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Pesticide Use Practices in Root, Tuber and Banana Crops by Smallholder Farmers in Rwanda and Burundi

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Abstract: Misuse and poor handling of chemical pesticides in agriculture is hazardous to the health of farmers, consumers and the environment. We studied the pest and disease management practices and the type of pesticides used in four root, tuber and banana (RTB) crops in Burundi and Rwanda through in-depth interviews with a total of 811 smallholder farmers. No chemical pesticides were used in banana in either Rwanda and Burundi, whereas the use of insecticides and fungicides in potato is quite frequent. Nearly all insecticides and about one third of the fungicides used are moderately hazardous. Personal protective equipment is used by less than a half of the interviewed farmers in both countries. Reported cases of death due to self- or accidental poisoning among humans and domestic animals in the previous 12 months were substantial in both countries. Training of farmers and agrochemical retailers in safe use of pesticide and handling, and use of integrated pest management approaches to reduce pest and disease damage is recommended.

Keywords: fungicides; insecticides; occupational health; personal protective equipment; poisoning; safety measures; training; integrated pest management.

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1. Introduction

Roots, tubers and bananas (RTB) are important cash and food security crops in many countries in sub-Saharan Africa (SSA). Banana (*Musa* spp.), cassava (*Manihot esculenta* Crantz), potato (*Solanum tuberosum* L.) and sweetpotato (*Ipomoea batatas* L. Lam) are highly important staple crops in the livelihoods of smallholder farmers in the Kivu region of Central Africa. Consumption of orange-fleshed sweetpotato, yellow cassava, east African cooking banana and table potato in combination with iron-rich beans (*Phaseolus vulgaris* L.) help to reduce malnutrition but also increases household cash income through sell of surplus food [1, 2]. Annual production of banana, cassava, potato and sweetpotato in Burundi is estimated at 1.363, 2.242, 0.181 and 0.664 million tons, and in Rwanda at 1.805, 3.159, 2.214 and 0.941 million tons, respectively [3]. Average per capita consumption of sweetpotato in Rwanda (89 kg kg/pers/yr) is almost six times higher than the world average of 14 kg/pers/yr. Banana consumption in Rwanda (144 kg/pers/yr) is also the second highest in the world. In addition, Rwanda is ranked 5th in the world in consumption of cassava [4]. Potato consumption in Rwanda was estimated at 125 kg/pers/yr [5].

There is also a growing interest in promoting diet-based approaches to fight malnutrition in SSA and one such example is the use of orange-fleshed sweetpotato to reduce vitamin A deficiency among children, pregnant women and breast-feeding mothers[6]. The pioneers of this biofortification program were recognized with the prestigious 2016 World Food prize [7]. Banana, cassava and potato are also among the 10 most important priority crops in the Crop Intensification Program of the Government of Rwanda to reduce food insecurity [8]. The RTB program of the CGIAR has also made substantial investments in Eastern, Central and Southern Africa towards achieving food and income security through funding research and development projects, including the Pest Risk Assessment (PRA) project that has activities in Burundi and Rwanda [9].

Despite the importance of RTB crops in the livelihoods of smallholder farmers, their production in Rwanda and Burundi is limited by numerous pests and diseases [4], which may cause yield losses of up to 100%. Most important are late blight caused by *Phytophthora infestans* (Mont.) de Bary, bacterial wilt caused by *Ralstonia solanacearum* Smith, aphids (*Aphis gossypii* Glover, *Aphis fabae* Scopoli, *Macrosiphum euphorbiae* Thomas, and *Myzus persicae* Sulzer) and potato tuber moth (*Phthorimaea operculella* [Zeller]) in potato; cassava mosaic virus disease (CMD), cassava brown streak disease (CSDS) and whitefly (*Bemisia tabaci* Gennadius) in cassava; Xanthomonas wilt of banana (BXW) caused by *Xanthomonas campestris* pv. *musacearum* (Yirgou & Bradbury 1968) Dye 1978 and Fusarium wilt caused by *Fusarium oxysporum* f. sp. *cubense* (E.F.Sm.) W.C.Snyder & H.N.Hansen in banana; sweetpotato virus diseases (SPVD) and sweetpotato weevils (*Cylas puncticollis* Boheman and *C. brunneus* Olivier) in sweetpotato [Okonya et. al., in preparation].

In response to high pest and disease pressure, farmers use several control measures to reduce yield and post-harvest losses including the application of pesticides. Unlike in non-commercial food crops, which command low prices in the local market, in high value cash crops in SSA like potato, coffee (*Coffea* spp.) cotton (*Gossypium hirsutum* L.), tomato (*Solanum lycopersicum* L.), eggplant (*Solanum melongena* L.), beans and a number of horticultural crops, farmers frequently use pesticides to control pests and diseases [10, 11]. Statistics on the annual rates of pesticide use in

Rwanda and Burundi are scarce but can be estimated at an average of 1 kg/ha. The proportion of large scale farmers using pesticides in Rwanda is increasing and was estimated at 46.7% in 2015 [12]. There is consensus among farmers in Burundi and Rwanda that the frequency of pesticide application per cropping system has increased in recent decades due to increased prevalence of pests and diseases. Recent studies in both countries reported that more than half of farmers used insecticides in beans and tomato [13, 14]. Pesticide use frequency on tomato was up to twice a week in Burundi with most farmers applying fungicides (Mancozeb 80%) directly on tomato fruits [14]. However, information on pesticide use practices in RTB crops in Rwanda and Burundi is not available, and studies on the use of personal protective equipment (PPE), exposure symptoms, handling, overuse are few.

