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EFFECT OF FERTILIZER TYPE AND AGE OF PLANT ON QUALITY OF BEANS OF TWO VARIETIES OF COCOA

BY

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EFFECT OF FERTILIZER TYPE AND AGE OF PLANT ON QUALITY OF BEANS OF TWO VARIETIES OF COCOA

KNUST

A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILISOPHY (MPhil. POSTHARVEST TECHNOLOGY) DEGREE

BY

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OCTOBER, 2015

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NYANSAPƆ WƆSANE NO BADWENMA

DECLARATION

I, hereby, declare that this submission is my own work towards the award of MPhil. Postharvest Technology and that to the best of my knowledge, it contains no material previously published by another author or material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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DEDICATION

I dedicate this work to God the Father, God the Son and God the Holy Spirit.

ACKNOWLEDGEMENT

I thank the Lord God Almighty of Heaven's Armies for His Protection and Guidance throughout my studies.

Special thanks goes to my supervisor, Mr. Patrick Kumah for his support and encouragement. May God keep him and bless him. I am also grateful to my cosupervisor, Dr. Laura Atuah.

To my colleagues, I would like to honour Martha Egyiri and Jessica Kukua Baidoo. To my precious seed, Eugenia Ohemaah Antwi-Bosiako, I say thank you for your support, encouragement and love. May the good Lord favour your lives.

I cannot forget my spiritual father, Mr. Godwin Agyeisaw. May God's favour always abound in your life. Finally to everyone who helped in diverse ways for the success of this work, I say God richly bless you.

ABSTRACT

Yield of cocoa in Ghana over the years keeps on declining despite government's interventions and this is as a result of the inability of some farmers to apply fertilizer on cocoa in their various farms. Soil amendments through the application of granular fertilizer, have made impact in areas where farmers do timely applications at the recommended dosages. However, little information is known about the foliar fertilizers recently introduced into the cocoa industry. This study, therefore, sought to assess the effect of Lithovit, a foliar fertilizer, and two others; Elite(organic) and Asaase wura(inorganic/conventional) edaphic fertilizers, on the physical and chemical qualities of two varieties of cocoa; Amelonado (Tetteh Quarshie) and Hybrid, at two different ages (6 and 8 years). Field work was done at Adansi Brofoyedru in Adansi North District in Ashanti Region of Ghana. Application of the three different types of fertilizers were carried out according to manufacturer's recommendations after which harvesting, fermentation and drying of the cocoa beans were done. The cocoa beans were then taken to the laboratory for physical and chemical assessment. The experimental design used was 2x2x3 factorial. From the study, the conventional fertilizer (Asaase wura) produced cocoa beans with low germinated beans (0.75%), purple beans (15.98%), mouldy beans (0.00%), weevil count (0.00%) and percentage purity (79.75%). Lithovit produced cocoa beans with good FFA content (1.68%), fat content (35.88%) and low moisture content (3.08%). Cocoa beans aged 8 years from the Amelonado (Tetteh Quarshie) variety also had cocoa beans with better quality such as low slaty count (257%: 2.57%), other defects (0.22%: 0.28%) and pH (5.26%: 5.32%) content, respectively, compared to cocoa beans 6 years of age and from the Hybrid variety. Generally, however, cocoa beans from all the treatments had good quality characteristics and were graded as GRADE 1 cocoa beans. The cocoa beans were

within the recommended standard for quality beans and were suitable for export irrespective of the fertilizer type, age of plant or variety of cocoa used.

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TABLE OF CONTENTS

DECLARATION i

DEDICATION ii

ACKNOWLEDGEMENT iii

ABSTRACT iv

LIST OF TABLES x

CHAPTER ONE **1**

1.0 INTRODUCTION 1

CHAPTER TWO **4**

2.0 LITERATURE REVIEW 4

2.1 INTRODUCTION 4

2.2 HISTORY OF COCOA PRODUCTION IN GHANA 4

2.2.1 Origin of Cocoa 4

2.4 CONTRIBUTION OF COCOA PRODUCTION TO THE ECONOMY OF GHANA 6

2.5 ROLE OF COCOA IN THE DEVELOPMENT OF GHANA 7

2.6 CAUSES OF LOW COCOA PRODUCTION IN GHANA 8

CHAPTER THREE **15**

3.0 MATERIALS AND METHODS 15

3.1 FIELD WORK 15

3.1.1 Study Location 15

3.1.2 Application of Fertilizer 15

3.1.3 Harvesting 16
3.1.4 Fermentation.. 16
3.1.5 Experimental Design 17
3.2 LABORATORY WORK 17
3.3.2 Determination of Moisture Content (%MC) 18
3.3.3 Determination of pH.. 18
3.3.4 Determination of Fat Content 18
3.3.5 Determination of Free Fatty Acid (FFA) 19
3.4 DATA ANALYSIS 20

CHAPTER FOUR 21

4.0 RESULTS 21
4.1 PHYSICAL CHARACTERISTICS (CUT TEST) 21
4.1.1 Germinated Beans Count of Cocoa 21
4.1.1.1 Effect of fertilizer type and age of plants on germinated cocoa beans 21
4.1.1.2 Effect of fertilizer type and cocoa variety on germinated cocoa beans 22
4.1.1.3 Effect of fertilizer type, age of plant and cocoa variety on germinated cocoa beans 23
4.1.2 Slaty Bean Count of Cocoa 24
4.1.2.1 Effect of fertilizer type and age of plants on slaty beans count of cocoa 24
4.1.2.2 Effect of fertilizer type and cocoa variety on slaty beans count of cocoa 25
4.1.2.3 Effect of fertilizer type, age of plant and cocoa variety on slaty beans count of cocoa 26
4.1.3 Purple Beans Count of Cocoa 27
4.1.3.1 Effect of fertilizer type and age of plants on purple beans count of cocoa 27
4.1.3.3 Effect of fertilizer type, age of plant and cocoa variety on purple bean count (%) of

cocoa ....
29

4.1.4 Mouldy Bean Count 30

4.1.4.1 Effect of fertilizer type and age of plants on mouldy beans count of cocoa 30
4.1.4.2 Effect of fertilizer type and cocoa variety on mouldy bean count of cocoa 31

4.1.4.3 Effect of fertilizer type, age of plant and cocoa variety on mouldy bean count of cocoa ....
32

4.1.5 Weevil Count in Cocoa Beans 33

4.1.5.1 Effect of fertilizer type and age of plants on weevil count in cocoa beans 33

4.1.5.2 Effect of fertilizer type and cocoa variety on weevil count in cocoa beans 34

4.1.5.3 Effect of fertilizer type, age of plant and cocoa variety on weevil count (%) in cocoa beans 35

4.1.6 Other Defects (Flatty beans) in Cocoa Beans 36

4.1.6.1 Effect of fertilizer type and age of plants on other defects (%) of cocoa beans 36

4.1.6.2 Effect of fertilizer type and cocoa variety on other defects in cocoa beans 37

4.1.6.3 Effect of fertilizer type, age of plant and cocoa variety on other defects in cocoa beans 39

4.1.7 Percentage Purity.. 40

4.1.6.1 Effect of fertilizer type and age of cocoa plants on purity (%) of cocoa beans 40

4.1.7.2 Effect of fertilizer type and cocoa variety on percentage purity of cocoa beans 41

4.1.7.3 Effect of fertilizer type, age of plant and cocoa variety on percentage purity of cocoa beans 42

4.2 BIOCHEMICAL CHARACTERISTICS 43

4.2.1 Free Fatty Acids (FFA) 43

4.2.1.1 Effect of fertilizer type and age of plant on FFA content of cocoa beans 43

4.2.1.2 Effect of Fertilizer Type and Cocoa Variety on FFA Content of Cocoa Beans 44

4.2.1.3 Effect of Fertilizer Type, Age of Plant and Cocoa Variety on FFA Content of Cocoa Beans 45

4.2.2 Fat 46

4.2.2.1 Effect of Fertilizer Type and Age of Plant on Fat content of Cocoa Beans 46

4.2.2.2 Effect of Fertilizer Type and Cocoa Variety on Fat Content of Cocoa Beans 47

4.2.2.3 Effect of Fertilizer Type, Age of Plant and Cocoa Variety on Fat Content of Cocoa Beans 48

4.2.3 pH 49

4.2.3.1 Effect of Fertilizer Type and Age of Plant on pH of Cocoa Beans 49

4.2.3.2 Effect of Fertilizer Type and Cocoa Variety on pH of Cocoa Beans 50

4.2.3.3 Effect of Fertilizer Type, Age of Plant and Cocoa Variety on pH of Cocoa Beans .. 52

4.2.4 Moisture Content 53

4.2.4.1 Effect of Fertilizer Type and Age of Plant on Moisture Content of Cocoa Beans 53

4.2.4.2 Effect of fertilizer type and cocoa variety on moisture content of cocoa beans 54

4.2.4.3 Effect of fertilizer type, age of plant and cocoa variety on moisture content of cocoa beans 55

CHAPTER FIVE 57

5.0 DISCUSSION 57

5.1 PHYSICAL QUALITY (CUT TEST) 57

5.1.1 Germinated Beans 57

5.1.2 Slaty Beans 58

5.1.3 Purple Beans 58

5.1.4 Mouldy Beans 59

5.1.5 Insect (Weevil) Count 60

5.1.6 Other Defects (Flatty beans) in Cocoa Beans 60

5.1.7 Percentage Purity.. 61

5.2 BIOCHEMICAL CHARACTERISTICS 61

5.2.1 Free Fatty Acids (FFA) 61

5.2.2 Fat Content of cocoa beans 62

5.2.3 pH of cocoa beans 63

CHAPTER SIX 65

6.0 CONCLUSION AND RECOMMENDATION 65

6.1 CONCLUSION 65

6.2 RECOMMENDATION 67

REFERENCES 68

APPENDIX 75

LIST OF TABLES

Table 4.1: Effect of fertilizer type and age of plant on germinated cocoa beans (%) 21

Table 4.2 Effect of Fertilizer type and cocoa variety on germinated cocoa beans 22

Table 4.3: Effect of Fertilizer type, age of plant and cocoa variety on germinated cocoa beans . 24

Table 4.4: Effect of fertilizer type and age of plant on slaty beans count (%) of cocoa 25

Table 4.5: Effect of Fertilizer type and cocoa variety on slaty beans count of cocoa 26

Table 4.6: Effect of fertilizer type, age of plant and cocoa variety on slaty beans count of cocoa 27

Table 4.7: Effect of fertilizer type and age of plant on purple beans count (%) of cocoa 28

Table 4.8: Effect of Fertilizer type and cocoa variety on purple beans count (%) of cocoa 29

Table 4.9: Effect of fertilizer type, age of plant and cocoa variety on purple bean count of cocoa

.... 30

Table 4.10: Effect of fertilizer type and age of plant on mouldy beans count (%) of cocoa. 31

Table 4.11: Effect of Fertilizer type and cocoa variety on mouldy beans count (%) of cocoa 32

Table 4.12: Effect of fertilizer type, age of plant and cocoa variety on mouldy bean count of cocoa 33

Table 4.13: Effect of fertilizer type and age of plant on weevil count (%) in cocoa beans. 34

Table 4.14: Effect of Fertilizer type and cocoa variety on weevil count (%) in cocoa beans. 35

Table 4.15: Effect of fertilizer type, age of plant and cocoa variety on weevil bean count (%) of cocoa 36

Table 4.16: Effect of fertilizer type and age of plant on other defects (%) in cocoa beans. 37

Table 4.17: Effect of Fertilizer type and cocoa variety on other defects (%) in cocoa 38

Table 4.18: Effect of fertilizer type, age of plant and cocoa variety on other defects (%) in cocoa 39

Table 4.19: Effect of fertilizer type and age of plant on purity (%) of cocoa beans 40

Table 4.20: Effect of Fertilizer type and cocoa variety on purity (%) of cocoa beans 41

Table 4.21: Effect of fertilizer type, age of plant and cocoa variety on purity (%) of cocoa beans 42

Table 4.22: Effect of fertilizer type and age of plant on FFA (%) content of cocoa beans 43

Table 4.23 Effect of Fertilizer type and cocoa variety on FFA (%) content of cocoa beans 44

Table 4.24: Effect of Fertilizer type, age of plant and cocoa variety on FFA (%) of cocoa beans 45

Table 4.25: Effect of fertilizer type and age of plant on Fat (%) content of cocoa beans 46

Table 4.26: Effect of Fertilizer type and cocoa variety on Fat (%) content of cocoa beans 48

Table 4.27: Effect of Fertilizer type, age of plant and cocoa variety on Fat (%) content of cocoa

beans 49
Table 4.28: Effect of fertilizer type and age of plant on pH of cocoa beans 50
Table 4.29: Effect of Fertilizer type and cocoa variety on pH of cocoa beans 51
Table 4.30: Effect of Fertilizer type, age of plant and cocoa variety on pH of cocoa beans 52
Table 4.31: Effect of fertilizer type and age of plant on moisture content (%) of cocoa beans ... 53
Table 4.32: Effect of Fertilizer type and cocoa variety on moisture content (%) of cocoa beans 55
Table 4.33: Effect of Fertilizer type, age of plant and cocoa variety on moisture content (%) of
cocoa beans 56

CHAPTER ONE

1.0 INTRODUCTION

Agriculture still remains the largest sector in the economy of Ghana and the contribution of the cocoa industry has been the most critical and contribute the largest percentage of agricultural growth. National outputs of cocoa in Ghana have really seen an appreciable increase in the last six years due to the programmatic policies put in place by the Cocoa Research Institute of Ghana in collaboration with the soil society of National Control of Pests and Diseases on all cocoa farms (Yawson *et al.*, 2010).

