KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

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PREVALENCE OF PESTICIDE RESIDUE LEVELS IN GHANA COCOA BEANS

BY

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DECLARATION

I hereby declare that this submission is my own work towards the MSc and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the university, except where due acknowledgement has been made in the text.

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DEDICATION

This thesis is entirely dedicated to my dad, Dr. Simon Kwaku Attah, a Senior Lecturer in the Microbiology Department, University of Ghana Medical School, Korle-Bu Teaching Hospital.

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ABSTRACT

Fermented cocoa beans with pesticide residues higher than the acceptable levels stipulated by importers face the possibility of being rejected. The use of these pesticides is inevitable owing to the havoc caused by pests. Organochlorine pesticide: imidacloprid and pyrethroid pesticides: fenvalerate, cypermethrin and permethrin were determined using high performance liquid chromatography (HPLC) and gas chromatography (GC). Eight hundred and seventy-three (873) samples for the 2013/14 cocoa season and 925 samples for the 2014/15 season were analyzed. The overall failure rate for all the smaples in the first season was 8.9% (78/873) and for all the bags/tonnage supplied, 9.1% (35275/387317). For the second season, the overall rate for the 925 samples analyzed was 15.6% (144/925) and for all the bags/tonnage supplied, 15.2% (68985/454357). For the first crop season, the Ashanti region recorded the highest sample failure rate of 10.9% (16/147). In the second season the failure rate pertaining to the number of bags/tonnage from the Volta region was the highest (100%). Pesticide residues in the samples or bags/tonnage were mainly due to cypermethrin followed by fenvalerate, imidachloprid and lastly, permethrin. A higher proportion of samples or bags/tonnage of cocoa beans contained cypermethrin and permethrin residues in the first cocoa season than the second season. The reverse was the case for fenvalerate and imidacloprid. Cypermethrin and fenvalerate residues were found in samples from all the regions. Residues of permethrin were found only in the samples from Goaso in the Brong Ahafo region and in samples from Nsokote in the Ashanti region. Imidacloprid residues were absent only in samples from the Ashanti region and the Volta region. On the whole, the highest proportions of residues were found in samples supplied from the Western South Region, Central Region and Eastern Region for cypermethrin, fenvalerate for the 2013/14 cocoa season. In the 2014/15 season, the highest supply of the beans with cypermethrin and fenvalerate residues were also supplied from the Western South Region and imidacloprid from the Western North Region (Tables 4.8a-4.8d). It is recommeded that training and effective communication with all stakeholders should be carried out with regards to the proper use of pesticides. Continuous monitoring needs to be done to ensure that pesticides are not abused by those who use them.

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LIST OF ABBREVIATIONS

CODAPEC	Cocoa Disease and Pest Control Project
OCP	Organochlorine Pesticides
EU	European Union
ICCO	International Cocoa Organization
WTO	World Trade Organization
ISSER	Institute of Statistical, Social and Economic Research
GDP	Gross Domestic Product
IMF	International Monetary Fund
COCOBOD	Ghana Cocoa Board
WHO	World Health Organisation
FAO	Food and Agriculture Organization
UNEP	United Nations Environmental Programme
CAC	Codex Alimentarius Commission
CODEX	Codex Alimentarius
MRL	Maximum Residue Limits
EEC	European Union Community
EPA	Environmental Protection Agency
MHLW	Health, Labour and Welfare
QCC	Quality Control Company Limited
p,p-DDD	Dichlorodiphenyldichloroethane
p,p-DDE	Dichlorodiphenyldichloroethylene
p,p-DDT	Dichlorodiphenyltrichloroethane

NOAEL	No Observable Effect Level
HPLC	High Performance Liquid Chromatography
GC	Gas Chromatography
SPE	Solid Phase Extraction
SCX	Strong Cation Exchange
SI	Silica
mg	Milligram
ml	Millilitre
Std	Standard
g	Gram
mm	millimetre
P	p-value
rpm	Revolutions per minute
^{o}C	Degree celcius
JMRL	Japanese Maximum Residue Limit
kg	Kilogram

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CHAPTER ONE

INTRODUCTION

1.1 The Cocoa tree (Theobroma cacao)

Theobroma cacao (Malvaceae) which originated from the rainforests of the Amazon basin of South America is now cultivated widely in other pla ces where this type of forest exists. It thrives well in the area located within the Tropics of Cancer and Capricorn where the climate is suitable for its growth. This evergreen plant grows to a height of 4–8 m. The cocoa tree does well at an altitude of up to about 1,000 meters above sea level and in areas where rainfall is about 10.2 cm (Rainforest Alliance, 2016). The plant does well in deep, well-drained nutrient-rich and moist soils and can survive in shady areas. The yield increases as the temperature also increases up to 32^{o}C with a corresponding decrease in humidity. *Theobroma cacao* requires a minimum of 1000 mm rainfall that is well distributed throughout the year and so it cannot survive in a very dry weather.

The leaves are green in colour and are alternate, entire and unlobed. They are between 10 cm and 40 cm long, and 5 cm and 20 cm wide. The flowers develop from the trunk and older branches directly and are found in clusters. The fruit also referred to as the pod is oblong in shape (about 10 cmx30 cm). When young the pod is green in colour, and when ripe it appears yellow, red or purple. Figure 1.1 is a photograph of the cocoa tree with fruits on the trunk. The pod contains 20 to 60 reddish-brown cocoa beans each of which is surrounded by a sugary pulp. Harvesting of the pods is normally done at the end of the rainy season.

Figure 1. 1: A photograph of a cocoa tree with fruits. (Source: Daanu, 2011).

1.1.1 Processing of cocoa beans

Ripened cocoa pods identified by their yellow or red colour (and not the green pods) are those that are normally harvested by farmers for processing. After harvesting the pods are gathered at a central location. The beans are removed from the pods after the pods are split or cracked with the blunt side of a machete or with other objects like a wooden mallet to remove the seeds with the pulp. The seeds with the pulp are then heaped on banana leaves at a dry place (Figure 1.2) and covered with the leaves. The seeds are allowed to undergo fermentation process. The fermentation process involves a lot of biochemical processes and it is a major step in the processing of cocoa beans. It is carried out so as to give flavour to the beans. As fermentation is in process, the seeds and pulp undergo "sweating", and the thick pulp liquefies. Intermittent stirring of the heaped beans boosts the process. The fermented pulp dribbles away, leaving the cocoa seeds behind for collection. Fermentation lasts for a period of 5-7 days (Owusu-Boateng and Owusu, 2015).

Following fermentation, drying of the cocoa beans are spread on woven mats that are placed on platforms raised above the ground. The beans are left in the sun and dried for 4-6 days and, even longer for about 14 days, depending on the climatic conditions including the humidity and temperature of the area. Drying is enhanced by constant raking of the beans and/or shuffling with the hand or bare feet. During this process, a mixture of red clay and water is sprinkled over the beans to give them a finer colour and protection against molds prior to shipment to the importing countries (Owusu-Boateng and Owusu, 2015).

Figure 1. 2: Cocoa beans heaped on banana leaves (Source: Owusu-Boateng and Owusu, 2015).

Figure 1. 3: Fermented cocoa beans spread out to dry (Source: www.verfotosde.org).

1.1.2 Health benefits of Cocoa

Cocoa beans are very beneficial and are the main ingredients in the production of all kinds of chocolates and cocoa products. Recent studies indicate that the cocoa bean contains healthy polyphenols or catechins of the flavonol group. A meta-analysis of medical trials on the effect of cocoa on blood pressure suggested cocoa flavanols can increase blood flow and reduce systolic and diastolic blood pressure numbers. Cocoa beans contain several flavanols which may also reduce risks of cardiovascular disease (Science Daily (2007).

1.1.3 Cocoa producing areas

Cocoa, *Theobroma cacao*, is a very important cash crop grown in the West African tropics, the Caribbean, South America and Asia. Cocoa production constitutes an important part of the rural economy in West Africa where over 70% of the world's cocoa is produced with about 21% from Ghana. Figure 1.4 is a map of Ghana showing Cocoa-growing regions and locations of cocoa sampling (Source: htpp://www.researchgate.net/figure/281742723_fig1). The industry is dominated by a large number of small scale farmers who are dependent on the crop for their livelihoods (Acquaah, 1999; Appiah, 2004). Cocoa is produced in countries in a belt between 10ºN and 10ºS of the equator, where the climate for the cultivation of cocoa trees is very suitable. Côte d'Ivoire, Ghana and Indonesia are the largest cocoa producing countries (http://www.icco.org/about-cocoa/growing-cocoa.html; 28/07/15 11:00 am).

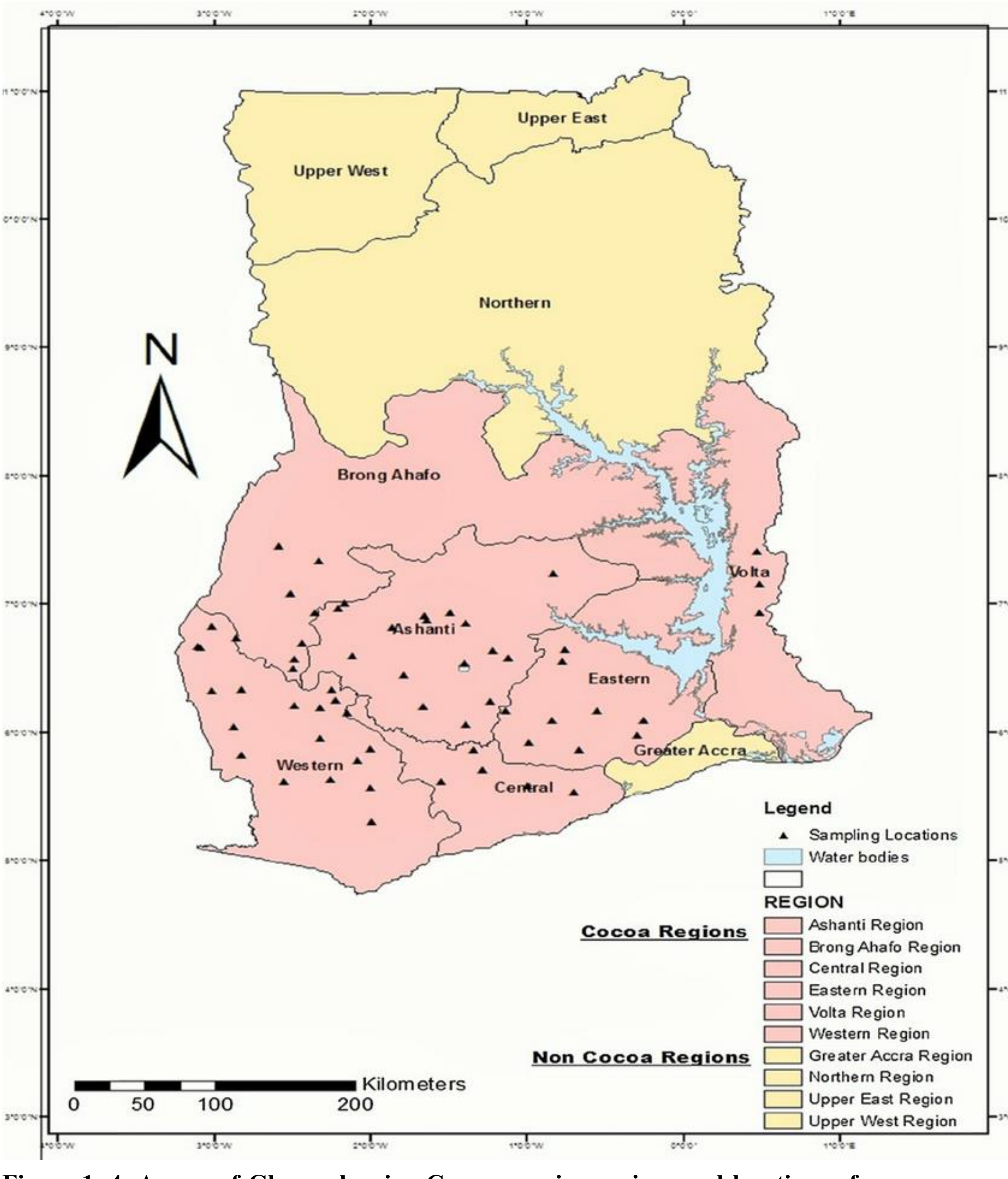

Figure 1. 4: A map of Ghana showing Cocoa-growing regions and locations of sampling (Source: htpp://www.researchgate.net/figure/281742723_fig1: Assessed on 08/Oct/2016).

1.2 Problem statement

There are repeated cases of failed consignments of agricultural products including cocoa due to excessive pesticide use and safe use of these products have become an issue of concern. Recent changes in the European Union (EU), North America and Japan regulations have called for a reflection on best practices of crop protection in cocoa and other commodity crops (ICCO, 2007).

The quality of cocoa imported into the EU and elsewhere is assessed based on traces of pesticides and other substances that have been used in the supply chain. Codex Alimentarius Commission (CAC), the Committee on Pesticide Residue of the FAO/WHO, determines the acceptable levels of active ingredients in foods. The CAC which was established in 1963 implements the Joint FAO/WHO Food Standards Programme with the aim of protecting the health of consumers and ensuring fair trade practices in the international food trade (Moy and Wessel, 2000). CODEX has set maximum residue levels (MRLs) of poisonous substances in commodities including cocoa on the international market. Commodities therefore are rejected by importing countries if the residual levels exceed the established CODEX levels.

In September 2008, the European Union Legislation on MRLs on Pesticides (Regulation 149/2008/EEC) came into effect. The regulation established MRLs of permitted pesticides on imported foods including cocoa. This consequentially indicated that all cocoa beans exported from Ghana to the EU effective September 2008 had to conform to the regulation.

The US Environmental Protection Agency (EPA) also established their Food Quality Protection Act of 1996 regulating the level of pesticide residues permitted on food.

This Act requires that all approved pesticides are properly used, handled, stored and disposed of.

This notwithstanding, the Ministry of Health, Labour and Welfare (MHLW) in Japan also established a new legislation that came into effect from May 2006, setting new MRLs for food products (Bateman, 2010).

CODEX, European Union, Japan, Canada, New Zealand, South Africa, Malaysia, Hong Kong, Korea, India, Israel, Russian Federation and Singapore set default pesticides MRLs for cocoa beans to be 0.01 mg/kg if no MRL exist (Azhar and Rahmat, 2011).

Moreover, accumulation of chemicals in the cocoa fat may change the taste of the beans and eventually products such as chocolate made from them. This is called tainting.

Entomologists are therefore tasked to ensure that recommended chemicals do not leave any residues, and that the dosage is the minimum that would give the optimum control under the agricultural conditions in the country. Humans are exposed to the health effects of pesticides when they consume foods contaminated with their residues (William *et al*., 2008; Bempah *et al*., 2011). Some of these effects are birth defects, fetal death, neuro-developmental disorder as well as leukemia (Https://en.wikipedia.org/wiki/Health_effects_of_pesticides).

There is therefore the pressing need to control and monitor them environmentally. Exposure to the harmful effects of pesticide use goes beyond the impact of Ghanaian farmers and includes the consumer population. A number of academic studies have been done to investigate the pesticide residues in food. These studies established the residues of pesticides in fish, water, sediments, fruits, vegetables, meat and human fluids in Ghana as positive (Darko, 2009).

Generally, pesticide residues in cocoa raise the greatest levels of concern, with exports to the EU identified as the largest market. Though there are significant country variations, in emphasis, the Ghanaian cocoa industry focuses on the Japanese standards for pesticides, despite the relatively small proportion (4%) of its export market. The industry has decided to do this because the Japanese requirements represent the most stringent specifications; therefore meeting these requirements makes it easier to meet other standards.

The goal of maintaining high levels of agricultural productivity and profitability while reducing pesticides use presents a significant challenge. There have been repeated cases of excessive levels of pesticide residues being found in cocoa produce and their safety has become an issue of concern. This has had negative economic impacts on the industry and the nation as a whole since such failure has prevented the industry from meeting the demands on the world market.

1.3 Objectives

The objective of this study is to ascertain the prevelance level of pesticides in Ghanaian cocoa beans, specifically, the study will ascertain and quantify the levels of

i). cypermethrin

ii) fenvalerate

iii) imidacloprid

iv) and permethrin residues in cocoa beans from the various cocoa districts of Ghana.

1.4 Justification

Since cocoa is a major cash crop in Ghana, and a major economic gain is achieved from the exportation of cocoa, there is the need to ascertain and identify the districts and farmers with high prevailing pesticide residue levels, which is what this project seeks to do by analyzing data of the pesticide residue analysis over a period of two cocoa seasons. This will enable the cocoa industry identify the problem areas in times of intervention and put in appropriate measures to reduce the incidences of cocoa failure rates due to pesticide residue levels thereby increasing yield and ensuring the safety of consumers.

1.5 Challenges of the Study

1. The inability to obtain adequate number of samples from some districts made them have higher prevalence making comparing comparisons and judgment unfair for such districts. In some cases, there were only single samples from district like Jasikan and Elluokrom etc.
2. Cocoa beans bought from the farmers are pooled together before being brought to the ware-houses. It is therefore not possible to trace the use of a particular pesticide to any particular cocoa farmer or to village/town.
3. Moreover, multiple pesticide residues cannot be tract to one particular farmer for the same reason.
4. It is also possible that some of the beans are transported across one district and mixed with those from other districts thereby making it difficult to tract their origin.

CHAPTER TWO

LITERATURE REVIEW

2.1 Economic importance of cocoa

Cocoa contributes significantly to the national foreign exchange earnings and provides employment to millions of Africans (Bateman, 2010). About 30% of Ghana's total export earnings come from cocoa which is the second most important commodity of export after gold. Ghana, the world's second largest cocoa producer, produced about 20% of the world's cocoa in 2005-2006 (ICCO, 2006). Cocoa is the main cash crop and singly the most important exported product in Ghana.

Over 700,000 households constituting around 6.3 million Ghanaians (about 30% of the national population) depend on cocoa production as their major source of economic activity and for their livelihood. In 2006, export of cocoa products such as cocoa butter, powder, beans, paste, and waste totaled US$1,241 million, equivalent to more than 33% of Ghana's merchandise exports (WTO, 2008).

Production and marketing of cocoa accounted for 32.2 per cent of export earnings (ISSER, 2008) and 8.5% of Gross Domestic Product (GDP) in 2006, compared with 4.9% in 1998, with the European Community as the main export destination for cocoa produced in Ghana (IMF, 2007).

In 2009, agriculture contributed to 46.7% of GDP compared with 41.4% the previous year. The increase largely had a consequential effect on the rehabilitation of cocoa production (Aryeetey and Kanbur, 2008).

The cocoa industry employs about 60% of the national agricultural labour force in the country (Appiah, 2004). Cocoa also contributes about 70-100% of the annual household income for the farmers (COCOBOD, 1998).

The saying 'Cocoa is Ghana, Ghana is Cocoa' portrays the important role cocoa plays in the economy of Ghana (COCOBOD, 2015). Ghana is one of the largest suppliers of cocoa on the world market and its cocoa sector employs millions of people. Just as the small scale farmers, the Ghanaian state also depends on the earnings from cocoa, and now more than ever since 2004 when cocoa became the main source of export revenue in Ghana (ICCO, 2006).

In terms of quality, Ghana over the years has been recognized as the world's leader in the production of premium quality cocoa and the quality of Ghana's cocoa has been a benchmark for acquiring cocoa from other countries (Osei, 2008).

Ghana cocoa continues to enjoy the high premium on the World's Commodities Markets because of its unsurpassable high quality. This cocoa comprise of very well fermented cocoa beans of dark brown uniform colour and sizes with good cocoa flavour potential and a moisture content between 6 and 8%, with no or very little damaged beans and foreign material (Amoa-Awua *et al*., 2006).

This status has over the years been diligently maintained due to effective quality control practices of the Quality Control Company Limited of COCOBOD (COCOBOD, 2010).

2.2 Cocoa production in Ghana

Africa's first crop of cocoa was planted in Ghana over a century ago by Tetteh Quarshie (COCOBOD, 2000) after which Ghana's cocoa production status grew and peaked in the mid-1960s, collapsed in the early 1980s, and was revived in the late

1980s (Jaeger, 1999). The country's production peaked in the 2002/2003 season to the same level that existed in the 1960's. The output of the Ghanaian cocoa reached 566,000 tonnes in the mid-1960s and later fell to about 159,000 tonnes in the early 1980s. The output increased to 350,000 tonnes at the end of 1999 and later reaching 700,000 tonnes in 2008 due to good agronomic practices and higher cocoa prices (COCOBOD, 2009).

2.3 Challenges in cocoa production

The cocoa industry has been confronted with lots of challenges like diseases and pest infestation over the years. This has contributed to Ghana losing its position as the world's leading producer of cocoa (Anim-Kwapong *et al.*, 2005). In the 1980s, cocoa production in Ghana reduced significantly due to some of these pest and diseases (PAN, 2001).

Cocoa is easily attacked by black pod disease, cocoa swollen shoot virus (CSSV), and insects such as cocoa capsids (*Distinthiella theobromae* and *Salbeligella singularis*). Pests and diseases are known to account for 30% loss in global cocoa yields annually, while site-specific losses can range from 10 to 80% *annually* (Duguma *et al.*, 1998).

2.4 Pests and disease control

A pesticide is any substance or mixture of substances intended for preventing, destroying or controlling any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage, transport or marketing of food, agricultural commodities, wood and wood products (WHO/FAO, 2009).

