UTILIZATION OF COCOA POD HUSK FOR THE PRODUCTION OF ORGANIC FERTILIZER AS A WASTE MANAGEMENT STRATEGY

BY

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ABSTRACT

Cocoa pod husks (CPH) disposal constitutes a serious problem in cocoa farms and cocoa processing areas. In its raw or processed form, CPH has the potential to be used as organic fertilizer but few studies have been conducted in Nigeria. This study was designed to determine the perceptions and practices of cocoa farmers regarding the disposal of CPH as well as its utilization of CPH as organic fertilizer to raise cocoa seedlings in nurseries.

In the experimental component, composite was made using CPH only and 1:1 v/v of CPH and Goat dung (GD) to mixture by weight. Raw CPH was allowed to decompose naturally. Exhausted soil devoid of any amendment was used as control. The three composite were monitored for 54 days and were used for cocoa seedling production using 25, 50, 100 and 200 kg ha^{-1} application rates with four replicates each for 10 weeks. A stratified random sampling using proportional allocation based on the number of cocoa farmers in the 36 farm settlements in Ado-Ekiti was done to select 400 cocoa farmers that were interviewed with the aid of a questionnaire. Descriptive statistics were used to analyse the data generated.

The composted CPH only, showed that it contained 4.9%Nitrogen, 0.6%Phosphorous, 3.6%Potassium, 33.3%Carbon and 17.0% moisture while the uncomposted CPH contained 2.7%Nitrogen, 0.1%Phosphorous, 3.0%Potassium, 31.8%Carbon and 11.7% ash content indicating that composting enhanced Nitrogen, Phosphorous, Potassium and Carbon contents. However, composted CPH+GD (1:1 v/v) contained 5.9%Nitrogen, 0.5%Phosphorous, 4.1%Potassium and 22.0% moisture. Composting thus improved Carbon, Nitrogen, Potassium and moisture contents as compared to composted CPH only and uncomposted CPH (control). The effects of composted CPH+GD (1:1 v/v), composted CPH only and uncomposted CPH on the plant height (16.1cm, 7.5cm and 9.5cm), stem girth (2.6cm, 1.6cm and 1.4cm) and number of leaves (10.5, 5.9 and 5.6) of the planted cocoa seedlings at the tenth week after planting showed that composted CPH+GD (1:1 v/v) medium was highest and significantly different ($P<0.05$) from those grown on composted CPH only and uncomposted CPH. Application rate of 200 kg ha^{-1} supported the highest plant height (15.5cm), stem girth (3.1cm) and number of leaves (11.0) of cocoa seedlings than the lower rates, which were not significantly different from themselves. All the participants submitted to leaving CPH in heaps after extracting the cocoa beans. About 93.0% believed that this practice could promote black pod disease while others (7.0%) believed that the heaps only occupy space in their plantations. Participants reportedly used CPH for soap making

(38.3%) and medicinal purposes (61.8%).

The performance of the seedlings raised on composted CPH+GD (1:1 v/v) suggests its potential as a good organic fertilizer for cocoa nursery. However, farmers have limited knowledge about its use as a fertilizer.

Keywords: Cocoa pod husk, Goat dung, Composting, Cocoa farmers and Cocoa seedlings.

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My sincere prayer for every body mentioned herein is that God would continually support you in every ramification of life.

CERTIFICATION

We certify that this research work was carried out under our supervision by Mr. Adeniyi Olarewaju ADELEYE of the Department of Epidemiology, Medical Statistics and Environmental Health, Faculty of Public Health, College of Medicine, University of Ibadan.

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DEDICATION

This work is dedicated to my late father, Chief Moses Ajibola Adeleye and my late mother in-law Mrs Idowu Emily Aduloju whose loving memories will forever reign in my veins.

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CHAPTER ONE

INTRODUCTION

Theobroma cacao is an important tropical rain forest species that is grown for its oil rich seed to produce cocoa and cocoa butter. The cocoa pod is composed of about 42% beans, 2% mucilage and 56% pod husk (Oladokun, 1995). By-products of cocoa include pod husks, shell and sweating. Better cocoa production will certainly be enhanced if economic use is made of the by products. Opeke (1992) reported that cocoa farmers will earn a little more for their labour if these by-products are put into utmost use. Presently, pod husks constitute a waste product in the cocoa industry and a serious disposal problem. They become a significant source of disease inoculums when used as mulch inside the plantation.

Cocoa pod husk (CPH) is the pericarp portion of the cocoa fruit and is 75 % of the whole fruit on fresh weight basis (Fagbenro, 1992). Millions of tonnes of CPH are produced as farm waste across the West African sub-region annually (Sobamiwa, 1998). A wide array of investigations in Nigeria and Ghana has indicated the potential usefulness of CPH in livestock feeds (Sobamiwa, 1997). Fresh or dried CPH may be used as livestock feed, but theobromine content (Ca. 0.4%) restricts the proportion that can be consumed and its use has been limited. Although acceptability by animals is satisfactory, digestibility is considered poor and depends on processing CPH (Adomako, 1972). Low digestibility of polysaccharides restricts the use of CPH for methane production in biodigestor (Lopez *et al.*, 1985). Reports indicate that pod meal can constitute 20 % of ration of poultry, 30 to 50 percent for pigs, and 50 percent for sheep, goats and dairy cattle, but these values may be too high (Wood and Lass, 1985).

Cocoa pod husks contain 3 to 4 percent potassium on a dry basis (Wood and Lass, 1985). Pod husk ash which is gotten from burning CPH, has been used to make soap in Ghana and Nigeria (Oduwole and Arueya, 1990; Arueya, 1991). According to the information available on www.zchocolat.com, Nigeria produces about 6% of cocoa currently produced in the world over. Cocoa pod husk, which is the major agricultural waste of the cocoa industry, has been found to be unusually rich in potassium and can constitute a viable source of potash production (Douglas, 2006; Adeoye *et al.*, 2001). Potash has a wide range of industrial uses, some of which are for the production of other potassium salts, dehydrating agents, fertilizer (KCL) and so on

The importance of potassium in plants, animals and humans, needs no emphasis. Potassium is referred to as the "Plant preferred" ion for maintaining the water content and hence the rigidity of each cell, a biophysical role. A large concentration of potassium in the cell sap creates conditions that permit water to diffuse into the cell through the porous cell wall. A rapidly growing cereal crop will take as much as 6kg K per hectare per day and sugar beet even more up to 8kg per hectare per day. If this rate of uptake is to be maintained, the potassium in the soil solution has to be replenished quickly which is only possible if the soil contains sufficient reserve of potassium.

Most of these reserves have accumulated from past application of fertilizers and manures and they must be maintained by applying fertilizer or manures containing potassium. The claim of Wood and Lass (1985), about CPH containing 3 to 4 % potassium is supported by the fact that crops grown near to where CPH had been dumped performed unusually well. It is on this basis that this study hopes to assess the management of CPH and develop a recycling method for its use in Agriculture.

1.1 Problem Statement

Cocoa pod husks have been reportedly put into use by several studies but there is an urgent need to put it into an easily practiced use because of its vast availability locally. Smith (1989) reported that there is about 1 million tonnes of dried CPH that are produced annually in Nigeria. Even though an appreciable percentage of these pod husks have been found to be used for feeding ruminants, the remaining percentage must be equally put into use to avert the imminent black pod disease it causes when left on the plantation unattended to.

1.2 Justification

Ekiti State is known to be one of the leading cocoa producing states out of the fourteen states known for cocoa production in Nigeria. Oladokun (1995) reported that Ondo State (Ekiti State inclusive then) produces about 70% of the cocoa production in Nigeria and that largely peasant farmers grow this. Cocoa pod husks are normally left on the cocoa plantations after the collection of cocoa beans in it. Cocoa farmers are loosing the rich nutrients in the CPH through this practice. Nigeria depends on the importation of potassium and spends a whole lot of money doing this. This study will go a long way in addressing how tonnes of CPH that are wasted annually by cocoa farmers can be recycled and managed to improve soil fertility.

1.3 Objectives

The general objective of this study is to assess the management of cocoa pod husk and develop recycling methods for its use in Agriculture.

The specific objectives of this study are to;

i. Assess the perceptions and practices of cocoa farmers concerning CPH.

ii. Determine the physicochemical properties of processed CPH

iii. Develop composting systems of CPH alone and CPH with an additional organic waste rich in nitrogen.

iv. Determine the physicochemical properties of the compost derived.

v. Assess the growth of cocoa seedlings on different composts made from CPH only or with other amendments.

CHAPTER TWO

LITERATURE REVIEW

2.1 Brief History of Cocoa

Cacao, or cocoa is an ancient crop having been harvested and used by the indigenous people of Central and South America for thousands of years. Cocoa was introduced to Europe during the 16th Century. Between 1825 and 1828 technology to separate the cocoa butter from the dried beans was developed, which led to manufacture of solid chocolate. The invention of milk – chocolate by the Swiss in 1876 led to the worldwide multi-billion-dollar chocolate processing industry (Crane *et al.* 2008).

The scientific name of cocoa is known as *Theobroma cacao.* There are two distinct types of cocoa, Criollo types (cocoa dulce) that was developed in the north of the Panama isthmus and forastero (cocoa amargo which originated in the Amazon basin. Criollo types were cultivated by the indigenous people of Central and South America and were the type Europeans were first exposed to. Commercial production commenced in Brazil using the Forastero types, mainly a uniform type called Amelonado. Both types were distributed throughout the Caribbean, where they hybridized in Trinidad, creating a distinct hybrid called Trinitaro. Spanish explores took cocoa to the Philippines where it spread throughout Southeast Asia, India and Ceylon Amelonado cocoa was taken to West Africa (Crane *et al.* 2008).

2.2 Description of the plant

Cocoa is small to medium sized tree (7.6 -9.1m) with few branches under tropical environments. Leaves are found toward the ends of the branches. Leaves are simple with a long petiole, which has a swelling at each end called a pulvinus. The pulvinus allows the leaf to swivel to catch sunlight. Leaves are lanceolate, bright green, and to 24 inches (61cm) long by 4 inches (10cm) wide. Young leaves have a pinkish red colour. They turn green as they mature. As the plant grows, new leaves, older ones may drop.

Cocoa flowers and fruits on the older branches and trunk (called cauliflorous flowering). One to five flowers arise from a special tissue along the leafless parts of the stem, called the cushion. Flowers are small, with five petal and sepals and ten stamens. They are hermaphroditic. The fruit is called a pod (technically it is a drupe), and the time from flower pollination to fully developed pod takes five to seven months or more. The pod has a thick peel (pericarp) and may be four to thirteen inches (10-33 cm) long. It may be cylindrical to round shaped with longitudinal ribs. The pod may be green or green-white, turning yellow upon ripening, or it may be red and develop some yellow colour upon opening. The pods are very attractive from an ornamental standpoint. Pods contain 20 to 60 seeds. Seeds are covered with white, pinkish or brownish, subacid mucilage that is sweet. Seeds may be extracted and the mucilage surrounding the seed consumed. The seeds are processed to make chocolate.

Seedling cocoa has a tap root that may extend several feet in deep soils. In addition, secondary shallow fibrous, roots radiate laterally from the trunk. These roots are the major roots for water and nutrient absorption. Crawling and flying insects pollinate Cocoa. Some cocoa types and varieties are self incompatible, requiring cross-pollination with a compatible variety. The Amelonado variety is fully self-compatible (Crane *et al*, 2005). Cocoa evolved as an undestroyed shade tree in hot, humid tropical rainforest areas dominated by cloudiness and with well distributed rainfall and a short dry period. Optimum temperatures for cocoa growth range from 65 to 90^0 F (18^0-32^0C). Temperatures below 50^0F (10^0C) may damage or kill the plant and temperatures in excess of 90^0F (32^0C) may limit plant growth. Flowering only occurs when temperatures are at or above 68^0F (20^0C). Cocoa requires access to soil moisture (water) nearly year round and thus benefit from regular watering during dry periods. Drought stress leads to leaf and flower drop and poor fruit production.