However, production on farms remain low at 500 kilograms per hectare against potential yields of over 2500 kilograms per hectare. This is as a result of the inability of some farmers to apply fertilizer on cocoa in their various farms. Many farmers in Ghana in the semi-deciduous and high rainfall belts depend on cocoa production as their source of livelihood. A number of other factors account for the low production or yields of cocoa in various fields of farmers. Some of these factors include diseases and pests, occasional drought and poor soil fertility. Soil amendment through the application of granular fertilizer has made impact in areas where farmers do timely application at the recommended dosages. Many farmers do not seem to enjoy the benefits of granular fertilizer application (Asaase wura) because it is tedious and often not affordable to purchase (Ofori, 2010).

The application of foliar fertilizers on the other hand has been considered as a better alternative to the granular fertilizer and the introduction of Lithovit by the COCOBOD is gaining popularity among farmers. The superiority of the foliar fertilizers has, however, not been assessed for different age groups of cocoa in Ghana. The current study therefore seeks to investigate the effect of the foliar fertilizer (Lithovit) on young and old cocoa farms and the quality of cocoa beans in comparison with the granular fertilizer popularly known as Asaasewura.

Yield of cocoa in Ghana over the years keeps on decreasing despite government interventions as a result of leaching of plant nutrients. The result of this is a low income for farmers and hence discouraging them from expanding their farms. Many farmers out of frustration and their quest to make a living abandon cocoa farming for other cash crops, which they think are more profitable and less capital intensive. This is a disincentive to the citizenry who are energetic and may be willing to take up the cocoa farming as a profession or business. The youth, for example, have resulted in searching for non-exiting jobs in sectors such as the emerging oil industry and small scale mining and or illegal mining (galamsey) activities, among others which has aggravated the already worrying situation.

This research, therefore, sought to assess the effect of Lithovit, a foliar fertilizer, and two others; Elite(organic) and Asaase wura(inorganic/conventional) edaphic fertilizers, on the physical and chemical qualities of two varieties of cocoa: Amelonado (Tetteh Quarshie) and Hybrid, at two different ages (6 and 8 years).

Specifically, the research work sought to:

1. Assess the effect of three fertilizer types on the physical characteristics of cocoa beans of the Amelonado (Tetteh Quarshie) and Mixed hybrid varieties of cocoa at two different ages;

2. Assess the effect of three fertilizer types on the chemical properties of cocoa beans of the Amelonado (Tetteh Quarshie) and Mixed hybrid varieties of cocoa at two different ages; and
3. Determine the best age that the different cocoa varieties responded best to the different types of fertilizers that were applied.

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CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

This chapter narrates literature on studies done by other researchers and publications relevant to the current study. It enlightens readers about the historical development of cocoa sector in Ghana. It also looks at the cocoa production and marketing in Ghana, government agricultural intervention policies in the cocoa sector, cocoa and Ghana's economy**,** cocoa yield in Ghana**,** in which comparison of cocoa production in Ghana and other major producing countries are examined. It also reviewed causes of low cocoa production in Ghana just to mention a few.

2.2 HISTORY OF COCOA PRODUCTION IN GHANA

2.2.1 Origin of Cocoa

Cocoa, *Theobroma cacao*, is native from Central and South America. The Mayan civilization began to cultivate cocoa trees over 2000 years ago. Within this civilization, cocoa seeds were given a high value because they were used as currency. Aztec civilization continued with the tradition of making a strong tasting drink called "*xocolatl*" giving energy and vitality. Cocoa was considered food of gods and its uses was reserved for people with high social standing. From the nineteenth century, the cocoa production increased rapidly with the development of the chocolate industry in Europe. Within this context, countries like Brazil and Ecuador became main producers. Later on, during the colonial times in Africa, cocoa cultivations was promoted first to Ghana and then spread through Nigeria, Cameroon and Ivory Coast (https://en.wikipedia.org/wiki/Theobroma_cacao).

In its natural state, the cocoa tree grows to a height of about 10 metres but is pruned to a height of 6 to 7 metres in order to facilitate the plucking of cocoa pods. Its pods grow directly on the branches and main trunk of the tree. The cocoa pods, about 25 cm long, contain about 30 to 40 cocoa beans. About fifty percent of the cocoa bean is a fat, known as cocoa butter, which is of great use in making confectionery (hppt://www.kish.in/cocoa_production_in_ghana/).

Cocoa requires a hot, wet climate. A mean shade temperature of 27°C, with daily variation less than 8°C, and well-distributed rainfall of at least 12 cm, is the ideal climatic conditions for the growth of cocoa. It also needs a well- drained porous soil and a shelter from strong winds and direct rays of the Sun. These conditions are found in the main high forest belt of Ivory Coast and in Ghana, in West Africa and in Brazil. Cocoa is a fairly adaptable crop, and was successfully grown in African countries, though the tree is the native of central and South America
(hppt://www.kish.in/cocoa_production_in_ghana/).

2.3 COCOA YIELD IN GHANA

Although cocoa has been cultivated for centuries in Central America, it is relatively new to Africa, and even more recent in Asia. In 1998, world production reached 2.7 million tons of cocoa beans. Africa holds a dominant position with almost 70% of production volumes, 40% coming from the Cote d'Ivoire. Ghana (15%) and Indonesia (12%) are two other important producers. The average yield is approximately 400 kg of beans/ha/year. Almost

90% of production comes from smallholdings of under 5 hectares, where cultivation is generally extensive. But production structures differ depending on the continent. In Ghana cocoa production occurs in the forested areas: Ashanti Region,

Brong-Ahafo Region, Central Region, Eastern Region, Western Region and Volta Region, where rainfall is 1,000-1,500 millimeters per year (Clark, 1994).

2.4 CONTRIBUTION OF COCOA PRODUCTION TO THE ECONOMY OF GHANA

Cocoa is the single most important agricultural export crop and major source of foreign exchange to Ghana. The crop accounted for 35.1% of agricultural exports and 4.3% of Gross Domestic Product (GDP) in 2007 and contributed to about 63% of the foreign exchange earnings from the agricultural sector and employs about 3.2 million workers including smallholder farm families, farm owners and service providers in Ghana (Baffoe-Asare *et al*., 2012). Again Cocoa continued to be the highest export crop earner for Ghana accounting for 8.2 percent of the country's GDP and 30 percent of total export earnings in 2010 (GAIN, 2012). It has been estimated that in 2010/2011 Ghana's exports of cocoa reached 1 004 000 MT (GAIN, 2012). In terms of world cocoa exports, Ghana has maintained its position as the 2nd largest exporter (by quantity) of cocoa beans for the period of 2005-2011.

The country ranked 8th, 9th and 7th in cocoa butter export in 2005, 2006 and 2009, respectively and moreover, in 2010 exports of cocoa butter and paste to the USA increased dramatically from 32 million USD to 86 million USD, most likely because of the higher quality of cocoa products produced in Ghana (GAIN, 2012). The fact that agriculture (including cocoa) is the driving force of the economy simply means a decline in this sector is likely to lead to a decline in the growth of the economy as a whole.

2.5 ROLE OF COCOA IN THE DEVELOPMENT OF GHANA

Breisinger *et al*. (2008) give some perspective on the role of cocoa in Ghana's development. The objective of their paper was to analyze the role cocoa might play in Ghana's effort to reach a Middle Income Country status, accelerate growth and reduce poverty. The paper confirmed that cocoa is the driver of growth and poverty reduction in Ghana. However, in order to be more effective, Ghana must produce an additional 60,000 tonnes per annum on its current production. The current ramp up in Ghana cocoa production is in part in response to such calls for increased cocoa production.

Breisinger *et al*. (2008) reported that it is unlikely that further growth in the cocoa sector would largely reduce poverty. Reasons such as the geographical concentration of cocoa production and the minute share of cocoa income in the poor's total agricultural income are given as support for their claim of limited potential of cocoa to reduce poverty. They also suggested that without further investment in cocoa processing sector, the country's share will remain below that of countries such as Cote D'Ivoire.

2.6 CAUSES OF LOW COCOA PRODUCTION IN GHANA

Ghana is a power to reckon with, with regard to the creation of cocoa on the planet and the economy depends intensely on the remote trade continuously made from it. However generation levels have not been predictable throughout the years with the exception of the mid-1980s and mid-2000s where the yield appears to have been on track, yet this had a few components of irregularity in it (Dormon *et al*., 2004).

The down pattern has been seen due to various elements. To start with is dry season, which is a noteworthy reason for low level of production of cocoa in the cocoa segment.
Amid this period flames get to be uncontrolled, and this is activated by the exercises of Marijuana smokers, rodent seekers and cultivating practices, for example, slash burn system. These typically cause extreme flame flare-up which can annihilate bunches of cocoa homesteads. This issue has been talked about by Thompson (2005) who argued that the drawn out dry spell in 1980s harmed an expected 30-40 percent increase of cocoa farmers situated in Volta, Ashanti and Brong-Ahafo districts of Ghana bringing on an exceptional decrease in the yield level of cocoa. As a consequence of that, most agriculturists got to be demoralized and deserted their farms, others took the danger and occupied with replanting activity.

Apart from the dry spell, the second element which causes the low cocoa output in Ghana is maturing cocoa trees. MOF (1999), affirmed this with a truth that an expected thirty (30) percent of zone under cocoa development has been useless because of the use of old trees. In addition the quantity of cocoa trees that are developed per hectare has not been encouraging; it has been lower than the prescribed number.

A few measurable systems and models have being utilized as a part of a few studies to examine the reasons for low creation of cocoa in Ghana. For example, in a study by Uwagboe *et al*., (2012), the decrease in efficiency of cocoa is ascribed to a great extent to irritation and maladies. In their examination from financial components in Integrated Pest Management Utilization among cocoa farmers and deliberation on inspecting utilization as a part of picking the respondents, the study uncovered that use of Integrated Pest Management was high (75.0%), which means that most farmers had embraced the method. So also, in the study by Dormon *et al*. (2004), a symptomatic study was done to comprehend agriculturist's perspectives on the issues of cocoa production in three towns in the Suhum-Kraboa Coaltar District, Eastern Region, Ghana. It was inferred that low efficiency was distinguished as the principal issue in the three towns.

The natural components incorporated the frequency of nuisances and illnesses. The financial reasons were circuitous and incorporate the low maker cost and the absence of enhancements like power, which prompts movement, as a consequence of work deficiencies and high work cost. It was further finished up from study that the organic and financial reasons for low efficiency are connected in such a way, to the point that taking them independently will not conquer the issue unless both are handled holistically.

Kyei *et al*., (2011) examined the elements that influence the specialized proficiency of cocoa farmers in the Offinso District in Ghana and the essential financial variables that influence their exhibitions. Examinations demonstrated that the model of creation were measurably noteworthy. Information variables expressed incorporate work, amount of compost, pesticides, present day hardware, time of trees and homestead sizes. It was presumed that work; capital and period of farm would prompt increment in yield. Wastefulness would diminish definitely if variable, for example, instructive level, cultivating background and family size of the farmer are expanded.

Anim-Kwapong and Frimpong (2005), utilizes different relapse investigation to dissect the effect of environmental change on cocoa creation. The numerous examination demonstrated that more than 60 percent of the variety in dry cocoa beans could be clarified by a first's mix year's aggregate yearly precipitation, complete precipitation in the two driest month and aggregate daylight length of time. Different variables that influence cocoa yield included dry spell (delayed dry seasons), low soil fruitfulness, bugs and infections, absence of access to enhance planting materials and low wages of most agriculturists.

2.7 FERTILIZER APPLICATION IN PRODUCTION OF COCOA IN GHANA

According to the Cocoa Research Institute of Ghana (1987), it is stated that yield of cocoa could be increased by 30% by applying fertilizer. However, it is uneconomical to apply fertilizer to young cocoa plants. It is recommended that fertilizer be applied to plantations 10 years and above at two year intervals. For the use of fertilizer to be effective, it must be done with good management practices such as timely weed control, removal of shades and removal of mistletoes. Since the 1980s, the Cocoa Research Institute of Ghana (CRIG) has recommended a single fertilizer formula, called Asase Wura, for the whole country. This formula contains N– 0% , PO–22%, KO-18% and small amounts of calcium, sulfur and magnesium (Appiah *et al*., 2000).