Inspections of pesticide retail outlets or banning the importation of certain pesticides require strict enforcement of pesticide legislation which is an expensive monitoring process that rarely receives enough national funding in many developing countries to protect farmers, consumers and the environment. Use of hazardous pesticides involves several risks and requires knowledge of health and safety measures during pesticide applications [15]. Risk of pesticide poisoning is also high when using leaking knapsack sprayers, purchasing pesticides in unlabeled containers, storing pesticides close to/with foodstuffs/food items or in the reach of children, and when PPE is used improperly. Due to this high risk of pesticide poisoning, adequate training of farmers and the use of PPE while handling pesticides is key. Factors that may increase risks of pesticide poisoning can include low level of income, fewer years of formal education, poor knowledge of negative effects of pesticide use, inability to read and understand pesticide labels, reluctance of farmers to use PPE based on their perceptions and attitudes of risk, lack of adequate farmer training in the use of pesticides and gender of person spraying.

Due to the negative effects of pesticides to human health [16-18], coupled with the need to introduce environmentally sustainable intervention measures including Integrated Pest Management (IPM) an investigation into pesticide use practices among smallholder farmers in Rwanda and Burundi was initiated. Results from this study could then feed into awareness creation of the current situation and highlight the need to enforce pesticide legislation and alternative control methods such as IPM. Findings of this study can be a great resource to several stakeholders in the pesticides value chain including policy makers, health professions, vector control programs, agricultural extension workers, sellers of chemical pesticides and smallholder farmers.

Improper use of pesticides has been linked to high levels of residues by persistent organic pollutants such as Dichlorodiphenyltrichloroethane (DDT) in tilapia fish from Lake Tanganyika [19], severe reductions in populations of beneficial insects such as pollinator bees and parasitoids [20], contamination of surface water in Lake Kivu with malathion, metalaxyl and carbendazim [21], human diseases and suicide [16, 22]. Pesticide residues have been reported in breast milk [23-25], fruits and vegetables [26].

Despite the harmful effects that can result from pesticide use, regulations on safe pesticide use are lacking in Burundi and Rwanda. This leaves decisions on pesticide storage, sale, packaging, labelling, transportation and handling to untrained commercial sellers who are only interested in

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maximizing profit. However, even in other countries where laws exist, their enforcement at farm and retail level remains a challenge.

This paper focusses on understanding the current pesticide use practices among the four RTB crops in both Rwanda and Burundi. This study was part of a larger project whose goal is to mitigate the likelihood of introduction, emergence, and spread of RTB pests and pathogens due to increased globalization of trade, human movement, farming practices and climate change [9]. Information gained in this study can be used by public health professions, policy makers, agricultural extension workers and research scientists when designing intervention programs on IPM including the safe use and handling of pesticides.

2. Materials and methods

2.1 Survey area and tool

The data were collected as part of a household survey carried out in Rwanda and Burundi [Okonya et al., in preparation]. Households interviewed were randomly selected and participation was entirely voluntary. Individual face-to-face farmer interviews were conducted in two project action sites of Rwanda (Ruhengeri watershed comprising the districts of Musanze, Burera, Ngororero, Gakenke and Nyabihu) and Burundi (Rusizi watershed near Lake Tanganyinka comprising the provinces of Bubanza, Bujumbura rural, Chibitoke and Muramvya). A total of 811 households which had grown at least one of the four RTB crops (banana, cassava, potato, and sweetpotato) in the previous cropping season were interviewed. In collaboration with the Rwanda Agricultural Board (RAB) and Institute des Sciences Agronomique du Burundi (ISABU), the questionnaire was translated into Kinyarwanda for Rwanda and into French for Burundi. Administering the questionnaire in Burundi was in French and Kirundi while in Rwanda it was in Kinyarwanda. Enumerators were trained for two days and the questionnaire was pre-tested in districts outside of the survey area.

The household survey specifically aimed to assess farm household demographics and the existing pest and disease control methods with special emphasis on the use of chemical pesticides, and their toxicity and application frequency; evaluate the protective measures used by farmers to reduce exposure to pesticides; document the cases of acute poisoning experienced by farmers while handling pesticides; determine the level of knowledge of farmers about pesticide handling including source of information, their attitudes and perceptions of negative effects and determine the factors that influence the number of PPE used (is it income/education/age/sex/attitude/other experience).

2.2 Ethical statement

Oral informed consent was sought from study participants after explaining the objectives of the study. Participation was therefore voluntary, and farmers were assured that the collected information will be treated fully confidentially. The farmers were also free to- or not to- answer any questions or to withdraw from further participation in this interview at any time. It was also explained that declining or withdrawing from the interview will not have any negative

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consequence to the farmer and will not prevent him/her from benefitting from the results of the survey. An equivalent of the labour cost for one day were paid to the farmer after the interviews as compensation for lost time.

2.3 Statistical analysis

ANOVA and chi square tests were used to analyze the survey data for descriptive parameters[27]. Further, we applied regression models to analyze relationships of different variables [28].

3. Results

3.1 Pest and disease management practices

Potato: In Burundi, most potato farmers (79.8%) use several cultural methods (Fig. 1) to control pests and diseases such as uprooting of infected plants to control bacterial wilt (73.6%), use of healthy pest and disease-free seed from NGOs, development agents, and/or agro-dealers to reduce virus diseases, bacterial wilt and potato tuber moth infestation (20.9%), crop rotation (44.2%), intercropping with maize (*Zea mays* L.), garden pea (*Pisum sativum* L.), beans or taro (*Colocasia esculenta* (L.) Schott) (34.9%), early planting (17.8%), or late planting to escape late blight infection (14.7%), use of physical traps to control mole rats (*Tachyoryctes* spp.) (17.8%), or handpicking of cutworms (*Agrotis* spp.) (16.3%). Use of fungicides (55%) is significantly higher compared to insecticides (11.2%). Fungicides are applied to control late blight while insecticides are mainly sprayed to control leafminer flies (*Liriomyza* spp.) and potato aphids. A considerable number of interviewed farmers couldn't specify the target insect pests (84.6%) or diseases (36.6%), respectively. Herbicides have not been mentioned by farmers to be used in potato.

