso de plaguicidas; sin embargo, no existe información al respecto en la región. Este estudio identificó los principales plaguicidas utilizados en la agricultura al aire libre (milpa) (OA) y en áreas cerradas (áreas techadas e invernaderos) (EA);

se evaluó su uso y manejo, así como la percepción ambiental y de salud de los agricultores al emplearlos. Se aplicaron 39 encuestas (38 preguntas) en el área de estudio (14 localidades de Yucatán). Los productos más cultivados fueron el chile habanero (*Capsicum chinense*) para áreas cerradas y el maíz (*Zea mays*) para agricultura al aire libre. Se reportó el uso de 33 ingredientes activos, algunos cuyo uso está restringido en México (p.ej., dicofol y metamidofos). El paraquat fue el plaguicida mas empleado. Los plaguicidas organofosforados (OP) fueron los más utilizados. Los agricultores conocen los riesgos a la salud y el ambiente por el uso de plaguicidas; sin embargo, fue evidente la falta de conocimiento sobre su uso indebido. Las encuestas mostraron deficiencias en la protección personal durante la aplicación y eliminación incorrecta de contenedores vacíos y residuos. Los análisis mostraron que el comportamiento de los agricultores sobre el manejo de plaguicidas y su percepción del daño a la salud y al ambiente fue multifactorial. Los resultados concluyen que los aspectos personales de los agricultores (idioma y educación) son la principal causa de problemas asociados con el uso indebido de plaguicidas y la falta de información y capacitación, lo que representa un riesgo para la salud humana y el medioambiente.

INTRODUCTION

In México, as in other countries, agriculture is essential at an economic level and guarantees the food supply for the population. According to the Mexican Agricultural and Fisheries Information Service (SIAP 2015) the total area used for agriculture in Mexico in 2015 was 22.1 million hectares. The state of Yucatán has space for agricultural use of 755 400 ha. The 15 years old and above population occupied in agricultural activities in Mexico was 5.5 million in 2015 (INEGI 2016). Yucatán has 100 700 workers in agriculture, livestock, forestry, hunting, and fishing activities (INEGI 2019). Pesticides play a significant role in agriculture activities, since agriculture is the largest consumer (around 85 % of the world's production) of pesticides to control various pests chemically (Gilden et al. 2010).

In Mexico, the use of 260 different pesticides has been reported. Of these, 34 are banned and 13 are restricted; moreover, among the 90 pesticide types forbidden in the USA, 30 are being produced in Mexico (Ruiz-Gamboa et al. 2018). Pesticides can transfer from one environmental matrix to another. Once the application of a pesticide is done, residues are deposited on the soil. Through infiltration processes, these compounds can be washed away by rain until they reach bodies of water. Consequently, residues transfer to the aquatic organisms or may eventually reach groundwater levels from where they can be extracted through wells for human use (Ortiz et al. 2014). Additionally, empty pesticide containers are the most common agrochemical wastes posing a potential hazard to human health and the environment since they contain pesticide residues (Jones 2014). In farming, individuals who deal with pesticides are prone to these chemical substances due to pesticide spills, direct spray contact due to missing protective equipment, or even pesticide drift (Damalas and Koutroubas 2016)

Regarding the use of pesticides, the World Health Organization (WHO) has established that three million acute pesticide poisonings occur worldwide, with 220 000 fatalities (Blair et al. 2014). Exposure to pesticides is not limited to workers directly exposed and includes nearby workers, their families, and residents near the cultivation areas. Therefore, farmworkers are often doubly exposed, both environmentally and occupationally, since it is common in this sector to live very close to cultivation areas (Serrano-Medina et al. 2019).

Acute health problems such as nausea, dizziness, vomiting, headaches, abdominal pain, and skin and eye problems are usually associated with exposition to pesticides (Ecobichon 1996). Li et al. (2014) report that neurological symptoms such as numbness or prickling and orthostatic dizziness or fainting are significantly associated with high-level pesticide exposure. In Yucatán, health problems related to the misuse and ingestion of pesticides have been reported (Pérez-Herrera et al. 2012). Another concern in the state of Yucatán is the presence of organochlorine (Polanco-Rodríguez et al. 2015) and organophosphates (Giácoman-Vallejos et al. 2017) pesticides in the groundwater (*cenotes*) and drinking water wells, respectively. This situation could be the cause of pesticide presence in the breast milk of indigenous women in the state (Polanco-Rodríguez et al. 2017).