In most cocoa producing countries, cocoa trees are over 50 years old, and the cocoa industry is now facing problems of aging trees and depleted soils because of continuous cropping with little or no added inputs (Hanak-Freud *et al*., 2000). In 1994, the Ghana Cocoa Board estimated that about 72% of farmers in Ghana produced less than 384 kg of cocoa $ha^{-1} \cdot year^{-1}$ without the use of fertilizers, while in the same period, yields of 1,300 kg $ha^{-1}.year^{-1}$ were reported from smallholder farmers who applied fertilizers (Appiah *et al*., 1997). Cocoa production has increased regularly since 2004 (Ruf, 2007). Teal *et al*. (2006) reported that during the same period, farmers increased the recommended amount of fertilizer from 22 to 230 kg ha^{-1}. This suggests that farmers appreciate the use of fertilizers as a way of increasing the profitability of their cocoa plantations.

2.7.1 Fertilizer and its Impact on Cocoa Production

Fertilizers are substances that supply plant nutrients or amend soil fertility and are applied to increase crop yield or quality, as well as sustain soil capacity for future crop production (IFA, 1992). Nutrient management is the key issue in sustainable soil fertility. N, P, K fertilization aims not only for a high economic return of the investment through optimized yield and quality, but also for minimum environmental hazards. The basic concept underlying integrated plant nutrition systems is the maintenance and possible increase of soil fertility for sustaining enhanced crop productivity through optimal use of all sources of plant nutrients, particularly inorganic fertilizer, in an integrated manner and as appropriate to each specific ecological, social and economic situation. Much research has established the importance of fertilizers in increasing the fertility of soil and in influencing its productivity. It has been observed that applying fertilizers causes many changes in the soil, including chemical changes that can positively or negatively influence its productiveness (IFA, 1992).

2.7.2 Global Trend of fertilizer usage

In 2006, the normal utilization of inorganic compost in Africa was 8 kg/ha contrasted with 73 kg/ha in Latin America and 135 kg/ha in Asia (MOFA, 2008). In light of the requirement for higher manure use in Africa, the Africa compost summit was held in Abuja (Nigeria). In 2006, under the support of the African Union (AU), New Partnership for African Development (NEPAD) and the administration of Nigeria. One of the outcome of that summit was the Abuja Declaration on Fertilizer for African Green Revolution, in which AU Member States set out to expand encouraging access to manure by farmers and to raise compost use to a normal of 50 kg/ha by 2015 (AU,2006).

As a prompt measure, the affirmation proposed, among others, the end of duties and taxes on manure and crude materials for compost. The acquaintance of savvy appropriation was with how to make manure progressively settled upon to initiate the statement. The motivation behind the savvy sponsorship was one of the five principle activity guides accessible toward little holder farmers in AU Member States. Altogether, the AU Member States vowed to put 10% of their national spending plan in agribusiness by the year 2008 (AU, 2006). Numerous administrations around the globe have executed compost appropriation projects to raise the level of manure use by little holder agriculturists (Crawford *et al*., 2006; Morris *et al*., 2007).

2.8 QUALITY OF COCOA BEANS

International Cocoa Ordinance specifies the grading criteria and quality categories of commercial cocoa beans (Wood and Lass 1985). Quality is defined by International cocoa trading bodies in terms of degree of fermentation and the extent of defects present, Criteria at fermentation, proportion of broken beans, the degree of mould and insect infestation and other adulteration (Wood and Lass 1985).The quality of cocoa beans exported is an important factor to consider in the cocoa industry since this will affect the quality of the final product. Dried Cocoa beans should be of good quality and free from all forms of off flavours and defectiveness. Defectiveness among cocoa beans includes flat, mouldy and geminated beans (Are and Gwynne-Jones, 1974). Off flavours in dried cocoa beans also include mouldy and smoky flavours. In order to produce good quality chocolate, it is necessary that the dried cocoa beans should not be excessively acidic, bitter or astringent, have a free acid content of less than 1%, moisture content should also be between 6-8 % and beans must be free from live insects, foreign objects, pest residue and harmful bacteria (Amoa- Awua *et al*., 2006). The quality of cocoa can be determined physically by performing a cut test on the dried cocoa beans.

2.10.1 Cut test

According to Boateng (2012), cut test is a physical analysis performed on the dried cocoa beans to assess their quality. Before this is performed, it is necessary that, the cocoa beans are properly fermented and completely dried, should be uniform in size and shape, free from broken beans, fragments and small pieces, free from foreign materials, free from beans of abnormal odour or flavor, free from admixture of any other seeds and impurities, have a moisture content of 6 – 7%. Beans become mouldy when their moisture content is over 8% and brittle when their moisture content falls below 5%. The cut test is performed on 300 beans of cocoa in every given sample. In the determination, beans are cut lengthwise through the middle, in order to expose the maximum cut surface of cotyledons. After cutting the beans lengthwise, the beans are placed on a white board to be examined and graded. Beans are examined for any form of defect.

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CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 FIELD WORK

3.1.1 Study Location

The field experiment was conducted at Adansi Brofoyedru in Adansi North District in Ashanti Region. The field was made up of two varieties of cocoa namely, Hybrid and Amelonado (Tetteh Quarshie) with each variety aged 6 and 8 years.

3.1.2 Application of Fertilizer

An established cocoa farm with two varieties, Amelonado (Tetteh Quarshie) and Hybrid aged 6 and 8 years were selected for the experiment. One hundred and twenty (110) trees

(1/4 of an acre) each were selected for the various treatments; Hybrid cocoa varieties aged 6 years, Hybrid cocoa varieties aged 8 years, Amelonado (Tetteh Quarshie) cocoa varieties aged 6 years and Amelonado (Tetteh Quarshie) cocoa varieties aged 8 years.

The trees were about 3m x 3m apart from each other.

In the treatment with Asaase wura (inorganic/conventional edaphic fertilizer), four hundred and fifty (450) kg of Asaase wura was applied to a hectare of cocoa trees (350 grams per tree). The Asaase wura fertilizer was applied to each tree using the ring method at a distance of 10cm from each tree.

Application of Elite (organic edaphic) fertilizer was at a rate of one thousand (1000) kg per a hectare (890g per tree).

In the application of Lithovit (organic foliar) fertilizer, 30mls of the Lithovit foliar fertilizer was mixed with 15litres of water (i.e. each tank) of a motorized machine. Ten (10) tanks were applied to a hectare of cocoa. The mixture was sprayed each month for six months. Both sides of the leaves were thoroughly sprayed for uniform and effective results.

Each of these treatments was replicated three times.

3.1.3 Harvesting

Cocoa beans from the inner part of each sub-sub plot (40 trees) were harvested at the fully ripped stage. This was done to eliminate trees at the borders of the row which might have been affected by drift of foliar fertilizer and fertilizers leached into the soil. Breaking of the pods was then done two days after harvesting and prepared for fermentation.

3.1.4 Fermentation

Each block of the cocoa pods was fermented separately using the heap fermentation method. Banana leaves were neatly arranged on the ground in a circular pattern for each heap. Short sticks were arranged beneath the banana leaves in the centre to help raise the heap to facilitate easy drainage of the sweating. Each heap was filled with cocoa beans, poured in the centre and covered well to prevent air entry. Short sticks were placed on top of the heap to prevent the top leaves from being blown off. The heap of beans was turned on the third and fifth day to allow proper fermentation. Fermentation was done for 6 days after which they were placed on a mat and dried for 5 days. The beans were then sent to the laboratory for physical and biochemical analysis.

3.1.5 Experimental Design

A 2x2x3 factorial experiment in a randomized complete block design with three (3) replications was used. The experimental factors were two (2) cocoa types; Hybrid and Amelonado (Tetteh Quarshie), two cocoa age groups; 6 and 8 years and three (3) fertilizer types; Asaase wura, Elite and Lithovit.

3.2 LABORATORY WORK

The physical analysis (cut test) was conducted at Quality Control Division at Asokwa junction, Adansi District in Ashanti Region while the biochemical analysis was conducted at Department of Horticulture laboratory at Kwame Nkrumah University of Science and Technology (KNUST), Kumasi.

3.3 PARAMETERS STUDIED

3.3.1 Cut Test

For cut test determination, 300 beans for each of the varieties were used. The beans were cut lengthwise through the middle in order to expose the maximum cut surface of cotyledons. Both halves of each bean were visually examined in normal daylight. Beans were categorized into mouldy, germinated, slaty, purple, weevil, other defects, total mouldy, total slaty, total purple and all other defects. Each defective bean was counted separately and the result for each kind of defect was expressed as a percentage of the 300 beans examined.

3.3.2 Determination of Moisture Content (%MC)

Two (2) g of granular cocoa sample was weighed into a weighed moisture can. The sample was oven-dried overnight at 110^{o}C for 24 hours. The sample in the moisture can then was cooled in a desiccator and re-weighed. The moisture content of the sample was calculated as:

% Moisture = D/B x 100

B = (A+B) – A

D= (A+B) – (A+C) = B – C

Where A = weight of moisture can, B = weight of sample, C = weight of dry sample and D = moisture weight

3.3.3 Determination of pH

The pH meter was calibrated at 20^oC using two buffers (pH 7.00 and 9.00). 40g of powdered cocoa beans was weighed into 100ml beaker and 60mls of boiling distilled water was added. The mixture was left to cool by stirring occasionally. The pH was then measured using the pH meter when the suspension had cooled to 20^oC.

3.3.4 Determination of Fat Content

2g of cocoa beans sample ground and mixed thoroughly was weighed and placed in a filter paper. The filter paper was folded to hold the sample. A piece of cotton wool was placed at the top which evenly distributed the solvent as it dropped on the sample during extraction. The sample packet was placed in the butt tubes of the Soxhlet extraction apparatus. The extraction flask was placed in an oven for about 5 minutes at 110^oC, allowed to cool and then weighed. The fat was extracted with petroleum ether for 2-3 hours without interruption by gentle heating. It was allowed to cool and the extraction flask dismantled. The ether was evaporated on a water bath until no odour of ether remained. It was then cooled at room temperature. The extraction flask and its extract were re-weighed and the weight recorded. Percentage ether extract was calculated as:

% Ether extract = B/C x 100

$$B = (A + B) - A$$

Where A = weight of flask, B = weight of ether extract, C = weight of sample

3.3.5 Determination of Free Fatty Acid (FFA)

Fat from the samples was extracted with petroleum ether (40–60^oC) in a Soxhlet apparatus using the AOAC (2005) method 963.15. FFA of the oils extracted was determined using the IOCCC (1996) method 42-1993. 25ml of 95% ethanol was added to the oil in the flask and 25mls of diethyl ether was added to it. Three (3) drops of phenolphthalein indicator was stirred to mix uniformly. The solution was titrated with 0.1M KOH by swirling constantly until a faint pink colour persisted for 30 seconds. The percentage FFA was determined. The analysis was conducted in triplicates and the mean values calculated as follows:

$$\text{Acid value} = \frac{56.1 \times T \times V}{W}$$

Where T = Concentration of Standardized KOH = 0.1M

V = Volume of KOH used in ml (Titre value)

W = Weight of fat sample (g)

$$\text{Free Fatty Acid} = \frac{\text{Acid Value}}{M}$$

Where M = Molecular weight of fat sample (2.82)

3.4 DATA ANALYSIS

Analysis of variance (ANOVA) was obtained by subjecting data collected to STATISTIX (Version 16.0) software. The differences between treatment means was determined using Tukey's highest significant difference (HSD) at 1% level of significance (p=0.01).

CHAPTER FOUR

4.0 RESULTS

4.1 PHYSICAL CHARACTERISTICS (CUT TEST)

4.1.1 Germinated Beans Count of Cocoa

4.1.1.1 Effect of fertilizer type and age of plants on germinated cocoa beans

The effect of fertilizer type and age of plant on germinated cocoa beans is presented in Table 4.1. From the results, lithovit fertilizer (2.03%) had the highest germinated cocoa beans followed by Elite fertilizer (1.50%) but was not significantly different ($p>0.01$) from each other. Asaase wura fertilizer (0.75%) significantly had the least germinated beans. Eight (8) year old cocoa beans (1.97%) had significantly the highest germinated beans while 6 year old cocoa beans (0.88%) had the least for age of plants.

The interaction between the fertilizer type and age of plant showed significance ($p<0.01$) in germinated beans. Eight (8) year old cocoa beans on which lithovit was applied (2.70%) had the highest germinated beans and was not significantly different ($p>0.01$) from 8 year old cocoa beans on which Elite was applied (1.85%). Six (6) year old cocoa beans on which Asaase wura was applied (0.15%) had the least germinated beans.

Table 4.1: Effect of fertilizer type and age of plant on germinated cocoa beans (%)

Fertilizer types	**Age of plants**		
	6 years	**8years**	**Mean**
Asaase Wura	0.15c*	1.35b	0.75b
Lithovit	1.35b	2.70a	2.03a
Elite	1.15b	1.85ab	1.50a
Mean	0.88b	1.97a	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.1.2 Effect of fertilizer type and cocoa variety on germinated cocoa beans Table 4.2 shows the effect of fertilizer type and variety of cocoa on germinated cocoa beans. The results showed lithovit fertilizer (2.03%) had the highest germinated cocoa beans followed by Elite fertilizer (1.50%) but were not significantly different (p>0.01) from each other. Asaase wura fertilizer (0.75%) significantly had the least germinated beans. For cocoa variety, Amelonado (Tetteh Quarshie) and hybrid varieties had germinated beans of 1.45% and 1.40% respectively with no significant differences

(p>0.01).