Government of Ghana in the year 2001 therefore initiated a nationwide Cocoa Disease and Pest Control Project (CODAPEC), to help address the two major causes of decline in cocoa production i.e. pests and diseases. This programme led to the spraying of cocoa farms across the country with insecticides and fungicides at no cost to the farmers. The exercise resulted tremendously in an increase in cocoa production output from 340,562 metric tons in the 2001/2002 crop season to 496,846 metric tons in the 2002/2003 crop season and subsequently to 736,000 metric tons in the 2003/2004 crop season (Appiah, 2004; ICCO, 2004).

The production of locally processed beans also jumped from 20% to 35% with further re-capitalization and expansion programs underway to reach a target of 50% in the near future.

However, along with positive impacts of the CODAPEC programme came some negative environmental impacts. An example of these negatives may be the destruction of part of the natural flora and fauna of the soil through physical and chemical deterioration after the pesticides are used on the farms (Cowell and Clift, 1997).

Pesticides have been used on cocoa for over 50 years now and notable research has been carried out independently in Ghana, Nigeria, Brazil, Cameroon, Costa Rica, Côte d'Ivoire, Indonesia, Malaysia and Togo. By the early 1970s, a number of effective control techniques had been established with little incentive for change until environmental awareness of pesticides use increased in the 1990s (ICCO, 2010).

2.5 Pesticide use

The use of chemicals in the control of pests began in the year 1950 and this led to the recommendation of the various categories of insecticides to be used by farmers since then. The COCOBOD recommended pesticides for insect pest management at present are Imidacloprid (Confidor®), Bifenthrin (Akatemaster®) and Thiamethoxam (Actara®). A survey conducted by Antwi-Agyakwa *et al*. (2016) in the Ashanti, Eastern, Volta and Western regions of Ghana on 147 cocoa farms found that the pesticides that were highly used by farmers were Imidacloprid and Bifenthrin insecticides. It was also noticed that the farmers used more insecticides than recommended by the COCOBOD. Of the three insecticides, confidor or "Akatemaster" was each used by 43% of the farmers across the three regions while 14% used Actara. Most of the farmers have used their insecticides of choice for a period ranging between 5 and 16 years. Some farmers by choice have decided not to do insecticide application on their farms whereas others do as much as 11 applications annually. Overlooking all the health hazards and concerns that come with application, most farmers do without adequate protective clothing. Accordingly, the commonly used pesticides are classified under WHO hazard category as class II. There is therefore the need to heighten the education and awareness on safe handling of pesticides and their usage in order to sustain effective pest management thereby protecting the farmers, consumers and the environment.

Very significant losses of cocoa are due to mirid destructions; therefore the need for on-target timing on the application of pesticides is very essential for increasing yield. This, notwithstanding, farmers have limited information on the expected mirid population for each season. This information could help the farmers to effectively use the pesticides. A study conducted in the Eastern and Ashanti regions in Ghana revealed that there was a wide variation in the application time of pesticides because of different sources of information being used as guides to start pesticide applications. About 56% lack information on the type, frequency and timing of pesticides to be used except for those belonging to farmer groups. (Awudzi *et al*., 2015).

2.6 Types of pesticides used

Organochlorine pesticides are the most commonly used pesticides. They are also considered to be responsible for a number of environmental consequences. One large regional example of such contaminations from pesticides and human health is perhaps that of the Aral sea-region in Asia (UNEP, 1993).

Organochlorine pesticides (OCPs) are the synthetic organic insecticides that contain carbon, chlorine and hydrogen. These pesticides are water soluble and highly lipophilic. OCPs are highly persistent in organisms and the environment (Perry *et al*., 1998). Since they are persistent and not expensive, OCPs such as dichloro-diphenyltrichloroethane (DDT), aldrin, endosulfan and imidacloprid had been widely used for pest control. Residues of these pesticides can be transferred and biomagnified throughout the food chain. Their levels could be accumulated and can cause adverse health effects in animals living at higher trophic areas, including humans (Perry *et al*., 1998; Cunningham *et al*., 2007).

Pyrethroids are synthesized derivatives of naturally occurring pyrethrins which are taken from pyrethrum, the oleo resin extract of dried chrysanthemum flowers. The development of the first generation pyrethroids occurred in the 1960s and these include bioallethrin, tetramethrin, resmethrin and bioresmethrin. They are more active than the natural pyrethrum but are unstable in sunlight. By 1974, a second generation of more persistent compounds notably; permethrin, cypermethrin and deltamethrin were discovered by the Rothamsted team. With over 3,500 registered formulations, pyrethrins and pyrethroids are estimated at 23% of the insecticide on the world market, and are widely used in agriculture, public health and food processing. (USEPA, 2005; Casida and Quistad, 1998). There has been great concerns about the environmental consequences of the widespread use, handling, and disposal methods of pesticides in spite of the benefits (especially with respect to food production and health management) derived from their use (Colin, 1999; Anitescu *et al.*, 2006).

Human exposure to pesticides and their effects occur by inhalation and ingestion through dermal contact, breathing of dust or sprays, handling of pesticide products, consumption through food, water and aquatic organisms.

Due to their toxicity and persistence in the environment, synthetic organochlorines have found extensive use in the environment (Colin, 1999; Eqani *et al.*, 2012).

While the best and widely recommended means of controlling pests and diseases is the non-chemical means, the use of chemicals such as fertilizers, insecticides and fungicides are inevitably unavoidable means of effective management of cocoa farms (Moy and Wessel, 2000; Opoku *et al.*, 2007; Adjinah and Opoku, 2010).

Just as the use of fertilizer world-wide increased by almost 250% over a twenty-year period from 1986-2006, pesticide use is also expected to increase with time though there is a difficulty monitoring it. Monitoring is difficult because of the secrecy in the continued use of some banned substances. The trends in the increased world food production suggest quite clearly the attribute of crops responding to increased use of pesticides and fertilizers (UNEP, 1991).

Fortunately, the potential harmful effect of chemical/pesticide use has always been clearly appreciated in the cocoa industry since the 1960s and the standards have been established by FAO and WHO for acceptable levels of residues in the beans exported to other countries. The objective of maintaining high levels of agricultural productivity and profitability while reducing the use of pesticides is a major challenge.

2.7 Pesticide residue in cocoa

Research conducted on fermented dry cocoa beans revealed the presence of organochlorine (aldrin, p,p-DDD, p,p-DDE, p,p-DDT, endosulfan Sulphate, beta-endosulfan, alphaendosulfan, chlorpyrifos and dimethoate) and organophosphate pesticides (thophosphos, Fenitrothion, Malathion and Parathion. Fenitrothion and Parathion insecticides), which are banned in Japan for use in the cocoa industry by Japan and the European Union (EU). Nonetheless, residues of approved chemicals used under the National Cocoa Diseases and Pest Control Programme (CODAPEC) were not detected. The research also revealed that there was significantly no difference in pesticide residue concentration between samples picked from both organic and inorganic farms in the Tano North district of the Brong Ahafo region (Daanu, 2011).

These banned pesticides, however, were used on cocoa but due to their tenacious and slow degradation nature, organochlorine pesticides tend to persist in the environment a long time after application and in organisms after long term exposure. An appreciable amount of some of these pesticides (beta-HCH, lindane, delta-HCH, aldrin, dieldrin, endrin, heptachlor, gamma-chlordane, alpha-endosulfan, beta-endosulfan, endosulfan sulfate, p,p'-DDT, p,p'-DDD, p,p'-DDE and methoxychlor) were found in fermented dry cocoa beans produced in Ghana. Endosulfan which was previously registered for cotton production was found in a wide range of the samples analysed (Frimpong *et al.*, 2012b)

Monitoring of food hazards like pesticides is today a worldwide priority to offer a far-flung evaluation of food quality to safe food to human and avoid harm. A study by Sandra B. (2012) on pesticide residues in cocoa beans samples from the Brong Ahafo and Ashanti regions in Ghana, deduced that 50% of samples from the Brong Ahafo region and 45% from the Ashanti region recorded residues higher than the EU allowable limits.

Cocoa beans sampled from five communities within the Twifo Praso district in the Central region were analysed for lindane residues. No residues were detected in samples taken from all the communities. It was then concluded that lindane is not considered a chemical hazard of concern to the industry and should not be a limiting factor to using cocoa beans from Twifo Praso for the production of cocoa products such as chocolate and creams (Owusu-Ansah *et al*., 2010).

Cocoa bean samples collected from both the Central and Eastern regions in Ghana to determine their pesticide residue levels recorded varying results for the pesticides of interest. Levels of chloropyrifos and cypermethrin from the Central region and chloropyrifos, permethrin and cypermethrin from the Western region were significantly high and found to be above the maximum residue levels (MRLs) set by both EU and Japan. The absence of both aldrin and DDE in the samples signifies the gradual disappearance of the organochlorines which have been banned. Levels of Bifenthrin detected in the samples from Central region were below both the EU and Japan maximum residue levels (JMRLs) and levels detected for 4,4-DDD and 4,4-DDT from the Western region were all below the MRLs set by the EU (Mohammed, 2015)

2.8 Pesticide residue in food

Developing nations in their efforts to overcome challenges of insect and disease attack use pesticides in the production of food, protection of forests, plantations and fibre (wood, cotton, clothing etc.). The use of these pesticides has played an advantageous role in tropical areas.

Over the years, there has been global dependence on such chemical agents and concerns have been raised on their excessive use/misuse, volatility, long haul transport and contamination of the environment. In their quest to seek greener pastures, a greater part of the agricultural labour-force in most developing countries have left for a few farmers to continue with the production of traditional food for local consumption and foreign markets. This is a transitional phase affecting most developing countries. These same countries are becoming the “breadbaskets” for other parts of the world by exporting non-traditional produce to regions with colder climates and shorter farming seasons and therefore attaining international trade credits.

In order to achieve these goals, the use of pesticides has been resorted to. The use of old, non-patent, highly toxic and cheap chemicals that are not environmentally friendly in most developing countries is an abuse and this has led to acute health problems and contamination of the environment worldwide (Ecobichon, 2001). Today's consumer has become more interested and concerned about food contaminants. Consumers in such developing nations have raised concerns on residues in local and fresh produce purchased by local community and their adverse health effects. Only a few of these nations have in place clearly expressed philosophies concerning pesticide use. There is a lack of rigorous legislation and regulations to control pesticides use as well as training programmes for personnel to inspect and monitor its use and to initiate training programmes for pesticide users (Ecobichon, 2001).

2.9 Effects of pesticide use

The quest to increase production by farmers has led to the increase use of chemicals. There is limited information on the toxic effects of these chemicals on non-target organisms which are also exposed to them. However, a questionnaire survey conducted within the Atwima Nwabiagya districts in the Ashanti region of Ghana to access the chemical effects of bifenthrin and thiamethoxam on its users revealed that the chemicals could cause skin rashes and irritations among other disease manifestations in them (Boakye, 2011).

A laboratory investigations conducted using rats alongside the survey also revealed that the chemicals could be toxic to exposed organisms. Indeed, thiametoxam at higher concentrations was found to affect the lungs and furs of the exposed rats. Rats exposed to high concentrations of both chemicals had significantly smaller weight compared to the control (Boakye, 2011).

Pesticide use which has become a necessary evil in agricultural production has increased human welfare and has addressed many agricultural challenges such as grain losses.

In spite of all these benefits, its usage may lead to unwanted trace residues in food, the environment and living tissues. In the environment, they are known to move beyond boundaries to have effects on non-target organisms. These pesticides when they manage to escape into the environment serve as economic loss to its user and is not able to control pests as supposed. This escape may also lead to contamination of the environment (Tiryakil *et al.*, 2010).

Since pesticide use has generated public health and environmental concerns, the EU has established MRLs on cocoa beans and its products. In spite of this, efforts have heightened and measures have been put in place for its reduction (Asogwa *et al.*, 2009).

Based on a study conducted in the Idanre local government area of Ondo state in Nigeria to investigate pesticides in common use in cocoa agriculture, dangers associated with their use and established regulatory incentive (if any) that protect farmers and farm workers against pesticide risk, it was revealed that most of the commonly used pesticides are the ones classified by the World Health Organization as moderately or highly hazardous which have either been banned or their use restricted in many advanced countries. This notwithstanding, marketers of these chemicals do claim that these pesticides are registered and pose no serious health hazards to users, by-standers, livestock, wild-life and the environment. Although the EPA in collaboration with the federal government of Nigeria has established legal and administrative procedures to protect users, information gathered shows that the farmers and workers do not take necessary precautionary action to prevent hazards associated with their use. Their effects lead to sicknesses such as headache, tiredness, vomiting, nausea, skin burns, skin itches etc. (Tijani, 2006).

There is an unsafe use of pesticides including the highly restricted and banned (especially in the industrialized countries) in third world countries to which larger numbers of their working populations are vulnerable. There is evidence of high rates of acute poisoning in these countries despite their under-registration. Limited studies on their chronic health effects have established neurotoxic, reproductive, and dermatologic effects (Wesseling *et al*, 1997).

2.10 Exposure of children to pesticides

Pesticides are usually used extensively in schools, homes and daycare centres to control roaches, rats and other vermin. Children are highly vulnerable and are at a greater risk of their exposure. Due to their close play on the ground, hand to mouth behaviour and unique dietary patterns these children tend to be exposed more to the pesticides than adults. Semi-volatile pesticides such as chlorpyrifos used indoors further expose them when they get absorbed on rugs, toys and other surfaces.

In extreme cases of exposure, children have limited ability to detoxification and elimination after taking the pesticides into their systems.

Moreover, the pesticides also retard growth and development (making the children more vulnerable) and cause differentiation of their vital organ systems. Lately, it was gathered from an experimental data that chlorpyrifos may be a developmental neurotoxicant whereas exposure in utero may cause biochemical and functional aberrations in foetal neurons as well as deficits in the number of neurons (Landrigan *et al.*, 1999).

A study was conducted to measure the air and surface chlorpyrifos residues for a 24-hour period after the application of Dursban broadcast application for fleas inside a residence. Interestingly, between 3 and 7 hours after application, concentrations recorded in both the ventilated and non-ventilated rooms in infant breathing zones were higher than those in the adult breathing zones. After 24 hours of application residues were still recorded. The total absorbed doses recorded for infants were found to be 1.2-5.2 times the human No Observable Effect Level (NOEL). Infant exposure to cholinesterase inhibiting compounds even after a properly conducted broadcast application could lead to doses at or above the threshold of their toxicological response.

There is therefore the need for felicitous regulatory policies and public education. Exposures to cholinesterase inhibiting compounds following properly conducted broadcast applications could result in doses at or above the threshold of toxicological response in infants, and should be minimized through appropriate regulatory policy and public education (Fenske, *et al.,* 1990).

2.11 Environmental fate of pesticides

Most water bodies found in cocoa growing areas are contaminated with organochlorine pesticides and this may be attributed to farming/agricultural activities (Okoya *et al*., 2013).

Sediments tend to accumulate higher concentrations of these pesticides than the water bodies in which they find themselves. This is due to the fact that they are hydrophobic; for this reason pesticides also accumulate in fatty tissues of organisms (Aydin and Yurdun, 1999).

The presence of pesticides and its residues endangers the existence of organisms in the soil whereas the runoffs and leaches from these contaminated soils also contaminate nearby water bodies. Moreover, these residues are likely to be transported through the root system to cocoa and other crops and in effect pose health risks to the consumer. Fosu-Mensah *et al*. (2016) found concentrations of chlorpyrifos and diazinon in cocoa samples taken from the Brong-Ahafo region in Ghana to have exceeded the WHO acceptable limits. This is of great concern since they pose as health hazards to the farming community (Fosu-Mensah *et al*., 2016).

2.12 Pests and diseases

Pest and diseases are considered the major causes of loses in the cocoa production in Ghana (Fosu-Mensah *et al*., 2016). Losses encountered on cocoa farms in Nigeria is largely due to destruction by pests and diseases. About 20 to 30% loss is due to cocoa mirid, *Sahlbergella singularis* while 17% of losses are attributed to cocoa pod borer, *Characoma strictigrapta*. The black pod disease which is caused by *Phytophtora megakarya* causes about 30 to 90% losses in the Nigerian cocoa industry (Ndubuaku *et al*., 2006).

One of the most critical limitations to high productivity worldwide in the cocoa production is the effect of pests and diseases. Particular pests and diseases found are centered around various geographical regions. Reported yield losses range from minor to almost 100 per cent (Schneider *et al.*, 2014).

2.13 Organochlorine pesticides

Organochlorine pesticides (OCPs) are persistent organic pollutants with high stability but not easily broken down. DDT and HCH have been banned in China since 1983 but due to its persistent nature traces are still found in some soil and water at present. Previous studies have proved the presence of OCPS in surface water at different levels. Water samples taken and analysed from Wenyu, Beiyun, Yanqing, Fangshan, Changping, and Shunyi Rivers located in a suburb of Beijing confirmed the presence of OCPs in them. These OCPs pose high risks to the environments and to human health (Jiawei, *et al*., 2008).

Although these chemicals are used to achieve the goal of increasing production, incidences of their effect on non-target substances or organisms and the environment have raised much concern. Soil samples were taken from cocoa farms within the Central Senatorial District of Ondo State, Nigeria and accessed for organochlorine contamination. The results proved positive for various organochlorine compounds including Endosulfan I and Endosulfan II (occurring most frequently with highest concentrations), Aldrin and Lindane. The concentrations measured showed a significant ($p<0.05$) correlation with the total organic matter (Aiyesanmi *et al*., 2012).

A study conducted investigated the varieties and concentrations of OCP residues in river water and sediments from cocoa-producing areas in Ondo Central Senatorial District of Nigeria. High levels of the OCPs were found with Endosulfan isomers having the highest occurrences. Results from this study also showed a positive correlation ($p<0.05$) between the OCP content in the compounds in the river and the organic and clayey matter. This is an indication that these river sediments play an important role in retaining the OCPs (Idowu, 2013)

2.14 Pyrethroids

Pyrethroids have since taken over the role organochlorine pesticides after their ban. These pesticides work by imitating the efficiency of the botanical. Only one of the six groups of esters of the natural pyrthrums is found in the pyrethroid pesticides and insects tend to develop resistance to them. Moreover latest pyrethroids developed are photo-stable hence, they are achingly toxic to the insects (Frimpong *et al*., 2012c)

Pyrethroids are synthetic pesticides characterised by a high knockdown and lethal activity, a wide spectrum, good residual activity, together with repellent and anti-feeding activity. Pyrethroids are widely used in the defense of plant health by controlling them against pests in cotton, fruits, vegetables, cereals etc. The pyrethroids earlier produced were deficient of destroying mites and soil pests. This called for later additions such as Fenpropathrin, have combined high acaricidal activity with insecticidal activity with insecticidal activity hence, the introduction of pyrethroids used in soils. There has therefore been an increase in its use since the registration of the first 'photostable' pyrethroids. (Hirano, 1989).

Pyrethroids are highly lipophilic in nature and have low water solubility hence, its strong adsorption to particulate matter. Under laboratory conditions, fish and some aquatic invertebrates introduced to water without particulate matter are highly intoxicated by pyrethroid insecticides. In this adsorbed state, the bioavailability of the fish is reduced drastically. Under field conditions, the impact of the pyrethroids are therefore presumed not to be as much as predicted by the laboratory test data.

Aquatic field studies carried out on natural farm ponds, streams and lakes which took place over a ten year period proved that algae, microorganism, annelids, gastropods and fish are unaffected by pyrethroid insecticides but for zoo-plankton and aquatic stage insects they may be affected (Hill, 1989). A study conducted on cocoa produce of Ghana revealed the presence of a number of pyrethroid pesticides at varying levels but none were found to have exceeded the EU and JMRLs. Nonetheless, Allethrin, Cypermethrin and Fenvalerate were at the marginal level of the JMRLs (Frimpong *et al*., 2012c).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Sampling method

The method adopted for the study was a systematic sampling method. Fermented dried cocoa beans were sampled from Tema and Takoradi take-over centres where cocoa beans from different districts and regions were received. Bags of cocoa beans were checked against application to ascertain the details. The consignment was divided into smaller lots of about 30 bags and the split wire was applied as widely as possible to detect foreign matter. The split wire is made up of copper metal of dimensions 50 mm long x 30 mm wide. The sampling horn made of aluminum metal was used to draw samples from all sides of each cocoa bag and bulked into a container. The dimension of the sampling horn is 100 mm long x 15 mm internal diameter. The bulked sample was thoroughly mixed and quartered. Two quarters of the opposite sides were rejected. The process was repeated until a final sample of 300 beans was obtained and put in a sample bag. The sample was then transported to the Research Laboratory of the Quality Control Company Ltd., Tema for analysis.

3.2 Preparation of standard solutions for GC and HPLC

Preparation of standard solutions were prepared using reagents (Table 3.1) and laboratory equipment in Table 3.2. Ten (10) milligrams of each pesticide standard was measured into a 10 ml volumetric flask and adjusted to volume with acetone and hexane (1:1) for GC and acetonitrile and water (2:1) for HPLC giving the resultant mixed standard concentration of 1000 μg/ml. Standard working solution of 10 μg/ml was obtained by diluting 1 ml of the stock solution up to the 100 ml mark of the volumetric flask using acetone and hexane (1:1) for GC and acetonitrile and water (2:1) for HPLC analysis. Working solutions from standard solution of 10 µg/ml were prepared according to the Table 3.3 and Table 3.4.

Calibration curve for HPLC was determined by running the instrument with the 0.02 µg/ml, 0.04 µg/ml and 0.08 µg/ml standards. Same was done to the GC using the standards 0.02 µg/ml, 0.05 µg/ml, 0.1 µg/ml, 0.2 µg/ml and 0.5 µg/ml.