Good farming practices seem to be a solution to avoid health and pollution problems related to pesticide management. Integrated pest management combines pest control practices that minimize the use of synthetic insecticides, it is economically and environmentally sustainable and safeguards human health (Pretty and Bharucha 2015). Proper crop management can decrease pests and disease incidents (Armengot et al. 2020), reducing the use of synthetic pesticides. However, it is crucial to be aware of pesticide management practices according to the context in order to implement these methods. Worldwide, some studies focused on pesticide handling practices in Iran (Bagheri et al. 2018), the perception of pesticide use by farmers in Peru (Ahmed et al. 2011), and the knowledge and attitude in the use of pesticide by farmers in India (Mohanty et al. 2013) have been developed.

As a particular case, farmers in Yucatán, México, have a lack of information about pesticide management and use in agricultural areas. This is aggravated by the fact that there is no record of the agricultural use of these substances in the state. In Mexico, recent studies report a lack of knowledge of farmers regarding pesticide management and the negative impact on family members (Pérez-Herrera et al. 2018, Ruiz-Gamboa et al. 2018, Esquivel-Valenzuela et al. 2019).

This study aimed to evaluate pesticide management and perception of farmers about environmental and health problems related to pesticide use in 14 localities of Yucatán in two types of agriculture: open-air and enclosed areas.

METHODOLOGY

Survey design

Surveys consisted of 38 questions considering aspects such as personal data (e.g., age, gender, language, education level), perception about the use of pesticides (10 items), perception about the risk of pesticides on the environment (four items), and health (five items), and pesticide management including personal protection equipment (19 items).

Study areas and survey application

Surveys were applied to 39 farmers in 14 localities of Yucatán State from summer 2014 to summer 2015. The respondents represent 100 % of the farmers in the localities selected. The study considered open-air (OA) and enclosed (EA) agriculture. The study area was chosen according to information from government institutions, literature, and the type of crops in Yucatán, according to INEGI (2010). The location of shade houses (enclosed areas) and open-air plantations in the city of Mérida, Yucatán were obtained from the Directorate of Economic Development of Mérida. The study considered six localities in Mérida, three with EA agriculture and three with OA agriculture. In South Yucatán, three localities of Peto and two of Tixméhuac were considered for survey application; in all cases, agriculture was type OA (**Fig. 1**). Ninety one percent of farmers in Mérida for EA agriculture and all farmers in Xoy and San Dionisio (OA) were surveyed. It is important to highlight that crop production in the surveyed areas is mainly for self-consumption and sale in local markets.

Data analysis

Data from the surveys were grouped by type of agriculture and descriptively analyzed. Additionally, a statistical χ^2 test of independence (95 % confidence) for the farmer's perception regarding the damage to health (affectation or not) and the environment (affectation or not), and their relationship (independence/dependence) with farmers age (< 30, 30-50, > 50 years old) and academic level (group 1: no education and basic education; group 2: high school and technician) was developed. Multiple correspondence analyses to know the relationship between age, farmer education, language, agriculture type, cultivated hectares, technical training, and time using pesticide with personal protection, health problems, final disposal of empty containers, and water washing instruments were developed. The analysis was done using the software Statgraphics Centurion XVII.

RESULTS AND DISCUSSIONS

Crop and personal characteristics

Results showed that for EA agriculture in the city of Mérida, 82 % of shade houses produce habanero pepper (*Capsicum chinense*). The remaining 18 % cultivated cucumber (*Cucumix sativus L*), sweet pepper (a variety of *Capsicum annuum*), x'cat-ik pepper (a variety of *Capsicum annuum*), pumpkin (*Cucurbita moschata*), and papaya (*Carica papaya*). The farmers' age average was 55 years (36-78 years), all males. Fifty five percent of them had studied primary school, 18 % secondary, 18 % preparatory, and only 9 % have engineering studies. 81 % of farmers speak the Mayan and Spanish languages, and the rest only Spanish.

For OA agriculture in the south of Yucatan, 20 different crops were reported, with maize (*Zea mays*) being the main crop, followed by habanero pepper, x'cat-ik pepper, and sweet pepper. The increase in the cultivation of habanero pepper in this region results

