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Malpractices in the use of agro-veterinary pesticides in plague endemic foci in Tanzania: Potential risk for development of insecticide resistance in flea vectors

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Abstract

Malpractices associated with use of agro-veterinary pesticides are increasingly associated with resistance development in arthropod vectors. We used a questionnaire and direct observations to identify malpractices in the use of pesticides in plague endemic foci, northern Tanzania, which could predispose plague-flea vectors to resistance development. Malpractices in the use of pesticides were common in both districts. More than 80% of the respondents were applying agro-pesticides over 3-times per cropping season, did not adhere to manufacturers' recommendations and had limited/no knowledge on safety procedures and adverse effects of the pesticides. Up to 49% of the respondents were applying pesticides over twice the recommended doses. The 3 out of 14 most commonly used agro-pesticides in Lushoto were master kinga72WP (mancozeb+cymoxanil), suracron720EC (profenos) and Sumo 5EC (lambda-cyhalothrin). The 3 out of 17 most commonly used agro-pesticides in Mbulu were Dursban50W (Chlorpyrifos), Duduban 450EC (Cypermethrin+chloropyrifos) and Dursban+farmerzeb. Cybadip (Cypermethrin) and paranex (alphacypermethrin) were the most commonly used veterinary pesticides. In conclusion, these results suggest high risk of contamination of environments or surfaces and exposure of flea vectors with agro-pesticides. Thus, warrant studies to show a causal link between misuse of agro-veterinary pesticides and development of resistance in fleas in endemic areas across Tanzania.

Keywords: Fleas, malpractices, pesticides, resistance

Introduction

Plague is a life-threatening disease caused by a highly infectious bacterium, *Yersinia pestis*. The disease is transmitted to humans from infected rodents primarily by fleas [1]. More than eight flea species can transmit the bacteria [2]. The most common and widely distributed species include *Xenopsylla cheopis*, *Xenopsylla brasiliensis* and *Dinopsyllus lypusus* [3]. The first two species have played a significant role in most plague outbreaks due to their high transmission efficiency and broad host preference [4].

Measures targeted on flea vectors, mostly chemical insecticides, remain the most effective and widely used approach for controlling plague. This approach has significantly reduced plague in most if not all endemic countries; however, its long-term effectiveness is challenged by the development of resistance in flea vectors. Some countries have reported resistance in plague flea vectors virtually against all recommended classes of insecticide [5, 6].

Based on classical thinking, all cases of insecticide resistance in arthropod vectors including fleas are exclusively attributed to selection pressure from the public health pesticides. Implying that, all quiescent plague endemic areas without long-standing application of public health pesticides are not at risk of insecticide resistance. This assertion might put such areas in great danger during plague outbreaks, which are often unpredictable because there are increasing reports associating agrochemicals to development of resistance in disease vectors [7-10]. To the best of our knowledge, no study has been conducted to assess malpractices of agro-veterinary pesticides in plague endemic foci in Tanzania which potentially predispose plague flea vectors to resistance development. Small-scale farmers in different parts of Tanzania are increasingly reported to misuse agro-veterinary pesticides, thus predisposing non-targeted organisms and ecosystems to pesticides-associated negative impacts [9, 10, 11-12]. Therefore, this study identified malpractices in the use of agro-veterinary pesticides which potentially enhance contamination of environments/surfaces and exposure of flea vectors to such pesticides.

The long-term exposure of plague flea vectors to agro-veterinary pesticides could purportedly select for insecticide resistance. The results would warrant for subsequent studies to confirm a causal link between identified malpractices and development of resistance in such vectors under realistic settings.

Materials and Methods

Study area

This study was done in the selected villages of Lushoto and Mbulu district, Southern Tanzania (Figure1). Lushoto district in Tanga region is situated at the West Usambara Mountains, which forms part of the Eastern Arc Mountains (04º22'-05º08'S, 038º05'-038º38'E). The district lies at the altitude of 900 to 2,250 m above the sea level. The long rain season runs from March to May; and short rain season runs from November to December, with a mean annual rainfall of 1070mm and temperature of 17ºC. The dry season runs from July to October. The district has a population of 492,441 people. Mbulu District in Manyara region is bordered to the north by Arusha region and lake Eyasi; and to the west by Singida region (3º57'1"S, 35º18' 40"E). It covers a total surface area of approximately 3,800km^2; and lies between 1000-2400 m above the sea level. The long rain season runs from January to May; and short rain season runs from November to December, with a mean annual rainfall of 994mm and temperature of 17.5 ºC. The dry season runs from June to October. The district has a population of 320,279 people.