Table 3. 1: Identification of reagents and materials

REAGENTS	GRADE	SOURCE
Acetonitrile	HPLC	Park Scientific Ltd, UK
Distilled water		
Ethyl acetate	HPLC	Deajung Chemicals & Metals Co. Ltd, Korea
n-Hexane	Pesticide	Deajung Chemicals & Metals Co. Ltd, Korea
Chem Elute	SPE Column	Agilent Technologies, USA
ENVI-Car/LC NH2, 500mg/500mg,6ml	SPE Column	Supelco USA (Analytical)
Diethyiether	Pesticide	Sigma Aldrich Co. UK
Acetone	Pesticide	Park Scientific Ltd, UK
Dichlorometane	Analytical Reagent	Deajung Chemicals & Metals Co. Ltd, Korea
SCX 500mg	SPE column	Thermo Scientific, USA
Methanol	HPLC	Park Scientific Ltd, UK
Filter paper No. 44	Whatman	Whatman International Ltd England
Membrane filter	Whatman	GE Healthcare, UK
SI column	SPE column	Thermo Scientific, USA

Table 3. 2: Equipment Identification

Equipment	Type
Gas Chromatograph	Shimadzu GC – 2010 with AOC 20i Autoinjector and AOC 20S Autosampler and Electron Capture Detector
Analytical Column	30m x 0.25mm internal diameter fused silica capillary column coated with VF-5ms (0.25µm film)
Centrifuge	
Vacuum manifold	Supelco
Macerator	IKA Ultra Turrrax Homogenizer
General laboratory glassware	Round bottomed flasks, volumetric flasks, centrifuge tubes, glass funnels, measuring cylinders, syringes
Glass vials	Screw cap and clear vial kit, 2ml
Hammer mill	Blender
Rotary film evaporator	Buchi Rotary evaporator (India)
Recirculating chiller	Buchi, B-740
Ultrasonic bath	Sanyo Company

Table 3. 3: GC spiking and calibration standards

Standard	Concentration (µg /ml)	Volume taken (ml)	Final volume (ml)	Standard concentration (µg/ml)
1	10	0.5	50	0.1
2	0.1	8	10	0.08
3	0.08	5	10	0.04
4	0.04	5	10	0.02

Table 3. 4: HPLC spiking and calibration standards

Standard	Concentration (μg /ml)	Volume taken (ml)	Final volume (ml)	Standard concentration (μg/ml)
1	10	25	50	0.5
2	0.5	4	10	0.2
3	0.2	5	10	0.1
4	0.1	5	10	0.05
5	0.05	4	10	0.02

3.3 Sample preparation

This method adopted is the partially modified multi-residue method for agricultural chemicals as carried out by the GC/ECD/MS and HPLC/PDAD, Agricultural Products Department of Food Safety of the Ministry of Health, Labour and Welfare, Japan (SOP, 2015).

3.3.1 Analytical Procedure

The essential steps of the analysis are extraction of the analyte from the sample, clean up (or purification) and the chromatographic analysis.

3.3.2 Extraction

The hammer mill was used in milling the cocoa beans sampled for pesticide residue analysis. Ten grams (10 g) of each sample was weighed into a 250 ml Nalgene jar. Twenty millilitres (20 ml) of distilled water was added and left for 15 minutes. One hundred millilitres (100 ml) of acetonitrile was then added and the mixture homogenized for 1 minute and the dispersing element was rinsed with about five millilitre (5 ml) acetonitrile. It was then centrifuged at 2,500 rpm for 5 minutes and filtered through Whatman (No. 4) filter paper into a 100 ml volumetric flask.

To the residue in the Nalgene jar thirty millilitres (30 ml) acetonitrile was added and homogenized for 1 more minute and the dispersing element rinsed again with five millilitres (5 ml) acetonitrile into the jar. The suspension was centrifuged at 2,500 rpm for 5 minutes and was filtered into the 500 ml round-bottomed flask. The residue in the Nalgene jar was discarded. The filtrate was concentrated to about 15 ml using the rotary evaporator at a temperature below 40^{o}C.

The fifteen milliliters (15 ml) concentrate was loaded into a diatomaceous earth column and left for 5 minutes. The residue was then allowed to pass through the column into a 250 ml round bottomed flask. Eighty millilitres (80 ml) n-Hexane was added through the column for GC clean up. One hundred and twenty millilitres (120 ml) of diethylether was added through the column for HPLC clean up. Each residue was concentrated to dryness using the rotary evaporator. Twenty five millilitres (25 ml) acetonitrile was pipetted to dissolve the dried residue for GC clean-up and twenty five millilitres (25 ml) acetone was pipetted to dissolve the dried residue for HPLC clean up.

3.3.3 Clean up using GCB/NH2 and SI column for GC

GCB/NH2 500 mg/500 mg was conditioned with five millilitre (5 ml) acetonitrile and five millilitre (5 ml) of the sample extract was loaded onto the column. It was eluted with twenty millilitre (20 ml) acetonitrile and evaporated. It was dissolved with two millilitres (2 ml) diethylether/n-hexane (2:8). The SI column was conditioned with ten millilitre (10 ml) n-hexane and the sample solution was loaded onto the column. It was then eluted with ten millilitres (10 ml) of diethyl ether/n-hexane (2:8) and evaporated to dryness. It was filled with one millilitre (1 ml) n-hexane/acetone (1:1) and put in a vial for GC analysis.

3.3.4 Clean up using SCX column for HPLC

The SCX column was conditioned with five millilitres (5 ml) acetone and five millilitres (5 ml) of the sample extract loaded onto the column. It was washed with ten millilitres (10 ml) acetone and then eluted with ten millilitres (10 ml) methanol. It was then concentrated to dryness below 40ºC. It was filled with one millilitre (1 ml) acetonitrile/water solution (2:8) and put in a vial for HPLC analysis.

3.4 Recovery test

Recovery test was performed by spiking cocoa samples with 0.5 µg/ml of HPLC standard and 0.1 µg/ml of GC standards. Exactly ten grams (10 g) of the milled cocoa samples were spiked with one millilitre (1 ml) of the standard solution. The samples were extracted after allowing the mixture to stand for 15 minutes. The spiked samples and blank samples without the standards were then extracted and analyzed by HPLC. Recovery was calculated using the formula below:

$$\%\ \text{Recovery} = \frac{\text{Amount of analyte recovered}}{\text{Amount of analyte spiked}} \times 100$$

3.5 Data management and statistical analysis

The data obtained were entered into a note book and into the Excel Spreadsheet and reconciled. All calculations (sum, percentages and correlation) were done within the Excel Spreadsheet. The Chi-square (χ^2) test for significance for comparing two proportions (with continuity correction) was performed using the King's College Hospital NHS Software (Rovan, 2001).The Japanese maximum residue levels (JMRLs) were used as the standard for the current analysis. The JMRLs for cypermethrin, fenvalerate, permethrin and imidacloprid are 0.02 mg/g, 0.01 mg/g, 0.05 mg/g, 0.05 mg/g, respectively.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results from the Ashanti Region

Table 4.1 shows the quantity of cocoa beans supplied by some cocoa districts within the Ashanti Region during the 2013/14 and 2014/15 cocoa seasons. Supplies of the cocoa beans came from 17 districts during the first season and from 14 districts during the second season. Supplies were not received from Akrokeri, Asankare and Obuasi during the second season. In the first season, Ashanti Bekwai supplied thehighest quantity (19.5%) of beans and Nyinahin supplied the highest (13.3%) during the second season. Accordingly, more samples for the analysis were drawn from supplies from these districts than the other districts. Figures 4.1 and 4.2 show pesticide failure rates for the samples and the corresponding bags/tonnage supplied from the districts in the Ashanti Region during the two seasons. Samples for the analysis were drawn from the supplies from all the 17 districts in the region for the two seasons. In the 2013/14 season samples from 52.9% (9/17) of the distrcts had pesticide levels above the JMRLs (i.e. above the acceptable limits). The only supply or sample that came from Effiduase during the this season failed the test. Considering the number of samples that failed the test against the number used for the test, Effiduase had the highest failure rate (Figure 4.1); however, the difference between this rate and those of the other districts in the region was not statistically significant. Based on the number of samples that failed the test, Ashanti Bekwai supplied the highest proportion of samples and this was 29.4% (5/17) of the total samples supplied.

Table 4. 1: Quantity of cocoa beans supplied by districts within the Ashanti Region during the 2013/14 and 2014/15 cocoa seasons.

	2013/14 Cocoa Season			2014/15 Cocoa Season		
District	**No. of Bags Supplied**	**Tonnage Supplied**	**No. of Samples Analyzed**	**No. of Bags Supplied**	**Tonnage Supplied**	**No. of Samples Analyzed**
Akrokeri	780	48.75	2	---	---	---
Ampenim	2,715	169.69	5	4,971	310.69	11
Antoakrom	5,223	326.44	13	7,232	452.00	15
Asankare	520	32.50	1	---	---	---
Ashanti Agona	1,426	89.13	3	2,090	130.62	4
Ashanti Bekwai	12,863	803.94	28	2,020	126.25	4
Effiduase	600	37.50	1	3,026	189.12	8
Juaso	5,892	368.25	15	7,907	494.19	17
Konongo	5,646	352.88	16	8,117	507.31	18
Mankraso	4,329	270.56	10	5,936	371.00	14
New Edubiase	6,618	413.63	15	6,723	420.19	13
Nkawie	1,024	64.00	3	2,379	148.69	6
Nsokote	5,345	334.06	11	2,328	145.50	5
Nyinahin	3,517	219.81	7	10,141	633.81	23
Obuasi	4,733	295.81	8	---	---	---
Offinso	1,282	80.13	3	3,780	236.25	11
Tepa	3,335	208.44	6	9,758	609.88	20
TOTAL	**65,848**	**4115.50**	**147**	**76,408**	**4,775.50**	**169**

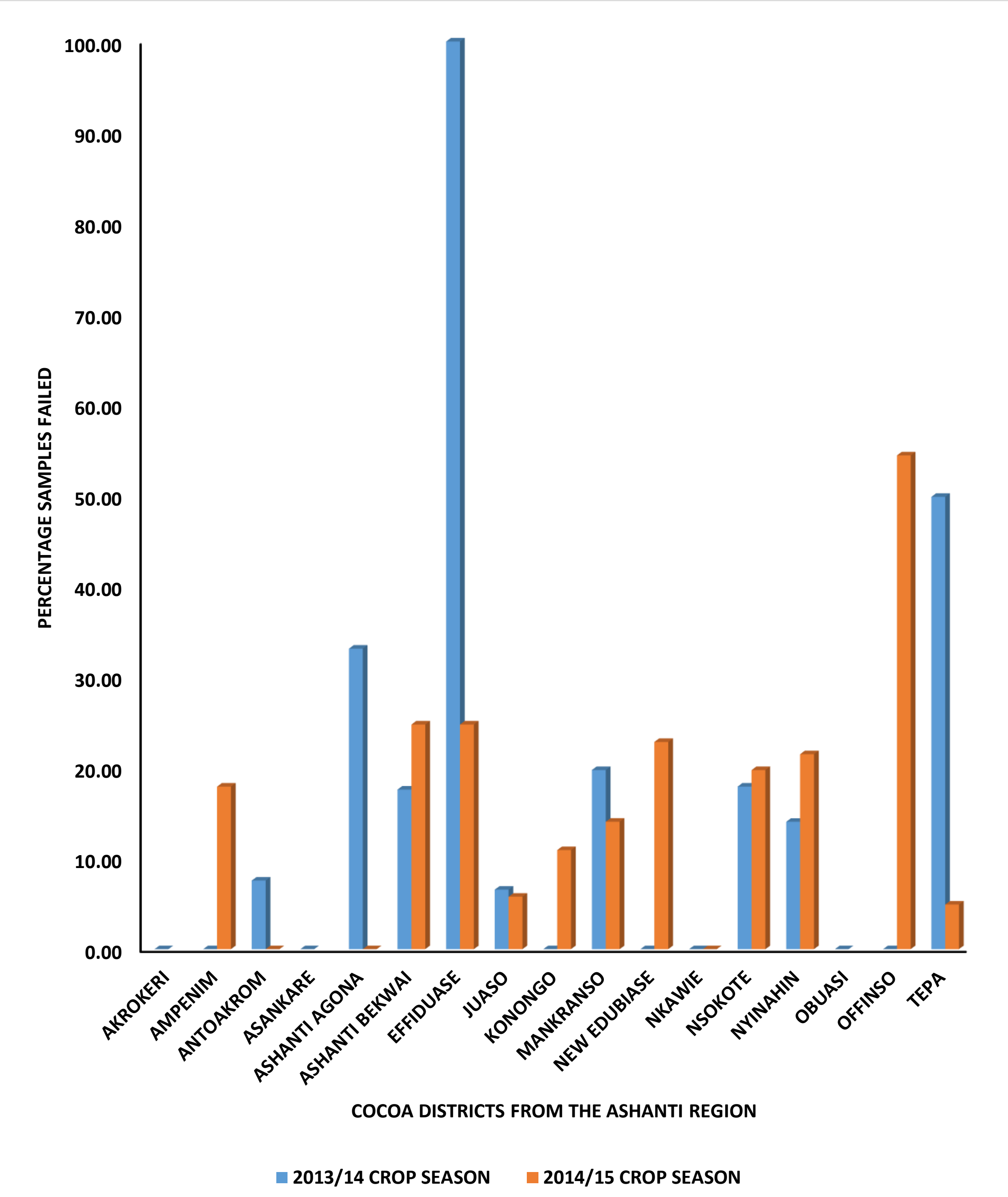

Figure 4. 1: Pesticide failure rates (%) for districts within the Ashanti Region in the 201314 and 2014/15 crop seasons.

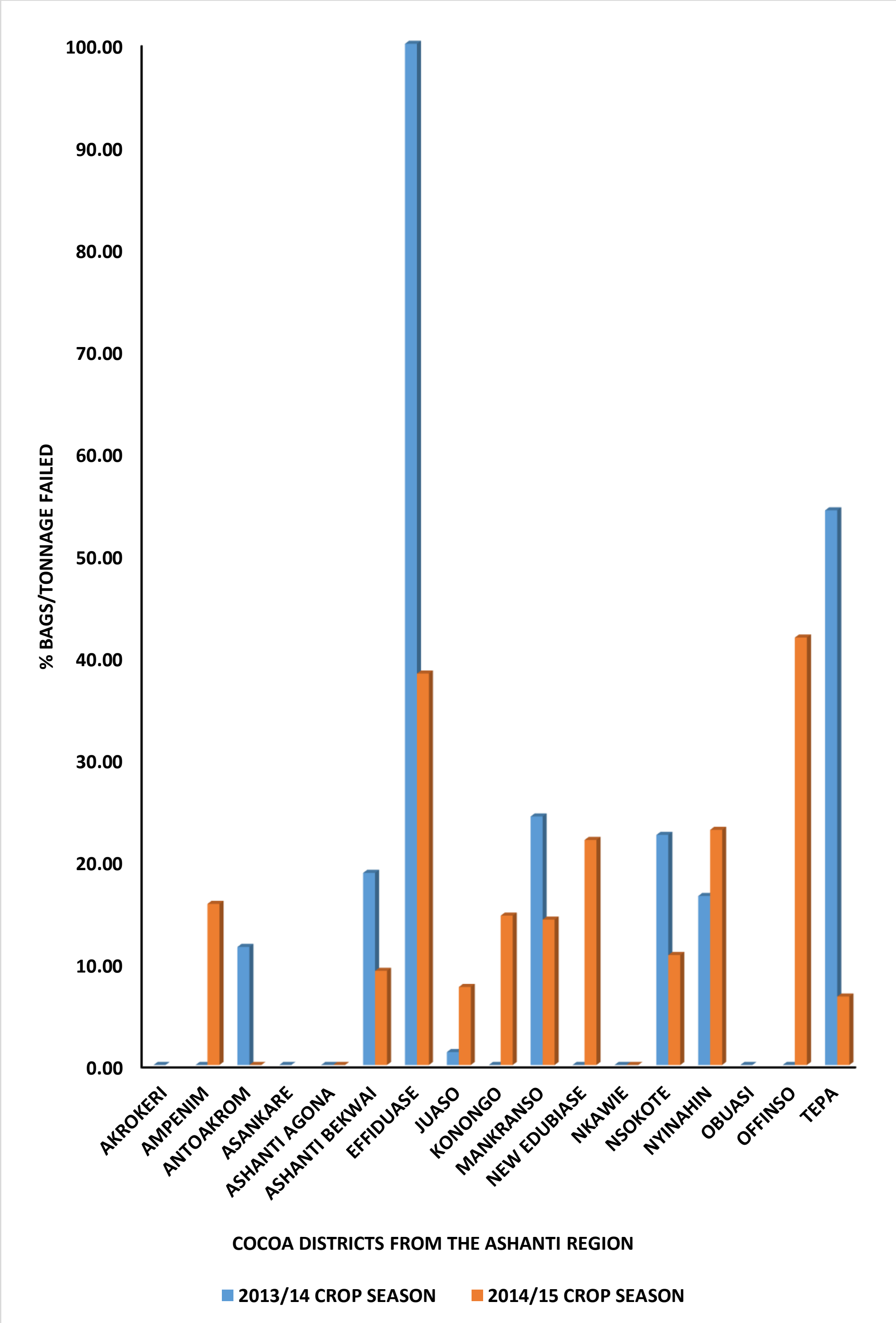

Figure 4. 2: Percentage of bags/tonnage from each district within the Ashanti Region for the 2013/14 and 2014/15 crop seasons that failed the pesticide analysis.

During the 2014/15 season, 78.6% (11/14) of the districts supplied samples that exceeded the JMRLs. Offinso recorded the highest rate of failure followed by Ashanti Bekwai and Effiduase. The difference between the failure rate of Offinso and that of Tepa or Juaso which recorded the lowest failure rates was significant ($\chi^2 \geq 3.84$; $p<0.05$; df=1). With regards to the number of samples that failed the test, Nyinahin supplied the highest tonnage of the beans and the sample failure rate was 19.2% (5/26). Some of the samples received from Antoakrom in the first season were found to contain some pesticide residues but this was not the case in the second season. The rates of failure pertaining to the samples taken from Juaso during the two seasons were almost the same. No significant pesticide residue was found in the samples from Akrokeri, Ampenim, Asankare, Konongo, New Edubiase, Obuasi and Offinso during the first season; from Antoakrom, Ashanti Agona in the second season and from Nkawie during both seasons. Although no significant amounts of pesticide residues were detected in the samples from Ampenim, Konongo, New Edubiase and Offinso in the first crop season, some of the samples drawn from there in the second season were found to have exceeded the JMRLs. Similar to the rate of sample failures, the highest rate of bags/tonnage that failed was recorded by Effiduase and the difference between this rate and that of Tepa which recorded the second highest rate was statistically significant ($\chi^2=446.1$; $P<0.001$; df=1).

Table 4.2 shows the number of samples of cocoa beans from the Ashanti Region that contained the residues of the various pesticides above the JMRLs. Samples from nine (9) districts contained residues of cypermethrin above the JMRLs in the first season and samples from eleven (11) districts also contained residues of this pesticide above the JMRLs in the second season. The samples from Ashanti Bekwai recorded the highest proportion (28.6%; 4/14) of samples containing cypermethrin residue above the JMRLs in the first season whilst Nyinahin and Offinso also recorded the highest (25%; 4/16) in the second season. Three (3) districts recorded samples with fenvalerate residues above the JMRLs in the first season whilst six (6) districts recorded same in the second season. Residues of imidacloprid above the JMRLs was found only in the samples from Antoakrom in the first crop season; this was not detected in any of the samples from the districts in the second season. Residues of permethrin above the JMRLs was detected only in samples brought from Nsokote in the second season. More samples were found to contain residues of cypermethrin than the other pesticides. This was followed by fenvalerate.

The proportion of samples that failed the test in the 2013/14 season was 10.9% (17/147); the quantity of bags from which these samples were drawn was 8,322 out of 6,5848 supplied by the region. The failure rate, therefore, was 12.6% with regards to the quantity of bags supplied. Similarly, the proportion of samples that failed the test in the 2014/15 season was 15.2% (26/169) and the proportion of bags/tonnage from which the samples were drawn constituted 13.2% (11025/76408) of the total supplied in the second season.

Table 4. 2: Number of samples of cocoa beans from the Ashanti Region that contained pesticide residues above the Japanese MRLs.

Districts in Ashanti Region	No. of samples with pesticides residues above the Japanese MRLs								
	PM	CP	FV	ID	CP & FV	CP & ID	CP & PM	FV & ID	CP, FV & ID
Akrokeri	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)
Ampenim	0(0)	0(1)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Antoakrom	0(0)	(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0)	0(0)
Asankare	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)
Ashanti Agona	0(0)	1(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Ashanti Bekwai	0(0)	4(1)	1(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Effiduase	0(0)	1(0)	0(1)	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)
Juaso	0(0)	1(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Konongo	0(0)	0(1)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Mankraso	0(0)	2(0)	0(2)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
New Edubiase	0(0)	0(3)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Nkawie	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Nsokote	0(0)	2(0)	0(0)	0(0)	0(0)	0(0)	0(1)	0(0)	0(0)
Nyinahin	0(0)	1(4)	0(0)	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)
Obuasi	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)
Offinso	0(0)	0(4)	0(2)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Tepa	0(0)	2(1)	1(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)

NB: PM = Permethrin; CP = Cypermethrin; FV = fenvalerate; ID = imidacloprid.

Figures outside and inside parentheses represent the number of samples for the 2013/14 and 2014/15 crop seasons respectively.

