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Potential Environmental and Health Impact of Pesticides Use and Safety Measures Adopted by Cocoa Farmers in Akyemansa District in the Eastern Region of Ghana

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Abstract
Pesticides are used in agriculture to control pests and diseases which affect crops and farm animals, and hence to increase yield. Pesticides are used by most farmers in the production of cocoa in Ghana. However, the improper use of pesticides can adversely affect the environment and human health. This study was conducted to assess the likely environmental and human health impact of the different pesticides used, and the safety measures adopted during pesticide application by cocoa farmers in the Akyemansa District, Ghana. Data were collected from 250 randomly selected farmers using interviews, field observations and focus group discussions on the pesticides used by the cocoa farmers, the safety measures adopted and the time of application. The total Environmental Impact Quotient (EIQ) values of the different pesticides used were determined, and were used to compare their likely impact on the environment and human health. Demographic data collected were analyzed using SPSS version 16 software package. Results from this study showed that, the farmers used 24 pesticides, out of which 10 (41.6%) were insecticides, 8 (33.3%) were herbicides, and 6 (25%) were fungicides. The total EIQ values of the different pesticides used ranged between 55.58 and 15.33. 130 (52%) of the respondents did not use Personal Protective Equipments (PPEs). Also, 145 (58%) respondents applied the pesticides and waited for some days before harvesting the cocoa. Over half, 156 (62.4%) of the respondents ate their meal before the application of pesticides, 70 (28%) ate their meals when they finished spraying after either washing their hands with water and soap or water only. But the rest stopped the spraying, ate their meals and continued. Cocoa farmers in Akyemansa mostly used insecticides to control pests and diseases and also adopted both safe and unsafe measures during pesticide application. Chlorfenvinphos, an insecticide had the highest total EIQ value (55.58), while Glyphosate, a herbicide had the lowest value (15.33). Bifenthrin (Akate master) and Imidacloprid (Confidor), moderately hazardous insecticides were most likely to impact negatively on the environment and human health.
Keywords: Pesticides, Environmental Impact Quotient, Health, Safety, Cocoa.

1. Introduction

Cocoa is a major cash crop in Ghana and West Africa (Asare, 2011, Gockowski *et al*., 2013, Okoffo *et al*., 2016), and it is of particular interest for Ghana and for the global chocolate industry (Danso-Abbeam et al., 2014). The cocoa sector provides more than half (70–100 %) of the income for roughly 800,000 smallholder farm families in Ghana, and provides food, employment, tax revenue and foreign exchange earnings for the country (Anim-Kwapong and Frimpong 2004; Ayenor *et al*., 2007; Anang 2011; Danso-Abbeam *et al*. 2014). The cocoa industry contributed approximately 16.48% (US$ 2,267.3 million) of total agricultural export receipts in 2013 (ISSER, 2014). It is a significant component of the rural economy since the industry is dominated by large numbers of small holder peasant farmers who depend on the crop for their livelihood (Appiah, 2004). Many small holder cocoa farmers in Ghana depend use the income from cocoa to pay children's school fees, health care and housing (Vigneri *et al.,* 2016)

However, cocoa like other tropical crops continues to be attacked by insects, diseases and other pests that must be controlled effectively and safely (Bateman, 2015) to prevent crop losses. Cocoa farmers in Akyemansa district in the Eastern Region and Ghana as a whole have adopted the use of pesticides to prevent or control insect pests, weeds, fungi and diseases in order to increase yield, and hence income. Although pesticides are developed through very strict regulations to function with reasonable certainty and minimal impact on human health and the environment (Damalas *et al*., 2011), the use of pesticides in most developing countries is becoming an increasingly serious environmental problem due to factors such as water contamination, ecosystem disruption and habitat contamination (Marquis, 2013). Regardless of the positive roles pesticides play in keeping pests and diseases below their economic injury level, their use has often been associated with unintended environmental and human health consequences (Dankyi *et al.,* 2014; Owombo *et al.,* 2014). The impact of pesticide on the environment depends on the level of exposure and the toxic properties of the pesticide (Li *et al*., 2015). The use of pesticides in the cocoa industry in Ghana has raised a lot of concerns about the safety of residues in cocoa beans, soils and water, as well as other potential harm to humans and the environment (Adeogun and Agbongiarhuoyi, 2009 ; Hou and Wu 2010; Adejumo *et al*., 2014).

