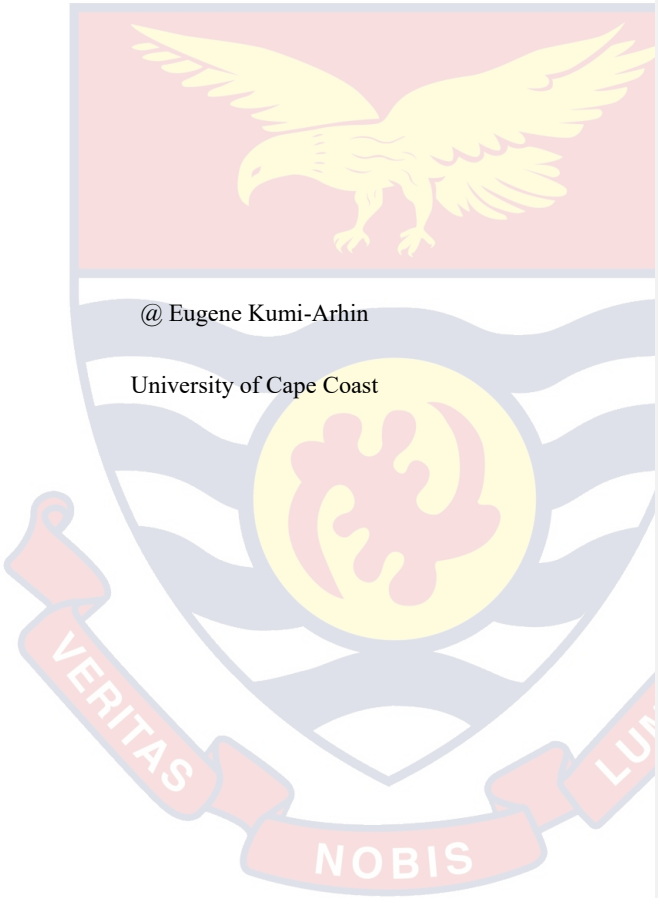
UNIVERSITY OF CAPE COAST

"THE CONTRIBUTION SOIL HEAVY METALS POLLUTION TO THE CAUSE OF DESTRUCTION OF THE COCONUT PALM IN SOME SELECTED AREAS OF THE CENTRAL REGION OF GHANA": (A CASE STUDY IN AJUMAKO-ENYAN ESSIAM TO BOBIKUMA).

EUGENE KUMI-ARHIN

2021



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BY

EUGENE KUMI-ARHIN

Thesis Submitted to the Department of Chemistry of School of Physical Science of the College of Agriculture and Natural Sciences, University of Cape Coast, in the Partial Fulfillment of the Requirement for the Award of Master of Philosophy Degree in Environmental Chemistry.

JANUARY, 2021.

DECLARATION

Candidate Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere, except where due acknowledgement has been made in the text.

Candidate's Signature …….. Date……

Candidate's Name……

Supervisor's Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in the accordance with the guidelines on supervision laid down by the University of Cape Coast.

Principal Supervisor's Signature ……..... Date……

Name ……...

Co-Supervisor's Signature…… Date……

Name ……...

ABSTRACT

Contaminations of soil by heavy metals are extremely threatening to both plant and animal lives. This study looked at the levels of heavy metals in the soils and stems of the coconut plantation farms from Ajumako-Enyan Essiam through to Bobikuma in the Central Region of Ghana and assessed its possible contribution to the destruction of the plant. One hundred soil and one hundred stem samples were collected. Heavy metals that were analyzed in these samples were Zinc, Iron, Copper, Nickel, Chromium, Lead, Manganese and Cadmium. Atomic Absorption Spectrometer (Shimadzu 7000 AS) was used to analyze the samples after the samples were digested. From the findings, the pHs of the soil were within acceptable limit for plant growth set by the WHO standard except soil sample site 10 for the wet season. For organic carbon, the data obtained shows that some sample sites (6 and 8) for the dry season and sample site (1, 2,3,4,6 and 7) had higher levels of organic carbon than the acceptable limit which 0.5-3.5 is set by WHO. The findings of electrical conductivity proves the soil on the various sites were non saline. The levels of cation exchange capacity proves the soil had adequate levels of the ions in the soil. Concentration of some of the selected heavy metals like Fe during the dry season in the soil samples exceeded the WHO standard for plant growth. For the stem samples, Fe, Zn, Cu and Pb having high levels of heavy metals in some sample sites. Finally, comparing the result to an unpublished thesis on where the coconut are dying, it can be seen that heavy metals might be a contributing factor to the death of the coconut palm.

KEY WORDS

Coconut Palm

Deficiency

Environment

Heavy Metals.

Pollution

Toxicity

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DEDICATION

To Mrs. Anastasia Afia Kumi-Arhin, Eugene Kumi-Arhin and Elliot Kumi-Arhin.

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LIST OF ACRONYMS

AAS	Atomic Absorptions Spectrometer
AES	Atomic Emission Spectroscopy
AFS	Atomic Fluorescence Spectroscopy
CEC	Cation-Exchange-Capacity
CVAAS	Cold Vapour Atomic Absorption Spectrometer
DNA	Deoxyribonucleic Acid
FAAS	Flame Atomic Absorptions Spectrometer
FAO	Food and Agriculture Organisation
FLAA	Flame Atomic Absorption Spectrometry
GFAA	Graphite Furnace AA
HDL	High Density Lipoprotein
ICP-AES	Inductivity Coupled Plasma Atomic Emission Spectrometry
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
ICP-MS	Inductivity Coupled Plasma Mass Spectrometry
ISO	International Organization for Standardization
LCFAs	Long-Chain Fatty Acids
LDL	Low Density Lipoprotein
MCFAS	Medium-Chain Fatty acids
MDL	Minimum Detection Limit
MLO	Mycoplasma – Like Organism
SOD	Superoxide Disumutase
UTI	Urinary Tract Infections
WHO	World Health Organisation

CHAPTER ONE

INTRODUCTION

The first chapter of this discourse covers the historical background of the study, the origin and distribution, the botany, the morphology, growth and development, climate and soils, mineral nutrient deficiencies, drought effects, stem tapering and the essence of coconut.

Background of the Study

The coconut palm (*Cocos nucifera* L.) is the most well-known member of the palm family (Last 2001). It is the only species recognized in the genus *Cocos* (Chan and Elevitch 2006). It is in the family Arecaceae (palm family), sub family Cocoideae, Genus *Cocos*, and species *nucifera* (Chan and Elevitch 2006). In many cultures around the world the local name for the coconut palm translates to "tree of life", "tree of heaven", or other such names because of the numerous uses and products derived from the coconut palm (Chan and Elevitch 2006; Last 2001; MOFA 2011; Frater 2004).

C. nucifera is found throughout the tropics, with different varieties in different locations (Chan and Elevitch 2006; Ghana Ministry of Food and Agriculture (B) 2011; Gunn et al. 2011; Noel et al. 2007; Quaicoe et al. 2009). In the southern parts of Ghana, coconut palms of the 'West African Tall' variety (Quaicoe et al. 2009) are common (Ghana Ministry of Food and Agriculture (A and B) 2011; Noel 2007; Quaicoe 2009; Okorley and Haizel 2004).

The coconut palm (*Cocos nucifera*) is a tropical tree species which once was the first major estate crop, extending over large uniform areas, but is now

primarily grown and harvested by small farmers. In addition to the production of vegetable oil for industrial uses from cosmetics and explosives to bio-fuels and health and wellness products, it is also a fiber crop, a food and beverage crop, and a visual amenity palm for tourist hotels, golf courses and city parks and village gardens throughout the tropics. From its natural habitat on the shoreline of uninhabited oceanic islands to inland locations on the fringes of deserts and the foothills of mountain ranges, it can provide every necessity for survival of castaways, subsistence consumption, local markets and international trade (Harries 1978).

Very little is known about the origin and early distribution of the coconut palm. Evidence suggests that the coconut and its related species already had a wide distribution during the Eocene to Oligocene eras (28-44 million years ago). At the dawn of agriculture (around 10,000 years ago), it appears to have been restricted to a region extending from South-east Asia to near Oceania and to the south of the Indian sub-continent. It is feasible that when humans started to harvest coconuts for consumption and multiplication, this initiated a long and progressive domestication process.

It is likely that within archipelagos and on islands, the spread of coconuts was based on a very small initial sample size, considering the bulk of the seed material and that the coconut reproduces by seed. The natural adaptation of coconuts to a dispersal mode by flotation means that sample size may have been limited to only a few nuts being the founders of populations on small islands and atolls. During this worldwide dissemination, these continued 'bottleneck events' have resulted in enormous genetic drifts in the founding populations. This process, facilitating a fragmentation of coconut genetic

diversity, was overlain by ritual and commercial exchanges of seeds, which tended to homogenize populations at a regional scale. The results of these partially opposed tendencies need to be analysed further because they have significant implications regarding the current genetic distribution of coconuts, in particular when being collected for conservation and multiple uses.

Optimizing conservation requires a better understanding of the biological, social and historical dynamics shaping coconut genetic diversity and its uses. The current pantropical coconut distribution was attained only relatively recently from 3,400 to 100 years ago, involving Austronesian seafarers from Malaysia and Pacific, Arab traders in the Indian Ocean, and Europeans exploring the Atlantic and the Pacific coasts of the Americas.

South-east Asia comprising Cambodia, Hainan Island, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam, is undoubtedly one of the most diverse regions for coconut cultivation. This is the region where the highly domesticated Dwarf coconuts are likely to have originated.

Archaeological evidence suggests that the coconut was present in the Pacific prior to human arrival. Early human settlers occupied the Sahul region about 45,000 years ago settling in New Guinea Island and Australia. These first settlers were not cultivators, but may have used coconuts as floatation aids to reach New Guinea and Australia Coconut fruit provided portable water and food for their rapid migration across Pacific Ocean.

In the 1800s, in most of the Pacific islands, each of the various clans had probably a limited number of coconut palms. However, they distinguished many coconut landraces which served many different purposes.

From 1870, coconut became a major colonial business and copra an international commodity. Commercial plantations of various sizes run by European settlers or companies had a ripple effect on the establishment of small plantations by Pacific islanders, geared to copra production. The number of coconut palms in the Pacific region greatly increased (probably 50 to 100-fold). In most cases planting techniques on the atolls consisted of clearing all the natural vegetation, letting it dry for a month, burning everything and importing coconut seednuts from another bigger island. These planting techniques were indeed harmful to the biodiversity of endemic species. They were also damaging from the perspective of conserving coconut genetic diversity. Agricultural landscapes and practices were brutally modified (Kirsch 2002).

In many islands, the human population was decimated by diseases brought by infected European mariners and traders, such as measles and influenza. These cataclysmic events changed the social representations of the coconut palm for the Pacific islanders, and exacerbated the erosion of traditional knowledge and the mix of biological resources. It has been estimated that more than half of the coconut landraces that had been developed by the islanders over several millennia were lost by dilution in the mass of coconut palms selected purely to produce copra.

By the end of the first century AD the Indian Ocean embraced a network of trade routes and coconut fruit became a popular trade commodity where exchanges were made between northern Africa, South-west Asia and the east coast of Africa (Cappers 2003). The main hubs were the Maldives and the

Laccadives Islands. In Tumbe village, Pemba, Tanzania, archaeobotanical data suggest that coconuts and rice were already under cultivation from the 7th to the 10th centuries. In South Oman, the tradition of using coconut fibres (*kambar*) to construct dhows and cordage is attested in the 9th century and has persisted among local fishermen and transoceanic traders (Pereira et al. 2011).

Coconut is still cultivated in Oman under irrigation. The Comoros Islands and Madagascar also formed an integral part of this trade route and show evidence of Bantu and Middle Eastern cultures. Molecular evidence has shown that a proportion of coconuts from Comoros and Madagascar were admixed with those from the Pacific and may be traced to earlier migrations around 1,500 years ago by Austronesians from eastern Kalimantan in South-east Asia. Soon after the opening of the navigation route to India by Vasco da Gama, coconut was introduced to the Cape Verde islands and from there to West Africa and to the Caribbean.

Historical and pre-historical knowledge about the dynamics of coconut cultivation and trade is still incomplete. During the 18th, 19th and even the 20th century, full boats loaded with coconut seeds were sent between continents, from Asia to the Pacific region and Indian Ocean, and vice versa. Therefore, it is imperative to establish and understand how traditional knowledge of diverse coconut germplasm might be of service to current agricultural and economic developments. In order to do this, coconut conservationists and agronomists should collaborate more closely with archaeologists and historians. Genetic diversity measures from the interface

between the landraces and cultivars have already provided crucial information concerning agricultural development.

Figure1: Pictures of some flourishing coconut palm at Agona Bobikuma in the Central Region of Ghana. (Field Survey, 2019)

The most important of all the palms is the coconut in the tropics. The coconut palm has many uses in the tropics as compared to the Western countries. The dried coconut meat is called "copra". Coconut oil which has many uses is obtained from the pressed copra. Coconut water is also obtained from the liquid inside the young, immature coconut. Coconut milk is extracted by squeezing the copra. Together, these products are offering consumers more choices in their quest for natural alternatives in their diets, personal care and lifestyle.

However, report shows that the presence of heavy metals beyond permissible limits adversely affects the environment, causing reduction in the quality of life and eventually death of the coconut palm (Neri et al., 2006).

Environmental pollution is the result of a pollutant in the environment, air, water and soil which are poisonous or toxic to life. It is therefore harmful to all living things including the coconut palm (Neri et al., 2006).

Heavy metal accumulation in agricultural soil has become a major concern for crop production as some heavy metals affect crops adversely. Cadmium for example is one of the hazardous elements which is not essential for plant growth. Higher levels of cadmium in the soil causes death of the palm with time. (Kabata- pendias and Pendias, 1992).

Furr et al, (1979) investigated the elemental composition of the coconut palm and reported trace quantities of most heavy metals but those of concern in higher quantities than expected were Ba, Br, Co, Cs, Cu, Ni and Se. Biddappa (1984) studied the distribution pattern of heavy metals in coconut crown affected by the root (wilt) disease and observed higher concentrations of heavy metals in the crown of diseased compared to similar studies conducted on healthy palms. Somashekar (1984) also investigated trace metal status of coconut plants of polluted area in Kerala. He found high concentrations of Ni and Cu in coconut root and leaf extract. Biddappa et al (1987) investigation on the effect of heavy metals on the P, K, Ca and Mg concentration in the leaves of coconut palms, indicated that heavy metals generally reduced P, K, Ca and Mg content of coconut leaves. He also found that leaf concentration of Fe, Mn, Zn and Cu were generally increased by heavy metal accumulation.

1.2 Statement of the Problem

The death of coconut palm has been linked to viruses, fungus and viroids. Cape St. Paul Wilt disease has been found to be a prevalent source of death of coconut palm in Ghana along the coastal belt (Nkansah-Poku et al.2009). Elevated levels of heavy metals has been reported in coconut growing areas where the coconuts are dying (Essuman et al).

Research work done for heavy metal levels in soils and stems along Apam to Ekumfi Ekotsi indicated high levels of heavy metals.

1.3 Objective of the study

The main objective of the study is to determine the effect of heavy metals on the coconut palm with the recommended limit for plant growth by WHO along the Ajumako to Bobikuma stretch in the Central Region of Ghana.

Specific Objectives:

The specific objectives of the study were to:

1. To determine the pH, dissolved organic matter, electrical conductivity, and cation exchange capacity of the soil.
2. To determine the levels of heavy metal concentration in soils and stems of the coconut palm (Pb, Ni, Cr, Zn, Fe, Cu, Mn and Cd).
3. To determine the contribution of the selected heavy metals to the toxicity of the coconut palm.

1.4 Significance of the Study

The study will determine whether or not high levels of heavy metals in soils significantly affect the coconut production. The study will help to develop antidotes (remediating the soil) to the challenges facing the farmers in the coconut production business and to provide data for guidance for researchers and farmers who grow coconut palm in Ghana.

Research Hypotheses (The null hypothesis)

Hypothesis 1: Metal levels are lower than recommended levels in the soils and stems at where the coconut are flourishing.

Hypothesis 2: Metal levels are higher than the recommended levels in soils and stems at where the coconut is dying.

1.6 Organisation of the study

The thesis was organised as follows:

Chapter one introduces the research and stated the rational for the study.

Chapter two presents a review of literature on the coconut farm and heavy metals. In chapter three, the sampling procedure, analytical methods employed for the acid digestion was described. In chapter four, the results are discussed. Finally, chapter five covers summary of findings, conclusions drawn from the study and recommendations that were made.

Chapter summary

In this chapter, a general overview of the study has been described. The chapter provides a general background to issues of coconut problems associated with heavy metals. A brief description of the study area. The main purpose behind this research, the significance of the study and the hypothesis with this study has been clearly stated in the chapter.

CHAPTER TWO

LITERATURE REVIEW

Introduction

The second chapter of the research report deals with the review of related Literature. Literature according to the Macmillan English Dictionary for Advanced Learners is "Books or other printed information about a subject". To "review" is to study or examine a situation, a policy or an idea again in order to decide whether it is still suitable or satisfactory. Literature review therefore has to do with the examination of the ideas that have been expressed on a subject matter. In this instance, the researcher is bent on examining what earlier researchers have opined about the impact of environmental pollution on coconut production at other places. The said challenges have been juxtaposed against those at the coastal belt of Ghana.

Kusi (2012) categorized sources of Literature into two: Topic Literature and Methodology Literature. Topic Literature entails those pieces of information relating to the subject area from which a problem is chosen for investigation. The essence of this is to unearth the existing theories and debates that are relevant to the research problems.

Henn et al (2006) added that Topic Literature brings out previous research findings which ensure the identification of the gaps in knowledge. The other side of the coin is Methodological Literature. They are those that make references to the key methodological debates.

The Coconut Problem

In a few years now, the price of fresh coconut just as the dry one has risen from as low as 50 Ghana pesewas (2011) to two Ghana cedis (2019), especially in the capital cities of Ghana. Coconut sellers point the climb in the price to rising cost of conveyance of the produce from the farm gates and more importantly the declining supply of the produce due to the overwhelming nature of a disease called, Cape Saint Paul Wilt. In the 1940's, there was a significant reduction in export because the Cape Saint Paul Wilt Disease (CSPWD) was causing a significant number of deaths in the southern Volta region (Anyane 1963).

After World War II, the demand and increased price for coconut stimulated more plantings of coconut palms, especially in the Western region (Anyane 1963), where the CSPWD was not yet present (Danyo 2011). In 1950, the Agricultural Produce Marketing Board assumed responsibility for overseas marketing of coconut copra, the mature kernel, and consequently played an important role in the expansion of the industry (Anyane 1963). There is enough evidence that a lot of coconut palms are dead and continue to die in Ghana, West Africa, Africa and in other parts of the world. There have been extensive studies on the various diseases that affect the coconut palm tree i.e. the destruction of the coconut palm tree [Nowell, (1923); Bhaskaran et al (1989).

However, it has also been reported that, the presence of heavy metals beyond permissible limits adversely affects the environment, reduces the quality of life and eventually death of the coconut palm plant (Neri et al., 2006). With

reference to the findings of these researchers, this study is investigating the effects of some heavy metals pollution on coconut palm in Ghana.

Below are some diseases that affect the coconut palm;

Lethal Yellowing Diseases (Cape St. Paul Wilt disease)

Cape Saint Paul Wilt Disease (CSPWD) is one of the global Lethal Yellowing Type Diseases (LYTD) specific to West Africa (Mpunami et al. 1999). LYTD are associated with the phytoplasma, phloem-restricted mollicutes, of the coconut that is spread primarily through insect vectors. It is also spread via vegetative propagation (Nipah et al. 2007). LYTD are characterized by an initial incubation stage where it is not observable, followed by browning then yellowing of fronds that then drop off, and premature fruit drop and dropping of inflorescence. Eventually, the entire crown will fall off, leaving the trunk with a power pole appearance (Dery et al. 2008; Danyo 2011; Mpunami et al. 1999; Nipah et al. 2007; Nkansah-Poku et al. 2009; Noel et al. 2007; Quaicoe et al. 2009).

Cape Saint Paul Wilt Disease (CSPWD) first appeared in Ghana in 1932 at Cape Saint Paul in the Volta region. This is also where the name for the disease was derived. The spread was slow but devastating, mostly destroying the coconut industry in the Volta region by 1950 (Anyane 1963; Danyo 2011; Quaicoe et al. 2009). Many plantations sustained a 100 percent mortality of coconut palms as the disease spread (Danyo 2011). In 1964, CSPWD was found at Cape Three Points, in the Western region, and after approximately 5 years, it began spreading quickly east and north, with a much slower westward expansion (Danyo 2011; Nkansah-Poku et al. 2009). CSPWD reached the

middle of the central region by 1983. Beginning in 2008, there were reports of the disease reaching the Eastern Region (Danyo 2011).

Figure 2: Groove of coconut palms with CSPWD mortality leaving power pole appearance and a single palm with advanced CSPWD symptoms.

Danyo (2011) estimated that 4.2 percent of the population, or 1.01 million Ghanaians, depend on the coconut as their source of income. The value lost to CSPWD was calculated based on the price of a single coconut estimated to have an income value of GHC 0.30 (0.30 Ghana cedi, or 30 pesewa; with the December 2010 exchange rate at GHC 1.4: USD 1). This estimate also assumes 48 coconuts per palm per year and 160 palms per hectare. With these numbers, Danyo (2011) calculated the income from coconuts per year to be GHC 2,304.00 per hectare of coconut palms. If there are approximately 462,000 coconut farmers cultivating one hectare of coconut palms, a 50 percent loss of the palms would result in lost annual incomes totaling GHC 532,224,000. This estimate is only from the coconut fruit. This does not include loss of income from supplementary items that come from other possible uses of the living coconut palm.

Over the years, the Ghanaian Department of Agriculture, along with others, have tried to develop methods to deal with CSPWD. There is no cure, the

exact vectors of spread are not all known, and resistance is still minimal. Currently, resistant varieties and hybrids are showing the most promise for combating CSPWD (Dery et al. 2008; Danyo 2011; Nipah et al. 2007; Nkansah-Poku et al. 2009; Quaicoe et al. 2009). Trials in Ghana to find resistant varieties started as early as 1956. In 1981, hybrid breading and testing started (Quaicoe et al. 2009). There have been at least 27 different varieties and hybrids tested for resistance (Quaicoe et al. 2009). The tested varieties include the following: 'Andaman Tall' (ADOT), 'Catigan Green Dwarf' (CATD), 'Cameroon Red Dwarf' (CRD), 'Equatorial Guinean Green Dwarf' (aka Brazilian Green Dwarf, EGD), 'Laccadive Tall' (LCT), 'Malayan Red Dwarf' (MRD), 'Malayan Yellow Dwarf' (MYD), 'Malayan Tall' (MLT), 'Panama Tall' (PNT), 'Rennell Island Tall' (RIT), 'Sri Lanka Green Dwarf' (SGD), 'Tacunan Green Dwarf' (TACD), 'Tagnanan Tall' (TAGT), 'Tahiti Tall' (aka Polynesian Tall, TAT), 'Vanuatu Tall' (VTT), and the local variety 'West African Tall' (WAT) (Dery et al. 2008).

Breeding of hybrid varieties of coconut palms is done for two reasons. The first objective was to make a variety with a higher resistance to CSPWD. This was done by taking two varieties, cross breading them, and then using the resultant hybrids in a disease resistance trial plantings. The second purpose of hybrids is to obtain disease resistance while preserving desirable characteristics of a non-resistant variety (Danyo 2011; Last 2001; Quaicoe et al. 2009). The first trials to use hybrids were done in 1981 and 1983, with 17 different hybrids planted (Quaicoe et al. 2009). The results of the 1981 and 1983 trials identified four varieties with some level of resistance and less than

50 percent infection rate; however, no hybrids showed complete resistance to CSPWD (Quaicoe et al. 2009). This trial was built upon by later trials.