Study population

The study was done in four (Viti, Lukozi, Ndabwa and Mavumo) and two (Arri and Mongahay) villages in Lushoto and Mbulu district respectively. All the six villages had a history of a plague outbreak. Crop cultivation is the main economic activity both in Lushoto and Mbulu district. The main crops in Lushoto district include maize, beans, potatoes, vegetables and fruits. The main crops include maize, beans, potatoes, wheat and vegetables. Besides, the communities in Mbulu district are actively involved in livestock keeping.

Data collection

The study villages were selected using a purposeful sampling technique based on two main criteria: having experienced plague outbreaks at least twice and proximity to active and/or fallow agricultural fields. Two hundred (200) randomly selected households, 100 per district, were used for this study. Salespersons from four agro-vet shops within each district were selected based on their involvement in such business within the last two years and above. Data collection was done using a standard questionnaire with structured and semi-structured questions. The questionnaire was written in English and translated into Kiswahili, a national language which was understood by all of the respondents in the study areas. Only one person per household/agro-vet shop was interviewed after a verbal consent. The questionnaire was supplemented with direct observations to confirm certain responses where participants could provide evidence, for example, presenting containers of the pesticides they were using and demonstrating the preparation of spray solutions. The survey aimed at gathering information related to the use of agro-veterinary pesticides: following manufacturers' application instructions and safety procedures, and routine practices in terms of commonly used pesticides, frequency of applying pesticides, use of agricultural pesticides on livestock and vice versa, compliance with applicable safety procedures, adherence to manufacturers recommended doses and keeping animals inside living houses.

Data analysis

The data were summarized and analyzed by using Epidemiological Information Epi Info^{TM} version 7.2.3.1(CDC) and Excel to obtain appropriate percentages and frequencies. These descriptive results are presented in figures and tables.

Results and Discussion

Socio-demographic characteristics

Majority of the respondents were males, 55(55%) in Lushoto and 58(58%) in Mbulu. Majority of the respondents were below 35 years of age followed by those of 36 and 45 years of age in Lushoto and Mbulu respectively. Most respondents in Lushoto (n = 71, 71%) and Mbulu (n = 83, 83%) had primary education. The proportion of respondents with secondary education was higher in Lushoto (24%) than Mbulu (14%). Only three (n=3) respondents across the study districts had a college education. The remaining respondents, 3(3%) in Lushoto and 2(2%) in Mbulu had formal education (Table 1). Farmers with primary education only are mostly unable to understand the manufacturer's labeling and instructions, particularly because they are written in English. Possibly due to illiteracy and cost, farmers in certain parts of Tanzania agree to buy and use pesticides without seeing the original packages, as pesticides were usually sold by weight or already diluted without labeling [13]. These increase the likelihood of pesticides misuse and risk of undesirable effects to the environment and non-targeted organisms. Arguably, the assurance that farmers and other end-users acquire the desirable knowledge and instructions from salesmen and extension workers would minimize the chances of malpractices and anticipated risks. Unfortunately, such extension services are either lacking or untimely across many rural communities including the current study area due to shortage of extension officers [14, 15]. Also, studies have reported poor quality services in most salesmen and extension offices across the country because they are either incompetent or did not undergo relevant training [15].

Common agricultural pesticides and malpractices

Most respondents, 91% in Lushoto and 93% in Mbulu reported using pesticides against crop pests during the 3-months cropping season. The rest, 9% in Lushoto and 7% in Mbulu reported that they were not using pesticides at all. The overreliance in chemical pesticides against insect pests of crops, livestock and humans is common in Tanzania and the rest of the world [16-18]. However, this is not surprising because pesticides remain the most efficient, cheap and widely accessible measure for control of insect pests [18, 19-20]. About one-third of agricultural, forestry and livestock production losses worldwide annually are associated with insect pests [19]. Because of that concern, crop production in Tanzania has correspondingly increased in tandem with the use of large quantities of pesticides.

