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Farmers' knowledge and perception of the use of pesticides in Arabica coffee, *Coffea arabica* agro-ecologies of Uganda

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Abstract

Low yields of coffee in Uganda are due to a number of factors with insects, diseases and weeds being paramount. In response, farmers respond by applying all kinds of pesticides to control these stresses. A questionnaire to elucidate farmers' knowledge and perceptions of pesticide use was therefore administered to 325 randomly selected respondents in the Arabica coffee growing regions of Uganda. Our results showed that only 23% of the respondents had ever used or were using pesticides, although, >50% of these respondents had knowledge on pesticides use. However, the methods of pesticide disposal were poor with >40% of these respondents disposing the wash water and unused/waste pesticide on their farms whereas, used containers were being burned. Also, >60% of these respondents were re-entering their coffee fields in less than one week after spraying. These practices expose the farmers, their animals and the environment to pesticide poisoning. Nevertheless, >50% of these respondents were aware of the negative effects pesticides are likely to cause to humans, animals and environment. Therefore, in order to minimize pesticide exposure and toxicity, training and awareness campaigns on pesticides use, particularly pesticide disposal should be rolled out to all the coffee growing agro-ecologies of Uganda.

Key words: Agro-ecologies, Arabica-coffee, disposal, farmers, handling, pesticide-use

1. Introduction

Coffee is a major and leading cash crop in Uganda, contributing US$545 million in foreign exchange the coffee year 2016/17 (UCDA, 2017). The crop is grown by over 1.3 million households (a quarter of which are headed by females), who are spread out over several production zones (Hill, 2005). Over 3.5 million Ugandans derive their livelihood from the crop along the value chain, from production to marketing (NUCAFE, 2005). There are two main types of coffee grown by farmers in the country, Robusta coffee, *Coffea robusta* Pierre ex A. Froehner which accounts for about 80% of the coffee and Arabica coffee, *Coffea arabica*, which occupies the remaining 20%. *C. robusta* is predominantly grown below 1200 meters above sea level (masl), while *C. arabica* dominates the highland regions above 1500 masl, particularly in the Mt. Elgon region located in the eastern part of the country (Musoli et al., 2001).

However, the productivity of Arabica coffee in Uganda remains at 0.5 tons of clean coffee per hectare which is far below the attainable yields (van Asten et al., 2011). This is due to a number of biotic factors - insect pests, diseases, weeds and parasitic nematodes, being paramount. Among the insect pests, the white stem borer (WSB), *Monochamus leuconotus*, the coffee berry borer (CBB), *Hypothenemus hampei* (Ferriere), antestia bug, *Antestiopsis* sp., coffee lace bug, *Habrochila* sp., coffee leaf miner, *Leucoptera caffeina* (Washbour), coffee mealybug, *Planococcus* sp. and coffee leaf skeletonizer, *Leucoplema dohertyi* (Warren) are the most important (Musoli et al., 2001; Jonsson et al., 2015; Kucel et al., 2016; Liebig et al., 2016).

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For the diseases, coffee berry disease (CBD) caused by *Colletotrichum kahawae* (Bridge and waller) and coffee leaf rust (CLR) caused by *Hemilea vastatrix* (Berkeley and Broome) dominate the spectrum in the region (Matovu *et al*., 2013). Weeds have also been reported to reduce coffee yields by over 50% (Nyabundi and Kimemia, 1998). On the other hand, although, plant-parasitic nematodes are among the less studied biotic constraints of coffee in Uganda (Rutherford, 2006), they have been reported to cause a substantial economic impact on coffee in other coffee-producing countries in East Africa (Maundu et al., 2014; Nzesya et al., 2014).

In response to these biotic constraints, farmers use all kinds of pesticides to manage them (Nyambo et al., 1996; Ngowi, 2003; Henry and Feola, 2013). This is because farmers consider pesticides a labor saving, effective and efficient tool for managing pests (Tandi et al., 2014). However, a number of farmers are still using the organochlorine, organocarbamates as well as organophosphate pesticides that are included in the Persistent Organic Pollutant (POP) category which are being phased out (Otut, 2017; Kagezi et al., in press). In addition to using these pesticides indiscriminately, farmers also use sub-standard and counterfeit pesticides (Henry and Feola, 2013; Liebig et al., 2016; Kagezi et al., in press). This is coupled with improper storage and disposal of unused pesticides or/and their containers (Okonya and Kroschel, 2015). All these could result into human/animal poisonings and/or accumulate as residues in food and the environment (Henry and Feola, 2013; Karungi et al., 2011), leading to the development of resistance in pests and diseases (Nyambo et al., 1996).