Combining different cultural practices are also a dominating farming practice in Rwanda (79.7%) to reduce pests and diseases. Uprooting of infected plants is applied to reduce bacterial wilt (64%). 43.6% of farmers also use healthy seed and 54.8% crop rotations, intercropping (25%), or planted early to escape pests and diseases (27.8%). The use of insecticides (41.2% *versus* 11.2% of farmers, respectively) and fungicides (75.3% *versus* 55%) was significant higher in Rwanda compared to Burundi (Fig 1).

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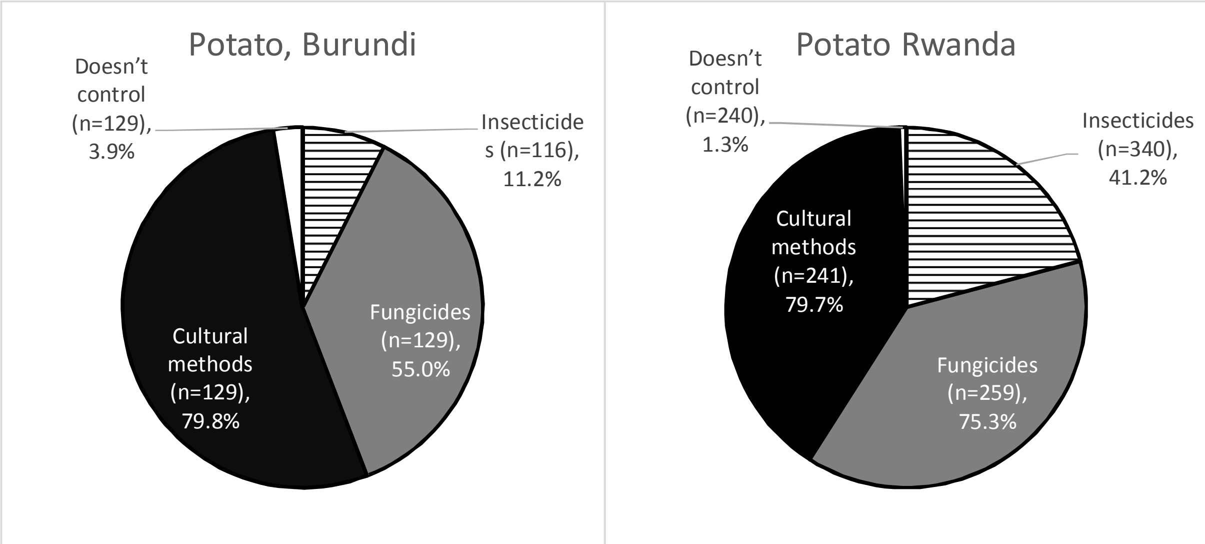

Figure 1: Pest and disease management practices used in potato in Burundi and Rwanda. Multiple responses were possible.

Sweetpotato: Cultural practices were widely used by farmers in Burundi (65.7%) to control sweetpotato pests and diseases (Fig. 2); this included uprooting of virus infected plants (74.1%), crop rotation (63.5%), intercropping with cassava, banana or beans (6.5%), and use of clean vines from private decentralized vine multipliers (13%). Few farmers (10%) do not control pests and diseases and 14% applied insecticides to control the sweetpotato butterfly. Farmers' didn't use either fungicides nor herbicides in both countries.

The proportion of Rwandan sweetpotato farmers using at least one cultural method was higher than in Burundi (83.1%). The most commonly used practice was crop rotation (56.6%) followed by the use of clean vines (49.6%), physical traps for mole rats (39.3%), uprooting of virus infected plants (38.7%) and early harvesting to control sweetpotato weevils (29.3%). Hand picking of sweetpotato butterfly larvae was practiced by 15 % of farmers. Like in Burundi, a small proportion of sweetpotato farmers applied insecticides in Rwanda (12.5%) to control the sweetpotato butterfly.

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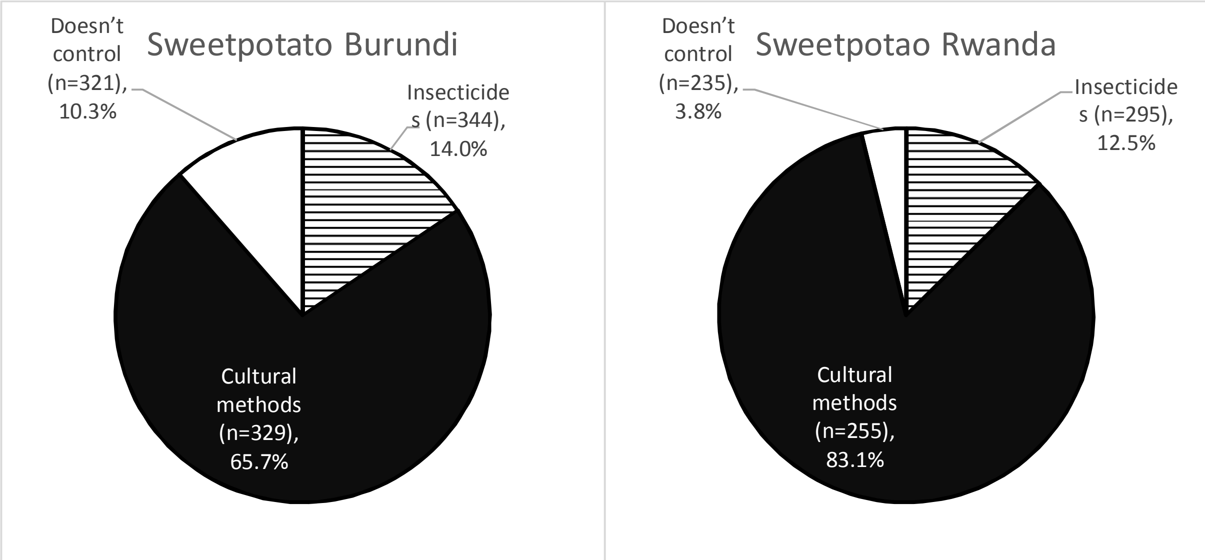

Figure 2: Pest and disease management practices used in sweetpotato in Burundi and Rwanda. Multiple responses were possible.