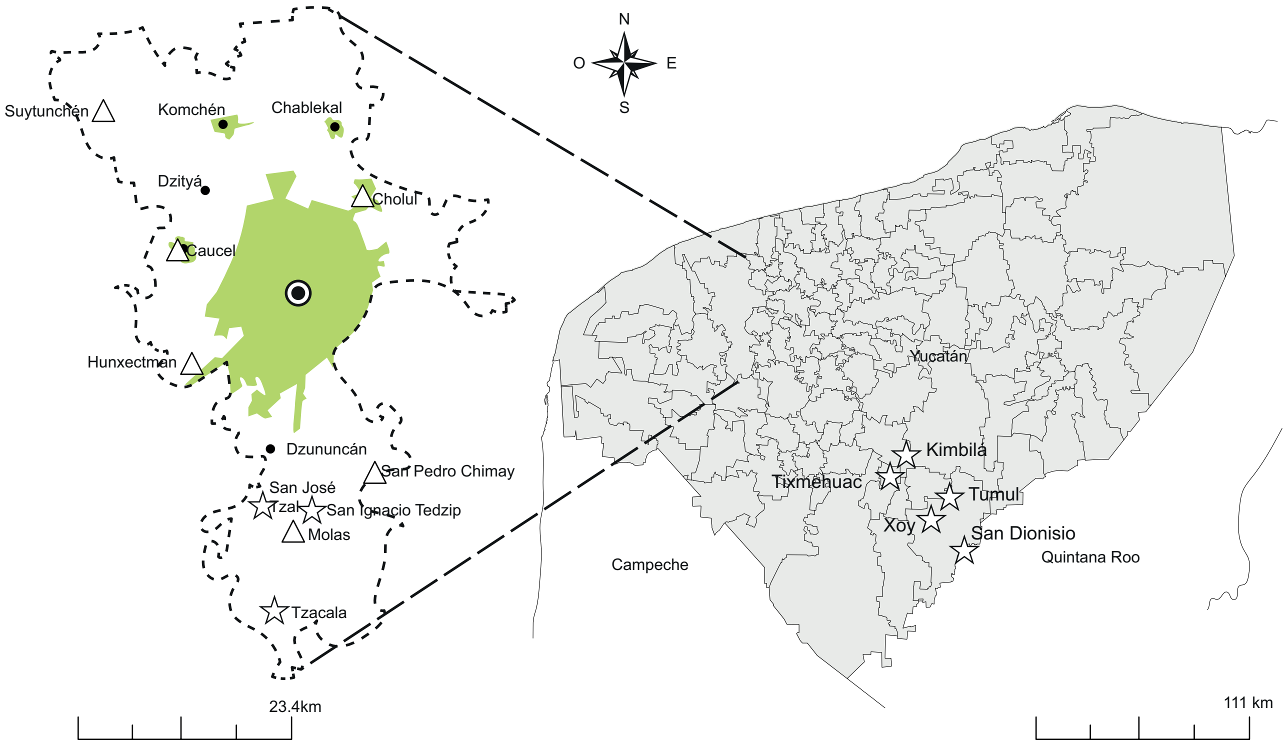

Fig. 1. Study area and localities of study. Stars: open-air agriculture; delta signs: enclosed-area agriculture.

from the boom that this product represents in the state (Ocampo 2014). For OA agriculture, the average age of farmers was 46 years (18-79 years). Eighty-one percent were men and 19 % were women. Thirteen percent did not have studies, 59 % had elementary studies, 15 % secondary education (high school), 8 % preparatory education, and 5 % a technical career. Seventy-three percent spoke Spanish and Mayan, and 27 % only Mayan. The difference in minimum age and educational level among farmers in both types of agriculture can be related to the facility of farmers in the vicinity of Mérida to access better education and migrate to the city, which represents an advantage compared to people living in other regions (López and Ramírez 2014).

Pests and pesticide management

Concerning pests, the whitefly was the most common; however, most pests for OA agriculture are directly related to maize, habanero pepper and the production of vegetables (SAGARPA 2015).

Farmers in both types of agriculture use chemical pesticides (100 % of the surveyed farmers). Merlín-Uribe et al. (2013) reported that most greenhouse farmers (94 %) in the Xochimilco area south of Mexico City used chemical pesticides, which coincides with our findings exhibiting a trend in enclosed agriculture in Mexico.

The most used active substances were paraquat and chlorpyrifos-ethyl for both types of agriculture (**Table I**). Pérez-Herrera et al. (2018) report the use of 24 active substances in Muna, at the south of Yucatán, which is less than the observed active substances in this study (33). However, the two most used pesticides observed in this study (paraquat and chlorpyrifos) were reported between the most used. Recently, Rodríguez-Bornios et al. (2020) reported 37 active substances used by farmers in Oaxaca, Mexico. Paraquat, chlorpyrifos, 2,4-D, diazinon, and others identified in the present study are widely used. Additionally, it is important to highlight that farmers usually change the pesticide types to avoid resistance to the pests, but paraquat and chlorpyrifos-ethyl are commonly used. The fact that the most used pesticides in this study are the same for both agricultural types was due to the similarity of the predominant. The finding that the most used pesticide in the studied area was paraquat represents a concern. This pesticide, which is widely used in Mexico, is banned in Austria, Denmark, Finland, and Sweden and seriously restricted in Germany (EAC 2008). In 2016 paraquat was still used in the agricultural fields

TABLE I. MOST USED SUBSTANCES IN ENCLOSED AND OPEN-AIR AGRICULTURE (n = 39).