Interactively, the effect of fertilizer type and variety of cocoa showed significances

(p<0.01). The highest germinated beans was recorded in Amelonado (Tetteh Quarshie) cocoa beans on which lithovit was applied (2.20%) followed by Amelonado (Tetteh

Quarshie) cocoa beans on which Elite fertilizer was applied (2.00%) but not significantly from each other. The least germinated beans were recorded in Amelonado (Tetteh Quarshie) cocoa beans on which Asaase wura was applied (0.15%)

Table 4.2 Effect of Fertilizer type and cocoa variety on germinated cocoa beans

Fertilizer types	**Varieties of cocoa**		
	Amelonado (Tetteh Quarshie)	**Hybrid**	**Mean**
Asaasewura	0.15c*	1.35ab	0.75b
Lithovit	2.20a	1.85ab	2.03a
Elite	2.00a	1.00bc	1.50a
Mean	1.45a	1.40a	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.1.3 Effect of fertilizer type, age of plant and cocoa variety on germinated cocoa beans

The effect of fertilizer type, age of plant and variety of cocoa on germinated cocoa beans is presented in Table 4.3. There were significant differences (p<0.01) among the interactions.

Eight (8) year old hybrid cocoa beans on which Asaase wura fertilizer was applied, 8 year old Amelonado (Tetteh Quarshie) on which Elite fertilizer and lithovit fertilizer was applied and 8 year old hybrid cocoa beans on which lithovit was applied recorded the highest (2.70%)germinated cocoa beans. The least (no germinated beans; 0.00%) was recorded in both 6 year old hybrid cocoa beans and 8 year old Amelonado (Tetteh Quarshie) cocoa beans on which Asaase wura was applied.

Table 4.3: Effect of Fertilizer type, age of plant and cocoa variety on germinated cocoa beans

VARIETIES	AGE OF PLANT	FERTILIZER TYPES	Germinated beans
AMELONADO (TETTEH QUARSHIE)	6	Elite	1.30abc*
		Lithovit	1.70ab
		Asaase wura	0.30bc
	8	Elite	2.70a
		Lithovit	2.70a
		Asaase wura	2.70a
HYBRID	6	Elite	1.00bc
		Lithovit	1.00bc
		Asaase wura	0.00c
	8	Elite	1.00bc
		Lithovit	2.70a
		Asaase wura	0.00c

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.2 Slaty Bean Count of Cocoa

4.1.2.1 Effect of fertilizer type and age of plants on slaty beans count of cocoa Table 4.4 shows the effect of fertilizer type and age of plant on slaty beans count of cocoa. Significant differences ($p<0.01$) were observed among the fertilizer types. Lithovit fertilizer applied (3.25%) had the highest slaty beans followed by Asaase wura fertilizer applied (2.92%) but were not significantly different from each other. Elite fertilizer applied (1.85%) recorded the least. For the age of plants, 6 year old cocoa beans (2.85%) which recorded the highest was not significantly different ($p>0.01$) from the 8 year old cocoa beans (2.50%) which had the least slaty beans.

The effect of fertilizer type and age of plants on slaty beans count of cocoa showed significance ($p<0.01$). The highest slaty beans was recorded in 8 year old cocoa beans on which lithovit was applied (3.50%) while the least was recorded in 8 year old cocoa beans on which Elite was applied (1.00%) but not significantly different ($p>0.01$) from 6 year old cocoa beans on which Elite was applied (2.70%).

Table 4.4: Effect of fertilizer type and age of plant on slaty beans count (%) of cocoa

Fertilizer types	**Age of plants**		
	6 years	**8years**	**Mean**
Asaase Wura	2.85a*	3.00a	2.93a
Lithovit	3.00a	3.50a	3.25a
Elite	2.70ab	1.00b	1.85b
Mean	2.85a	2.57a	

*Figures on the same column followed by the same letters are not significantly different ($p=0.01$)

4.1.2.2 Effect of fertilizer type and cocoa variety on slaty beans count of cocoa Table 4.5 shows the effect of fertilizer type and cocoa variety on slaty beans count of cocoa. From the results, Lithovit fertilizer applied (3.25%) had the highest slaty count cocoa beans followed by Asaase wura fertilizer applied (2.93%) but was not significantly different ($p>0.01$) from each other. Elite fertilizer applied (1.85%) significantly had the least slaty count cocoa beans. Amelonado (Tetteh Quarshie) and hybrid varieties had 2.57% and 2.78% of slaty count of cocoa beans respectively but showed no significant differences ($p>0.01$).

Interactively, effect of fertilizer type and variety of cocoa on slaty beans count showed no significant differences ($p<0.01$). However, the highest slaty bean count was recorded in hybrid cocoa bean on which lithovit was applied (3.50%). The least slaty bean count were recorded in both hybrid and Amelonado (Tetteh Quarshie) cocoa varieties on which Elite was applied (1.85%).

Table 4.5: Effect of Fertilizer type and cocoa variety on slaty beans count of cocoa

Fertilizer types	**Varieties of cocoa**		
	Amelonado (Tetteh Quarshie)	**Hybrid**	**Mean**
Asaase wura	2.85a*	3.00a	2.93a
Lithovit	3.00a	3.50a	3.25a
Elite	1.85a	1.85a	1.85b
Mean	2.57a	2.78a	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.2.3 Effect of fertilizer type, age of plant and cocoa variety on slaty beans count of cocoa

The effect of fertilizer type, age of plant and cocoa variety on slaty beans count cocoa is presented in Table 4.6. There were significant differences ($p<0.01$) among the interaction. Eight (8) year old hybrid cocoa variety on which lithovit fertilizer was applied (4.00%) had the highest slaty beans count of cocoa. The least (1.00%) slaty beans count was recorded in 8 year old Amelonado (Tetteh Quarshie) and hybrid varieties on which Elite fertilizer was applied.

Table 4.6: Effect of fertilizer type, age of plant and cocoa variety on slaty beans count of cocoa

VARIETIES	AGE OF PLANT	FERTILIZER TYPES	Slaty count
AMELONADO (TETTEH QUARSHIE)	**6**	**Elite**	2.70ab*
		Lithovit	3.00ab
		Asaase wura	2.70ab
	8	**Elite**	1.00b
		Lithovit	3.00ab
		Asaase wura	3.00ab
HYBRID	**6**	**Elite**	2.70ab
		Lithovit	3.00ab
		Asaase wura	3.00ab
	8	**Elite**	1.00b
		Lithovit	4.00a
		Asaase wura	3.00ab

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.3 Purple Beans Count of Cocoa

4.1.3.1 Effect of fertilizer type and age of plants on purple beans count of cocoa

Table 4.7 shows the effect of fertilizer type and age of plants on purple beans of cocoa. From the results, no significant difference (p>0.01) was observed among the individual effects. Purple bean count of asaase wura, lithovit and Elite fertilizers applied were 15.93%, 17.58% and 17.67% respectively while 6year old and 8 year old cocoa beans had purple count of 17.45% and 16.66% respectively.

There were also no significant difference (p>0.01) among the effect of fertilizer type and age of plants on purple beans count of cocoa. However, 6 year old cocoa on which Elite fertilizer was applied (19.35%) had the highest count of purple beans while 6 year old cocoa on which Asaase wura fertilizer was applied (15.85%) had the least count.

Table 4.7: Effect of fertilizer type and age of plant on purple beans count (%) of cocoa

Fertilizer types	**Age of plants**		
	6 years	**8years**	**Mean**
Asaase Wura	15.85a*	16.00a	15.93a
Lithovit	17.15a	18.00a	17.58a
Elite	19.35a	15.98a	17.67a

Mean	17.45a	16.66a

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.3.2 Effect of fertilizer type and cocoa variety on purple bean count of cocoa

The effect of fertilizer type and cocoa variety on purple beans of cocoa is presented in Table 4.8. From the results, no significant difference (p>0.01) was observed among the individual effects. Purple bean count of asaase wura, lithovit and Elite fertilizers applied were 15.93%, 17.58% and 17.67% respectively while Amelonado (Tetteh Quarshie) and hybrid cocoa beans had purple bean count of 16.67% and 17.43% respectively.

The effect of fertilizer type and age of plants on purple beans count of cocoa showed no significant differences (p>0.01). However, hybrid cocoa variety on which Elite fertilizer was applied (19.15%) had the highest count of purple beans while Amelonado (Tetteh Quarshie) cocoa variety on which Asaase wura fertilizer was applied (15.85%) had the least count.

Table 4.8: Effect of Fertilizer type and cocoa variety on purple beans count (%) of cocoa

Fertilizer types	**Varieties of cocoa**		
	Amelonado (Tetteh Quarshie)	**Hybrid**	**Mean**
Asaase wura	15.85a*	16.00a	15.93a
Lithovit	18.00a	17.15a	17.58a
Elite	16.18a	19.15a	17.67a
Mean	16.68a	17.43a	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.3.3 Effect of fertilizer type, age of plant and cocoa variety on purple bean count (%) of cocoa

The effect of fertilizer type, age of plant and cocoa variety on purple beans count of cocoa is presented in Table 4.9. There were no significant differences ($p<0.01$) among the interaction. However, the highest (20.00%) purple beans count was recorded in 6 year old hybrid cocoa beans on which Elite fertilizer was applied and 8 year old Amelonado (Tetteh Quarshie) cocoa beans on which lithovit was applied. The least (13.67%) purple beans count was recorded in 8 year old Amelonado (Tetteh Quarshie) variety on which Elite fertilizer was applied.

Table 4.9: Effect of fertilizer type, age of plant and cocoa variety on purple bean count of cocoa

VARIETIES	AGE OF PLANT	FERTILIZER TYPES	Purple count
AMELONADO (TETTEH QUARSHIE)	6	Elite	18.70a*
		Lithovit	16.00a
		Asaase wura	16.70a
	8	Elite	13.67a
		Lithovit	20.00a
		Asaase wura	15.00a
HYBRID	6	Elite	20.00a
		Lithovit	18.30a
		Asaase wura	15.00a
	8	Elite	18.30a

Lithovit	16.00a
Asaase wura	17.00a

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.4 Mouldy Bean Count

4.1.4.1 Effect of fertilizer type and age of plants on mouldy beans count of cocoa Table 4.10 shows the effect of fertilizer type and age of plants on mouldy bean count of cocoa. Significant differences ($p<0.01$) were observed among the individual effects. Lithovit fertilizer applied had the highest (0.25%) mould bean count followed by Asaase wura and Elite fertilizers the least with no mould count (0.00%). For the age of plants, 8 year old cocoa beans had the highest mould bean count of 0.17% while 6 year old cocoa beans recorded no mould count (0.00%).

Effect of fertilizer type and age of plants on mouldy bean count of cocoa showed significance ($p<0.01$). The highest (0.50%) mouldy bean count was recorded in 8 year old cocoa beans on which lithovit fertilizer was applied. Six (6) year old cocoa beans on which asaase wura, lithovit and Elite fertilizers were applied as well as 8 year old cocoa beans on which Asaase wura and Elite fertilizers were applied recorded no bean count (0.00%).

Table 4.10: Effect of fertilizer type and age of plant on mouldy beans count (%) of cocoa.

Fertilizer types	Age of plants		
	6 years	8years	Mean
Asaase Wura	0.00b*	0.00b	0.00b
Lithovit	0.00b	0.50a	0.25a
Elite	0.00b	0.00b	0.00b
Mean	0.00b	0.17a	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.4.2 Effect of fertilizer type and cocoa variety on mouldy bean count of cocoa Table 4.11 shows the effect of fertilizer type and cocoa variety on mouldy beans count of cocoa. Lithovit fertilizer applied had significantly the highest mouldy bean count followed by both Asaase wura and Elite fertilizers which had no mouldy bean count (0.00%). For varieties of cocoa beans, hybrid variety had the highest mouldy bean count with Amelonado (Tetteh Quarshie) variety recording the least.

The effect of fertilizer type and cocoa variety on mouldy beans count of cocoa was significantly different ($p<0.01$) from each other. Hybrid cocoa variety on which lithovit was applied had the highest (0.35%) mould bean count followed by Amelonado (Tetteh Quarshie) on which lithovit was applied (0.15%). Both Amelonado (Tetteh Quarshie) and hybrid cocoa varieties on which Elite and Asaase wura varieties were applied had no record (0.00%) of mouldy bean count.