4.2 Results from the Western North Region

Table 4.3 shows the quantity of cocoa beans supplied by the cocoa districts within the Western North region during the 2013/14 and 2014/15 cocoa seasons. Cocoa beans were received from eighteen (18) and fifteen (15) cocoa districts within the Western North Region in the 2013/14 and 2014/15 crop seasons,zz respectively. Bonsu Nkwanta district supplied the highest quantity of cocoa beans for the first season followed by the Sefwi Joaboso district and then the Akontombra district. More samples were drawn from these districts for the analysis during this season. In the second season, Dadieso took the lead in the quantity of bags/tonnage supplied followed by Bonsu Nkwanta and Akontombra. More samples were also drawn from the supplies of these districts for the analysis.

Table 4. 3: Quantity of cocoa beans supplied by districts within the Western North Region during the 2013/14 and 2014/15 cocoa seasons.

	2013/14 Cocoa Season			2014/15 Cocoa Season		
District	**No. of Bags Supplied**	**Tonnage Supplied**	**No. of Samples Analyzed**	**No. of Bags Supplied**	**Tonnage Supplied**	**No. of Samples Analyzed**
Akontombra	5,236	327.25	9	15,207	950.44	30
Asempaneye	600	37.50	1	5,423	338.94	10
Awaso	1,547	96.69	2	498	31.13	1
Bibiani	640	40.00	1	---	---	---
Boako	1,198	74.88	2	2,919	182.44	6
Bodi	3,610	225.62	6	9,525	595.31	17
Bonsu Nkwanta	6,440	402.50	19	16,855	1,053.44	33
Dadieso	200	12.50	1	18,253	1,140.81	36
Debiso	1,217	76.06	2	1,200	75.00	2
Essam	180	11.25	1	2,895	180.94	5
Proso	319	19.94	1	---	---	---
Sefwi Adabokrom	1175	73.4	5	---	---	---
Sefwi Anhwiaso	3363	210.2	6	3,674	229.63	9
Sefwi Asanwinso	1,848	115.50	3	9,480	592.50	21
Sefwi Bekwai	3,850	240.62	6	3,648	228.00	8
Sefwi Juaboso	5244	327.75	12	5,977	373.56	15
Sefwi Kaase	539	33.69	2	4,138	258.63	7
Sefwi Wiawso	2,770	173.12	6	7,949	496.81	16
TOTAL	**40,805**	**2,550.31**	**85**	**107,641**	**6,727.57**	**216**

Figures 4.3 and Figure 4.4 show pesticide failure rates (%) for samples and bags/tonnage from the districts within the Western North Region for the 2013/14 and 2014/15 crop seasons. Samples from six (6) of the districts (33.3%) were found to contain pesticide residues above the JMRLs in the first season whilst samples from 13 out of 15 (86.7%) of the districts were found to contain same in the second season. Boako had the highest proportion of samples and/or bags/tonnage with pesticide residues above the JMRLs for both seasons. A statistically significant difference in the failure rates of the samples was found between Boako and Sefwi Asawinso only in the second season (χ^2=44; $p<0.05$; df=1). Based on the total number of samples that failed the test, Sefwi Anhwiaso recorded the highest failure rate 28.6% (2/7) in the first season and Dadieso the highest 31.1 % (13/45) in the second crop season.

Sefwi Anhwiaso and Sefwi Kaase ranked second in terms of the level of pesticide residues in their samples in the first and second seasons respectively. No significant amount of pesticide residues were detected in samples drawn from 10 districts in the first season and from two (2) districts in both seasons. More bags from Boako were found to contain pesticide residues that exceeded the JMRLs during the second season than the first season ($\chi^2<33.065$; $p<0.001$; df=1). Comparing the quantity of bags/tonnages with residue levels above the JMRLs, a statistically significant difference was found between the supplies from Boako and those from the other districts for the first season ($\chi^2<33.065$; $p<0.001$; df=1) and for the second season ($\chi^2<180.6$; $p<0.001$; df=1). Sefwi Anhwiaso supplied 26.4% (916/3,469) of the bags/tonnage with residues above the JMRLs in the first season and Dadieso supplied

28.9% (6,553/22,663) in the second season. The proportion of samples found to contain pesticide residues higher than the JMRLs in relation to the total number of samples analysed was 8.2% (7/85) for the first cocoa season and 21.3% (46/216) for the second season; and the proportion pertaining to the bags/tonnage supplied was 8.5% (3,469/40,805) for the first season and 21.1% (22,663/107,641) for the second season.

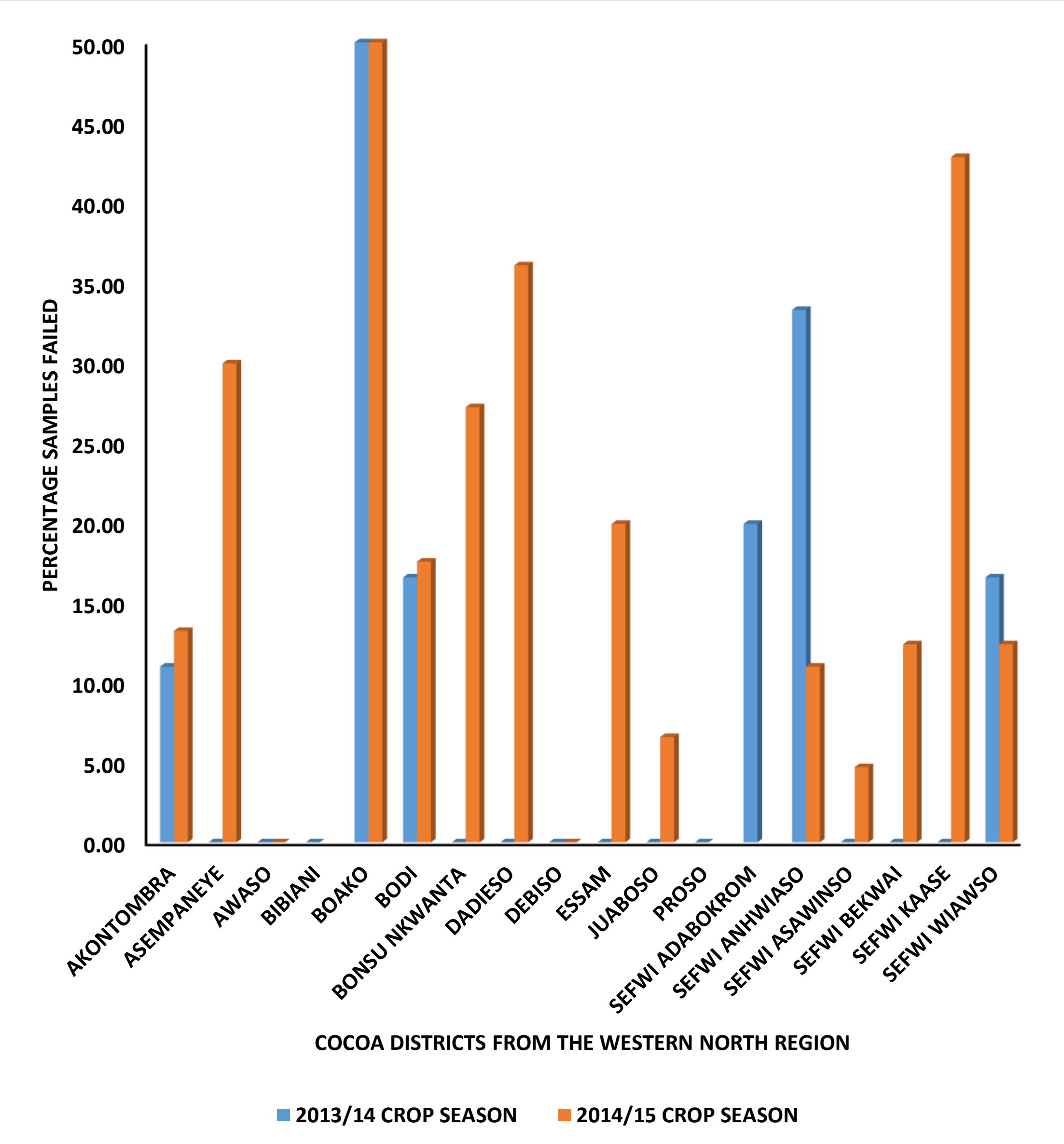

Figure 4. 3: Pesticide failure rates (%) for the districts within the Western North Region for the 2013/14 and 2014/15 crop seasons.

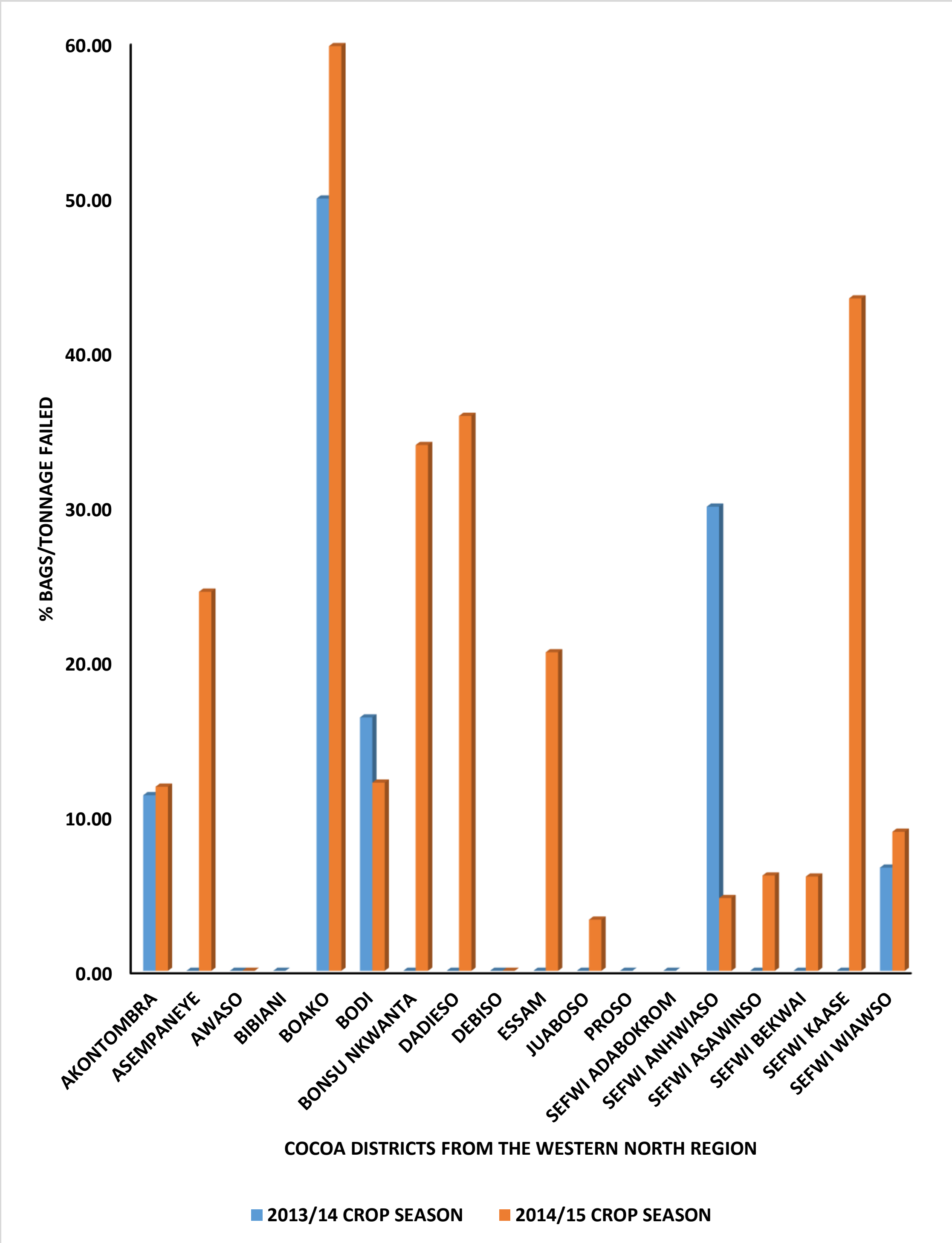

Figure 4. 4: Percentage of bags/tonnage from each district within the Western North Region for the 2013/14 and 2014/15 crop seasons that failed the pesticide analysis.

Table 4.4 shows the number of samples of cocoa beans from the Western North Region that contained pesticides residues above the JMRLs. Supplies from six (6) districts contained cypermethrin residues in the first season above the JMRL. In the second season, supplies from ten (10), seven (7) and six (6) districts contained cypermethrin, fenvalerate and imidacloprid above the JMRLs respectively. Samples from 4 districts contained residues of more than one pesticide. No sample was found to contain residues of permethrin above the JMRLs in both seasons. More samples were found to contain residues of cypermethrin than the other pesticides followed by fenvalerate for both seasons.

Table 4. 4: Number of samples of cocoa beans from the Western North Region that contained pesticides residues above the Japanese MRLs.

Districts in Western North Region	Number of samples failed per pesticide								
	PM	CP	FV	ID	CP & FV	CP & ID	CP & PM	FV & ID	CP, FV & ID
Akontombra	0(0)	1(1)	0(1)	0(1)	0(0)	0(1)	0(0)	0(0)	0(0)
Asempaneye	0(0)	0(2)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Awaso	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Bibiani	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(0)	0(0)	0(--)
Boako	0(0)	1(3)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Bodi	0(0)	1(3)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Bonsu Nkwanta	0(0)	0(3)	0(5)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)
Dadieso	0(0)	0(12)	0(1)	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)
Debiso	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Essam	0(0)	0(0)	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)
Proso	0(0)	0(--)	0(--)	0(--)	0/--)	0(--)	0(0)	0(0)	0(--)
Sefwi Adabokrom	0(0)	1(--)	0(--)	0(--)	0(--)	0(--)	0(0)	0(0)	0(--)
Sefwi Anhwiaso	0(0)	2(0)	0(0)	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)
Sefwi Asanwinso	0(0)	0(0)	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)
Sefwi Bekwai	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Sefwi Juaboso	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Sefwi Kaase	0(0)	0(0)	0(0)	0(1)	0(1)	0(0)	0(0)	0(0)	0(1)
Sefwi Wiawso	0(0)	1(0)	0(1)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)

NB: PM = Permethrin; CP = Cypermethrin; FV = fenvalerate; ID = imidacloprid.

Figures outside and inside parentheses represent the number of samples for the 2013/14 and 2014/15 crop seasons respectively.

4.3 Results from the Western South Region

Cocoa beans were received from 16 districts in the first season and from 19 districts in the second season from the Western South Region (Tables 4.5 and 4.6; Figures 4.5 and 4.6). In the first season, 68.8% (11/16) of the districts supplied samples with pesticide residues above the JMRLs. Bogoso supplied the highest quantity of cocoa beans both in the first season and in the second season. More samples were drawn from Bogoso and Wassa Akropong for the test for both seasons. Samreboi recorded the highest failure rate in the first season and a significant difference was found between this rate and that of Bogoso only ($\chi^2<11.5$; $p<0.001$; df=1). The only sample drawn from Elluokrom contained pesticide residues above the JMRLs and a statistical difference was found only between this rate and that of Beppoh ($\chi^2<7.5$; $p<0.05$; df=1). The rate of failure were also high in the supplies from Takoradi followed by Nkroful. No samples were found to contain pesticide residues above the JMRLs in three districts in the first season and in six (6) districts in the second season and in two districts when both seasons are taken into consideration. Dunkwa supplied the highest quantity of bags/tonnage that contained the pesticide residues above the JMRLs in the first season and the difference between the failure rate of this district and those of the other districts is significant ($\chi^2<199.1$; $p<0.001$; df=1). In all, 9.2% (23/249) of samples and 8.6% (9697/113300) of the bags/tonnage from all the districts in the region were found to contain pesticide residues above the JMRLs in the first season. In the second season, 14.2% (42/296) of samples and 14.4% (19774/137713) of the bags/tonnage from all the districts in the region were found to contain pesticide residues above the JMRLs. The supplies from 10 districts from the region contained cypermethrin residues and those from 4 districts contained fenvalerate residues above the JMRLs in the first season. In the second season, supplies from 9 districts contained cypermethrin residues and from six (6) districts, fenvalerate residues above the JMRLs. Supplies from one (1) district and from 2 districts contained imidacloprid residues above the JMRLs. No sample was found to contain residues of permethrin above the JMRLs in both seasons.

Table 4. 5: Quantity of cocoa beans supplied by districts within the Western South Region during the 2013/14 and 2014/15 cocoa seasons.

District	2013/14 Cocoa Season			2014/15 Cocoa Season		
	No. of Bags Supplied	**Tonnage Supplied**	**No. of Samples Analyzed**	**No. of Bags Supplied**	**Tonnage Supplied**	**No. of Samples Analyzed**
Agona Amenfi	2,470	154.38	4	5,540	346.25	11
Ankwaso	---	---	---	311	19.44	1
Asankragwa	9,158	572.38	17	6,113	382.06	13
Atieku	---	---	---	594	37.12	2
Beppoh	---	---	---	11,835	739.69	24
Bogoso	39,080	2,442.50	85	27,790	1,736.88	61
Dadieso	6,257	391.06	11	---	---	---
Diaso	2,344	146.50	4	9,334	583.38	16
Dunkwa	4,265	266.56	16	2,584	161.50	9
Elubo	---	---	---	989	61.81	4
Elluokrom	1,293	80.81	2	663	41.44	1
Enchi	9,701	606.31	17	16,466	1,029.12	29
Esiama	567	35.44	1	1,800	112.5	3
Manso Amenfi	3,103	193.94	5	154	9.62	1
Nkroful	1,155	72.19	2	1,144	71.5	2
Prestea	---	---	---	1,366	85.38	3
Samreboi	3,752	234.50	8	13,321	832.56	25
Takoradi	5,817	363.56	17	5,831	364.44	14
Tarkwa	6,900	431.25	19	4,150	259.38	7
Wassa Akropong	16,738	1,046.12	40	27,728	1,733	70
Wassa Amenfi	700	43.75	1	---	---	---
TOTAL	**113,327**	**7,037.50**	**249**	**137,713**	**8,607.06**	**296**

Table 4. 6: Number of samples of cocoa beans from the Western South Region that contained pesticides residues above the Japanese MRLs.

Districts in Western South Region	Number of samples failed per pesticide								
	PM	**CP**	**FV**	**ID**	**CP & FV**	**CP & ID**	**CP & PM**	**FV & ID**	**CP, FV & ID**
Agona Amenfi	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Ankwaso	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)
Asankragwa	0(0)	1(1)	1(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Atieku	--	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)
Beppoh	--	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)
Bogoso	0(0)	2(7)	0(0)	0(2)	0(2)	0(0)	0(0)	0(0)	0(0)
Dadieso	0(--)	2(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)
Diaso	0(0)	1(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Dunkwa	0(0)	4(0)	1(0)	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)
Elubo	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)
Elluokrom	0(0)	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Enchi	0(0)	0(3)	1(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Esiama	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Manso Amenfi	0(0)	1(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Nkroful	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Prestea	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)
Samreboi	0(0)	3(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Takoradi	0(0)	1(5)	0(1)	1(0)	0(4)	0(0)	0(0)	0(0)	0(0)
Tarkwa	0(0)	1(1)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Wassa Akropong	0(0)	2(7)	1(3)	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)
Wassa Amenfi	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)

NB: PM = Permethrin; CP = Cypermethrin; FV = fenvalerate; ID = imidacloprid.

Figures outside and inside parentheses represent the number of samples for the 2013/14 and 2014/15 crop seasons respectively.

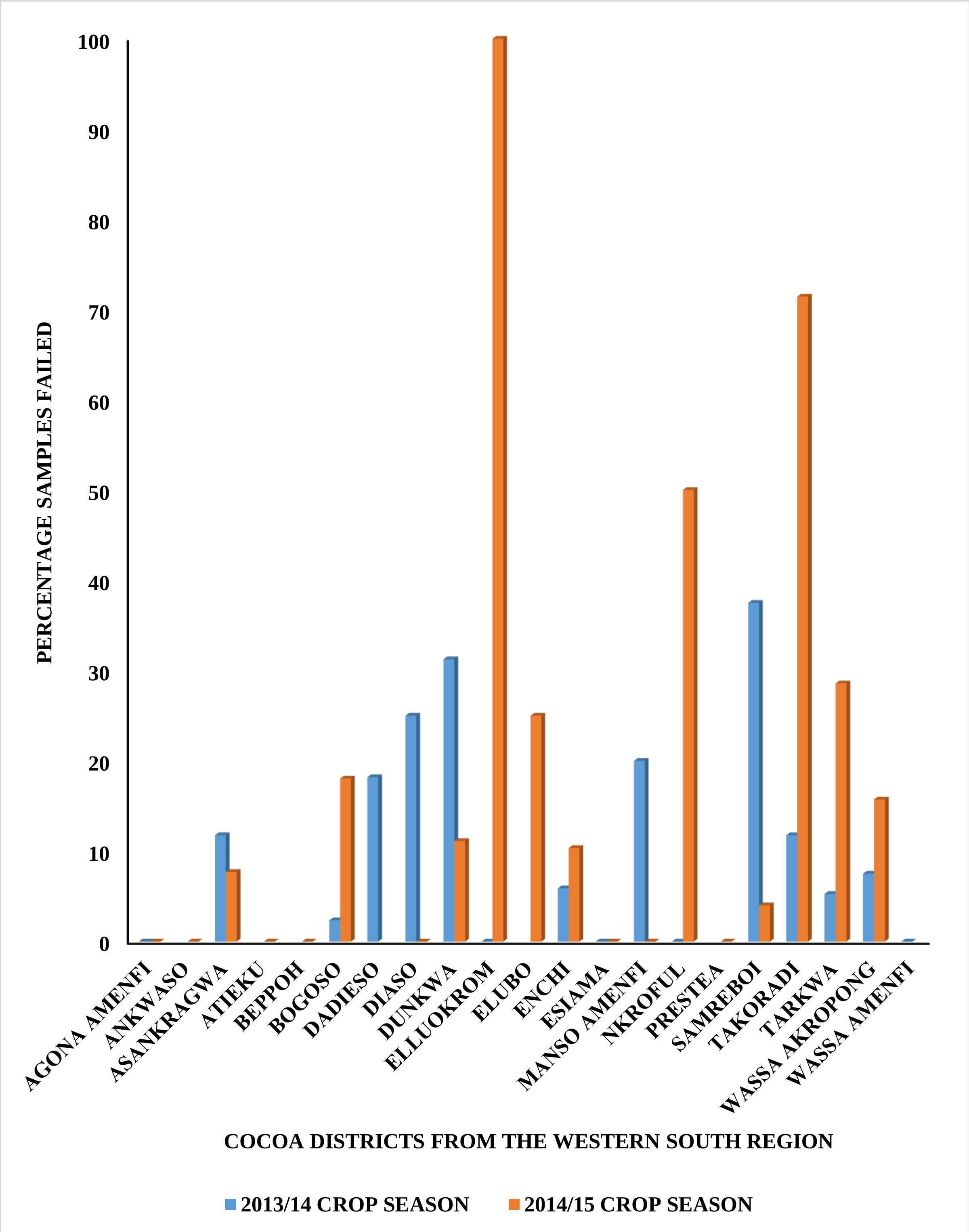

Figure 4. 5: Pesticide failure rates (%) for districts within the Western South Region for the 2013/14 and 2014/15 crop seasons.