Recent survey conducted by Kagezi et al. (*In press*) reported a total of 22 active ingredients of pesticides being used by farmers in the diverse Arabica coffee agro-ecologies in Uganda to manage the various biotic stresses. These were 13 insecticides (59%), five fungicides (23%) and four herbicides (18%). Three insecticides - carbofuran (Furadan 5), dichlorvos 100% (Lava 100% EC) and fenitrothion (Sumithion/Fenitrothion) as well as one herbicide, gramoxone (Paraquat) which were being used are on the list of banned chemicals in Uganda (Otut, 2017). This could raise potential health concerns among farmers, their family members and animals as well as the environment due to exposure to these pesticides (Lekei et al., 2014; Okonya and Kroschel, 2015). There is therefore a need to develop a systemic understanding of farmer's behavior and knowledge as a basis for formation of future intervention programs (Henry and Feola, 2013). Farmers with limited knowledge of the use and safe handling of pesticides have been reported to suffer more exposure to the pesticides (Tandi et al., 2014; Okoffo et al., 2016). However, farmers' knowledge and perceptions of the use and handling of pesticides in the diverse Arabica coffee agro-ecologies of Uganda is limited (Liebig *et al*., 2016), though, scanty information exists in Robusta coffee growing regions of Uganda (Munyuli, 2011). This information is vital for guiding research, policy and other agendas on pesticide use since their misuse can cause serious negative effects on humans, livestock and environment.

A study was therefore conducted to assess farmers' knowledge and perceptions on pesticide use in the Arabica coffee growing regions of Uganda. Specially, the study aimed at determining farmers' knowledge on pesticides of: - (i) sources and storage, (ii) labels and toxicity colors, (iii) handling and application, (iv) disposal, (v) re-entering fields after spraying, (vi) negative effects, and (vii) source of information and training. The information generated is vital for developing an Integrated Pest Management (IPM) program with reduction and sustainable use of pesticides in the Arabica coffee growing regions.

2. Materials and methods

This section presents the materials and methods used to collect the data in the study area

2.1 Description of the study area

The study was conducted in the three Arabica coffee growing regions of Uganda, namely, Mt. Elgon, West Nile and southern in February-March, 2017. In each region, three districts were selected randomly by writing the names of all the districts in the region on separate papers and randomly picking three of them. The selected districts were: - Kapchorwa, Manafwa and Sironko (Mt. Elgon region), Arua, Nebbi and Zombo (West Nile region) and Ibanda, Kisoro and Mitooma (southern region) (Fig. 1).

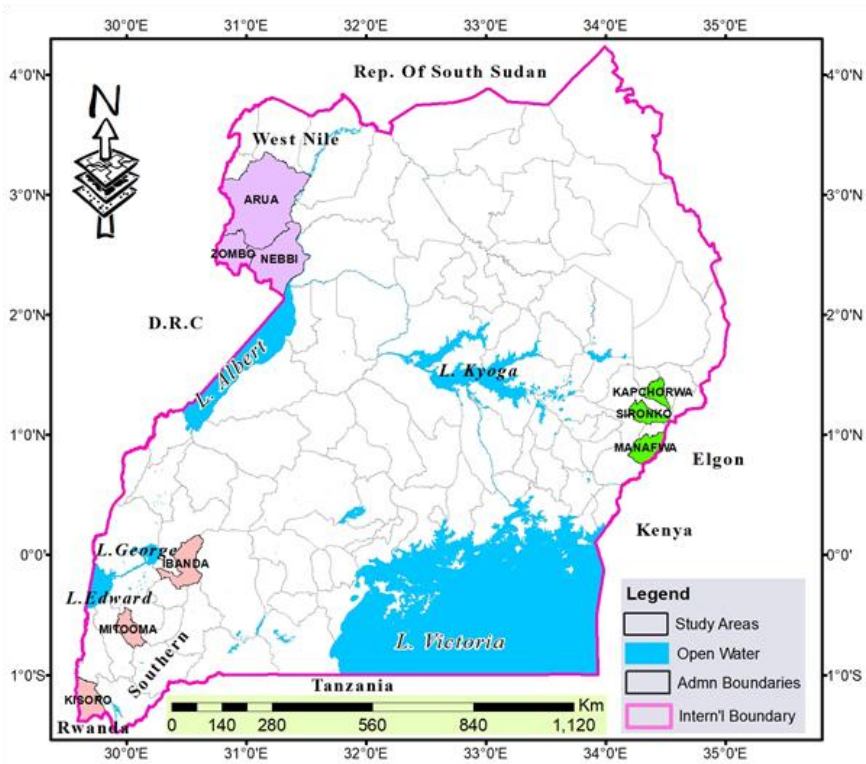

Figure 1: Location of the study areas within Uganda and the districts of the study areas

2.2 Sample selection and data collection

In each district, one sub-county was also randomly selected by using the same sampling procedure as for the region. A list of all coffee growing households in the sub-county was obtained from the sub-county extension officers and Uganda Coffee Development Authority (UCDA) regional coordinators. A total of 40 households (where applicable) were selected randomly irrespective of the size of their coffee gardens or their economic status using the sampling procedure described above. It should be noted that in some district was less than the required. A total of 325 households were selected as follows: - Kapchorwa (40), Manafwa (38) and Sironko (38) in Mt. Elgon region, Ibanda (40), Kisoro (14) and Mitooma (40) in southwestern region, and, Arua (34), Nebbi (41) and Zombo (39) in West Nile region.