A number of studies have been conducted on pesticide use, their safety measures as well as the environmental impact of pesticide application on different crops (Tijani , 2006; Macharia et al., 2009; Oluwole and Cheke, 2009; Sande *et al*., 2011; Tijani and Nurudeen, 2012; Gesesew *et al*., 2016; Tam,2016; Mustapha *et al*., 2017). However, most studies on pesticide use in cocoa farming mostly concentrated on insecticides but not fungicides or herbicides, and did not take into account the potential impact of the pesticides on human health. The aim of the present study therefore was to assess the likely environmental and health impact of the different pesticides used by cocoa farmers in the Akyemansa District of Ghana, and the safety measures adopted during pesticide application. The specific objectives were to identify the different types of pesticides used by the cocoa farmers, to evaluate the safety measures adopted by farmers during pesticide application, and with the intent to determine the total Environmental Impact Quotient (EIQ) values of the various pesticides used to ascertain those likely to have adverse effects on the environment and human health.

2. Methodology

2.1 Study Area

The study was conducted in Akyemansa District in the Eastern Region of Ghana. The district lies on longitude 1^0 10W and 1^o O E. (Fig 1). The major rivers in the district are the Pra at its western boundary and the Birim at its southern border (MOFA, 2015b). The district which has a land size of 611.80 km^2 is within the wet semi-equatorial climatic zone. The mean temperature range between a minimum of 25.2 ^oC and a maximum of 27.9 ^oC, and the relative humidity is about 55-59 % throughout the year (Ghana Statistical Service, 2014). The annual rainfall is between 1500 mm and 2000 mm with the main rainy season from March to July and a minor one between September and November, and these climatic conditions make the district ideal for the cultivation of cocoa, The population of Akyemansa District is 97,374 and majority of the district's population (87.2%) make a living from farming and 85 % of those grow cocoa (Ghana Statistical Service, 2014).