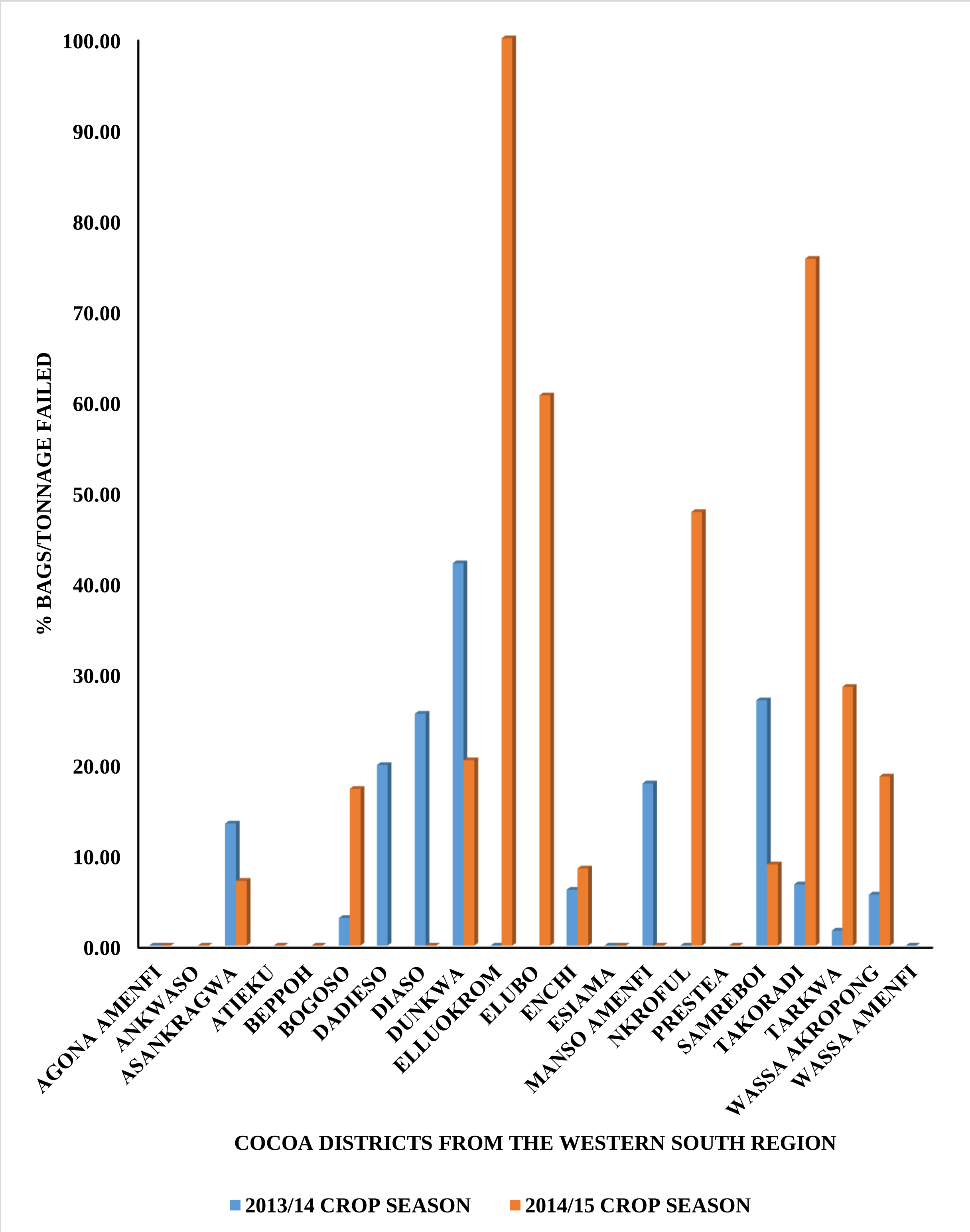

Figure 4. 6: Percentage of bags/tonnage from each district within the Western South Region for the 2013/14 and 2014/15 crop seasons that failed the pesticide analysis.

4.4 Results from the Brong-Ahafo Region

Sample were analysed from 10 cocoa districts in the first cocoa season and six (6) districts in the second season from the Brong-Ahafo Region (Tables 4.7 and 4.8; Figures 4.7 and 4.8). Kasapin was the highest supplier of the cocoa beans and that quantity constituted 38% (17,109/45,002) of the total quantity supplied from the region in the first season and 47.7% (10,810/22,662) in the second season (Tables 4.7).

In the 2013/14 cocoa season, 40% (4/10) of the districts failed to meet the requirements (Figure 4.7). The Dormaa Ahenkro district recorded the highest failure rate both for the number of bags/tonnage (50.4%) or the number of samples (50%) drawn for the test in the first season. The difference between the percentage of bags/tonnage that failed compared to the other districts within the region was significant ($\chi^2 \geq 95.3$; $p<0.001$; df=1); however, no significant difference was found between the proportion of samples that failed. All the samples from the rest of the districts namely, Asumura, Bonsu Nkwanta, Kasapin, Kukuom, Nkrankwanta and lastly, Sankore passed the test. In the second crop season, 50% (3/6) of the districts failed to meet the requirements. Dormaa Ahenkro recorded the highest rate of failure although no significant difference was found between the rate for this district and that of Goaso or Kasapin (Figure 4.7). A significant amount of pesticide residues was found in the supplies from the Sunyani district also. The highest percentage of bags/tonnage that failed the test was recorded by Goaso and the difference of the rate between this district and the rates of the other districts in the second season was significant ($\chi^2 \geq 112.1$; $p<0.001$; df=1). No pesticide residues was found in the samples supplied by 4 districts in the first season, by one district in the second season and by two districts when both seasons are taken into consideration. The rest of the districts passed the test. However, Asumura and Nkrankwanta did not record any significant failure rates in both seasons. The overall failure rate for the quantity of bags/tonnage supplied was 6.3% (2818/45002) and for the samples drawn for the test, 6% (5/84)

for the 2013/14 season; for the 2014/15 season, the quantity of bags/tonnage supplied was 12.1% (2737/22662) and for the samples drawn for the test, 12.2% (5/41). Residues of cypermethrin were found in samples from 4 districts in the first season and in samples from 2 districts in the second season (Table 4.8). Fenvelerante residues above the JMRLs were found in the samples from Sunyani whilst same was found in the samples from Dormaa Ahenkro and Kasapin in the first and second seasons respectively. Imidacloprid residues above the JMRLs was found in a sample from Kasapin in the second season. The only sample in the region that contained permethrin above the JMRL was received from Goaso in the first season.

Table 4. 7: Quantity of cocoa beans supplied by districts within the Brong-Ahafo Region during the 2013/14 and 2014/15 cocoa seasons.

	2013/14 Cocoa Season			**2014/15 Cocoa Season**		
District	**No. of Bags Supplied**	**Tonnage Supplied**	**No. of Samples Analyzed**	**No. of Bags Supplied**	**Tonnage Supplied**	**No. of Samples Analyzed**
Asumura	3,162	197.63	6	200	12.50	1
Bonsu Nkwanta	270	16.88	1	---	---	---
Dormaa Ahenkro	1,191	74.44	2	6,083	380.19	11
Goaso	6,171	385.69	12	3,273	204.56	6
Hwidiem	3,644	227.75	6	---	---	---
Kasapin	17,109	1,069.31	30	10,810	675.62	19
Kukuom	4,950	309.38	10	---	---	---
Nkrankwanta	1,800	112.50	3	1,100	68.75	2
Sankore	3,226	201.63	6	---	---	---
Sunyani	3,479	217.44	8	1,196	74.75	2
TOTAL	**45,002**	**2,812.63**	**84**	**22,662**	**1,416.38**	**41**

Table 4. 8: Number of samples of cocoa beans from the Brong-Ahafo Region that contained pesticides residues above the Japanese MRLs.

Districts in Brong-Ahafo Region	Number of samples failed per pesticide								
	PM	**CP**	**FV**	**ID**	**CP & FV**	**CP & ID**	**CP & PM**	**FV & ID**	**CP, FV & ID**
Asumura	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Bonsu Nkwanta	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)
Dormaa Ahenkro	0(0)	1(0)	0(2)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Goaso	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)	1(0)	0(0)	0(0)
Hwidiem	0(--)	1(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)
Kasapin	0(0)	0(0)	0(0)	0(1)	0(1)	0(0)	0(0)	0(0)	0(0)
Kukuom	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)
Nkrankwanta	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Sankore	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)	0(--)
Sunyani	0(0)	1(0)	1(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)

NB: PM = Permethrin; CP = Cypermethrin; FV = fenvalerate; ID = imidacloprid.

Figures outside and inside parentheses represent the number of samples for the 2013/14 and 2014/15 crop seasons respectively.

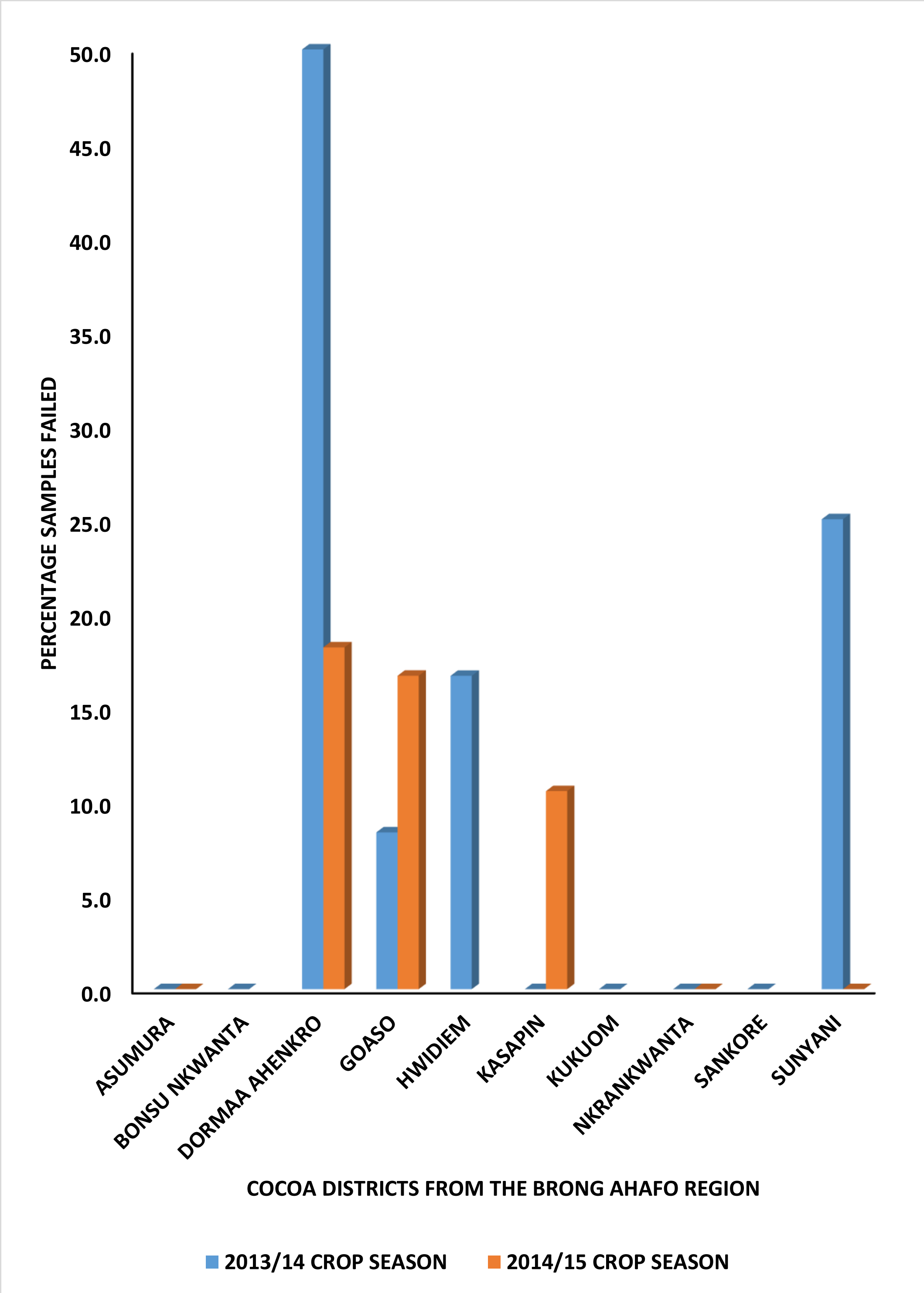

Figure 4. 7: Percentage of bags/tonnage from each district within the Brong-Ahafo Region for the 2013/14 and 2014/15 crop seasons that failed the pesticide analysis

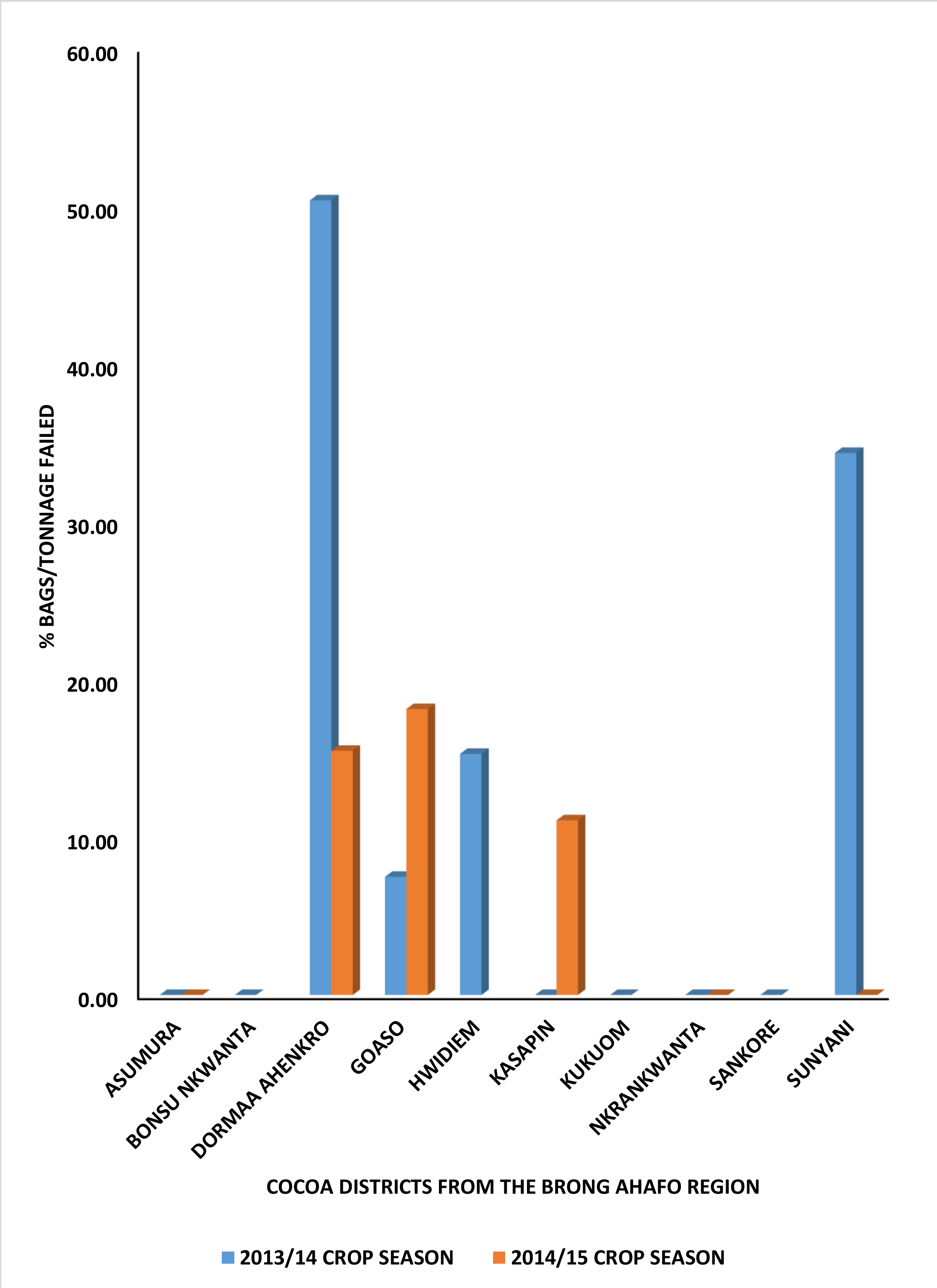

Figure 4. 8: Percentage bags/tonnage failed per districts in the Brong-Ahafo Region for the 2013/14 and 2014/15 crop seasons.

4.5 Results from the Central Region

Cocoa beans were supplied by 7 districts and 8 districts in the Central Region for the 2013/14 and 2014/15 cocoa seasons respectively. Twifo Praso supplied the highest quantity of bags/tonnage of cocoa beans in the first season and Agona Swedru, the highest in the second season. More samples were drawn from these districts for the analysis than from the other districts (Table 4.9). In the first season, 85.7% (6/7) of the districts failed the analysis (Figures 4.9 and 4.10). The highest failure rate was recorded for Agona Swedru and a significant difference was found between this rate and that of Twifo Praso only ($\chi 2=5.4$; $p<0.05$; df=1). In the second season, all the 8 districts failed to meet the requirement with Twifo Nyinase, Assin Breku and Agona Nyaakrom recording the highest failure rates and Agona Swedru, the lowest. With regards to the bags/tonnage supplied, Agona Nyaakrom recorded the highest failure rate and the difference between this rate and those of the other districts was statistically significant ($\chi 2\geq 34.5$; $p<0.001$; df=1) in the 2013/14 season, and ($\chi 2\geq 12.2$; $p<0.001$; df=1) in the 2014/15 season. The overall sample failure rate was 7.9% (15/189) and for the failure rate with regards to the quantity of bags/tonnage supplied was 7.4% (5,435/73,540) for the first season. For the second season, the sample failure rate was 14.5% (16/110) and for the quantity of bags/tonnage supplied was 16.2% (8,383/51,859).

Table 4. 9: Quantity of cocoa beans supplied by districts within the Central Region during the 2013/14 and 2014/15 cocoa seasons.