Since 1992, the use of pesticide has rapidly increased following agrochemical trade liberalization in the country [11]. From then on, the availability and access to pesticides including unregistered products have erratically increased throughout the country [11]. This study documented over 14 brands of agro-pesticides. These agro-pesticides belonged to five main classes including carbamates, pyrethroids, organophosphates, organochlorines and avermectins. However, pyrethroids were the most predominant pesticides. In Lushoto, the most commonly used pesticides were master kinga72WP (mancozeb 640g/kg+cymoxanil 80g/kg) (44%), suracron720EC (profenos 500g/l EC) (25.3%) and Sumo 5EC (lambda-cyhalothrin) (18.7%) (Table 3). In Mbulu, the most commonly pesticides were Dursban50W (chlorpyrifos) (29%), Duduban 450EC (Cypermethrin 10g/lt+chlorpyrifos 35g/lt) (18%) and Dursban+farmerzeb (Chlorpyrifos 48%, Mancozeb 80%WP) (Table 4). These and other pesticides documented in the present study are also common elsewhere in the country [15, 17, 21]. Most chemical products used against fleas and other arthropod vectors belong to the first four classes, but pyrethroids are the most widely spread and used. This suggests a high likelihood of cross-resistance in flea vectors emanating from agro-pesticides commonly used in the study area, particularly when such chemicals are applied in ways that enhance exposure. Most public health pesticides are reformulations of pesticides that were once used in agriculture [22]. This emphasizes the assertion that on-going use of agricultural and veterinary chemistries similar to those used against fleas poses a threat to resistance development.

This study documented several malpractices related to the use of agro-veterinary pesticides, all of which enhance the possibility of exposing fleas to those chemicals. Excessive use of pesticides within a 3-month cropping season was common across the study districts. In Lushoto, the majority (n=73; 80%) applied pesticides more than three times per cropping season. In Mbulu likewise, the majority applied pesticides two (n=39; 42%) or more than three times (n=35; 38%) per cropping season (Fig. 3). Although all respondents reported to had acquired the necessary knowledge on the type, handling and applications of pesticides from the salesmen and extension officers, the majority did not adhere to the application and safety instructions indicated by the manufacturers. 49 (53.4%) respondents in Lushoto and 39 (42%) respondents in Mbulu applied more than twice the recommended doses. The rest, 18 (19.8%) in Lushoto and 25 (27%) in Mbulu (Fig. 3), claimed to apply recommended doses; however, they were unable to demonstrate that. As such, agricultural fields are excessively contaminated with such pesticides thus potentially increasing the likelihood of exposing flea vectors while on contaminated rodents and/or burrows. During rains, soils in rodent burrows and other habitats become contaminated via run-off of pesticides. Studies have reported alarming contamination of soils, water, air and other types of environments with agricultural chemicals [23-25]. Larval and adult fleas are predominantly associated with rodents and therefore they are mainly found on loose soils of rodent burrows in agricultural fields and other environments. Consequently, the fleas coincidentally contact untargeted pesticides and other control agents. Resistance to various chemicals in rodent fleas may be selected either at the larval or adult stage. Gratz [26] reported that indoor residual spraying (IRS) with DDT against mosquitoes affected the susceptibility of plague flea vector *Xenopsylla cheopis*. Oftentimes farmers get tempted to use agricultural pesticides as alternatives against fleas and other public health pests because they are comparatively cheaper. Our co-workers witnessed such practices during their previous visits to the present study areas. Switching of pesticides to unintended uses is also common elsewhere [27], and thus increases the risk of exposure and selection for resistance in fleas.

Common veterinary pesticides and risk of flea exposure

Three veterinary pesticides in Lushoto and five in Mbulu district were used for control of livestock pests and all of them were pyrethroids. In Lushoto, the most commonly used pesticides were cybadip (cypermethrin) followed by paranex (alphacypermethrin) and tick-tick (permethrin) (Fig. 1). The first two were by far the most commonly used pesticides in Mbulu (Fig. 2). These pesticides were mainly used on goats and cattle against ticks. Most respondents (95%) did not adhere to the manufacturer's recommended doses, safety procedures and frequency of application. These chemicals were only applied during excessive infestation and in doses far less than recommended, possibly due to their high cost. Like elsewhere in Tanzania, cans and other leftovers of these pesticides were disposed of haphazardly [15] thus enhancing contamination of the environment and other surfaces. As such, fleas can be exposed to those chemicals, most likely on lower doses than required, either on treated animals and/or contaminated soils/surfaces. Livestock serve as alternative blood-meal sources for fleas [28]. Exposure through animals is potentially enhanced by frequent interactions between commensal rodents and domestic animals. These interactions are frequent in areas where animals are kept inside living houses during the night. The tendency of keeping livestock inside living houses during the night was observed in Mbulu during the current study.

