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A SURVEY ON THE PESTICIDE APPLICATION PRACTICES AND PRESENCE OF PESTICIDE RESIDUES ON MANGOES IN NEGROS ORIENTAL, PHILIPPINES

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ABSTRACT – "Carabao" mango trees are pervasively applied with pesticides as a principal pest management strategy. This study examined the pesticide application practices of mango-sprayer contractors and determined the presence of pesticide residues on harvested fruits, soils, and water samples from randomly selected mango farms in the province of Negros Oriental, Philippines. One hundred randomly chosen sprayer-contractors were interviewed using a structured questionnaire to determine their pesticide application practices. On the other hand, pesticide residue determination on mango fruits was done by the National Pesticide Analytical Laboratory of the Bureau of Plant Industry, Quezon City, using the Gas Chromatographic method. Results show that insecticides were used in all of the surveyed farms at least six (6) times using chemicals that belong to eight (8) subgroups, the most frequently used of which were organochlorines (87%) and Thiocarbamate (50%). A total of 13 different active ingredients were applied, with Thiodan (Endosulfan), a banned chemical, having the greatest number of users at 87%. Respondents applied a "cocktail" of 4 to 5 pesticides per application. The rate of pesticide application per fruiting season was relatively high, averaging 1138.88 grams of active ingredient/ tree. Results of the Multi Residue Analysis (MRA) show that residues of organophosphates, specifically, Chlorpyrifos, were detected in 11 fruit samples out of 60 tested, but not in soil and water samples. Thus, it is argued that the current pesticide management strategy in some mango farms in the province has resulted in fruit contamination with pesticide residues rendering some of these fruits potentially unsafe for human consumption.

Keywords: pesticide contamination, pesticide residues, pesticide use, residue analysis

INTRODUCTION

Mango (*Mangifera indica*), a tropical fruit belonging to the family Anacardiaceae, is referred to as King of fruits for its exquisite aroma, taste, and high nutritional value (Lebaka, et al, 2021). In 2015, the Philippines ranked seventh among the world's top exporters of fresh and dried mango, with exports valued at US$91 million holding a 4% share of the global market (UNComtrade, 2016). The country's mango industry provides a source of livelihood to about 2.5 million farmers (PCARRD-DOST, 2011). The Carabao mango, also known as Manila Super Mango in the world market, is considered the most important

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cultivar grown in the Philippines (PCARRD, 2016). In 2018, the country produced 711,660 MT of fresh mangos from a total production area of 185,858 hectares contributing significantly to the country's agricultural export earnings valued 4.3 billion pesos. In the same year, the country exported fresh mangoes valued at P990.97 million, with Hongkong, Korea, and Japan as major export markets, and processed mango products valued at more than P3.3 billion pesos (PSA, 2019). The mango industry plays an important role in the Philippines' economy, providing a source of livelihood to about 2.5 million farmers (PCARRD-DOST, 2011).

However, the continued viability of the mango industry is continuously threatened by a variety of pests that affect yield performance and quality of produce. Mangoes are susceptible to insect infestation and disease infection, particularly at the flowering and fruit development stages (Rivera, 2009). Close to 400 species of insect pests have been reported to infest mango in different parts of the world (Pena et al. 1998). In Pakistan, about 86 species of mango insect pests have been recorded, of which fruit flies, mealybug, scale insects, and mango hoppers were considered the most damaging (Giani, 1968 as cited by Hussain, et al., 2002). In the Philippine context, mango farmers deal with many insect pest pressures requiring the use of effective control strategies to prevent losses and ensure high productivity. Left uncontrolled, these pests cause severe economic losses. As reported, insect pests have the potential to reduce yield by as much as 60% (Navarajan, 2007) to 70% (Chin et al., 2010) if ineffectively managed. In extreme cases, insect pest damage ranging from 10 to 100% may persist despite the use of insecticides (Mossler and Crane 2009). This view is not without basis since, as propounded by Banjo *et al.* (2010), crop losses due to pest damage may range from 10 to 90%. Specifically for mangos, Chin et al., (2015) contended that fruit flies, a significant pest on mangos, could cause damage by as much as 70%, under severe infestation.

Driven by the need to boost agricultural productivity, most farmers resort to the use of agrochemicals, particularly pesticides (Parveen, 2010). The principal management approach for mango pests and diseases in the Philippines has been through the application of a wide range of pesticides, the majority of which belong to older chemical groups such as Dithiocarbamates, Organophosphates, and Pyrethroids (Bodnaruk, 2008). While on the process of developing an Integrated Pest Management (IPM) for Mango in Palawan, Philippines, Medina, et al (2005) reported that the crop protection practice of mango farms in the area consisted of only chemical control. Various pesticides are used over this fruit on a massive scale to minimize the economic losses caused by different kinds of pests various (Hussain, et al., 2002).

However, excessive, and continuous use of pesticides has caused deleterious effects on the ecosystem *(*Sharma et al., 2010). Environmental contaminations from pesticides disrupt natural water, air, and soil functions, and alter the eco-system, resulting in detrimental effects on nutrient cycles or the toxicity of non-target organisms (Jeyanthi and Kombairaju, 2005). According to Miller (2004), 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, including non-target species, air, water, bottom sediments, and food. The pervasive use of pesticides has resulted in the presence of their toxic residues in various environmental components (Bhanti M and Taneja A, 2007*)*. In a study on pesticide contamination on the environment in a vegetable producing area in the Philippines, groundwater and drinking water harbored pesticide residues (Byuiyan and Castañeda, 1995). Monocrotophos and Endosulfan residues persisted in deep soil layers (Paningbatan *et al*., 1993).