	Percentage of surveyed farmers			Percentage of surveyed farmers	
	EA	OA		EA	OA
Abamectin	9	4	Permethrin	45	--
Glyphosate*	36	8	Ylidenamine	18	--
Paraquat*	82	46	Carbufuran	12	--
Diuron	9	4	Chlorothalonil	--	8
Acetamiprit	9	4	Oxytetracycline	--	4
Oxamyl	27	8	Chlorantranilipol	--	4
Mancozeb	27	8	2,4-D	--	27
Chlorpyrifos-ethyl*	73	38	Metalaxil-M	--	4
Methamidophos	27	8	2,4-D amino	--	12
Paration-methyl	9	4	Cypermethrine	--	4
Deltamethrin	9	--	Plicloram-2,4-D	--	4
Avermectin	6	--	Monocrotophos	--	4
Methomyl	18	--	Malathion	--	8
Endosulfan	8	--	Cyhalothrin	--	8
Pymetrozine	9	--	Captan	--	4
Dicofol	18	--	Emamectin Benzoate	--	4
Imidacloprit	36	--			

EA: enclosed area; OA: open area.
*Most used active substance for both EA and OA.

in Mexico because it was not forbidden (COFEPRIS 2016); however, in 2018 this pesticide still appears in the list of products allowed by Mexican Federal Commission for Protection against Health Risks (COFEPRIS 2018). The National Institute of Ecology and Climate Change (Martínez-Arroyo et al. 2020) reports that paraquat is forbidden in 38 countries but not in Mexico; it is even reported as the most exported pesticide in Mexico. Recent studies report the use of paraquat to control pests in agriculture in Mexico (Rodríguez-Bornios et al. 2020).

Direct contact with paraquat solutions or aerosols may cause skin burns and dermatitis, and if ingested, it induces nausea, vomiting, and diarrhea (Wen-Tien 2013). Studies in other countries have reported the use of these active substances in farming despite their restriction globally; Iran is one of them (Bagheri et al. 2018). The use of glyphosate, carbofuran, and 2,4-D, which use has been recently reported by Góngora-Echeverría et al. (2017) in Yucatán, is also reported in this study. It is very important to note that according to FAO/WHO (2015), for this study 62 % of all farmers surveyed used pesticides belonging to class Ia and Ib (red label), 54 % used class III (blue label), 42% class U (green label) and 15% class II (yellow label).

Regarding pesticide application, 100 % of the farmers uses backpack sprinklers in both types of agriculture. About the protection used in pesticide application, 73 % of the farmers in EA and OA agriculture used some personal protection, according to the surveys. For both types of agriculture, most used items were cover mouths, rubber boots, long-sleeve shirts, gloves, aprons, and glasses. It is interesting to note the use of plastic bags to protect the backs from possible spills. It is also important to note that the protection used is entirely inadequate, based on the guideline's recommendations for basic personal protection during handling and applying pesticides (FAO/WHO 2020). Rodríguez-Bornios et al. (2020) report only 10 % of farmers using protection during pesticide application in a locality of Oaxaca, Mexico. This information shows the issues related to personal protection of farmers in some areas in Mexico. The area studied in this research presents the same situation.

About empty pesticide containers, different dispositions such as bagging, burning, throwing down, throwing inside the fields, saving cellar, and burying were registered in the surveys, being the first two the most prevalent for EA and OA, respectively. For all cases, farmers did not follow the established Mexican standards such as NOM-003-STPS-1999, which regulates hygiene and security conditions to prevent risks from handling and use of pesticides in agricultural activities (STPS 1999). Ruiz-Gamboa et al. (2018) report 30 % of the urban pest control operators in Mérida, Yucatán, are acquainted with policies related to pesticide application, which is a low percentage considering these people should be trained. However, this situation seems to be similar in other countries. Marnasidis et al. (2018) established that farmers seem to ignore their duty to clean and deposit empty pesticide containers to specific collection points in a study area in Greece, which was related to the unawareness of the impacts of improper handling and disposal of containers and unfamiliarity with management practices. Therefore, improper disposal of empty pesticide containers can harm humans, animals, and the environment (Mohanty et al. 2013).