Cocoa is a shade loving plant and grows best with about 25% shades. It may be planted under the canopies of tall over hanging trees or next to building or structures. However, cocoa planted in deep shade tends to be spindly and non-productive. Cocoa does not tolerate windy conditions and should be planted in only wind-protected areas (Crane *et al*, 2008).

2.3 Uses of Cocoa

Cocoa seeds are the source of commercial cocoa, chocolate and cocoa butter. Fermented seeds are roasted, cracked and ground to give a powdery mass from which fat is expressed. This is the cocoa from which a populur beverage is prepared. In the preparation of chocolate, this mass is mixed with sugar, flavouring and extra cocoa fat. Milk chocolate incorporates milk as well. Cocoa butter is used in confectionaries and in manufacture of tobacco, soap and cosmetics. Cocoa butter has been described as the world's most expensive fat, used rather extensively in the emollient "bullets" used for hemorrhoids (Duke, 1983).

2.4 Folk Medicine of Cocoa

Cocoa has been reported to be antiseptic, diuretic, ecbolic, emmenagogue, and parasitic pesticide. Cocoa is a folk medicine for alopecia, burns, cough, dry lips, eyes, fever, listlessness, malaria, nephrosis, parturition, pregnancy, rheumatism, snakebite and wounds (Duke and Wain, 1981). Cocoa butter is applied to wrinkles in the hope of correcting them (Leung, 1980).

2.5 Chemistry of Cocoa

A 100g content of the seed is reported to contain 456 calories, 3.6g H_2O, 12.0g Protein, 46.3g fat, 34.7g total carbohydrate, 8.6g fiber, 3.4g ash, 106mg Ca, 537mg P 3.6mg Fe, 30Ng β-carotene equivalent, 0.17mg thiamine, 0.14mg riboflavin, 1.7mg niacin, and 3mg ascorbic acid (Duke, 1983).

According to Duke (1983), the edible pulp of the fruit contains 79.7-88.5% water, 0.5-0.7% albuminoids, astringents, etc; 8.3-13.1% glucose, 0.4-0.9% sucrose, a trace of starch, 0.2-0.4% non-volatile acids (as tartaric), 0.03% fe_2O_3 and 0.4% mineral salts (K, Na, Ca, Mg). The shell contains 11.0% moisture, 3.0% fat, 13.5% protein, 16.5% crude fiber, 9.0% tannins, 6.0% pentosans, 6.5% ash and 0.75% theobromine. Raw seeds contain (mg/100g) 0.24 thiamine, 0.41 riboflavin, 0.09 pyridoxine, 2.1 nicotinamide, and 1.35 pantothenic acid.

The component fatty acids of cocoa butter are 26.2% palmitic and lower acids, 34.4% stearic and higher acids, 37.3% oleic acid, 2.1% linoleic and traces of isoleic. In g/100g, the individual amino acids in the water soluble fractions of unfermented and fermented beans are lysine 0.08, 056; histidine 0.08, 0.04; arginine 0.08,0.03, threonine 0.14,0.84; serine 0.88,199; glutamic acid 1.02, 1.77; proline 0.72,1.97; glycine 0.09, 0.35; alanine 1.04, 3.61; valine 0.57, 2.60; isoleucine 0.56, 1.68; leucine 0.45, 4.75; tyrosine 0.57, 1.27; and phenylalanine 0.56-3.366 g/100g (Duke, 1983). Unfermented and fermented beans contain P-hydroxy benzoic acid, vanillic acid, p-coumaric acid, ferulic acid and syringic acid, while the fermented beans also contain protocatechuic; phenylacetic, phloretic acid and the lactone esculetin and 0-and p-hydroxylphenyl acids.

Chocolate is particularly high in phenylehtylamine, perhaps serving as medication. Theophylline is a potent CNS and cardiovascular stimulant with diuretic and bronchiol smooth muscle relaxant properties. This drug was proven effective in preventing and treating apnea in premature infancy. Cocoa contains over 300 volatile compounds, including esters, hydrocarbons lactones, monocarbonyls, pyrazines, pyrroles, and others. The important flavour components are aliphatic esters, polyphenols, unsaturated aromatic carbonyls, pyrazines, diketopiperazines and theobromine (Duke 1983).

Cocoa butter contains mainly triglycerides of fatty acids that consist primarily of oleic, stearic and palmitic acids. Over 73% of the glycerides are present as monounsaturated forms (oleopalmitostearin and oleodistearin), the remaining being mostly diunsaturated glycerides (palmitodiolein and stearodiolein), with lesser amounts of fully saturated and triunsaturated (triolein glycerides). Linoleic acid has been reported to be up to 4.1%. Also present in cocoa butter are small amounts of sterols and methylsterols; sterols consist mainly of β-sitosterol, stigmasterol and campesterol, with a small quantity of cholesterol. In addition to alkaloids (mainly theobromine), tannins, and other constituents, cocoa pod husk contains a pigment that is a polyflavone glycoside with a molecular weight of over 1500. This pigment is heat and light resistant, highly stable at pH 2 to 11 and useful as a food colourant; it was isolated at a 7.9% yield (Leung, 1980).

2.6 By-Products of *Theobroma cacao*

Several commercial products are obtainable from cocoa seeds which are actively traded internationally (Green wood – Barton, 1965). One strategy to increase income for cocoa growers is to identify and commercialize new products and by-products. Some of the by-products of cocoa that could be useful and increase the income of cocoa farmers are discussed below;

2.6.1 Cocoa Pulp

Cocoa seeds are surrounded by an aromatic pulp which arises from the seed teguments (technically an aril). The mucilaginous pulp is composed of spongy parenchymatous cell containing cell sap rich in sugars (10 to 13%), pentosans (2 to 2%), citric acid (1 to 2%), and salts (8 to 10%) (Lopez, 1986).

During on-farm processing of cocoa seed (the exportable product) the pulp is removed by fermentation and is hydrolyzed by microorganisms. Hydrolyzed pulp is known in the industry as "Sweating". During fermentation, the pulp provides the substrate for various microorganisms which are essential to the development of chocolate flavour precursors, which are fully expressed later, during the roasting process. Fermentation thought to be simply an easy way to remove the pulp to facilitate drying, but its importance to cocoa quality has been well established (Lopez, 1986).

The schedules for fermentation vary according to location and season, chamber size, depth of seed layer, and physical turning of the seed. Although pulp is necessary for fermentation, often more pulp occurs than is needed. Excess pulp, which has a delightful tropical flavour has been used to produce the following products; cocoa jelly, alcohol, vinegar and processed pulp. Approximately 40 litres of pulp can be obtained from 800kg of wet seeds. Cocoa jelly is produced by cooking fresh pulp mixed with sugar at the rate of 300 to 600g to one litre pulp. The pulp contains about 1% pectin (Wood and Lass, 1985). The Jelly has a fruit – acid flavour and is a popular delicacy in Baha, Brazil.

By controlled fermentation and distillation, sweating can be made into an alcoholic spirit with 43 % ethanol. Alcohol produced can be further fermented by *Acetobacter* specie to produce acetic acid, but vinegar is not yet a commercial product (Samsiah *et al*, 1991). Cocoa sweating has been shown to be a suitable substrate for fermentation of coconut water by *Acetobacter aceti* subspecies *Xylinum*. Nata is processed to an agar-like product, packed in syrup and is consumed as a desert in Asia.

The pulp can be consumed from in the form of juices and "Shakes". In small stalls, seeds with pulp are extracted from individual pods and placed, as ordered, in a modified food blender in which a metal disc with holes instead of blades. Milk or water is added and after a few seconds of blending the contents are poured through a strainer, producing a frothy, delicious, refreshing beverage. Enough pulp is usually left on the seed for normal fermentation, but pulp less seeds can also be added to intact seed to complete fermentation. Pulp can be preserved by freezing and used for ice-cream, yoghurt flavouring, and juice concentrates. Because of the expense of the freezing process, cocoa pulp has not been marketed outside Bahia. It is believed that this product could have large scale acceptance and can be recommended for market studies in temperate countries (Figueira *et al*, 1994).

Extraction of pulp does not interfere with subsequent seed fermentation, and reduction of pulp before fermentation may be beneficial to cocoa quality (Schwan and Lopez 1988). In

Brazil, seed quality is improved by the removal of pulp in order to reduce acidity. Commercial decupling machines of various sizes have been development based on a revolving cylinder, which removes about 60% of the pulp and does not injure the seeds. Batria alone produces about 300,000 tonnes of dry cocoa seeds. Each ton of dry seeds represents 300,000 tones of pulp of which 60% will be needed for fermentation leaving an excess of percentage will be needed for fermentation, leaving an excess of 120,000. If only 10% of this quantity would be utilized in Bahia alone, there would be sufficient raw product available to produce 12,000 tonnes of pulp (Figueiera *et al*, 1994).

2.6.2 Cocoa Pod Husks

Each ton of dry seeds represents about 10 tonnes of husk (fresh weight). At the present time, pod husks are a waste product of the cocoa industry and present a serious disposal problem (Figueira *et al*, 1994). Cocoa pod husks have been put into several uses in the past and in the present. Majority of the studies done, published and unpublished on CPH would be discussed herein.

2.7 Uses of Cocoa Pod Husks

2.7.1 Soap Making

Cocoa pod husks contain 3 to 4% potassium on a dry basis (Wood and Lass, 1985; Adeoye *et al*., 2001). Pod husk ash has been used to make soap in Ghana and Nigeria. (Oduwole and Arueya, 1990; Arueya, 1991). Black soap is known as Anago soap or Alata soap in Ghana, and as Ose Dudu in Nigeria. Black soap is made from roasted cocoa (chocolate) pods, plantain skins' ashes mixed with palm oil. Black soap has been used for centuries in countries like Ghana and Nigeria. Its methods and secrets have been passed down from generation to generation to keep the soap close to Mother nature and avoid exploitation and limitations. This African Black soap is not the mass produced African black soap in boxes all over the market (PR Web, 2006).

The traditional black soap which contains mainly water, cocoa pod ashes, plantain skins' ashes and palm oil is made by stripping tiny coconuts from the oily husk. The oil filled husks are packed into a hand press which has a centre with a huge threaded shaft. The heavy steel top to the press is then put in place and muscle power forces the orange palm oil from the fiber. The pure palm oil gotten is used in cooking and making of the soap. The palm oil and cocoa pod ashes is cooked and stripped. Soap is then formed foaming to the surface and later scooped off and place on a cooling table (PR Web, 2006).

2.7.2 Cocoa Pigment

A cocoa pod husk extract called cocoa pigment, which is a mixture of condensed or polymerized flavonoids (such as anthocyanidins, catechins, leukoanthy cyanidin), sometimes linked with glucose, has been utilized in Japanese food industries Recently, this extract has been shown to inhibit cytopathic effects of HIV in cell culture (Unten *et al*, 1991). The anti-HIV activity was attributable to interference with the virus absorption, rather than inhibition of the virus replication after adsorption.

2.7.3 Cocoa Pod Gum

Lysigenous cavities filled with mucilaginous substances occur in roots (Primary and secondary tissues), stems primary and secondary tissues) flowers and leaves (petioles, stipules, pulvni, palisade layer and midrib) of cocoa (Brooks and Guard 1952) indicated the presence of large amounts of gums in cocoa tissues as well as fruit husks (Figueira *et al*, 1994).