District	2013/14 Cocoa Season			2014/15 Cocoa Season		
	No. of Bags Supplied	**Tonnage Supplied**	**No. of Samples Analyzed**	**No. of Bags Supplied**	**Tonnage Supplied**	**No. of Samples Analyzed**
Agona Nyaakrom	---	---	---	1,777	83.31	4
Agona Swedru	4,465	279.06	16	12395	833.44	28
Assin Breku	6,632	414.50	19	1,140	74.44	2
Assin Fosu	11,370	710.62	30	10027	578.94	18
Breman Asikuma	8,317	519.81	24	9514	649.44	22
Cape Coast	9,461	591.31	27	4425	254.94	10
Twifo Nyinase	11,921	745.06	28	1190	52.81	2
Twifo Praso	21,374	1,335.88	45	11391	738.69	24
TOTAL	**73,540**	**4,596.25**	**189**	**51859**	**3,266.00**	**110**

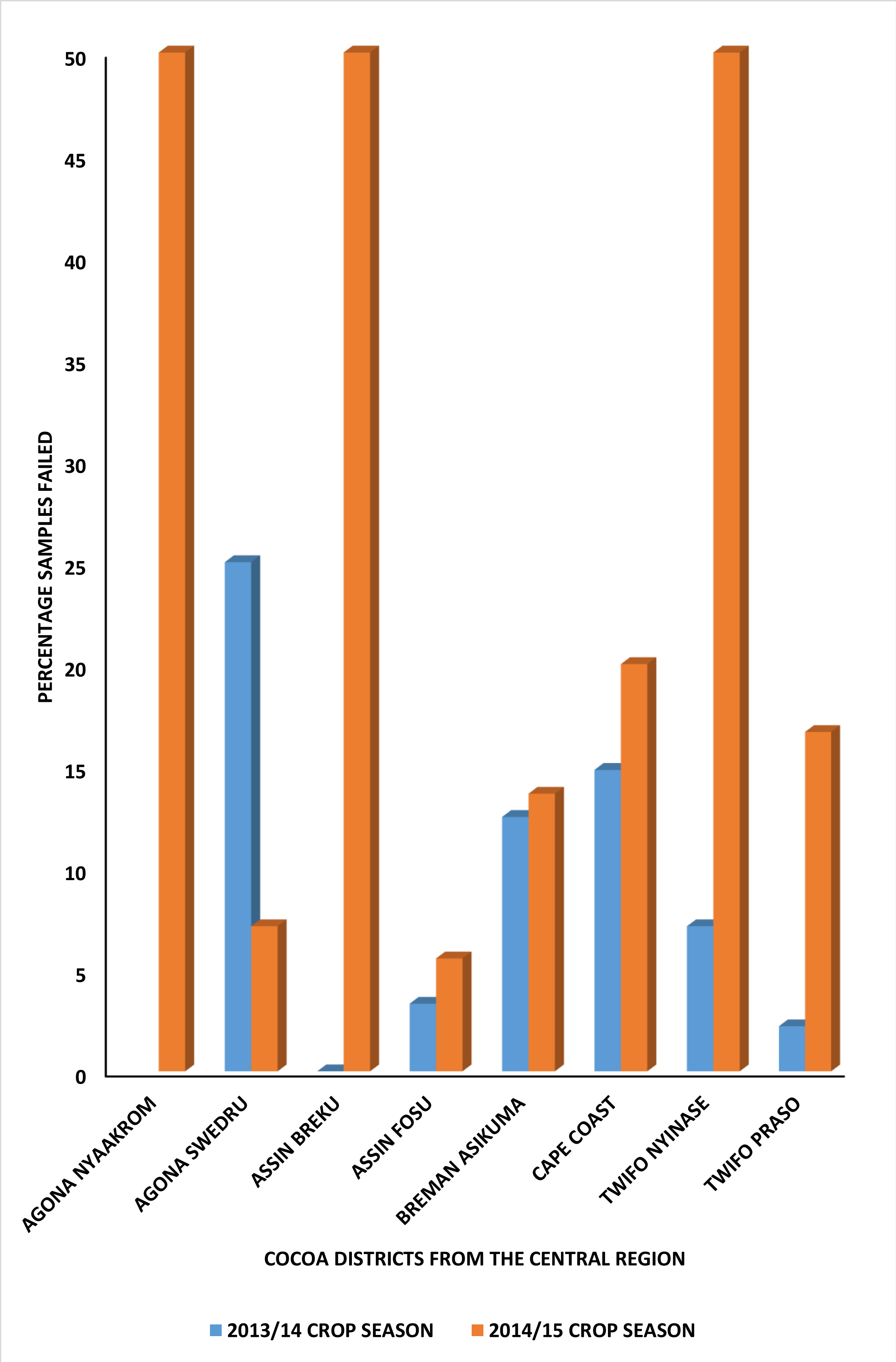

Figure 4. 9: Pesticide failure rates (%) for districts within the Central Region for the 2013/14 and 2014/15 crop seasons.

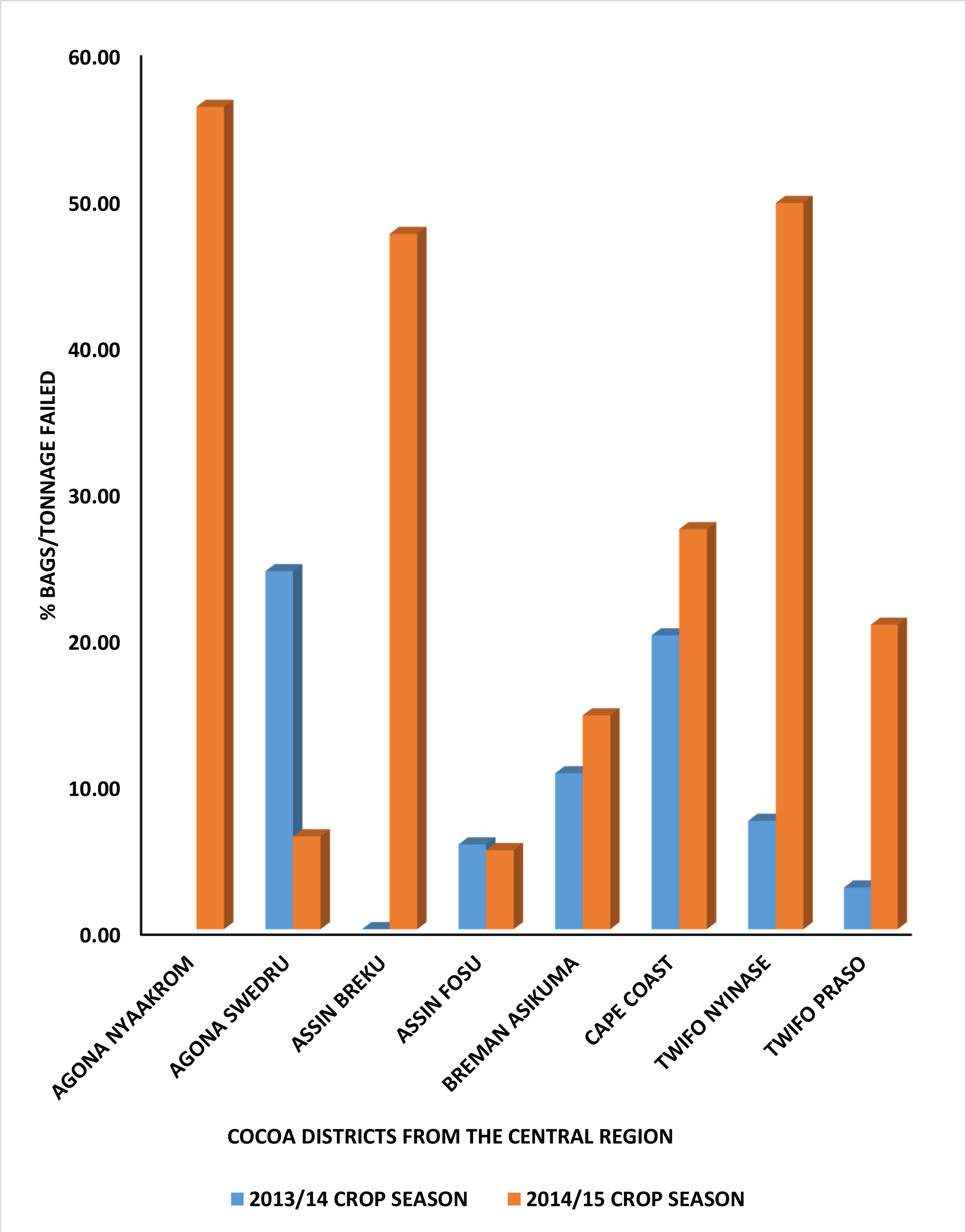

Figure 4. 10: Percentage of bags/tonnage from each district within the Central Region for the 2013/14 and 2014/15 crop seasons that failed the pesticide analysis.

Table 4.10 shows the number of samples of cocoa beans from the Central Region with pesticides residues above the JMRLs.Residues of cypermethrin above the JMRLs were found in samples from 6 districts and from 8 districts in the first and second seasons respectively. Residues of fenvalerate above the limit were found from 3 districts in the first season and from 6 districts in the second season. The only sample with imidacloprid residues above the limit was brought from Agona Swedru in the first season and Twifo Praso in the second season. No sample was found to contain residues of permethrin above the JMRLs in both seasons.

Table 4. 10: Number of samples of cocoa beans from the Central Region with pesticides residues above the Japanese MRLs.

Districts in Central Region	Number of samples failed per pesticide								
	PM	**CP**	**FV**	**ID**	**CP & FV**	**CP & ID**	**CP & PM**	**FV & ID**	**CP, FV & ID**
Agona Nyaakrom	--(0)	--(1)	--(1)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)
Agona Swedru	0(0)	1(1)	2(1)	1(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Assin Breku	0(0)	0(0)	0(0)	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)
Assin Fosu	0(0)	1(0)	0(0)	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)
Breman Asikuma	0(0)	1(1)	2(2)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Cape Coast	0(0)	3(2)	1(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Twifo Nyinase	0(0)	2(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Twifo Praso	0(0)	1(2)	0(1)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)

NB: PM = Permethrin; CP = Cypermethrin; FV = fenvalerate; ID = imidacloprid.

Figures outside and inside parentheses represent the number of samples for the 2013/14 and 2014/15 crop seasons respectively.

4.6 Results from the Eastern Region

Akim Oda in the Eastern Region supplied the highest quantity of bags/tonnage and 31.4% (37/118) and 25.6% (29/139) of samples were drawn for the analysis for the first and second seasons respectively (Table 4.11). In the first season, 63.6% (7/11) of the districts failed to meet the requirements (Figure 4.11 and 4.12). The Koforidua district recorded the highest failure rate although no significant difference was found between this rate and those of the other districts. However, a significant difference was found between the number of bags/tonnage from this district that failed and those from the other districts ($\chi^2 \geq 177.19$; $p<0.001$; df=1) (Figure 4.12). The rest of the districts met the requirement during this season. The Nkawkaw district supplied the highest quantity of cocoa beans in the second season. In this season, 50% (7/14) of the districts failed to meet the requirements. All the samples drawn from New Tafo failed the analysis and the difference in the rates between this district and the other districts was significant ($\chi^2 \geq 347.9$; $p<0.001$; df=1) (Figure 4.12). No samples from Kade, New Tafo, Nkawkaw and Ofoase failed in the first season, and none from Akoase, Akroso, Anyinam, Asamankese, Kade, Koforidua and Nsutam also failed in the second season.

Table 4. 11: Quantity of cocoa beans supplied by districts within the EasternRegion during the 2013/14 and 2014/15 cocoa seasons.

District	**2013/14 Cocoa Season**			**2014/15 Cocoa Season**		
	No. of Bags Supplied	**Tonnage Supplied**	**No. of Samples Analyzed**	**No. of Bags Supplied**	**Tonnage Supplied**	**No. of Samples Analyzed**
Akim Achiase	2,300	143.75	6	3,676	229.75	8
Akim Oda	16,303	1,018.94	37	15,309	956.81	29
Akoase	4,050	253.12	7	3,833	239.56	10
Akroso	---	---	---	180	11.25	1
Anyinam	---	---	---	2,286	142.88	4
Asamankese	2,069	129.31	5	3,980	248.75	8
Kade	2,373	148.31	7	5,986	374.12	16
Kibi	7,781	486.31	14	6,978	436.12	16
Koforidua	2,494	155.88	5	4,133	258.31	9
New Tafo	581	36.312	1	600	37.50	1
Nkawkaw	4,870	304.38	15	5,389	336.81	11
Nsutam	---	---	---	117	7.31	1
Ofoase	2,577	161.06	**9**	4,432	277.00	14
Suhum	2,830	176.88	12	2,971	185.69	11
TOTAL	**48,228**	**3,014.25**	**118**	**59,870**	**3,741.88**	**139**

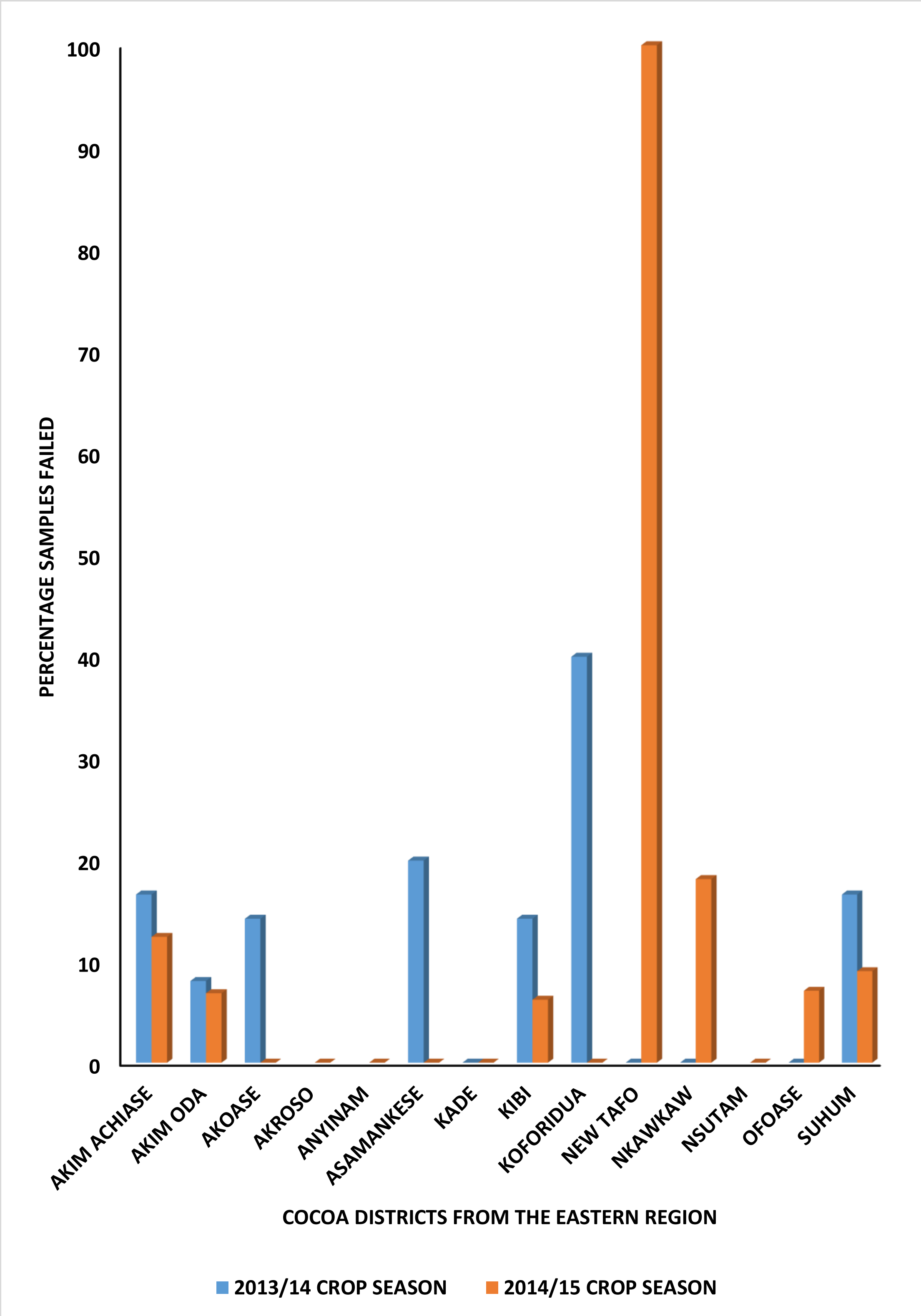

Figure 4. 11: Pesticide failure rates (%) for districts within the Eastern Region for the 2013/14 and 2014/15 crop seasons.

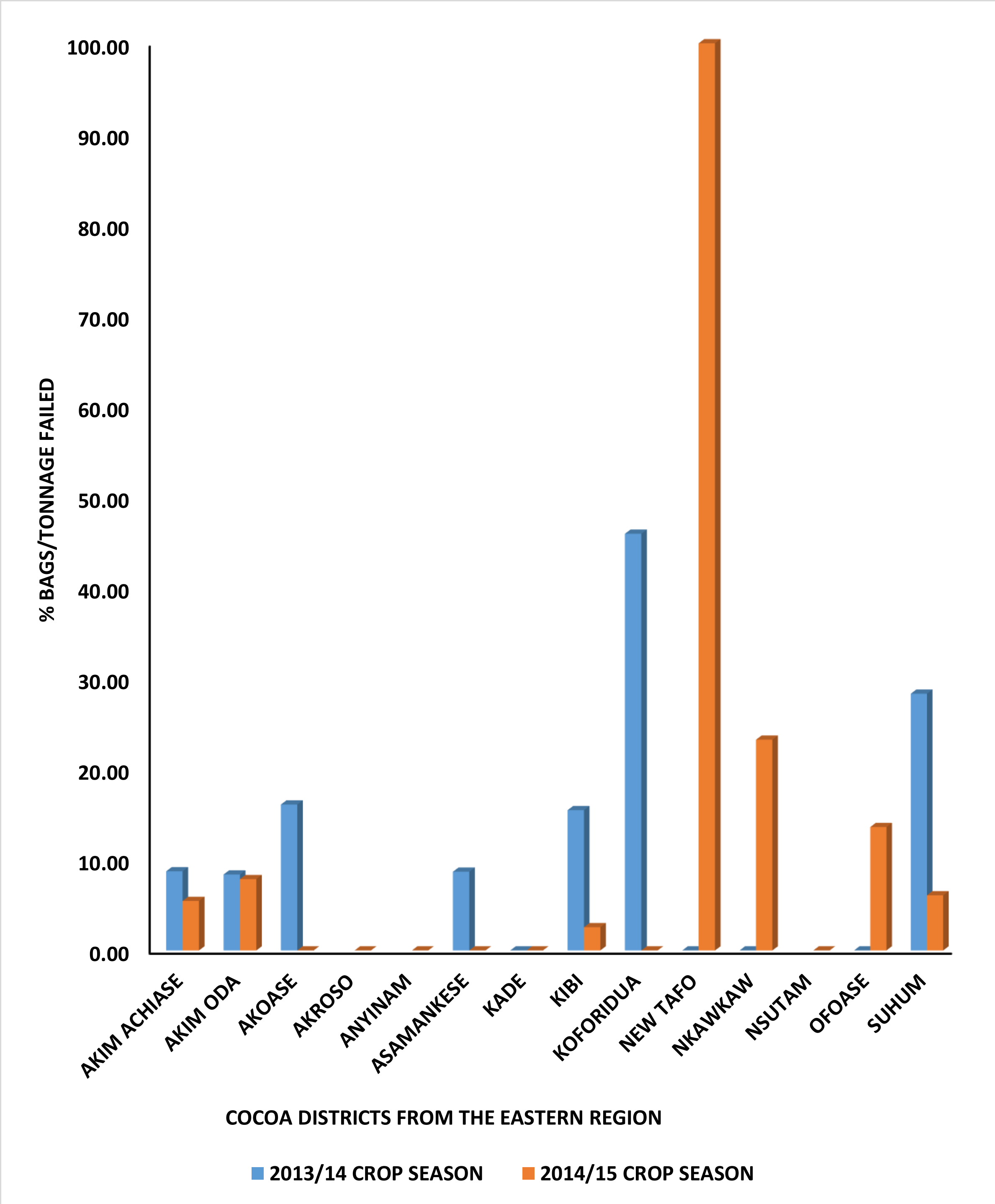

Figure 4. 12: Percentage of bags/tonnage from each district within the Eastern Region for the 2013/14 and 2014/15 crop seasons that failed the pesticide analysis.

Table 4.12 shows the number of samples of cocoa beans from the Eastern Region that contained pesticides residues above the JMRLs. Samples from three (3) districts contained residues of cypermethrin above the JMRLs in the first season and, also, in the second season. Four (4) districts supplied samples that contained fenvalerate residues above the JMRLs in the first season and five districts supplied same in the second season. Only two (2) districts supplied samples with imidacloprid residues above the JMRLs, and this was detected in the first season only. No sample was found to contain residues of permethrin above the JMRLs in both seasons. The overall sample failure rate is 10.2% (12/118) and for the quantity of bags/tonnage is 11.5% (5,534/48,228) for the first season. For the second season, the sample failure rate was 6.5% (9/139) and for the quantity of bags/tonnage supplied, 7.0% (4,209/59,870).

Table 4. 12: Number of samples of cocoa beans from the Eastern Region that contained pesticides residues above the Japanese MRLs.

Districts in Eastern Region	Number of samples failed per pesticide								
	PM	**CP**	**FV**	**ID**	**CP & FV**	**CP & ID**	**CP & PM**	**FV & ID**	**CP, FV & ID**
Akim Achiase	0(0)	0(0)	1(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Akim Oda	0(0)	3(1)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Akoase	0(0)	0(0)	0(0)	1(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Akroso	--	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)
Anyinam	--	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)
Asamankese	0(0)	0(0)	1(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Kade	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Kibi	0(0)	(0)	1(1)	1(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Koforidua	0(0)	2(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
New Tafo	0(0)	0 (1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Nkawkaw	0(0)	0 (0)	0(2)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Nsutam	--(0)	--(0)	--(0)	--(0)	--(0)	--(0)	--/0	--(0)	--(0)
Ofoase	0(0)	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Suhum	0(0)	1(1)	1(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)

NB: PM = Permethrin; CP = Cypermethrin; FV = fenvalerate; ID = imidacloprid.

Figures outside and inside parentheses represent the number of samples for the 2013/14 and 2014/15 crop seasons respectively.

4.7 Results from the Volta Region

The only supply from the Volta Region in the 2013/14 season came from the Hohoe district and this consisted of 594 bags which was equivalent to 37.1 tonnes. In the second season, the only supply from the Volta Region was also received from the Jasikan district and that supply consisted of 194 bags equivalent to 12.1 tonnes. Whereas the sample from the Hohoe district passed the analysis that from the Jasikan district failed for fenvalerate only.