Environmental and health issues

Regarding the environmental risk, it was found that water sources were close to 82 % of the shadow houses (EA). Sixty four percent of the farmers observed changes in the region's fauna, specifically in the disappearance of some birds, iguanas, and bees, according to their answers. In OA agriculture, 46 % of the cultivated areas have water wells near or within, and 54 % of these are used for personal consumption, which increases the risk of groundwater pollution by pesticides. Official Standard NOM-003-CNA-1996 establishes that wells should be 30 m away from potential pollution sources (SEMARNAT 1997); unfortunately, this is not the case in agricultural fields where data were collected for this research. Concerning wildlife in these agricultural areas, farmers reported no longer seeing animals such as birds, bees, rabbits, mountain turkeys, reptiles, armadillos, and mice, which coincides with the types of animals affected by the use of pesticides in the Yucatán peninsula, according to Cobos-Gasca et al. (2011).

Table II presents the most common symptoms and illnesses of farmers for both agriculture types. Results showed that hives (36 %) for EA agriculture and vomiting (19 %) for OA agriculture were the most common symptoms presented by farmers after pesticide application. Most of the symptoms observed are consistent with the use of organophosphorus compounds (Ecobichon 1996, Jamal et al. 2002, McCauley et al. 2006).

TABLE II. MOST COMMON SYMPTOMS RELATED TO PESTICIDE APPLICATION FOR ENCLOSED AND OPEN-AIR AGRICULTURE (n = 39).

	Percentage of surveyed farmers	
	EA	OA
Dizziness	9	12
Vomiting	18	19
Red eyes	9	12
Diarrhea	9	8
Headache	18	8
Fainting	9	4
Shaking chills	9	0
Skin burns	18	8
Intoxication	0	12
Hives	36	15

EA: enclosed area; OA: open area.

Statistical data analysis

From the statistical test of independence at 95 % confidence for the perception regarding the damage to health and the environment, as well as its relationship with age and academic level of the farmer (maybe the two most important farmers' characteristics), the opinion was found to be independent for both age and academic level ($P > 0.05$). These results coincide with those presented by Ahmed et al. (2011), where the education level of farmers was not significant in their perception of pesticide use on factors such as human and animal health, and the pesticide harmfulness to the environment.This is important because it implies that the approach of farmers to pesticide management and damage to human health and the environment is multifactorial.

To identify relationships between variables, three multiple correspondence analyses were carried out: (1) crop and personal characteristics with pesticide management (**Fig. 2**); (2) crop and personal characteristics with protection methods (**Fig. 3**), and (3) crop and personal characteristics with health issues (**Fig. 4**).

Figure 2 shows that two dimensions explain most of the variability (39.0007 %). The analysis indicates that crop field storage (ST4-.CF) is related to open area agriculture (AT-.OA). The storage of pesticides in the cellar (ST2-.CE) was related to farmers with preparatory education (EDU-.PRE). Additionally, the empty pesticide container disposal in the cellar (CFD5-.SC) is strongly related to agriculture in enclosed areas (AT-EA). In the same way, throwing empty pesticide containers in the field (CDF4-.TIF) as a way of disposal seems to be related to a time over 30 years using pesticides (T-UP.>30 years) and high school level education (EDU-.HS). However, these factors are close to the axis origin, meaning their relationship is not too strong. Additionally, it can be observed that when agriculture activities are developed in an area of 6-10 ha (C-AREA.6-10 ha), water for cleaning devices usually stays in the bag pack (CWD5-.SBP) used for aspersion. It was interesting to observe the relationship between farmers