Banana: Out of 244 and 209 banana farmers interviewed in Burundi and Rwanda respectively, none of them used any pesticide. However, 85.6% of banana farmers in Burundi and 75.4% in Rwanda used at least one cultural control method. Among the various cultural control methods, uprooting/removal of diseased plants to control banana *Xanthomonas* wilt was the most frequently used practice (94.5% in Burundi and 73.6% in Rwanda). Use of clean suckers (17.1% in Burundi and 44.2% in Rwanda), crop rotation (17.1% in Burundi and 15.5% in Rwanda) and intercropping of banana with millet and sweetpotato (48.7% in Burundi and 36.4% in Rwanda) were additional cultural control methods reported in the survey.

Cassava: A few cassava farmers (2.3% in Burundi and 4% in Rwanda) applied chemical insecticides to control the mealybug (*Phenacoccus manihoti* Matile-Ferrero), and cassava whiteflies (Fig. 3). Use of at least one cultural control method in cassava was common in Rwanda as well (95.9%). The cultural control methods used by farmers in Rwanda were uprooting of infected plants (80.9%), crop rotation (52.1%), intercropping with maize (48.9%) and use of virus free cuttings from the Agricultural research stations (46.8%).

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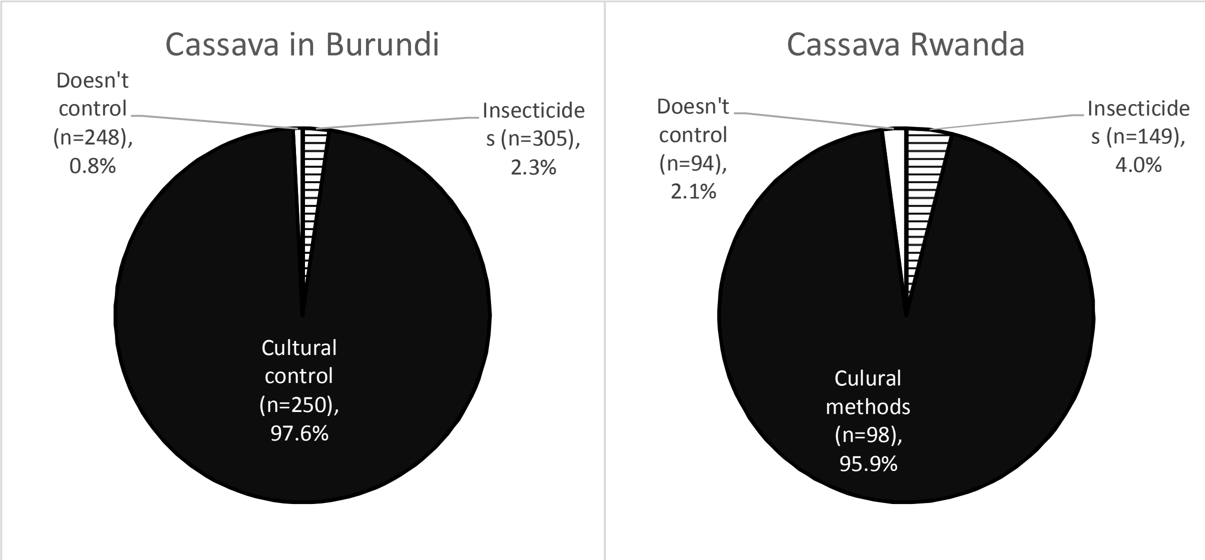

Figure 3: Pest and disease management methods used in cassava in Burundi and Rwanda. Multiple responses were possible.

3.2 Pesticides used

Active ingredients and toxicity classes

The ten insecticides used by interviewed farmers in Rwanda were based on four active ingredients (chlorpyriphos, cypermethrin, profenofos, and dimethoate) either individually formulated or in combination and belonging to the WHO Class II (moderately hazardous) (Table 1)[29]. Malathion dust, a slightly hazardous insecticide (WHO Class III), was used for protecting seed potato from potato tuber moth infestations during storage. Using own farm potato seed is a common practice in both countries.

The eight types of fungicides reported in the survey were used exclusively for late blight control in potato, and consisted of the active ingredients mancozeb, metalaxyl and benomyl. Metalaxyl is moderately hazardous (WHO Class II) while mancozeb and benomyl are both unlikely to present acute hazard in normal use (WHO Class U). Only two fungicides (Dithane and Ridomil) and two insecticides (Dursban and Rocket) were used in Burundi in potato.

Most farmers didn't know the name of the pesticides used. Except for Ridomil, the rest of powder-based fungicides used in potato were locally referred to as Dithane, which was mostly shown in unlabeled transparent plastic bags; in many cases it wasn't possible to verify the true active ingredient. Insecticides were referred to as "simakombi" by farmers who didn't know the exact name.

Table 1: Commercial names, active ingredients, and WHO toxicity classes of pesticides used by farmers of RTB crops in Rwanda and Burundi.