Table 4.11: Effect of Fertilizer type and cocoa variety on mouldy beans count (%) of cocoa

Fertilizer types	Varieties of cocoa		
	Amelonado (Tetteh	**Hybrid**	**Mean Quarshie)**
Asaase wura	0.00c*	0.00c	0.00b
Lithovit	0.15b	0.35a	0.25a
Elite	0.00c	0.00c	0.00b
Mean	0.05b	0.12a	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.4.3 Effect of fertilizer type, age of plant and cocoa variety on mouldy bean count of cocoa

The effect of fertilizer type, age of plant and cocoa variety on mouldy bean count of cocoa is presented in Table 4.12. There were significant differences ($p<0.01$) among the interactions. The highest mouldy bean count was recorded in 8 year old hybrid cocoa on which lithovit applied (0.70%) was followed by 8 year old Amelonado (Tetteh Quarshie) cocoa on which lithovit was applied (0.30%). Six (6) and 8 year old hybrid and Amelonado (Tetteh Quarshie) varieties on which Asaase wura and Elite fertilizers were applied and 6 year old Amelonado (Tetteh Quarshie) and hybrid varieties on which lithovit was applied recorded no mould bean count (0.00%).

Table 4.12: Effect of fertilizer type, age of plant and cocoa variety on mouldy bean count of cocoa

VARIETIES	AGE OF PLANT	FERTILIZER TYPES	Mould Count

AMELONADO (TETTEH QUARSHIE)	**6**	**Elite**	0.00c*
		Lithovit	0.00c
		Asaase wura	0.00c
	8	**Elite**	0.00c
		Lithovit	0.30b
		Asaase wura	0.00c
HYBRID	**6**	**Elite**	0.00c
		Lithovit	0.00c
		Asaase wura	0.00c
	8	**Elite**	0.00c
		Lithovit	0.70a
		Asaase wura	0.00c

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.5 Weevil Count in Cocoa Beans

4.1.5.1 Effect of fertilizer type and age of plants on weevil count in cocoa beans The effect of fertilizer type and age of plant on weevil count in cocoa beans is presented in Table 4.13. Elite fertilizer applied (0.08%) significantly had the highest weevil count while lithovit and Elite fertilizers applied had no record (0.00%) of weevil count. Six (6) year old cocoa beans (0.05%) had significantly the highest weevil count for the age of plants while 8 year old cocoa bean had no record (0.00%).

Interaction between fertilizer type and age of plant on weevil count in cocoa beans showed significance ($p<0.01$). Six (6) year old cocoa beans on which Elite was applied (0.15%) had the highest weevil count. Six (6) year old cocoa beans on which Asaase wura and lithovit was applied and 8 year old cocoa beans on which asaase wura, lithovit and Elite fertilizers were applied recorded no weevil count (0.00%).

Table 4.13: Effect of fertilizer type and age of plant on weevil count (%) in cocoa beans.

Fertilizer types	**Age of plants**		
	6 years	**8years**	**Mean**
Asaase Wura	0.00b*	0.00b	0.00b
Lithovit	0.00b	0.00b	0.00b
Elite	0.15a	0.00b	0.08a
Mean	0.50a	0.00b	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.5.2 Effect of fertilizer type and cocoa variety on weevil count in cocoa beans Table 4.14 shows the effect of fertilizer type and cocoa variety on weevil count in cocoa beans. Elite fertilizer applied (0.08%) significantly had the highest weevil count while lithovit and Elite fertilizers applied had no record (0.00%) of weevil count. Amelonado (Tetteh Quarshie) cocoa beans (0.05%) had significantly the highest weevil count for the varieties of cocoa while hybrid cocoa beans had no record (0.00%).

The effect of fertilizer type and cocoa variety on weevil count of cocoa showed significance ($p<0.01$). Amelonado (Tetteh Quarshie) cocoa beans on which Elite was applied (0.15%)

had the highest weevil count. Amelonado (Tetteh Quarshie) cocoa beans on which Asaase wura and lithovit was applied and hybrid cocoa beans on which asaase wura, lithovit and Elite fertilizers were applied recorded no weevil count (0.00%).

Table 4.14: Effect of Fertilizer type and cocoa variety on weevil count (%) in cocoa beans.

Fertilizer types	Varieties of cocoa		
	Amelonado (Tetteh Quarshie)	Hybrid	Mean
Asaase wura	0.00b*	0.00b	0.00b
Lithovit	0.00b	0.00b	0.00b
Elite	0.15a	0.00b	0.08a
Mean	0.05a	0.00b	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.5.3 Effect of fertilizer type, age of plant and cocoa variety on weevil count (%) in cocoa beans

The effect of fertilizer type, age of plant and cocoa variety on weevil count in cocoa beans is presented in Table 4.15. There were significant differences ($p<0.01$) among the interactions. The highest weevil count was recorded in 6 year old Amelonado (Tetteh Quarshie) cocoa on which Elite was applied (0.30%). Eight (8) year old hybrid and Amelonado (Tetteh Quarshie) varieties on which asaase wura, Elite and lithovit fertilizers were applied and 6 year old Amelonado (Tetteh Quarshie) and hybrid varieties on which lithovit and Asaase wura was applied recorded no weevil count (0.00%).

Table 4.15: Effect of fertilizer type, age of plant and cocoa variety on weevil bean count (%) of cocoa

VARIETIES	AGE OF PLANT	FERTILIZER TYPES	Weevil Count
AMELONADO (TETTEH QUARSHIE)	**6**	**Elite**	0.30a*
		Lithovit	0.00b
		Asaase wura	0.00b
	8	**Elite**	0.00b
		Lithovit	0.00b
		Asaase wura	0.00b
HYBRID	**6**	**Elite**	0.00b
		Lithovit	0.00b
		Asaase wura	0.00b
	8	**Elite**	0.00b
		Lithovit	0.00b
		Asaase wura	0.00b

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.6 Other Defects (Flatty beans) in Cocoa Beans

4.1.6.1 Effect of fertilizer type and age of plants on other defects (%) of cocoa beans

Table 4.16 shows the effect of fertilizer type and age of plant on other defects of cocoa. Asaase wura fertilizer applied (0.68%) had significantly the highest mean for other defects (flatty beans) followed by lithovit fertilizer applied (0.18%) and then Elite fertilizer applied (0.08%) which were not significantly different (p>0.01) from each other. For the age of plants, 6 year old cocoa beans (0.40%) had significantly the higher mean for other defects (flatty beans) while 8 year old cocoa beans (0.22%) had the least.

The effect of fertilizer type and age of plant on other defects of cocoa showed significant differences (p<0.01). Asaase wura applied on 6 year old cocoa beans (0.85%) had the highest mean for other defects followed by Asaase wura applied on 8 year old cocoa beans (0.50%). Elite applied on 6 year old cocoa beans and lithovit applied on 8 year old cocoa beans had no record (0.00%) of other defects.

Table 4.16: Effect of fertilizer type and age of plant on other defects (%) in cocoa beans.

Fertilizer types	**Age of plants**		
	6 years	**8years**	**Mean**
Asaase Wura	0.85a*	0.50b	0.68a
Lithovit	0.35bc	0.00d	0.18b
Elite	0.00d	0.15cd	0.08b
Mean	0.40a	0.22b	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.6.2 Effect of fertilizer type and cocoa variety on other defects in cocoa beans The effect of fertilizer type and cocoa variety on other defects in cocoa beans is presented in Table 4.17. Asaase wura fertilizer applied (0.68%) had significantly the highest other defects followed by lithovit fertilizer applied (0.18%) and then Elite fertilizer applied

(0.08%) which were not significantly different (p>0.01) from each other. For varieties of cocoa, Amelonado (Tetteh Quarshie) and hybrid cocoa beans had 0.28% and 0.33% other defects respectively and were not significantly different (p>0.01) from each other.

Interactively, the effect of fertilizer type and cocoa variety on other defects in cocoa beans, were significantly different (p<0.01) from each other. Asaase wura applied on Amelonado (Tetteh Quarshie) cocoa beans (0.85%) had the highest other defects followed by Asaase wura applied on hybrid cocoa beans (0.50%). Elite applied on Amelonado (Tetteh Quarshie) cocoa beans and lithovit applied on Amelonado (Tetteh Quarshie) cocoa beans had no record (0.00%) of other defects.

Table 4.17: Effect of Fertilizer type and cocoa variety on other defects (%) in cocoa

Fertilizer types	Varieties of cocoa		
	Amelonado (Tetteh Quarshie)	**Hybrid**	**Mean**
Asaase wura	0.85a*	0.50b	0.68a
Lithovit	0.00d	0.35bc	0.18b
Elite	0.00d	0.15cd	0.08b
Mean	0.28a	0.33a	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.6.3 Effect of fertilizer type, age of plant and cocoa variety on other defects in cocoa beans

Table 4.18 shows the effect of fertilizer type, age of plant and cocoa variety on other defects in cocoa beans. There were significant differences ($p<0.01$) among the interactions. Both 6 and 8 year old Amelonado (Tetteh Quarshie) and hybrid on which Asaase wura fertilizer was applied had the highest other defects (1.00%). Six (6) year old hybrid on which Elite fertilizer was applied, 6 year old Amelonado (Tetteh Quarshie) on which lithovit fertilizer was applied, 8 year old hybrid on which Asaase wura fertilizer was applied, 8 year old Amelonado (Tetteh Quarshie) on which Elite fertilizer was applied and 8 year old Amelonado (Tetteh Quarshie) and hybrid on which lithovit fertilizer was applied recorded no other defects (0.00%).

Table 4.18: Effect of fertilizer type, age of plant and cocoa variety on other defects (%) in cocoa

VARIETIES	AGE OF PLANT	FERTILIZER TYPES	Other defects
AMELONADO (TETTEH QUARSHIE)	**6**	**Elite**	0.00c*
		Lithovit	0.00c
		Asaase wura	0.70ab
	8	**Elite**	0.00c
		Lithovit	0.00c
		Asaase wura	1.00a
HYBRID	**6**	**Elite**	0.00c
		Lithovit	0.70ab
		Asaase wura	1.00a
	8	**Elite**	0.30bc
		Lithovit	0.00c
		Asaase wura	0.00c

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.7 Percentage Purity

4.1.6.1 Effect of fertilizer type and age of cocoa plants on purity (%) of cocoa beans

Table 4.19 shows the effect of fertilizer type and age of cocoa plants on purity of cocoa beans. From the results, 6 year old cocoa plant (78.17%) was not significantly different from 8 year old cocoa plant. For the fertilizer types, cocoa plants on which Asaase wura was applied recorded significantly the highest purity percentage (79.75%) than cocoa plants on which lithovit (77.08%) and Elite (77.58%) fertilizers were applied.

The interaction between the fertilizer type and age of cocoa plants showed significance ($p<0.01$).

Six (6) year old cocoa plant on which Asaase wura was applied had the highest percentage purity of 80.35% while 6 year and 8 year old cocoa plant on which Elite and lithovit were applied respectively had the least (76.00%) percentage purity.

Table 4.19: Effect of fertilizer type and age of plant on purity (%) of cocoa beans

Fertilizer types	**Age of plants**		
	6 years	**8years**	**Mean**
Asaase Wura	80.35a*	79.51ab	79.75a
Lithovit	78.15b	76.00c	77.08b
Elite	76.00c	79.15ab	77.58b
Mean	78.17a	78.10a	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.1.7.2 Effect of fertilizer type and cocoa variety on percentage purity of cocoa beans

From the results (Table 4.20), Amelonado (Tetteh Quarshie) cocoa varieties (78.50%) was not significantly different ($p>0.01$) from hybrid cocoa varieties (77.77%) for percentage purity. However, cocoa plants on which Asaase wura was applied recorded significantly the highest purity percentage (79.75%) than cocoa plants on which lithovit (77.08%) and Elite (77.58%) fertilizers were applied.

There were significant differences ($p<0.01$) in percentage purity for the interaction between the fertilizer type and cocoa variety. The highest percentage purity was recorded in Amelonado (Tetteh Quarshie) variety on which Asaase wura was applied while the least was recorded in Amelonado (Tetteh Quarshie) and hybrid varieties on which lithovit and Elite fertilizers were applied respectively.

Table 4.20: Effect of Fertilizer type and cocoa variety on purity (%) of cocoa beans

Fertilizer types	Varieties of cocoa		
	Amelonado (Tetteh Quarshie)	**Hybrid**	**Mean**
Asaase wura	80.35a*	79.15ab	79.75a
Lithovit	76.65c	77.50bc	77.08b
Elite	78.70abc	76.65c	77.58b
Mean	78.50a	77.77a	

*Figures on the same column followed by the same letters are not significantly different ($p=0.01$)

4.1.7.3 Effect of fertilizer type, age of plant and cocoa variety on percentage purity of cocoa beans

The effect of fertilizer type, age of plant and cocoa variety on percentage purity of cocoa beans is shown in Table 4.21. From the results, significant differences ($p<0.01$) were observed among the various treatments. Eight (8) year old Amelonado (Tetteh Quarshie) on which Asaase wura was applied and 6 year old Hybrid on which Asaase wura was applied had the highest (81.00%) percentage purity. The least percentage purity (74.00%) was recorded in 8 year old Amelonado (Tetteh Quarshie) cocoa plant on which lithovit was applied.