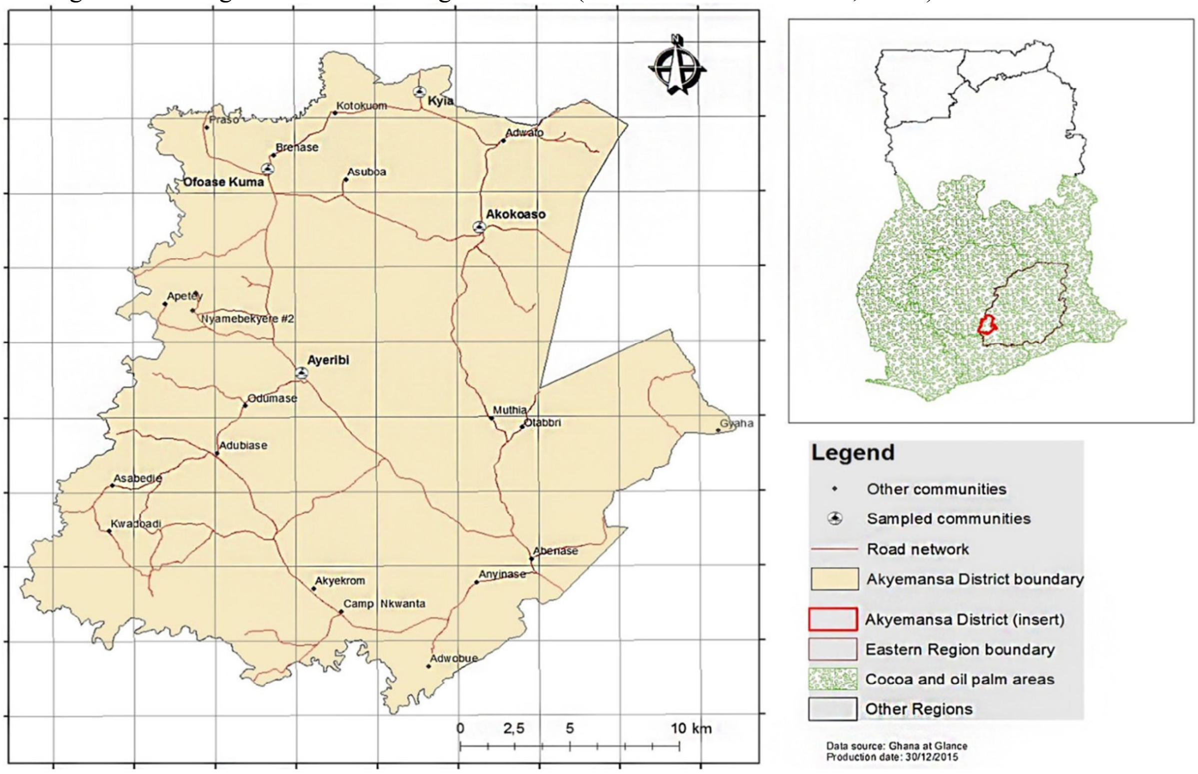

Figure 1: Location of study area.(Source: Deans *et al.,* 2017)

2.2 Data Collection

The field work was carried out from October 2017 to December 2017 in ten (10) randomly selected villages from the district. The villages were Abenase, Adjobue, Anyinase, Akyerkrom, Asiedu, Camp Nkwanta, Dwaha, Kyeremenkene, Otabi and Yeboah. Twenty five (25) cocoa farmers in each of the selected villages constituting a total of 250 were also selected using simple random sampling technique. Data were collected using interviews and field observations. Focus group discussions were also carried out to double check the individual responses. Data were obtained on the pesticides used by the cocoa farmers, pesticide use safety measures and the time of application. The trade names of the pesticides mentioned by the farmers and observed in the field were crosschecked at some agrochemical shops to determine their common names or active ingredients. Basic information about the pesticides i.e. active ingredient, composition, formulation, quantity and application rate were obtained from the pesticide label.

2.3 Determination of Environmental Impact Quotient (EIQ) values

The EIQ values of the different pesticides were determined using the EIQ total values from Kovach et al., (2004). The formula for estimating the EIQ value of individual pesticides is stated below and is the average of the farm worker, consumer, and ecological components.

EIQ={C[(DT*5)+(DT*P)]+[(C*((S+P)/2)*SY)+(L)]+[(F*R)+(D*((S+P)/2)*3)+(Z*P*3)+(B*P*5)]}/3

DT = dermal toxicity D = bird toxicity
C = chronic toxicity S = soil half-life
SY = systemicity Z = bee toxicity
F = fish toxicity B = beneficial arthropod toxicity
L = leaching potential P = plant surface half-life
R = surface loss potential

The values in the equation were determined by toxicological information from various data bases including Extension Toxicology Network (EXTOXNET),CHEN-NEWS,SELCTTV, information sheets of the chemical manufacturers and sources of public data available from the US Environmental Protection Agency (Kovach et al., 2004). The information on chronic toxicity value (C) included in the human health portion of the equation comes from studies of genetic mutations in animals, and the teratogenic, reproductive and oncological effects of these chemicals (Kovach et al., 1992). The EIQ values of pesticides used by farmers in this study were taken from the updated database of more than 450 active ingredients that are available on a Cornell University website (http://nysipm.cornell.edu/publications/eiq/). However, for the active ingredients of pesticide that were not available at that site, the EIQ of a chemically similar product which in the same hazard classification of the World Health Organization was used (IPCS, 2006). EIQ values of the pesticides used were divided into three categories of impact on humans and the environment, and were rated as low (EIQ = 0 to 20), medium (EIQ = 21 to 40) and high (EIQ ≥ 41) (Mazlan and Mumford, 2005). Although the field Use EIQ values give a better comparison of the environmental impact of pesticides (Kovach et al., 2004), we resorted to use the total EIQ only since most of the farmers interviewed were unable to provide an estimate of the use rate. Also, the application rate for many of the pesticides varies considerably depending on the site, time, or host target (Kniss and Coburn, 2015).