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No	Trade name	Active ingredient	WHO toxic class [a]	Target pest or disease
	Insecticides			
1	Dursban 48EC	Chlorpyrifos 48%	II	Sweetpotato armyworm (*Spodoptera* spp.), sweetpotato butterfly (*Acraea acerata* Hew. and the sweetpotato whitefly (*Bemisia tabaci* Gennadius) in sweetpotato
2	Rocket44 EC	Cypermethrin 4% + Profenofos 40%		
3	Cyper	cypermethrin 5%		
4	Cyper green			
5	CyperLacer 5 EC			
6	Cypermethrin			Cassava mealybug (*Phenacoccus manihoti* Matile-Ferrero), cassava whitefly (*Bemisia tabaci* Gennadius) in cassava
7	Dudu			
8	Dudu cyper			
9	Dimethoate	Dimethoate 40%		
10	Tafgor 40 EC			
				Ants (*Dorylis* spp.), aphids (*Aphis gossypii* Glover, *Aphis fabae* Scopoli, *Macrosiphum euphorbiae* Thomas, and *Myzus persicae* Sulzer), cutworm (*Agrotis* spp.), leafminer fly (*Liriomyza* spp.) and whitefly (*Bemisia tabaci*) in potato
11	Malataf 57 EC	Malathion 57%	III	Potato tuber moth (*Phthorimaea operculella* [Zeller]) during potato storage
	Fungicides			
1	Ridomil Gold	Mancozeb 64% + Metalaxyl 4%	II	Potato late blight in potato fields
2	Emexyl	Mancozeb 64%+Metalaxyl 8%		
3	Victory 72 WP			
4	Safari max			
5	Safarizeb		U	
6	Dithane M45	Mancozeb 80%		
7	Mancozeb 80 WP			
8	Benlate	Benomyl		

[a] II: moderately hazardous; III: slightly hazardous; U: unlikely to present acute hazard in normal use.

Pesticides application frequency

In potato, insecticides were always mixed with fungicides and applied with a mechanical knapsack sprayer. During a cropping season (3-4 months for potato, 3-12 month for sweetpotato and 6-12 months for cassava), the number of pesticide applications was highest among farmers of potato, for both fungicides and insecticides (10.2 ± 2.1) and lowest for insecticides (2.6 ± 0.2) among sweetpotato farmers in Burundi (Fig. 4). In Rwanda, the number of fungicide and insecticide applications per season in potato were on average 6.7 and 5.0, respectively.

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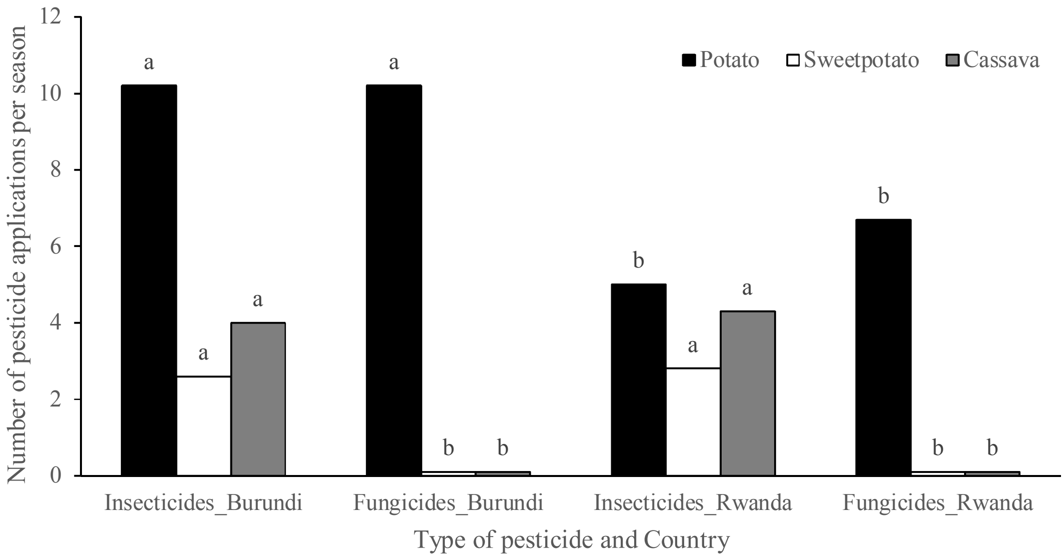

Figure 4: Frequency of pesticide applications by farmers of RTB crops in Rwanda and Burundi. Mean values with the same letter in a country are not significantly different at $P \leq 0.05$.

Use of personal protective equipment (PPE) during application

Less than a half of interviewed farmers in both Burundi and Rwanda used PPE (Fig. 6). More than half of the farmers bathe after spraying in the two countries. No farmer wore eye goggles in Rwanda and only 4% reported the use of eye goggles in Burundi. Less than 10% of the farmers in both Burundi and Rwanda reported wearing hand gloves and waterproof jackets. Instead of face and nose masks, handkerchiefs were often used.

Reasons for not using PPEs were high cost (100% of farmers in Burundi, and 31% of farmers in Rwanda), unavailability at the local market (31% of the farmers in Rwanda), and no awareness about the use of appropriate PPEs (35%); 18% of the farmers didn't see any need to use PPE.