A semi-structure questionnaire elucidating farmers' knowledge and perceptions of pesticide use was developed in English language but administered in local dialects with the help of the Uganda Coffee Development Authority (UCDA) regional coordinators and sub-county extension officers. Specifically, the questionnaire captured information on: - demographic characteristics of the study population as well as farmers' knowledge of pesticides including: - the sources and storage, labels, handling, disposal, re-entry into coffee fields after spraying, negative effects to human being, livestock and the environment, and, source of information and training.

2.3 Data analysis

The raw data were coded and entered into Microsoft Office Excel 2010 (Microsoft Corporation, Redmond, WA, USA) and then analyzed using SAS v. 9.1 for Windows (SAS, 2008). Descriptive results were expressed as frequencies and percentages for categorical variables, and as means±SD for continuous variables. In addition, chi square was used to test the significance of differences between categorical variables. We used $\alpha \leq 0.05$ as a criterion for statistical significance.

3. Results and Discussion

This section presents the results obtained in the study as well as providing the discussion on the observed results.

3.1 Demographic characteristics of the study population

The demographic characteristic of the respondents interviewed in the Arabica coffee growing regions of Uganda is summarized in table 1.

Of the 325 households interviewed, the majority (62%) were males and significantly (χ^2=6.1504; p=0.0131) different from the number of females (38%) interviewed. Similar findings have been reported in other coffee growing regions of Uganda (Isoto et al., 2008; Mbowa et al., 2014; Ochago et al., 2017; Karki et al., 2018) as well as in other developing countries like Kenya (Akiri et al., 2015), Tanzania (Lekei et al., 2014) and Jamaica (Ncube et al., 2011; Henry and Feola, 2013). This could be a clear indication that coffee farming in most developing countries is mostly dominated by males and this is because they have better access to resources (Isoto et al., 2008; Ochago et al., 2017). The crop is even termed as a "male" crop in these settings (Isoto et al., 2008; Fry, 2010; Akiri et al., 2015; Ochago et al., 2017; Stein, 2017). This implies that in countries like Uganda where coffee production development programs are being promoted, females are likely to benefit less than their male counterparts (Mbowa et al., 2014).

The average age of the respondents in the study area was 50±16.5 years with a range of 18-110 years. Dominance of Uganda coffee production by the aged farmers has also been observed by Munyuli (2011), MAAIF (2013) and Mbowa et al. (2014). This implies that the predominantly unemployed youth in the country could potentially gain less from current initiatives targeting production of coffee along the value chain. This calls for creation of programs that attract the youth to engage in coffee production (Mbowa et al., 2014).

On the other hand, the level of education attained by the respondents varied significantly (χ^2=41.2615; p<.0001), with the majority (46%) of them having attained only the primary level of education. Low level of education of farmers has also been reported in other coffee agro-ecologies (Isoto et al., 2008; Henry and Feola, 2013; Lekei et al., 2014). This implies that most of the farmers involved in coffee production at primary level are generally illiterate. This has implications as farmers with limited formal education might be at higher risk in using pesticides. This is possibly due to difficulties in understanding and interpreting the instructions and safety procedures on the product labels which are usually presented in English language (Henry and Feola, 2013; Diomedi and Nauges, 2016).

Table 1: Demographic characteristics of the respondents (%) interviewed in the major Arabica coffee, *Coffea arabica* growing regions of Uganda

Region	District	Sex		Age	Level of education				N
		Males	Females	(years)	None	Primary	Secondary	Tertiary	
Mt. Elgon	Kapchorwa	60.0	40.0	42.2±13.9	20.0	37.1	28.6	14.3	40
	Manafwa	53.8	46.2	51.0±19.5	5.1	66.7	20.5	7.7	39
	Sironko	69.2	30.8	52.2±12.4	10.5	52.6	21.1	15.8	38
Regional mean		*61.0*	*39.0*	*48.4±16.0*	*11.9*	*52.1*	*23.4*	*12.6*	*117*
Southwestern	Ibanda	72.5	27.5	50.3±13.7	7.7	56.4	20.5	15.4	40
	Kisoro	57.1	42.9	57.0±21.0	21.4	35.7	28.6	14.3	14
	Mitooma	60.0	40.0	43.3±15.0	12.5	67.5	20.0	0.0	40
Regional mean		*63.2*	*36.8*	*50.2±16.1*	*10.4*	*40.2*	*17.8*	*8.2*	*94*
West Nile	Arua	58.8	41.2	54.9±19.1	16.1	61.3	16.1	6.5	34
	Nebbi	63.4	36.6	50.6±16.6	7.9	52.6	34.2	5.3	41
	Zombo	66.7	33.3	50.6±1+1	19.4	63.9	13.9	2.8	39
Regional mean		*63.0*	*37.0*	*52.0±17.2*	*10.9*	*44.7*	*16.6*	*4.4*	*114*
Overall mean		*62.4*	*37.6*	*50.2±*16.5	*11.1*	*45.7*	*19.2*	*8.4*	*325*