A cross of MYD x VTT is a heavily used hybrid for replanting to help prevent a total collapse of the coconut industry (Ghana Ministry of Food and Agriculture (B) 2011; Quaicoe et al. 2009). The 1981 and 1983 trials showed a low susceptibility to the disease (Quaicoe et al. 2009).

Furthermore, Dery et al. (2008) 2006 plots showed a 66.7 percent infection rate. This seemingly high rate of infection occurred in one of the most disease resistant strains and was the best hybrid tested by Dery et al. (2008). It performed well in multiple locations, and it is recommended for planting in areas far ahead of the disease front. This hybrid was used for a massive coconut planting during the 2011 World Food Day in Ghana in the Nzema East municipal (Ghana Ministry of Food and Agriculture (B) 2011; Ghana Ministry of Food and Agriculture (C) 2011). In 1995, the highly resistant SGD was crossed with the resistant VTT.

The resulting hybrid has been under screening at Agona junction (near Cape Three Points) and there has yet to be an incidence of CSPWD to occur in this hybrid (Quaicoe et al. 2009). While Dery et al. (2008) and Quaicoe et al. (2009) did not have data for a SGD x VTT hybrid screening exposure to CSPWD, both expect a high resistance and infection rate under 37 percent and recommend use of this hybrid for planting in all locations. There are now seed gardens capable of producing enough SGD x VTT hybrids to plant 200-300 ha each year (Quaicoe et al. 2009). This type is now being distributed to farmers in Ghana. Different varieties, hybrid or pure, are able to cross pollinate, in a

natural setting (Enaberue et al. 2006); therefore, locals hope that the resistant strains will continue to breed with each other and the local varieties to build resistance in future wild type generations.

Cadang-Cadang disease

Cadang-Cadang is a disease caused by Coconut Cadang-Cadang viroid (CCCVd), a lethal viroid of coconut (Cocos nucifera), anahaw (Saribus rotundifolius) buri (Corypha utan), and African oil palm (Elaeis guineensis). The name Cadang-Cadang comes from the word gadang-gadang that means dying in Bicol (Hanold and Randles 1991). It was originally reported on San Miguel Island in the Philippines in 1927/1928. "By 1962, all but 100 of 250,000 palms on this island had died from the disease," indicating an epidemic (Haseloff J. Mohammed 1982). Every year one million coconut palms are killed by CCCVd and over 30 million coconut palms have been killed since Cadang-Cadang has been discovered. CCCVd directly affects the production of copra, a raw material for coconut oil and animal feed. Total losses of about 30 million palms and annual yield losses of about 22,000 tons of copra have been attributed to Cadang-Cadang disease in the Philippines (Zelany B. 1980). Viroids are small, single-stranded RNA molecules, ranging from 246 to 375 nucleotides long. Unlike viruses, they do not code for protein coats but contain genes for autonomous replication. With abilities to cause serious disease, they are more commonly found in a latent stage, and their mode of infection is mainly mechanical, though documented cases exist of vertical transmission through pollen and seed (Maramorosch, K. 1991). The sequence and structure prediction of CCCVd has been documented. There are four low-molecular-weight RNA species (ccRNAs) found associated with

Cadang-Cadang disease (Randles J.W. 1981). Of the four, two are related with the early stage of the disease: ccRNA 1 fast and ccRNA 2 fast. After several years, two other species appear and predominate: ccRNA 1 slow and ccRNA 2 slow. Moreover, they share sequence homology with other viroid's (Haseloff 1982).

Conditions for a viroid to infect its host include wounds on the host or infected pollen grain deposited into an ovule (Agrios 2005). Randles (1987), detected that the reduction of the nut size in the early stages of the disease is due to reduced thickness of the husk and shell. Later, the kernel is also reduced. Maramorosch (1993), realized that the first symptom of the disease is the development of a small rough, circular bright yellow tinny spot on the leaf lamina of the third or fourth leaf below the spear. In cause of time, the spot becomes enlarged and forms blotches or streaks. Hanold and Randles (1991), discovered that compared to those of normal leaves, the leaf colour of diseased palms often is orange-yellow or bronze. Leaves and leaflets of the affected palms are also smaller and more brittle than normal, and the leaflets have a tendency to bend over or to break in the centre. Gradually, leaves take on an erect position in the crown. The stipules of the leaves of affected trees remain attached to the base of the leaves, giving them a winged appearance. Nut production ceases and leaf production slows down. This causes a gradual reduction in the number of leaves until only a tuft of small, erect, yellowish-green leave at the apex of the trunk is left. Randles (1988), indicated that all efforts to control the Cadang-Cadang disease by eradication have failed, probably because the infection may have spread before visible symptoms appear. But Pacumbaba and Alfiler, 1987 reported a very low rate of spread,

indicating a significant reduction in disease incidence after eradication. Maramorosch, 1993 stresses the possibility of disease control by cleaning the knives used, by dipping them in a solution of concentrated sodium carbonate (Na_2CO_3). It is difficult to understand why this possible control method has never been used before. Pacumbaba and Alfiler, (1987), discovered that of the above control measure the effects may become visible only after several years; because several palms may have already been infected at the start of the trial, but gradually the number of palms affected should decline, especially in an area where the disease appearance is recent.

Lethal Disease

Phytoplasma, members of the class Mollicutes, are minute, cell wall-less prokaryotes that generally are confined to the phloem of plants. Phytoplasma have been associated as the probable cause of diseases in several hundred plant species (Agrios, 1978). Lethal yellowing (LY), a disease associated with phytoplasma (Maramorosch, 1972), affects at least 30 species of palm (Harrison, 1999) and has killed millions of coconut palm trees (Cocos nucifera L.) throughout the Caribbean, Florida, and Mexico, and currently threatens the Central American region. In coconut, LY causes different visual symptoms such as nut drop, leaf yellowing and senescence, and palm death (McCoy, 1983). Affected palms on Mafia are cut and burnt as soon as they are observed which may contribute to the low incidence. The islands of Zanzibar and Pemba are still free of the disease. A few cases of the disease have been observed at all times in Kenya as well, but the economic impact is very low. The Bagamoyo disease in Tanzania and the disease in Mozambique, called

'doença desconhecida', or 'unknown disease' is similar to the lethal disease (Ohler, 1984).

Field observations and infection rates shows decreasing disease incidence with increasing age. This could suggest that the most susceptible palms in the population gradually succumb whereas the resistant ones remain. However, in resistance trials, the progeny of surviving old palms showed no decrease in susceptibility. Preliminary results of resistance trials in Tanzania indicated that, distinct from Lethal Yellowing, none of the imported varieties, including dwarfs, show promising resistance to the lethal disease. Losses in hybrids are not lower than in corresponding tall parents, another indication that there is no resistance in dwarf parents. Consequently, no hybrid or variety has shown enough resistance for commercial exploitation. Contrary to the situation with Lethal Yellowing in Jamaica, where several dwarf varieties show excellent resistance, some tall varieties show intermediate resistance and their hybrids good, commercially acceptable resistance. In the present trials, promising resistance to the lethal disease was observed only in sub-populations of the local East African Tall (EAT), specifically a sub-population from Tanga. Lower losses in this sub-population suggest that the EAT is not uniformly susceptible to the lethal disease. In areas where the lethal disease has existed for a long time, resistance to the disease in the surviving population may have come to predominate. (Schuiling *et al*., 1992a).

Bud Rot Disease

Bud Rot, one of the most common diseases of coconut, is common in the very humid regions. The disease may kill a few palms each year if control measures

are not taken. According to Renard and Darwis (1993), there has been a resurgence of symptoms caused by Phytophtora more or less everywhere in the coconut growing zone. In certain regions in the Ivory Coast, up to 50% of the coconut palms initially planted are killed by Bud Rot. Bennet et al. (1986) suggest that a Diptera, Telostylinus sp., probably feeding on sugary exudates of young nuts which leak on the husk surface of healthy and diseased nuts could be a vector of the fungus. Uchida et al (1992) recorded that the pathogen that causes the Bud Rot in Hawaii resembles P. Katsurae. Steer and Coates-Beckford, (1990) reported *phytophthora parasitica* as the causal agent of Bud Rot in Costa Rica. Steer and Coates-Beckford (1990) observed in greenhouse trials in Jamaica that both species of *Phytophthora*, as well as another isolate, *Thielaviopsis paradoxa (ceratocystisparadoxa*), caused Bud Rot only in wound – inoculated coconut seedlings, and that isolate of *P, palmivora* varied in virulence. The bacterium *Enterobacter sp*., the most frequently occurring organism in the crowns, caused tissue necrosis.

Jamaica (1989) indicated that *T. paradoxa* always produced leisons and nutfall in the laboratory test inoculations in the leaf axils with sporangial suspensions of *P. palmivora* isolate from diseased palms, developed Bud Rot in two years old seedlings. Similarly, five-year-old palms in the field developed Bud Rot when inoculated in young leaf axils during the wet season. When trees that show symptoms of Bud Rot are dissected, the following revelations become bare; an evil smelling internal rot and a consistent soft cheese which is pale pink in colour. The rot is surrounded by a brown border and a few brown fibres towards the base in the unaffected areas. Although the

meristem is unaffected, there is poor supply to tissues above it that causes withering of the spear and youngest leaves.

A dissection of the stem at the early stage of the coconut palm that has been affected by the bud rot shows that the rot originates from behind the growing point in the soft tissues of the bud. (Quillec et al.1984).

High humidity found on low badly drained lands, in plantations in very dense stand and under extensive rainfall trigger the Bud Rot. The older leaves remain green and retain their positions for several months.

With the bud rot disease; there is abnormal loss of small to almost mature nuts as a common early sign of the disease. The leaves of the palm fall progressively, starting with the youngest one. The fall of the leave spans over a period of one year. The pungent smell of the rotting bud is inevitable. Rain water and insects are causal agents of the bud rot. The infection starts around the floral parts and extends toward the apex of the nut and inside toward the shell. Quillec et al. (1984), the disease is characterized by the presence of irregular lesions spreading from the surface of the nut to the endosperm and the nut stalk. In young nuts, lesions penetrate the soft shell. According to De Franqueville and Renard, (1989), the infested tester becomes grey and sticky. The adjacent infected endosperm is more translucent and softer than usual. In older nuts with hard shells, the fungus penetrates through the germ pore Thevenin et al. (1994).

Control would, in the first place, involve measures to reducing the relative humidity of the atmosphere in the plantation. Such measures might include improved drainage, wide spacing for better aeration, and adequate weed

control. Affected palms should be cut down and burnt as soon as possible. This deters breeding of rhinoceros beetles (*Oryctes rhinoceros* L.), which serve as carriers of the fungi spores (Abad, 1985). Uchida *et al*., (1992) also emphasize preventive measures against the spread of *P. katsurae*. They recommend prompt removal of all diseased materials from the plantation. Renard and Quillec, 1984 reported that Fosetyl-Al (aluminium fosetyl) and Ridomil injected into the stem was very effective in controlling the disease. Stem injection with this chemical against *P. katsurae* is practised on a large scale in commercial plantations in the Ivory Coast. Grahame (2016). Renard and Dollet, 1991 reported that stem injection with Phosethyl A1 and Metalaxyl offers complete protection against Bud-Rot. Although Metalaxyl is not effective against *Phytophthora*-induced nutfall, Phosethyl reduces loss of crop by at least 80%. According to Grahame (2016), chemical spraying is difficult and costly in tall palms but may be an effective method in young plantations and a relatively inexpensive fungicide such as Bordeaux mixture may be used, as long as no copper toxicity is induced. Abad, (1985) recommends removal of infected tissues including those bordering the infected lesion, and subsequent treatment with a solution of any copper-based fungicide at 3 tablespoons per gallon of water. However, Quillec *et al*. (1984) state that at the stage of the first visible symptoms, the disease is already too far advanced for curative treatment.

Heavy metals

A heavy metal is a member of an ill – defined subset of elements that exhibit metallic properties, which would mainly include the transition metals, some metalloids, lanthanides and actinides. Many different definitions have been

proposed, some based on density, some on atomic weight and some on chemical properties or toxicity. Heavy metals can include elements lighter than carbon and can exclude some of the heaviest metals.

The term "Heavy metal" is a general collective term which applies to a group of metals and metalloids with atomic density greater than 4 g/cm^3 or 5 times or more greater than that of water (Hawkes 1997). The most important accepted source of heavy metals is geologic parent quantifiable or rock outcropping. The conformation and concentration of heavy metals hinge on the rock type and environmental situations that activate the weathering process The geological plant materials normally have in elevation concentration of Cr, Mn, Co, Ni, Cu, Zn, Cd, Sn, Hg, and Pb (Nagajyoti et al 2010).

Inorganic and organic fertilizers are the most important sources of heavy metals (Bolan and Duraisamy 2003). Agrarian soils in countless parts of the world are somewhat, moderately to heavily contaminate by heavy metal toxicity. Such heavy metals as Cd, Cu, Zn, Ni, Co, Cr, Pb, and As pollute the soils. This could be unpaid to longstanding use of sewage sludge application, dust from smelters, phosphatic fertilizers, industrial waste and bad watering practices in agricultural lands (Bell et al., 2001; Schwartz et al., 2001; Passariello et al., 2002). The principal answer of plants is the generation of reactive oxygen species (ROS) upon exposure to high levels of heavy metals. Various metals either generate ROS directly through Haber-Weiss reactions or overproduction of ROS and occurrence of oxidative stress in plants could be the indirect consequence of heavy metal toxicity (Wojtaszek, 1997; Mithofer et al., 2004). The indirect mechanisms include their interaction with the antioxidant system (Srivastava et al., 2004), disrupting the electron transport

chain (Qadir et al., 2004) or disturbing the metabolism of essential elements (Dong et al., 2006). One of the most deleterious effects induced by heavy metals exposure in plants is lipid peroxidation, which can directly cause biomembrane deterioration. Malondialdehyde (MDA), one of the decomposition products of polyunsaturated fatty acids of membrane is regarded as a reliable indicator of oxidative stress (Demiral and Türkan, 2005).

Conversely, plants have developed a very latent mechanism to combat with such adverse environmental heavy metal toxicity problems. Plants produce low molecular weight thiols that demonstrate high affinity for toxic metals (Bricker et al., 2001). The most important/critical low molecular weight biological thiols are glutathione (GSH) and cysteine. GSH is a sulfur-containing tri-peptide thiol with the formula γ-glutamate-cysteine-glycine. GSH synthesis is catalyzed by two ATP dependent enzymes γ-glutamylcysteine synthetase (GSH1) and glutathione synthetase (GSH2). GSH is a substrate for phytochelatin synthesis and crucial for detoxification of heavy metals such as cadmium and nickel (Freeman et al., 2004). Phytochelatins (PCs) are small, heavy metal-binding, cysteine-rich polypeptides with the general assembly of $(\gamma\text{-Glu-Cys})_n\text{Gly}$ ($n = 2–11$). The PCs are present not only in plants but also in fungi and other organisms (Grill et al., 1985; Gekeler et al., 1988; Piechalak et al., 2002). Their synthesis is catalyzed by the enzyme phytochelatin synthase (PCS) (Tomaszewska et al., 1996. PCs form complexes with toxic metal ions in the cytosol and subsequently transport them into the vacuole (Salt and Rauser, 1995).

Harmful effects of numerous heavy metals in coconut palm

Pollution of agrarian soil by heavy metals has developed a critical environmental apprehension due to their possible adverse ecological effects. Such toxic elements are well-thought-out as soil pollutants due to their extensive occurrence, and their grave and long-lasting toxic effects on plants grown on such soils. Cadmium (Cd) is a silvery-white metallic element that can easily be shaped. The atomic number of cadmium is 48; the element is one of the transition elements in group 12 (or IIb) of the periodic table. Cadmium melts at 321° C (610° F), boils at 767° C (1413° F), and has a specific gravity of 8.64; the atomic weight of cadmium is 112.41. When heated, cadmium burns in air with a bright light, forming the oxide CdO. Due to its high rates of soil-to-plant transfer, cadmium is a contaminant found in most human foodstuffs, which renders diet a primary source of exposure among nonsmoking, non-occupationally exposed populations (McLaughlin *et al.,* 2006). The intensive care limit of cadmium (Cd) in agrarian soil is 100 mg/kg (Salt et al., 1995). But this threshold is continuously exceeded because of several anthropological activities. Plant contact to high levels of Cd grounds decrease in photosynthesis, water uptake, and nutrient uptake. Coconut palms grown in soils containing high levels of Cd show noticeable symptoms of injury. This is echoed in terms of growth inhibition, browning of root tips, chlorosis, and finally, the coconut palm dies (Wójcik and Tukiendorf, 2004; Mohanpuria et al., 2007).

Soil is also contaminated with zinc (Zn) in addition to Cd by urban composts or sewage sludge, emissions from municipal waste incinerators, fertilizers,

residues from metalliferous mining, the metal smelting industry, and other human actions. Zn is a vital nutrient for living organisms, whereas Cd is non-essential and hypothetically toxic for higher plants, animals and humans. Concentrations of Zn found in contaminated soils frequently exceed those required as nutrients and may cause phytotoxicity. Zinc has an electron configuration of [Ar]3d104s2 and is a member of the group 12 of the periodic table. Zinc is a metallic chemical element; it has the symbol Zn and atomic number 30. It is the first element in group 12 of the periodic table. According to Wikipedia zinc is, in some respects, chemically similar to magnesium, because its ion is of similar size and its only common oxidation state is +2. Zinc is the 24th most abundant element in the Earth's crust and has five stable isotopes. It is a moderately reactive metal and strong reducing agent (CRC, 2006). The surface of the pure metal tarnishes quickly, eventually forming a protective passivating layer of the basic carbonate $Zn_5(OH)_6(CO_3)_2$, by reaction with atmospheric carbon dioxide (Porter, 1994). This layer helps prevent further reaction with air and water.

Zinc burns in air with a bright bluish-green flame, giving off fumes of zinc oxide. Zinc reacts readily with acids, alkalis and other non-metals. Extremely pure zinc reacts only slowly at room temperature with acids. Strong acids, such as hydrochloric or sulfuric acid, can remove the passivating layer and subsequent reaction with water releases hydrogen gas (Holleman *et al.,* 1985). Zn concentrations in the range of 150 to 300 mg/kg have been measured in polluted soils (de Vries et al., 2002; Warne et al., 2008). High levels of Zn in soil inhibit many plant metabolic functions; result in retarded growth and cause senescence. Zinc toxicity in plants limit the growth of both root and

shoot (Choi et al., 1996). Zinc toxicity also causes chlorosis in the younger leaves, which can extend to older leaves after prolonged exposure to high soil Zn levels (Ebbs and Kochian, 1997). The chlorosis may arise partly from an induced iron (Fe) deficiency as hydrated $Zn^{2+}$and Fe^{2+} ions have similar radii (Marschner, 1986). Excess Zn can also give rise to manganese (Mn) and copper (Cu) deficiencies in plant shoots. Such deficiencies have been attributed to a hindered transfer of these micronutrients from root to shoot. This deterrent is based on the fact that the Fe and Mn concentrations in plants grown in Zn-rich media are greater in the root than the shoot (Ebbs and Kochian, 1997). Another typical effect of Zn toxicity is the appearance of a purplish-red color in leaves, which is attributed to phosphorus (P) deficiency (Lee et al., 1996).

Copper (Cu) is considered as a micronutrient for plants (Thomas et al., 1998) and plays on important role in CO_2 assimilation and ATP synthesis. Cu is also an essential component of various proteins like plastocyanin of photosynthetic system and cytochrome oxidase of respiratory electron transport chain (Demirevska-kepova et al., 2004). But enhanced industrial and mining activities have contributed to the increasing occurrence of Cu in ecosystems. Cu is also added to soils from different human activities including mining and smelting of Cu-containing ores. Mining activities generate a large amount of waste rocks and tailings, which get deposited at the surface. Excess of Cu in soil plays a cytotoxic role. It induces stress and causes injury to plants. This leads to plant growth retardation and leaf chlorosis (Lewis et al., 2001). Exposure of plants to excess Cu generates oxidative stress and ROS (Stadtman

and Oliver, 1991). Oxidative stress causes disturbance of metabolic pathways and damage to macromolecules (Hegedus et al., 2001).

Since the beginning of the industrial revolution, pollution of the biosphere with toxic metals has accelerated dramatically (Swaminathan, 2003). Chromium (Cr) is a heavy metal that causes serious environmental contamination in soil, sediments, and groundwater (Shanker et al., 2005). Worldwide anthropogenic discharge of Cr in fresh water bodies has been estimated to be 3550 mt (Nriagu, 1990). Cr (VI) is a very toxic, powerful epithelial irritant and a proven human carcinogen established by International Agency for Research on Cancer (IARC), the Environmental Protection Agency (EPA) and the World Health Organization (WHO). Excess of Cr causes inhibition of the growth of the coconut palm. Chlorosis in young leaves, nutrient imbalance, wilting of tops, and root injury are symptoms of Cr toxicity (Chatterjee and Chatterjee, 2000; Dixit et al., 2002; Sharma et al., 2003; Scoccianti et al., 2006). Inhibition of chlorophyll biosynthesis has also been reported in terrestrial plants (Vajpayee et al., 2000). Toxic effects of Cr on plant growth and development include alterations in the germination process as well as in the growth of roots, stems and leaves. Cr also causes deleterious effects on the physiological processes of the coconut palm; these processes include photosynthesis, water relations and mineral nutrition. (Shanker et al., 2005).

Lead (Pb) is one of the ubiquitously distributed most abundant toxic elements in the soil. The toxic level of Pb in soil results from disposal of municipal sewage sludge, mining and smelting activities, Pb containing paints, paper and

pulp, gasoline and explosives. It exerts adverse effect on morphology, growth and photosynthetic processes of plants. High level of Pb also causes inhibition of enzyme activities, water imbalance, alterations in membrane permeability and disturbs mineral nutrition (Sharma and Dubey, 2005). According to Reddy et al., (2005) Pb inhibits the activity of enzymes at cellular level by reacting with their sulfhydril groups. Moreover, high Pb concentration also induces oxidative stress by increasing the production of ROS in plants.

Nickel (Ni) is a transition metal and found in natural soils at trace concentrations except in ultramafic or serpentinic soils. However, Ni^{2+} concentration is increasing in certain areas by human activities such as mining works, emission of smelters, burning of coal and oil, sewage, phosphate fertilizers and pesticides (Gimeno-García et al., 1996). Ni^{2+} concentration in polluted soil may reach 20- to 30-fold (200–26,000 mg/kg) higher than the overall range (10–1000 mg/kg) found in natural soil (Izosimova, 2005). Excess of Ni^{2+} in soil causes various physiological alterations and diverse toxicity symptoms such as chlorosis and necrosis in different plant species (Zornoza et al., 1999; Pandey and Sharma, 2002; Rahman et al., 2005), Samantaray et al., (1997), realized that plants grown in high Ni^{2+} containing soil showed impairment of nutrient balance and resulted in disorder of cell membrane functions. Thus, Ni^{2+} affected the lipid composition and H-ATPase activity of the plasma membrane as reported in *Oryza sativa* shoots (Ros et al., 1992). Moreover, Gonnelli et al. (2001) reported an increase in MDA concentration of Ni^{2+} sensitive plants compared to a Ni^{2+} tolerant *Silene*. Such changes might disturb membrane functionality and ion balance in the cytoplasm, particularly of K^+, the most mobile ion across plant cell membrane.

Other symptoms observed in Ni^{2+}-treated plants were related with changes in water balance. The decrease in water uptake is used as an indicator of the progression of Ni^{2+} toxicity in coconut palm (Sharma, 2002).