Gum from cocoa pod husk contains 2 – 3% protein after treatment with a cation exchange resin, indicating that they were protein – polysaccharides (Figueira *et al.* 1994). They reported that gums from cocoa pod husk contained galactose, glucose, rhamnose, arabinose, xylose, galactose acid and glucose acid. According to Figueiera *et al* (1994) gum can be obtained from cocoa pod husk by sun drying and boiling twice freshly collected samples in 70% ethanol (100 – 120g wt/l) for 30 minutes for depigmentation, then extracted twice with 70% hot methanol (30 minutes and 10 minutes respectively). The remaining tissues were dried briefly, homogenized in distilled water, and centrifuged at 1500g for 30 minutes. The supernatant was then concentrated and gum was precipitated with 3 volumes of 95% ethanol and collected by centrifugation for 30 minutes at 4200g. The pellet was redissolved in water and freeze dried. Statistically, gum from cocoa pod husk gave the comparable viscosity as gum Karaya at 5% concentration. Both gums, however, gave a pseudoplatic behaviour and gave an average of 72% Centipoise and 18.4 Centipoise respectively at 5% of concentration with cone number CP 40 at the shear rate of 45.0 sec^{-1} in room temperature.

In terms of calorie value, gum from cocoa pod husk gave a lower value compared to gum Karaya at P=0.05. Calorie value of gum from cocoa pod husk was recorded as 2.6065Kcal/g and 3.6896 Kcal/g for gum Karaya by ISOPERIBOL Colorimeter model PARR 1261. Gum Karaya, once an important gum has been used as an emulsifier, stabilizer and viscosifier for food products and as a lixative/adhesive in pharmaceutical industry. In recent years, gum Karaya has become relatively expensive due to tapping restrictions in India (Anderson *et al*, 1982; Figueira *et al*, 1994). Thus, a substitute gum would be of interest and gum from cocoa pod husks might serve as a replacement and provide an additional source of reveal to the cocoa industry.

Krishna and Subba-Rao (1976, 1978, and 1980) also isolated gums from the seed pulp. Polysaccharides of cocoa were first characterized by Whistler *et al* (1956), who found differences in hot-water-soluble polysaccharides between seed and pod husks. Blakemore *et al* (1966) examined the hot water soluble fraction of husk polysaccharide and concluded that the major part of this fraction was a pectic material. Cocoa pod husks were examined as a source of pectin by mild acid extraction by Adomako (1972) and Berbert (1972) or citrus pectin in gel-forming ability. Krishna and Subba-Rao (1978, 1980) found that gums from seed pulp were effective in low concentration as a binder for pharmaceutical pills, and reported that suspending properties were superior to tragacanth, sodium alginate, Sodium, carboxy – methyl cellulose and methyl cellulose.

Gum karaya produced from various *Sterculia* species mainly *S. urens* has been used in the food and medical industry, but its used has diminished because its supply is variable and unreliable. Figueira *et al*, (1994) have characterized cocoa gums from pod husks and stems to evaluate their potential as a replacement for gum Karaya or as a new commercial product. Their results indicated that an average yield of 1.5% of fresh weight and 8.4% dry weight for stem gum, and 0.7% of fresh weight and 8.7% dry weight for pod gum Cocoa pod gum was closer in composition to gum Karaya than stem gum (Table 2.1). Both cocoa gums contained the same monosaccharide as gum Karaya but with the addition of arabinose and with higher proportions of rhamnose. The major component of stem gum was glucose, not found in other two gums and also contained more glucuronic acid.

2.7.4 Utilization of Cocoa Pod Husk in Livestock Feeds

The use of cocoa pod husk in livestock feeds in Nigeria came into focus in the mid-seventies when the Cocoa Research Institute of Nigeria (CRIN), Ibadan began collaborative studies with the Department of Animal Science, Obafemi Awolowo University, Ile-Ife. Reports in the literature indicated that similar investigations on and in the use of CPH in livestock rations, began about the same time in Ghana. The use of CPH in livestock feeds has been extensively studied and expectedly, these studies have been restricted to the cocoa producing regions of the world particularly in West Africa and tropical Central and South America. Nigeria, Ghana, Brazil and Costa Rica have featured prominently.

Cocoa pod husk feeding has cut across a wide range of animals; sheep (Devendra 1977); Otchere *et al* (1983); Chicks (Adeyanju *et al*; 1977; Olubamiwa and Longe, 1999); Growing rabbits (Oduguwa *et al*, 1999); Growing Pullets (Sobamiwa and Akinwale, 1999); Ruminants (Smith 1984); Smith and Adegbola, 1985; Smith *et al*, 1988; Adeyanju *et al*, 1977); Growing Japanese quails (Olubamiwa *et al*; 1999) etc.

Table 2.1. Comparison of Sugar in cocoa gum and gum karaya

Gum source	Rhamnose	Arabinose	Galactose	Glucose	Xylose	Mannose	Galacturonic acid	Glucuronic acid
Gum karaya	1.6	0.0	1.0	0.1	0.0	0.0	1.3	0.6
Cocoa stem gum	2.0	1.7	1.0	2.8	0.0	0.0	1.1	1.4
				Cocoa pod gum				
Figueira *et al* (1992)	2.4	2.1	1.0	0.1	0.1	0.0	1.1	0.6
Whistler *et al* (1956)	1.0	0.3	1.0	0.0	0.0	0.3	0.0	0.0
Blakemore *et al* (1966)	0.4	0.2	1.0	0.4	Trace	0.3	1.3	0.0
Adamoko (1972)	0.6	0.4	1.0	Trace	0.3	0.0	13.4	0.0

Source: Figueira *et al*, 1994

Olubamiwa and Longe (1999) reported the evaluation of the optimal biological and economical level of cocoa husk inclusion in production diets for boiler starter. They prepared seven isonitrogenous rations including the control. The test diets were prepared in forms of mash, crumbled pellets and 2.5% palm oil supplemented mash, each containing 10 and 15% cocoa pod husk. The inclusion of CPH into the control (mash) diet was largely at the expense of maize. A total of 140, 7-day old Hypeco broiler chicks were selected as the middle weight range (82±2g/diet) from a batch of 200 to cut down on experimental error since the birds were mixed sex. They were randomly divided among 14 battery brooder pens. Duplicate groups were then assigned to each of the 7 diet treatments in a completely randomized design and fed the respective diets for three weeks.

The summary of the results of biological and economic performance of experimental chicks is shown in Table 2.2. It was observed that weight gain and feed efficiency were similar on the control of 10 Cocoa pod husk diets (CPHDs) but lower on 15 CPHDs. This observation indicated that the optimal biological level of CPH in boiler starter diets is 10%. This agrees with the previous reports on the performance of boiler chicks on CPH based diets (Adeyanju *et al*, 1977; Atuabene *et al.* 1985; Sobamiwa and Longe 1998) which was linked to the combination of lower ME and high fibre content of CPH. This arose from dietary every dilution (Such as occurred when CPH replaces maize) which reduces broiler performance (Lott *et al* 1992; Bockholt *et al*; 1994) and the fact that the growing chick is extremely sensitive to the presence of dietary fibre (Graham and Aman, 1987). Although feed cost/kg feed was least in the 15 CPHDs; feed intake was high while bird growth was retarded with corresponding low return. Based on the results of biological and economical efficiencies of the experimental diet (Table 2.2) the optimal level of CPH in broiler started diets is 10%. Mortality was nil on all group and tibia ash content (an indirect method of assessing leg bones strength) did not differ on the diets. These data give further indications that the 10% cocoa pod husk diets are similar to the control.

Table 2.2. Biological and economic performance of experimental chicks

Diets	Weeks after feeding						
	2	3	4	5	6	7	SEM
Weight gain	478.5 a	447.0 a	479.0 a	382.5 b	328.4 b	366.3 b	12.4
Feed intake (g/bird)	1116.0 a	1140.2 a	1091.0 ab	964.3 c	1022.0 bc	975.0 c	23.1
Feed efficiency	2.3 bc	2.6 b	2.3 bc	2.5 b	3.1 a	2.7 a	0.9
DM digestibility (% DM)	78.0 b	77.5 bc	77.7 c	73.0 c	68.0 d	71.2 cd	0.1
N retention (% DM)	78.5 b	70.2 c	80.1 b	72.0 c	70.1 c	71.5 c	0.1
Fat retention (% DM)	87.9 a	86.5 ab	88.7 a	88.5 a	84.0 bc	82.1	0.7
Abdominal fat (% body weight)	1.4 ab	1.3 ab	1.8 a	1.0 bc	0.3c	0.8 c	0.3
Tibi ash (%)	48.5	50.4	50.8	50.7	50.4	48.6	1.1
Gross revenue ₦/bird	69.9	53.1	68.4	54.9	42.8	51.0	-
Brid mortality (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Olubamiwa and Longe, 1999

Means in the same row with different letters differ significantly ($P<0.05$).

<u>key</u>

Diet 2 = 10% cocoa pod husk (CPH)

Diet 3 = 10% CPH

Diet 4 = 10% CPH + 2.5% palm oil mash

Diet 5 = 15% CPH mash

Diet 6 = 15% CPH

Diet 7 = 15% CPH + 2.5% palm oil mash.

Tuah *et al* (1999) reported the effects of levels of CPH and NaOH – treated corn cob on the reproductive performance of Djallonke sheep in Ghana. Fifty gimmers of the Djallonke breed of sheep ranging in body weight from 5 to 13 kg were allocated to five diets containing respectively, 0,150, 300, 450 and 600 g kg^{-1} CPH for 150 days. After the 150 day individual feeding phase, their was no significant effect on the reproductive parameters length averaged 17.2±0.44 days and peak progesterone level (8.0±0.84 nmol/L) was attained on day 14 of the cycle Progesterone profiles during pregnancy were similar for all animals irrespective of dietary treatment reaching a peak between days 12 and 119 (18.2-23.3 nmol/L) becoming negligible by day 154 (Tuah *et al* 1999).

Replacement value of cocoa husk meal for maize in diets of growing pullets was studied by Sobamiwa and Akinwale (1999). In the study, 108 ten-week old Nera pullets were allocated in triplicates in a completely randomized design to four isonitrogenous dietary treatments. The treatments were equalized for weight at the average of 0.7kg body weight per bird. The rations included the control diet (CD), and 100, 150 and 200g kg^{-1} cocoa pod husk meal diets in which cocoa pod husk meal replaced maize. The four diets were fed to birds up to 20 weeks of age. Therefore, all groups were switched to a common 18% crude protein corn-soya bean meal layers' mash to 26 weeks of age. The Metabolisable Energy (ME) contents of cocoa husk meal diets were lowered across the treatments as cocoa husk meal replaced maize. This was reported to be unexpected because of the market difference in the ME contents of cocoa husk meal and maize (Sobamiwa and Akinwale, 1999). Furthermore, feed intake was identical up to 20 weeks of age on all treatment. Feed efficiency was best on control diet up to 20 weeks of age. Control diet was however the most expensive feed being 15% costlier than the 200g kg^{-1} cocoa husk meal diet (Table 2.3). Also, feed cost per bird during this period was at least 10% higher on control diet than on any cocoa husk meal diet.

A study conducted by Smith (1989), revealed the solutions to the practical problems of feeding cocoa pods to ruminants. He reported that the widespread nature of cocoa

Table 2.3. Growth performance and cost of production of growing pullets fed with cocoa husk – based diets during 10-20 weeks of age

Parameters	0	100	150	200	SEM
Feed intake (g/b/d)	68.0^{b}	68.0^{b}	67.3^{a}	71.3^{a}	1.22
Weight gain (g/b/d)	12.6^{a}	9.7^{b}	8.8^{b}	9.0^{b}	0.65
Feed: gain	5.4^{b}	7.1^{a}	7.7^{a}	8.0^{a}	0.29
Feed cost (N/kg)	19.4	17.9	17.2	16.4	Na
Feed cost (N/b/10 wks)	92.4	82.9	80.9	81.9	Na
Age at first egg (wks)	17.7^{b}	18.0^{b}	20.0^{a}	19.7^{a}	0.3
Body weight at first egg (kg/bird)	1.4^{a}	1.3^{b}	1.3^{b}	1.3^{b}	0.1
Egg production to week 20 (%)	36.3^{a}	19.0^{ab}	2.0^{b}	5.3^{b}	10.4
Average egg weight to week 20 (g)	32.0^{b}	34.7^{ab}	42.3^{a}	40.7^{a}	2.2

Source: Sobamiwa and Akinwale, 1999;

(g/b/d) refers to g bird-[1] day-[1]

Means followed by the same letter(s) in each row are not significantly differently ($P<0.05$).