3.2 Pesticides use

The use of pesticides in the Arabica coffee growing regions of Uganda was generally low, with only 23% of the respondents reporting that they were using or had ever used pesticides (Table 2). This percentage was significantly (χ^2=29.16; p<.0001) different from those who had never used pesticides (77%). This finding is in agreement with several earlier studies that have reported low usage of pesticides in Robusta coffee growing regions of Uganda (Egonyu et al., 2009; Kagezi et al., 2013; Mbowa et al., 2014; Liebig et al., 2016). Although our data collection tool did not capture the reasons for the low usage of pesticides, related studies in the coffee growing regions of Tanzania reported limited availability of pesticides as the main reason for the low usage (Ngowi, 2003). Furthermore, pesticide usage varied significant (χ^2=17.773; p=0.0001) across the Arabica coffee growing regions, with the highest percentage of users (39%) being recorded in southern Uganda while, the lowest (11%) in West Nile. This could in part be due to the fact that farmers in the southern region use a lot of pesticides even on other crops, particularly, potatoes (Okonya and Kroschel, 2015).

Table 2: Respondents (%) who were using or had ever used pesticides in the major Arabica coffee, *Coffea arabica* growing regions of Uganda

Region	District	Farmers (%)	N
Mt. Elgon	Kapchorwa	25.0	40
	Manafwa	17.9	39
	Sironko	13.2	38
Regional mean		*18.7*	*117*
Southern	Ibanda	60.0	40
	Kisoro	14.3	14
	Mitooma	42.5	40
Regional mean		*38.9*	*94*
West Nile	Arua	8.8	34
	Nebbi	12.2	41
	Zombo	12.8	39
Regional mean		*11.3*	*114*
Overall mean		*23.0*	*325*

Our results also showed that pesticide use was dependent on sex ($p=0.0121$) but neither on age nor educational level ($p>0.05$; table 3). Gender differences in pesticides use have also reported in coffee agro-ecologies (Henry and Feola, 2013) and other agricultural settings (see; Atreya, 2007; Wang et al., 2017). The details of the pesticides which were being used by the farmers in the C. arabica coffee growing regions of Uganda are presented in Kagezi et al. (*In press*).

Table 3: Sex, age and education level as determinants of respondent's usage of pesticides in the Arabica coffee, *Coffea arabica* growing regions of Uganda

Parameter	DF	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	1	0.085	0.6849	0.0154	0.9013
Sex	1	0.7673	0.3057	6.3011	0.0121
Age	1	0.00676	0.0084	0.6467	0.4213
Education	1	-0.2571	0.1715	2.2472	0.1339

3.3 Source and storage of pesticides

Respondents mentioned six sources where they were obtaining pesticides, with 86% of them mentioning input dealers (Table 4a). Related studies conducted in other cropping systems have also identified input dealers as a major source of pesticides for farmers (Tandi et al., 2014; Mattah et al., 2015; Okonya and Kroschel, 2015). These input dealers could therefore be utilized in disseminating information on pesticide use and handling as well as integrated pest management (IPM) strategies so as to reduce pesticide misuse and exposure (Jallow et al., 2017). They could be trained so that they also offer training to the farmers who come to buy pesticides from their input shops (Berocan et al., 2014; Afari-Sefa et al., 2015; Jallow et al., 2017).

Our results further showed that more than 60% of the respondents were storing the pesticides in their houses, particularly in the general store (27%) and bedrooms (25%; table 4b). This practice of farmers storing pesticides in their houses has been reported to be common in other coffee agro-ecologies (Ngowi et al., 2001; Lekei et al., 2014). This presents high potential and chances for exposure of the farmers and their family members to pesticide toxicity (Lekei et al., 2014) through direct inhalation (Damalas and Koutroubas, 2016). Even those farmers or their family members who are not directly participating in the application of pesticides are likely to be affected since most of the formulations tend evaporate at high house temperatures (Ngowi et al. 2001).