Sources of Metals in Solids

The two main pathways of metal pollution of soils are anthropogenic source and weathering of rocks. Turpeinen (2002) stated that anthropogenic source of metal pollution can be divided into five main groups. Cadmium, Mercury, Lead and Arsenic gets contaminated to the soil through smelting and metalliferous mining.

Above the beyond, industry are the main cause of black smoke that pollutes the environment after coming from the combustion of carbon and oil. As a result of this type of mining, cadmium, copper, mercury, nickel, and zinc are either applied to the soil or are generated through the process.

Copper arises in four oxidation states. These are Cu, Cu^{+}, $Cu^{2+}$and Cu^{3+}. However, the Cu^{2+} is the most common form. Most copper deposit exists in the form of sulfide materials. Copper has a wide range of applications in industry and agriculture. In the manufacturing of textiles, antifouling paints, electrical conductors, plumbing fixtures, pipes and cooking utensils, copper is used extensively. Copper compounds are often found in wood preservatives, pesticides and fungicides, and sulfate is used as fertilizer. The use of such fertilizers and fungicides does not only introduce copper in the atmosphere but also there is the introduction of the copper into the soil. *Cocos nucifera* grows in soil and consequently excess copper can have adverse effect on the plant.

Secondly, atmospheric deposition is a source of metal toxicity of soils. Arsenic, cadmium, chromium, copper, lead, mercury and uranium are present

in the atmosphere and these are deposited in soils. In motor traffic, CO is transmitted into atmosphere. This eventually is deposited in and around the soil.

These are arsenites and arsenates in which arsenic is combined with metals such as iron, nickel, copper, and cobalt (CCME, 2001).

The last but not least source of metals in soil is waste disposal. In Ghana, waste is deposited just anywhere. The waste that is deposited just anywhere contains heavy metals like arsenic, cadmium, copper, lead, chromium, mercury and zinc. Some fertilizers have various concentrations of lead. Land application of sewage sludge, animal waste as a result of animal production, coal residues, municipal refuse incineration and auto emissions are all anthropogenic sources of lead in soils. McKeague and Wolynetz (1980) reported the mean concentration of total lead in uncontaminated Canadian soils which were remote from water bodies to be 20 mg/ kg.

Due to the high solubility of sulfate (SO_3^{2-}) minerals, especially in more acidic surroundings, copper and ions are naturally released into the environment. The mobility of copper in soil depends on the soil pH and the content of organic compounds and other minerals with which copper might interact. Copper precipitates with various ions such as sulfide (S^{2-}), carbonate (CO_3^{2-}) and hydroxide (OH^-) which are rather immobile elements in the soil. The clay fraction of a soil has a significant effect on the copper content and usually, clay soils have higher concentration of copper. Much copper exists in the surface layers of the soil mainly due to the current anthropogenic sources of copper as well as bioaccumulation of the element. Consequently, the copper

concentration in soil can be very high reaching concentrations of 3500 ppm close to industrial sources of pollution, and 1500 ppm in agricultural areas.

Physicochemical analysis of soils

Total organic carbon / total organic matter

Total organic carbon (TOC) is the carbon (C) stored in soil organic matter (SOM). Organic carbon (OC) enters the soil through the decomposition of plant and animal residues, root exudates, living and dead microorganisms, and soil biota. SOM is the organic fraction of soil exclusive of non-decomposed plant and animal residues.

Nevertheless, most analytical methods do not distinguish between decomposed and non-decomposed residues. SOM is a heterogeneous, dynamic substance that varies in particle size, Carbon content, decomposition rate, and turnover time.

Soil Organic Carbon (SOC) is the main source of energy for soil microorganisms. The ease and speed with which SOC becomes available is related to the SOM fraction in which it resides. In this respect, SOC can be partitioned into fractions based on the size and breakdown rates of the SOM in which it is contained.

Soil Organic Matter (SOM) contains approximately 58% C; therefore, a factor of 1.72 can be used to convert OC to SOM. There is more inorganic C than TOC in calcareous soils. TOC is expressed as percent C per 100 g of soil (Edwards *et al*., 1999;

http://soilquality.org/indicators/total_organic_carbon.html retrieved on 29th November 2012).

Soil pH

Soil pH generally refers to the degree of soil acidity or alkalinity. Chemically, it is defined as the log10 hydrogen ions (H^+) in the soil solution. The pH scale ranges from 0 to 14; a pH of 7 is considered neutral. If pH values are greater than 7, the solution is considered basic or alkaline; if they are below 7, the solution is acidic. A few changes in the pH units can induce significant changes in the chemical environment and sensitive biological processes. For example, a soil with pH 5 is 10 or 100 times more acidic than a soil with pH 6 or 7, respectively. Sources of H+ ions in soil solution include carbonic acid produced when carbon dioxide (CO_2) from decomposing organic matter, root respiration, and the soil atmosphere is dissolved in the soil water. Other sources of H^+ ions are root release, reaction of aluminum ions (Al^{3+}) with water, nitrification of ammonium from fertilizers and organic matter mineralization, reaction of sulfur compounds, rainwater, and acid rain.

Certain soils are more resistant to a drop or rise in pH (buffering capacity). Soil pH affects the soil's physical, chemical, and biological properties and processes, as well as plant growth. The nutrition, growth, and yields of most crops decrease where pH is low and increase as pH rises to an optimum level (Smith and Doran, 1996; http://soilquality.org/indicators/soil_ph.html retrieved on 29th November 2012).

Cation exchange capacity

The cation exchange capacity (CEC) of a soil is a measure of the quantity of negatively charged sites on soil surfaces that can retain positively charged ions (cations) such as calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^{+}), by electrostatic forces. Cation exchange sites are found primarily on clay minerals and organic matter (OM) surfaces. Soil OM will develop a greater CEC at near-neutral pH than under acidic conditions (pH-dependent CEC). Thus, addition of an organic material will likely increase a soil's CEC over time. On the other hand, a soil's CEC can decrease with time as well, through e.g. natural or fertilizer-induced acidification and/or OM decomposition. Soil CEC is normally expressed in one of two numerically equivalent sets of units: meq/100 g (milliequivalents of charge per 100 g of dry soil) or cmolc/kg (centimoles of charge per kilogram of dry soil) (Ross and Kettering, 2011).

Mineral nutrient deficiencies

Magnesium Insufficiency

Chlorine Insufficiency

Calcium Insufficiency

Iron Insufficiency

Manganese Insufficiency

Copper Insufficiency

Boron Insufficiency

Zinc Insufficiency

Nitrogen Insufficiency

Sulphur Insufficiency

Phosphorus Insufficiency

Drought, stem tapering, lightning damage premature shedding

Aekola et al (2008), discovered that heavy metals like iron, tin, copper, manganese and vanadium occur naturally in the environment and could serve as plant nutrients depending on their concentrations. Mercury, lead, cadmium, silver, chromium and many others that are indirectly distributed as a result mostly of human activities could be very toxic even at low concentrations. These metals are non-biodegradable and can undergo global ecological cycles. The use of dump sites as farm lands is a common practice in urban and sub-urban centres in Ghana because of the fact that decayed and composted wastes enhance soil fertility. These wastes often contain heavy metals in various forms and at different contamination levels. Some heavy metals like Mn, Pb, Hg and Zn are particularly hazardous to plants, animals and humans. Municipal waste contains such heavy metals as arsenic, cadmium, calcium, iron, mercury, manganese, lead, nickel and zinc. Soil is a vital resource for sustaining two human needs, which is quality food and quality environment. Plants grown on a land polluted with municipal, domestic or a land polluted with municipal, domestic or industrial waste can absorb heavy metals in the form of mobile ions present in the soil through their roots or through foliar absorption. These absorbed metals get bioacumulated in the roots, stems, fruits, grains and leaves of plants.

Magnesium Deficiency

The role of magnesium is vital to plant growth and health. Magnesium deficiency in plants is common where soil is not rich in organic matter or is very light.

Magnesium deficiency also occurs on the oldest leaves, but as distinct broad lemon-yellow to orange bands appear along the margins of the leaves, the centres of the affected leaves remain dark green with an abrupt transition from yellow to green (Broschat, 1984, 2005c). In some palms with palmate leaves (fan palms), some leaves do not show a broad yellow band around the perimeter of the leaf, but rather broad yellow bands around the margins of each leaf segment, the centres of which remain distinctly green are visible symptoms. Both patterns of Mg deficiency (leaf and leaf segment chlorotic banding) have been observed on different leaves on a single palm. Magnesium deficiency usually does not cause necrosis, yet necrosis caused by K deficiency is common on palms showing Mg deficiency. Canary Island date palms (*Phoenix canariensis*) in Florida frequently display deficiencies of both elements on the same palm. Where they co-occur, classical K deficiency symptoms (translucent and necrotic spotting and leaflet tip necrosis) will be seen on the oldest leaves and the yellow-banded Mg-deficient leaves will be observed above the K-deficient leaves, often in midcanopy (Broschat, 2005c). Transitional leaves show K deficiency symptoms toward the leaf tips, but Mg deficiency symptoms appear toward the leaf base. Chlorosis caused by Mg deficiency is permanent and cannot be eliminated from affected leaves by application of Mg fertilizers. Rather, the deficiency will be gradually eliminated from the canopy by replacement of older symptomatic leaves with newer Mg-sufficient leaves. The process of correcting K and Mg deficiencies can take from one to three years. Magnesium deficiency in palms is accentuated by high levels of N and K in landscape soils (Broschat, 2005c; von Uexkull and Fairhurst, 1991). In container production, Mg

deficiency is usually indicative of insufficient or exhausted dolomite in the container substrate.

Phosphorus Deficiency

Although P deficiency has generally not been a problem in palms grown in the United States, it can be a serious limiting factor in acid tropical soils where African oil palm (*Elaeis guineensis*) or coconut palms (*Cocos nucifera*) are grown commercially (Manciot et al., 1979). Symptoms are not particularly distinctive, but appear as a uniform light olive-green coloration of the foliage. Purplish spots and/or leaflet tip necrosis may be present on the oldest leaves (Bull, 1958; Elliott et al., 2004). However, the most important symptom of P deficiency in all species is a sharp reduction in growth rate, with "pencil-pointing" or tapering of the trunk occurring in chronic situations (Broschat, 1984; von Uexkull and Fairhurst, 1991).

Potassium Deficiency

Potassium deficiency is by far the most common deficiency of palms growing in production fields or landscapes throughout much of the world. However, in container production, it is much less common than N deficiency. Symptoms vary according to species and severity. In many species, the earliest symptoms consist of translucent yellow-orange and/or necrotic spots on the oldest leaves (Broschat, 1990; Bull, 1961a). As the deficiency progresses, marginal and/or tip necrosis of the leaflets appears (von Uexkull and Fairhurst, 1991). In some species, spotting is never observed and leaflet tip necrosis is the only visible symptom. As with N deficiency, K is a highly mobile element within palm canopies and symptoms are most severe on the oldest leaves and toward the

tips of each affected leaf. When viewed from a distance, many K-deficient palms appear to have an orange-bronze cast to the older leaves. In other cases, K-deficient palms of the same species may show only leaflet necrosis (Broschat, 1990).

Potassium deficiency causes premature senescence of the older leaves and thus strongly affects the number of leaves that a palm can support. In a severely K-deficient palm, once all of the older leaves have died from the deficiency, the palm then goes into a rapid state of decline, with the trunk tapering (pencil-pointing), new leaves emerging chlorotic and with extensive leaflet necrosis, and finally, death of the meristem (Elliott et al., 2004). Potassium deficiency is the most common cause of mortality in royal palms (*Roystonea regia*) in Florida landscapes (Broschat, 2005a). Routine removal of unsightly K-deficient leaves on palms and fertilization with high N:K ratio fertilizers have been demonstrated to accelerate the rate of decline from K deficiency (Broschat, 1994, 2005b).

Iron Deficiency

Iron deficiency appears on newly emerging leaves as a uniform or interveinal chlorosis. In severe cases, new leaves may emerge almost white in color, with extensive leaf tip necrosis. Because Fe tends to accumulate in older leaves (Broschat, 1997), symptomatic leaves may green up as they mature. Leaf spot diseases such as exserohilum leaf spot (caused by *Exserohilum rostratum*) on foxtail palm (*Wodyetia bifurcata*) often are associated with Fe deficiency (Broschat and Elliott, 2005a). This cannot be controlled with fungicides unless the Fe deficiency is first corrected. The most common cause of Fe deficiency

in palms is poor soil aeration, with related factors that reduce root surface area, or metabolic rate such as root rot diseases. Deep planting have similar effects (Broschat and Donselman, 1985). Palms growing in calcareous soils may exhibit Fe deficiency, but not to the degree that dicot trees or shrubs are affected. Iron deficiency is common in palms grown in containers in which the substrate has decomposed. This reduces root zone aeration.

Manganese Deficiency

Manganese deficiency is similar to Fe deficiency, in that, new leaves emerge with interveinal chlorosis. However, Mn-deficient leaves differ. They also show longitudinal necrotic streaking within the leaflets (Broschat, 2005a; Bull, 1961b). In more severe cases, the distal ends of the leaflets become completely necrotic and curled, giving the leaf a frizzled appearance. Because Mn deficiency occurs only on newly expanding leaves, it is commonly called "frizzletop" (Dickey, 1977). These frizzled leaves are usually much shorter in length than normal leaves. The presence of Mn deficiency symptoms in midcanopy or lower leaves is indicative of a chronic Mn deficiency, whereas a few tiny and severely frizzled leaves at the top of the canopy followed by normal-sized and colored mid- to lower canopy leaves is characteristic of an acute Mn deficiency. The latter is often fatal in palms. Chronic Mn-deficient palms are superficially similar in appearance to those with late-stage K deficiency, with both displaying small, chlorotic, and necrotic-tipped leaflets. However, on Mn-deficient leaves, symptoms are most severe at the base of the leaf, whereas the reverse pattern characterizes K-deficient leaves (Broschat, 2005a). Mn deficiency is usually caused by high soil pH, although transient, cold temperature-induced Mn deficiency is fairly common in coconut palms in

Florida (Broschat and Donselman, 1985). The use of composted sewage sludges as soil amendments or fertilizers has also been shown to cause severe and long lasting Mn deficiencies in palms (Broschat, 1991a).

Other nutrient deficiencies

Insufficiencies of some heavy metals like chloride (Cl), Zinc (Zn), Sulfur (S), Copper (Cu), and Molybdenum (Mo) have been induced experimentally in several species of palms using sand culture methods (Bull, 1961a;), Deficiencies of these elements are rarely encountered in the landscape or in field nursery.

Sulfur deficiency causes chlorosis of the youngest leaves, with leaf size and leaflet tip necrosis increasing with increasing severity (Broeshart et al., 1957; Broschat, 1984; Manciot et al., 1980). It has been reported on coconut palms in New Guinea and Madagascar, and on African oil palms in Ivory Coast (Ollagnier and Ochs, 1972).

Copper is one of the most immobile micronutrients or trace elements needed in very small amounts and required in all plant parts. Functions as a catalyst in photosynthesis and respiration; essential for the overall metabolism in plants, absorbed as cupric ions (Cu^{2+}). Reversibly oxidized from Cu^{+} to Cu^{2+} .Associated with certain enzymes involved in redox reactions. Forms a component of enzymes such as phenolases, ascorbic acid oxidase and tyrosinase. It is a constituent of plastocyanin, for this reason plays a role in photophosphorylation. Maintains the carbohydrate - nitrogen balance. Higher concentration of copper is toxic to plants. Copper deficiency has been reported on African oil palms grown in Sumatra (Ng and Tan, 1974).

Broschat (1984) found that experimentally induced chloride (Cl)-deficient clustering fishtail palm (*Caryota mitis*) and pygmy date palm (*Phoenix roebelenii*) had chlorotic new leaves, with leaflets in the latter species remaining partially fused around their margins, giving them a ladder-like appearance. Although visible symptoms of this deficiency have never been reported in palm production, fruit yields for coconut and African oil palm have been significantly improved with Cl fertilization in the Philippines (Magat et al., 1988; Ollagnier and Ochs, 1971).

Analysis of nutritive syndromes

The basic tools for diagnosing or analyzing nutrient deficiencies or toxicities in common agronomic and horticultural crops is based on leaf and soil analysis, records of plants versus leaf or soil nutrient concentrations are really lacking for the palm species . von Uexkull and Fairhurst (1991) provide critical foliar elemental concentrations for African oil palm and Elliott et al. (2004) give similar values for areca palm, bamboo palm (*Chamaedorea seifrizii*), parlor palm, kentia palm (*Howea forsterana*), lady palm (*Rhapis excelsa*), and pygmy date palm. Leaf, and especially soil, nutrient concentrations often do not correlate well with visual symptoms expressed by palms. For instance, foliar Fe concentrations are often poorly correlated with chlorosis severity in many species of plants (Jones et al., 1991). Also, foliar B concentrations in the youngest fully expanded leaves reflect the B status of the palm about four months before the sampling date and not the current B status (Broschat, manuscript in preparation). The presence of sufficient plant-available nutrients in the soil is no guarantee that such nutrients will actually be taken up by the palm in adequate amounts. Thus, the primary means of

diagnosing palm nutritional disorders is by visual symptoms Elliott et al. (2004) and Broschat (2005a).

The earlier part of the Literature review has touched on the deficiencies of the heavy metals on the coconut.

Growth and Development of the coconut palm tree

A well-developed coconut fruit kept in a conducive atmosphere starts to germinate soon after harvesting. The rate at which the germination process progresses is determined by environmental conditions such as temperature, humidity and many more as well as genetic factors. The germination speed is dependent on the variety. According to Harries (1981) the time taken from reaping to sprouting distinguishes later germinating *Niu kafa* types from early germinating *Niu val* types.

According to Shivashankar (1991), as the fruits mature, growth inhibitory factors develop in the water and kernel, functioning in initiating and maintaining the dormancy of the embryo. The fruits contain a carefully poised complement of stimulators and inhibitors. Any shift in the relative proportions of the stimulators and inhibitors is crucial in the overall regulation of germination and timing of various metabolic events which occur during germination. Very dry conditions retard germination.

The cylinder-shaped nucleus entrenched in the endosperm under the soft eye is separated into two parts by a small spherical contraction. As per the first morphological sign of germination, the nucleus enlarges and the apical part of the nucleus, the basal part, or cotyledon starts growing and develops into the "apple" or haustorium. The haustorium has a pale yellow color on the outside

but the inside is cream-white. It is a spongy tissue and grows steadily until it gets into close contact with the endosperm.

Through the haustorium, the undeveloped palm absorbs nutrients from the water in the cavity and from the endosperm. The plant is nearly wholly supported by the endosperm during the first four months after germination. Thereafter, there is a gradual turnover from internal to external assimilation by photosynthesis. Eighteen months afterwards, the endosperm is completely exhausted and rotten. Directly after germination, the principal root appears from the apical mass, followed by the plumule which appears like a conic hump in the opposite direction. As the stem grows, the part of the epical mass encircling the plumule differentiates into a tubular structure, the coleoptile. It is from the coleoptile that a pointed shoot of leathery leaves develops and grows through the husk. The principal roots and the adventitious roots develop concurrently with the apical shoot.

Foale (1991) and Ouvrier (1984) observing the growth and development of the PB-121 hybrid seedling, found that the roots of the seeds grew regularly each year with a period of stagnation between each 52 and 65 months of age. Between 16 and 65 months, the root system grew much more slowly than the rest of the coconut. The result is a temporary imbalance between the roots and the leaves.

The dimension of the leaf (petiole + rachis) increases rapidly up to 19 of the 52 months in a year. With a planting system of 8.5 meters triangular, there are about 160 palms per ha. With this system, at 52 months, there is struggle among the “plants” for light. When progressing in age, the coconut palm

shows a change in crown shape. Depending on the uniformity of the zone in question, a mean of at least 25 palms per 25-50 ha is prescribed, Rognon and Boutin (1988). When unfavorable conditions exist, the stem becomes narrower. It then forms a pencil point. This is a characteristic of old senile palms. Ordinarily, the base of the stem swells and forms a bole. Most dwarf coconuts do not have boles. However, under very favourably environmental conditions, it can happen that even dwarf palms develop slight swellings at the foot of the stem.

By and large, coconut palms are considered to have an economic life span of about seventy years. Nevertheless, this rest on very much on growing situations. Occasionally, very old palms still produce amazingly high yields. Conversely, in commercial coconut production, it is doubtful whether the maintenance of old coconut plantations is economically preferable and will facilitate future replanting as the plantation consists of different age groups.

Climate Requirement

The Palmae are essentially tropical plants and the coconut is no exclusion. It is grown throughout the tropical world between latitudes 23° N and 23° S.

Temperature

The ideal temperature for coconut is 27° C and the despicable diurnal disparity is between 5° C and 7° C, Coomams (1975) found out that fruit set is directly influenced by the monthly minimum temperatures below 23° C, over a range period preferably four months to 18months before harvest. Moreover, Coomans observed a significant positive correlation between the annual yield and the mean annual minimum temperatures over a period of 18months before

harvesting. Additionally, a confident correlation amongst the number of female flowers per inflorescence and insolation and temperature between the 29th and 30th month, before harvest, determine the extent of the yield. In sum, it has been observed that at low temperatures, the yield of the coconut is limited. Low temperatures unfavorably affect not only the fruiting of the plant but also the quality of fruits produced. The harm caused by low temperatures is realized in the abnormal or imperfect development of the meat of the fruit. The noticeable signs are the irregular nature of the meat and the numerous wrinkles on the fruit. The nuts are at their fastest development stage between 5 and 6 months after flowering. This is the period within which the nuts are vulnerable to cold. The cold weather in such a period causes the young nut to split or fall. Zushun (1986) observed that the lower limit of the nut is 13° C. Zushum also observed that withering of the mature leaves, the killing of spear leaves and non-uniform development of the leaves occur during cold weather.

Rainfall

Even distribution of rainfall probably is the most important factor influencing coconut yield. Since the crop is produced continuously through the year and the nuts takes a year to mature from pollination, ideally the tree should never undergo severe water stress. The optimum total annual rainfall lies between 1300 and 2300mm per year, although the coconut tree will tolerate a far higher rainfall provided soil drainage is good.

Uneven distribution of annual rainfall may be compensated for by special environmental conditions under which coconuts are so often grown, that is, where seepage of groundwater occurs through a plantations. Where coastal

beach plantings are backed by rainfall freshwater swamps and lagoons, the water level will be slightly above that of the sea so that percolation of the swamp water takes place seaward and supplies the coconuts even when rainfall is deficient for short periods. The highest yields of coconut have been found under such specialized ecological conditions. An additional and important factor is that freshwater carries traces of mineral nutrients which allow the coconut to flourish on almost sterile sands.

When rain-fed trees undergo a prolonged drought, the effect can persist for up to two and half years which shows the reduction in the number of nuts picked on four occasions during each year and in addition, the reduction in nuts by drought, the amount of copra per nut is also reduced. These factors seriously reduce the total crop yield per acre.

As Patel and Anandnan (1936) pointed out, the inflorescence is initiated some 16 months before a spathe opens. Severe drought at this period may kill the growing part, causing the inflorescence to abort. This will affect production of nuts up to 28-30 months later.

Light intensity

The coconut palm is a light-requiring species and does not grow well under any shade or very cloudy conditions. The etiolated appearance of trees growing under the shade of old trees is well known. In West Africa the yield of copra is related to the daily hours of sunshine during the final maturation period of the nut.

Wind

Coconuts grown in coastal areas are often exposed to strong sea winds. Provided adequate soil moisture is available the trees tolerate these winds well. The wind rises transpiration and subsequently, there is water and nutrient uptake. The drying effect helps to prevent the development of certain fungus diseases. Strong winds and especially cyclones do considerable damage, distorting leaves, inflorescences and bunch and tear them off.