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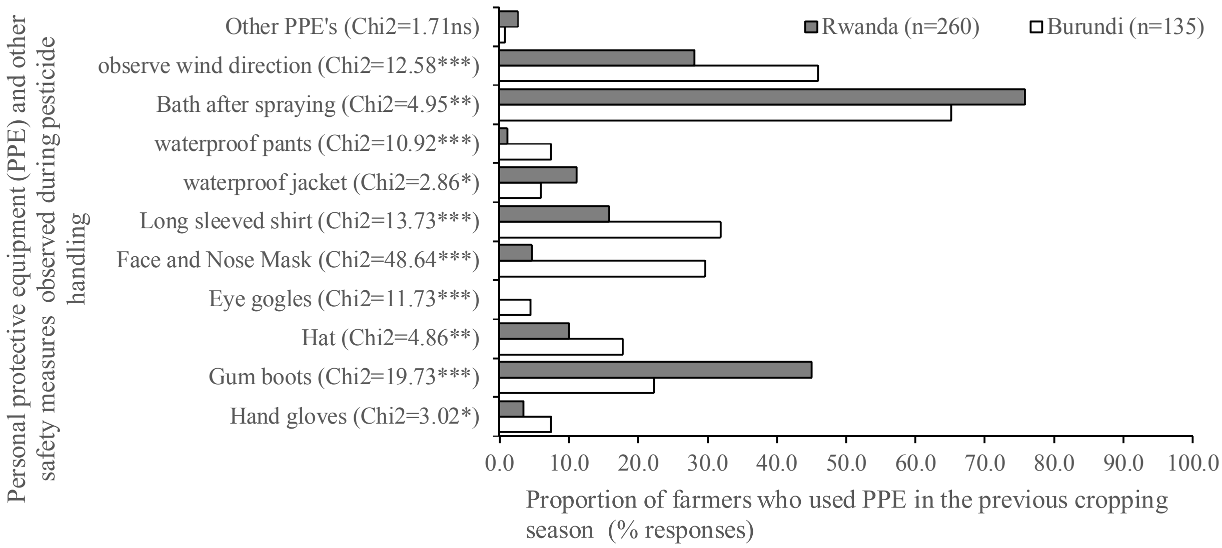

Figure 5: Use of personal protective equipment and other safety measures during pesticide handling by potato farmers in Rwanda and Burundi. ***, **, and * indicate statistical significance at $P \leq 0.01$, $P \leq 0.05$, and $P \leq 0.1$, respectively. ns: not statistically different at $P \leq 0.1$.

Regression model results on PPE use

The results of the Zero-inflated negative binomial (ZINB) regression model showed that Burundi farmers were less likely to use PPE, yet those who actually did, used a higher number of PPE's compared to farmers in Rwanda. The number of PPE was also positively affected by the size of the potato field and the frequency of the pesticide applications. Additionally, the use of PPE was higher for those farmers who had personally experienced some symptoms of poisoning. Interestingly, the model did not find any statistically significant impact of education, age, management training and income on the number of PPE used. On the contrary, the participation in farmer organizations had a negative effect on the use of PPE. This result could be attributed to the common use of equipment by groups of farmers that reduces the ownership of protective equipment.

Symptoms after pesticide applications and reported consequences of pesticide poisoning

The most commonly reported symptoms experienced by farmers in Burundi after pesticide applications were skin itching (60%), teary eyes (57%), burning eyes (53%) and reddened eyes (51%) (Fig. 6). More farmers in Burundi had experienced some form of negative health symptoms than their counterparts in Rwanda.

In Rwanda, the five most commonly reported symptoms were flu (33%), headache (28%), coughing (255), nausea (23%) and skin itching (21%). Less common symptoms of pesticide poisoning in Rwanda were stomach ache (2%), heavy sweating (4%) and death of domestic

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animals (4%). Self-reported cases of death among the interviewed farmers due to self- or accidental- poisoning for humans and domestic animals in the previous 12 months were substantial in both countries, i.e. 14 people and 10 animals in Rwanda and 11 people and 13 animals in Burundi.