Table 4.21: Effect of fertilizer type, age of plant and cocoa variety on purity (%) of cocoa beans

VARIETIES	AGE OF PLANT	FERTILIZER TYPES	Percentage Purity
AMELONADO (TETTEH QUARSHIE)	**6**	**Elite**	77.07b*
		Lithovit	79.30ab
		Asaase wura	79.7ab
	8	**Elite**	79.30ab
		Lithovit	74.00d
		Asaase wura	81.00a
HYBRID	**6**	**Elite**	74.30cd
		Lithovit	77.00bcd
		Asaase wura	81.00a
	8	**Elite**	79.00ab
		Lithovit	78.00ab
		Asaase wura	77.70bc

*Figures on the same column followed by the same letters are not significantly different ($p=0.01$)

4.2 BIOCHEMICAL CHARACTERISTICS

4.2.1 Free Fatty Acids (FFA)

4.2.1.1 Effect of fertilizer type and age of plant on FFA content of cocoa beans

Table 4.22 shows the effect of fertilizer type and age of plant on FFA of cocoa beans. From the results, there were no significant differences (p>0.01) among the individual effects. However, the highest FFA content was recorded when Asaase wura fertilizer was applied (1.83%), followed by Elite fertilizer (1.72%) with lithovit fertilizer (1.68%) recording the least. For the age of plants, 8 year cocoa plant had the highest (1.77%) FFA content while 6year old cocoa plant had the least (1.72%).

The effect between the fertilizer type and age of plant also showed no significance (p>0.01). The FFA content in the beans ranged from 1.71%- 1.84% and 8 year cocoa plant on which Asaase wura fertilizer was applied recorded the highest FFA (1.84%) content while 6 year old cocoa plant on which Elite fertilizer was applied (1.71%) recording the least.

Table 4.22: Effect of fertilizer type and age of plant on FFA (%) content of cocoa beans

Fertilizer types	Age of plants		
	6 years	8years	Mean
Asaase Wura	1.82a*	1.84a	1.83a
Lithovit	1.64a	1.72a	1.68a
Elite	1.71a	1.73a	1.72a
Mean	1.72a	1.77a	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.2.1.2 Effect of Fertilizer Type and Cocoa Variety on FFA Content of Cocoa Beans

The effect of fertilizer type and cocoa varieties are shown in Table 4.23. Fertilizer types individually showed no significant difference as well as varieties of cocoa. However, the application of Asaase wura fertilizer (1.83%) gave cocoa beans with the highest FFA contents followed by Elite fertilizer (1.72%) with lithovit fertilizer recording the least. Amelonado (Tetteh Quarshie) variety (1.78%) recorded the highest FFA content while Hybrid variety (1.71%) recorded the least.

Interactively, no significant differences ($p>0.01$) were observed among the fertilizer types and cocoa varieties. However, the highest FFA content was recorded in hybrid variety (1.85%) on which Asaase wura fertilizer was applied while the least was recorded in hybrid variety on which lithovit fertilizer was applied.

Table 4.23 Effect of Fertilizer type and cocoa variety on FFA (%) content of cocoa beans

Fertilizer types	Varieties of cocoa		
	Amelonado (Tetteh Quarshie)	Hybrid	Mean
Asaase wura	1.81a*	1.85a	1.83a
Lithovit	1.81a	1.55a	1.68a
Elite	1.72a	1.72a	1.72a
Mean	1.78a	1.71a	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.2.1.3 Effect of Fertilizer Type, Age of Plant and Cocoa Variety on FFA Content of Cocoa Beans

Table 4.24 shows the effect of fertilizer type, age of plant and cocoa variety on FFA content of cocoa beans. From the results, no significant differences were observed among the interactions. However, marginally, the highest FFA content was recorded in 8 year old Amelonado (Tetteh Quarshie) cocoa plant on which lithovit fertilizer was applied (1.94%) followed by 8 year old Hybrid cocoa plant on which Asaase wura fertilizer was applied (1.90%) while the least FFA content was recorded in 8 year old Hybrid cocoa plant on which lithovit fertilizer was applied (1.50%).

Table 4.24: Effect of Fertilizer type, age of plant and cocoa variety on FFA (%) of cocoa beans

VARIETIES	AGE OF PLANT	FERTILIZER TYPES	Free Fatty Acid (%)
AMELONADO (TETTEH QUARSHIE)	**6**	**Elite**	1.63a*
		Lithovit	1.68a
		Asaase wura	1.84a
	8	**Elite**	1.81a
		Lithovit	1.95a
		Asaase wura	1.78a
HYBRID	**6**	**Elite**	1.79a
		Lithovit	1.59a
		Asaase wura	1.79a
	8	**Elite**	1.65a
		Lithovit	1.50a

Asaase wura	1.90a

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.2.2 Fat

4.2.2.1 Effect of Fertilizer Type and Age of Plant on Fat content of Cocoa Beans Table 4.25 shows the effect of fertilizer type and age of plant on fat content of cocoa beans. From the results, significant differences (p>0.01) were observed among the fertilizer types. Elite fertilizer applied on cocoa plants yielded the highest fat content (40.79%), Asaase wura fertilizer followed with fat content of 36.50% while lithovit fertilizer recorded the least fat content of 35.88%. However, Elite fertilizer applied was not significantly different (p>0.01) from Asaase wura fertilizer applied which was also not significantly different (p>0.01) from lithovit fertilizer applied. There was no significant difference (p>0.01) between the ages of plants. 6 and 8 year old cocoa plants had fat contents of 38.06% and 37.39% respectively.

The effect of fertilizer type and age of plant on fat content of cocoa beans also showed no significance (p>0.01). However, 6 year old cocoa plant on which Elite fertilizer was applied (41.00%) had the highest fat content while 8 year old cocoa plant on which

Asaase wura fertilizer was applied (35.00%) had the least.

Table 4.25: Effect of fertilizer type and age of plant on Fat (%) content of cocoa beans

Fertilizer types	**Age of plants**		
	6 years	**8years**	**Mean**
Asaase Wura	38.00a*	35.00a	36.50ab

Lithovit	35.17a	36.58a	35.88b
Elite	41.00a	40.58a	40.79a
Mean	38.06a	37.39a	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.2.2.2 Effect of Fertilizer Type and Cocoa Variety on Fat Content of Cocoa Beans

The results show the effect of fertilizer type and variety of cocoa on fat content of cocoa beans (Table 4.26). Elite fertilizer applied on cocoa plants (40.79%) significantly had the highest fat content followed by Asaase wura applied (36.50%) with lithovit (35.8%) recording the least. Elite fertilizer applied was significantly different ($p<0.01$) in fat content from lithovit fertilizer applied but not significantly different ($p>0.01$) from Asaase wura fertilizer applied. Asaase wura fertilizer applied was also not significantly different ($p>0.01$) in fat content from lithovit applied. For variety of cocoa, Amelonado (Tetteh Quarshie) cocoa plant (38.31%) was not significantly different in fat content from hybrid cocoa plant (37.14%)

Interaction between fertilizer type and variety of cocoa showed significant differences ($p<0.01$). Amelonado (Tetteh Quarshie) plant on which Elite fertilizer was applied had the highest fat content of 43.25% while the least fat content of 34.08% was recorded in Amelonado (Tetteh Quarshie) on which Asaase wura fertilizer was applied. However, Amelonado (Tetteh Quarshie) on which Elite fertilizer was applied (43.25%) was not significantly different ($p>0.01$) from Amelonado (Tetteh Quarshie) on which lithovit fertilizer was applied (37.58%) but significantly different ($p<0.01$) from those on which Asaase wura fertilizer was applied (34.08%). For the hybrid, no significant differences (p>0.01) were observed among the asaase wura, lithovit and Elite fertilizers applied.

Table 4.26: Effect of Fertilizer type and cocoa variety on Fat (%) content of cocoa beans

Fertilizer types	Varieties of cocoa		
	Amelonado (Tetteh Quarshie)	Hybrid	Mean
Asaase wura	34.08b*	38.92ab	36.50ab
Lithovit	37.58ab	34.14b	35.88b
Elite	43.25a	38.33ab	40.79a
Mean	38.31a	37.14a	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.2.2.3 Effect of Fertilizer Type, Age of Plant and Cocoa Variety on Fat Content of Cocoa Beans

Table 4.27 shows the effect of fertilizer type, age of plant and variety of cocoa on fat content of cocoa beans. From the results, 6 year old Amelonado (Tetteh Quarshie) cocoa plant on which Elite fertilizer was applied (46.17%) was significantly the highest in fat content while 6 year old Amelonado (Tetteh Quarshie) cocoa plant on Asaase wura fertilizer (30.67%) was applied recorded the least.

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Table 4.27: Effect of Fertilizer type, age of plant and cocoa variety on Fat (%) content of cocoa beans

VARIETIES	AGE OF PLANT	FERTILIZER TYPES	Fat (%)
AMELONADO (TETTEH QUARSHIE)	**6**	**Elite**	46.17a*
		Lithovit	36.00abc
		Asaase wura	30.67c
	8	**Elite**	40.33abc
		Lithovit	39.17abc
		Asaase wura	37.50abc
HYBRID	**6**	**Elite**	35.83abc
		Lithovit	34.33abc
		Asaase wura	45.33ab
	8	**Elite**	40.83abc
		Lithovit	34.00bc
		Asaase wura	32.50c

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.2.3 pH

4.2.3.1 Effect of Fertilizer Type and Age of Plant on pH of Cocoa Beans

The effect of fertilizer type and age of plant on pH content of cocoa beans are shown in Table 4.28. From the results, Asaase wura fertilizer applied (5.48) had significantly higher pH content than lithovit fertilizer (5.43) and Elite fertilizer applied (5.41) which were not significantly different (p>0.01) from each other. For the age of plants, 6 year old cocoa plant (5.62) was significantly higher in pH value than 8 year old cocoa plant (5.25) which had the least.

Interactively, effect of fertilizer type and age of cocoa plant showed significant differences (p<0.01) in pH. Six (6) year old cocoa plant on which Elite fertilizer was applied (5.70) had the highest pH content while 8 year old cocoa plant on which Elite fertilizer was applied (5.12) had the least.

Table 4.28: Effect of fertilizer type and age of plant on pH of cocoa beans

Fertilizer types	**Age of plants**		
	6 years	**8years**	**Mean**
Asaase Wura	5.50c*	5.45d	5.48a
Lithovit	5.65b	5.20e	5.43b
Elite	5.70a	5.12f	5.41b
Mean	5.62a	5.26b	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.2.3.2 Effect of Fertilizer Type and Cocoa Variety on pH of Cocoa Beans

Table 4.29 shows the effect of fertilizer type and variety of cocoa on pH of cocoa beans. The results showed there were significant difference (p<0.01) among the fertilizer types and varieties of cocoa. For the fertilizer types, Asaase wura fertilizer (5.48) had the highest pH, followed by lithovit fertilizer (5.43) with Elite fertilizer (5.41) recording the least. The lithovit fertilizer was, however, not significantly different (p>0.01) in pH from the Elite fertilizer. For the varieties of cocoa, hybrid variety (5.56) was significantly higher in pH value than the Amelonado (Tetteh Quarshie) variety (5.32) which had the least.

The effect of fertilizer types and varieties of cocoa on pH showed significant differences ($p<0.01$). The highest pH (5.70) was recorded in hybrid variety on which Asaase wura fertilizer was applied while the least pH content (5.25) was recorded in Amelonado (Tetteh Quarshie) variety on which Asaase wura fertilizer was applied. Hybrid variety on which lithovit (5.50) and Elite (5.47) fertilizers were applied showed no significant difference ($p>0.01$). Amelonado (Tetteh Quarshie) variety on which lithovit and Elite fertilizers were applied were also not significantly different ($p>0.01$) from each other.

Table 4.29: Effect of Fertilizer type and cocoa variety on pH of cocoa beans

Fertilizer types	**Varieties of cocoa**		
	Amelonado (Tetteh Quarshie)	**Hybrid**	**Mean**
Asaase wura	5.25d*	5.70a	5.48a
Lithovit	5.35c	5.50b	5.43b
Elite	5.35c	5.47b	5.41b
Mean	5.32b	5.56a	

*Figures on the same column followed by the same letters are not significantly different ($p=0.01$)

4.2.3.3 Effect of Fertilizer Type, Age of Plant and Cocoa Variety on pH of Cocoa Beans

Table 4.30 shows the effect of fertilizer type, age of plant and variety of cocoa on pH of cocoa beans. Significant differences ($p<0.01$) were observed among the interactions. The highest pH (5.80) was recorded in 6 year old hybrid cocoa plants on which both Asaase wura and lithovit fertilizers were applied. The least pH was recorded in 8 year old Amelonado (Tetteh Quarshie) plant on which Elite fertilizer was applied.