Key

Na= Not available.

processing sites which makes it difficult and expensive to collect and transport the cocoa pods to sites of utilization and the need to grind the pods prior to feeding are identified as the main physical constraints while high cell wall and low cell content of the material constitute the main nutritional constraints to its effective utilization.

Dried pod has been reported to contain 6-10% crude protein, 24-42% crude fibre, 49-61% nitrogen-free extracts, 9-16% ash made up primarily of potassium salts (Owusu – Domfeh, 1972; Devendra, 1977; Otchere *et al*, 1983; Smith and Adegbola, 1985). This nutrient profile is similar to that of many tropical grasses (Ademosun and Kolade, 1973). The materials therefore have good potential as a feed ingredient particularly for ruminants. About one million tonnes of cocoa pods are generated annually on Nigeria cocoa plantations. It is difficult to assess what amount is available for animal feeding. Most of the available pod is annually wasted because cocoa-growing and processing is to a large extent carried out by individual smallholder scattered all over the cocoa producing areas. Many of the farms are not easily accessible, and when accessible, may not produce enough pods to encourage setting up a collection service. The lack of easily accessible processing centres in areas where large amounts of pod can be collected is one of the major constraints to the utilization of CPH as animal feed (Smith, 1989).

Smith (1984) indicated that transportation costs for collecting pods from sites of production to the site of utilization accounted for 78% of the total cost of producing a tonne of dried CPH for feeding. The farther apart the production sites are from each other and from the sites of utilization, the higher the transportation costs, and the less attractive the use of pod will become. He further reported that if it were to be possible to centralize cocoa processing, a large part of the constraint of collection and transportation could be overcome. A more practical solution would be to use the CPH at or near the site of production. The major target users would therefore have to be the cocoa farmer or his neighbour keeping a few goat and sheep. On the other hand manufacturers who may want to use the compounded ruminant diets or as energy diluents in pellets or finishing swine feeds may contract cocoa farmers to supply dried pods once or twice a year (Smith, 1989).

In the study conducted by Olubajo *et al* (1989) on cocoa pod silage and cocoa-pod-grass silage in goat and sheep nutrition, it was reported that the depressed dry matter content of the pre-ensiled grass-cocoa-pod mixtures was as a result of the high moisture content of the cocoa pod husk when compared to that of elephant grass that was used as a control in the study, while cocoa pod replacement led to an increase in nitrogen-free extract as a result of the higher content of this nutrient in the cocoa pod. The slight decrease in the crude protein content of the ensiled products may be attributed to loss of volatile nitrogen products from protein fermentation. The high pH values of the silages are attributable in the limited available soluble carbohydrates in the ensiled mixtures as well as to the high ash content in the pre-ensiled mass most especially in the 100% cocoa pod which may have inhibited or lowered the activities of acid forming *lactobacilli* thereby limiting the level of lactic acid production in the ensiled mass.

The relatively low nitrogen utilization of cocoa pod silage or of any of its grass silage combinations could be attributed to its concentration either in the pre-ensiled mixtures or in the silages when compared with that of the control diet as its concentration was similar in all the treatments. It could however be due to the presence of as yet unidentified inhibitors in the cocoa pod (Olubajo *et al.* 1989). Awolumate (1982) was of the opinion that pesticides used in plant protection, tannins, theobromine and polyphenols if present in cocoa pod can affect the voluntary intake, digestion and metabolism in animals. They also decrease palatability and digestibility of protein. Chlorogenic acid present in cocoa components is found to cause motor activity in ruminants and rats affecting decreased weight and feed conversion efficiency. This may account for the low values obtained for the cocoa-pod diets (Olubayo *et al.* 1989).

2.8 Strategies for Eliminating Nutritional Constraints of Using CPH as Animal Feed

The generally low nutritional value of cocoa pod is a major constraint to its being used efficiently as animal feed. It is low in protein (6%) and high in cell wall components (24% lignin) (Smith *et al.* 1989). This poor nutrient profit accounts for its low rumen degradability and overall poor digestibility and may constitute a constraint to optimally utilizing the material as a feed ingredient. Two proven strategies are suggested as remedies to this nutritional constraint that is chemical treatment and supplementation (Smith, 1989).

Chemical treatments of fibrous crop residues, similar in composition and nutritive value to cocoa pods have reportedly improved their utilization to such an extent as to make their utilization as feed ingredients feasible and profitable (Jackson, 1977; Doyle *et al.* 1986).

None of the proven chemicals such as sodium hydroxide, calcium hydroxide, potassium hydroxide and ammonia are suitable local farmers because of high cost and scarcity of the chemicals and hazards associated with their use. A suitable alternative which under limited testing appears as effective as sodium hydroxide is the caustic ash solution of some crop residues. Cocoa pod ash, for example, contains about 44mg of potassium per Kg, and according to Adebowale (1985), the ash solution contains about 21% and 29% OH ions in the form of the NaOH and KOH respectively.

This property was effectively exploited by Smith *et al* (1988) who used different concentrations of cocoa pod ash solutions as a chemical to treat cocoa pod in an attempt to improve its feed value. As shown by Smith (1989) in Table 2.4, a linear increase in the rumen degradability of cocoa pod treated with its own ash solutions of increasing concentration was observed. More significantly, the improvement in rumen degradability obtained by cocoa pod ash solution treatment was similar to that obtained by using NaOH solutions of equivalent alkalinity. The authors also reported that treated cocoa pod based diets were better digested by both goats and sheep than untreated pod based diets as shown in Table 2.5. Control diet contained 50% untreated cocoa pod while test diets contained 50% treated cocoa pod.

This treatment method has the potential to remove a major constraint to the efficient utilization of cocoa pod as a livestock feed. The technology should be attractive to cocoa farmers who generate cocoa pod on their farms. The technology involved is simple and the farmers are used to handling the ash which is used locally as a base for soap manufacture (Smith, 1989). Another treatment method which may improve the feed value of pod is ensiling pod with poultry manure or urea. Both manure and urea would liberate ammonia which has been shown to effectively improve the utilization of fibrous residues through ammonization of cell walls (Doyle *et al*, 1986).

Table 2.4. Rumen degradability of treated cocoa pod

Nutrients	% NaOH solution				% pod ash solution			
	2	4	6	8	2	4	6	8
Dry matter	34.8	41.1	47.6	52.6	37.0	46.3	54.8	55.4
Acid-detergent fibre	24.6	33.8	38.6	42.5	26.7	35.9	44.2	46.6
Neutral detergent fibre	15.0	25.9	35.7	36.5	15.3	29.8	44.7	41.7

Source: Smith (1989).

Table 2.5. Digestibility (%) of treated and untreated cocoa pod by goats and sheep

	Sheep		Goat	
	Untreated	Treated	Untreated	Treated
Dry matter	45.2	45.5	46.3	59.8
Acid-detergent fibre	12.4	30.7	31.0	36.2
Neutral detergent fibre	15.6	39.5	37.9	40.2

Source: Smith (1989)

Sobamiwa and Longe (1994) studied the effect of alkali concentration and treatment on the chemical composition and nutritive value of CPH. It was reported that increasing alkali concentration decreased the amounts of crude fibre, hemicellulose, cellulose and crude protein but increased total ash, sodium, copper, iron, manganese and zinc contents of CPH. Treated CPH showed an increasing water consumption of chickens and ultimately increased the growth of chickens compared with untreated CPH when fed as feed to the chickens. In order to improve the nutritive value of CPH most, it is necessary to remove salt deposition and residual alkali which may have masked the effect of alkali treatment (Sobamiwa and Longe, 1994).

2.9 Cocoa Pod Husk as Media for Culturing

Awuah and Frimpong (2002) reported the use of cocoa based media for culturing *Phytophthora palmivora* which is the causal agent of black pod disease of cocoa. Green cocoa pod husk agar, ripe cocoa pod husk agar, and ripe cocoa mucilage agar, were prepared and assessed for their clarity and for potential support to mycelia growth and sporulation of *P. palmivora*. Oatmeal agar, Potato-dextrose agar, vegetable 8 juice agar and pineapple crown agar were included for comparison.

Green cocoa pod husk agar and ripe cocoa pod husk agar when compared with other media performed substantially well in clearing and supporting the best aerial mycelia growth but both green cocoa mucilage agar and ripe cocoa mucilage agar apart form differences in radial growth, were similar in all other respects and are recommended for culturing *P. palmivora* (Awuah and Frimpong, 2002).

2.10 Propagating Media

The media can be made of different types of soil such as sand loam, silt, clay and with the organic part which might be poultry dung, cow dung, goat dung, compost, all of which are found suitable but depending on the plant to be grown on the medium. According to Hudson and Dale (1975), a good medium must be sufficiently firm and dense to hold the cuttings in place during rooting, sufficiently porous that excess water drains away therefore permitting adequate aeration and sufficiently retentive of moisture that watering does not have to be too frequent among other qualities.

2.11 Types of Media used for Growth Experiments

Growing media could be natural or artificially prepared media for suitability of plants growth. These media can be sand, loam, peat or sawdust (Moyosore, 2006).

2.11.1 Sand

According to Hundson and Dale (1975), sand consists of small rock fragments ranging from about 0.05mm – 2.0mm in diameter formed as a result of the weathering of various rocks. Its mineral composition depends on the type of the rock. Sand is chemically inactive or inert since quart-grains have little power to hold water or nutrients. Sand is the heaviest of all rooting media used, a cubic foot of dry sand weighting about 48.87kg. Some contain virtually no mineral nutrient and has buffering capacity. It is used mostly in combination with organic materials (Baker, 1962).

2.11.2 Peat

Patck (1965) and Lucas *et al* (1971) stated that peat is composed of remains of aquatic, marsh; bug or swamp vegetation which has been preserved under water in a partially decomposed state depending upon the vegetation from which it originates, state of decomposition, mineral content and degree of acidity.

2.11.3 Loam

Loam soils alone are not satisfactory for the propagation in nurseries. They are often heavy and poorly aerated or tend to become sticky after watering upon drying; they shrink, forming a hard and cracked surface. In order to provide suitable potting mixtures of good texture, sand and some organic matter such as peat moss or sawdust or shredded bark are usually added. (Matkin and Chandler, 1971; Furuta, 1970).

2.12 Materials Used In Potting Mixtures

2.12.1 Manures

The term "manure" was originally used for describing waste materials such as goat dung, cow dung, poultry dung, compost and other natural substances that are applied on the soil on whose primary objective is that of enriching the soil for increased crop production. Raymond and Roy (1992) reported that the use of manure is as old as Agriculture and will continue to be the best method of maintaining soil fertility because of its safe utilizable qualities to lives.

Agboola (1982) asserted that manure constituted the chief source of crop nutrients before 1960's in maintaining soil fertility in humid tropics.

a. Goat Dung

There is dearth of information on the use of goat dung in crop production. This may be partly due to the relatively little quantity of dung produced by the animal per day compared with other livestock couple with their highly mobile nature which makes large spot collection difficult. Except large stock is kept gathering enough materials for commercial farm fertilizer will not easily be achieved (Odiete, 1997). He further stated that with recent call to increased mixed farming and animal protein intake, efforts are now being geared towards boosting goat production.