Marty et al (1986) studied the effects of cyclones on coconut palms in the Vanuata Archipelago. He observed that light soils, quickly get drenched with heavy rainfall, many palms get blown over and partly uprooted. On heavier soils, providing good anchorage, coconut stems are twisted to the extent that some of them break either at the bole or at the upper third part of the stem. As a result of heavy storm, some bunches fall prematurely because they lose their leaf support.

Ramison (1988) observed that in addition to scorching of the leaves, sea sprays reduce the number of bunches and fruits per palm, especially in the first three rows of palms. There is the addition that most inflorescences of palms subjected to such sea sprays were without button-nuts.

Nut Shedding

During the first few month after the inflorescence appears, there is a significant loss of the so called “button nuts”. This loss is due to physiological opposition since for more female flowers are produced than can mature on the tree. The condition is analogous in any ways to cherelle wilt in cacao. Generally only some 30% of the flowers produced reach maturity and the

effect of fertilizers on increasing yield is not through decreasing fall of nuts, but rather by increasing the number of flowers produced.

Shedding of immature nuts

A more serious problem is loss by shedding of maturing nuts which have passed the button nut stage. Loss of nuts 3-5 months old is often greater at the end of a long dry spell and is sometimes accentuated when heavy rain follows a drought.

A morphological shedding of nuts may occur in trees with a long, weak bunch stalk and thin leaf frond bases. The leaf may break allowing the bunch to slip downward with a jerk, thereby causing shedding of immature nuts. This emphasizes the need for selecting planting material which does not carry this undesirable character.

Types of Coconut

Coconut (*Cocos nucifera* L.) is the sole species of the genus *Cocos* have its place to the subfamily Cocoideae which contains 27 genera and 600 species. It is a diploid with 32 chromosomes (2n=32). As such, hybridization is mostly intraspecific.

The major classification of coconut based on stature or height is as follows:

Tall palms, sometimes referred to as var. *typica* (Nar). They are widely planted both for household and commercial use and grow to a height of 20-30 m. They are slow maturing and flower 6-10 years after planting. They are long-lived with an economic life of about 60-70 years, although much older

palms are known to exist and yield well. They are normally cross-pollinating and therefore considered to be heterozygous.

Dwarf palms, sometimes referred to as var. *nana* (Griff). These are believed to be mutants from tall types with short stature, 8-10 m when 20 years old. They begin bearing about the third year at less than 1 meter high. They have a short productive life of 30-40 years. They are normally self-pollinating and therefore considered to be homozygous

The Use of Coconut

The coconut palm stands out of all the trees that exist as it provide mankind with more uses and products. The coconut has got to be the most versatile fruit used. Grown on the Palm Tree, every part of the coconut and the tree has virtually got a use and has been used by different countries in different ways. Known as "***The Tree of Life***" in The Philippines and "***The tree of a 1,000 uses***" in the Malaya language, coconuts have a history of important uses worldwide. Coconut oil is the most nutrient-dense part of the coconut. It is solid at room temperature like butter and doesn't break down in heat or light.

For years, "health" advice has warned against consuming saturated fats, and coconut oil was thrown out with the rest without good reason. The coconut oil is used to produce soap, shampoos and pomade for hair and skin as well as hormone support, mental boost and many more. The deposit is a vital source of food for farm animals. The coconut water from the fresh nuts is a widespread beverage. The jelly-like kernel is sold as desiccated coconut used in food and confectionary. The husk of the nut provides an important fiber, coconut coir that is used for robes, carpets and brushes in some parts of the

world. The shell of the nut is used for household utensils and the charcoal made from it is an excellent basic material for activated coal. As an alternative of being used for nut production, the inflorescences can be tapped, yielding sup with sugar content, from which sugar, alcoholic beverages and vinegar can be made. The leaves are used for roof thatching. Further, the midribs of the leaves are used for brooms.

Moreover, coconut wood is used for house building, furniture and tool handles. As a result of its natural distribution, sailors have taken the nut with them for food and drink during their voyages.

The benefits of Coconut Oil

Studies have proved coconut oil to be one of the fittest foods on the globe. Coconut oil benefits and uses go beyond what most people realize.

Topical Uses of Coconut Oil

1. Natural skin softener and moisturizer.
2. Reduces fine lines, puffiness and dark circles under the eyes
3. Prevents skin infections.
4. Anti-Wrinkle.
5. Soothes Sunburn and treats blisters and burns.
6. Removes makeup.
7. Improves skin tone, elasticity, and age spots.
8. Heals itchy skin and stops burning from insect bites including snake bites.
9. Lessens varicose vein occurrences.
10. Removes head lice.

11. Conditions the hair, prevents split-ends and treats dry flaky scalp including dandruff.
12. Heals nail fungal conditions.

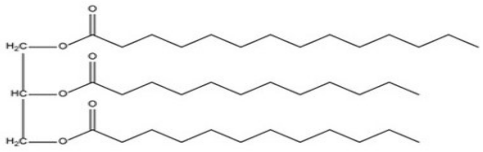
Medicinal Uses of Coconut Oil

1. Eases acid reflux and gives relief in gallbladder disease.
2. Stabilizes blood sugar levels and insulin production.
3. Kills viruses such as flu and infectious diseases.
4. Protects against cancers in the colon, breasts, and digestive tract.
5. Protects against intestinal disorders.
6. Reduces pain and inflammatory conditions such as arthritis.
7. Strengthens the liver.
8. Relieves symptoms of Chronic Fatigue Syndrome.
9. Soothes earaches when combined with olive oil and garlic.
10. Protects against Alzheimer's disease.
11. Improves calcium and magnesium absorption, promoting strong bones.
12. Helps stabilize female hormones and prevents hot flushes and vaginal dryness during menopause.

The benefits of Coconut Oil

Research have proved coconut oil to be one of the healthiest foods on the earth. Coconut oil benefits and uses go beyond what most people realize. Research has finally revealed the secrets to this amazing fruit; namely healthy fats called medium-chain fatty acids (MCFAs), these unique fats include: Caprylic acid, Lauric acid and Capric acid.

Diagrammatic nature of coconut oil



About 62 % of the oils in coconut are made up of these 3 healthy fatty acids (Caprylic acid, Lauric acid and Capric acid.) and 91 % of the fat in coconut oil is healthy saturated fat.

Majority of fats taken into the human body takes a longer time to digest, but MCFAs found in coconut oil provide the perfect source of energy because they only have to go through a 3 step process to be turned into fuel. Other fats go through a 26 step process. Unlike long-chain fatty acids (LCFAs) found in plant based oils, MCFAs are easier to digest, not readily stored as fat, are anti-microbial and anti-fungal, smaller in size, allowing easier cell permeability for immediate energy and processed by the liver, which means that they are instantaneously transformed to energy as a replacement for being stored as fat.

According to medical research, coconut oil benefits the body in the following ways:

The digestion of MCFAs by the liver creates ketones which are a readily accessible energy by the brain. Ketones supply energy to the brain without the need of insulin to process glucose into energy.

Recent research has shown that the brain actually creates its own insulin to process glucose and power brain cells. As the brain of an Alzheimer's patient has lost the ability to create its own insulin, the ketones from coconut oil could create an alternate source of energy to help repair brain function. (www. draxe.com - coconut oil benefits.)

Coconut oil is high in natural saturated fats. Saturated fat not only increases the healthy cholesterol (known as HDL) in the body, but also helps to convert the LDL "bad" cholesterol into good cholesterols. By increasing the HDLs in the body, it helps promote heart health, and lowers the risk of heart diseases.

Coconut oil has been known to clear up and heal urinary tract infections (UTI) and kidney infections. The MCFAs in the oil work as a natural antibiotic by disrupting the lipid coating on bacteria and killing them. Also, there is a study showing that coconut oil directly protects the liver from damage. Coconut water also helps hydrate and support the healing process. Doctors have even injected the coconut water to clear up kidney stones. Coconut is a super powerful food.

In a study in India, the high levels of antioxidants present in virgin coconut oil reduced inflammation and healed arthritis more effectively than leading medications.

In another recent study, coconut oil that was harvested with only medium heat was found to suppress inflammatory cells. It worked as both an analgesic and anti-inflammatory.

Coconut oil has two qualities that help it fight cancer because of the ketones produced in its digestion. Tumor cells are not able to access the energy in ketones and are glucose dependent. It is believed that a ketogenic diet could be a possible component of helping cancer patients recover.

Besides, as the MCFAs digest the lipid walls of bacteria, they also can kill the helicobacter pylori bacteria that have been known as increasing the risk of stomach cancer. Even in studies where cancer is chemically induced, the introduction of coconut oil prevents cancer from developing.

Coconut oil contains lauric acid, which is known to reduce candida, fights bacteria, and creates a hostile environment for viruses. Many diseases today are caused by the overgrowth of bad bacteria, funguses, viruses and parasites in the body.

One can replace grains and sugar in one's diet with coconut oil as natural fuel source when one is sick. Sugar feeds the growth of bad bacteria. Instead, take one table spoon of coconut oil three times daily when sick and consume plenty of vegetables and bone broth as well.

In a 2004 study published in the Journal of Neurobiology of Aging, they found that the MCFAs found in coconut oil improved the memory conditions in older people.Across all the patients, there was a marked improvement in their recall ability after taking this fatty acid. As the MCFAs are absorbed easily in the body and can be accessed in the brain without the use of insulin, they are able to fuel brain cells more efficiently.

Coconut oil is easy to digest, but also produces a longer sustained energy and increases the body metabolism. When taking a quality non-processed coconut oil, one can get the most benefit as its MCFAs are sent directly to the liver to be converted into energy.

Today, many triathletes will use coconut oil as their source of fuel during training and races for long distance events. One can make a homemade energy fuel by mixing coconut oil, raw honey and chia seeds together. Simply put together one tablespoon of each and consume 30 minutes prior to exercise.

Coconut also improves digestion as it helps the body to absorb fat-soluble vitamins, calcium and magnesium.

If coconut oil is taken at the same time as omega-3 fatty acids, it can make them twice as effective, as they are readily available to be digested and used by the body. Coconut oil can help improve bacteria and gut health by destroying bad bacteria and candida. Candida imbalance especially can decrease stomach acid which causes inflammation and poor digestion.

The MCFAs of coconut oil do not need the pancreatic enzymes to be broken down, so taking coconut oil eases the strain on the pancreas.

Additionally, this super fat is so easy to digest that it has been known to improve the symptoms of gallbladder diseases as well. If other long-chain fats are replaced with coconut oil, it improves gallbladder and total body health.

Coconut oil is wonderful as a face cleanser, moisturizer and sun screen, but also it can treat many skin disorders. The fatty acids (Caprylic and Lauric) in coconut oil reduce inflammation internally and externally and moisturize making them a great solution for all types of skin conditions.

It protects the skin and has many antioxidants that make it ideal for healing the skin. In addition, the antimicrobial properties balance out the candida or fungal sources that can cause many skin disorders.

Oil pulling with coconut oil has been used for centuries as a way to cleanse the mouth of bacteria and helps heal periodontal diseases. Coconut oil is one of the most effective oils for oil pulling due to its high concentration of antibacterial MCFAs.

By swishing the oil in the mouth, the oil denatures the bacteria and sticks to it. Removing oral bacteria greatly reduces the risk of periodontal diseases. To

heal the gums and repair the teeth, coconut oil pulling 20 minutes a day, three times a week is recommended.

Oxidative stress and free radicals are the two biggest culprits of osteoporosis. Since coconut oil has such high levels of antioxidants which help fight free radicals, it is a leading natural treatment for osteoporosis.

Another amazing coconut oil benefit is that it increases calcium absorption in the gut. Research with osteoporosis has found that coconut oil does not only increase bone volume and structure in subjects, but also it decreases bone loss due to osteoporosis.

When cells refuse to respond to insulin and no longer take in glucose for energy, then they are considered insulin resistant. The pancreas then pumps out more insulin to compensate and create an overproduction cycle. Insulin resistance is the precursor to Type II diabetes.

The MCFAs in coconut oil help balance the insulin reactions in the cells and promote healthy digestive process. They take off the strain on the pancreas and give the body a consistent energy source that is not dependent on glucose reactions which can prevent insulin resistance and Type II diabetes

Because of the energy creating abilities of coconut oil; it is no wonder that it is beneficial in losing weight. It helps to burn fat and decreases appetite. It is especially helpful in losing belly fat.

Coconut's ability to help in the shedding of fat has been well established. A 1985 study published in the Journal of Toxicology and Environmental Health proved that a single injection of capric acid resulted in "initially rapid, then gradual decrease in food consumption and a parallel loss of body weight" in male rats.

It might seem counterintuitive to assume that eating coconut oil (a fat) will contribute to fat loss, but it is actually quite logical. The key to understanding this phenomenon lays in the multidimensional ability of the MCFAs to control a variety of physiological processes. For example, in the 1985 study mentioned above, it was discovered that capric acid shows significant improvements in thyroid function, helps lower resting heart rate, and assists the body in burning fat for energy.

More recently, the Obesity Research Journal published a study from Boston University Medical School that gives us a clue why MCFAs have fat burning ability.

Testing the effects that MFCAs have on fat breakdown, adipose (fatty) cells in rats were pretreated with caprylic acid. It was observed that fat breakdown occurred at such a significant level that it literally mimicked the characteristics of fasting. Fasting, in this sense, is not to be regarded as negative, but positive in that the body uses its energy reserves most effectively and speeds up the breakdown of needless fat reserves.

In the words of the researchers who conducted this study, "Such changes could contribute, in part, to weight loss in animals and humans associated with dietary medium-chain fatty acids."

MCFAs are not just good for burning fat; they are also great for building muscles. The MCFAs found in coconut are also used in popular muscle building products like Muscle Milk.

The vast majority of heavily produced supplements however, use processed forms of MCFAs. By eating actual coconuts however, the "real deal "is

obtained. Three tablespoons of coconut oil to a muscle building shake is recommended daily.

For dandruff or dry hair, coconut oil has the perfect fatty acids to help improve these conditions. Homemade coconut lavender shampoo improves the hair. Straight coconut oil is an all-natural hair conditioner. To get rid of dandruff and to thicken hair massage, one tablespoon of coconut oil mixed with 10 drops of rosemary essential oil into the scalp for 3 minutes has been recommended. Then shower 30 minutes later.

A study published in the Journal of Antimicrobial Agents and Chemotherapy found cupric acid and lauric acid in coconut oil effective natural treatment for candida albicans and yeast infections.

To effectively kill candida and treat yeast infections, remove processed sugar and refined grains from your diet and consume plenty of healthy fats. Take one tablespoon of coconut oil three times daily as a supplement.

According to research published in the medical journal Food and Function, coconut oil improves antioxidant levels and can slow aging. Coconut oil works by reducing stress on the liver and by lowering oxidative stress.

Also, it has been found that coconut oil supports detoxification because of how it works with the liver. To naturally slow aging, take one tablespoon of coconut oil with anti-oxidant rich berries for breakfast. It can also be applied directly to the skin for additional benefits and smoothing.

Using coconut oil benefits the hormones as well. Coconut oil helps naturally balanced hormones because it is a great source of saturated fat including lauric

acid. Studies have shown that coconut oil is an excellent fat to consume during menopause and also may have positives effects on estrogen levels.

In order to naturally balance hormones, reduce sugar and grain consumption and load up on healthy fats from coconut, avocado, flax seeds and ghee.

Harries (1990 and 1992) did not underestimate the commercial value of the coconut. This is about why the researcher decided to conduct a research into the challenges that bedevil coconut production at the coastal areas of Ghana in this twenty first century. The addition of the coconut to the traditional export crops will give Ghana foreign exchange and will also solve part of the unemployment problem in Ghana. Coconut plays an important role in households all over the tropical world. It is estimated that about 70 % of the coconuts are consumed in the producing countries. Out of the total nuts produced, about half is consumed in the form of oil, or for industrial use, Punchihewa (1991). A study in East Kalimantan, Indonesia showed that per capita consumption per annum of coconut oil by the year 2001 average about 3.5 kg or 4.8 kg and 2.2 kg per annum for urban and rural consumers respectively, Darwis (1991).

Chapter summary

In this chapter a discussion is made on the growth of the coconut palm. Also, an in-depth review of some diseases that affect the coconut palm were thoroughly looked at as it is the focus of this study. Moreover, the chapter provides knowledge of heavy metals contaminations on soil to the growth of the palm. Extensive literature review is provided on physicochemical analysis and the benefits of coconut palm in general.

CHAPTER THREE

RESEARCH METHODOLOGY

Introduction

Today's world is filled with a number of complex issues. Many of these issues call for critical study. Research is one critical way by which issues confronting mankind can be examined. The types of research worth considering are qualitative and quantitative researches. Quantitative research is the traditional approach for investigating phenomena Physics, Biology and Chemistry. It is concerned with the acquisition and interpretation of data which can be presented in the form of discrete units that can be compared with other units by using statistical techniques (Maykut and Morehouse, 1992).

Creswell, (2017) however, sees quantitative research as an intricate7 fabric that is composed of minute pieces of thread, with many colors and different textures and a variety of blends of materials. This is about the reason for him defining quantitative research as "An inquiry process of understanding based on distinct methodological traditions of inquiry that explores a social or human problem." With that the researcher builds a complex holistic picture, analyses words and reports detailed views of informants and conducts the study in a natural setting.

Quantitative research is designed to enable the researcher understand people and the socio-cultural context within which they live. The choice therefore is between the scientific empirical tradition and the naturalistic

phenomenological mode. For this paper, the quantitative research is what has been resorted to.

Study Area

The geographical location of the towns where the samples were collected for the study were Ajumako, Nkwantanum, Hasowodze, Mozano and Bobikuma in the Central Region of Ghana. This area is a forest reserve area where their major occupation is farming. Most of the people in this area engage in coconut production as their major source of income. There are quite a number of towns in Ghana where the palm is grown, however, because of time limitations; the research was restricted to Ajumako-Enyan-Essiam through to Bobikuma in the Central Region specifically where many coconut trees are flourishing.

Sample Collection and Sampling Procedure.

The composite sampling procedure was employed in taking samples. Soil and fresh coconut stem samples were obtained from the five farms by randomly taking soils from a depth of 0 – 15 cm and stored in a sealed rubber. The stems were also collected and sealed in a rubber. Ten stem and ten soil samples were randomly taking from each site. The total sample taken during the dry season (A) was fifty stem samples and fifty soil samples. The same sampling technique was employed during the wet season (B). Ten stem and ten soil samples were taken from each farm. Total samples taken during the wet season was fifty stem samples and fifty soil samples.

Apparatus and Materials

1. Analytical balance
2. Heating source with magnetic stirrer
3. Digestion vessels
4. Thermometer
5. Graduated cylinder
6. Drying ovens
7. pH meter
8. Volumetric flask
9. Filter paper

Distilled Water

De-ionized distilled water was used for all the sample preparation.

Acids Used for Digestion

Analytical grade nitric acid (concentrated) HNO_3 (70 %), hydrochloric acid (36.0 %) and HF from Fluka Chemicals were used for the acid digestion.

Preparation of Standard Solutions for Calibration Curves

Standard solutions of cadmium, chromium, copper and nickel were prepared from the 100 mg/L reference solutions suitable for flame atomic absorption spectrometry analysis which were purchased from Fisher Scientific, New Jersey, and USA. These standards were diluted to the concentrations ranging from 0.1mg/L to 50 mg/L and stored in polypropene bottles for use.

Cadmium

0.100 g of cadmium metal was weighed in a 50 mL oven-dried beaker dissolved in 4.0 mL concentrated HNO_3. 8.0 mL concentrated HNO_3 was added to the metal and this was diluted with distilled water to 1000 mL in a volumetric flask. (1.00 mL = 100 µg Cd).

Chromium

To an oven-dried 50 mL beaker was equipped with a stirrer and 0.1923 g of CrO_3, 30 mL distilled water was added and stirred. After dissolution, the solution was acidified with 10 mL concentrated HNO_3 and diluted to 1000 mL with deionized distilled water in a volumetric flask. (1.00 mL = 100µg Cr).

Copper

To an oven-dried 50 mL beaker equipped with a stirrer was added 0.100 g copper metal and 2.0 mL concentrated HNO_3 (70 %) and stirred. Additional 10.0 mL concentrated HNO_3 (70 %) was added and diluted with de-ionized distilled water to 1000 mL in a volumetric flask. (1.00 mL = 100 µg Cu).

Nickel

To an oven-dried 50 mL beaker equipped with a stirrer was added 0.100 g of nickel.10 mL hot concentrated HNO_3 (70 %). and stirred. The solution was then cooled and diluted to 1000 mL in a volumetric flask with de-ionized water. (1.00 mL = 100µg Ni).

Harris, C. Daniel, (2010).

Sample treatment

Soil and stem samples were kept in different zip-locked plastic bags and labelled. The samples were then carried in a cardboard boxes to the laboratory for further analysis. Soil and stem samples were air dried at the same temperature and cleaned off any stones and other foreign materials. Soil samples were grounded in a mortar and stem samples were milled and passed through a 2 mm sieve and were stored in a sealable plastic bags.

Determination of pH of the Soil Sample

About 10 g of air-dried soil samples were placed in a 100 mL oven dried beaker and 50 mL de-ionized water was added. The suspension was stirred and the pH measured after18 hours of equilibration. The pH of the suspension was measured potentiometrically with a glass electrode versus a calomel reference electrode. Before starting the series of measurement the potentiometer is calibrated with a buffer solution of pH 4 & 8.

The buffer solution was prepared by dissolving 61.2 g of potassium biphthalate in a 1 L of hot water. This was then diluted six times to obtain 0.05 molar stock solutions with a pH of 4.

Soil samples were air dried, ground with a mortar and pestle and then sieved through a 2 mm sieve to achieve a homogenous sample. Soil pH was determined in distilled water, using a pH meter (PHYWE model) with a soil: solution ratio of 1:1.

Estimation of Soil Organic Matter

Soil organic matter content was estimated using Walkley and Black method. In an oven dried 500 mL Erlenmeyer flask equipped with a magnetic stirrer

and thermometer was added 10 mL of 1.0 M $K_2Cr_2O_7$ solution. 20 mL concentrated H_2SO_4 (98%) was added to the mixture and stirred for 25 minutes at a temperature of 70°C. 150 mL de-ionized distilled water and 10 mL of 85% concentrated H_3PO_4 was added to the mixture. About 0.2g NaF and 1.0 mL diphenylamine indicator was then added and the mixture was titrated d with 1.0 M ferrous ammonium sulphate (Mohr's salt) solution until a brilliant green colour was observed. A blank titration, without any soil, was carried out in the same way. With the endpoint of the blank and the soil samples obtained, the organic matter content was calculated for each sample (Walkley and Black, 1934).

Estimation of Electrical Conductivity (EC)

Electrical conductivity (EC), of the soil samples was determined by measuring 40 g of the soil samples into 250 mL Erlenmeyer flask, 80 mL of distilled water was added and stoppered. The solution was placed in a mechanical shaker for about one hour. The solution was then filtered.

The conductivity electrode was washed with distilled water and rinsed with standard KCl solution.

Estimation of Cation Exchange Capacity (CEC)

The exchangeable cations were extracted using ammonium acetate solution. Five grams (5 g) of the soil sample was weighed into 100 mL extracting bottle and 20 mL of 1 M ammonium acetate solution was added, stirred and allowed to stand overnight.

The suspension was then filtered into a 100 mL volumetric flask. The leaching process was continued with successive 20 mL volumes of ammonium acetate

allowing the funnel to drain between each addition. The process was continued till nearly 100 mL of filtrate was collected. The filtrate was made up to 100 mL with ammonium acetate solution. Aliquots of the extract were used for the determination of Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}. (Rowell, D.L.1994).