Furthermore, when applied excessively, pesticide residues can remain on foods and pose a significant hazard to the health of consumers (Hussain et al., 2002; Wang et al., 2015). Most pesticide residues are ingested into the human body through contaminated fruits, vegetables, cereals, water, and other food commodities (Sriare injestedvastava et al., 2011). Due to the increased use of pesticides in orchards, residues may remain in the raw fruits and their products such as juices, nectar, jellies, etc. (Perret et al., 2002). The study of Bempah, et al., (2011) monitoring pesticide residues in fruits and vegetables in Kumasi Metropolis, Ghana reported that 58% of 25 mango fruit samples tested contained one or more pesticide residues, of which 19% had pesticide levels above the Maximum Residue Level (MRL). Hence, Jeyanthi and Kombairaju (2005) propounded that the most damaging ecological disturbance of injudicious use of pesticides is the existence of a high concentration of pesticide residues in the food chain, including cereals, pulses, vegetables, fruits, etc. Complicating matters is the practice of using non-authorized active ingredients (usually highly toxic pesticides) in many countries (as cited by Wang, et al., 2015).

The dearth of published studies examining the extent of pesticide usage on mango farms in the country and the effects of excessive pesticide use on the safety of mango fruits, and on the environment provided the impetus for this study. This study sought to examine the pesticide application practices of mango sprayer-contractors in selected municipalities in the province of Negros Oriental specifically in terms of the profile of chemicals used, and the frequency, system of application, and dosage of pesticide applied. Secondly, the study also sought to determine the presence of pesticide residues on harvested fruits, soils, and water samples from randomly selected mango farms in the province. Data on pesticide application practices were mainly based on the mango sprayers' recollection of their practices. On the other hand, the detection of pesticide residues on environmental samples (water, and soils) was limited to the 25 specific chemicals covered in the Multi-Residue Analysis (MRA) performed by the National Pesticide Analytical Laboratory (NPAL) of the Bureau of Plant Industry (BPI), Quezon City, using the Gas Chromatographic method.

METHODOLOGY

Research Design

This study is descriptive, employing both survey methodology and observational methods for data collection.

Sampling Strategy

Purposive quota sampling was employed to obtain the 100 mango sprayer-contractors as respondents for this study. Included in the sample were contractors, hired sprayers, or sprayer-contractors who were engaged in mango spraying in the province of Negros Oriental for at least two years at the time of the survey.

Locale of the Study

The study was conducted in the province of Negros Oriental, Philippines, with GPS coordinates 9.6282° N, 122.9888° E (Figure 1) . Mango producing municipalities in the southern and northern parts of the province comprised the study sites. The sprayer-contractors randomly selected for this study had mango spraying operations in four (4) northern municipalities such as Ayungon (9.8501° N, 123.1389° E), Bindoy (9.7945° N, 123.0564° E), Manjuyod (9.6739° N, 123.1014° E), Amlan, and five southern municipalities including Bacong (9.2392° N, 123.2644° E), Valencia (9.2803° N, 123.1914° E), Dauin (9.1991° N, 123.2363° E) , Zamboanguita (9.1701° N, 123.1464° E), and the city of Dumaguete (9.3068° N, 123.3054° E).

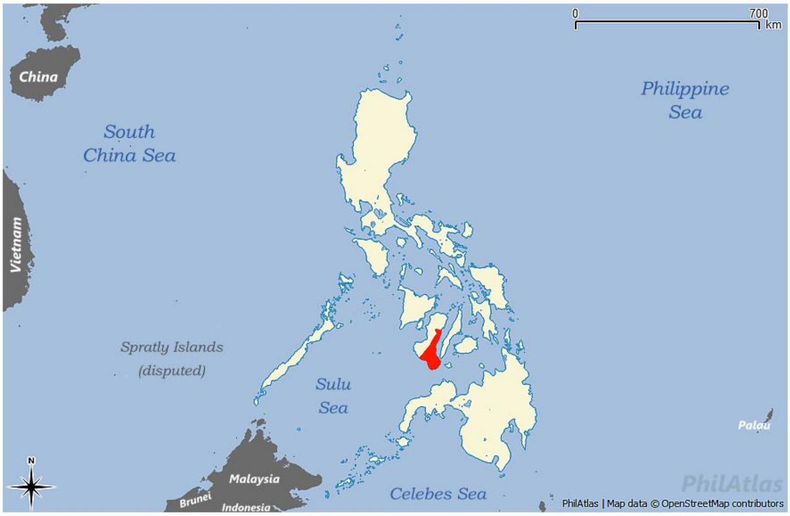

Figure 2. Map of the Philippines showing the location of the province of Negros Oriental.

Data Collection Methods

Pesticide Application Practices

The study utilized both primary and secondary data collection methods. Mango sprayer-contractors provided primary data through face-to-face interviews by trained enumerators using a structured interview schedule. Unstructured interviews were also conducted with key informants to illicit needed details on pest management practices. Observational methods were employed on selected mango farms and sprayer-contractors for required information on pesticide application practices. On the other hand, secondary statistical data were obtained from the websites of the Philippine Statistics Authority and the Bureau of Agricultural Statistics.

Pesticide Residue Determination

Laboratory tests to detect pesticide residues in selected samples were performed by a duly accredited laboratory**.** The National Pesticide Analytical Laboratory of the Bureau of Plant Industry (NPAL-BPI) in Quezon City was co-opted to perform Multi-Residue Analysis (MRA) on 60 mango fruit samples, 15 soil samples, and 15 water samples from the surveyed farms.

The Gas chromatographic method for the determination of pesticide residue in fruits, soil, and water using Gas-Liquid Chromatography, Agilent Model 6890 equipped with Electron Capture Detector (ECD) and Flame Photometric Detector (FPD) or Nitrogen Phosphorous Detector (NPD) was the method of analysis used by NPAL-BPI.

Mango fruits were randomly collected from the surveyed farms on the day of harvest. From each mango farm, two sets of fruit samples weighing one (1) kg per sample were obtained. One set of fruit sample is placed and sealed in polyethylene bags and flown to the NPAL laboratory within 24 hours from harvest for MRA. The other set is placed in an unsealed polyethylene bag and allowed to fully ripen before submission to NPAL.