Table 4: Source and storage of pesticides as mentioned by respondents (%) in the Arabica coffee, *Coffea arabica* growing regions of Uganda

Region	Mt Elgon (N=22)	Southern (N=43)	West Nile (N=13)	Grand mean (N=78)
Source of pesticides				
Input dealers	95.5	90.7	53.8	85.9
Extension	0.0	4.7	15.4	5.1
NGO's	4.5	0.0	23.1	5.1
Fellow farmers	0.0	4.7	0.0	2.6
Coffee exporters	0.0	0.0	7.7	1.3
Other retail shops	0.0	2.3	0.0	1.3
Storage of pesticides				
General store	23.8	37.2	0.0	27.3
Agro-input store	47.6	14.0	30.8	26.0
Bedroom	14.3	32.6	15.4	24.7
Uses everything	9.5	2.3	38.5	10.4
Inside house	0.0	4.7	0.0	2.6
Garden	4.8	2.3	0.0	2.6
Kitchen	0.0	2.3	0.0	1.3
In cupboard	0.0	0.0	7.7	1.3
Under cupboard	0.0	2.3	0.0	1.3

3.4 Information on pesticides

Respondents mentioned 12 sources of information about pesticides and their use (Table 5a). Overall, mass media (42%) and extension (30%) were the most mentioned sources of information. At regional level, a similar trend was observed in southern region (54 and 47% respectively), but for Mt. Elgon, mass media (46%) and input dealers (32%) were the most important whereas, fellow farmers (39%) and previous experience (31%) were for West Nile region. These sources of information on pesticides have also been reported in several research studies conducted in other coffee agro-ecologies (Ngowi, 2002, 2003; Kagezi et al., 2013; Lekei et al., 2014). Mass media and extension are major channels of communication between farmers and experts to improve handling and use of pesticides (Ngowi, 2002).

More than half of the respondents reported that they were able to read as well as understand the labels on the pesticides (Table 5b). This has also been reported by Ngowi (2003) and Lekei et al. (2014) in coffee agro-ecologies of Tanzania. However, only 37% of the respondents were able to interpret the toxicity color codes on labels on pesticide containers (Table 5d), as observed by Lekei et al. (2014). This is probably in part due to the low level of education by the majority of the interviewed respondents in our study.

Table 5: Sources of information on pesticides by the respondents (%) and their ability to read (%), understand as well as awareness of the color codes on pesticide labels (%) in the Arabica coffee, *Coffea arabica* growing regions of Uganda.

Region	Mt Elgon (N=22)	Southern (N=43)	West Nile (N=13)	Grand mean (N=78)
(a) Source of information				
Mass media	45.5	53.5	0.0	42.3
Extension	13.6	46.5	0.0	29.5
Fellow farmers	9.1	32.6	38.5	26.9
Input dealers	31.8	16.3	7.7	19.2
Previous experience	22.7	11.6	30.8	17.9
NGO's	4.5	2.3	15.4	5.1
Cooperative unions	0.0	7.0	0.0	3.8
Pesticide label	9.1	0.0	0.0	2.6
Research	4.5	0.0	0.0	1.3
School	4.5	0.0	0.0	1.3
No information	4.5	0.0	0.0	1.3
Coffee buyers	4.5	0.0	0.0	1.3
(b) Pesticide label				
Reading the labels	68.2	60.5	69.2	64.1
Understanding the labels	68.2	51.2	61.5	57.7
(c) Toxicity color codes				
Awareness of color codes	50.0	32.6	30.8	37.2

3.5 Pesticide handling

The pesticides were mainly applied by the men member of the households (73%), but also to a less extent by the male workers (24%) and female members of households (7%; table 6a). Our finding corroborates with studies by Mansingh et al. (2003) and Norton et al. (2015). Women in developing countries usually tend to shy away from spraying because the knapsack sprayer is too heavy for them to carry (Norton et al., 2015; Perez et al., 2015; Schreinemachers et al., 2017). However, they usually contribute indirectly to crop protection by fetching water for mixing the chemicals (Ssekabembe and Odong, 2008).

The most commonly used equipment for applying pesticides was the knapsack sprayer (91%), though 8% of the respondents were also using hand held sprayers (Table 6b). The knapsack sprayer is one of the most common equipment used for spraying pesticides in various coffee agro-ecologies (Ngowi et al., 2001). Farmers prefer using the knapsack sprayer because it is generally cheap and readily available (Asogwa and Dongo, 2009; Mengistie et al., 2017). However, using this type of equipment might be very dangerous to the user as it may expose his/her to leakages (Tandi et al., 2014; Damalas and Koutroubas, 2016), particularly when the sprayer is old or aging (Matthews, 2008; Tandi et al., 2014).

Our results further showed that 62% of the respondents were applying the pesticides as single formulation (Table 6c), an observation also made by Ngowi et al. (2007). However, 37% of the respondents were applying the pesticides as mixtures. Application of pesticides in a mixture formulation is a common practice in coffee agro-ecologies (Ngowi et al. 2001; Ngowi, 2003). Of the respondents who were applying the pesticides as mixtures, 39% of them were mixing an insecticide with a fertilizer or an insecticide and a fungicide (25%; table 6d). This is in agreement with studies by Ngowi et al. (2001) and Ngowi (2003). Mixing of pesticides was mostly done with the aim of reducing costs of application (50%) and increasing efficiency and effectiveness (32%; table 6e), an observation also made by Warnock and Cloyd (2005) and Xiao-yan et al. (2016). However, farmers usually mix pesticides without considering their compatibility or active ingredients but rather rely on the perceived efficacy based on their trade names (Amoako et al., 2012). This practice is therefore not only dangerous to the plant but also to the user of the pesticide. Secondly, mixing pesticides makes treatment of pesticide poisoning difficult as different groups of pesticides have different modes of action (for diagnosis) and antidotes (for treatment) (Ngowi, 2003).