Goat dung has an average nutrient potential of 2.8% N, 1.92% P_2O_5 and 1.72 K_2O while goat urine contains 2.55% N, 0.09% P_2O_5 and 3.97% K_2O (Raymond and Roy, 1992). Salem (1975) gave a range of between 10-5%moisture, 2-3% N, 0.4-0.7% P_2O_5 and 1.0-1.5% K_2O for goat dung. On the basis of this composition, if goat dung is well handled and adequately applied to maize either sole or in combination with inorganic fertilizer, an appreciable response of growth and yield should be expected (Raymond and Roy, 1992). Anthony (1996) confirmed that goat manure makes a very good fertilizer. He further stated that the dropping can be mixed with forage residues, soil or urine to rot before use.

b. Cow Dung

Raymond and Ray (1992) gave a breakdown of beef cattle waste composition as 2.8% N, 2-1.0% P, 1-3 K, 1.5 Mg, 1-3 Na and total soluble salts 6-15%. According to Jin-Hyung *et al* (1996), application of cattle manure improved soil pH, organic matter, available phosphate and exchangeable cations in the soil. It was further stated that application of cattle manure increased plant growth, height, stalk diameter and silage yields. It was later concluded that 40 tonnes cattle manure per hectare should be applied to forage maize.

c. Poultry Litter

Poultry manure contains 2.5% N, 1-2% P, 1-2% K, 2.3% Mg, 1-2% Na and 2.5% total soluble salts (Raymond and Roy, 1992; Adeoye *et al.*, 1993). According to Anthony (1995), poultry manure is pure poultry excrement produced in battery cage house, and it should be generally dried before use. Poultry manure can be used in most crops but because of its high nitrogen content, it is important to adjust nitrogen fertilizer used to avoid excess. It was further stated that conversely, its potassium content is relatively low so that potassium fertilizer may be especially needed (Anthony, 1995).

d. Compost

According to White (1987), compost is made by accelerating the rate of humification of plant and animal residues in well aerated compost heaps. Manure and compost are in essence slow release fertilizer. Nutrients are slowly released from the added organic materials through the microbially induced mineralization process. The use of organic substrate (compost) offers great advantages over the convectional topsoil (Adam *et al.* 2003; Akanbi *et al.* 2002). Organic substrates, according to these authors, provide adequate nutrients to seedlings better root substrate relation than convectional soil mix and less predispose the seedlings to soil borne pests and disease. While a wide range of crop residues, organic wastes and other industrial by-products could be used as organic growing medium. Preference of any should largely be determined by consideration of availability, economics, physical and chemical characteristics (Akanbi *et al.* 2002).

2.13 Some Important Nutrients in Manure

For plants to grow well and produce fruits it is important that the media used contains the essential nutrients, there are sixteen of them and based on the quantities of requirement can be classified into macro or micro- nutrients. Out of the macronutrients three viz. N, P and K are usually contained in organic fertilizer or material

2.13.1 Nitrogen

Iwafor *et al* (1990) observed that the yield and plant height were significantly increased by Nitrogen fertilizer. Nitrogen is an important constituent of protein protoplasm and chlorophyll molecule that impact deep protoplasm and deep green colour in leaves and promote vegetative growth. He further stated that protein content and leaf succulence increase with increased nitrogen uptake.

2.13.2 Phosphorous

The importance of phosphorus was long known and vitally important in the storage of energy and transfer of other aspects of plant growth. A research conducted in I.I.T.A. (1984) showed that the yield of cowpea correlated with increase in the varying levels of phosphorus fertilization.

2.13.3 Potassium

Potassium has two roles in the functioning of plant cells. First, it has an irreplaceable part to play in the activation of enzymes which are fundamental to metabolic processes, especially the production of proteins and sugars. Secondly, potassium is the plant preferred ion for maintaining the water content and rigidity of each cell. A large concentration of potassium in the cell sap, creates conditions that cause water to move into the cell through the porous cell wall. Potassium helps plants combat the adverse effects of drought and frost damage and insect attack. It also improves fruit quality and the oil content of many oil-producing crops (http//:www.efoma.be).

Adetoro (1983) also confirmed that potassium affects numerous plant physiological processes and also encourage the formation of carbohydrate compound. He also stated further that potassium is highly important in photosynthesis and that it has positive effect on the formation in photosynthesis and that it has positive effect on the formation of chlorophyll and growth of roots.

Beegle and Durst (2001) reported that potassium in animal manure is almost totally dissolved in the liquid fraction, so it is important to conserve that portion of the manure. They further stated that as long as liquid is not lost, handling and surface or incorporated application, do not affect potassium content or availability.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of study area

The study was carried out in selected farm settlements located in Ado – Ekiti Local Government Area of Ekiti State. Ado – Ekiti is located between longitude $4^0 45^1$ to $5^0 45^1$E and latitude $7^0 15^1$ to $8^0 5^1$N (Salami *et al.* 2006).

3.2 Survey study

Four hundred cocoa farmers were randomly selected and interviewed using interviewer administered questionnaire within 36 farm settlements of Ado-Ekiti Local Government Area. This number of cocoa farmers in this study was obtained based on the following statistical parameters

$n = Z^2pq/d^2$

Where n = the desired sample size

z = 1.96 (95% confidence interval)

p = 0.50 (50% proportion)

q = 0.05

d = 0.05 (degree of accuracy)

$n = (1.96)^2 (0.05) (0.05) / 0.05^2$

n = 384 cocoa farmers

This number was made up to 400 of cocoa farmers with a view to accommodating the effect of loss due to attrition. A stratified random sampling using proportional allocation based on the number of cocoa farmers in the 36 farm settlements in Ado- Ekiti was done to select the 400 cocoa farmers that were interviewed with the aid of a questionnaire

Having got 400 cocoa farmers based on the proportional allocation, a simple random sampling through the use of balloting was adopted in selecting the cocoa farmers that were actually interviewed.

The questionnaire was made up of sections containing socio-demographic features, current perceptions and practices of cocoa farmers regarding CPH, area of land occupied by cocoa plantation and management of alternative wastes. About five research assistants were trained and subsequently assisted in the collection of data from the cocoa farmers. A pretest of the questionnaire was conducted before the actual commencement of the data collection from the cocoa farmers. Descriptive statistics such as bar graphs, pie-charts and frequency tables were used to summarize the results.

3.3 Experimental Studies

The experimental studies were divided into two viz. Laboratory analyses and green house experiments.

3.4 Collection of Materials

3.4.1 Collection of Fresh Cocoa Pod Husks

A multistage sampling technique (2-stage) was used to select the farm settlement where the study actually took place. 30kg of fresh cocoa pod husks with average weight of 93g each was selected for use in the composting systems set up.

3.4.2 Collection of Goat Dung

About 10kg of goat dung used in one of the compositing systems set up was collected from different locations where goats are reared around Ajilosun area in Ado – Ekiti metropolis.

3.4.3 Collection of Uncomposted Cocoa Pod Husks

About 2kg of already dumped CPHs that were allowed to decompose naturally for 54 days with average weight of 83g each was selected for use. The selected CPHs were chopped into small bits, sun dried for five days and ground into powder with a grinder provided by Bisolab Ventures Ado – Ekiti. This was labelled "uncomposted CPH"

3.4.4 Collection of Exhausted soil

About 90kg of exhausted soil was collected from the gully erosion site in Ajilosun, Ado-Ekiti.

3.5 Composting Systems

Two types of composts were employed in this study. The first being the composting of 10kg of fresh cocoa pod husks plus 10kg of goat dung. The fresh cocoa pod husks were chopped into small bits and later mixed thoroughly with the goat dung by pounding until a homogenous mixture was perceived. The mixture was heaped and labeled "composted CPH + GD 1:1 v/v".

Second, 20kg of fresh cocoa pod husks was equally chopped into small bits, pounded and heaped as done above. This was labeled "composted CPH only". The two composts were continuously mixed everyday for 54 days with the monitoring of change in temperature and moisture content of the heaps. Monitoring of the Nitrogen, Phosphorus, Potassium and Organic Carbon together with other nutrient elements was done on the 1st, 8th, 15th, 36th and 54th day of composting. The mixture of the two heaps was done to accomplish the release of nutrients gradually through mineralization as reported by Moyosore (2006).

3.6 Preparation of Potting Media

The exhausted soil was sieved to remove stones, pebbles and other foreign materials and to enhance thorough mixing of the fertilizer materials. The exhausted soil was bagged and washed with distilled water procured from Bisolab Ventures Limited, Ado – Ekiti. The washing of the exhausted soil was done for 3 days consecutively after which it was air dried properly.

The three fertilizer materials were prepared as follows

Assuming 2×10^{6}kg soil is in 1 hectare (Standard Soil Science estimates as communicated by Professor G.O Adeoye of Department of Agronomy, Ibadan)

Therefore 2×10^{6}kg soil requires 2.5 tonnes of fertilizer

1kg soil will require $\frac{2{,}500\text{kg}}{2 \times 10^{6}\text{kg}}$

10kg soil will require $\frac{2.5 \times 10^{3}}{2 \times 10^{6}} \times 10$

$$= \frac{2.5 \times 10^{4}}{2 \times 10^{6}}$$

$$= \frac{2.5}{2} \times 10^{4-6} \times 10^{3}$$

$$= \frac{2.5}{2} \times 10^{4-6+3}$$

$$= 1.25 \times 10$$

$$= 12.5\text{g}$$

This means that 12.5g of fertilizer materials would be mixed with 10kg of exhausted soil. In order to make up for four rates of application of fertilizer materials, 25, 50, 100 and 200kg^{-1} ha were employed in the green house experiment.

3.7 Green House Experiment

The green house experiment was conducted between March and May, 2007. Sixty polythene bags were filled with 10kg of the composite samples of exhausted soil. Four rates of fertilizer materials were thoroughly mixed with 48 of the polythene bags containing the soil. The remaining twelve bags were made to be devoid of any fertilizer materials with a view to checking if the exhausted soil contained any minute nutrients after the thorough washing with distilled water. These twelve bags devoid of any amendment were used as the control for this experiment.

The polythene bags were arranged using Randomized Complete Block Design (RCBD) in the green house. This arrangement implies that 16 polythene bags were maintained for each of the fertilizer materials amended with the soil.

3.8 Operations involved in planting and post planting of cocoa seedlings

To assess the efficiency of the fertilizer materials, cocoa seedlings were used as a test crop. Fresh cocoa seeds were collected from the pod and soaked in water up to six hours. Water was drained and the seeds were allowed to stay over night. This was done in accordance with the method of ensuring adequate growth of seeds by Anand *et al* (1995).

The cocoa seeds were planted in the 60 polythene bags with four replicates maintained for each rate of fertilizer materials amended with the soil in the green house. The filled polythene bags were watered before the planting of cocoa seeds and watering continued twice a day at 0.7 litre per bag until the experiment was terminated at the tenth week.

3.9 Laboratory Analyses of the Materials Used

3.9.1 Physiochemical Analyses of the Composts

The two composts developed in this study were analyzed for organic carbon, total nitrogen, total phosphorus, total potassium, moisture content, ash content and pH in water.

3.9.1.1 Determination of Organic Carbon

The organic carbon in the composts was analyzed by employiog Walkley – Black wet oxidation method. This was done by grinding about 2grammes of each sample from the composts so as to allow it pass through 0.5mm sieve 1 g of the sample was weighed in duplicate and transferred to 25ml Erlemeyer flask. 10ml of potassium heptaoxodichromate (IV) [$K_2Cr_2O_7$] solution was accurately pipette into each flask and swirled gently to disperse the sample. Twenty ml of concentrated H_2SO_4 was rapidly added using an automatic pipette directing the stream into the suspension. The flask was immediately swirled gently until the sample and the reagents were mixed and later swirled more vigorously for one minute. The flask was rotated again and allowed to stand on a sheet of asbestos for about 30 minutes 100ml of distilled water was added after standing for 30 minutes. This was followed by the addition of 3 drops of indicator and titrated with 0.5N ferrous sulphate solution. The mixture was titrated drop by drop until the colour of the mixture changed to light green, then to dark and finally the ferrous sulphate was added drop by drop until the colour changed sharply from blue to red.