Observation of the Coconut Palm farm

The coconut palms in the areas selected were observed between December 2018 and May 2019. This was done to find out what the development patterns of the palms throughout the rainy and the dry seasons. Most of the farmers transplant their seedlings before the start of the rainy season. Soil water dilution affect the heavy metals uptake during the two seasons of the year Dongus et al, (2009). Nitrogen deficiency, for instance, is felt most when there is poor distribution of rainfall Cooper et al (1987).

Sample Preparation and Analytical procedure for Soil Samples

Standard methods were used during the collection, preservation and analysis of the samples. Soil samples were collected from a depth of 0- 15 cm around a live coconut tree. In all 200 different soil samples were collected from various locations at Ajumako-Enyan-Essiam through to Bobikuma in the Central Region in two different seasons. For estimating the heavy metals contents of the soil samples, acid digestion was done to remove organic matter and also ionized the metals. Open beaker hot plate aqua regia procedure was used.

Digestion of soil samples

To an oven dried beaker (250 mL) equipped with a magnetic stirrer was added about 1.00 gram of dry weight soil samples, 7.5 mL concentrated HCl (36 %) and 2.5 mL concentrated HNO_3 (70 %) and stirred for 30 min at a temperature

of 70 ºC. Yellow to brown fumes were given off after heating the solution for 30 min. The sample was allowed to cool for 10 min and 10 mL distilled water was added with stirring. The solution was filtered with a whatman filter paper into 50 mL volumetric flask. More distilled water was added to reach the 50 mL mark. The reagents were used to prepare blanks for background contamination. The resultant digestates were transferred into sampling bottles and were analyzed for heavy metals (Pb, Ni, Cr, Zn, Fe, Cu, Mn and Cd) using AAS (SHIMADZU-A7000).

The formula for calculating the concentration of heavy metals in mg/kg

$$\text{Concentration (mg/kg)} = \frac{Concentration\left(\frac{mg}{L}\right) * V}{M}$$

Where V= Final volume (50 mL) of solution.

M= Initial weight (0.5 g) of sample measure.

Quality control

Polytetrafluorethylene (PTFE) materials were avoided. All containers employed during the sample preparation and analysis procedures were washed thoroughly with nitric acid prior to use. All laboratory disposables (Polypropylene or glass) were rinsed with nitric acid before usage.

Linearity was evaluated in the 0.01–30 /L concentration range. Five calibration curve points were constructed (three replicates) and used to check the linearity of the instrument response and also for quantification. Standard mixtures were prepared to obtain concentrations of 0.001, 0.002, 0.004, 0.006 and 0.008 ppm. The regression coefficients (R^2) of the calibration curve were calculated by plotting area ratio versus concentration. For most of the targeted compounds (Cu, Pb, Fe, Mn, Cr, Cd, Ni and Zn), regression coefficient was

0.99 suggesting a good linearity. Three blank samples were analyzed and the average concentrations of each analyte in the blanks was used to correct the concentration of the corresponding analyte in the test samples (i.e. analyte concentration in blanks was subtracted from the corresponding analyte concentration in test sample).

Since no certified reference material was available, trueness of measurements and intra-laboratory reproducibility were assessed by spiking a mixture of internal standards (100 /L) into deionized water and then extracted following the same procedures used for the real samples (five replicates). The intra-laboratory reproducibility of the method was determined by calculating the relative standard deviation (% RSD). The obtained RSD values were largely satisfactory, indicating a fairly good precision for most of the analyte.

The limit of detection (LOD) and limit of quantification (LOQ) were determined. Limit of detection, defined as the concentration that yielded signal to noise ratio of 3 was determined for each sample. LOQ, defined as the concentration that yielded signal to noise ratio of 10, was also estimated in the same way for the individual samples. The median LOD and LOQ values were reported as the threshold value for each analyte.

$LOD = 3 * S_{bl}$

Where S_{bl} is the standard deviation of the method blank.

$LOQ = 10 * S_{bl}$

Where S_{bl} is the standard deviation of the method blank.

Chapter summary

This chapter is subdivided into two parts, sampling and sample analysis. A stepwise presentation of sampling procedures used to obtain samples have

been outlined. All analytical procedures employed for analyzing the samples have been outlined in the chapter.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

Two hundred soil samples from various locations in Ajumako-Enyan-Essiam through to Bobikuma were analysed for the concentration of eight heavy metals namely Copper, Iron, Cadmium, Nickel, Zinc, Chromium, Lead and Manganese. The results were compared with permissible limits for heavy metals in soil by World Health Organization and Dutch standards for unpolluted soils WHO (1996).

pH of Soil Sample in the dry season (A) and wet seasons (B)

The pH and the soil organic matter were determined for the soil and stem samples collected. Tables 1 show the results of pH, organic matter, cation exchange capacity and electrical conductivity for the soil samples. Values of pH ranged between 4.88 and 7.25. This suggests that some soil sample sites were slightly acidic and other sampling sites being basic for all the soil samples.

The above parameters have their own importance as they are part of the environmental conditions necessary for conductance of life processes. For example, a low or high pH can affect the coconut palm. If the pH is too low that is below 4, most nutrients can be dissolved easily which can cause an excess of manganese, aluminium and iron. Also, it can cause deficiencies of phosphorus, potassium, magnesium, and molybdenum and soil life is prohibited. If the pH is greater than 8, most nutrients dissolve less easily

causing calcium, iron and phosphate compounds to precipitate. Again if the pH is lower than 4 or higher than 8 it will cause damage to the roots.

Table 1. Physico-Chemical Parameter Results

Sample Identity	pH(A)	pH(B)	% OC(A)	% OC(B)	EC(ms) sample A	EC(ms) sample B	CEC ($Cmol_C/kg$) Sample A	CEC ($Cmol_C/kg$) Sample B
1	6.688±0.40	7.074±0.43	2.598±1.04	3.878±2.16	0.154±0.08	0.196±0.08	5.042±0.86	2.732±0.53
2	6.08±1.91	6.812±2.02	2.004±1.44	3.608±2.13	0.22±0.15	0.144±0.09	4.246±1.43	1.97±0.94
3	5.632±1.80	6.542±1.95	2.812±1.24	4.688±2.22	0.082±0.13	0.248±0.16	4.452±0.16	1.558±0.88
4	5.47±1.74	5.894±1.90	2.346±1.18	6.476±2.73	0.116±0.11	0.2±0.14	3.848±1.30	2.066±0.87
5	6.784±1.79	6.19±1.86	1.856±1.12	2.398±2.57	0.076±0.10	0.132±0.13	3.872±1.31	2.75±0.94
6	6.55±1.79	5.802±1.82	3.778±1.37	3.858±2.38	0.128±0.10	0.112±0.12	4.42±1.31	3.5±1.03
7	6.2±1.78	5.802±1.82	3.374±1.43	3.666±2.37	0.152±0.09	0.082±0.12	5.458±1.50	2.112±0.94
8	5.93±1.78	5.108±1.78	4.012±1.48	2.936±2.27	0.106±0.09	0.164±0.12	5.97±1.59	2.086±0.94
9	7.25±1.81	5.206±1.77	2.692±1.40	2.804±2.17	0.202±0.09	0.088±0.11	4.27±1.55	2.598±0.92
10	6.95±1.83	4.878±1.74	2.77±1.40	1.316±2.17	0.116±0.09	0.04±0.11	4.302±1.52	1.856±0.90

In addition, heavy metals including manganese and iron are absorbed so well that they can poison the plant (necrosis). Values of pH between 7 and 8 are not immediately harmful for the plant, but in the long run nutrients such as iron, phosphate and manganese will be deficient (the result is ,chlorosis and development problems).

The recommended pH ranges for the coconut palm by WHO are 5.5 –7.5 (WHO, 1996). The pH of all the soil samples collected were within the standard range. The acidity or alkalinity of the soil could not be a factor for aiding in the absorption of the heavy metals.

Soil Organic Carbon for Soil Samples for the Dry Season (A) and Wet Season (B)

Organic matter content in the various soil samples for both the dry season (A) and the wet season (B) ranges from 1.32 % to 6.48 %. From the table of result, it was observed that some sample site in both the dry season and the rainy season had levels of organic carbon a little above the recommended levels of organic matter for plant growth by WHO standard. The recommended levels of organic matter by WHO is 0.5 % to 3.5 %. During the dry season (A), soil samples sites 6 and 8 had levels of organic carbon to be 3.78 % and 4.01 % respectively. Also, during the wet season (B), soil sample sites 1, 2, 3, 4, 6, and 7 had levels of organic carbon greater than the WHO standard for organic matter in soils.

Conductivity for Soil Sample A and B

Soil electrical conductivity is an indirect measurement that correlates very well with several soil physical and chemical properties such as particle size

and soil texture (Wiatrak, 2009). Sands have low conductivity and clays have high conductivity. Boulding (1994) classified EC of soils as: non saline < 2; moderately saline 2-8; very saline 8-16; extremely saline >16. Results of soil electrical conductivity obtained from the soil samples had values < 2 (Table 1).

The electrical conductivity of the samples therefore can be classified as non-saline. From the data, it was observed that, soil samples during the dry season (A) and during the wet season (B) had low salt accumulation or less soluble salts and will not affect the growth of plants. Plants absorb essential plant nutrients in the form of soluble salts, but excessive accumulation of soluble salts, called soil salinity, suppresses plant growth and result in death of plants (Maas, 1984).

Cation Exchange Capacity (CEC)

Cation Exchange Capacity is a measure of the quantity of cations that can be adsorbed and held by a soil. Cation Exchange Capacity is dependent on the organic carbon and clay in soil. Soil with low Cation Exchange Capacity are more likely to develop deficiencies in potassium, magnesium and other cations while soil with high Cation Exchange Capacity are less susceptible to leaching of these cations (CUCE 2007). In general, the higher the organic carbon and clay content, the higher the Cation Exchange Capacity. The Cation Exchange Capacity gives the soil a 53 buffering capacity which may slow down the leaching of nutrient cations and positively charged pollutants because they affect both soluble and exchangeable metal levels (Yoo and James, 2002).The results obtained for soil sample site (A) which is the dry season and soil sample site (B) which is the wet season ranges from 1.86 $Cmol_C/kg$ to 5.97

$Cmol_C/kg$. This indicate that Cation Exchange Capacity for the soil samples were good for coconut growth. The low values recorded could also be attributed to the low levels of organic carbon in the soil

Table 2 Levels of Heavy Metals for Soil Sample in the Dry Season (A)

Sample identity	Cu(mg/kg)	Fe(mg/kg)	Mn(mg/kg)	Pb(mg/kg)	Cr(mg/kg)	Ni(mg/kg)	Cd(mg/kg)	Zn(mg/kg)
1	8.171±3.80	1391.736±143.89	95.814±35.01	ND	ND	3.642±0.71	0.048±0.02	ND
2	6.693±0.63	1128.139±253.58	58.397±21.08	ND	0.022±0.00	2.762±0.76	0.047±0.03	ND
3	2.737±0.38	1029.601±123.10	47.055±8.67	1.746±18.72	ND	3.246±0.96	0.004±2.20	5.645±3.04
4	1.396±0.28	635.54±98.27	43.0401±9.90	4.386±1.22	ND	3.276±0.52	0.002±0.00	2.531±0.39
5	5.651±2.37	1921.317±136.36	33.373±13.12	0.792±0.00	0.98145±1.78	3.525±0.73	ND	33.622±12.53
6	5.676±3.17	1863.324±244.70	33.061±8.50	ND	16.7326±0.00	4.173±0.38	ND	33.478±16.68
7	2.45±0.00	696.799±244.70	13.256±7.02	ND	ND	3.910±0.48	0.005±0.00	4.836±0.45
8	2.561±1.60	1163.754±339.51	28.962±22.29	ND	ND	3.337±0.57	0.004±0.00	9.165±9.19
9	1.145±0.64	993.758±372.91	32.932±23.70	ND	ND	3.066±0.18	0.004±0.00	33.349±23.92
10	0.595±0.00	890.587±552.88	30.749±32.81	ND	0.818±0.00	3.360±0.23	0.013±0.03	32.261±16.61

Table 3 Levels of heavy metals for stem sample in the dry season (A)

Sample identity	Cu(mg/kg)	Fe(mg/kg)	Mn(mg/kg)	Pb(mg/kg)	Cr(mg/kg)	Ni(mg/kg)	Cd(mg/kg)	Zn(mg/kg)
1	2.016±0.61	24.718±3.08	2.424±0.51	1.756±0.53	ND	2.690±0.49	ND	2.457±1.67
2	2.119±0.67	31.788±13.70	2.896±1.31	4.041±1.47	ND	2.705±0.80	ND	5.136±2.73
3	1.971±0.74	36.740±13.18	2.165±1.25	0.616±1.36	ND	2.509±0.81	ND	0.953±2.45
4	3.413±1.66	34.545±12.06	2.801±1.17	ND	ND	3.158±0.85	ND	2.777±2.13
5	11.408±8.46	35.473±11.49	2.230±1.08	ND	ND	3.2005±0.88	ND	3.227±1.97
6	2.247±7.74	32.557±10.96	ND	ND	ND	2.231±0.86	ND	2.200±1.83
7	2.412±7.18	35.015±10.70	0.469±1.19	ND	ND	2.354±0.83	ND	2.358±1.71
8	11.226±9.06	34.319±10.48	0.527±1.20	ND	ND	2.488±0.84	ND	3.524±1.70
9	36.572±14.55	32.773±10.35	ND	ND	ND	1.814±0.83	ND	2.263±1.72
10	19.994±15.55	35.747±10.31	0.113±1.21	ND	1.109±0.03	1.993±0.82	2.101±0.00	1.935±1.65

Table 4 Levels of heavy metals for soil sample in the Rainy season (B)

Sample identity	Cu(mg/kg)	Fe(mg/kg)	Mn(mg/kg)	Pb(mg/kg)	Cr(mg/kg)	Ni(mg/kg)	Cd(mg/kg)	Zn(ppm)
1	0.462±0.00	386.752±26.28	17.670±3.42	3.734±0.70	ND	1.257±0.20	0.271±0.27	12.398±16.63
2	ND	361.158±47.25	17.211±5.00	6.073±1.42	ND	1.868±0.29	0.056±0.04	4.960±2.71
3	1.356±1.83	218.602±130.77	8.767±5.11	7.051±1.42	ND	1.289±0.23	0.060±0.05	3.878±1.68
4	ND	270.824±60.09	10.077±4.33	9.798±1.54	ND	1.587±0.28	0.064±0.00	2.525±0.42
5	0.622±0.08	489.642±5.27	5.604±0.00	7.924±0.55	0.540±0.20	1.700±0.14	ND	7.488±0.37
6	0.508±0.17	524.124±31.98	6.188±0.94	10.803±1.26	0.961±0.47	2.189±0.30	ND	8.711±0.73
7	ND	176.005±49.87	4.352±2.36	9.925±1.18	ND	1.566±0.19	ND	1.140±0.23
8	ND	182.102±37.58	5.815±2.67	10.234±2.87	ND	1.527±0.38	ND	1.444±0.86
9	ND	234.728±74.04	4.291±2.56	9.951±2.96	0.492±0.00	1.298±0.46	ND	9.864±7.32
10	ND	244.381±77.44	8.215±3.05	11.738±3.15	0.204±0.00	1.099±0.46	ND	2.051±6.35

Table 5 Levels of heavy metals for stem sample in the Rainy season (B)

Sample identity	Cu(mg/kg)	Fe(mg/kg)	Mn(mg/kg)	Pb(mg/kg)	Cr(mg/kg)	Ni(mg/kg)	Cd(mg/kg)	Zn(mg/kg)
1	20.117±0.00	82.037±8.87	4.719±0.57	1.945±0.82	1.300±0.49	3.533±0.83	ND	8.120±1.40
2	7.795±0.11	51.913±1.57	4.450±0.85	2.366±1.04	0.820	2.523±0.54	ND	8.350±4.16
3	3.841±2.16	34.620±27.58	2.739±1.48	1.543±0.82	ND	2.489±1.11	ND	1.281±3.79
4	2.396±0.00	37.684±25.78	2.776±1.40	ND	ND	2.282±1.02	ND	0.666±3.96
5	1.618±0.38	33.489±5.83	2.059±0.00	0.547±0.00	ND	2.130±0.13	ND	0.776±0.07
6	2.268±0.00	29.454±23.51	2.357±1.37	ND	ND	2.138±1.01	ND	0.205±3.80
7	5.212±0.26	41.063±13.85	3.185±0.63	ND	ND	2.599±0.32	ND	0.684±0.89
8	11.477±4.56	42.986±7.04	3.496±2.08	ND	ND	2.484±1.14	ND	0.392±1.06
9	ND	39.434±21.93	1.863±1.45	ND	ND	2.672±0.98	ND	0.391±3.36
10	3.427±1.77	43.868±22.25	2.580±0.81	ND	ND	2.160±0.92	ND	0.366±0.19

Table 6- Maximum acceptable limits (mg/kg) and toxicity levels (mg/dm^3) of heavy metals in soils and stems by World Health Organization and Dutch standards

Elements/metals	Target value of soil(mg/kg)	Target value of stem(mg/kg)	Toxicity levels(mg/dm^3)
Zn	50	0.60	130
Cu	36	10	>50
Cr	100	1.30	>100
Pb	85	2.0	>300
Ni	35	10	>500
Cd	0.8	0.02	>0.8
Fe	1500	20	>100
Mn	20-3000	200	>3000

Source: Field survey WHO (1996)

Copper

Copper concentration in the soil samples from Ajumako Enyan Essiam through to Bobikuma ranged between 0.60 mg/kg to 8.17 mg/kg for the dry season and 0.00 mg/kg to 1.36 mg/kg for the wet season. The levels of heavy metals in the stem samples during the dry season ranges from 1.97 mg/kg to 36.57 mg/kg and that of the wet season ranged from 0.00 mg/kg to 20.12 mg/kg. The permissible limit according to WHO standard is 36 mg/kg for unpolluted soils and 10 mg/kg (Table 6) for stem samples. None of the soil samples exceeded the permissible limits of Cu for plant growth set by WHO in both seasons. Four (4) out of the ten (10) stem samples indicated copper toxicity in the dry season whereas one (1) stem sample site in the wet season exceeded the WHO limit of 20 mg/kg for plant growth. On the whole, the

samples that have lower concentrations as compared to the WHO outweigh those that had higher levels of copper in the stem. The high levels of copper obtained may be toxic to the survival of the coconut plant with time. Comparing the data obtained for both the dry season and wet season, it was observed that heavy metal levels during the dry season for both the stem and soil sample were higher than the levels detected during the wet season. This could be as a result of low level of organic matter in the soil. Soils with low organic matter can easily be leached.

Marschner (1995) reported that soils with higher concentration of copper accumulates in the root tissue and does not translocate to the shoot. Marschner also reported that the accumulation causes a reduction in the number and length of root hairs on the main root and also damages the root cuticle and the root meristem. The accumulation causes the effect of copper toxicity is largely on root growth and morphology. The copper turns to accumulate in the root tissue with little translocate to the shoots Marschner (1995). It causes a reduction in the number and length of root hairs on the main root. It also damages the root cuticle and root meristem. High concentration of copper decreases the shoot concentration of nutrient cation Ca, K, Mg and Mn. Therefore the effect of copper on root hair proliferation suggest a consequently death of the coconut palm due to nutrient deficiency or inhibition of nodulation Marschner (1995). From the table of result, copper levels in the soil were within the acceptable limit of plant growth by WHO. The coconut in these areas are really flourishing and the low levels of copper in the soil can be a contributing factor.

Figures 3 and 4 are graphs representing the mean concentrations of copper in the soil and stem samples taken for both the dry season (A) and the wet season (B).

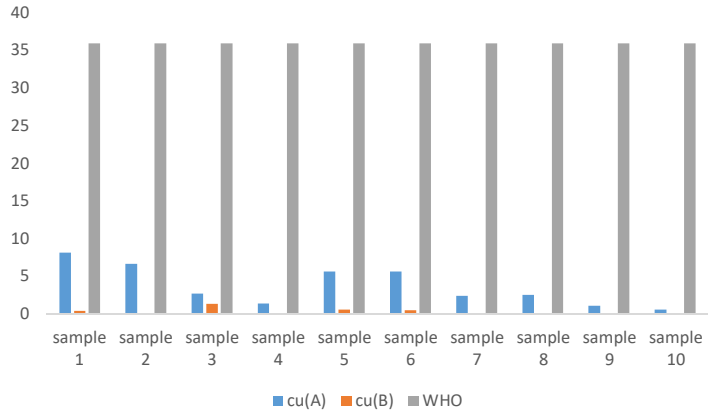


Figure 3. Mean Concentrations of Cu in mg/kg on Soil for Dry Season and Wet Seasons.

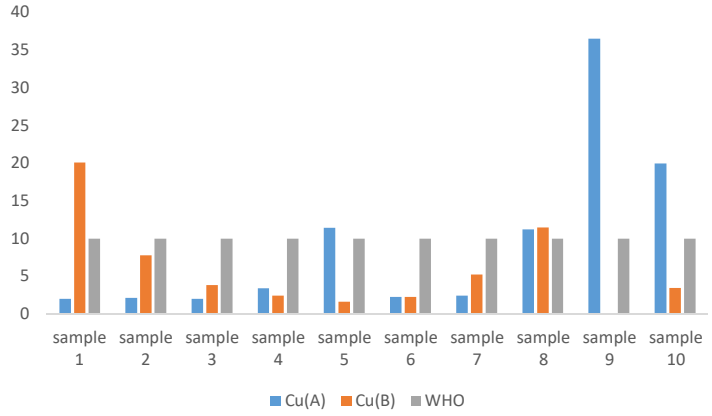


Figure 4. Mean Concentration of Cu in mg/kg on Stem for the Dry and Wet Seasons.

The ash bars represent the WHO limits of copper concentrations for soil and stem, the blue bar represent samples in the dry season and the orange bar represent samples in the wet season. For soil samples, it was observed that the levels of heavy metals were far below the WHO standard for both the wet and the wet season. Also taken the data for the stem samples into consideration, it was observed that sample sites 1 and 8 for the dry season had higher levels of heavy metals in the stem as compared to the WHO standard. Sample site 5, 8, 9 and 10 for the dry season had higher levels of heavy metals in the stem samples. Although coconut samples in these areas were flourishing, they can be affected with time. On the whole, the samples that have lower concentrations than those of the WHO outweigh those that have higher concentrations.

Iron

In the analysis performed on the soil and stem samples from Ajumako Enyan Essiam through to Bobikuma, the following results were obtained.

The iron content ranged between 67.42 mg/kg to 2058.48 mg/kg for the soil samples and between 61.7645mg/kg and 20.3243 mg/kg for the stem samples. Comparing the values obtained from the study with WHO's limit of 20 mg/kg for stem and 1500 mg/kg for soil samples it was observed that two sample sites had their level of concentration in the soil samples higher than the recommended level of iron in soil for plant growth set by WHO. Also from the findings for the stem samples, it was observed that all the sample sites had higher levels of iron in the stem as compared to the WHO standard of 20 mg/kg. WHO (1996).

The coconut in these areas are flourishing since majority of the sampling site had levels of concentration lower than the recommended levels needed for plant growth by WHO. The stem had higher levels and this can affect the coconut palm with time.

Cleide Aparecida de Abreu et, al., in Routine Soil Testing to Monitor Heavy Metals and Boron observed that values in soil above 100 mg Fe dm^{-3} with conditions of low potassium and phosphorus status and poor drainage give rise to problems of iron toxicity to crops in general. Soil analysis is an important tool to assess the nutrient needs of a plant. Excess nutrient of any kind reduces yields.