More than half of the respondents were wearing protective gear while spraying (Table 6f), as also reported by Henry and Feola (2013). However, most (70%) of them reported that they were using gumboots only as the protective gear (Table 6g).

Our finding is in line with reports by Henry and Feola (2013), Lekei et al. (2014) and Mattah et al. (2015). Putting on only gumboots is completely inadequate as sole protection (Lekei et al., 2014) as it increases chances of exposure of farmers to pesticide toxicity (Ngowi, 2003). This practice of not using the full protective gear during pesticide use by farmers could be explained by the lack of or limited knowledge of the dangers associated with handling pesticides but also because of lack of money to buy the gear (Okonya and Kroschel, 2015).

It was also notable that 58% of the respondents took into consideration the wind direction during spraying (Table 6h), following the wind as recommended (Ntow, 2008; Afari-Sefa et al., 2015; Khanal and Singh, 2016). However, 37% of the respondents were not considering the direction of the wind while spraying, an observation also made by Atreya et al. (2012). This may create problems such as lack of proper spray on targeted crop, bad odor, difficulty in spraying as well as difficulty in breathing by the person applying the pesticides (Khanal and Singh, 2016).

Furthermore, 83% of the respondents washed the sprayers immediately after spraying (Table 6i), as observed also by Ntow (2018), Tandi et al. (2014), Afari-Sefa et al. (2015) and Perez et al, (2015). This practice is very important in order to protect against cross-contamination in subsequent loads and to ensure safe disposal of any excess chemicals and wash-water (Watkins et al., 1994).

Table 6: Application of pesticides by respondents (%) in the Coffee Arabica, *Coffea arabica* growing regions of Uganda

Region	Mt. Elgon (N=22)	Southern (N=43)	West Nile (N=13)	Grand mean (N=78)
Person who applies the pesticides				
Man	77.3	69.8	76.9	73.1
Male worker	22.7	30.2	7.7	24.4
Woman	0.0	11.6	7.7	7.7
Youth	0.0	9.3	0.0	5.1
NGO's	0.0	00	7.7	1.3
Type of sprayer used				
Knapsack	100	97.7	53.8	91
Hand held	0.0	2.3	38.5	7.7
Motorized	4.5	0.0	0.0	1.3
(c) How pesticides are applied				
Singly	63.6	65.1	46.2	61.5
Mixtures	36.4	32.6	46.2	35.9
(d) Types of pesticide mixtures				
Insecticide/Fertilizer	62.5	42.9	0.0	39.3
Insecticide/Fungicide	0.0	28.6	50.0	25.0
Insecticide/Insecticide	12.5	7.1	16.7	10.7
Insecticide/Herbicide	25	0.0	0.0	7.1
Insecticide/Fungicide/Herbicide/Fertilizer	0.0	0.0	33.3	7.1
Herbicide/Detergent	0.0	7.1	0.0	3.6
Herbicide/Herbicide	0.0	7.1	0.0	3.6
(e) Why pesticides are applied as a mixture				
Reduce labor	37.5	50.0	66.7	50.0
Increase efficiency and effectiveness	50	28.6	16.7	32.1
Reduce costs	12.5	21.4	0.0	14.3
Farmer was told	0.0	14.3	16.7	10.7
(f) Use of protective gear				
Yes	50.0	60.5	46.2	55.1
(g) Protective gear used when spraying				
Gumboots	54.5	88.5	16.7	69.8
Gloves	54.5	19.2	83.3	37.2
Face and nose mask	18.2	30.8	16.7	25.6
Coverall	36.4	11.5	16.7	18.6
Long sleeved shirts	27.3	11.5	16.7	16.3

(h) Consideration of the direction of wind when spraying				
In the direction of wind	59.1	46.5	92.3	57.7
No consideration	36.4	48.8	0.0	37.2
Against the wind	4.5	2.3	0.0	2.6
Morning before it is windy	0.0	2.3	0.0	1.3
(i) Treatment of sprayers after spraying				
Washes immediately after spraying	90.9	76.7	84.6	83.3
Nothing	4.5	20.9	15.4	15.4
Washes anytime	4.5	2.3	7.7	5.1

3.6 Pesticide disposal

Our results showed that 68% of the respondents were disposing off the wash-water on their farms while a few (17%) were disposing it in the bush (Table 7a). This supports observations by Ntow (2008) and Okoffo et al. (2016). On the other hand, 36% of the respondents were disposing the unused/waste pesticide on their farms while 33% were re-using them and 11% disposing the unused/waste pesticides in the bush (Table 7b). This has also been reported by Tandi et al. (2014) and Okoffo et al. (2016). Such kinds of disposal may lead to contamination of soil on the farm and environment through runoff, leaching or aerial distribution to other areas (Gerken et al., 2001). It also exposes the farmers, their family members as well as animals to pesticide toxicity (Tandi et al., 2014; Afari-Sefa et al., 2015).