Blank titration was made in the same manner but without the sample to standardize the dichromate. The organic carbon content of the sample was calculated using the formular below.

$$\% \text{ Organic carbon} = \frac{(\text{Meq } FeSO_4 \text{ for blank} - \text{meq } FeSO_4 \text{ sample}) \times 0}{\text{Weight of the air dry sample}}$$

Correction factor (f) = 1.33

meq = Normality of solution x ml of solution used

3.9.1.2 Total Phosphorus

Colorimetric determination of phosphorus was done using vanadomolybdate (yellow) method. It was done by pipetting 10ml of sample solution from wet digestion into a 100ml volumetric flask after which 60ml of distilled water was added. 20ml of vanadomolybdate reagent was added within 5 minutes and diluted to volume. The mixture was mixed and allowed to stand for 10 minutes. Per cent transmittance was determined at 400nm. Phosphorus was then determined from a curve made from the standards.

3.9.1.3 Total Nitrogen

Total Nitrogen was determined in the samples by using Micro-kjeldahl method. The sample was ground to pass 40mesh screen. Duplicate samples containing about 25 to 50mg were weighed on a single cigarette paper and folded in for quantitative transfer to 50ml kjeldahl flask; 2ml distilled water was added and allowed to stand for 30 minutes; and 0.02g powdered pumice (spatula tip) 1.33g K_2SO_4 catalyst mixture and 1.5ml concentrated H_2SO_4 were added to the sample in the flask. The mixture was subsequently heated cautiously on digestion rack until frothing stopped. There was increased heat to gentle boiling with a view to letting H_2SO_4 condense to about one quarter way up neck of the flask. A few drops of 30% H_2O_2 were used to wash isolated sample particles down neck of the flask. After the digest cleared for about 30 minutes, boiling was continued for 30 minutes longer and later allowed to cool. 10ml of deionized water was added slowly with swirling. The swirling continued until undissolved materials were in suspension The distillation apparatus was flushed out for 5 minutes with steam to clean and bring it up to temperature.

The 50ml receiver flask containing 5ml boric acid-indicator solution under condenser of distillation apparatus was placed so that the tip was about 4cm above solution. The flask was then attached with digester and diluted sample to steam jet arm of distillation apparatus 10ml of 50% NaOH = 5% $Na_2S_2O_3$ solution was added through funnel stop clock. When about 1ml of NaOH was left in funnel, it was quickly rinsed with about 15ml of water leaving 2ml in funnel after closing stopper. Distillation was commenced immediately by closing steam by pass forest, then opening inlet stop clock on steam jet arm of distillation apparatus. Distillation was stopped when it reached 35ml mark on receiver flask. Condenser tip was subsequently rinsed with deionized water after which it was titrated to first pink colour with 0.01N H_2SO_4. The total nitrogen in the sample was calculated as follows;

$$\% N = \frac{(T - B) \times N \times 1400}{S}$$

Where T = sample titration (ml)

B = Blank titration (ml)

N = Normality of H_2SO_4 (to 3 decimal places)

S = sample weight (mg)

3.9.1.4 Total Potassium

10g of compost sample was weighed into a flask and 100ml of 1ml neutral ammonium acetate solution was added. The content was stirred intermittently for every 15 minutes for 1 hour. The aliquot was then collected through filtrate. Standard preparation for 0, 2.4,6.8 and 10ppm were made for standardizing the coming 400nm flame photometer used for the reading of potassium. The emission percentage read from the standard was used in plotting a graph from which the composts' sample potassium was determined. The determination was made using the calculation.

$$\text{Formular} = \frac{R \times V \times D}{W}$$

Where	R	=	Emission readings from graph
	V	=	Volume of initial ammonium acetate used
	D	=	Dilution factor
	W	=	Weight of sample used

3.9.1.5 Moisture Content

Moisture can was weighed empty and tagged (W_0). About 2g of sample were added and the moisture can was reweighed and labeled (W_1). The moisture can together with the sample was dried in the hot air drying oven at 105-110^{0}C for 24 hours. After the drying in the oven at the stipulated degree and hours above, it was cooled in the desiccator. The can with the dry sample labeled (W_2) was weighed. The dried sample was again returned to the oven for further 24 hours to make sure that the drying was complete. The weighing of (W_2) was done until constant weight was obtained. The moisture content was determined by using the formula indicated below.

$$\% \text{ moisture} = \frac{W_1 - W_2}{W_1 - W_0} \times 100$$

3.9.1.6 Ash Content

The crucible was weighed empty and recoded as (W_0) after which sample together with the crucible was weighted (W_1). It was latter ashed in the Muffle furnace at 500 – 6000C for 3 hours. The sample was subsequently cooled in a desiccator. The weight of the crucible and dry sample was labeled (W_2)

Procedure for calculation

$$\% Ash = \frac{W_2 - W_0 \times 100}{W_1 - W_0}$$

3.9.1.7 pH Determination of Sample

3.9.1.7.1 pH Determination In Water

This was done using the glass electrode pH meter. 20g of air-dry sample was weighed into 50ml beaker after which 20ml of distilled water was added and allowed to stand for 30 minutes. The mixture was occasionally stirred with a glass rod. Electrodes of the pH meter were partly inserted into the settled suspension and the pH of the sample was measured. This was done carefully by not stirring the suspension during measurement. The results were recorded as "sample pH measured in water".

3.9.1.7.2 pH Determination in KCl

Twenty grammes of sample was weighed to a 50ml beaker and 20ml of distilled water was added. The mixture was equilibrated for 30 minutes with occasional stirring. The pH was determined in a beaker containing 1M KCl and reported as "sample pH measured in 1M KCl".

3.9.2 Physicochemical Analyses of Exhausted Soil Used

Before the washing of the exhausted soil used in this study, it was subjected to several analyses, which eventually prompted the washing off of the revealed minerals and nutrients. In order to avert repetition of the determination procedures, some procedures found to follow the same trend with the analyses of the composts would not be discussed fully. The only seen difference in the procedures mentioned here was the change of the composts' sample to exhausted soil sample. These instances were seen in the determination of organic carbon and determination of soil potassium

3.9.2.1 Determination of Soil Nitrogen

Two grammes of 0.5mm sieved soil was weighed into a Kjeldahl flask, and then into flask with 10ml of H_2SO_4 and 1 tablet of selenium catalyst were added. The mixture was digested for 2 hours and 45minutes until a grey colour, near clear solution was achieved. After leaving cool, the content was washed into a 100ml volumetric flask with distilled water and made to mark. 5ml of 2% boric acid plus 4 drops of mixed indicator of bromocresol green and Methyl red were put into a 100ml flask. The flask was then put under the condenser to ensure that the tube was directly put into the Boric acid to prevent NH_3 escaping during distillation. 10% KOH and 10ml of digest were introduced through the distillation set top funnel. The content was distilled until the conical flask containing Boric acid and mixed indicator reached the 50ml mark. 0.01M HCl was put into a burette to titrate the solution containing trapped NH_3. The end point titre value was noted

Procedure for calculation

$$\% \text{ Nitrogen} = \frac{T \times M}{W} \times \frac{0.04}{1} \times \frac{V_1}{V_2} \times 100$$

Where	T	=	Titre value
	M	=	Molarity of acid
	W	=	Weight of soil
	V_1	=	Volume of digested sample
	V_2	=	Value of sample used or distillation

3.9.2.2 Determination of Soil Phosphorus

5g of air dried 2mm sieved soil was weighed into a plastic container and 35ml of phosphorus extracting solution was added. The mixture was stirred for 1 minute before filtration to obtain aliquots. Standards were prepared for 0, 0.2, 0.4 and 1ppm by pipetting 0.2ml of 50ppm stock solution into 50ml flask and adding 8ml of ascorbic acid plus distilled water to mark. This took care of 0.2ppm standard and the process was repeated for 0.4, 0.8 and 1ppm receptively.

10ml of aliquot was collected into 50ml flask and 7ml of ascorbic acid was added and topped with distilled water. The content was allowed to stay for 1 hour for development of blue colour. Soil and standards absorbance reading was done through the Novaspec spectrophotometer at a wave length of 660 Microns. The standard readings were used in graph plotting for the determination of phosphorous.

$$\text{Formular} = \frac{R \times V \times S}{W} = \text{ppm}$$

Where	R	=	Readings from graph (absorbance)
	V	=	Volume of extracting solution used
	D	=	Dilution factor
	W	=	Weight of soil sample used

3.9.2.3 Determination of Soil Calcium and Magnesium (EDTA Method)

A volume of 20ml of NH_4OAC extracted aliquot was pipetted into a flask of which 10 drops of 2% KCN, 10 drops of 5% ammonium hydrogen chloride, 100ml of distilled water, 15ml of concentrated ammonia solution serving as buffer and 5 drops of Eriochrome Black T indicator were put. A wine colour was noticed. Titration with 0.01m EDTA was done and the colour of the mixture changed to deep blue at the end point. The above procedure gave a combination of Ca^{2+} and Mg^{2+} in the soil. To obtain Ca^{2+} content alone the following procedure was followed.

A volume of 100ml distilled water was added to 20ml sample aliquot and 10ml of 20% potassium hydroxide (buffer), 10 drops of 2% KCN and small quantity of alcscrine powder indicator were added. A wine colour was obtained which was then titrated with 0.01M EDTA to obtain a deep blue end point.

Procedure for calculation

$$\% Ca^{2+} = T \times 0.01M \times \frac{V^1}{V^2} = \frac{100}{10} \times \frac{40}{10} \text{ or } T \times 0.01M \times V_1 \times \frac{100}{V^2}$$

Where T = Titre value gotten from EDTA titration

0.01M = Molarity of acid

V_1 = Total volume of initial extracting solution

V_2 = Volume of extract used

100 = Soil %

W = Weight of soil

40 = Atomic mass of Ca^{2+}

24 = Atomic mass of Mg^{2+}

3.10 Data Collection and Statistical Analyses

Data collected were analyzed using descriptive statistics such as bar graphs, pie-charts and frequency tables. Data was collected on the two composting systems employed in this study. Physicochemical properties of the materials used and temperature change during the composting in this study were involved in data collection. Data was equally collected on the agronomic variables of cocoa seedlings planted as experimental plant in the green house. The following agronomic parameters were considered:

(a) The height of cocoa seedlings in centimeters

(b) The stem girth in centimeters

(c) The number of leaves

All these parameters were measured for 10 weeks after planting (WAP) and data were subjected to analysis of variance (ANOVA) and mean separated using Duncan multiple range tests as reported by SAS (1995). Again, Pearson correlation coefficient between rate of application of fertilizer materials and agronomic variables of cocoa seedlings at different stages of growth was equally determined in this study.

CHAPTER FOUR

RESULTS

4.1 Survey Studies

The results obtained from the age distribution of cocoa farmers in Ado – Ekiti Local Government farm settlement in Figure 4.1 indicated that out of the 400 participants that took part in this study, the age range of participants between 51 to 60 years was the highest with 38.8%, while the lowest (1.5%) range was for 81 to 90 years. The sex of the participants was 90.0% for male and 10.0% for female (Figure 4.2). The marital status of the participants is presented in Table 4.1. The distribution indicated that 84.5% of the participants were married; 0.5% was single; 3.05% were separated; 9.0% were window and 2.5% were divorced.

Participants are predominantly farmers (Table 4.2), with 85.3% practicing farming on a full time basis; others combine farming with other activities such as trading (9.25%), carpentry (1.00%), civil servant (1.00%), electrician (0.75%) and teaching (2.75%). The distribution of participants according to educational background showed that 60.0% of the participants had no formal education, 4.0% participants attended Quranic School, 25.3% participants attended primary school, and 6.8% participants attended secondary school while the remaining 4.0% participants attained tertiary education (Table 4.3).