2.4 Data Analysis

The demographic data obtained during the survey were statistically analyzed using SPSS version 16 software package. This analysis aimed to get an overview of variables studied in frequency and percentage form.

3. Results and Discussion

3.1 Demographic characteristics of respondents

The demographic characteristics of respondents in the study area are shown in Table 1. Majority (73.2 %) of the respondents were males while 26.8 % were females indicating that cocoa farming in Akyemasa as in other parts of Ghana is a male dominated occupation, and this might be due to its labour intensive nature which makes it less attractive to most females (Okoffo *et al*., 2016). This result is in line with that of a study conducted by Tijani (2006**) ;** Anang *et al.,* (2013) and Boateng *et al*., (2014).

Most (83.2%) of the farmers were 42 years and above while 13.2% were between 30 and 41 years. Only 3.6 % of the farmers were between the ages 18 and 29 years (Table 1). This shows that the youth in the study area were not much involved in cocoa farming. However, there is the likelihood that a lot of the youth in Akyemansa District and Ghana as a whole will soon get into cocoa and other crops farming as a result of the introduction of the 'planting for food and jobs' programme by the Government of Ghana, which aims at making farming attractive to the youth, and to provide them with employment.

Out of the 250 respondents, 102 (40.8%), 13 (5.2 %) and 3 (1.2%) had received formal education at the basic, secondary and tertiary levels respectively (Table 1). However, 132 (52.8) had no formal education, and as a result could not read or write. This observation was evidenced by the fact that 182 (72.8%) of the respondents did not read the pesticide label before application. Most of these farmers therefore obtained information about pesticides from the retailers. The low level of education among the farmers observed in this study is however different from results in other studies by Anang *et al.,* (2013), Boateng *et al*., (2014) and Okoffo *et al*.,(2016) in different cocoa growing areas in Ghana, in which they reported that majority of the farmers had some form of formal education.

Although all the respondents were farmers, some were engaged in other occupations in addition to farming. Almost half 122 (48.8%) of the respondents engaged in farming only, 120 (48%) were farmers and artisans or traders, and 7(2.8%) were farmers and government employees. Only 1 (0.4) of the respondents was a farmer and a student. Many people in cocoa growing regions in Ghana have the perception that income from cocoa farming is seasonal, and hence engaged in cocoa farming in addition to their full time occupation to meet their financial needs at certain times of the year. However, one can harvest cocoa every month for more and regular income provided the farm is well managed.

Table 1: Demographic characteristics of cocoa farmers in the study area (N= 250)

Profile	Category	Frequency	Percentage
Gender	Male	183	73.2
	Female	67	26.8
Age	18-29	9	3.6
	30-41.	33	13.2
	42 and above	208	83.2
Educational level	Illiterate	132	52.8
	Basic	102	40.8
	Secondary	13	5.2
	Tertiary	3	1.2
Occupation(s)	Farming only	122	48.8
	Student + Farming	1	0.4
	Government employee + Farming	7	2.8
	Traders/ Artisans + Farming	120	48.0

3.2 Pesticides used by the cocoa farmers.

Cocoa farmers in the study area used insecticides, fungicides and herbicides to control insects, fungi and weeds respectively. Some of these pesticides with different trade names have the same active ingredients. Out of the 24 pesticides used by the farmers, 10 (41.6%) were insecticides, 8 (33.3%) were herbicides, and 6 (25%) were fungicides (Table 2). Insecticides were used by most of the farmers probably because insects, particularly mirids were seen to be the most serious threats to cocoa production and directly reduce the yield of produce. The most used insecticides were Akate Master (Bifenthrin) 59.6%, Confidor (Imidacloprid) 43.2%, Galil (Imidacloprid+Bifenthrin) 20.8% (Table 2). Akate Master (Bifenthrin), Confidor (Imidacloprid), Galil (Imidacloprid+ Bifenthrin) were used by majority of the farmers probably because they have been approved and recommended by the Ghana Cocoa Board (COCOBOD) for the management of mirids in Ghana (Cocobod, 2014). This observation is in line with a study by Awudzi et al., (2016) which showed the vast majority of the farmers applied insecticides for mirid control on their farms. However, some farmers used unapproved insecticides such as Frankofen (Fenvalerate) 10%, Akate Suro (Diazinon) 3.2%, Buffalo 3.2%, (Chlorfenvinphos) 3.2%, Lambda (Lamda–Cyhalothrin) 1.2% and Sunpyrifos (Chorpyrifos-ethyl) 1.6% probably because they were readily available at the pesticide selling shops and were also affordable.