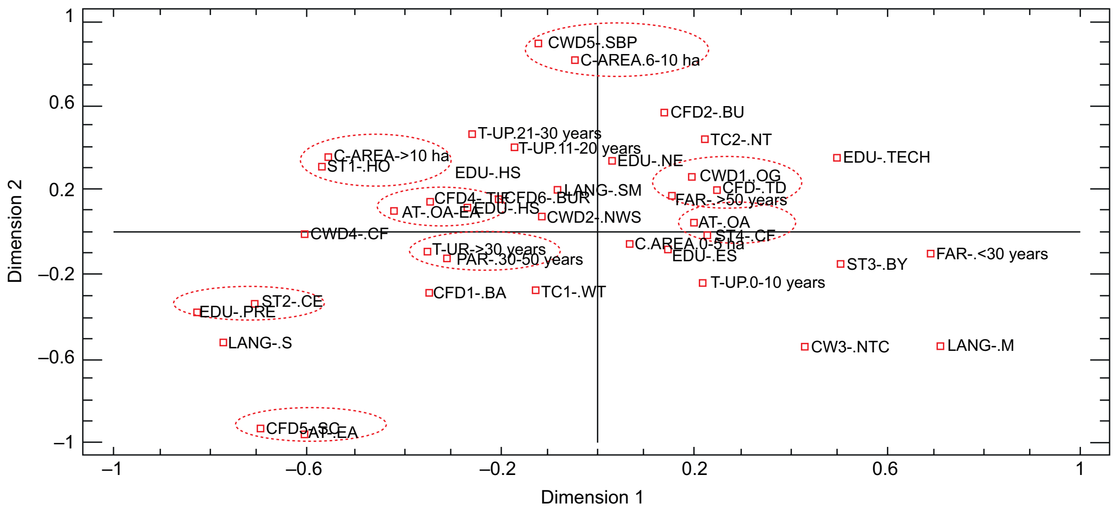

Fig. 2. Multiple correspondence analysis for (1) crop and personal characteristics and (2) pesticide management. FAR: farmer age range (< 30, 30-50, > 50 years); EDU: education level (NE: no education, ES: elementary school, HS: high school, PRE: preparatory, TECH: technician); LANG: language (S: Spanish, M: Mayan, SM: Spanish-Mayan); TC: technical situation (WT: with training, NT: no training); T-UP: time using pesticides (0-10, 11-30, > 30 years); C-AREA: cultivated area (0-5, 6-10, >10 ha); AT: agricultural type (OA: open air, EA: enclosed area); ST: storage (HO: house, CE: cellar, BY: backyard, CF: crop field); CFD: container final disposal (BA: bagging, BU: burn, TD: thrown down, TIF: thrown inside fields, SC: save cellar, BUR: buried); CWD: cleaning water disposal (OG: on the ground, NWS: next to water supply, NTC: next to crop, CF: crop field, SBP: stay in the backpack).

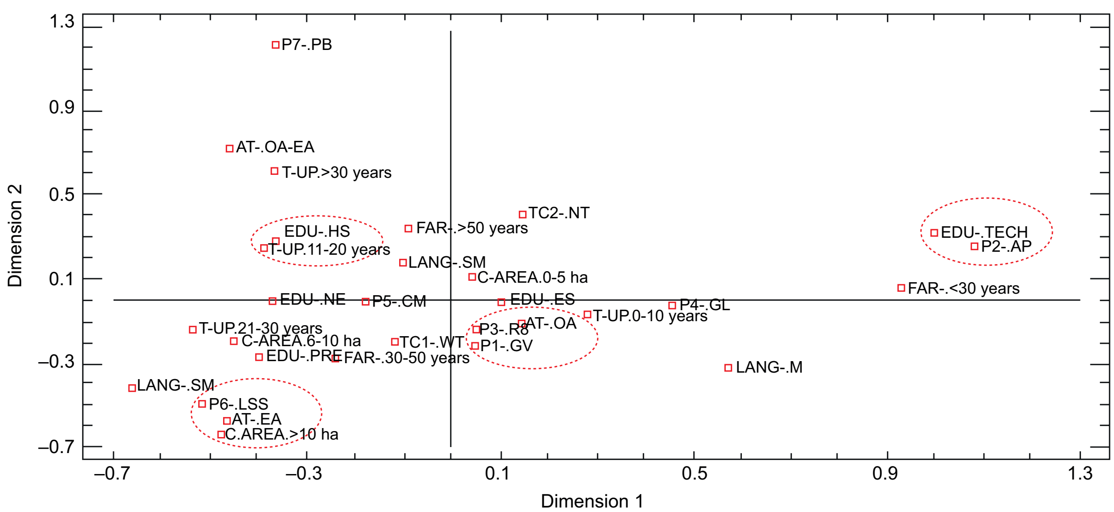

Fig. 3. Multiple correspondence analysis for (1) crop and personal characteristics and (2) protection methods. FAR: farmer age range (< 30, 30-50, > 50 years); EDU: education level (NE: no education, ES: elementary school, HS: high school, PRE: preparatory, TECH: technician); LANG: language (S: Spanish, M: Mayan, SM: Spanish-Mayan); TC: technical situation (WT: with training, NT: no training); T-UP: time using pesticides (0-10, 11-30, > 30 years); C-AREA: cultivated area (0-5, 6-10, >10 ha); AT: agricultural type (OA: open air, EA: enclosed area); P: personal protection (GV: gloves, AP: apron, RB: rubber boots, GL: glasses, CM: mouth cover, LSS: long sleeve shirt, PB: plastic bag).

over 50 years old (FAR-.>50 years) and throwing down empty containers as final disposal (CFD3-.TD), elementary education (EDU-.ES), and final disposal of cleaning water on the ground (CWD1-.OG); however, they are close to the axis, which implies the relationship is not too strong. The figure shows a relationship between an agricultural area over 10 ha (C-AREA.>10 ha) and the storage of pesticides