On the other hand, water samples from streams, rivers, or wells located close to or inside any of the surveyed mango farms were collected at 2.5 liters per sample, and placed in clean amber-colored water bottles. Soil samples were randomly collected from the surveyed mango farms, placed and sealed inside polyethylene bags, and submitted to the NPAL for pesticide residue tests. Fruit and water samples were placed inside coolers and were transported by plane to the NPAL-BPI, Quezon City within 24 hours of specimen collection.

The MRA covered a total of 25 pesticides belonging to only three chemical subgroups namely organophosphates which included 11 pesticides, Organochlorines (8 pesticides), and Pyrethroids (6 pesticides) (Table 1).

Table 1. Pesticides belonging to three chemical subgroups namely Organophosphates, Organochlorines and Pyrethroids covered in the MRA conducted by NPAL, BPI**.**

Organophosphates	Organochlorines	Pyrethroids
Mevinphos	Lindane	Lambdacyhalothrin
Dimethoate	Aldrin	Permethrin
Diazinon	Heptachlor	Cyfluthrin
Isazophos	Alpha-Endosulfan	Cypermethrin
Methyl Parathion	Beta-Endosulfan	Fenvalerate
Fenitrothion	Endosulfan Sulfate	Deltamethrin
Malathion	Heptachlor Epoxide	
Chlorpyrifos	4,4-DDE	
Phenthoate		
Profenofos		
Triazophos		.

Data Analysis

Data were encoded and analyzed using a SPSS. Descriptive statistics were used to summarize, describe, and anlyze the data. Frequency counts and percentages were used to describe categorical data. On the other hand, measures of central tendency and variability such as Mean, Range, and Standard Deviation were used to describe and analyze numerical data.

RESULTS

Data for the pesticide application practices of the mango-sprayer contractors were obtained through face-to-face interviews using a structured interview schedule. On the other hand, samples of freshly harvested fruits, soils and water from randomly selected mango farms were collected and transported to the NPAL of the BPI for MRA to determine the presence of pesticides belonging to three chemical subgroups Namely Organophosphates, Organochlorines, and Pyrethroids.

Pesticide Application Practices

Pesticides, mainly insecticides, and fungicides were used extensively in mango farms covered in the study by the sprayer-contractors. Regardless of the season, all of the surveyed sprayer-contractors applied insecticides as a principal insect pest management strategy. Although not as extensively, fungicides were also used by 54% of the sprayers during the wet season, and by 51% during the dry season.

Profile of Pesticides Used

The insecticides applied on bearing mango trees belonged to eight (8) subgroups or chemical families, with a combined total of 13 different active ingredients, contained in a total of 15 different chemical trade names. Figure 2 shows the distribution of sprayer-contractors by subgroup of chemicals used. The top five chemical families in terms of the percentage of respondents using them were Organochlorine (87%), Thiocarbamate (50%), Pyrethroids (46%), Carbamate (45%), and Thiadizin (20%). Chemicals that were least used were Organophosphates + Carbamate (7%), organophosphates (4%), and Pyrethroids + Neonicotin (4%). The data indicate that mango sprayers did not use only one but multiple subgroups of insecticides during the flowering and fruiting stages of induced mango trees.

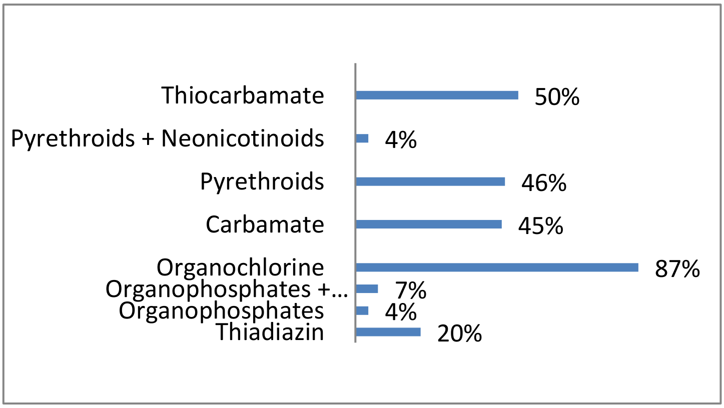

Figure 2. Subgroups/chemical families of insecticides applied on induced mango trees and percentage of sprayer-contractors using them. Multiple responses were noted and counted; pesticides were mixed per application.

By active ingredient, the most frequently used pesticides were Endosulfan (87%), Cartap Hydrochloride (43%), Beta-Cyfluthrin (34%), Methomyl (26%), and Cypermethrin (25%) (Table 1).

The application of fungicides on bearing mango trees was not as pervasive since they were used only by 54 of the surveyed sprayer-contractors during the wet season, and by 51 during the dry season. The two subgroups/ families of fungicides used were Strobilium and Dithiocarbamate.

Toxicity Profile of Pesticides

Table 2 shows the toxicity profile of the different pesticides applied by mango sprayers of bearing fruit-bearing trees based on the World Health Organization (WHO) system of classification. None of the surveyed sprayers used extremely hazardous pesticides (IA), however, more than one third (34%) applied IB pesticides that are categorized as highly hazardous. This category includes Beta-Cyfluthrin, Methomyl, and Beta-Cypermethrin. Most (87%) of the respondents used moderately hazardous chemicals (II) comprising largely of Endosulfan, Cartap Hydrochloride, Cypermethrin, Carbaryl, Fenvalerate, Lambda-cyhalothrin, and others. All the fungicides that were reportedly used are accorded a U classification which means that they are unlikely to present acute hazards in normal use.

Mode of Action, Status of Registration, and Pre-Harvest Interval

Eleven (11) of the 15 insecticides applied by sprayer-contractors were “contact” insecticides, while only four (4) were “systemic” (Table 2). The systemic insecticides used contained Bufrofezin, Carbaryl, Cartap Hydrochloride as active ingredients. On the other hand, the “contact” insecticides are applied on the trees’ canopy including flowers, leaves, branches, etc., and are intended to be toxic to insects present in these plant parts upon direct contact.