4.8 Comparing results from all the cocoa regions

A total of 90 districts (80 in the first season and 77 in the second season) supplied cocoa beans to the Tema and Takoradi take-over centres. Table 4.13 shows the total number of bags/tonnage of cocoa beans supplied from all the cocoa districts in the two crop seasons. A total of 387,317 bags of cocoa were supplied in the first season and 456,347 bags in the second season. The Western South Region led in the quantity supplied for both seasons. The region supplied 29.2% (113,300/387,317) of the total quantity in the first season and 30.2% (137,713/456,347) of the total in the second season. Similarly, the highest number of samples were drawn from this region for analysis in both seasons. In total, more beans from all the regions were supplied in the second season than in the first season. Figures 4.13 and 4.14 are pesticide failure rates and the proportion of bags/tonnage from the cocoa regions respectively that failed during the 2013/14 and 2014/15 crop seasons. For the first crop season the Ashanti region recorded the highest sample failure rate of 10.9% (16/147) but no significant difference was found between this rate and those of the other regions. However, a significant difference was found between this region and the other regions with regards to the percentage of bags/tonnage that failed ($\chi^2 \geq 105.1$; $p<0.001$; df=1) in the first season. In the second season, the failure rate pertaining to the number of bags/tonnage from the Volta Region was the highest and the difference between the region and that of the other regions was significant ($\chi^2 \geq 717.8$; $p<0.001$; df=1). The overall failure rate from the regions for all the samples was 8.9% (78/873) and for all the bags/tonnage supplied, 9.1% (35,275/387,317) for the first cocoa season. For the second season, the overall rate for all the samples was 15.6% (144/925) and for all the bags/tonnage supplied, 15.2% (68,985/454,357). A significant difference was found between the overall sample failure rate for the 2014/15 season and that of the 2013/14 season ($\chi^2=17.6$; $p<0.001$; df=1). Same was found for the two seasons with regards to the total number of bags/tonnage supplied ($\chi^2=7110.6$; $p<0.001$; df=1). A perfect correlation was found between the quantity of the cocoa bags/tonnage supplied and the number of samples drawn for the analysis in both seasons ($r = 0.93\text{-}1.0$). However, no good correlation was found between the quantity of bags/tonnage supplied and the number of bags that failed the analysis.

With regards to the proportion of districts that supplied the beans with pesticide residues more than the JMRLs, no significant difference was found between them. Proportionately more districts in the Central Region supplied cocoa beans that contained pesticide residues higher than the JMRLs in the first season. In the 2014/15 season, all the 8 districts in the Central Region and Jasikan the only district in the Volta Region that supplied cocoa beans contained more pesticide residues higher than the

JMRLs. The Central region had the highest number or proportion of districts that supplied fermented cocoa beans that contained cypermethrin residues 100% (8/8) and fenvalerate residues 75% (6/8). The Western region also had the highest number or proportion of districts that supplied the highest percentage of samples with imidacloprid residues 38.9% (7/18). Only Nsokote in the Ashanti region and Goaso in the Brong-Ahafo region supplied samples that contained permethrin residues of all the samples supplied during the two seasons.

The lower limits of the ranges with regards to the concentrations of the pesticide residues in the samples irrespective of the regions from which they were brought was zero (0) mg/g for all samples, but the upper limits were as follows: cypermethrin, 0.08 mg/g; fenvalerate, 0.06 mg/g; imidacloprid, 0.28 mg/g and permethrin 0.07 mg/g for the 2013/2014 season. For the 2014/15 season, the upper limits for the pesticides were as follows: cypermethrin, 0.71 mg/g; fenvalerate, 0.34 mg/g; imidacloprid, 1.57 mg/g and permethrin, 0.06 mg/g. These upper limit values are higher than the JMRLs. The mean concentration for cypermethrin residues in the total supply during the 2013/14 season was 0.01 mg/g, and for each of the other pesticides it was zero (0) mg/g. For the 2014/15 season, the mean concentration for cypermethrin was 0.02 mg/g and for each of the other pesticides it was 0.01 mg/g.

Table 4. 13: Total quantity of cocoa beans supplied and samples from the cocoa regions analyzed for pesticide residues.

	2013/14 Cocoa Season			**2014/15 Cocoa Season**		
Cocoa Regions	**No. of Bags Supplied**	**Tonnage Supplied**	**No. of Samples Analyzed**	**No. of Bags Supplied**	**Tonnage Supplied**	**No. of Samples Analyzed**
Ashanti	65,848	4,115.50	147	76,408	4,775.50	169
Western North	40,805	2,550.31	85	107,641	6,727.56	216
Western South	113,300	7,081.25	249	137,713	8,607.06	296
Central	73,540	4,596.25	189	51859	3,241.19	110
Eastern	48,228	3,014.25	118	59,870	3,741.88	139
Brong-Ahafo	45,002	2,812.63	84	22,662	1,416.38	41
Volta	594	37.12	1	194	12.13	1
TOTAL	**387,317**	**24,207.31**	**873**	**456,347**	**28,521.69**	**972**

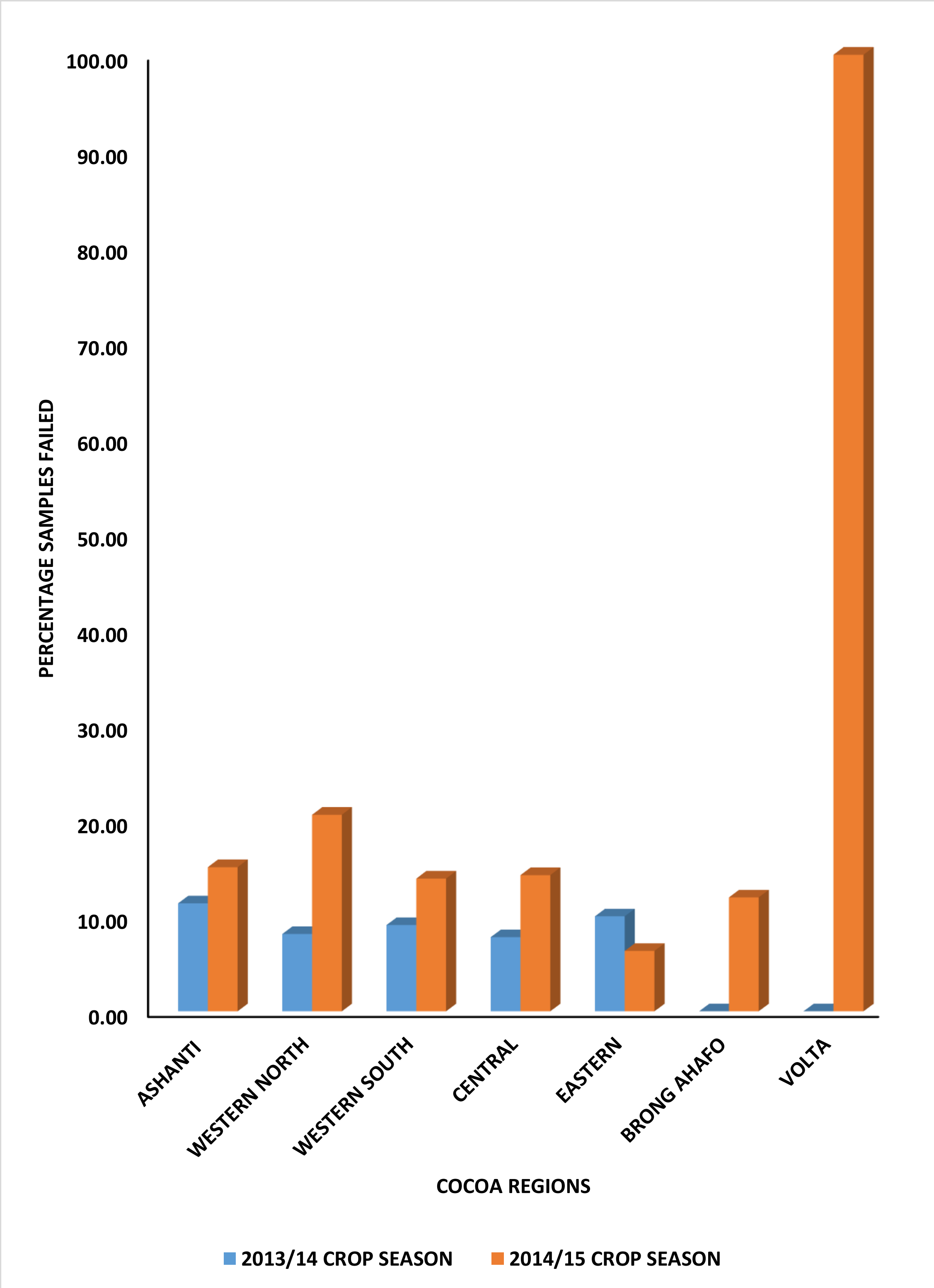

Figure 4. 13: Pesticide failure rates (%) for the cocoa regions for the 2013/14 and 2014/15 crop seasons.

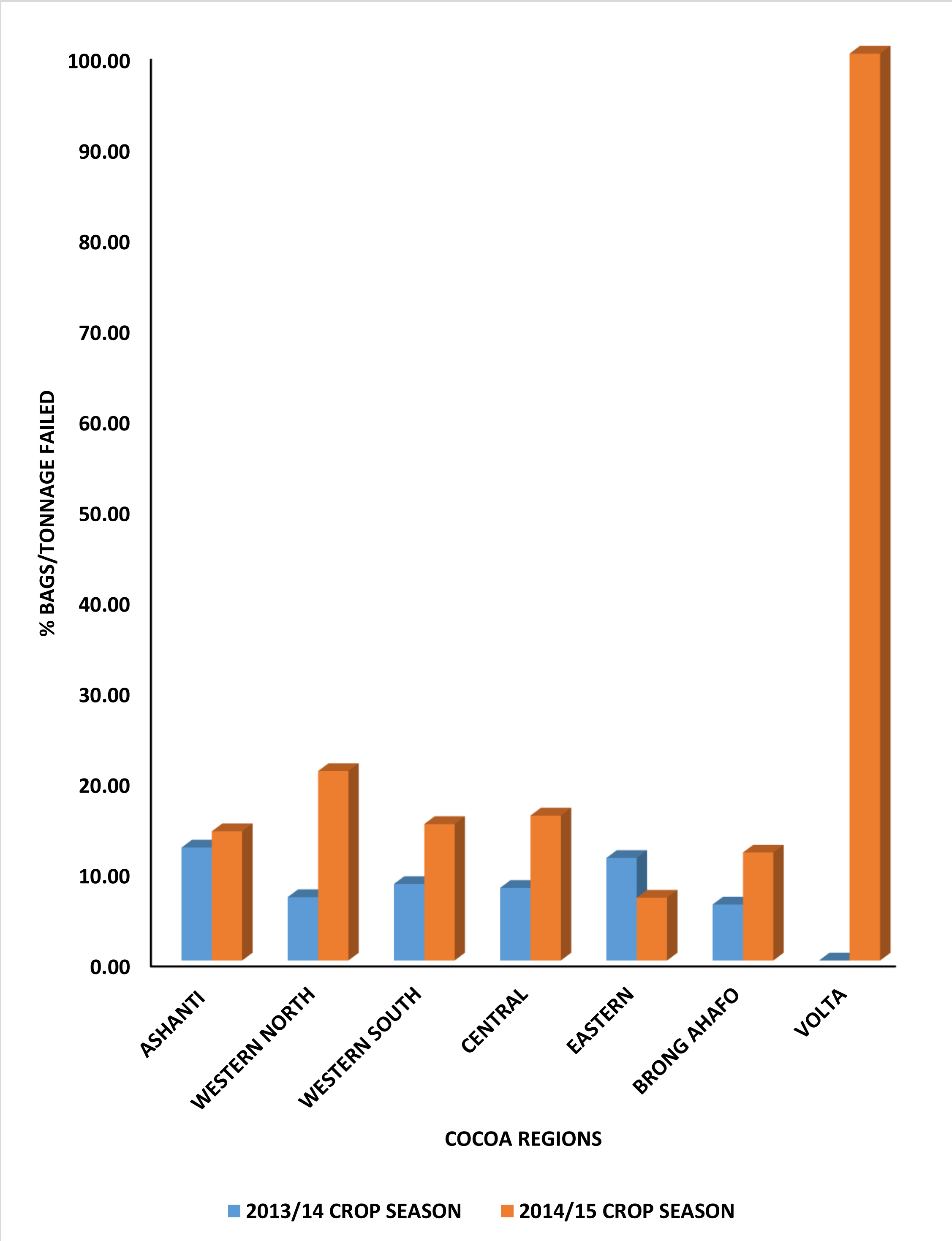

Figure 4. 14: Percentage bags/tonnage failed for each cocoa region for the 2013/14 and 2014/15 crop seasons.

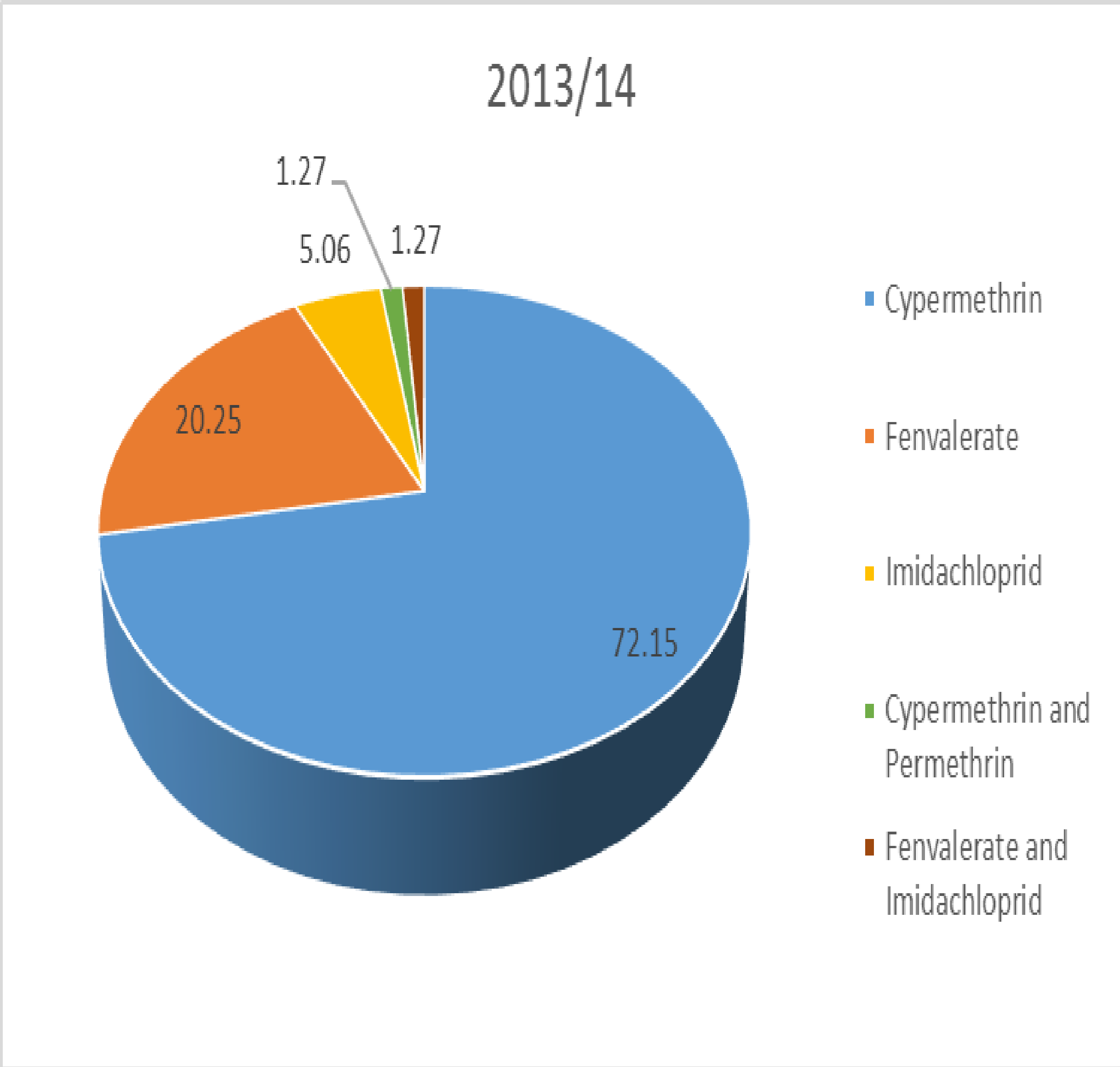

Figure 4. 15: Percentage of samples failed for the pesticides during the 2013/14 crop season.

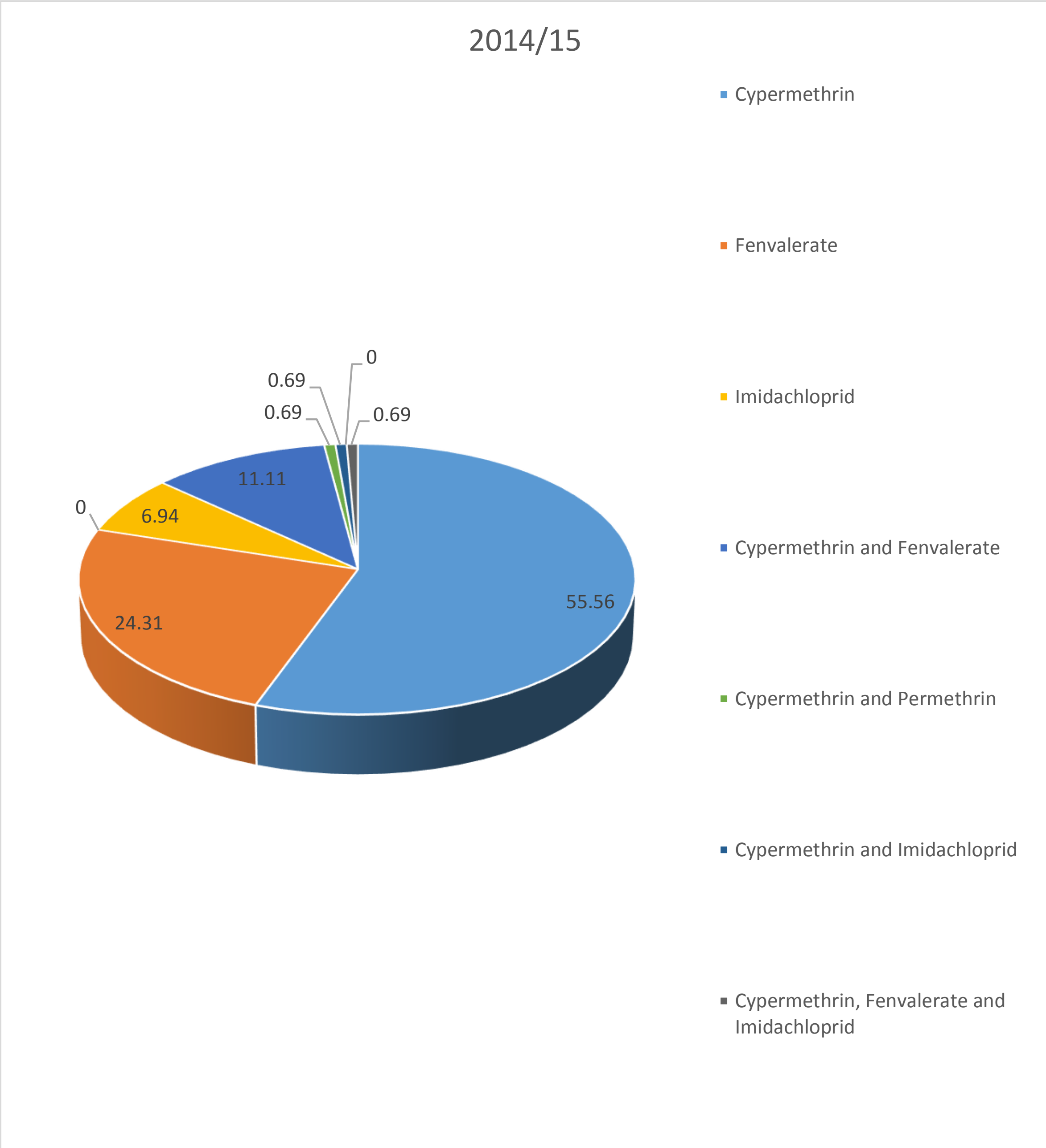

Figure 4. 16: Percentage of samples failed for the pesticides during the 2014/15 crop season.

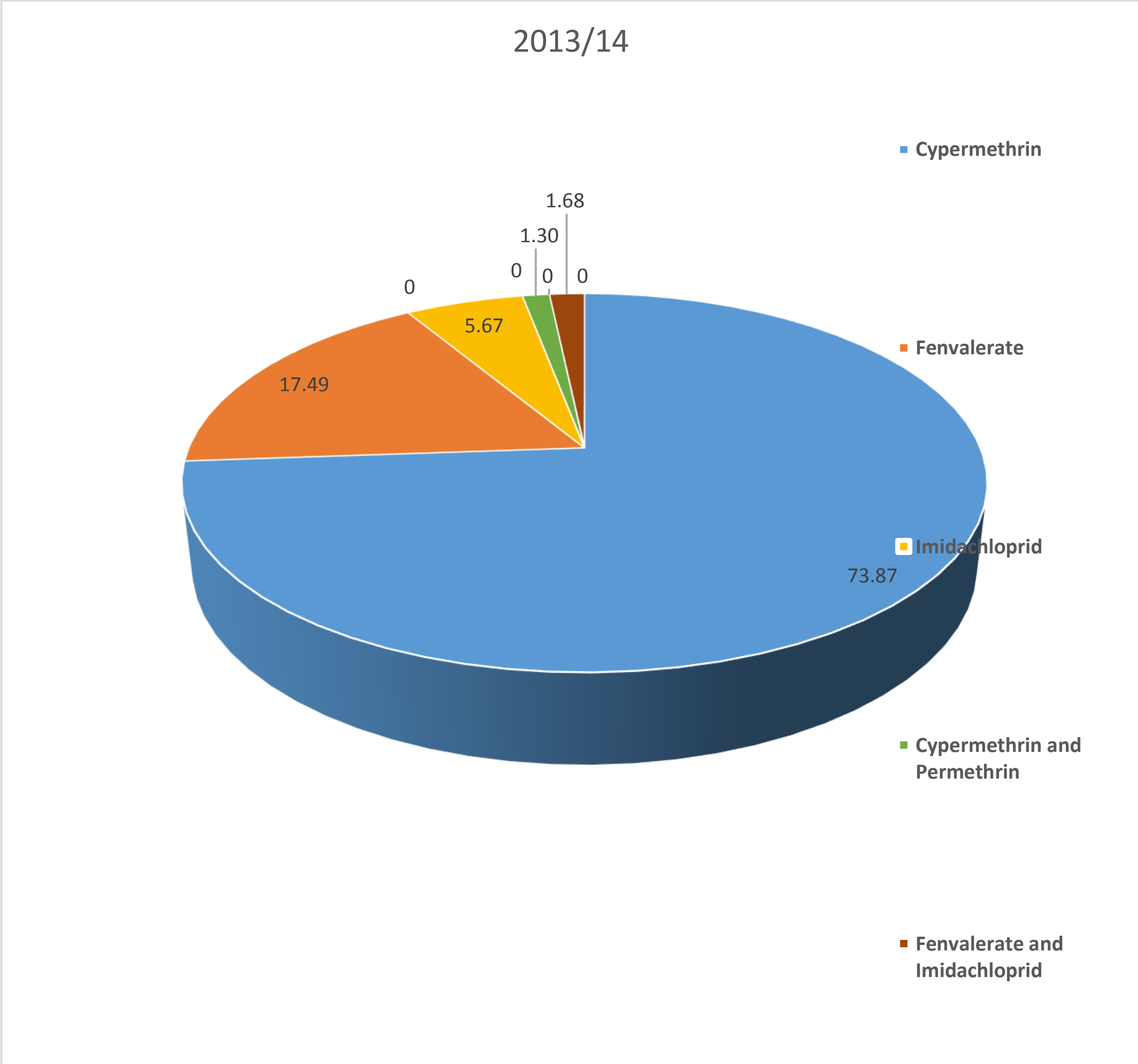

Figure 4. 17 : Percentage of bags/tonnage failed for the pesticides during the 2013/14 crop season.