Common pesticides against fleas

The majority of pesticides that respondents reported to use in Lushoto and Mbulu belonged to two main classes: pyrethroids and carbamates (Table 5). However, like in agro- and veterinary-pesticides, pyrethroids were the most predominant class. Synthetic pyrethroids have become the most popular and prevalent active ingredients for public health use due to their relatively low mammalian toxicity but high invertebrate potency at low levels, resulting in rapid immobilization ('knockdown') and killing [29].

The animals, mainly calves and goats, were only sprayed on body parts preferred by the fleas using small portable hand sprayers. The powder formulation of carbamates was sprinkled inside living houses with hands. The application of flea control pesticides in study districts was restricted indoors on a few parts of the house and was done exclusively during the dry season when flea abundance was intolerably high. Even during that period of high infestation, only a few respondents reported affording chemical pesticides. Alternatively, they poured hot water on the floors of their living houses. Therefore, the use of deployment of specific flea control pesticides was probably inadequate to select for resistance.

Conclusions

Any forms of malpractices which enhance the exposure of plague vectors to agro-veterinary pesticides constitute risk factors for resistance development. The present study documented a suite of malpractices including abnormally high frequency of agro-pesticide application, use of abnormally high doses of agro-pesticides and poor adherence to the application, disposal and safety procedures for agro-veterinary pesticides. These malpractices/injudicious uses are potentially enhancing contamination of environments/surfaces and exposure to flea vectors (thereof). As such, flea vector populations across the two plague endemic districts are purportedly in a high risk of developing insecticide resistance from agro-veterinary chemicals. The results warrant studies to confirm a causal link between malpractices on agro-veterinary pesticides and the development of resistance in fleas across plague endemic foci across Tanzania.

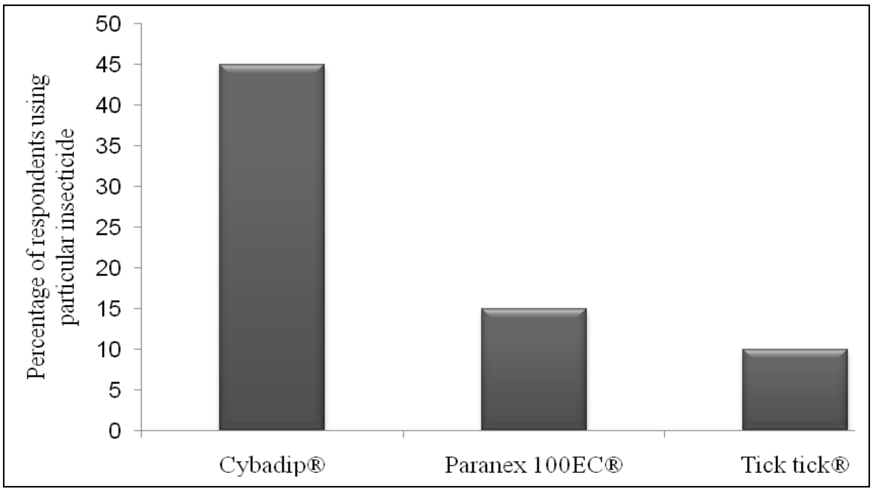

Fig 1: Veterinary pesticides commonly used against livestock pests in Lushoto district: Cybadip® (cypermethrin 15%m/v), Paranex100EC® (alphacypermethrin) and Tick tick® (permethrin). All of them are pyrethroids.