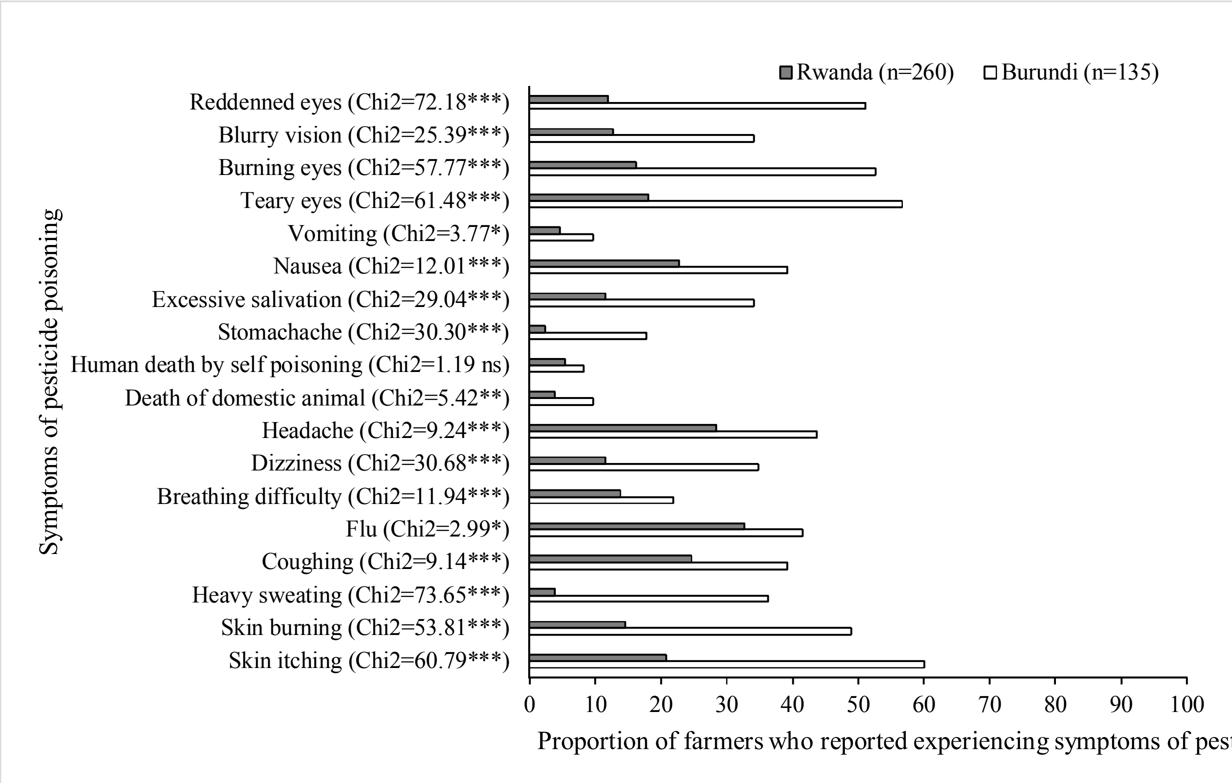

Figure 6: Symptoms after pesticide applications and consequences of pesticide poisoning reported by farmers in Burundi and Rwanda. ***, **, and * indicate statistical significance between the two countries at $P \leq 0.01$, $P \leq 0.05$, and $P \leq 0.1$, respectively. ns: not statistically different at $P \leq 0.1$).

Various pesticide parameters

Retailers of agrochemicals were the main source for purchasing pesticides in Burundi (43.9%) and Rwanda (76.2%) followed by general household merchandise shops (39% in Burundi and 21.1% in Rwanda) (Table 4). Whereas, most of the farmers asked other farmers which type of pesticide to buy in Burundi (36.6%), their counterparts in Rwanda depended more on their own experience (51.8%). Information about pesticide use dosages was provided mainly by the agrochemical retailers (48% in Burundi and 27.4% in Rwanda).

Routine pesticide application was more common in Rwanda (70.8%) than in Burundi (36.1%). More than a half of the respondents (62.6% in Burundi and 54% in Rwanda) reported using damaged knapsack sprayers which could increase chances of body contact with the chemical pesticides, therefore contributing to poisoning cases. Selling of pesticides in unlabeled containers was more common in Burundi (70.5%) than in Rwanda (40.8%). Only 20% of farmers in Burundi

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and 17.3% in Rwanda could read and understand the pesticide label. The proportion of farmers who could tell the toxicity of pesticides from its label were very low (3.4% and 13.4% in Burundi and Rwanda, respectively). Knowledge of negative impacts of pesticide use on the environment was also very low (12.6% of farmers in Burundi and 29.2% in Rwanda). Killing of domestic animals and killing of beneficial insects such as pollinator bees were the most well-known negative effects of pesticide use to the environment by 37.5 % and 45% of the farmers in Burundi and Rwanda, respectively.

Table 2: Sources of information for farmers of RTB crops regarding the use of pesticides and general awareness and pesticide use practices in Burundi and Rwanda (total number of respondents in parentheses).

	% responses		**Chi^2**
Various pesticide parameters	**Burundi**	**Rwanda**	
Sources to buy pesticides			48.75***
(1) Agrochemical retailers	43.9 (123)	76.2 (223)	
(2) Agricultural extension workers	10.6 (123)	0.0 (223)	
(3) General household merchandise shops	39.0 (123)	21.1 (223)	
(4) Other farmers	4.1 (123)	1.4 (223)	
(5) Weekly market	2.4 (123)	1.4 (223)	
Recommendations on type of pesticide by			16.64***
(1) Other farmers	36.6 (123)	29.3 (222)	
(2) Own experience	30.1 (123)	51.8 (222)	
(3) Agrochemical retailers	33.3 (123)	18.9 (222)	
Recommendations on pesticide doses			32.05***
(1) Not needed, can read the pesticide label	5.7 (123)	19.6 (230)	
(2) Other farmers	16.3 (123)	33.0 (230)	
(3) Not needed, own experience	30.1 (123)	20.0 (230)	
(3) Agrochemical retailers	48.0 (123)	27.4 (230)	
Pesticide use practices and general awareness about its use			
(1) Follow a fixed timetable to apply pesticides	36.1 (122)	70.8 (226)	39.40***
(2) Use of damaged knapsack sprayers	62.6 (115)	54.0 (137)	1.89^{ns}
(3) Pesticides purchased in labelled containers	29.5 (122)	59.2 (223)	27.81***
(4) Can read and understand the pesticide label	20.0 (75)	17.3 (156)	0.25^{ns}
(5) Can tell toxicity of pesticides from its label	3.4 (117)	13.4 (217)	8.44***
(6) Knows the negative effects of pesticide use	12.6 (135)	29.2 (257)	13.56***
(7) Knowledge of alternative (non-chemical) control methods	8.2 (135)	8.2 (255)	0.53 ^{ns}
(8) May cause harmful effects to humans, animals and environment			12.36**
(8a) May causes human diseases like cancer	25.0 (16)	18.3 (60)	
(8b) May cause death of beneficial insects	25.0 (16)	45.0 (60)	
(8c) May cause death of domestic animals	37.5 (16)	11.7 (60)	

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(8d) May cause damage to part of crops if overdosed	6.3 (16)	1.7 (60)
(8e) May help people to commit suicide	6.3 (16)	21.7 (60)
(8f) May pollute water sources	0.0 (16)	1.7 (60)

***, **, and * indicate statistical significance between countries at $P \leq 0.01$, $P \leq 0.05$, and $P \leq 0.1$, respectively. ns: not statistically different at $P \leq 0.1$. n = number of respondents.