Table 2. Profile of pesticide used by sprayer-contractors, status of registration, and pre-harvest interval.

Subgroup of Pesticides	Active Ingredient (a.i.)	Chemical Name	Toxici-ty (WHO) *	Mode of Actio n	Status of Registratio n for Mango Use	Number of Farmers Using the Chemical	Recomme nded Pre-harvest Interval (days)	Sprayer’s pre-harvest interval (days)
				INSECTICIDES				
Thiadiazin	Bufrofezin	Applaud	III	S	R	20	15	30
Organophosphat es	Fenthion	Lebaycid	II	C	R	3	7	30
Organophosphat es + Carbamates	Chlorpyrifos + BMPC	Brodan	II	C	NR	7	21	2-5
Organochlorine s	Endosulfan	Thiodan	II	C	R**	87	7	20
Carbamates	Carbaryl	Sevin	II	S	R	19	1	30
	Methomyl	Scorpio	IB	C	NR	26	10	30
Pyrethroids	Beta-Cypermethrin	Chix	IB	C	R	15	1	20
	Beta-Cyfluthrin	Bulldock	IB	C	R	34	14	20
	Cypermethrin	Cymbush	II	C	R	19	7	20
		Knockout	II	C	R	25	7	20
	Fenvalerate	Sumicidi n	II	C	R	17	3	60
	Lambdacyhalo thrin	Karate	II	C	R	14	2	20
Pyrethroids + Neonicotinoids	Lambda-cyhalothrin + Thiamethoxam	Alika		C	R	4	-	30
Thiocarbamates	Cartap Hydrochloride	Padan	II	S	R	20	10	40
		Rampage	II	S	R	43	10	30
				FUNGICIDES				
Strobilium	Azoxystrobin	Amistar	U	S	R	46	7	40
Dithiocarbamat es	Propineb	Antracol	U	C	R	3	7	40
	Mancozeb	Manzate	U	S	R	4	7	87

***Ia** = Extremely Hazardous, **Ib** = Highly Hazardous, **II** = Moderately Hazardous, **III** = Slightly Hazardous, **U** = Unlikely to present acute hazard in normal use
**Banned in the market
S = Systemic; C = Contact
Source: http://fpa.da.gov.ph/index.php/regulatory/pesticide-division. “Registered Pesticides for Mango as of 01 January 2010”

Based on the list of registered pesticides for mango as of January 1, 2010, provided by the Fertilizer and Pesticide Authority (FPA), two of the insecticides used by the sprayer-contractors were not officially registered for use on mango trees. Chlorpyrifos + BMPC (Brodan) and Methomyl (Scorpio), which were applied on mango trees by a total of 33 sprayer-contractors have not been approved for mango application.

Table 2 also shows the recommended pre-harvest interval of the different chemicals, as well as the actual pre-harvest interval practiced by the surveyed sprayer-contractors during the period covered in the study. Results show that, except for one, namely Brodan with Chlorpyrifos+BMPC as active ingredients, all the chemicals were applied weeks or even months earlier than the recommended pre-harvest interval which bodes well for the safety of harvested fruits. On the other hand, all three of the fungicides used were registered for use on mangos, and all were applied by the sprayer-contractors much earlier than the recommended 7 days PHI at 40 to 87 days before harvest.

Frequency of Pesticide Application

Table 3 presents data on the frequency of pesticide application on flowering and fruit-bearing mango trees during the wet and dry seasons. Insecticides were applied at varying frequencies ranging from 4 to 7 applications. However, the average number of pesticide applications during the wet and dry seasons was practically the same at 6.42 and 6.43 applications, respectively. It should be noted that the majority (57%) of the sprayer-contractors applied insecticides on florally-induced mango trees seven times, regardless of the season.

On the other hand, the use of fungicides on mango trees was not as pervasive as that of insecticides irrespective of the season. During the wet season, only 54% of the sprayer-contractors applied fungicides, with the number declining to 51% during the dry season. Fungicide application during wet and dry seasons ranged from 0 to 7, with an average of 1.39 applications during the wet season, and 1.3 applications during the dry season.

Table 3. Frequency of pesticide applications per flowering-fruiting season during wet and dry seasons by sprayer-contractors.

Frequency of Pesticide Application	**Wet Season** (N=100)		**Dry Season** (N=100)	
	Percent Reporting		**Percent Reporting**	
Insecticides				
1-2 applications	-		-	
3-4 applications	4.0		3.0	
5-6 applications	39.0		40.0	
Above 6 applications	57.0		57.0	
Mean		*6.42*		*6.43*
Range		*4-7*		*4-7*
Standard Deviation		*0.79*		*0.79*
Fungicides	**N=54**		**(N=51)**	
1-2 applications	31 (57.41)		28 (54.90)	
3-4 applications	19 (35.19)		19 (37.25)	
5-6 application	1(1.79)		1 (1.96)	
Above 6 applications	3 (5.36))		3 (5.88)	
Mean		*1.39*		*1.30*
Range		*0-7*		*0-7*
Standard Deviation		*1.63*		*1.63*

System of Pesticide Application

Table 4 shows that most (90%) of the surveyed sprayer-contractors applied a “cocktail” of pesticides per application, with only 10 applying one chemical at a time. Note that the majority of those who followed a mixed system of pesticide application used a cocktail or combination oof 4 to 5 different chemicals per application**.**

Table 4. Percentage of sprayer-contractors by system of pesticide application based on the number of chemicals mixed/combined per application per fruiting season.