A relatively small proportion of the respondents used herbicides probably because most cocoa farmers preferred mechanical weed control, by weeding to chemical control, by herbicide, especially when the cocoa tree canopy is formed. The formation of tree canopy prevents light from reaching the floor of the farm, thus inhibiting the growth of light loving plants. However, during the seedling stage of the development of the cocoa plant, farmers used a combination of weeding and herbicides to control weeds. The commonly used herbicides were Sunphosate (Glyphosate) 34.4%, Serosate (Glyphosate) 27.2%, Adwumawura (Glyphosate) 14.4%, Gramaxone (Paraquat) 14.8%, and Weedoff (Paraquat) 11.6% (Table 2). Some of the farmers interviewed did not use herbicides at all, because they claimed these negatively affected soil fertility and therefore reduce crop yield. This claim can however be ascertained through future research.

Similarly, a small proportion of the farmers used fungicides probably because most of them rely on cultural methods to control fungal diseases. The common methods used were pruning and the removal of chupons which involve cutting excess branches after the main harvest so that cocoa trees can receive more light to keep fungal diseases under control (Cocobod Ghana. 2012). The most used fungicides were Champion (Copper Hydroxide) 9.2%, Nordox super (Cuprous oxide) 4.4%, Kocide (Cupric Hydroxide) 6 (2.4%), Fungikill (Copper Hydroxide) 13.6%, Funguran (Copper Hydroxide) 2%, and Redomil (Metalaxyl-M+ Cuprous oxide) 5.2% (Table 2). These fungicides have been approved by the Cocobod of Ghana for use by cocoa farmers (Adjinah and Opoku, 2010), and were readily available.

Table 2. Pesticides used by cocoa farmers in the study district.

Trade name	**Common name**	**Action**	**Chemical class or group**	**No of Farmers (%)**
Akate Master	Bifenthrin	I	Pyrethroid	149 (59.6%)
Akate Power	Thiamethoxam	I	Neonicotinoids	28 (11.2%)
Frankofen	Fenvalerate	I	Pyrethroid	25 (10%)
Akate Suro	Diazinon	I	Organophosphate	8 (3.2%)
Confidor	Imidacloprid	I	Neonicotinoids	108 (43.2%)
Galil	Imidacloprid+Bifenthrin	I	Neonicotinoids + Pyrethroid	52 (20.8%)
Consider	Imidacloprid	I	Neonicotinoids	3 (1.2%)
Buffalo	Chlorfenvinphos	I	Organophosphate	8 (3.2%)
Lambda	Lamda –Cyhalothrin	I	Pyrethroid	3 (1.2%)
Sunpyrifos	Chorpyrifos-ethyl	I	Organophosphate	4 (1.6 %)
Champion	Copper Hydroxide	F	Inorganic	23 (9.2%)
Nordox super	Cuprous oxide	F	Inorganic	11 (4.4%)
Kocide	Copper Hydroxide	F	Inorganic	6 (2.4%)
Redomil	Metalaxyl	F	Acylamines	13 (5.2%)
Fungikill	Copper Hydroxide	F	Inorganic	34 (13.6)
Funguran	Copper Hydroxide	F	Inorganic	5 (2%)
Round up	Glyphosate	H	Organophosphate	8 (3.2%)
Serosate	Glyphosate	H	Organophosphate	68 (27.2)
Gramaxone	Paraquat	H	Bipyridyl	37 (14.8%)
Weed off	Paraquat	H	Bipyridyl	29(11.6%)
Adwuma Wura	Glyphosate	H	Organophosphate	36 (14.4%)
Sunphosate	Glyphosate	H	Organophosphate	87(34.8%)
Atrazine	Atrazine	H	Triazine	13 (5.2%)
Condemn	Glyphosate	H	Organophosphate	9 (3.6%)

Action, I= Insecticide, F= Fungicide, H= Herbicide.