Table 4.30: Effect of Fertilizer type, age of plant and cocoa variety on pH of cocoa beans

VARIETIES	AGE OF PLANT	FERTILIZER TYPES	pH
AMELONADO (TETTEH QUARSHIE)	**6**	**Elite**	5.70b*
		Lithovit	5.50d
		Asaase wura	5.20f
	8	**Elite**	5.00g
		Lithovit	5.20f
		Asaase wura	5.30e
HYBRID	**6**	**Elite**	5.70b
		Lithovit	5.80a
		Asaase wura	5.80a
	8	**Elite**	5.23f
		Lithovit	5.20f
		Asaase wura	5.60c

*Figures on the same column followed by the same letters are not significantly different ($p=0.01$)

4.2.4 Moisture Content

4.2.4.1 Effect of Fertilizer Type and Age of Plant on Moisture Content of Cocoa Beans

The effect of fertilizer type and age of plant on moisture content of cocoa beans is presented in Table 4.31. From the results, Elite fertilizer (4.15%) had the highest moisture content followed by Asaase wura fertilizer (3.88%) which was not significantly different ($p>0.01$) from each other. However, lithovit fertilizer (3.08%) had significantly the least moisture content. For the age of plants, 6 year old cocoa plant (3.95%) had significantly the highest moisture content while 8 year old cocoa plant (3.46%) had the least.

The interaction between the fertilizer type and age of plant showed significant differences ($p<0.01$) in their moisture contents. Eight (8) year old cocoa plant on which Elite fertilizer was applied (4.69%) was highest in moisture content while 6 year old cocoa plant on which lithovit fertilizer was applied (2.90%) had the least moisture content.

Table 4.31: Effect of fertilizer type and age of plant on moisture content (%) of cocoa beans

Fertilizer types	**Age of plants**		
	6 years	**8years**	**Mean**
Asaase Wura	3.87ab*	3.89ab	3.88a
Lithovit	2.90c	3.25bc	3.08b
Elite	3.60bc	4.70a	4.15a

Mean	3.46b	3.95a

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.2.4.2 Effect of fertilizer type and cocoa variety on moisture content of cocoa beans

The effect of fertilizer type and cocoa variety on moisture content of cocoa beans is shown in Table 4.32. The results showed that Elite fertilizer (4.15%) had the highest moisture content followed by Asaase wura fertilizer (3.88%) which were not significantly different ($p>0.01$) from each other. However, Lithovit had significantly the least moisture content of 3.08%. For the variety, Amelonado (Tetteh Quarshie) variety (3.87%) which had the highest moisture was not significantly different from hybrid variety (3.53%) which had the least moisture.

The effect of fertilizer type and cocoa variety on moisture content of cocoa beans was significantly different ($p<0.01$) from each other. Amelonado (Tetteh Quarshie) variety on which Asaase wura was applied (4.39%) was significantly the highest in moisture content but not significantly different ($p>0.01$) from both hybrid (4.32%) and Amelonado (Tetteh Quarshie) (3.97%) plants on which Elite fertilizer was applied. The least moisture content was recorded in hybrid plant on which lithovit was applied (2.92%).

Table 4.32: Effect of Fertilizer type and cocoa variety on moisture content (%) of cocoa beans

Fertilizer types	Varieties of cocoa		
	Amelonado (Tetteh Quarshie)	Hybrid	Mean
Asaase wura	4.39a*	3.36bc	3.88a
Lithovit	3.24bc	2.92c	3.08b
Elite	3.97ab	4.32a	4.15a
Mean	3.53a	3.87a	

*Figures on the same column followed by the same letters are not significantly different (p=0.01)

4.2.4.3 Effect of fertilizer type, age of plant and cocoa variety on moisture content of cocoa beans

Table 4.33 shows the effect of fertilizer type, age of plant and cocoa variety on moisture content (%) of cocoa beans. From the results, significant differences ($p<0.01$) were observed among the interactions. The highest moisture content was recorded in 8 year old hybrid cocoa plant on which Elite fertilizer was applied (4.85%) while the least moisture content was recorded in 6 year old hybrid cocoa plant on which lithovit was applied (2.82%). Six (6) year old Amelonado (Tetteh Quarshie) (2.99%) and hybrid (2.82%) cocoa plants and 8 year old Amelonado (Tetteh Quarshie) (3.49%) and hybrid (3.01%) cocoa plants on which lithovit was applied were not significantly different ($p>0.01$) from each other.

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Table 4.33: Effect of Fertilizer type, age of plant and cocoa variety on moisture content (%) of cocoa beans

VARIETIES	AGE OF PLANT	FERTILIZER TYPES	Moisture content (%)
AMELONADO (TETTEH QUARSHIE)	**6**	**Elite**	3.40abc*
		Lithovit	2.99c
		Asaase wura	4.55ab
	8	**Elite**	4.54ab
		Lithovit	3.49abc
		Asaase wura	4.24abc
HYBRID	**6**	**Elite**	3.80abc
		Lithovit	2.82c
		Asaase wura	3.19bc
	8	**Elite**	4.85a
		Lithovit	3.01bc
		Asaase wura	3.53abc

*Figures on the same column followed by the same letters are not significantly different ($p=0.01$)

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CHAPTER FIVE

5.0 DISCUSSION

5.1 PHYSICAL QUALITY (CUT TEST)

5.1.1 Germinated Beans

Germinated beans are a defect in cocoa in which the beans in the shell has been pierced, split or broken by the growth of the seed germ (Boateng, 2012). From the results, six year old cocoa beans on which Asaase wura was applied had the least germinated beans. Amelonado (Tetteh Quarshie) on which Asaase wura was applied had the least germinated beans and 8 and 6 year old Amelonado (Tetteh Quarshie) and Hybrid cocoa beans on which Asaase wura was applied also had the least germinated beans. The percentage of germinated beans allowed is 3% according to the international cocoa standard (Wood and Lass, 1985) and the recorded germinated beans for all the treatments showed that the values were within that set by international standards. This may be due to the fact that favourable conditions were not created for the growth of the cotyledon and this corroborates a report from Niemenak *et al*. (2006). Afoakwa *et al*. (2011) also reported that the cotyledons die and are not able to grow when enough acid is generated. This implies, irrespective of the fertilizer used, the type of cocoa or age of the cocoa plant, the germinated beans will not exceed the allowable percentage recommended by international cocoa standards and the quality of the beans would be maintained if the cocoa beans are stored properly.

5.1.2 Slaty Beans

Slatiness in cocoa beans is identified when the beans have a grey colour more than half of its surface (Boateng, 2012). The results showed that significant differences ($p<0.01$) in slatiness of cocoa beans were observed among the various treatments. Eight (8) year old Amelonado (Tetteh Quarshie) and Hybrid cocoa beans on which Elite fertilizer was applied had the least slaty beans count (1.00%). Slaty beans occurs when cocoa beans are not properly fermented (Hii *et al*., 2009) and Asare (2010) reported that it affects the quality of the beans which eventually leads to poor aroma and brown colour of chocolate. Slaty beans which does not exceed 3% qualifies to be a Grade 1 (one) cocoa as per the quality standard set by the Ghana Cocoa Board (COCOBOD, 2012). Cocoa beans from fertilizers (elite, lithovit and asaase wura) applied on the 6 and 8 year old Amelonado (Tetteh Quarshie) and Hybrid cocoa beans recorded slight percentage of such beans especially cocoa plants on which Elite fertilizers were applied. Thus, the fertilizers, age of cocoa and the cocoa varieties under study, have no negative influence in terms of slatiness on the cocoa beans so far as the beans are properly fermented.

5.1.3 Purple Beans

From the study, the purple beans count ranged between 13.67%-20% for all the treatments. A report from QCC (2010), sets Grade I cocoa to have percentage purple content levels of up to 20% is while up to 30% is acceptable for Grade II. Any higher amount in a parcel of cocoa beans is given a critical look with regards to acceptability in quality. The cocoa samples under study were within the set standard and could be classified as Grade I cocoa beans. High purple beans results in excessive astringency in the final product which mask the chocolate flavour (Hii *et al*, 2009). High purple beans in cocoa are also attributed to poor fermentation (Wood and Lass, 1985) which implies the cocoa samples from the various treatments were properly dried.

5.1.4 Mouldy Beans

According to Boateng (2012), cocoa beans are said to be mouldy when its internal parts have mould appearances visible to the naked eye. Mouldy beans cause off-flavours during processing of cocoa and increase the free fatty acid (FFA) content of cocoa butter (Wood and Lass, 1985). Irregular drying of cocoa beans also leads to beans with high moisture content which results in beans with high mould incidence (Ghosh and Cunha, 1975).

From the study, Amelonado (Tetteh Quarshie) and hybrid cocoa beans on which Elite and Asaase wura fertilizers were applied irrespective of their ages had no record of mouldy beans. This may be attributed to the fact that the beans were well dried. Application of lithovit fertilizer produced cocoa beans with mouldy beans (0.70%) but did not exceed the allowable quality standard (3%) set by Ghana Cocoa Board (COCOBOD, 2012). The value recorded for mouldy beans was also not significant enough to cause reduction in the bean quality. Therefore, application of the various treatments did not affect the quality of the cocoa beans when the cocoa beans were properly dried.

5.1.5 Insect (Weevil) Count

Insect damaged bean are beans that have their internal parts infested with insects (Boateng, 2012). During the study, no insect count was recorded in 6 and 8 year old Amelonado (Tetteh Quarshie) and Hybrid cocoa beans on which Lithovit and Asaase wura was applied. This might be attributed to the fact that the beans were analysed for cut test immediately after fermentation and drying without long storage. Insects grow in the cocoa beans during storage and affect the quality of the beans. However, slight percentage (0.30%) of insect count was present in six (6) year old cocoa beans on which Elite was applied but the value was not significant to affect the quality of the beans. Beans with less than 3% insect count is graded as a Grade one (1) cocoa. Therefore, irrespective of the cocoa type; Amelonado (Tetteh Quarshie) or hybrid and cocoa age; 6 or 8 years, when sprayed with the three fertilizers produced Grade 1 cocoa beans which can be exported.

5.1.6 Other Defects (Flatty beans) in Cocoa Beans

Significant differences ($p<0.01$) were observed for other defects in the various treatments. Boateng (2012) reported that cocoa is graded 1 when it contains not more than 3% count of all other defects. Six (6) and eight (8) year old Amelonado (Tetteh Quarshie) and Hybrid on which Asaase wura was applied recorded the highest (1.00%) other defects. However, it was within the acceptable limit for quality cocoa beans. This could be attributable to the fact that practices required to produce quality cocoa beans been conformed to. This also shows the various treatments applied on the cocoa beans did not affect the quality of the beans and can be graded as Grade 1 cocoa which is exportable.

5.1.7 Percentage Purity

Percentage purity is the overall assessment of how all the defects affect the quality of the cocoa beans. The study showed 6 and 8 year old Amelonado (Tetteh Quarshie) and hybrid respectively on which Asaase wura was applied had the highest percentage purity. The reason for this could be because the Asaase wura applied gave cocoa beans with lower record of other defects such as mouldiness, slatiness and weevil bean count. However, the percentage purity record for the other treatments was refreshingly high which indicates the cocoa beans could quality as a Grade 1 cocoa suitable for export.

5.2 BIOCHEMICAL CHARACTERISTICS

5.2.1 Free Fatty Acids (FFA)

According to Selamat *et al*. (1996), free fatty acids (FFA) are carboxylic acids released from Triglycerides through the effects of lipase or an oxidation reaction. Free fatty acids indicate the amount of rancidity in cocoa beans and Dand (1997) reported that FFA more than 1.75% in cocoa beans is unacceptable. The free fatty acid content in cocoa usually becomes higher (more than 1%) if the cocoa is stored improperly for a long period of time and this affects quality of chocolate. From the results, there were no significant differences among the treatments**.** However, 6 and 8 year old Amelonado (Tetteh Quarshie) and Hybrid on which Asaase wura was applied, 8 year old Amelonado (Tetteh Quarshie) on which Elite and lithovit was applied and 6 year old hybrid on which Elite was applied had FFA more than 1.75%. The higher FFA observed in these cocoa beans might be attributable to lipases naturally present in the beans and those introduced by microbial activity during fermentation. These lipases present in the cocoa beans tend to breakdown the triglycerides into separate groups of the fatty acids and glycerol thereby making the fatty acids available (Dand, 1997). This action results in rancidity of the cocoa beans.

5.2.2 Fat Content of cocoa beans

The cocoa bean contains a high amount of fat of about 45-55% of its weight. Through research, some varieties are found to contain higher amounts. The results showed there were variations in the fat content of the cocoa beans under study. Six (6) year old Amelonado (Tetteh Quarshie) cocoa plant on which Elite was applied as well as 8 year old hybrid on which Asaase wura was applied were the only treatments which had fat content within the reported fat range of cocoa beans. The variations might be due to edaphic factors and shading at where the cocoa plants are grown. High ambient temperatures at the growing site might have also contributed to the variations in the fatty acid composition of the triacylglycerides in the cocoa beans (Quao, 2010).