On the basis of ethnic grouping, 95.5% of the participants were Yoruba, 2.5% participants are Ibo while the remaining 2.0% belongs to other tribes in Nigeria as shown in Table 4.4. The religion of the participants is shown in Table 4.5.

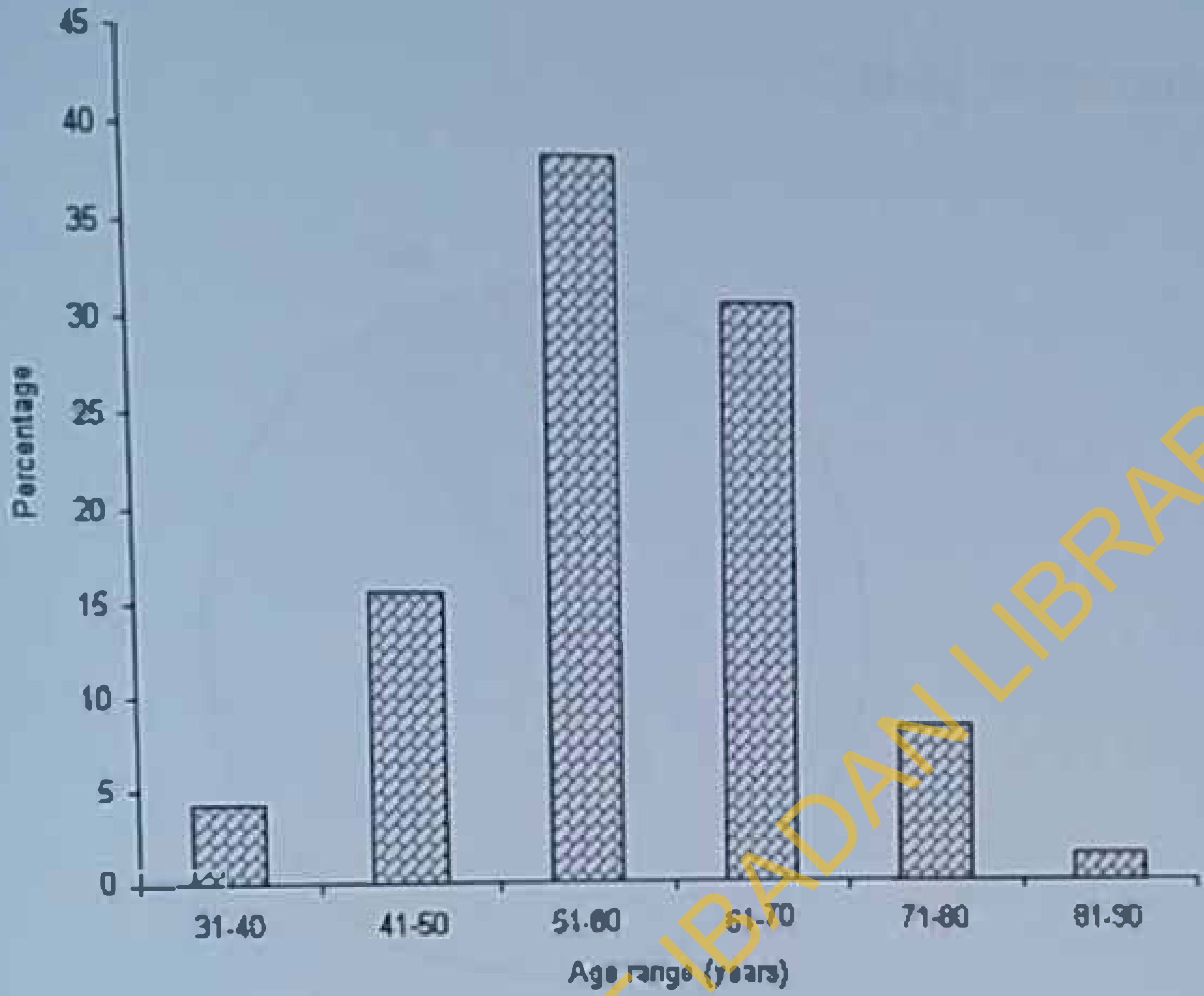

Fig.4.1. Age distribution of cocoa farmers in Ado-Ekiti farm settlements

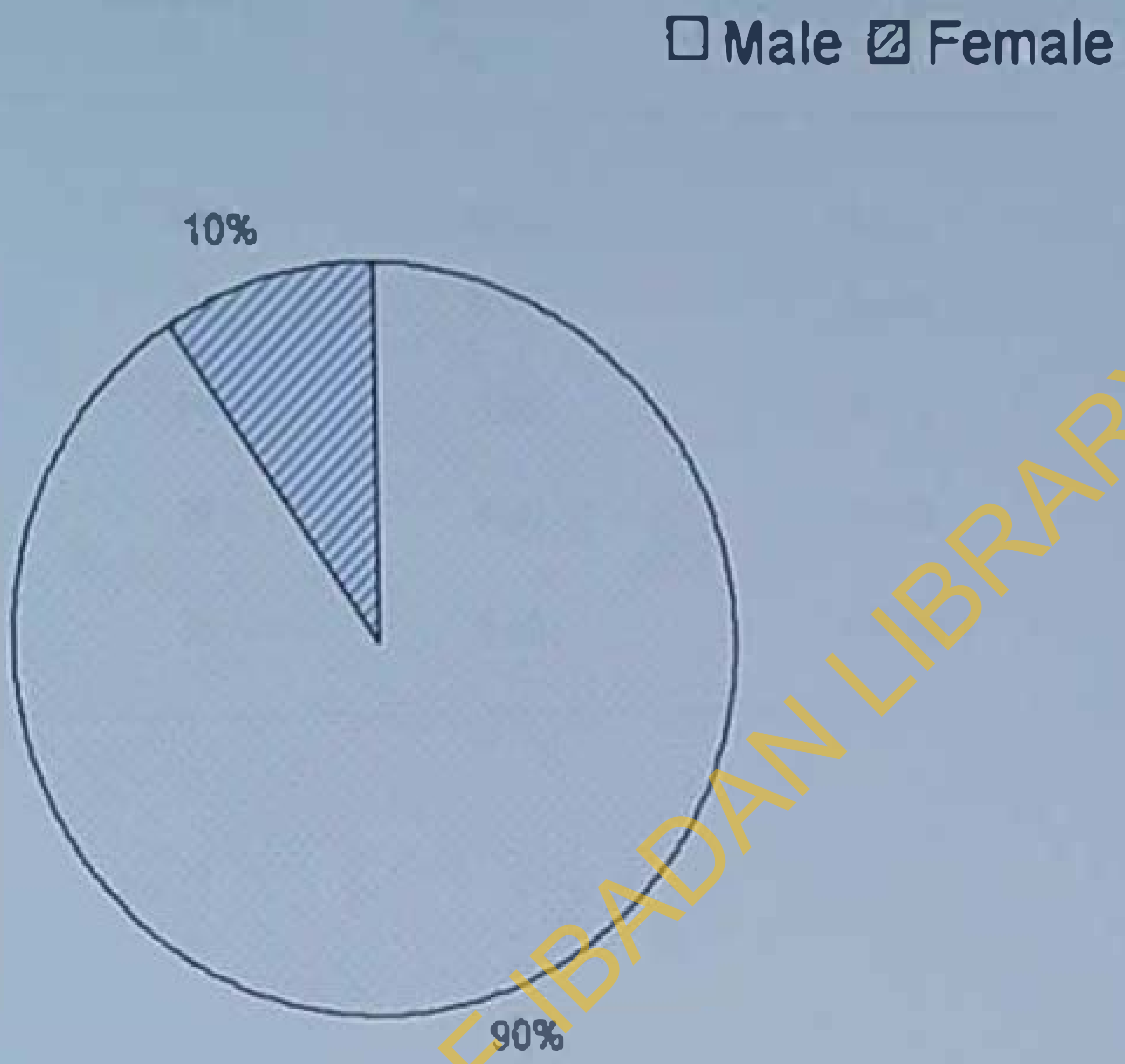

Fig 4.2 Sex distribution of the respondents drawn from 36 farm settlements in Ado-Ekiti

Table 4.1. Marital status of the participants

Marital Status	Frequency (n)	Percentage (%)	Cumulative percentage
Married	338	84.50	84.50
Single	2	0.50	85.00
Separated	14	3.05	88.50
Widowed	36	9.00	97.50
Divorced	10	2.50	100.00

Table 4.2. Major occupation of the participants

Occupation	Frequency (n)	Percentage (%)	Cumulative percentage
Farming	341	85.25	85.25
Trading	37	9.25	94.50
Carpentry	4	1.00	95.50
Civil servant	4	1.00	96.50
Electrician	3	0.75	97.25
Teaching	11	2.75	100.00

Table 4.3. The highest level of education attained by participants

Education	Frequency (n)	Percentage (%)	Cumulative percentage
None	240	60.0	60.0
Quranic School	16	4.0	64.0
Primary school	101	25.3	89.3
Secondary school	27	6.8	96.0
Tertiary e.g. NCE, OND, HND, BSc. And Ph.D	16	4.00	100.0

Table 4.4. The ethnic group of the participants

Ethnic group	Frequency (n)	Percentage (%)	Cumulative percentage
Yoruba	382	95.50	95.50
Ibo	10	2.50	98.00
Others	8	2.00	100.00

Table 4.5. The religion of the participants

Religion	Frequency (n)	Percentage (%)	Cumulative percentage
Christianity	275	68.75	68.78
Islam	89	22.25	91.00
Traditional	36	9.00	100.00

Majority of the participants were Christians (69.8%) while 22.3% were Muslims while only 9.0% practice traditional religions.

The perception of the participants on the consequence of leaving CPH in heaps on their farms indicated that 93.0% of the participants believed such practice promotes black pod disease during the fruiting stage. Others (7.0%). believed that it only occupies space and completely ignorant of their negative consequences (Figure 4.3).

The economic importance of CPH from the participants' perception is presented in Figure 4.4. Majority of the participants (61.75%) admitted knowledge of CPH being used as herb that cures certain diseases such as Malaria, epilepsy and certain skin diseases. Other participants (38.25%) admitted to knowing that CPH can be used in soap making.

The number of cocoa plantation owned by participants is shown in Figure 4.5. it can be inferred that 31.00% of the participants had one cocoa plantation each, 35.75% of the participants had two cocoa plantations each, 15.50% of the participants had three cocoa plantations each, 9.00% participants had four cocoa plantations each while the remaining 8.75% participants had above five cocoa plantations. The size of the cocoa plantations ranged between one and more than five hectares as shown in Figure 4.6. Participants with one hectare of cocoa plantation were 14.74% while 28.0% of the participants had two hectares each, 19.0% of the participants had three hectares each, 20.3% participants had four hectares of each while 18.0% participants had above five hectares of cocoa plantation each.