3.3 Safety measures adopted during pesticide application

The safety of the applicator and the consumer is very paramount during pesticide use because of the health effects of pesticides. The use of Personal Protective Equipments, PPEs (wellington boots, goggles, rubber gloves, nose masks, overalls and hats) has been recommended to small-holder farmers for decades in order to protect them from the effects of pesticides (Bateman, 2015). From our study, 130 (52%) of the respondents did not use personal protective equipment while 120(48%) did (Table 3). A smaller proportion of respondents used the PPEs because majority of them did not see the necessity of using them. This might also be due to illiteracy and lack of knowledge on the extent to which pesticides poses a health hazard (Damalas and Hashemi, 2010, Blanco-Muñoz et al 2011). The results of this study agree with that of Ogunjimi and Farinde (2012a) and Antwi-Agyakwa (2013) which stated that a small percentage of cocoa farmers actually used PPEs during pesticides application while majority did not see the use of PPE to be necessary. Similarly, a study conducted by Oluwole and Cheke (2009) revealed that most farmers did not use any form of protective equipment when mixing and applying pesticides. The non usage of PPEs is very common with farmers in developing countries (Ajayi and Akinnifesi, 2007). Some of these farmers however, used handkerchief or a small piece of cloth to cover their nose to protect them from inhaling the pesticides. This observation also agrees with that of Kalayou and Amare (2015).

Application of pesticides in the right quantity and at the right time can be one of the most important considerations for avoiding harmful residues on produce. Pesticides must be applied taking into account the Pre-Harvest Interval (PHI): which is the minimum permitted number of days between the last spray and harvest (Bateman, 2015). Although the PHI was stated on the pesticide label, farmers did not strictly adhere to it probably because most of them were unable to read. From this study, 145 (58%) respondents applied pesticides and waited for about two weeks before harvest, while 142(40.8%) applied after harvest. Only 3(1.2 %) of respondents applied pesticides very close to the time of harvest (Table 3). This is an indication that farmers wait for some time between pesticide application and harvest to ensure that the crop will meet the required pesticide residue tolerance level.

Table 3. Safety measures used during pesticide application by cocoa farmers in the study district.

Item	Level	Frequency	Percentage
Use of Personal Protective Equipments (PPE)	Yes	120	48
	No	130	52
Hand washing with soap and water before eating	Yes	124	49.6
	No	126	50.4
Time of application	Before harvest	145	58
	Close to harvest	3	1.2
	After harvest	102	40.8
Time of eating	Before application	156	62.4
	During application	24	9.6
	After application	70	28
Reading of pesticide label before application	Yes	68	27.2
	No	182	72.8

As a common practice in Ghana, most farmers send an already prepared meal to the farm or prepare the meal at the farm which is eaten before, during or after the day's work. Over half, 156 (62.4%) of respondents ate their meal before application while 70(28%) ate their meal after application. Few of the respondents 24(9.6%) stopped the application, ate their meals and continue after eating (Table 2). This shows that most of these famers were aware of the health implications of consuming pesticide contaminated meals. Less than half, 124(49.6%) of the respondents washed their hands with soap and water while 126 (50.4%) did wash with water only (Table 2). Hand washing with water only could possibly lead to pesticide contamination and exposure (Damalas and Eleftherohorinos, 2011).

3.4 Potential Environmental and health impact of pesticides used.

The environment and human health are likely to be affected negatively because of the frequent use of unapproved pesticides with high EIQ values by farmers, and the non-use of PPEs. The total Environmental Impact Quotient (EIQ) values of the various pesticides used by the farmers are shown in Table 4. In general, the EIQ values of the pesticides used ranged between 15.33 and 55.58. Chlorfenvinphos (Buffalo), an insecticide had the highest value while Glyphosate, a herbicide had the lowest value. Six out of the 25 pesticides were in high impact category, thirteen in medium impact category, and four in low impact category.