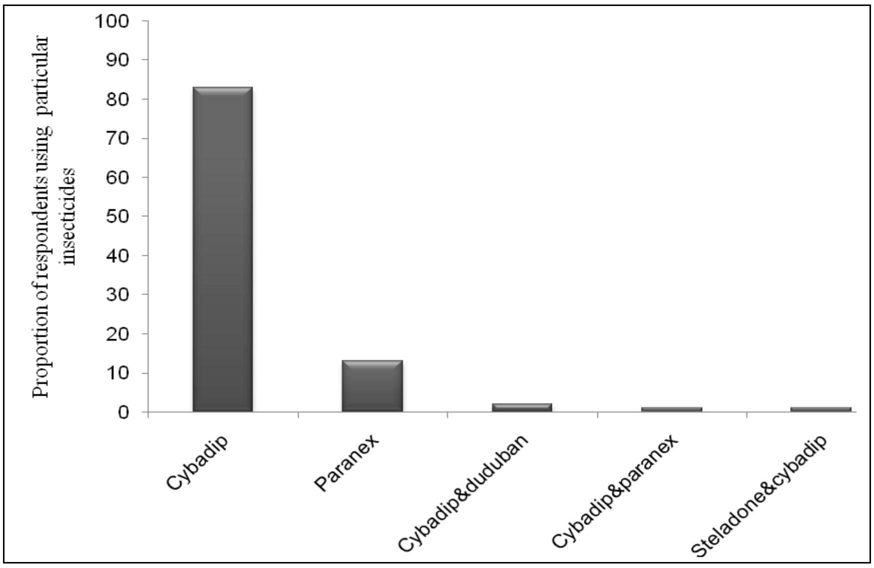

Fig 2: Veterinary pesticides commonly used against livestock pests in Mbulu district: Cybadip® (cypermethrin 15%m/v), Paranex® (alphacypermethrin), Cybadip® & Paranex® and Steladone® & cybadip®. The last two sets of insecticides represent cases where respondents reported to be using the two insecticides interchangeably.

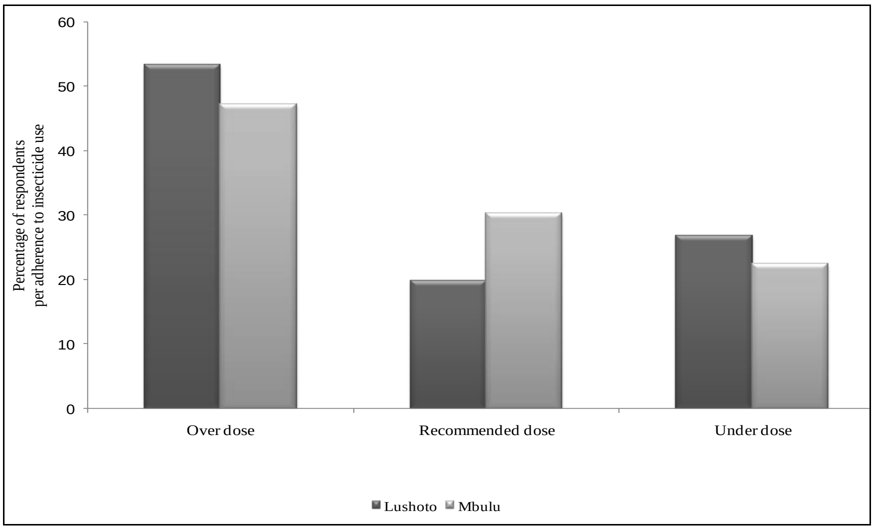

Fig 3: The respondents' adherence to manufacturers recommended doses of agricultural pesticides in Lushoto and Mbulu district.

Table 1: Socio-demographic characteristics of respondents from Lushoto and Mbulu district (each n=100)

Category	Percentage of respondents in Lushoto district (%)	Percentage (%) of respondents in Mbulu district (%)
Male	55	58
Female	45	42
Age categories		
Less than 35	41	20
36 to 45	25	52
46 to 55	21	18
More than 55	13	10
Education level		
Formal	3	2
Primary	71	83
Secondary	24	14
College/University	2	1

Table 3: Commonly used agricultural pesticides in Lushoto district (n = 91)