5.2.3 pH of cocoa beans

The study showed there were significant differences in the pH of the cocoa beans to which the fertilizers were applied. The pH of the treatments was within the range of 5.85.00. Cocoa beans with higher pH of 5.5–5.8 are considered not well fermented, with a low fermentation index and cut test score and those with lower pH of 4.75–5.19 are considered well-fermented (Afoakwa *et al*., 2008). pH of cocoa beans during fermentation is very important as it dictates the fermentative quality of the beans. Fermentation days affect the pH of beans which also increases the enzyme activities.

Lower pH increases the acidity, bitterness and astringency of processed cocoa beans (Hensen *et al*., 1998), thereby affecting the flavour development. pH less than 4.5 causes final reduction in flavour precursors and an over-acid final product. The pH of the cocoa beans under study was within the acceptable range required for processing of cocoa into quality chocolate.

5.2.4 Moisture Content

The recommended moisture content of cocoa beans is reported to be between 7.5-8% Amoa- Awua *et al*. (2006) and high moisture content results in mould infestation. The moisture content of cocoa beans under study ranged between 4.85%- 2.82% and were within the recommended moisture content of cocoa beans for the international market. The cocoa beans from the various treatments resulted in beans with lower moisture content. However, ICCO (2009) reported that very low moisture content causes beans to be brittle which leads to breakages and this increases the proportion of waste. Low moisture content of cocoa beans also tends to reduce the weight of the beans leading to loss of revenue for the country. Thus, the cocoa beans could be stored for a longer period as the water content which promotes the bacterial growth and subsequently mould growth has been removed to the minimum level. Takrama and Adomako (1996) corroborates this by reporting that to avoid spontaneous mould and bacterial growth during storage and transport, moisture content must be reduced to less than 7.5 % during drying. The low moisture content in the cocoa beans also indicated the beans were well fermented and dried.

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CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

This study was conducted to assess the effect of Lithovit, a foliar fertilizer, and two others; Elite (organic) and Asaase wura (inorganic/conventional) edaphic fertilizers, on the physical characteristics and biochemical properties of two varieties of cocoa at two different ages.

The results showed that 6 year old Hybrid cocoa plant on which Asaase wura (econventional/daphic) fertilizer was applied had the least percentage germinated beans of the cocoa beans. Eight (8) year Amelonado (Tetteh Quarshie) cocoa plant on which Elite(organic/edaphic) fertilizer was applied had the least slaty count of cocoa beans while the least purple beans was recorded in 8 year old Amelonado (Tetteh Quarshie) plant on which Asaase wura(conventional/edaphic) fertilizer was applied. Amelonado (Tetteh Quarshie) cocoa beans on which both Asaase wura (conventional/edaphic) and Elite (organic/edaphic) fertilizers were applied and were 6 years old had the least mouldy bean count. Weevils were not recorded in 8 year old Hybrid on which Asaase wura (conventional/edaphic) and lithovit fertilizers were applied while 8 year old Amelonado (Tetteh Quarshie) on which Elite (organic/edaphic) fertilizer was applied had low count of other defects. Percentage purity was also high in 6 year old Amelonado (Tetteh Quarshie) on which Asaase wura (conventional/edaphic) fertilizer was applied.

For the chemical characteristics of the cocoa beans, significant differences ($p<0.01$) were observed among the treatments. Six (6) year old Hybrid on which lithovit was applied had the best FFA content. Recommended fat content (45-55%) of cocoa beans was observed in six (6) year old Amelonado (Tetteh Quarshie) cocoa plant on which Elite was applied as well as 8 year old hybrid on which Asaase wura was applied. The best pH value was recorded in 8 year old Amelonado (Tetteh Quarshie) on which Elite (organic/edaphic) fertilizer was applied. The study also revealed the moisture content in the cocoa beans from the various treatments especially 6 year old Amelonado (Tetteh Quarshie) varieties on which lithovit organic foliar fertilizer was applied were lower and below the recommended moisture content of cocoa beans (less than 7.5%). This indicates the cocoa beans were well fermented and dried and could be stored for a longer period without mould growth.

In conclusion, irrespective of the type of the fertilizer (Lithovit, Elite or Asaase wura) applied, the type of cocoa used (Amelonado (Tetteh Quarshie) or Hybrid cocoa plant) and the age of the cocoa plant (6 or 8 years), the quality of the cocoa beans was not affected and would be suitable for export so far as the recommended activities such as proper fermentation and drying are followed.

However, generally, cocoa beans from the organic foliar fertilizer (lithovit) had the best chemical qualities while the conventional edaphic fertilizer (Asaase wura) performed better for the physical qualities of the beans. Cocoa beans aged 8 years old and of the Amelonado (Tetteh Quarshie) variety also had the best qualities compared to cocoa beans aged 6 years and of the Hybrid variety.

6.2 RECOMMENDATION

It is, therefore, recommended that similar works should be done to evaluate how storage of cocoa beans under such treatments over a period of time could affect the quality of cocoa beans of the two varieties.

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APPENDIX

Analysis of Variance Table for AOD

Source	DF	SS	MS	F	P
rep	2	0.042	0.0208		
years	1	2.250	2.2500	7.56	0.0117
trt	2	19.355	9.6775	32.51	0.0000
vareity	1	17.640	17.6400	59.26	0.0000
years*trt	2	31.785	15.8925	53.39	0.0000
years*vareity	1	20.250	20.2500	68.03	0.0000
trt*vareity	2	15.435	7.7175	25.93	0.0000
years*trt*vareity	2	50.685	25.3425	85.14	0.0000
Error	22	6.548	0.2977		
Total	35	163.990			

Grand Mean 2.4333 CV 22.42

Analysis of Variance Table for PURITY

Source **DF** **SS** **MS** rep 2 4.313E- **F** **P**
27 2.157E-27

years 1 0.04000 0.04000 0.05 0.8223 trt 2 48.5450
24.2725 31.34 0.0000 vareity 1 4.84000 4.84000
6.25 0.0204 years*trt 2 47.9150 23.9575 30.93
0.0000 years*variety 1 4.84000 4.84000 6.25 0.0204
trt*vareity 2 11.9150 5.95750 7.69 0.0029
years*trt*vareity 2 50.8850 25.4425 32.85 0.0000

Error	22	17.0400	0.77455
Total	35	186.020	

Grand Mean 78.133 CV 1.13

Analysis of Variance Table for Germinate

Source	**DF**	**SS**	**MS**	**F**	**P**
rep	2	0.0267	0.0133		
years	1	10.5625	10.5625	51.37	0.0000
trt	2	9.8550	4.9275	23.97	0.0000
variety	1	0.0225	0.0225	0.11	0.7439
years*trt	2	0.6950	0.3475	1.69	0.2076
years*vareity	1	1.3225	1.3225	6.43	0.0188
trt*vareity	2	7.6650	3.8325	18.64	0.0000
years*trt*vareity	2	7.2650	3.6325	17.67	0.0000
Error	22	4.5233	0.2056		
Total	35	41.9375			

Grand Mean 1.4250 CV 31.82

Analysis of Variance Table for Mould

Source	**DF**	**SS**	**MS**	**F**	**P**
rep	2	7.908E-33	3.954E-33		
years	1	0.25000	0.25000	137.50	0.0000

trt	2	0.50000	0.25000	137.50	0.0000
variety	1	0.04000	0.04000	22.00	0.0001
years*trt	2	0.50000	0.25000	137.50	0.0000
years*vareity	1	0.04000	0.04000	22.00	0.0001
trt*vareity	2	0.08000	0.04000	22.00	0.0000
years*trt*vareity	2	0.08000	0.04000	22.00	0.0000
Error	22	0.04000	0.00182		
Total	35	1.53000			

Grand Mean 0.0833 CV 51.17

Analysis of Variance Table for Others

Source	**DF**	**SS**	**MS**	**F**	**P**
rep	2	0.02792	0.01396		
years	1	0.30250	0.30250	12.87	0.0016
trt	2	2.48000	1.24000	52.76	0.0000
variety	1	0.02250	0.02250	0.96	0.3385
years*trt	2	0.50000	0.25000	10.64	0.0006
years*vareity	1	0.72250	0.72250	30.74	0.0000
trt*vareity	2	0.78000	0.39000	16.59	0.0000
years*trt*variety	2	0.98000	0.49000	20.85	0.0000
Error	22	0.51708	0.02350		
Total	35	6.33250			

Grand Mean 0.3083 CV 49.72

Analysis of Variance Table for Purple

Source	**DF**	**SS**	**MS**	**F**	**P**
trt	2	23.057	11.5286	2.62	0.0936
vareity	1	5.138	5.1378	1.17	0.2908
years	1	5.601	5.6011	1.27	0.2705

trt*vareity	2	23.501	11.7503	2.67	0.0898
trt*years	2	30.637	15.3186	3.48	0.0471
vareity*years	1	0.134	0.1344	0.03	0.8627
trt*vareity*years	2	48.234	24.1169	5.48	0.0110
Error	24	105.667	4.4028		
Total	35	241.969			

Grand Mean 17.056 CV 12.30

Analysis of Variance Table for Slaty

Source	**DF**	**SS**	**MS**	**F**	**P**
rep	2	0.0338	0.01688		
years	1	1.1025	1.10250	1.80	0.1933
trt	2	12.8850	6.44250	10.52	0.0006
vareity	1	0.4225	0.42250	0.69	0.4151
years*trt	2	8.3850	4.19250	6.85	0.0049
years*vareity	1	0.1225	0.12250	0.20	0.6590
trt*vareity	2	0.3950	0.19750	0.32	0.7277
years*trt*vareity	2	0.6950	0.34750	0.57	0.5750
Error	22	13.4713	0.61233		
Total	35	37.5125			

Grand Mean 2.6750 CV 29.25

Analysis of Variance Table for Weevil

Source	**DF**	**SS**	**MS**	**F**	**P**
rep	2	0.00167	0.00083		
years	1	0.02250	0.02250	27.00	0.0000
trt	2	0.04500	0.02250	27.00	0.0000
vareity	1	0.02250	0.02250	27.00	0.0000
years*trt	2	0.04500	0.02250	27.00	0.0000
years*vareity	1	0.02250	0.02250	27.00	0.0000

trt*vareity	2	0.04500	0.02250	27.00	0.0000
years*trt*vareity	2	0.04500	0.02250	27.00	0.0000
Error	22	0.01833	0.00083		
Total	35	0.2675			

Grand Mean 0.0250 CV 115.47

Analysis of Variance Table for FFA

Source	**DF**	**SS**	**MS**	**F**	**P**
rep	2	0.06140	0.03070		
trt	2	0.14480	0.07240	2.83	0.0808
vareity	1	0.05063	0.05063	1.98	0.1737
years	1	0.01823	0.01823	0.71	0.4080
trt*vareity	2	0.16987	0.08493	3.32	0.0551
trt*years	2	0.00727	0.00363	0.14	0.8685
vareity*years	1	0.06334	0.06334	2.47	0.1301
trt*vareity*years	2	0.12376	0.06188	2.42	0.1126
Error	22	0.56340	0.02561		
Total	35	1.20268			

Grand Mean 1.7425 CV 9.18

Analysis of Variance Table for Fat

Source	**DF**	**SS**	**MS**	**F**	**P**
rep	2	4.18	2.090		
trt	2	171.93	85.965	7.59	0.0031
vareity	1	12.25	12.250	1.08	0.3096
years	1	4.00	4.000	0.35	0.5584
trt*vareity	2	165.38	82.688	7.30	0.0037

trt*years	2	29.54	14.771	1.30	0.2915
vareity*years	1	38.03	38.028	3.36	0.0805
trt*vareity*years	2	349.26	174.632	15.42	0.0001
Error	22	249.15	11.325		
Total	35	1023.72			

Grand Mean 37.722 CV 8.92

Analysis of Variance Table for Ph

Source	DF	SS	MS	F	P
rep	2	0.00056	0.00028		
trt	2	0.02889	0.01444	52.00	0.0000
vareity	1	0.51361	0.51361	1849.00	0.0000
years	1	1.17361	1.17361	4225.00	0.0000
trt*vareity	2	0.20222	0.10111	364.00	0.0000
trt*years	2	0.46222	0.23111	832.00	0.0000
vareity*years	1	0.03361	0.03361	121.00	0.0000
trt*vareity*years	2	0.14222	0.07111	256.00	0.0000
Error	22	0.00611	0.00028		
Total	35	2.56306			

Grand Mean 5.4361 CV 0.31

Analysis of Variance Table for moisture

Source	DF	SS	MS	F	P
rep	2	1.0427	0.52133		
trt	2	7.4366	3.71831	19.78	0.0000
variety	1	1.0201	1.02010	5.43	0.0294
years	1	2.1316	2.13160	11.34	0.0028
trt*vareity	2	2.8847	1.44236	7.67	0.0030
trt*years	2	1.8337	0.91683	4.88	0.0177
vareity*years	1	0.0144	0.01440	0.08	0.7846
trt*vareity*years	2	0.3662	0.18311	0.97	0.3933

Error	22	4.1362	0.18801
Total	35	20.8661	

Grand Mean 3.7017 CV 11.71

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