Although Chlorfenvinphos, a very hazardous insecticide had the highest EIQ value (55.58) and was in a high impact category, a small proportion 8 (3.2%) of the respondents used it, which suggests that it is not likely to impact significantly on the environment and human health. Bifenthrin (Akate master), a moderately hazardous insecticide also in a high impact category was used by majority 149 (59.6%) of the respondents. It can therefore be deduced that Bifenthrin is likely to impact significantly on the environment and human health. Also, Imidacloprid, a moderately hazardous insecticide in a medium impact category had a relatively high EIQ value (36.71) and it was used by a significant number, 108 (43.2%) of the respondents. This could also make a significant impact on the environment and human health. Diazinon (Akate Suro) another moderately hazardous insecticide with a high EIQ value and in a high impact category is also not likely to impact significantly on the environment and human health because it was used by few respondents.

Table 4. Total EIQ values of the pesticides used by the cocoa farmers

Trade name	Common name	EIQ-total	WHO class	Impact Category
Akate Master	Bifenthrin	44.35	II	High
Akate Power	Thiamethoxam	33.3	III	Medium
Frankofen	Fenvalerate	49.6	II	High
Akate Suro	Diazinon	44.03	II	High
Confidor	Imidacloprid	36.71	II	Medium
Galil	Imidacloprid+Bifenthrin	NK(40.52)*	II	High
Consider	Imidacloprid	36.71	II	Medium
Buffalo	Chlorfenvinphos	55.58	1b	High
Lambda	Lamda –Cyhalothrin	44.17	II	High
Sunpyrifos	Chorpyrifos	26.85	II	Medium
Champion	Copper Hydroxide	33.20	II	Medium
Nordox super	Cuprous oxide	33.2*	II	Medium
Kocide	Copper Hydroxide	33.20	II	Medium
Redomil	Metalaxyl	29.40	II	Medium
Fungikill	Copper Hydroxide	33.20	II	Medium
Funguran	Copper Hydroxide	33.2	II	Medium
Round up	Glyphosate	15.33	III	Low
Serosate	Glyphosate	15.33	III	Low
Gramaxone	Paraquat	24.73	II	Medium
Weed off	Paraquat	24.73	II	Medium
Adwuma Wura	Glyphosate	15.33	III	Low
Sunphosate	Glyphosate	15.33	III	Low
Atrazine	Atrazine	22.85	III	Medium
Condemn	Glyphosate	15.33	III	Low

Ib = highly hazardous ; II =moderately hazardous; III = slightly hazardous; U = unlikely to present acute hazard in normal use; NK = not known (WHO, 2004; PAN, 2009,).

4. Conclusion and Recommendations

This study revealed that cocoa farmers at Akyemansa District in the Eastern Region of Ghana used insecticides (41.6%), herbicides (33.3%) and fungicides (25%) to control pests and diseases. Some of the pesticides used were not approved for use by the Cocobod of Ghana. Also, the farmers adopted both safe and unsafe measures during pesticide application. Chlorfenvinphos, an insecticide had the highest total EIQ value of 55.58, while Glyphosate a herbicide had the lowest value of 15.33. Bifenthrin (Akate master) of WHO class II and Imidacloprid (Confidor) also of WHO class II, were most likely to impact negatively on the environment and human health because both insecticides were in a high impact category, and were used by majority of respondents.

The implications to those actively involved in the registration, distribution and use of pesticides are enormous. It should be ensured that, all stake holders is the use of pesticides are educated about the safe use of pesticides to prevent negative effects on the environment and human health. Pesticide retailers who are the major of information on pesticides in Ghana must be trained periodically to become abreast with current issues regarding pesticides. Farmers should stop over relying on pesticide use and adopt Integrated Pest Management practices. Also, the pesticide registration department of the EPA of Ghana should intensify their periodic checks at the pesticide retailing shops to flush out unapproved pesticides.

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