Furthermore, 46% of the respondents were burning the empty pesticide containers (Table 7c), a practice which has also been reported in coffee agro-ecologies of Jamaica (Abebe et al., 2011), Tanzania (Lekei et al., 2014) and Papua New Guinea (Diomedi and Nauges, 2016). Burning of used pesticide containers releases fumes which might be poisonous to humans and their animals through inhalation (Daniels, 2006). Inhalation exposure provides the fastest route of entry into the bloodstream (Desalu et al., 2014). This practice can also result into environmental contamination (Zyoud et al., 2010),

Table 7: Disposal of the wash-water, unused/waste pesticides and used pesticide containers by respondents (%) in the Arabica coffee, *Coffea arabica* growing regions of Uganda

Region	Mt Elgon (N=22)	Southern (N=43)	West Nile (N=13)	Grand mean (N=78)
(a) Wash water				
On-farm	40.9	81.4	69.2	67.9
Bush	36.4	7.0	15.4	16.7
Waste pit	9.1	4.7	7.7	6.4
Does not wash	0.0	4.7	0.0	2.6
Stream	4.5	2.3	0.0	2.6
Gives to other farmers	4.5	0.0	0.0	1.3
(b) Unused/waste pesticide				
On-farm	25.0	46.5	15.4	35.5
Re-used	20.0	44.2	15.4	32.9
Bush	15.0	4.7	23.1	10.5
Hole	10.0	0.0	15.4	5.3
Waste pit	10.0	4.7	0.0	5.3
Pit latrine	15.0	0.0	0.0	3.9
Uses all	15.0	0.0	0.0	3.9
Stream	0.0	0.0	7.7	1.3
Burning	0.0	2.3	0.0	1.3
(c) Used pesticide containers				

Burning	35.0	58.1	23.1	46.1
Throwing them away	20.0	30.2	15.4	25.0
Pit latrine	40.0	4.7	0.0	13.2
Burying	0.0	4.7	23.1	6.6
Storing other chemicals	0.0	4.7	0.0	2.6
Storing water and other stuff	5.0	0.0	0.0	1.3
Selling	0.0	2.3	0.0	1.3
Pit	0.0	2.3	0.0	1.3

3.7 Re-entering coffee fields after spraying

Most of the respondent (63%) were re-entering their coffee fields less than one week after spraying with pesticides while almost one third of them were re-entering after a week (Table 8). This finding is in agreement with studies in Philippines by Perez et al. (2015). Nevertheless, this practice exposes the farmers, their family members and animals for long periods of time resulting into pesticide toxicity through direct inhalation from direct spray or by contact with pesticide residues on the crop or soil (Burns et al., 2007; Perez et al., 2015; Damalas and Koutroubas, 2016). Human exposure to hazardous pesticides leads to several different acute and chronic health effects and may affect the health of both farmers and consumers (Thundiyil et al., 2008; Mostafalou and Abdollahi, 2013; de Bon et al., 2014).

Table 8: Time taken by the respondents (%) to re-enter their coffee fields after spraying in the Arabica coffee, *Coffea arabica* growing regions of Uganda

Time	Mt Elgon (N=22)	Southern (N=43)	West Nile (N=13)	Grand mean (N=78)
Less than one week	72.8	55.8	69.3	62.8
One week	13.6	34.9	23.1	26.9
More than a week	9.1	7.0	0.0	6.4

3.8 Negative effects of pesticides to human being, livestock and the environment

Respondents mentioned 14 negative effects caused by pesticides on human beings, with 45% reporting death (Table 9a). They also reported coughing (15%), itchy skin and dizziness (13%). These negative effects on human beings have also been reported in several other research studies in coffee (Henry and Feola, 2013; Lekei et al., 2014). Similarly, 72% of the respondents mentioned death as the major effect of pesticides on their animals, as also reported by Gesesew et al. (2016). Furthermore, the respondents mentioned 10 negative effects of pesticides on the environment, with declining soil fertility (35%), reduction of beneficial organisms (30%), pollution of water sources (17%) and loss of crop diversity (15%) being the most outstanding. Our findings agree with studies by Parveen (2010) and Abbassy (2017). In order to mitigate some of these negative impacts therefore, integrated pest management (IPM) approaches that blend traditional, knowledge-based pest-control methods and judicious use of pesticides should be utilized (Roubos et al., 2014; USDA, 2014; Alam et al., 2016; Clausen et al., 2017).