Class of pesticide	Trade name	Active ingredient	Percentage of respondents (%)
Carbamates	Master kinga72WP	Mancozeb 640g/kg+Cymoxanil 80g/kg	44
Organophosphates	Suracron 720EC	Profenos 500g/l EC	25.3
Pyrethroids	Sumo 5EC	Lambda-cyhalothrin	18.7
Organophosphates	Profecron 720 EC	Profenos 500g/l EC	15.4
Pyrethroids	Karate 5EC	Lambda-cyhalothrin	15.4
Pyrethroids	Ninja plus 5%EC	Lambda-cyhalothrin	14.3
Avermectins/neonicotinoids	Dudumectin	Emamectin 4.8% + acetameprid 6.4%	14.3
Carbamates	Farmerzeb 80WP	Mancozeb 80%WP	11
Carbamates	AMSAC	Indoxacarb 14.5%SC	7.6
Carbamates	Indofil M45	Mancozeb 80%	4.4
Pyrethroids	Kungfu	Lambda-cyhalothrin	4.4
Organochlorines	DDT		3.3
Organophosphates	Wilcron	Profenos 720EC	3.3
Carbamates	Dithane M55	Mancozeb 80%	2.1

Table 4: Commonly used agricultural pesticides against crop pests in Mbulu district (n = 93)

Class of pesticide	Trade name	Active ingredient	Percentage of respondents (%)
Organophosphates	Dursban	Chlorpyrifos48%	29
Pyrethroids/ organophosphates	Duduban	Cypermethrin 10g/lt+chloropyrifos 35g/lt	18
Organophosphates/ Carbamates	Dursban, farmerzeb	Chlorpyrifos48%, Mancozeb 80%WP	9
	No pesticide use		9
Pyrethroids/ Organophosphates	Duduban, ninja	Cypermethrin 10g/lt+chloropyrifos 35g/lt	8
Carbamates	Farmerzeb	Mancozeb 80%WP	6
Pyrethroids	Ninja plus	Lambda-cyhalothrin 50g/lt	5
Pyrethroids/ Organophosphates	Duduban, dursban	Cypermethrin 10g/lt+chloropyrifos 35g/lt, Chlorpyrifos 48%	2
Pyrethroids/ Organophosphates/ Carbamates	Duduban, farmerzeb	Cypermethrin 10g/lt+chloropyrifos 35g/lt, Mancozeb 80%WP	2
Pyrethroids/organophosphates	Karate, Dursban	Lambda-cyhalothrin, Chlorpyrifos 48%	2
Avermectins/neonicotinoids	Dudumectin	Emamectin 4.8%+ acetamiprid 6.4%	1
Organophosphates/ Pyrethroids	Dursban, karate	Chlorpyrifos48%, Lambda-cyhalothrin	1
Carbamates/ Organophosphates	Farmerzeb, duduban Dursban	Mancozeb80%WP,cypermethrin 10g/lt+chloropyrifos 35g/lt, Chlorpyrifos48%	1
Carbamates/ Pyrethroids	Farmerzeb, ninja	Mancozeb 80%WP, Lambda-cyhalothrin	1
Pyrethroids	Karate	Lambda-cyhalothrin	1
Pyrethroids/ Organophosphates	Karate, duduban	Lambda-cyhalothrin, cypermethrin 10g/lt+chloropyrifos 35g/lt	1
Pyrethroids	Karate, ninja	Lambda-cyhalothrin	1
Carbamates	Thionix	Zinc dimethyl dithiocarbamate 98.2%	1

Table 5: Commonly used pesticides against fleas in Mbulu and Lushoto district

District	Class of pesticide	Trade name	Active substance	Percentages of respondents (%)
Mbulu	Pyrethroids	Cybadip	Cypermethrin	42
		No Pesticide use		16
	Carbamates	Dudu dust	Carbaryl 75g/kg	14
	Organophosphates	Dursban	Chlorpyrifos 48%	12
	Pyrethroids	Paranex	Alphacypermethrin	8
	Carbamates	Akheri powder	Carbaryl5%w/w+Lambdacyhalothrin 0.1%w/w	5
	Pyrethroids	Cybadip, dudu dust	Cypermethrin, Carbaryl 75g/kg	1
	Pyrethroids/ Organophosphates	Cybadip Dursban	Cypermethrin, Chlorpyrifos 48%	1
Lushoto	Carbamates/ Pyrethroids	Akheri powder	Carbaryl 15%w/w + Lambda cyhalothrin 0.1w/w	4
	Pyrethroids	Paranex100EC	Alphacypermethrin	2
	Pyrethroids/ Organophosphates	Duduban	Cypermethrin 10g/lt+chloropyrifos35g/lt	1

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Author's contributions
All authors contributed to data collection and analysis, drafting or revising the article, gave final approval of the version to be published, and agree to be accountable for all aspects of the work.

Competing interests
The authors declare that they have no competing interests.

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