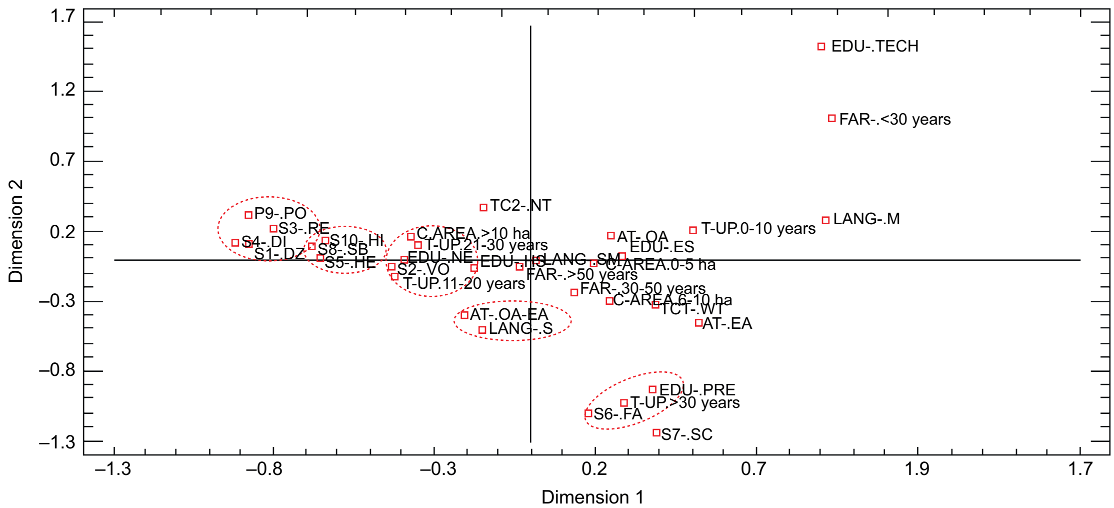

Fig. 4. Multiple correspondence analysis for (1) crop and personal characteristics and (2) health issues. FAR: farmer age range (< 30, 30-50, > 50 years); EDU: education level (NE: no education, ES: elementary school, HS: high school, PRE: preparatory, TECH: technician); LANG: language (S: Spanish, M: Mayan, SM: Spanish-Mayan); TC: technical situation (WT: with training, NT: no training); T-UP: time using pesticides (0-10, 11-30, > 30 years); C-AREA: cultivated area (0-5, 6-10, >10 ha); S: symptoms (DZ: dizziness, VO: vomiting, RE: red eyes, DI: diarrhea, HE: headache, FA: fainting, SC: shaking chills, SB: skin burns, PO: poisoning, HI: hives).

at home (ST1-.HO). It was observed that a range of 30-50 years of age (FAR-.30-50 years) for farmers was related to having used pesticides over 30 years (T-UP.>30 years). In general, aspects such as the age of farmers, cultivated area, and time using pesticides seem to have more influence on the methods used for the final disposal of empty containers and cleaning water. However, the final disposal methods can be considered as not proper (FAO/WHO 2008). Ahmed et al. (2011) reported that farmers' age is not significant on their perception about chemicals and waste effects, human and animal health in agricultural areas. Recently, Esquivel-Valenzuela et al. (2019) reported that farmers in the Comarca Lagunera, Coahuila, Mexico don't have a specific place to mix pesticides and dispose the residues. Additionally, they report that 61 % of farmers dispose empty pesticide bottles by throwing them in the fields or burning them, which seems to repeat in other agricultural areas in Mexico. Campo Limpio is an initiative focused on proper empty pesticide bottle management in Mexico. In April 2019, it reported a pickup of 5525 t, of which 24 % came from southeastern Mexico, where the study area of this research is located. In Yucatán state in 2016 only one collection center for empty bottles of pesticides was registered, according to the last statistics (Campo Limpio 2016, 2019). It is insufficient for the farmer's needs; however, it is a good beginning.

Regarding protection methods, **figure 3** shows the multiple correspondence analysis (two dimensions explain 41.6142 % of the variability). Important aspects relating personal protection to some agriculture characteristics (i.e., agriculture type and cultivated area) and personal aspects of farmers such as education level, age, language, time using pesticides and technical condition) were analyzed. It is observed that regarding personal protection, farmers with technical education (EDU-.TECH) wear an apron (P2-.AP) as protection during aspersion; this relationship is strong (factors far away from the axis origin). In enclosed areas (AT-.EA) and cultivated areas over 10 ha (C-AREA.>10 ha), farmers usually wear long sleeve shirts (P6-.LSS) as personal protection; however, these three aspects are not close to the axis origin, meaning their relationship is strong. Farmers in an open area (AT-.OA) usually wear gloves (P1-.GV) and rubber boots (P3-.RB) as personal protection. Age > 50 years old (FAR-.>50 years) for farmers is not related to wearing personal protection. Finally, the graphic shows that farmers using pesticides for 11-20 years (T-UP.11-20 years) usually have a high school education level (EDU-.HS). Here it can be observed that education level and agriculture characteristics such as cultivated area and open or enclosed agriculture influence the use of protection by farmers.