Iron toxicity in plants comprises the microbial reduction of insoluble Fe^{3+} soluble Fe^{2+}. Iron toxicity in plants takes place when there is relatively high intake of Fe^{2+} by the roots and this is transported to the leaves. The Fe^{2+} excess causes free radical production that impairs cellular structure irreversibly. This process damages the coconut palm membranes, DNA and proteins (Arora et al 2002: de Dorlodot et al 2005). Iron toxicity in the palm is complemented by a reduction of the palms photosynthesis. As a result, the yield is adversely affected. Moreover, there is increase in oxidative stress and ascorbate peroxidase activity (Sinha et al 1997).

Iron toxicity also causes bushy brown roots, floating brackish red scums on the surface of the leaves, tinny brown spots and shy tillering. Toxicity of iron also causes bronzing and stippling of leaves of the coconut palm.

Normal coconut plants exclude excess Fe, and respiration inhibitors increase Fe uptake by roots. Salt reduces the power of excised roots to oxidize Fe^{2+} absorbed by roots. Salt treatment also decreases water uptake and increases Fe

concentration in shoots. Total Fe absorption decreases, but the percentage of Fe translocation increases.

Tolerance of palm to Fe toxicity is influenced by many factors including the age of the palm. The younger palm is more nutritionally susceptible than the older palm. The ability to exclude excess Fe is lower in palms that are deficient in Ca, Mg, P, Mn and especially K. Thus, it will not be over stretching the fact to state that, the application of Ca, Mg, P, Mn and K could minimize the excess Fe.

Figures 5 and 6 are graphs representing the mean concentrations of iron in the soil and stem samples taken for both the dry season (A) and the wet season (B).

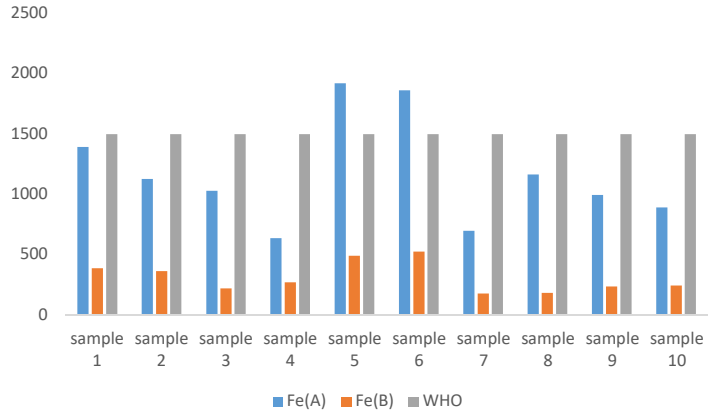


Figure 5. Mean concentrations of Fe in mg/kg on soil for dry and wet seasons

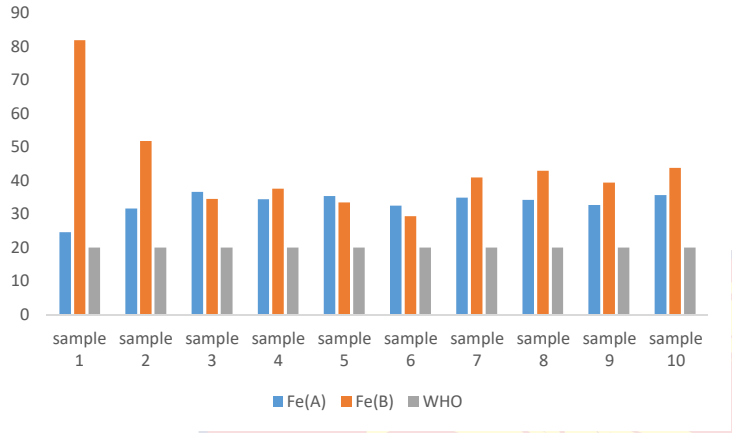


Figure 6. Mean concentrations of Fe in mg/kg on stem for dry and wet seasons

The ash bars represent the WHO limits of copper concentrations for soil and stem, the blue bar represent samples in the dry season and the orange bar represent samples in the wet season. For soil samples, it was observed sample site 5 and 6 had higher levels of iron in the soil than the recommended level by WHO which is 1500 mg/kg. For the stem samples, it was observed that all sample sites had higher levels of iron in the stem samples as compared to the standard by WHO which is 20 mg/kg. Although coconut palms in these areas are flourishing, higher levels of heavy metals in the stem and some soil sample site can affect the palm with time.

Manganese

One of the heavy metals needed by the biological system is manganese. Manganese plays an essential role in living things, including humans. Its functions include oxidative phosphorylation, fatty acid and cholesterol

metabolism, mucopolysaccharide metabolism and the activation of some enzymes.

The concentration of manganese in the soil samples from Ajumako through to Bobikuma ranged from 13.26 mg/kg and 95.81 mg/kg. For the stem samples, the concentration varied from 2.90 mg/kg to as low as values not detected. The WHO standard of manganese in soils suitable for the growth of coconut palms is 20-3000 mg/kg (WHO, 1996). The comparisons therefore indicate that the values are within the WHO standards. Since the soil and stem had levels of heavy metals within the acceptable limit for plant growth, it can be a contributing factor for the flourishing coconut in these areas.

Figures 7 and 8 are graphs representing the mean concentrations of manganese in the soil and stem samples taken for both the dry season (A) and the wet season (B).

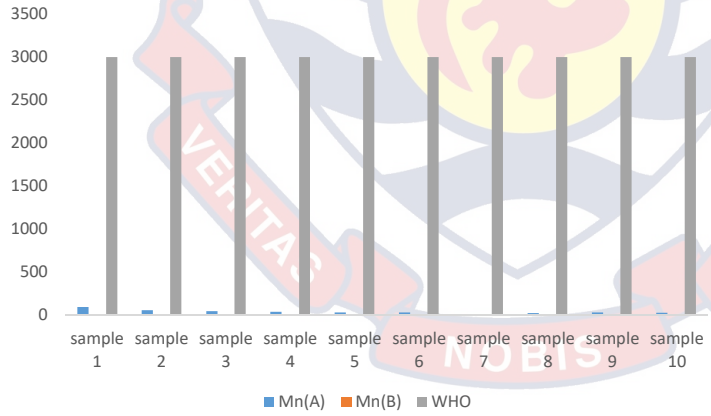


Figure 7. Mean concentrations of Mn in mg/kg on soil for the dry season and wet seasons

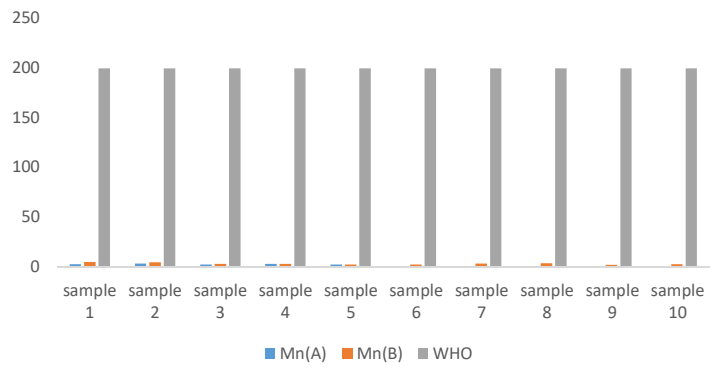


Figure 8. Mean concentrations of Mn in mg/kg on stem for the dry season and wet seasons

The ash bars represent the WHO limits of copper concentrations for soil and stem, the blue bar represent samples in the dry season and the orange bar represent samples in the wet season. For soil samples, it was observed sample site 5 and 6 had higher levels of iron in the soil than the recommended level by WHO which is 1500 mg/kg. For the stem samples, it was observed that all sample sites had higher levels of iron in the stem samples as compared to the standard by WHO which is 20 mg/kg. Although coconut palms in these areas are flourishing, higher levels of heavy metals in the stem and some soil sample site can affect the palm with time.

Lead

The concentration of lead in the soil samples from various sites in Ajumako through to Bobikuma varied from 0.00 mg/kg to 4.39 mg/kg and that of the stem samples varied from 0.00 mg/kg to 4.04 mg/kg for the dry season.

Again the concentration of lead in the soil samples for the wet season ranged from 3.73 mg/kg to 11.74 mg/kg while the values for the stem samples were 0.00 mg/kg to 2.37 mg/kg respectively.

Meanwhile, the WHO permissible limit of lead within both the wet and dry seasons for soil samples is 85 mg/kg and for stem samples is 2 mg/kg. A comparison of the concentrations of lead in soil samples for both the dry and wet seasons were below the permissible limit set by WHO standards however Table 4.3 indicated that the lead concentrations for the stem samples in the dry was 4.04 mg/kg and this was a significant figure above the WHO standard limit of 2.0 mg/kg again in the wet season, there was a slight significant figure of 2.37 mg/kg compared the 2.0 mg/kg set by WHO.

It was observed that out of the 10 sampling sites, only 1 had high concentrations of lead with reference to the permissible limits set by the WHO in both the dry and wet seasons for the stem samples and since the stem stores high quantities of absorbed plant food (heavy metals) this could account for the reason why coconut with the sampling sites were generally flourishing.

Figures 9 and 10 present the concentrations of chromium in the soil and stem samples respectively taken from Ajumako through to Bobikuma.

Chromium

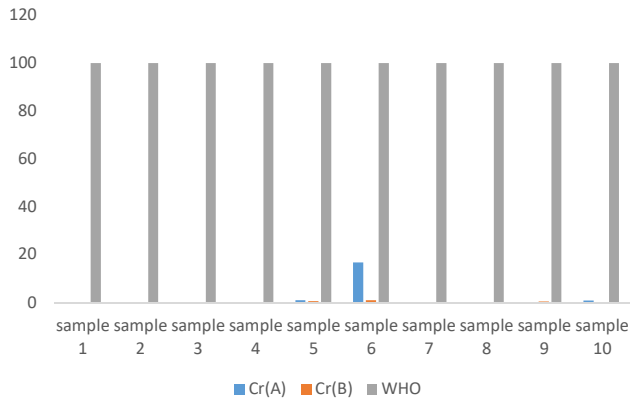


Figure 9. Mean concentration of Cr in mg/kg on soil for the dry and wet seasons

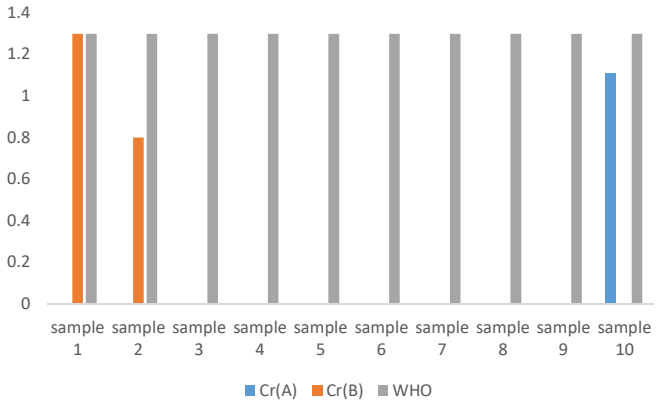


Figure 10. Mean concentrations of Cr in mg/kg on stem for the dry and wet seasons.

The Cr concentrations for the dry season ranged from 0.00 mg/kg to 16.73 mg/kg in soil samples and 0.00 mg/kg to 1.12 mg/kg in the stem samples. Also, the Cr concentrations for the wet season ranged from 0.00 mg/kg to 0.96 mg/kg in soil samples and 0.00 mg/kg to 1.30 mg/kg in the stem samples. The permissible limits of Cr recommended by WHO is 100 mg/kg in soil samples and 1.3 mg/kg in stem samples in either seasons. The discoveries are lower than the standard permissible limits, WHO (1996). A higher concentration of chromium in the coconut plant may be as a result of the different kinds of chromium. They differ in their effects and the mode by which they enter the air, water and the soil. $Cr^{3+}$and Cr^{6+} form through natural processes and human activities. Chromium is not an essential trace element for plant growth but it is one of the toxic essential heavy metals.

It was observed that coconut in the sampling site was thriving and this could be attributed to the permissible proportions of Cr in both the soil and stem samples in either seasons.

Nickel

The concentration of Ni in the soil and stem samples in Ajumako through to Bobikuma were below the detection limit. The recommended limit for Ni in soils as recommended by WHO (1996) is 35 mg/kg while the limit in stem samples is 10 mg/kg.

Tables 2 and 3 indicated that for the dry season, the concentrations of nickel in the soil samples in Ajumako through to Bobikuma was between 2.76 mg/kg to 4.17 mg/kg and that of the stem samples were 1.81mg/kg to 3.20 mg/kg respectively. Again Tables 4 and 5 indicated that for the wet season, the

concentrations of nickel in the soil samples was between 1.10 mg/kg to 2.19 mg/kg and that of the stem samples were 2.16 mg/kg to 3.53 mg/kg respectively.

From the findings, the concentrations of nickel in all the samples were below the permissible limits set by WHO either in the dry season or the wet season. The existence of these recommended concentrations of Ni in both soil and stem samples could be a contributing factor to the flourishing coconut plantations within the sampling sites.

Cadmium

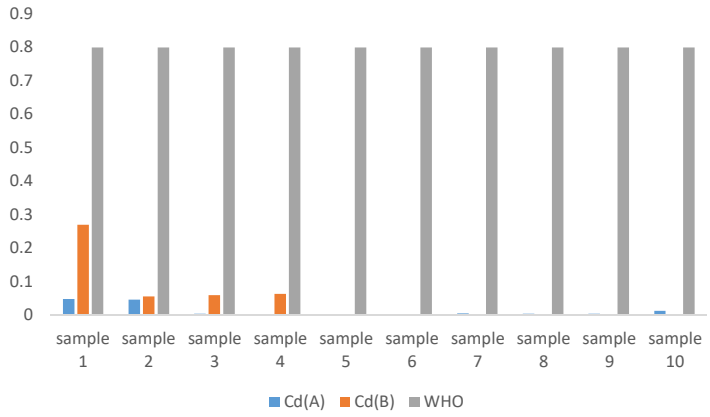


Figure 11. Mean concentrations of Cd in mg/kg on soil for the dry and wet seasons.

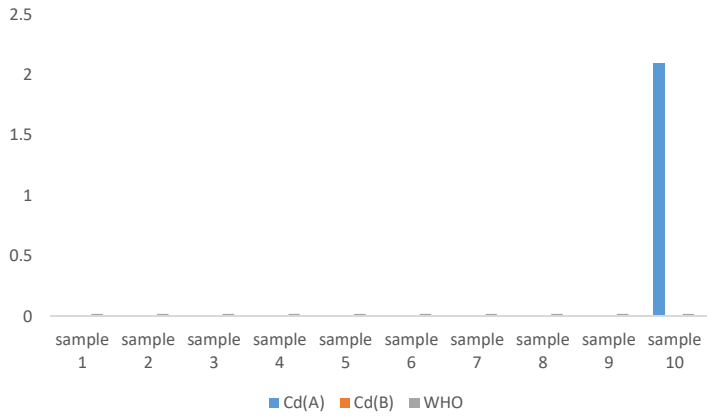


Figure 12. Mean concentrations of Cd in mg/kg on stem samples for the dry and wet season.

Figure 11 indicated that the concentrations of cadmium in the soil samples in Ajumako through to Bobikuma ranged between 0.00mg/kg to 0.05 mg/kg. Figure 12 revealed that the stem samples were found in the range of 0.00 mg/kg to 2.10 mg/kg. These represented values in the dry season.

Again Figures 11and 12 revealed that for the wet season, the concentrations of cadmium in the soil samples ranged between 0.00 mg/kg to 0.27mg/kg while the stem samples recorded no Cd concentrations.

However, WHO recommends permissible limits of 0.8 mg/kg for soil samples and 0.02 mg/kg for stem samples. From the findings, all the soil samples have concentrations below the permissible level but for the stem samples only one out of the ten stem samples had concentration which was above the WHO standard. The availability of permissible quantities of Cd in the sampling site could account for the reason why coconut is flourishing, however the site

showing the concentration of 0.27mg/kg is likely to have effects on coconut with time.

Zinc

Table 2 showed that the concentrations of zinc in the soil samples from Ajumako through to Bobikuma ranged between 2.53 mg/kg to 33.62 mg/kg. Table 3 revealed that the stem samples varied from 0.95 mg/kg to 5.14 mg/kg. These values represented readings in the dry season.

Table 4 showed that the concentrations of zinc in the soil samples ranged between 1.14 mg/kg to 12.40 mg/kg. Table 3 revealed that the stem samples varied from 0.21 mg/kg to 8.12 mg/kg. These values represented readings for the wet season. The WHO permissible limits of zinc for soil samples range between 50mg/kg. The stem sample permissible limit is 0.60 mg/kg. WHO (1996).

The outcome of the experiment revealed that the zinc content of soil samples in both the dry and wet season were within the WHO permissible limits, however, the Zn concentrations for the stem samples were significantly higher than the WHO permissible limits.

Concentrations of zinc in contaminated soils cause phytotoxicity. High levels of zinc in soil inhibit coconut palm metabolic functions. This results in the retarded growth and senescence palm. Thus based on the findings Zn concentrations in stem samples it obvious that though the coconut plantations in the sampling site were thriving, there is a high possibility of retarded plant growth and death in the near future.

Relations between metals in Soils and Stems of the Coconut Palm.

The statistical analysis was conducted to identify possible correlations and variability in the heavy metal levels in the soil and stem of the coconut palm. The relationship between two variables is generally considered strong when their **r** value is larger than 0.7. The correlation r measures the strength of the linear relationship between two quantitative variables. Values of r near 0 indicate a very weak linear relationship. Table 7 shows the Pearson's correlation between the selected heavy metals during the dry season. Strong correlation indicates that these elements have common sources. Strong correlation values usually fall within 0.8-0.9, average correlation fall within 0.5-0.7 and weak correlation fall within 0.3-0.5(Cohen, J. 1998). From the table, there was a strong correlation between cadmium and manganese. Pb and Zn correlated weakly with all the other elements. Copper correlated well with iron, manganese and cadmium and correlated weakly with Pb, Cr, Ni and Zn, this might be due to the anthropogenic activities in the study sites. Iron correlated averagely with Cr and weakly with Cu, Mn, Pb, Ni, Cd and Zn.

SOIL DRY

Table 7. Pearson's correlation matrix between the selected heavy metals in the dry season soils in the dry season.

	Cu	Fe	Mn	Pb	Cr	Ni	Cd	Zn
Cu	1.000							
Fe	0.674	1.000						
Mn	0.672	0.177	1.000					
Pb	-0.307	-0.358	0.031	1.000				
Cr	0.262	0.583	-0.151	-0.180	1.000			
Ni	0.186	0.390	-0.202	-0.177	0.650	1.000		
Cd	0.645	0.002	0.804	-0.302	-0.254	-0.330	1.000	
Zn	-0.226	0.473	-0.457	-0.302	0.456	0.243	-0.510	1

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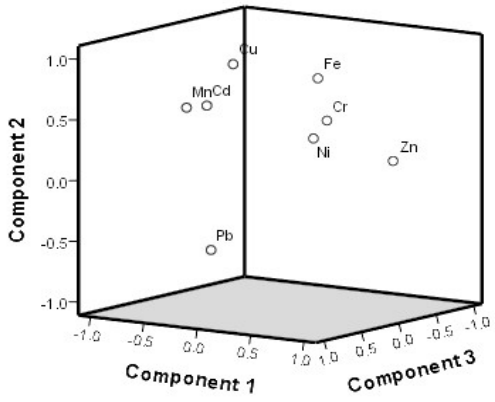
Table 8. Principal Component analysis for selected heavy metals in soils in the dry season

	Component		
	1	2	3
Cu		0.895	
Fe		0.829	
Mn		0.503	
Pb			0.737
Cr	0.639		
Ni	0.596		
Cd		0.459	
Zn	0.787		

From the above data, (table 8), the principal component analysis (PCA), was used to determine which of the heavy metals might be emanating from the same source. From the above data Cr, Ni, and Zn might be coming from the same source because they correlated well with each other. Also, Fe, Mn, and Cd were in the same component, which means they might all be coming from a similar source. Pb was the only metal found in the third component which also suggest that Pb was coming from a different source as compared to the

other heavy metals. The presence of such metals suggest that anthropogenic activities in such areas such as fertilizer application, expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints might have contributed to the strong loading of the metals (Prego and Cobelo-Garcia, 2003).

Figure 13: component Plot loading showing metal loadings on soil in the dry season



From the above figure, the component plot showing metal loadings on soil samples indicate three component. The result obtained from above can be concluded that they may be coming from the same source since they correlate very well. Also, Fe, Cr, Ni, and Zn are in one component and might also be coming from a common source since there is a correlation between these metals. Pb can be seen to be separated from all the other metals. This data confirms the Principal Component Analysis where Mn, Cd and Cu are emanating from the same source, from the component loading analysis it can

also be seen that they are clustered in one component. Fe, Cr, Ni and Zn were also in one component which can also be seen in that of the principal component analysis. From the Principal Component Analysis, Pb was seen in the third component, which is being the only metal separated from the rest of the metals. From the component loading it can also be seen that lead is separated from the other heavy metals indicating Pb emanating from a different source. Some sources of Pb include fallout from the discharge of community waste incinerators, smelters, or foundries; dumping or burning of lead batteries and their casings; and emission fallout from vehicles fueled with leaded gasoline.

STEM DRY

Table 9: Pearson's correlation matrix between the selected heavy metals in the dry season stem samples

	Cu	Fe	Mn	Pb	Cr	Ni	Cd	Zn
Cu	1.000							
Fe	0.151	1.000						
Mn	-0.537	-0.230	1.000					
Pb	-0.346	-0.481	0.583	1.000				
Cr	0.330	0.245	-0.356	-0.171	1.000			
Ni	-0.579	-0.038	0.831	0.201	-0.407	1.000		
Cd	0.330	0.245	-0.356	-0.171	1.000	-0.407	1.000	
Zn	-0.131	-0.216	0.363	0.639	-0.236	0.382	-0.236	1.000

From table 9, there is a strong correlation between Nickel and manganese. The occurrence of these metals indicate anthropogenic activities such as industrial activities, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues around the study sites. Cr correlated weakly with all the other elements. Zn also correlated weakly with the other elements except with Pb which the correlation was neither high nor low. Copper correlated weakly with the other element. Iron correlated weakly with all the other elements. The correlation in general was weak in this analysis.

Table 10 Principal Component Analysis (PCA) of Stem Samples

	Component		
	1	2	3
Cu		0.602	
Fe			0.601
Mn	0.826		
Pb		0.643	
Cr		0.602	
Ni	0.765		
Cd		0.602	
Zn	0.575		

From table 10, the principal component analysis (PCA), data is analysed to determine which of the heavy metals might be coming from the same source. From the table Ni, Mn, and Zn might be emanating from the same source because they correlated strongly with each other and in the same component. Also, Pb, Cu, Cr and Cd correlated strongly so suggesting they are from the same source, the presence of such metals suggest that anthropogenic activities such as industrial activities, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues in such areas might have contributed to the strong loading of the metals (Prego and Cobelo-Garcia, 2003). The third component had Fe which suggest that iron is emanating from a different source and not from the same source with the other heavy metals.

From figure 14.0 which is the component plot showing metal loadings on soil samples indicate three component. The result obtained from figure 14, it can be deduced that Cu, Cd and Cr may be emanating from the same source since they correlate very well. Also, Pb, Mn, Ni, and Zn suggest that they may be coming from the same source since they correlate strongly and Fe can be seen to be separated from all the other metals. This really depicts metals emanating from the same source and can be attributed to anthropogenic activities in the study site.