System of Pesticide Application	Percent Reporting N=100
One pesticide only	10
Mixed/Combined	
2 - 3 pesticide combinations	35
4 - 5 pesticide combinations	44
6 - 7 pesticide combinations	11

Dosage of Pesticide Application

Considering all pesticides, the total dosage or quantity of active ingredients applied per mango tree by the surveyed sprayer-contractors was calculated to determine the intensity of pesticide application per mango tree regardless of the season (Table 5). Data show that 84% of the respondents applied pesticide dosages that exceeded 500 gram a.i./tree per fruiting season. Of these, the majority employed a rate of application that exceeded 1000 gram a.i./tree/ fruiting season. Few (15%) sprayers utilized 500 gram a.i./tree/fruiting season or less. The mean dosage of the application was 1138 gram a.i./tree/fruiting season with a range of 165 to 2,700 gram a.i./tree. Inter-sprayer variation was quite large given the standard deviation of 678.488 gram a.i./tree/fruiting season.

Table 5. Total dosage of pesticides applied per tree per flowering to fruiting season in gram of active ingredient (gram a.i./tree).

Range of Pesticide Dosage Applied (gram a.i.)	Percent Reporting N=100	
1 - 500	15	
501 - 1000	38	
1001 and Up	46	
Mean		*1138.88*
Range		*165.0 – 2, 700*
Standard Deviation		*678.488*

Data in Figure 3 presents a comparison of the recommended dosage of each pesticide used by the sprayer-contractors in grams of active ingredient per 200 li with the actual dosage or rate of application per chemical. The data show that except for Sumicidin, the dosage or rate of application of each of the 14 insecticides applied by the respondents on mango trees per 200 li was below the recommended rate which means that on a per chemical basis per 200 li, the respondents were using an underdose of each chemical.

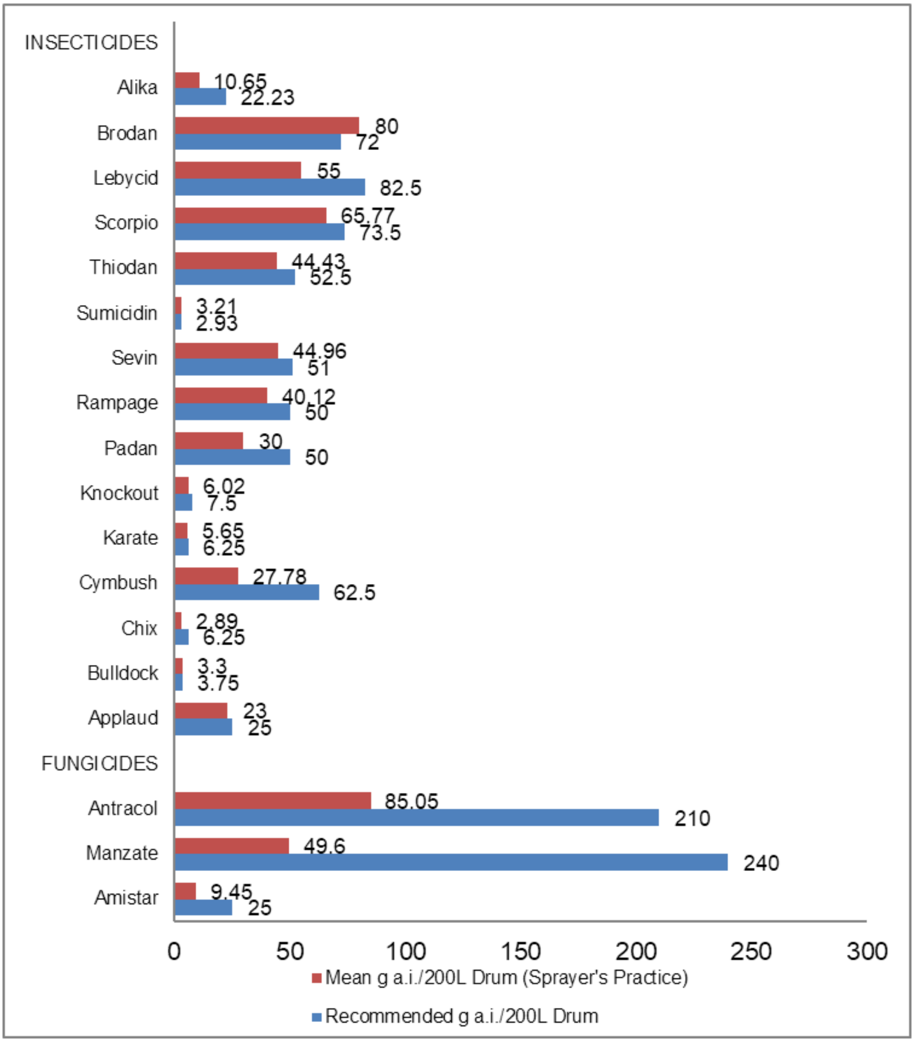

Figure 3. Recommended dosage* (gram a.i.)/200 li drum and mean dosage of chemical (gram a.i.)/drum applied by sprayer-contractors. (*per chemical brand formulator).

Pesticide Residues in Mango Fruits

Table 6 presents the results of the MRA conducted on mango fruits by the NPAL of the BPI using Gas-Liquid Chromatography. The MRA covered a total of 25 pesticides belonging to only three chemical subgroups namely organophosphates which included 11 pesticides, Organochlorines (8 pesticides), and Pyrethroids (6 pesticides) (Table 1).

Results show that some mango fruit samples obtained from randomly selected farms covered in the study yielded positive results for the presence of Organophosphates , particularly Chlorpyrifos. Findings show that of the 60 fruit samples (30 freshly harvested, 30 fully ripe fruits) tested, a total of 11 (18.33%) were found to contain residues of Chlorpyrifos that exceeded the Limit of Quantification (LOQ) of 0.01 µg/li. This proves that pesticide application during the fruiting stages of mango may leave residues on the harvested fruits. However, the test did not detect the presence of any of the Organochlorines, and Pyrethroids covered in the MRA.