These results mean that a low education level (> 50 years) makes farmers wear inappropriate protection or not use any at all. The results obtained coincide with a previous study developed by Sharifzadeh et al. (2018), who report that education affected farmers' safety behaviors when working with pesticides, indicating that farmers with high educational levels are more likely to show safety behaviors. In Mexico, Official Standard NOM-256-SSA1-2012 (SSA 2013) establishes the use of personal protection equipment such as overall, boots, work shirts, and gloves when handling pesticides, even considering workers must change their clothes after fumigations. Maybe the average temperature in the study area affects the use of proper protection. FAO and WHO (FAO/WHO 2020) consider some special aspects regarding personal protection in tropical regions which can be applied in this context. However, according to the results, there is a lack of correct pesticide management and personal protection.

Finally, the relationship of age, education level, language, and time of using pesticides, cultivated hectares, and type of crops with health issues according to multiple correspondence analysis (two dimensions explain 46.3207 % of the variability) is shown in **figure 4**. The analysis reveals a very dense distribution of the studied characteristics. A relationship between symptoms such as diarrhea (S4-.DI), dizziness (S1-.DZ), red eyes (S3-.RE), and poisoning (S9-.PO) can be seen. The analysis shows that skin burns (S8-.SB), hives (S10-.HI), and headaches (S10-.HE) usually are presented together. It is interesting to appreciate that farmers without education (EDU-.NE) working in a big agricultural area (C-AREA.>10 ha) and 11-20 years using pesticides present vomiting (S2-.VO) as a symptom from their farming activity. Previously, in **figure 3** it can be observed that farmers' characteristic such as no education (EDU-.NE) and lack of technical training (TC2-.NT) are not related with any protection type, which can explain the reported symptoms. Fainting (S6-.FA) is usually present in farmers that have worked with pesticides for more than 30 years (T-UP.>30 years). It is important to note that technical education (EDU-.TECH) is not related to any symptom, which supports the importance of education level in pesticide handling during agricultural activities. In general, education level seems to be related to the presence or absence of symptoms. Similar to the analysis for personal protection, time using pesticides and the cultivated area is related to symptoms like vomiting or fainting. This could mean that the leading cause of health issues is the exposure to pesticides in time (accumulative concentrations) (Li et al. 2014).

All the above information supports that inadequate protection during the application of pesticides makes farmers more vulnerable due to the different ways in which pesticides can reach the body (dermal, ocular, eye, and respiratory pathways) (Kim et al., 2017). The study confirms that the observed problems related to pesticide use and management respond entirely to the lack of information and training of farmers. This situation is related to social aspects such as education level and geographic status because most farmers surveyed live in rural areas. Farmers must get technical training focused on good agricultural practices, which has proven to have positive effects on health and the environment in agriculture areas (Alfaro-Montero et al. 2012). A recent study shows that previous training of farmers was related to increased knowledge on pesticides and beliefs regarding pesticide hazard control, which was accompanied by elevated safety behavior in farmers (Damalas and Koutroubas 2017). Midingoyi et al. (2018) report that the adoption of integrated pest management techniques provided during farmers' training increases field production and reduces the damage to the environment and human health. This supports the importance of technical training of farmers.

CONCLUSIONS

For both agricultural types (EA and OA) the most used pesticide was paraquat, which is restricted in many countries but not in Mexico. According to surveys, pesticide application in farms is carried out without government supervision, and a lack of technical advice was observed. Pesticides classified as extremely and highly hazardous (red label) were the most used (62 %). Environmental problems were reported in surveys. Animals such as iguanas, birds, and bees are directly affected in agricultural areas according to the farmers' perception. A negative effect on health was reported too; farmers suffered vomiting, hives, diarrhea, headache, fainting, and other symptoms at some point. The social conditions of farmers affect how they protect themselves, store pesticides, and dispose waste and empty containers. According to the results, farmers need technical training regarding good agricultural practices, adequate management of agrochemicals, empty pesticide container disposal, and proper protection, both personally and for the environment. However, it is necessary that training is given in Spanish and Mayan, because many farmers speak a poor Spanish. These results represent an important first step for showing the real situation of the Yucatán crop fields to agricultural and health authorities, so that they can focus their priorities on human safety concerning pesticide use in agriculture.

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