Table 9: Negative effects of pesticides mentioned by respondents (%) in the Arabica coffee, *Coffea arabica* growing regions of Uganda

Region	Mt Elgon (N=22)	Southern (N=43)	Grand mean (N=65)
(a) Effect on human beings			
Know the effect			
Yes	77.3	81.4	79.4
Effects			
Death	70.6	20.0	45.3
Coughing	17.6	11.4	14.5
Itchy skin	11.8	14.3	13.1
Dizziness	0.0	25.7	12.9
Running nose	0.0	20.0	10.0
Eye irritation	5.9	11.4	8.7
Skin burning	11.8	2.9	7.4
Headache	0.0	14.3	7.2
Bad smell	0.0	8.6	4.3
No effect	0.0	8.6	4.3
Vomiting	5.9	0.0	3.0
Cancer	0.0	2.9	1.5
Sickness	0.0	2.9	1.5
(b) Effect on livestock			
Know the effect			
Yes	81.8	65.1	73.5
Effects			
Death	100.0	44.4	72.2
Sickness	5.6	48.1	26.9
Nothing	0.0	14.8	7.4
(c) Effect on environment			
Know the effect			
Yes	50.0	58.1	54.1
Effects			
Decline in soil fertility	18.2	52.0	35.1
Reduction of beneficial organisms	36.4	24.0	30.2
Pollution of water sources	18.2	16.0	17.1
Loss of crop diversity	18.2	12.0	15.1
Nothing	9.1	0.0	4.6
Hardening of soils	0.0	8.0	4.0
Development of resistance to pests and diseases	0.0	4.0	2.0
Air pollution	0.0	4.0	2.0
Reduce crop yields	0.0	4.0	2.0
Repel insects and birds	0.0	4.0	2.0

3.8 Training on pesticides

Furthermore, 71% of the respondents who were using pesticides had received training on their use (Table 10a). However, this our finding contradict results observed in other coffee agro-ecologies where less than 40% of the farmers had received training on pesticide use and management (Henry and Feola, 2013; Lekei et al., 2014). Training of farmers in pesticide use and management is a prerequisite towards minimizing their misuse and toxicity (Mattah et al., 2015). This training should however be led by extension and research (Okonya and Kroschel, 2015). It should also be practically-oriented involving farmer field schools (FFS') as evidence shows that this is one of the most effective ways to change the behavior of the farmers (Lund et al., 2010; Clausen et al., 2017). Thirdly, the information provided should be up-to-date, accurate and in a format that can easily be understood by persons with limited literacy skills (Berocan et al., 2014; Jallow et al., 2017). The training should also take an Integrated Pest Management (IPM) approach involving alternative cropping systems that are less dependent on pesticides (Jallow et al., 2017; Clausen et al., 2017), This will reduce exposure of pesticides to farmers, their family members and animals as well as the environment (Tandi et al., 2014; Clausen et al., 2017).

Respondents mentioned 10 agents that had trained them on pesticides use and handling - with extension being prominently reported (47%), but also to a less extent - fellow farmers (23%) as well as input dealers and NGO's (14%; table 10b). This finding agrees with study results by Ngowi et al. (2002) and Lekei et al. (2014) and emphasizes the importance of extension in the training of farmers (Ngowi et al., 2001; Lund et al., 2010; Kagezi et al., 2013). However, there is a need to first train the extension personnel in various aspects of pesticide handling, use, storage and their effects on human, animals and environment as a way of improving the information they communicate to the farmers (Ngowi et al., 2002).

Table 10: Training on pesticides as mentioned by respondents (%) in the Arabica coffee, *Coffea arabica* growing regions of Uganda

Region	Mt Elgon (N=22)	Southern (N=43)	West Nile (N=13)	Grand mean (N=78)
(a) Training				
Has ever received	72.7	79.1	53.8	73.1
(b) Training agent				
Extension	43.8	55.9	14.3	47.4
Farmer to farmer	31.3	23.5	0.0	22.8
Input dealers	25.0	11.8	0.0	14.0
NGO's	0.0	5.9	85.7	14.0
Mass media	0.0	14.7	0.0	8.8
School	12.5	0.0	0.0	3.5
Research	6.3	0.0	0.0	1.8
Cooperative union	0.0	2.9	0.0	1.8

4. Conclusions

Our study determined farmers' knowledge of pesticide use in the diverse Arabica coffee, growing regions of Uganda. Pesticide use was low - only 23% of the respondents had used or were using pesticides, although, more than half of them had knowledge on pesticide use. However, more than 40% of these respondents were disposing the wash water and unused pesticide on their farms and also burning the used pesticide containers. Also, >60% of these respondents were re-entering the sprayed fields in less than a week after spraying. These practices expose farmers, their family members and animals as well as the environment to pesticides which may lead to pesticide poisoning. Therefore, training of farmers, extension as well as other stakeholder along the coffee value chain should be emphasized and rolled out in all the coffee growing agro-ecologies of Uganda. This will play a role in minimizing pesticide exposure and therefore toxicity.

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