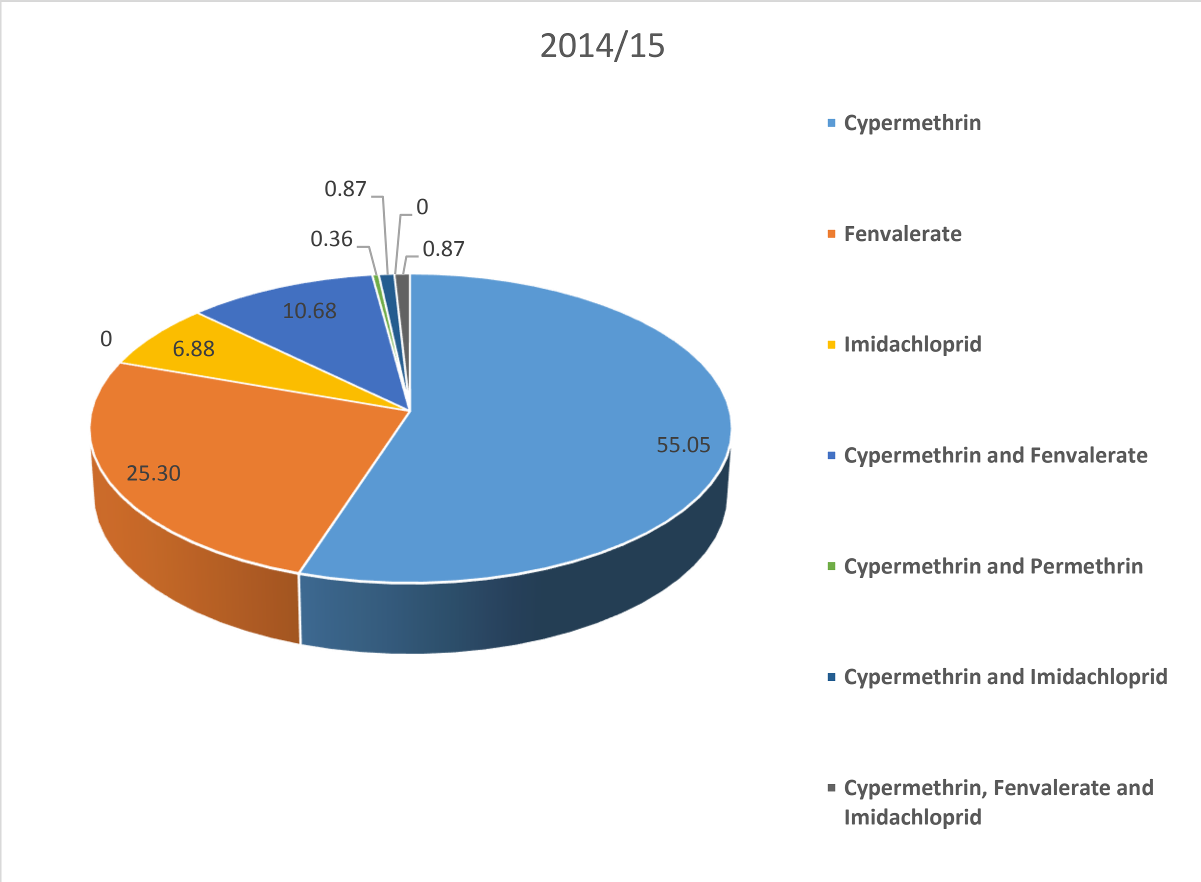

Figure 4. 18: Proportionate percentage bags/tonnage pesticide failures for 2014/15 crop season.

Figures 4.15 and 4.16 are pie charts showing the percentages of samples that failed the analysis in the 2013/14 and 2014/15 cocoa seasons respectively. Figure 4.17 and 4.18 are also pie charts showing the percentage of bags/tonnage that failed the analysis in the 2013/14 and 2014/15 seasons respectively. Tables 4.14 shows the percentage of samples with pesticide residues from the individual regions out of the total supplied from all the regions during the 2013/14 cocoa season.Districts from theWestern South Region, Central Region and Eastern Region supplied the highest proportion of samples that contained cypermethrin, fenvalerate and imidacloprid residues respectively during the season. Similarly, Table 4.15 shows the percentage of samples with pesticide residues from the individual regions out of the total obtained from all the regions during the 2014/15 cocoa season.Whereas districts from the Western North and Western South Regions supplied the highest number of samples that contained cypermethrin residues, districts from the Western North alone supplied the highest number of samples that contained fenvalerate and imidacloprid residues during this season. Tables 4.16 and 4.17 also show the number and percentage of bags/tonnage of the fermented cocoa beans with pesticide residues above the JMRLs supplied during the 2013/14 and 2014/15 seasons. Districts from the Western South Region supplied the highest proportion of bags/tonnage that contained residues of cypermethrin and fenvalerate whilst districts from the Eastern Region supplied the highest proportion containing imidacloprid residues during the first season. During the second season, the district from the Western North Region supplied the highest proportion of bag/tonnage of the beans containing the residues of cypermethrin, fenvalerate and imidacloprid.

Table 4. 14: Number and percentage of samples with pesticide residues above the Japanese minimum residue levels supplied during the 2013/14 cocoa season.

Region	CP		FV		ID		CP +PM		FV + 1D		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Ashanti	14	25	2	13	0	0	0	0	1	100	17	22
Western North	7	12	0	0	0	0	0	0	0	0	7	9
Western South	18	32	4	25	1	25	0	0	0	0	23	29
Central	9	16	5	31	1	25	0	0	0	0	15	19
Eastern	6	11	4	25	2	50	0	0	0	0	12	15
Brong-Ahafo	3	5	1	6	0	0	1	100	0	0	5	6
Volta	0	0	0	0	0	0	0	0	0	0	0	0

NB: CP = cypermethrin; FV = Fenvalerate; ID = Imidaclprid; PM = Permethrin.

Table 4. 15: Number and percentage of samples with pesticide residues above the Japanese minimum residue levels supplied during the 2014/15 cocoa season.

Region	CP		FV		ID		CP + FV		CP +ID		CP + PM		CP+FV+ID	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Ashanti	16	20	7	20	0	0	2	13	0	0	1	100	0	0
W. North	26	33	8	23	6	60	3	19	1	100	0	0	1	100
W. South	26	33	6	17	2	20	8	50	0	0	0	0	0	0
Central	8	10	5	14	1	10	2	13	0	0	0	0	0	0
Eastern	3	4	6	17	0	0	0	0	0	0	0	0	0	0
Brong-Ahafo	1	1	2	6	1	10	1	25	0	0	0	0	0	0
Volta	0	0	1	3	0	0	0	0	0	0	0	0	0	0

NB: CP = cypermethrin; FV = Fenvalerate; ID = Imidaclprid; PM = Permethrin; W = Western.

Table 4. 16: Number and percentage of bags/tonnage of cocoa beans with pesticide residues above the Japanese minimum residue levels supplied during the 2013/14 season.

Region	CP		FV		ID		CP + PM		FV + 1D	
	No.	%	No.	%	No.	%	No.	%	No.	%
Ashanti	6512	25	210	19	0	0	0	0	600	100
Western North	3469	13	0	0	0	0	0	0	0	0
Western South	7438	28	2079	33	180	9	0	0	0	0
Central	4179	16	1196	19	600	30	0	0	0	0
Eastern	3105	12	1179	19	1250	62	0	0	0	0
Brong Ahafo	1754	7	600	10	0	0	464	100	0	0
Volta	0	0	0	0	0	0	0		0	0

NB: CP = cypermethrin; FV = Fenvalerate; ID = Imidaclprid; PM = Permethrin.

Table 4. 17: Number and percentage of bags/tonnage of cocoa beans with pesticide residues above the Japanese minimum residue limits supplied during the 2014/15 season.

Region	CP		FV		ID		CP +FV		CP + 1D		CP + PM		CP+FV+ID	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Ashanti	6918	18	3000	17	0	0	858	12	0	0	249	100	0	0
Western North	13066	34	4164	24	2847	60	1386	19	600	100	0	0	600	100
Western South	12064	32	34375	20	787	17	3448	47	0	0	0	0	0	0
Central	3954	10	2844	16	510	11	1075	15	0	0	0	0	0	0
Eastern	1380	4	2829	16	0	0	0	0	0	0	0	0	0	0
Brong-Ahafo	594	2	943	5	600	13	600	8	0	0	0	0	0	0
Volta	0	0	194	1	0	0	0	0	0	0	0	0	0	0

NB: CP = cypermethrin; FV = Fenvalerate; ID = Imidaclprid; PM = Permethrin.

4.9 Discussion

The study involves the analysis of organo-chlorine and pyrethroid pesticide residues in fermented cocoa beans from all the cocoa regions in Ghana. The organo-chlorine pesticide determined was imidacloprid and pyrethrioids were fenvalerate, cypermethrin and permethrin. Before the commencement of this study, not much work had been carried out in relation to the analysis of cocoa beans for the detection of pesticide residues in Ghana. Sandra (2012) for her thesis project work at the Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi investigated the presence of pesticide residues in cocoa samples from the Ashanti and Brong-Ahafo regions, whilst Mohammed (2015) carried out similar investigations also for her thesis project at the KNUST on samples from the Central and Western regions of Ghana. The pesticide investigated were Chloropyrifos, Endosulfan (I and II), Profenefos, Fenvalerate, Bifenthrin, Permethrin (I and II), Cypermethrin (I, II and T), HCH (α, β, γ and δ), Aldrin, Heptachlor – exo– epoxide, Dieldrin, 4,4–DDD, 4,4–DDT and Heptachlor regions. In the work carried out by Sandra (2012) in the Ashanti region, she detected high levels of cypermetherin, permethrin and fenvalerate residues in the cocoa beans from the districts in the Ashanti region above the JMRLs. In this study, high levels of cypermethrin residues above the JMRLs were detected in samples from Nyinahin, Mankraso and Juaso in the 2013/14 season. In the 2014/15 season, higher residue concentrations of this pesticide above the JMRLs were detected in the samples from Ampenim, Nyinahin, Offinso, Juaso, and New Edubiase. However, permethrin and fenvalerate residue concentrations in the samples from the districts in the region in both seasons were all within the acceptable range. Cypermethrin and permethrin residue concentrations in samples from the Brong-Ahafo region were above the acceptable level. With the exception of the samples from Sunyani and Nyinase, samples from other districts within the region all had higher levels of fenvalerate residues above the acceptable level in them. In the current work cypermethrin residue concentrations were higher than the JMRLs in samples from Sunyani and Hwidiem in the 2013/14 season and those from Goaso in both the 2014/13 and 2014/15 seasons. The concentration of permethrin residues was higher only in the samples from Goaso in the 2013/14 season. In both seasons, fenvalerate residue concentrations were within the acceptable range.

Mohammed (2015), in her work, found that the concentration of cypermethrin II and III residues were higher in all the samples from the Central region that were analyzed than the JMRLs. For cypermethrin I the pesticide residue concentrations were higher than the JMRLs only in the samples received from Assin Breku, Agona Swedru and Breman Asikuma, Twifo Hemang and Atieku. In the current study, values of cypermethrin residues in samples from Assin Fosu, Agona Swedru, Breman Asikuma, Twifo Praso and Cape Coast were also found to be higher than the JMRLs in the first season; in the second season higher values than the JMRLs were found in samples from Assin Breku, Assin Fosu, Breman Asikuma, Twifo Praso and Cape Coast. In the case of the concentrations of permethrin and fenvalerate, the residue concentration values in samples from all the districts in the region (except for Assin Fosu for permethrin) were higher than the JMRLs. In the current study, the concentration of fenvalerate residues were higher than the JMRLs in samples from Agona Swedru, Breman Asikuma and Cape Coast in the 2013/14 season and Agona Swedru, Assin Breku, Assin Fosu, Breman Asikuma and Twifo Praso in the 2014/15 season. However, the values for permethrin were all found to be below the JMRL for this pesticide. The cypermethrin, permethrin and fenvalerate residue concentrations of the samples from the districts of the Western region were all below the acceptable levels. In the current work, cypermethrin residues from Sefwi Anhwiaso in the 2013/14 season and from Sefwi Kaase and Sefwi Anhwiaso in the 2014/15 season were higher than the acceptable levels. Fenvalerate residue levels were also higher than the JMRLs in samples from Sefwi Kaase and Sefwi Anhwiaso in the 2014/15. The concentration of permethrin residues were within the acceptable range.

In the current study, 5% and 15% of the samples analyzed for the 2013/14 and 2014/15 crop seasons respectively were found to be above the Japanese MRLs. The reduced failure rates compared to that of Sandra (2012) and Mohammed (2015) may be due to improvement in the Good Agricultural Practices adopted by the farmers and also the proper supervisory roles played by various stake holders in the cocoa production chain. The higher failure rate recorded in the 2014/15 crop season compared to the 2013/14 crop season may be attributed to the negligence of pesticide application along the value chain and the use of unapproved pesticides by stakeholders.

Daanu (2011) determined the concentration of pesticide residues in fermented dried cocoa beans in Asukese and its environs in the Tano North district of the Brong-Ahafo region. In this work, cypermethrin and fenvalerate concentrations in cocoa beans were found to have exceeded the acceptable levels specified by Japan and the European

Union. He also detected permethrin concentrations above the acceptable levels in three sample collection sites. Frimpong *et al.* (2012a; 2012b) in their work found high amounts of lindane, Beta-HCH and Delta-HCH in the samples in the dried fermented cocoa beans sampled from the Tema and Takoradi ports. According to him the widest range of organochlorine pesticides detected was from endosulfan, a chemical that was previously registered for cotton production in Ghana. Frimpong *et al*. (2012c) determined the presence of allethrin, cypermethrin, fenvalerate, bifenthrin, fenpropathrin, lambda-cyhalothrin, permethrin, cyfluthrin and deltamethrin in cocoa beans. Although the mean residues concentrations of allethrin, cypermethrin andfenvalerate were detected, none of these synthetic pyrethroids pesticides mean residue concentrations exceeded the European Union or Japanese MRLs.

The investigations carried out by these workers were based on smaller samples compared to the current work. In the current work, more samples were analyzed from more districts within the cocoa regions in Ghana. However, the investigation of both workers targeted a wider range of pesticides than the current study has sought to investigate. In this study, pesticide residues from cocoa beans were assessed against the Japanese standard. Since the Japanese standard is higher than the standards other major importing countries such as the European Union (EU), any consignment that is accepted based on the Japanese standard will be accepted by the other importing countries.

The current study revealed that fenvalerate which is not approved for use on cocoa, was the second most occurring pesticide for both crop seasons. Currently, Ghana has approved the use of 254 pesticides while 26 have been banned and a small number are restricted for use (EPA Ghana, 2009). The approved ones for cocoa production in the country are Promecarb, Confidor (imidacloprid), Actellic (Primiphos Methyl), Akate Master (Bifenthrin) and Actara (Thiamethoxam) (ICCO, 2010; Antwi-Agyakwa *et al*., 2016) and the unapproved ones are Endosulfan, Chloropyrifos, lindane, pyrethroid, cypermethrin, primiphos Methyl, Lamda Cyhalothrin among others. A study revealed that lindane and endosulfan, which were restricted for use on cocoa, coffee and maize farms were being used on vegetables, alongside with DDT which has also been banned (Amoah *et al*., 2006).

A survey conducted in the Ashanti, Eastern, Volta and Western regions of Ghana on 147 cocoa farms revealed that farmers used more insecticides than recommended by the COCOBOD disregarding the health concerns associated with the pesticides (Antwi-Agyakwa *et al*., 2016). Most farmers, due to their level of illiteracy and ignorance, fail to appreciate the health issues associated with the abuse of pesticides and they continue to patronize unapproved pesticides to the detriment of their health. Their main concern is about high yield of the crop. This makes them sometimes lose focus and tend to seek information from wrong sources.

A study conducted in the Eastern and Ashanti regions of Ghana revealed that about 56% of farmers lack information on the type, frequency and timing of pesticides to be used except for those belonging to farmer groups (Awudzi *et al*., 2015). Wrong information or illiteracy may lead to the unapproved use of these pesticides, mishandling and their abuse. The prevalence of pesticide residues in cocoa beans can bring about the imposition of trade sanctions meted out by international trade partners (Frimpong, 2011). Repeated occurrences of pesticide failures of cocoa consignments may lead to their rejection, economic consequences, toxicity and diseases and destabilization of development projects in the country.

The detection of residues of unapproved pesticides in the cocoa beans may be due to the their use by farmers for other purposes such as killing of flies on the farm and leaching of polluted water from farms. The use and/or abuse of these unapproved pesticides are usually due to the chemical sellers' persuasion of farmers- and improper education. Contamination of cocoa beans with pesticides can occur in several ways. According to Belitz *et al*. (2004) also contamination of cocoa beans can occur directly by treating the crop with pesticides before harvest, storage and distribution. It can occur indirectly by uptake from the soil of residual pesticides by the subsequent cocoa farming, from the atmosphere or drifting from neighbouring fields, or from a storage space pretreated with pesticides.Based on a study conducted in the Idanre local government area of Ondo state in Nigeria to investigate pesticides in common use in cocoa agriculture, dangers associated with their use and established regulatory incentive (if any) that protect farmers and farm workers against pesticide risk, it was revealed that most of the commonly used pesticides were the ones classified by the World Health Organization as moderately or highly hazardous that have either been banned or their use restricted in many advanced countries (Tijani, 2006). This notwithstanding, marketers of these chemicals do claim that these pesticides are registered and pose no serious health hazards to users, by-standers, livestock, wild-life and the environment. Although the EPA in collaboration with the federal government of Nigeria has established legal and administrative procedures to protect users, information gathered shows that the farmers and workers do not take necessary precautionary action to prevent hazards associated with the use of these chemicals. Their effects lead to sicknesses such as headache, tiredness, vomiting, nausea, skin burns, skin itches etc. (Tijani, 2006).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Of the eight hundred and seventy-three (873) samples analyzed for the 2013/14 cocoa season the overall failure rate for all the smaples was 8.9% and for all the bags/tonnage supplied, 9.1%. For the second season, the overall rate for the 925 samples analyzed was 15.6% and for all the bags/tonnage supplied, 15.2%. For the first crop season, the Ashanti region recorded the highest sample failure rate of 10.9%. In the second season the failure rate pertaining to the number of bags/tonnage from the Volta region was the highest (100%). Pesticide residues in the samples/bags were mainly due to cypermethrin followed by fenvalerate, imdachloprid and lastly, permethrin. A higher proportion of samples/bags of cocoa contained cypermethrin and permethrin residues in the first cocoa season than the second season. The reverse was the case for fenvalerate and imidacloprid. Cypermethrin and fenvalerate residues were found in samples from all the regions. Residues of permethrin were found only in the samples from Goaso in the Brong Ahafo region and in samples from Nsokote in the Ashanti region. Imidacloprid residues were absent only in samples from the Ashanti region and the Volta region.

5.2 Recommendations

1. Since pesticide use is unavoidable and has serious health hazards and environmental consequences when abused, stakeholders would need to be trained regularly on its proper applications, disposal and health implications of abuse.
2. Effective communication with all stake holders especially farmers should be encouraged and improved upon. Appropriate communication methods/ tools should be employed to ensure effective communication at various levels.
3. Effective monitoring should be carried out to ensure the use of only approved and appropriate pesticides by all stakeholders and violators should be severely sanctioned.
4. Further work should be done to analyze data produced over a longer period to give a better judgment to the trend of pesticide use/abuse. This will offer a better picture of the trend.
5. Further work should be done to estimate the probable risks associated with pesticide residues in cocoa beans.
6. The high occurrences of fenvalerate residues in cocoa needs to be investigated.
7. Farmers who are not members of existing farmer groups must be compelled to join these groups so that they can benefit from training and other important information relayed to the various groups.

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