Comparing the level of pesticide residues detected on fruit samples with the Maximum Residue Limit (MRL), results show that two (18.18 %) of the samples contained pesticide residues that exceeded the MRL for Chlorpyrifos. The data show that the pesticide application practices used by some of the surveyed sprayer-contractors had resulted in the contamination of a number of fruit samples with pesticide residues at levels considered unsafe for human consumption.

Table 6. Classification and level of pesticide residues detected in mango fruit samples.

Classification of Pesticide	Pesticide Residue Detected	Quantity of Residue per Sample Mature Green (mg/kg) (LOQ=0.01)	Quantity of Residue per Sample Ripe Mango (mg/kg)	Maximum Residue Limit (MRL) (mg/kg) (0.05)
Organophosphates	Chlorpyrifos		0.02	< MRL
	Chlorpyrifos	0.01	0.03	< MRL
	Chlorpyrifos	0.02	0.04	< MRL
	Chlorpyrifos		0.04	< MRL
	Chlorpyrifos		0.04	< MRL
	Chlorpyrifos	**0.09***	0.02	> MRL *
	Chlorpyrifos	0.04	**0.17***	> MRL *

Where: * = Residue Level > MRL.

No Pesticide Residues Detected in Water and Soil Samples

Results of the tests show that none of the 15 water samples and 15 soil samples tested contained detectable traces (LOQ of 0.01) of any of the 25 chemicals covered by the multi-residue analysis used by NPAL. Although residues of Chlorpyrifos were detected in 18% of the fruit samples tested, none of the tested water and soil samples were found positive for its presence. It is instructive to reiterate, however, that many of the sprayer-contractors used other chemicals such as Thiadizine (20 farmers), Carbamates (45 farmers), Thiocarbamates (63 farmers), and Neonicotinoids (4 farmers) that were not covered by the MRA performed by NPAL which even if present could not have been detected. Hence, subsequent studies on testing pesticide residues in mango fruits, water, and soils must be expanded to include those pesticides that were widely used by farmers but were not covered in the present tests.

DISCUSSION

The use of pesticides as a principal pest management strategy has become an integral practice in all the surveyed farms and by all sprayer-contractors. This was not unexpected since, in the absence of effective pest control alternatives, pesticide management is considered as the core component even in the IPM strategy (PCARRD, 2006). Pesticides, mainly insecticides, and fungicides were used extensively since the surveyed mango farms encountered severe cases of infestation of certain insect pests and incurred substantial yield losses as a result. As reported, insect pests have the potential to reduce yield by as much as 60% (Navarajan, 2007) to 70% (Chin et al., 2010) if ineffectively managed. Regardless of the season, all of the surveyed sprayer-contractors applied insecticides as a principal insect pest management strategy. Although not as extensively, eungicides were used by more sprayer-contractors during the wet season than the dry season because of the higher incidence of fungal attacks. According to Mariyono, J. and M. Battharai (2009), a key motive and rationality for using pesticides including its level and intensity of use by farmers is the economic motive of reducing yield loss and increasing income. They explained that farmers' decision to apply pesticides on a crop is a preventive strategy against crop failure due to pest and disease attack.

Pesticide Application Practices

Insect pests at the flowering and fruit development stages were applied with insecticides that belonged to eight (8) subgroups or chemical families, with a combined total of 13 different active ingredients. This indicates that mango sprayers did not use only one but multiple subgroups of insecticides during the flowering and fruiting stages of induced mango trees. Indeed, most (90%) of the respondents applied a mixture of pesticides per application, with only 10 applying one chemical at a time. The majority of those who followed a mixed system of pesticide applications used a cocktail of 4 to 5 different chemicals per application**.** This practice of combining more than one pesticide especially those that have different trade names but the same common names and thus the same active ingredient (a.i.) is discouraged. According to Salameh *et al*. (2004), combined chemicals could be a dangerous concoction, because the mixing of pesticides can alter their chemical properties, thereby increasing its detrimental effects. The combination of hazardous pesticides and the absence of appropriate precautions are detrimental to the farmers' health (Salameh *et al*., 2004; Chitra Grace *et al.,* 2006).

Furthermore, results show that, except for one, all the chemicals used by sprayer-contractors were applied weeks or even months earlier than the recommended pre-harvest interval which bodes well for the safety of harvested fruits. The pre-harvest interval refers directly to the number of days required to lapse, between the date of final pesticide application and harvest, for residues to fall below the tolerance level established for that crop or for a similar food type (Prodhan et al., 2018). At this time, the harvested produce is presumed to be safe and pesticide-free. However, seven (7) of the sprayer-contractors applied the unregistered Chlorpyrifos 2 to 5 days before harvest, instead of the recommended 21 days PHI. Hence, residues of this chemical were detected in a total of 11 fruit samples indicating pesticide contamination on harvested fruits (Table 6).

From flower induction, mango trees go through four flowering stages starting from bud emergence (10 -14 DAFI), bud elongation (15-21 DAFI), early opening, or pre-bloom (22-26 DAFI), and full bloom (27-33 DAFI). Subsequently, fruit development stages comprising of fruit set (34-60 DAFI), fruit development (61-89 DAFI), and fruit maturity (90-120 DAFI) occur. Majority of the surveyed sprayer-contractors scheduled their pesticide application to coincide with these seven (7) developmental stages with or without severe pest infestation, with the majority (57%) applying pesticides at each stage thereby incurring a total of seven (7) applications, regardless of the season. Insecticides were applied at varying frequencies ranging from 4 to 7 applications with an average of 6.42 and 6.43 applications, respectively, during the wet and dry seasons. Typically, insecticides are applied three times before fruit wrapping with light insect pest infestation, and four times with severe insect pest infestation before fruit wrapping, suggesting shorter time intervals between applications for the latter. Also commonly practiced is the application of insecticide immediately before wrapping or on the day of the wrapping, with the last two applications done at about 70-80 DAFI, and 90 to 95 DAFI, or in some farms a few days before harvest with heavy infestation of black ants. Pesticides are extensively used because they reduce yield losses thereby giving economic benefits to the farmers. Losses to pests are estimated to increase by 10% if no pesticides were used at all, and specific crop losses could range from o to nearly 100% (Pimentel et al., 1992). The loss could vary by location, nature of farming, history of pest infestation, and many other factors (Mariyono and Battharai, 2009).