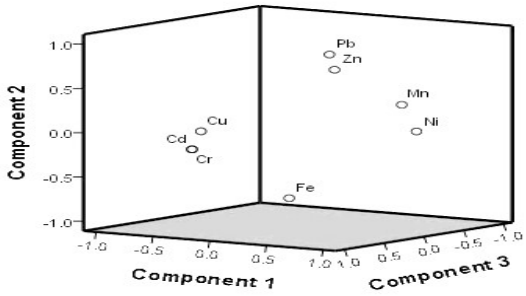


Figure 14. Component plot showing metal loadings on stem in the dry season

WET SEASON SOIL

Table 11. Pearson's correlation matrix between the selected heavy metals in the wet season soil samples

	Cu	Fe	Pd	Cr	Ni	Mn	Cd	Zn
Cu	1.000							
Fe	0.267	1.000						
Pd	0.034	0.232	1.000					
Cr	-0.400	-0.269	-0.778	1.000				
Ni	0.129	0.674	-0.445	0.372	1.000			
Mn	-0.027	0.625	-0.043	0.085	0.514	1.000		
Cd	0.215	0.171	0.790	-0.816	-0.389	-0.281	1.000	
Zn	0.251	0.633	0.298	-0.510	0.480	0.082	0.527	1.000

From the table above (table 14), there is an average correlation between iron and Nickel and manganese. The occurrence of these metals indicate anthropogenic activities around the study sites. Cr correlated weakly with all the other elements. Zn also correlated weakly with the other elements except with Fe which the correlation was average. Copper correlated weakly with all the other element. Chromium correlated weakly with all the other elements and some even were inversely correlated. The correlation in general was weak in this analysis.

Table 12. Principal Component Analysis(PCA) of Soil Samples

	Component		
	1	2	3
Cu			-0.761
Fe		0.852	
Pd	0.836		
Cr	-0.938		
Ni		0.934	
Mn		0.721	
Cd	0.914		
Zn	0.658		

From the above data, (table 12), the principal component analysis (PCA), data is analysis to determine which of the heavy metals might be coming from the same source. From the above data Pb, Cd, and Zn might be emanating from the same source because they correlated strongly with each other and Cr correlating inversely with these metals and in the same component, this suggest the anthropogenic activities at the study site. Also, Fe, Ni, and Mn correlated strongly so suggesting they are from the same source, the presence of such metals suggest that anthropogenic activities in such areas might have contributed to the strong loading of the metals (Prego and Cobelo-Garcia, 2003). The third component had Cu which is inversely correlated suggest that iron is emanating from a different source and not from the same source with the other heavy metals.

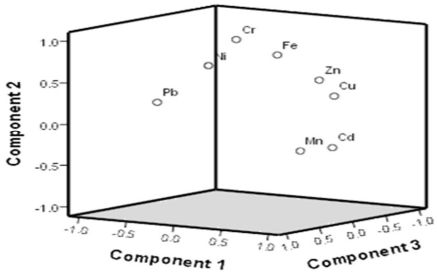


Figure 15. Component Plot showing metal loadings on soils in the wet season.

From the above data which is the component plot showing metal loadings on soil samples indicate three component. The result obtained from above can be concluded that Cu, Cd and Cr may be emanating from the same source since they correlate very well. Also, Pb, Mn, Ni, and Zn suggest that they may be coming from the same source since they correlate strongly and Fe can be seen to be separated from all the other metals. This really depicts metals emanating from the same source and can be attributed to anthropogenic activities in the study site.

STEM WET

Table 13. Pearson's correlation matrix between the selected heavy metals in the wet season stem samples

	Cu	Fe	Mn	Pb	Cr	Ni	Zn
Cu	1.000						
Fe	0.892	1.000					
Mn	0.874	0.815	1.000				
Pb	0.533	0.594	0.706	1.000			
Cr	0.810	0.919	0.851	0.797	1.000		
Ni	0.807	0.888	0.675	0.525	0.793	1.000	
Zn	0.699	0.810	0.861	0.889	0.961	0.668	1.000

From the table above (table 17.0), Cu correlated strongly with almost all the other heavy metals, the only average correlation for Cu was with Pb, Fe correlated strongly with almost all the heavy metals except Pb which correlated averagely. Mn, Pb, Cr, Ni and Zn all correlated strongly with any other heavy metal. The general strong correlation in the analysis suggest that the heavy metals under study emanate from the same source and is related to anthropogenic activities in the study site.

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Table 14. Principal component Analysis (PCA) of Stem Samples

	Component
	1
Cu	.892
Fe	.941
Mn	.918
Pb	.795
Cr	.973
Ni	.849
Zn	.934

From table 14 it can be seen that only one component was produced. This is as a result of the high correlation rate between the metals of interest. This shows the metals are highly emanating from the same source as a result of anthropogenic activities in the study site. From the above data, there cannot be any component plotting/loading since the component is only one.

Chapter summary

This chapter represents the focal point of the research report. All the findings from conducting of this research has been presented in this chapter. It includes findings on physicochemical parameters, heavy metals concentrations in both the stem and the coconut palm for the dry and wet seasons.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Overview

Contaminations of soil by heavy metals are extremely threatening to both plant and animal lives. This study looked at the levels of heavy metals in the soils and stems of the coconut plantation farms from Ajumako-Enyan Essiam through to Bobikuma in the Central Region of Ghana and assessed its possible contribution to the destruction of the plant.

One hundred soil and one hundred stem samples were collected. Heavy metals that were analyzed in these samples were Zinc, Iron, Copper, Nickel, Chromium, Lead, Manganese and Cadmium. Atomic Absorption Spectrometer (Shimadzu 7000 AS) was used to analyze the samples after the samples were digested.

Summary

In both the stem and soil samples collected, concentration of Pb, Mn, Cd, Cu, Fe, Cr, Ni and Zn were measured from coconut plantations in Ajumako-Enyan-Essiam through to Bobikuma in the Central Region of Ghana. For each sample site, the random sampling procedure was used in the collection of the samples of soils and stems in each plantation. Experiment and subsequent analysis were done to determine the contamination with regards to heavy metals and other physicochemical parameters.

Conclusion

All Physico-chemical parameters analyzed were within the WHO permissible limits except a few samples sites that fall outside the Dutch standards

Although there were higher concentrations, there were no visible sign and symptoms; there could be some effects and visible sign in the long term.

A few of the stem samples have their concentrations a little above the Dutch standard for plant growth.

Finally, comparing the result to an unpublished thesis on where the coconuts are dying, it can be seen that heavy metals might contribute immensely to the death of the coconut palm.

Recommendations

Other growing sites of the coconut palm could be identified and assessed for heavy metals concentrations.

Isotopic analysis could be carried out to identify the causes of the metal pollution in the soils and stems and remediation options propounded.

Further research should be done where the coconut seedlings would be planted on neutral soils and inject higher concentrations of heavy metals as well as lower concentration of heavy metals to see the effect they will both have on the palm.

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APPENDIX I

Physico-Chemical Parameter Results

Table 19. RESULT FOR SOIL SAMPLE

Sample id	pH(A)	pH(B)	%OC(A)	%OC(B)	EC(m) sam.A	EC(ms) sam. B	CEC ($Cmol_C/kg$) Sam. A	CEC ($Cmol_C/kg$) Sam. B
1	6.83	7.50	3.22	7.66	0.25	0.32	4.34	3.28
2	6.50	7.17	3.35	2.43	0.03	0.15	6.21	2.27
3	7.30	6.77	3.01	3.32	0.14	0.13	5.15	2.36
4	6.26	7.42	0.82	3.37	0.20	0.22	4.07	2.41
5	6.55	6.51	2.59	2.61	0.15	0.16	5.44	3.34
6	4.75	6.28	0.83	3.03	0.09	0.14	4.99	2.24
7	6.49	7.43	3.60	0.92	0.11	0.06	4.55	1.93
8	6.05	6.55	4.41	3.19	0.15	0.11	5.01	0.83
9	6.51	6.40	0.13	3.24	0.15	0.09	3.08	1.57
10	6.60	7.40	1.05	7.66	0.60	0.32	3.60	3.28
11	6.00	6.73	2.61	2.58	0.13	0.09	4.16	2.08
12	5.83	6.62	1.81	2.37	0.08	0.09	4.31	0.70
13	6.01	6.03	3.35	3.58	0.09	0.19	4.55	1.39
14	5.26	5.83	3.40	7.08	0.05	0.16	4.56	1.71
15	5.06	7.50	2.89	7.83	0.06	0.71	4.68	1.91
16	5.55	6.50	2.27	8.96	0.05	0.07	4.46	2.92
17	5.76	6.10	3.76	2.34	0.18	0.12	3.63	1.35
18	6.16	6.38	1.28	3.22	0.13	0.26	3.94	1.05
19	5.48	5.04	1.31	7.00	0.08	0.38	3.40	2.06
20	4.40	5.45	3.11	10.86	0.14	0.17	3.81	2.95
2 1	6.95	6.45	1.78	2.80	0.07	0.20	3.64	2.61
22	7.10	5.80	1.62	2.82	0.10	0.10	4.36	1.36
23	6.58	5.56	1.46	0.66	0.05	0.08	4.43	2.58
24	6.66	6.10	1.13	3.17	0.05	0.10	2.23	3.30
25	6.63	7.04	3.29	2.54	0.11	0.18	4.70	3.90

26	6.88	6.10	1.20	5.79	0.05	0.07	3.39	3.51
27	6.48	5.51	2.60	4.03	0.07	0.09	4.44	3.77
28	6.28	5.62	4.26	3.14	0.08	0.08	4.29	3.94
29	6.80	6.20	4.28	3.14	0.15	0.12	5.18	3.23
30	6.31	5.58	6.55	3.19	0.29	0.20	4.80	3.05
3 1	5.62	5.48	4.46	2.76	0.13	0.17	6.54	2.09
32	5.80	5.00	0.49	3.20	0.13	0.08	2.28	1.39
33	6.63	7.23	5.16	1.94	0.14	0.07	6.88	2.94
34	6.42	5.69	3.36	8.45	0.15	0.05	5.23	1.88
35	6.53	5.61	3.40	1.98	0.21	0.04	6.36	2.26
36	5.20	5.42	3.01	3.11	0.12	0.06	6.44	2.40
37	6.10	5.22	3.18	5.08	0.19	0.14	4.91	2.22
38	6.05	4.57	5.85	3.23	0.04	0.07	6.12	1.70
39	6.00	5.21	4.75	1.73	0.07	0.42	5.84	2.39
40	6.30	5.12	3.27	1.53	0.11	0.13	6.54	1.72
4 1	7.45	6.03	2.11	2.69	0.23	0.13	3.41	2.52
42	6.79	5.50	3.16	2.87	0.18	0.04	4.73	2.98
43	7.45	3.88	2.98	2.18	0.33	0.12	4.91	3.01
44	7.25	4.99	2.56	2.74	0.13	0.10	4.70	2.59
45	7.31	5.63	2.65	3.54	0.14	0.05	3.60	1.89
46	7.13	5.04	1.68	0.60	0.09	0.05	5.14	2.60
47	6.54	4.88	2.96	3.06	0.18	0.04	4.52	2.06
48	7.01	4.55	3.36	0.50	0.24	0.04	4.10	1.55
49	6.82	5.32	0.87	1.41	0.03	0.04	3.13	1.54
50	7.25	4.60	4.98	1.01	0.04	0.03	4.62	1.53

APPENDIX II

TABLE 20.0 RESULTS FOR HEAVY METALS FOR SOIL SAMPLE A (DRY SEASON)

Sample id	Cu(ppm) ±SD	Fe(ppm) ±SD	Mn(ppm) ±SD	Pb(ppm) ±SD	Cr(ppm) ±SD	Ni(ppm) ±SD	Cd(ppm) ±SD	Zn(ppm) ±SD
1	8.4933 ±0.0022	1377.6361 ±0.438	115.8859 ±0.0755	ND	ND	3.8849 ±0.0006	0.0459 ±0.0008	ND
2	9.2133 ±0.0026	1466.4671 ±0.3946	131.2283 ±0.0833	ND	ND	4.2013 ±0.0015	0.0628 ±0.0007	ND
3	8.34320 ±0.0016	1508.0892 ±0.3898	109.8644 ±0.0618	ND	ND	3.1706 ±0.0012	0.0364 ±0.0002	ND
4	6.0722 ±0.0011	1148.5937 ±0.3341	43.3093 ±0.0272	ND	ND	2.6457 ±0.0006	0.0190 ±0.0002	ND
5	8.7344 ±0.0018	1457.8955 ±0.4013	78.7800 ±0.0449	ND	ND	4.3073 ±0.0009	0.0757 ±0.0002	ND
6	7.1361 ±0.0006	1364.8953 ±0.3522	58.5469 ±0.0333	ND	ND	2.7792 ±0.0001	0.0256 ±0.0008	ND
7	6.2972 ±0.0012	1061.7073 ±0.3219	64.2051 ±0.0405	ND	0.02189 ±0.0002	2.3088 ±0.0004	0.0961 ±0.0003	ND
8	7.4651 ±0.0006	1364.1023 ±0.3747	87.9791 ±0.0535	ND	ND	3.3860 ±0.0007	0.0559 ±0.0002	ND
9	5.7919 ±0.0006	749.3577 ±0.2269	29.8596 ±0.0193	ND	ND	1.7818 ±0.0005	0.0252 ±0.0005	ND
10	6.7740 ±0.0012	1100.6320 ±0.3279	51.3934 ±0.0319	ND	ND	3.5530 ±0.0003	0.0329 ±0.0005	ND
11	6.3625 ±0.0023	1358.1413 ±0.4877	60.8083 ±0.0317	3.1123 ±0.0005	ND	3.1123 ±0.0005	0.0077 ±0.0057	8.8601 ±0.0137
12	1.82 ±0.0018	1074.5475 ±0.3587	39.035 ±0.0188	1.625 ±0.0005	ND	1.935 ±0.0005	ND	3.185 ±0.0043
13	1.8109	914.1667	55.6940	3.1990	ND	4.4701	0.00O7	9.7736

	±0.0018	±0.3069	±0.0276	±0.0003		±0.0006	±0.0006	±0.0124
14	1.3245	825.4125	35.7791	0.7608	ND	3.5976	ND	2.2365
	±0.0012	±0.3005	±0.0188	±0.0003		±0.001		±0.0038
15	2.3692	975.7389	43.9583	0.03150	ND	3.1153	0.0012	4.1715
	±0.0017	±0.3408	±0.0219	±0.0005		±0.001	±0.0005	±0.0053
16	1.6189	761.5353	53.1328	3.0707	ND	2.6624	0.0019	3.0420
	±0.0015	±0.2711	±0.0272	±0.0003		±0.0005	±0.001	±0.0032
17	1.6220	644.6794	50.7799	4.6005	ND	3.7560	0.0005	2.6914
	±0.0011	±0.2259	±0.0254	±0.0006		±0.0003	±0.0001	±0.0047
18	1.3975	589.1127	45.6939	ND	ND	3.2471	ND	2.2872
	±0.001	±0.2076	±0.0231			±0.0006		±0.003
19	1.4153	682.2307	30.1920	5.4873	ND	3.8443	0.0022	2.6077
	±0.0016	±0.2358	±0.0148	±0.0004		±0.0006	±0.0002	±0.0037
20	0.9260	500.1421	35.4018	ND	ND	2.8711	0.0041	2.0260
	±0.0012	±0.1715	±0.0185			±0.0005	±0.0002	±0.0023
21	6.5301	1922.4441	42.5236	ND	0.0944	4.4635	0.0003	39.2524
	±0.0043	±0.6229	±0.0208		±0.0001	±0.0007	±0.0007	±0.0473
22	1.5983	1715.9853	10.1909	ND	3.6492	3.4323	ND	11.5842
	±0.0014	±0.4989	±0.0055		±0.0018	±0.0005		±0.0132
23	5.6724	1880.1740	39.0248	0.7916	0.0906	3.2023	ND	35.6175
	±0.004	±0.6162	±0.0211	±0.0007	±0.0006	±0.0003		±0.0427
24	7.6602	2058.4771	37.9542	ND	0.0916	2.5494	ND	39.6627
	±0.0051	±0.5063	±0.0204		±0.0015	±0.0004		±0.0469
25	6.7946	2029.5036	37.1736	ND	ND	3.9780	0.0003	41.9951
	±0.0043	±0.5417	±0.0188			±0.0004	±0.0004	±0.0493
26	8.7530	2014.7805	43.1066	ND	ND	3.6493	0.0011	49.6310
	±0.0061	±0.5588	±0.0218			±0.0009	±0.0009	±0.059
27	7.4171	1906.8572	31.3206	ND	ND	4.3257	0.0002	34.5054
	±0.0051	±0.5458	±0.0163			±0.0014	±0.0003	±0.0409
28	6.0716	1880.5635	38.2725	ND	ND	4.2818	0.0002	40.4942
	±0.0048	±0.5583	±0.0163			±0.0008	±0.0007	±0.0477
29	5.7061	2066.9379	32.0706	ND	16.7326	4.6420	0.0015	37.3260
	±0.004	±0.6027	±0.0151		±0.0015	±0.0012	±0.0007	±0.0407
30	0.4337	1447.4805	20.5385	ND	ND	3.9644	0.0018	5.4313

	±0.0008	±0.5231	±0.0122			±0.0009	±0.0005	±0.3091
31	4.6237	1076.6131	15.1198	ND	ND	3.8998	0.0029	6.3447
	±0.0008	±0.3583	±0.0102			±0.0006	±0.0006	±0.0032
32	ND	475.9734	7.7871	ND	ND	4.2903	0.0038	12.9916
		±0.3591	±0.0058			±0.0008	±0.0003	±0.0049
33	0.2806	578.2793	6.9268	ND	ND	3.3165	0.0054	1.0916
	±0.0003	±0.1481	±0.0051			±0.0005	±0.0008	±0.0138
34	ND	803.0830	20.8067	ND	ND	3.7714	0.0035	1.8475
		±0.2268	±0.0043			±0.0005	±0.0006	±0.0013
35	ND	550.0438	15.6382	ND	ND	4.2719	0.0070	1.9055
		±0.3017	±0.0119			±0.0012	±0.0009	±0.0024
36	ND	821.7171	28.1906	ND	ND	4.6547	0.0045	2.1665
		±0.2024	±0.0087			±0.0007	±0.0001	±0.0014
37	ND	633.2747	21.6564	ND	ND	2.7852	0.0063	3.3127
		±0.301	±0.0163			±0.0004	±0.0012	±0.0015
38	1.4286	1753.7024	57.3653	ND	ND	3.7395	0.0022	6.3940
	±0.0003	±0.2244	±0.0121			±0.0005	±0.0009	±0.0034
39	3.6938	1524.5108	19.7308	ND	ND	2.7434	0.0020	10.1053
	±0.0019	±0.5783	±0.0254			±0.0007	±0.0003	±0.0074
40	ND	1085.5663	17.8652	ND	ND	2.7618	0.0027	23.8472
		±0.5081	±0.0097			±0.0007	±0.0006	±0.0117
41	0.6330	1252.8620	53.6248	ND	ND	2.7983	0.0009	46.5801
	±0.0009	±0.3792	±0.0095			±0.0007	±0.001	±0.029
42	1.8632	1149.6872	50.9968	ND	ND	3.0221	0.0035	51.8744
	±0.001	±0.4379	±0.0232			±0.0008	±0.001	±0.0582
43	0.9394	1357.3507	45.6870	ND	ND	3.0729	0.0041	53.0224
	±0.0019	±0.4093	±0.0228			±0.0004	±0.0006	±0.0637
44	ND	725.8431	8.1993	ND	ND	3.1335	0.0048	13.1360
		±0.482	±0.021			±0.0007	±0.0003	±0.0658
45	ND	483.0480	6.1507	ND	ND	3.3035	0.0071	2.1310
		±0.2364	±0.00			±0.0006	±0.0002	±0.0128
46	0.6909	1414.5055	47.6466	ND	ND	2.7709	0.0025	42.0154
	±0.0005	±0.1835	±0.0043			±0.0005	±0.0004	±0.0015

47	ND	714.7277 ±0.464	21.0628 ±0.0203	ND	ND	3.1972 ±0.0006	0.0037 ±0.0006	30.1164 ±0.0485
48	ND	1406.9730 ±0.2484	8.5900 ±0.0105	ND	0.8181 ±0.0007	2.5457 ±0.0007	0.0029 ±0.0003	37.2353 ±0.037
49	0.49891 ±0.0006	849.3107 ±0.4748	45.6958 ±0.005	ND	ND	4.3063 ±0.0001	0.0040 ±0.0001	37.7133 ±0.0427
50	ND	67.4184 ±0.3117	ND	ND	ND	3.9811 ±0.0007	0.0505 ±0.0011	14.2270 ±0.0473

TABLE 21.0 RESULT FOR HEAVY METAL STEM SAMPLE A (DRY SEASON)

Sample id	**Cu(ppm) ±SD**	**Fe(ppm) ±SD**	**Mn(ppm) ±SD**	**Pb(ppm) ±SD**	**Cr(ppm) ±SD**	**Ni(ppm) ±SD**	**Cd(ppm) ±SD**	**Zn(ppm) ±SD**
1	3.0579 ±0.0019	25.3978 ±0.011	2.4412 ±0.0028	2.3255 ±0.0003	ND	3.2495 ±0.0006	ND	4.9855 ±0.0125
2	1.9659 ±0.0009	26.1933 ±0.0103	2.4483 ±0.0025	0.6021 ±0.0003	ND	2.8473 ±0.001	ND	3.1483 ±0.0091
3	1.7588 ±0.0008	28.4267 ±0.0117	3.1774 ±0.0035	0.02513 ±0.0005	ND	2.4855 ±0.001	ND	1.0340 ±0.0041
4	1.4446 ±0.0009	20.3243 ±0.009	2.3668 ±0.0029	2.2546 ±0.0003	ND	1.9548 ±0.0005	ND	2.1231 ±0.0066
5	1.8510 ±0.0007	23.2473 ±0.009	1.6859 ±0.0023	3.5704 ±0.0006	ND	2.9150 ±0.0003	ND	0.9933 ±0.0036
6	1.9122 ±0.0005	61.7645 ±0.0245	3.9279 ±0.0039	ND	ND	2.5758 ±0.0006	ND	4.3096 ±0.0098
7	1.4858 ±0.0009	26.5200 ±0.0103	3.2961 ±0.0027	4.0408 ±0.0004	ND	2.8309 ±0.0006	ND	4.1507 ±0.0096
8	2.8671 ±0.0004	21.2292 ±0.009	0.2306 ±0.0014	ND	ND	1.9871 ±0.0005	ND	1.9600 ±0.0054
9	2.2897 ±0.0002	24.8661 ±0.0092	4.5568 ±0.0045	ND	ND	3.3893 ±0.0007	ND	ND