4. Discussion

Which control measures are used for pest and disease management in the four crops? No pesticides were applied in banana plantations because pesticide use in banana is not economical and the three most important banana diseases in the study areas (i.e., banana bacterial wilt, fusarium wilt and BBTD) cannot be controlled with pesticides. The other banana pests and diseases such as banana nematodes, yellow and black sigatoka are not so severe at high altitude areas (above 1400 m asl in Rwanda) where this study was carried out. A similar explanation is valid for not using fungicides in cassava and sweetpotato fields. Additionally, pesticides are not cheap and cannot easily be afforded by most farmers. The use of fungicides vis-a-vis insecticides followed the general trend for these two countries, with more farmers using fungicides than insecticides in potato [4]. Of all the pesticide imports in Rwanda, 75% are fungicides, mainly mancozeb and ridomil which are meant to be used in potato, tomato and coffee [4].

Cultural control methods were quite popular across the four crops and this could be because of the relatively low cost and ease of implementation. Promising results in neighboring Uganda by CIP and the national agricultural research organization have produced a genetically modified potato variety (Vic 1) that is resistant to potato late blight, such varieties have potential to reduce the amount of pesticides used in potato [30]. In sweetpotato, research efforts in the East African region are underway to promote the use of virus-free planting materials by making clean vines available through decentralized vine multipliers [31]. In banana, together with other management methods, single diseased stem removal has also been shown to be effective in management of banana bacterial wilt on small farms in the eastern and central African countries [32]. In cassava, community phytosanitation has been recommended to be effective in managing cassava brown streak disease and cassava mosaic disease [33].

Pesticide active ingredients and toxicity classes: In our survey, we didn't encounter any extremely- or highly- hazardous pesticide, probably because pesticide imports now follow strict regulations and pesticides banned by the Rwandan government cannot be on the market. Previously, Burundi was reported to use Aldicarb (an extremely hazardous insecticide and nematicide) and Dichlorvos (a highly hazardous insecticide and parasiticide) [11]. It should be noted, however, that some farmers may have intentionally declined to show the enumerators any pesticide that has been banned for use in either country. This is because there are reports of cheap banned pesticides on the black market that are sourced from D.R. Congo [4]. Also, the fact that several pesticides were stored in unlabeled containers made it impossible for the enumerators to verify their active ingredients.

Chemical pesticides application frequency: the average number of pesticide sprays per season observed in this study for potato (10.2 applications) is comparable to the weekly sprays that were

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reported for tomato in Burundi (about 12 times per season of three months) [14]. However, we find it not necessary to do routine weekly pesticide application if the severity of pests and diseases is below the economic injury levels. Proper timing of pesticide application often requires constant monitoring of pest and disease severity and the failure of pest and disease monitoring coupled with the fear of crop loss to pest and diseases is one key driver to routine pesticide application.

Use of personal protective equipment (PPE) during application: Use of PPE and other protective measures like bathing after spraying or observing wind direction are essential in reducing occupation hazards. A positive correlation was found between a higher number of PPE used, and experienced pesticide poisoning symptoms. Lack of money to buy PPE, unavailability of PPE at the local market, plus reluctance to use them were the main reasons reported by farmers for not using PPE. Similar reasons have been reported for farmers in other African countries such as Uganda [34]. Our analysis also revealed that personal experiences from pesticide poisoning are an important factor determining the use of PPE. Furthermore, farmers with larger fields who make higher use of chemicals are more likely to own bigger sets of PPEs, whereas farmer organizations that may offer pesticide use services seem to act as a disincentive for farmers to own and use PPE.

Pesticide (source of info., knowledge of toxicity, selling in unlabeled containers, routine spraying, negative effects): The low numbers of farmers who were aware of the negative effects of pesticide use observed in this study is probably the reason why the majority of them didn't use the recommended PPE during pesticide application. A high proportion of farmers (70.5%) are buying pesticides in unlabeled containers. Refilling and selling pesticides in unlabeled containers is a common practice of 96% of agrochemical retailers in Burundi and Rwanda [14]. One of the justifications for the continued sale of pesticides in unlabeled containers is the small proportions in which farmers buy pesticides. Due to the fragmented small farm sizes (<0.1 ha) coupled with low purchasing power, most small holder farmers are not able to afford large pesticides quantities at a time, like the 50 kg bags in which some chemicals are packed (for example, Mancozeb). Selling of pesticides in unlabeled containers such as beer or drinking water bottles not only gives the opportunity to scurrilous sellers to dispose of expired chemicals, but also can increase risk of unintended poisoning of children. The proportion of farmers (63.9%) who followed a fixed timetable to apply pesticides in RTB crops in Burundi were lower than the 89% reported among tomato and vegetable farmers by Mutshail et al. [14], probably because vegetable crops such as tomato, cabbage (*Brassica oleracea* L.) are of higher commercial value than RTB crops making the farmers less risk averse. It is normally the fear of loss that makes farmers to routinely apply pesticides [34, 35].

Limited information on self-reported cases of pesticide poisoning could be found in both Burundi and Rwanda. The World Health Organization reported 10 fatalities in Burundi in 2003 due to pesticide poisoning [11]. In neighboring countries, however, research showed that cases of pesticide poisoning are common [34]].

Since most farmers get information about pesticides from agrochemical retailers it's imperative to have these agrochemical retailers trained and certified to reduce cases of pesticide poisoning among farmers. Results from this study can be generalized to represent the perceptions, attitudes and practices of all RTB farming households in Burundi and Rwanda since the sample size is sufficient.

Conclusions and recommendations

We recommend training of farmers and agrochemical retailers of pesticides in safe use of pesticide and handling; formation of regulations or guidelines for safe pesticide use, handling and storage; ensuring that laws governing pesticide use are enforced, use of integrated pest management approaches to reduce pest and disease damage, use of pictograms instead of text to teach uneducated farmers about pesticide toxicity.

A shift from sole reliance on pesticides to use of IPM approaches that are more sustainable and environmentally friendly approaches should be prioritized and promoted through increased funding. Biosafety policy regulations by governments that enable the release of promising late blight resistant GM potato need to be set in place.

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