Use of Banned/ Disapproved Pesticides

The most widely-used family of insecticide in terms of the percentage of respondents using them (87%) were Organochlorine. This subgroup of insecticides was introduced in the 1940s against a variety of insect pests. However, the use of this pesticide has been stopped by the U.S. EPA due to its environmental persistence and adverse effects on wildlife and human health. Organochlorines have long environmental half-lives and tend to bioaccumulate and biomagnify in organisms (Barr and Needham, 2002). In particular, most of the sprayer-contractors used the organochlorine Endosulfan. As reported, the use of technical grade Endosulfan and its related alpha isomers and formulations has been banned as pesticides by the FPA because of its ill-effects to health and environment as per FPA Board Resolution No. 01, Series of 2015 [https://fpa.da.gov.ph/index.php/information-resources/pesticide-regulatory-data]. This chemical is no longer available in the local market, however, the surveyed sprayer-contractors can obtain unlabeled "Thiodan" from "backdoor" sources through the intercession of their mango buyers. This corroborates the finding of Plianbangchang et al., (2009) who, in a study on pesticide use patterns among 130 small-scale farmers in Phitsanulok, Thailand in 2007-2008 also reported pervasive and improper use of the banned endosulfan.

Thirty-three surveyed sprayer-contractors used two insecticides that were not approved for mango use by the FPA namely the organophosphate Chlorpyrifos + BMPC (Brodan), and the Carbamate Methomyl (Scorpio). Organophosphorus compounds are acutely toxic, broad-spectrum pesticides that are known to cause irreversible inhibition of the enzyme acetylcholinesterase. On the other hand, Carbamates are reversible inhibitors of the enzyme acetylcholinesterase. Kumar (2015) mentioned that these chemicals kill insects by inhibiting acetylcholinesterase. Thus, these insecticides kill the insects by causing a general release of hormones from the nervous system. With some exceptions, this organophosphorus insecticide does not persist in the environment. However, their large-scale use and their decomposition rates in the environment cause these compounds to accumulate in soils, from where they subsequently enter groundwater and rivers (Sirotkina, Lyagin, and Efremenko, 2012). The improper use of unregistered and non-authorized active ingredients, usually highly toxic pesticides, is not unique to the study areas since it is a practice that is reported to be still existing among some farmers in developing countries (Wang, et al., 2015).

Fungicide Application

On the other hand, the use of fungicides on mango trees was not as pervasive as that of insecticides irrespective of the season. Fungicide application during wet and dry seasons ranged from 0 to 7, with an average of 1.39 applications during the wet season, and 1.3 applications during the dry season. The difference in the percentage of fungicide users between seasons is attributed to the higher incidence of fungus-related infections during the wet season. The data suggest that fungicide use was regarded by a larger number of respondents to be more indispensable during the wet season than the dry season where the incidence of scab, in particular, is widely observed to be higher. Key informants revealed that fungicides are also typically used as preventive measures against the onset of sooty mold and anthracnose during the flowering stages. On the other hand, late applications of fungicides particularly during the fruit set to pre-harvest stages are intended to prevent anthracnose and scab incidence. Left uncontrolled, severe sooty mold infections affect the photosynthetic activity and phytochemical metabolism by damaging leaves and the pericarp of immature fruits thereby lowering yield (Chowdry, 2015). On the other hand, severe scab and anthracnose infections are seen to have a direct impact on fruit esthetic quality thereby causing a reduction in the market value of the fruits.

Dosage of Pesticide Application

Considering all pesticides, the mean total dosage of application was 1138 g.a.i./tree/fruiting season. Inter-sprayer variation was quite large given the standard deviation of 678.488 g.a.i./tree/fruiting season, indicating that some applied excessive quantities of pesticides. However, when the actual dosage of application per 200 li is compared with the recommended dosage per 200 li of water**,** results show that except for Sumicidin, the dosage of application for each of the 14 insecticides applied on mango trees per 200 li was below the recommended rate. This means that on a per chemical basis per 200 li, the respondents were using an underdose of each chemical. However, it should be noted that chemicals were very rarely used alone (Table 4). The pervasive practice is the use of a cocktail of 4 to 5 different chemicals per application thereby increasing the overall rate of application. Additionally, the sprayer-contractors applied pesticides on average about six to seven times, which means that the total dosage per chemical and the total dosage or rate of application for all mixtures of chemicals applied could be much higher. Hence, the dosage of pesticide application might be correspondingly high. This is consistent with the observations of Mariyono, J. and M. Battharai (2009) who reported that higher doses of pesticide application are brought about by the intensity of pest infestation as observed by farmers, frequency of spray in a season, and cocktail method of pesticides spray, among others. All of these factors were present in the surveyed cases.

Pesticides Detected on Mango Fruits Tested

Results show that some mango fruit samples obtained from randomly selected farms yielded positive results for the presence of pesticide residues. Of the 60 fruit samples tested, 11 (18.33%) were found to contain residues of Chlorpyrifos, two (18.18%) of which exceeded the MRL. This proves that pesticide application during the fruiting stages of mango in some farms left residues on the harvested fruits at levels considered unsafe for human consumption. This situation has the potential to put consumers' health at risk since according to Willis (1988) as cited by Rola *et al*. (1999) the acceptable daily intake for an individual is "the level of pesticide residue intake below which the health risks is too small to be of concern; the amount of a chemical which can be consumed every day for an individual's entire lifetime with the practical certainty, based on all known fact, that no harm will result."