10	2.0399 ±0.0007	24.5597 ±0.0086	2.4708 ±0.0027	ND	ND	2.7399 ±0.0005	ND	10.1242 ±0.0208
11	1.1517 ±0.0006	49.0319 ±0.0213	0.3208 ±0.0013	0.6157 ±0.0007	ND	2.4907 ±0.0003	ND	1.0682 ±0.0027
12	3.3225 ±0.0006	27.2903 ±0.0104	2.1467 ±0.0006	ND	ND	2.1467 ±0.0002	ND)	0.2317
13	1.6201 ±0.0006	31.3308 ±0.014	ND	ND	ND	1.7192 ±0.0004	ND	0.6906 ±0.0014
14	1.7801 ±0.0005	37.7171 ±0.0126	3.1436 ±0.0035	ND	ND	3.1827 ±0.0004	ND	0.6142 ±0.0015
15	1.9821 ±0.0001	38.3320 ±0.0132	3.0477 ±0.0033	ND	ND	3.0080 ±0.0009	ND	2.1610 ±0.0052
16	1.7473 ±0.0005	35.3132 ±0.0126	2.8755 ±0.0033	ND	ND	3.3956 ±0.0014	ND	2.8498 ±0.0069
17	2.2565 ±0.0005	35.8383 ±0.0174	2.5093 ±0.0031	ND	ND	3.4461 ±0.0008	ND	3.4052 ±0.0075
18	1.8061 ±0.0006	32.1243 ±0.0133	2.3709 ±0.0029	ND	ND	3.0890 ±0.0012	ND	1.5362 ±0.0046
19	9.0823 ±0.0005	33.6375 ±0.0084	2.0342 ±0.0028	ND	ND	2.8385 ±0.0009	ND	1.8964 ±0.0043
20	2.1750 ±0.0135	35.8117 ±0.0068	4.2143 ±0.002	ND	ND	3.0219 ±0.0006	ND	4.1976 ±0.0096
21	2.1565 ±0.0007	35.5083 ±0.0109	2.5525 ±0.0026	ND)	ND	3.2063 ±0.0008	ND	3.6041 ±0.0074
22	47.0145 ±0.0006	34.9927 ±0.0098	1.7151 ±0.0023	ND	ND	2.7459 ±0.0005	ND	2.8004 ±0.0058
23	2.6638 ±0.0318	35.8917 ±0.0214	3.1962 ±0.0038	ND	ND	3.0287 ±0.0005	ND	1.3310 ±0.0023
24	2.8820 ±0.0009	37.6729 ±0.0239	1.9910 ±0.0023	ND	ND	3.6225 ±0.0012	ND	3.2571 ±0.007
25	2.3212 ±0.0002	33.3005 ±0.0244	1.6960 ±0.0028	ND	ND	3.3990 ±0.0007	ND	5.1434 ±0.0109
26	2.0369 ±0.0008	31.2192 ±0.0101	ND	ND	ND	1.8977 ±0.0004	ND	3.7710 ±0.0087

27	2.1620 ±0.0007	30.0327 ±0.0093	ND	ND	ND	2.3567 ±0.0005	ND	1.2212 ±0.0021
28	2.4487 ±0.0005	32.9928 ±0.0101	ND	ND	ND	2.0055 ±0.0007	ND	2.1201 ±0.0051
29	2.3475 ±0.0006	34.1862 ±0.0088	ND	ND	ND	2.1791 ±0.0007	ND	1.1933 ±0.0016
30	2.2416 ±0.0003	34.3532 ±0.0089	ND	ND	ND	2.7138	ND	2.6942
31	2.1682 ±0.0006	34.7156 ±0.0136	0.0448 ±0.0011	ND	ND	2.1182 ±0.0007	ND	1.9683 ±0.0029
32	2.4674 ±0.0007	33.6935 ±0.008	0.3496 ±0.0012	ND	ND	2.2466 ±0.0008	ND	1.7497 ±0.0031
33	2.3821 ±0.0005	35.7001 ±0.0134	0.6328 ±0.0015	ND	ND	2.4814 ±0.0004	ND	3.5909 ±0.0078
34	2.4866 ±0.0004	36.0838 ±0.0101	0.5070 ±0.0017	ND	ND	2.3038 ±0.0007	ND	2.1695 ±0.0032
35	2.5546 ±0.0006	34.8840 ±0.0164	0.8088 ±0.0023	ND	ND	2.6204 ±0.0006	ND	2.3138 ±0.004
36	45.2662 ±0.0293	33.7274 ±0.0163	0.9042 ±0.002	ND	ND	1.8670 ±0.0005	ND	2.4447 ±0.0051
37	2.7430 ±0.0005	33.5253 ±0.0116	0.2264 ±0.0013	ND	ND	2.4234 ±0.0006	ND	3.6251 ±0.0074
38	2.7287 ±0.0005	34.2435 ±0.0145	0.1683 ±0.0014	ND	ND	1.7987 ±0.0007	ND	2.5060 ±0.0047
39	2.6281 ±0.0005	34.8719 ±0.0139	0.8085 ±0.0018	ND	ND	3.4072 ±0.001	ND	6.4456 ±0.0238
40	2.7650 ±0.0005	35.2256 ±0.0113	ND	ND	ND	2.9451 ±0.0007	ND	2.6006 ±0.0046
41	36.5718 ±0.0107	32.7725 ±0.0063	ND	ND	ND	1.8142 ±0.0003	ND	2.2633 ±0.0045
42	2.5936 ±0.0007	31.6997 ±0.0053	ND	ND	ND	1.7548 ±0.0003	ND	1.1678 ±0.0011
43	76.0592 ±0.0477	35.9165 ±0.0092	ND	ND	ND	2.0899 ±0.0003	ND	2.1594 ±0.0043

44	42.5083 ±0.0253	37.2311 ±0.0217	ND	ND	ND	1.9556 ±0.0006	ND	3.7948 ±0.0057
45	3.6528 ±0.0011	36.0838 ±0.0158	0.1111 ±0.0012	ND	ND	1.9975 ±0.0002	ND	6.6697 ±0.0137
46	39.0011 ±0.0224	36.6485 ±0.0128	0.1128 ±0.001	ND	ND	1.8231 ±0.0006	ND	1.5266 ±0.0017
47	3.4329 ±0.001	36.2397 ±0.0152	ND	ND	1.0867 ±0.0007	2.0061 ±0.0008	ND	2.8751 ±0.0044
48	51.763±0.0301	37.7191 ±0.0215	ND	ND	1.1311 ±0.0006	2.5150 ±0.0003	2.1011 ±0.0004	2.0618 ±0.0028
49	2.9984 ±0.0013	32.3826 ±0.0191	ND	ND	ND	1.5193 ±0.0002	ND	1.5032 ±0.0015
50	2.7767 ±0.0005	37.9179±0.0103	ND	ND	ND	2.0990 ±0.0005	ND	1.7093 ±0.0019

APPENDIX III

TABLE 22.0 RESULTS FOR HEAVY METALS FOR SOIL SAMPLE B (RAINY SEASON)

Sample id	Cu(ppm) ±SD	Fe(ppm) ±SD	Mn(ppm) ±SD	Pb(ppm) ±SD	Cr(ppm) ±SD	Ni(ppm) ±SD	Cd(ppm) ±SD	Zn(ppm) ±SD
1	0.8309 ±0.0051	365.9753 ±0.5672	19.3590 ±0.0587	3.9950 ±0.0002	ND	1.4064 ±0.0014	0.4599	42.1361 ±0.0453
2	ND	413.8133 ±0.5365	14.9220 ±0.0389	2.5986 ±0.0007	ND	0.9721 ±0.0007	0.0823	4.9395 ±0.0203
3	ND	353.7834 ±0.5106	14.0642 ±0.0405	3.7282 ±0.0004	ND	1.1194 ±0.0011	ND	5.6597 ±0.0344
4	ND	408.9079 ±0.5158	17.5061 ±0.0443	3.8368 ±0.0002	ND	1.4327 ±0.0018	ND	4.2638 ±0.0222
5	0.0929 ±0.0015	391.2777 ±0.5558	22.5002 ±0.0634	4.5102 ±0.0007	ND	1.3558 ±0.0015	ND	4.9910 ±0.0286
6	ND	415.1170 ±0.5147	24.2952 ±0.0611	5.2010 ±0.0014	ND	1.6629 ±0.002	0.0063	3.4686 ±0.0168
7	ND	355.3352 ±0.5197	14.8235 ±0.0421	4.5345 ±0.0005	ND	1.4926 ±0.0017	ND	1.9958 ±0.0101
8	ND	286.6226 ±0.35	11.1406 ±0.0267	5.5586 ±0.0004	ND	1.9204 ±0.0015	0.0830	5.5586 ±0.0276
9	ND	380.7130 ±0.5169	16.1137 ±0.0417	7.0851 ±0.0008	ND	2.0870 ±0.0008	0.0818	4.5925 ±0.023
10	ND	368.0035 ±0.4602	19.6818 ±0.0486	7.9859 ±0.0015	ND	2.1769 ±0.0011	0.0525	9.1851 ±0.0463
11	ND	247.8965 ±0.3555	9.2641 ±0.0229	6.4301 ±0.0008	ND	0.9793 ±0.001	0.0616	4.0088 ±0.021
12	ND	194.6190 ±0.2744	6.9762 ±0.0179	7.13521 ±0.0006	ND	1.3335 ±0.001	0.0059	3.2238 ±0.0147
13	ND	245.0542 ±0.3432	9.0746 ±0.0228	6.8792 ±0.001	ND	1.1267 ±0.001	ND	2.2856 ±0.0087

14	2.6486 ±0.0082	21.3792 ±0.0082	2.1770 ±0.004	6.5709 ±0.0001	ND	1.5064 ±0.0007	ND	3.2011 ±0.0142
15	0.0638 ±0.0011	384.0622 ±0.547	16.3432 ±0.0427	8.2409 ±0.0012	ND	1.4976 ±0.001	0.1123 ±0.0056	6.6694 ±0.0346
16	ND	362.3530 ±0.5005	13.5518 ±0.0354	12.3124 ±0.0006	ND	1.4390 ±0.0013	ND	2.7471 ±0.0104
17	ND	288.2155 ±0.3639	9.7869 ±0.0223	9.8473 ±0.001	ND	1.3246 ±0.0014	ND	2.7189 ±0.0107
18	ND	218.0610 ±0.3146	15.2983 ±0.0416	9.4286 ±0.0003	ND	1.5413 ±0.0013	ND	2.3749 ±0.0106
19	ND	269.2094 ±0.3904	5.5765 ±0.0145	9.2755 ±0.0012	ND	1.5739 ±0.0006	0.0639 ±0.0015	2.9286 ±0.0123
20	ND	216.2825 ±0.2937	6.1718 ±0.0169	8.1248 ±0.0004	ND	2.0568 ±0.0019	ND	1.8578 ±0.0079
21	0.7728 ±0.0019	516.2595 ±0.5241	6.8950 ±0.0154	10.3283 ±0.0008	0.9932 ±0.0012	1.6195 ±0.0009	ND	9.1331 ±0.037
22	ND	395.5787 ±0.5004	2.5757 ±0.0092	5.5965 ±0.0014	0.1892 ±0.0015	1.1783 ±0.0019	ND	4.4759 ±0.0239
23	ND	465.6822 ±0.6465	4.9818 ±0.0159	6.7580 ±0.0002	ND	1.7010 ±0.0011	ND	6.3809 ±0.0349
24	0.4920 ±0.0035	531.6160 ±0.6125	6.7869 ±0.0192	8.0808 ±0.0014	0.3496 ±0.0018	1.8989 ±0.0022	ND	8.9875 ±0.048
25	0.6009 ±0.0033	539.0743 ±0.5657	6.7815 ±0.0184	8.8553 ±0.0003	0.6295 ±0.0017	2.1024 ±0.003	ND	8.4613 ±0.0457
26	0.4218 ±0.003	540.0402 ±0.5933	6.8991 ±0.0197	9.0335 ±0.0011	0.6290 ±0.0015	1.9533 ±0.0016	ND	8.5115 ±0.0453
27	0.5776 ±0.0032	550.2492 ±0.5994	6.5197 ±0.0169	10.9516 ±0.0013	1.4994 ±0.0016	2.3999 ±0.002	ND	8.3550 ±0.0444
28	0.7126 ±0.0037	516.5149 ±0.601	6.4071 ±0.0182	10.7985 ±0.0011	1.1379 ±0.0019	2.3904 ±0.0019	ND	9.4540 ±0.0548
29	0.3186 ±0.0029	542.2973 ±0.5676	6.5763 ±0.0173	10.6485 ±0.0012	1.2014 ±0.0017	2.4248 ±0.0019	ND	9.4437 ±0.0498

30	ND	471.5198 ±0.6121	4.5380 ±0.0131	12.5822 ±0.0008	0.3362 ±0.0013	1.7789 ±0.0013	ND	7.7907 ±0.0429
31	ND	217.4268 ±0.1838	3.1659 ±0.0092	10.9477 ±0.0008	ND	1.5076 ±0.0007	ND	1.1938 ±0.0026
32	ND	120.2446 ±0.1604	1.8323 ±0.0058	9.3312 ±0.0007	ND	1.2649 ±0.0011	ND	0.9063 ±0.0023
33	ND	238.7663 ±0.3293	8.1408 ±0.0227	10.3142 ±0.0003	ND	1.6408 ±0.0014	ND	1.3927 ±0.0045
34	ND	149.5142 ±0.1979	4.0092 ±0.0108	8.1636 ±0.0005	ND	1.7474 ±0.0003	ND	0.8901 ±0.0026
35	ND	154.0725 ±0.2062	4.6099 ±0.0125	10.8666 ±0.001	ND	1.6707 ±0.0008	ND	1.3167 ±0.0028
36	ND	153.0544 ±0.2186	3.9471 ±0.0121	9.0405 ±0.0004	ND	1.4083 ±0.0008	ND	1.2983 ±0.0051
37	ND	182.8811 ±0.2635	6.7638 ±0.0202	8.8967 ±0.0006	ND	1.5498 ±0.0011	ND	1.4896 ±0.004
38	ND	154.7107 ±0.2058	2.5906 ±0.0074	10.8694 ±0.0013	ND	1.7604 ±0.0008	ND	1.3163 ±0.0033
39	ND	230.7958 ±0.3206	10.2858 ±0.0289	10.9816 ±0.0015	ND	1.5123 ±0.0009	ND	1.8511 ±0.0049
40	ND	189.0680 ±0.2555	5.4855 ±0.0151	11.3826 ±0.0004	ND	1.4017 ±0.0008	ND	1.2671 ±0.0033
41	ND	258.8410 ±0.2308	8.3847 ±0.0202	12.8258 ±0.0014	0.4918 ±0.0008	1.9113 ±0.0013	ND	30.7503 ±0.1347
42	ND	331.1405 ±0.4569	5.8492 ±0.0181	10.2178 ±0.0009	ND	1.4080 ±0.0018	ND	9.6514 ±0.0545
43	ND	279.6976 ±0.379	2.7143 ±0.0095	7.6443 ±0.0003	ND	1.0359 ±0.0015	ND	1.6561 ±0.0066
44	ND	140.1375 ±0.1821	2.9077 ±0.0098	9.5941 ±0.0011	ND	1.2340 ±0.0006	ND	2.0910 ±0.0096
45	ND	163.8216 ±0.2176	1.5972 ±0.0053	9.4730 ±0.0014	ND	0.9005 ±0.0009	ND	5.1706 ±0.0279
46	ND	314.9123 ±0.4205	13.3259 ±0.0366	13.7391 ±0.0013	ND	1.3353 ±0.0009	ND	3.6950 ±0.0169

47	ND	290.9827 ±0.385	7.9098 ±0.0222	11.5974 ±0.0011	0.2044 ±0.0004	1.2734 ±0.0013	ND	1.6551 ±0.0061
48	ND	191.3561 ±0.2791	8.4645 ±0.0259	9.8281 ±0.0006	ND	0.7910 ±0.001	ND	1.6380 ±0.0066
49	ND	177.5123± 0.2228	5.0986 ±0.0127	12.0637 ±0.0012	ND	0.7212 ±0.0007	ND	1.3554 ±0.0042
50	ND	247.1436± 0.3364	6.2773 ±0.017	11.4611 ±0.0003	ND	1.3722 ±0.0005	ND	1.9105 ±0.0082

TABLE 23.0 RESULTS FOR HEAVY METALS FOR STEM SAMPLE B (RAINY SEASON)

Sample id	**Cu(ppm) ±SD**	**Fe(ppm) ±SD**	**Mn(ppm) ±SD**	**Pb(ppm) ±SD**	**Cr(ppm) ±SD**	**Ni(ppm) ±SD**	**Cd(ppm) ±SD**	**Zn(ppm) ±SD**
1	26.7920 ±0.0192	94.1121 ±0.0133	5.4177 ±0.0035	2.3707 ±0.0001	0.7884 ±0.0011	4.7288 ±0.0015	ND	8.5280 ±0.0091
2	ND	86.5433 ±0.0293	4.0406 ±0.0035	1.5024 ±0.0006	ND	3.6398 ±0.0005	ND	8.3914 ±0.0081
3	4.6792 ±0.0057	73.8442 ±0.0224	5.1720 ±0.0038	1.1786 ±0.0008	ND	3.6819 ±0.0003	ND	9.1148 ±0.0072
4	ND	73.0470 ±0.0268	4.3548 ±0.0044	1.4972 ±0.0007	1.7742 ±0.0007	2.4509 ±0.0004	ND	8.8903 ±0.0098
5	28.8786 ±0.0208	82.6365 ±0.0292	4.6120 ±0.0043	3.1749 ±0.0011	1.3442 ±0.0007	3.1619 ±0.0003	ND	5.6740 ±0.0044
6	ND	58.1128 ±0.0173	4.7641 ±0.0037	2.9716 ±0.0011	1.9409 ±0.0007	3.8493 ±0.0006	ND	11.7722 ±0.0138
7	13.0130 ±0.0109	52.8525 ±0.0177	4.9405 ±0.0038	1.8799 ±0.0018	0.2669 ±0.0009	2.5207 ±0.0004	ND	10.5337 ±0.013
8	ND	34.1963 ±0.0121	3.6690 ±0.0033	1.7531 ±0.0008	0.2509 ±0.0005	2.8874 ±0.001	ND	4.6287 ±0.0018
9	5.2622 ±0.0059	58.3138 ±0.0193	3.8401 ±0.0037	3.3478 ±0.0006	0.8223 ±0.0009	1.2995 ±0.0005	ND	10.3470 ±0.0123

10	5.1110 ±0.0057	56.0896 ±0.0179	5.0358 ±0.0036	1.8788 ±0.0008	ND	2.0587 ±0.0005	ND	4.4674 ±0.0026
11	4.6236 ±0.0008	25.3988 ±0.0011	2.3474 ±0.0030	1.5432 ±0.0007	ND	2.8537 ±0.002	ND	2.6754 ±0.0123
12	3.0580 ±0.0019	31.9212 ±0.0101	2.5754 ±0.0007	ND	ND	2.8455 ±0.001	ND	0.5674 ±0.0013
13	ND	20.3234 ±0.009	2.7825 ±0.0004	ND	ND	2.9548 ±0.0006	ND	ND
14	ND	62.4567 ±0.0250	2.1013 ±0.0127	ND	ND	1.5984 ±0.0005	ND	ND
15	ND	32.9982 ±0.0111	3.8899 ±0.0006	ND	ND	2.1905 ±0.0004	ND	0.5996 ±0.0014
16	1.9222 ±0.0006	20.5386 ±0.0122	3.7741 ±0.0005	ND	ND	1.8917 ±0.0005	ND	0.6124 ±0.0015
17	2.7160 ±0.0140	29.5896 ±0.0192	2.9045 ±0.0003	ND	ND	3.0008 ±0.0009	ND	1.1238 ±0.0023
18	ND	23.8427 ±0.0117	2.3905 ±0.0032	ND	ND	2.0021 ±0.0007	ND	0.5498 ±0.0012
19	2.5487 ±0.0005	66.1448 ±0.0300	2.6552 ±0.0032	ND	ND	2.5376 ±0.0006	ND	0.4343 ±0.0010
20	ND	48.3019 ±0.0201	2.1565 ±0.0022	ND	ND	1.9778 ±0.0005	ND	0.6121 ±0.0015
21	1.9771 ±0.0009	58.2138 ±0.0192	2.0587 ±0.0032	0.5467 ±0.0005	ND	2.1950 ±0.0002	ND	2.3121 ±0.0123
22	ND	33.2828 ±0.0225	ND	ND	ND	3.2134 ±0.0013	ND	0.3124 ±0.0008
23	ND	26.8443 ±0.0031	ND	ND	ND	1.2345 ±0.0003	ND	0.3312 ±0.0008
24	1.1678 ±0.0011	28.6742 ±0.0108	ND	ND	ND	2.0965 ±0.0006	ND	0.4111 ±0.0007
25	1.7093 ±0.0019	20.4323 ±0.009	ND	ND	ND	1.9098 ±0.0005	ND	0.5129 ±0.0011
26	1.8670 ±0.0005	23.7324 ±0.009	ND	ND	ND	2.4411 ±0.001	ND	0.2109 ±0.0004

27	ND	26.2500 ±0.0103	ND	ND	ND	1.2435 ±0.0004	ND	0.1999 ±0.0003
28	1.9409 ±0.0007	22.1933 ±0.008	ND	ND	ND	1.9986 ±0.0012	ND	ND
29	ND	37.2967 ±0.0229	2.4837 ±0.0031	ND	ND	1.6745 ±0.0007	ND	ND
30	2.9948 ±0.0013	37.7991 ±0.0102	2.2312 ±0.0030	ND	ND	3.3312 ±0.0007	ND	ND
31	9.8032 ±0.0006	32.8362 ±0.0181	2.0311 ±0.0018	ND	ND	2.7687 ±0.0005	ND	0.1465 ±0.0006
32	ND	37.9171 ±0.0216	1.9100 ±0.0022	ND	ND	1.0304 ±0.0005	ND	0.6001 ±0.0003
33	3.5538 ±0.0012	53.2585 ±0.0181	4.8450 ±0.0037	ND	ND	3.3890 ±0.0007	ND	1.9061 ±0.0132
34	3.5097 ±0.0020	52.4323 ±0.0177	3.9531 ±0.0057	ND	ND	3.0541 ±0.0003	ND	0.5332 ±0.0015
35	3.9811 ±0.0007	28.8687 ±0.0208	ND	ND	ND	2.7546 ±0.0005	ND	0.2321 ±0.0012
36	ND	94.2221 ±0.0134	5.7711 ±0.0036	ND	ND	2.1128 ±0.0001	ND	0.4411 ±0.0010
37	ND	35.7000 ±0.0134	3.4412 ±0.0032	ND	ND	2.2811 ±0.0007	ND	0.5954 ±0.0015
38	ND	34.4088 ±0.0164	2.7853 ±0.0030	ND	ND	2.6624 ±0.0008	ND	0.3211 ±0.0013
39	8.2508 ±0.0090	30.2730 ±0.0094	1.9853 ±0.0027	ND	ND	1.8765 ±0.0004	ND	0.2097 ±0.0012
40	14.7022 ±0.0437	20.3244 ±0.009	ND	ND	ND	3.4890 ±0.0014	ND	ND
41	ND	38.2020 ±0.0132	2.4509 ±0.0028	ND	ND	3.2134 ±0.0010	ND	ND
42	ND	49.1930 ±0.0214	2.0097 ±0.0012	ND	ND	3.0765 ±0.0011	ND	0.3208 ±0.0014
43	ND	33.7563 ±0.0067	2.4325 ±0.0032	ND	ND	2.0011 ±0.0007	ND	0.4408 ±0.0017

44	ND	43.9588 ±0.0219	0.5117 ±0.0015	ND	ND	3.3226 ±0.0007	ND	0.6382 ±0.0022
45	ND	32.0607 ±0.0151	1.9078 ±0.0027	ND	ND	1.7473 ±0.0004	ND	0.1638 ±0.0065
46	5.2333 ±0.0058	30.2012 ±0.144	2.0008 ±0.0012	ND	ND	1.5667 ±0.0004	ND	0.4998 ±0.0032
47	3.3522 ±0.0006	39.350 ±0.0189	3.1110 ±0.0031	ND	ND	1.6623 ±0.0005	ND	0.2329 ±0.0044
48	1.6960 ±0.0024	20.3855 ±0.0121	ND	ND	ND	1.4422 ±0.0002	ND	ND
49	ND	78.0087 ±0.0448	3.4213 ±0.0033	ND	ND	3.6234 ±0.0007	ND	ND
50	ND	51.3943 ±0.0319	1.7865 ±0.0017	ND	ND	2.5050 ±0.0003	ND	ND