Although there is a dearth of recently published reports on pesticide residues on mango fruits in the Philippines, some studies in the Asian region reported pesticide contamination in mango fruits. For instance, Srivastava, et al., (2014) in their study determining the presence of 17 organophosphate pesticide residues in mango in Lucknow, India found that 20% of mango samples tested showed the presence of malathion and chlorpyrifos, although below the maximum residues limits. Similarly, in their study determining pesticide residues in selected varieties of mango picked directly from mango trees in some selected areas in Pakistan, Hussain, et al., (2002), found all samples were contaminated with pesticides, although the residual levels were within the permissible limits being set by FAO/WHO Codex Alimentarius

Commission. Furthermore, results of the study of Bempah, et al., (2011) monitoring pesticide residues in fruits and vegetables in Kumasi Metropolis, Ghana showed that 58% of 25 mango fruit samples tested contained one or more pesticide residues, with 19% of the samples having residues that exceeded the MRL. Jeyanthi and Kombairaju (2005) propounded that the most damaging ecological disturbance of the injudicious use of pesticides is the existence of a high concentration of pesticide residues in the food chain.

The presence of residues in the harvested fruits may be attributed to the failure of some sprayers to follow pest management practices that are in accord with good agricultural practices. Some farmers did not strictly observe proper pre-harvest intervals nor avoided chemicals that are not officially registered for use on mango such as the detected chemical, Chlorpyrifos. Note that some sprayers applied the unregistered Brodan with Chlorpyrifos as active ingredient 2 to 5 days before harvest in violation of the recommended pre-harvest interval.

Non-Detection of Pesticide Residues on Water and Soil Samples

Results show that none of the 15 water samples and 15 soil samples tested contained detectable traces (LOQ of 0.01) of any of the 25 chemicals covered by the multi-residue analysis used by NPAL. Although residues of Chlorpyrifos were detected in 18% of the fruit samples tested, none of the water and soil samples tested were found positive for its presence. Chlorpyrifos is moderately persistent in soils with a half-life from less than 1 day to more than 240 days depending on soil types, soil moisture, soil ph, and initial concentrations (Sing et al., 2003 as cited by Derbalah et al (2003). These factors may have influenced their non-detection. However, although not observed in the present study, the cited studies proved that pesticide use on crops may result in the contamination of water and soils. The chemical residues in the soil pose danger to soil organisms as well as contaminate surrounding water bodies through runoff and leaching. As reported, environmental contaminations from pesticides, disrupt natural water, air, and soil functions, and alter the eco-system, resulting in detrimental effects on nutrient cycles or the toxicity of non-target organisms (Jeyanthi and Kombairaju, 2005).

It is instructive to reiterate, however, that many of the sprayer-contractors used other chemicals such as Thiadizine (20 farmers), Carbamates (45 farmers), Thiocarbamates (63 farmers), and Neonicotinoids (4 farmers) that were not covered by the MRA performed by NPAL which even if present could not have been detected. Hence, subsequent studies on testing pesticide residues in mango fruits, water, and soils must be expanded to include those pesticides that were widely used by farmers but were not covered in the present tests.

CONCLUSION

Pesticide application was the core pest management strategy in all of the surveyed farms and by all sprayer-contractors. It is a pervasive and deeply entrenched practice spawned by farmers' aversion to production risks brought about by the destructive effects of pests on yield and profit.

Pesticide use was extensive with all mango farms applied with varying combinations of insecticides belonging to 8 chemical families, with 13 different active ingredients, not all of which were registered for use on mangos. Fruit-bearing mango trees were calendar-sprayed about 7 times coinciding with each of the 7 flowering and fruit development stages mostly using a cocktail of 4 to 5 chemicals per application particularly during the flowering stages. Except for Chlorpyrifos which were applied 2 to 5 days before harvest, all of the other pesticides were applied following the prescribed pre-harvest interval.

Although, on a per chemical basis per 200 li of water, sprayer-contractors used rates of pesticide application within the recommended dosage in terms of grams of the active ingredient, the high frequency of application coupled with the use of a cocktail of 4 to 5 chemicals per application could have affected the overall rate of pesticide application, and the nature of the chemicals as a result of the mixture.

Frequent application, short pre-harvest interval, and use of unregistered pesticides resulted in the contamination of 18% of fruit samples with residues of Chlorpyrifos. Two of these samples contained residue levels which exceeded the MRL for Chlorpyrifos making them unsafe for human consumption. The prevailing pesticide application practices and dosage of application appeared to leave no detectable pesticide residues on soil and water samples.

RECOMMENDATIONS

Based on the findings of the study, the following recommendations are made.

1. Future studies may consider examining the extent of use and misuse of banned chemicals such as "Thiodan", and pesticides unregistered or unauthorized for use on mangoes and other crops such as chlorpyrifos and methomyl.
2. Pesticide residue tests in succeeding studies should not be limited to the detection of 25 insecticide residues belonging to three chemical families namely: Pyrethroids, Organophosphates, and Organochlorines. It should encompass Thiadizine, Carbamates, Thiocarbamates, and Neonicotinoids, as well as the organophosphate Fenthion that were not covered by the MRA, performed by NPAL even if they were applied by the sprayers.

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STATEMENT OF AUTHORSHIP

JE C. Cubelo conducted the literature search, prepared the conceptual framework, gathered primary and secondary data, transcribed the interviews, processed the data, performed the analysis, and drafted the manuscript on the section on fungicide and pesticide dosage application, and detection of pesticide residues from mango fruit, water and soil. He undertook the writing of the methodology, formulated recommendations and reviewed the overall output of this paper. T.A. Cubelo also conducted the literature search on pesticide application, gathered primary and secondary data, processed the data, performed the analysis, and drafted the manuscript on the section on pesticide application practices and use of banned or disapproved pesticides. Both authors collaborated in the writing of the introduction part of this article and discussed the results and recommendations as well as commented on the manuscript.

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