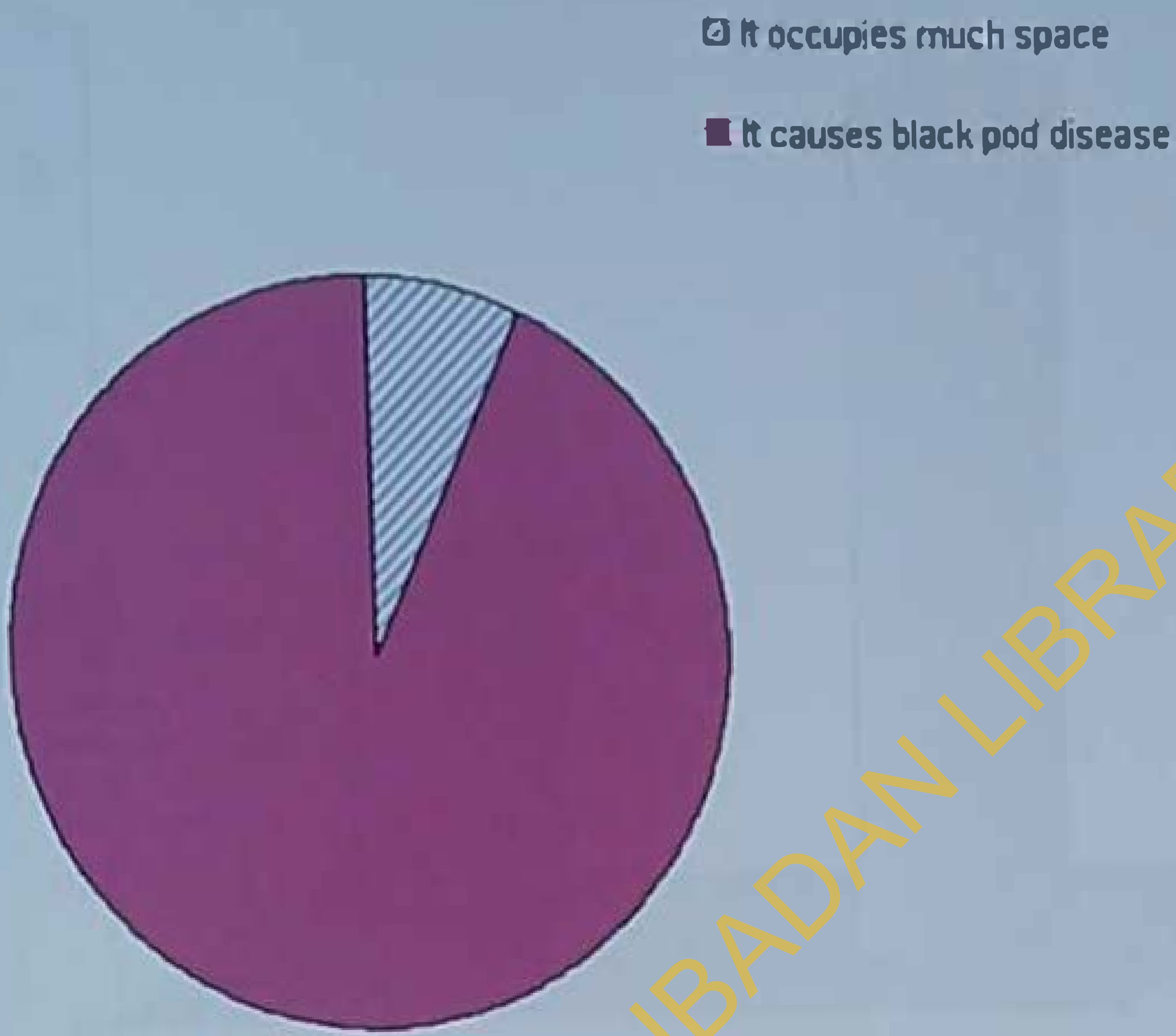

Fig. 4.3. Problems faced by cocoa farmers in disposing cocoa pod husk

Fig 4.4 Participants' perception of the economic importance of cocoa pod husk

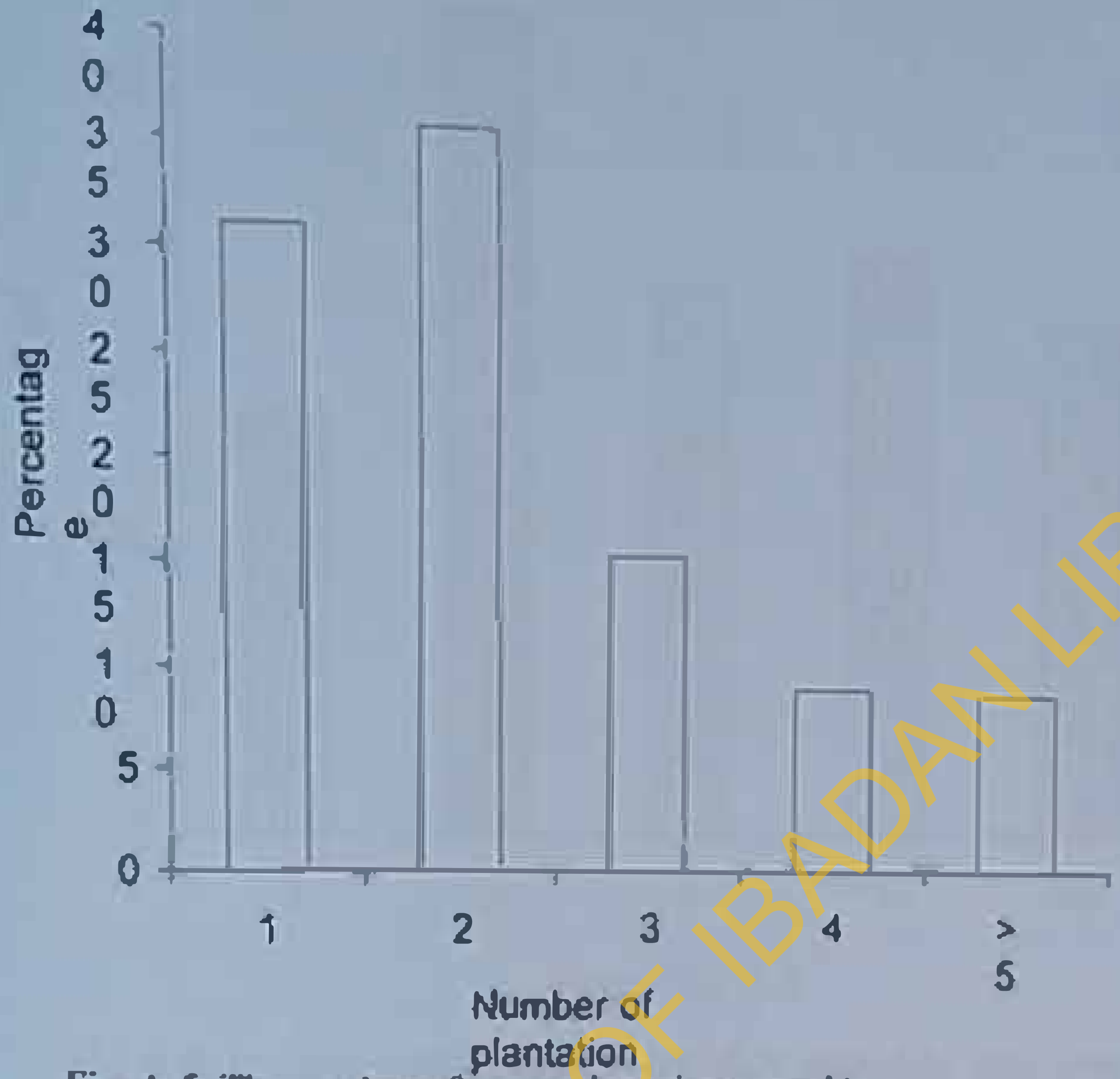

Fig. 4. 5. The number of cocoa plantation owned by participants

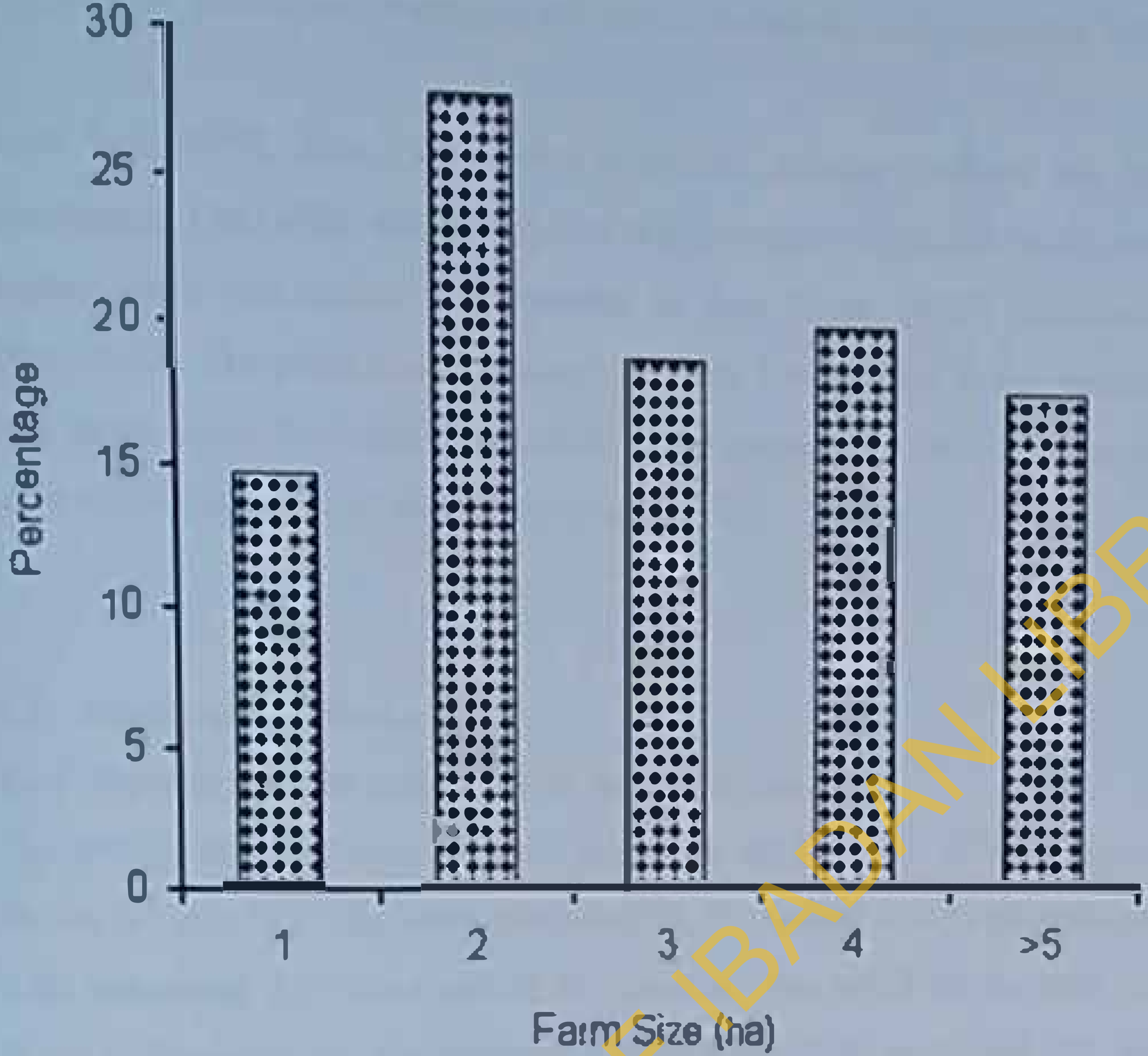

Fig. 4.6. The hectrage of cocoa plantation owned by participants

Sources of labour for clearing of cocoa plantation by participants are shown in Figure 4.7. It was seen that 77.25% participants employ labourers to clear their cocoa plantations while only 22.75% participants manage their cocoa plantations using personal labour.

Apart from CPH, other wastes that constitute disposal problem on farmers' farm were investigated. Out of the 400 participants in this study, only 0.25% stated that Kola pod husk is another waste that requires management on their farms. 5.50% participants responded that other wastes like palm kernel, Banana, Mango, Orange and so on, require management on their farms while the majority (94.25%) of the participants felt there was no other waste that warrants management on their farms (Figure 4.8).

4.2 Experimental Studies

4.2.1 Physicochemical properties of the media used

The physicochemical properties of goat dung used in one of the composting systems are shown in Table 4.6. The dung contained 54.2% carbon, 0.61% phosphorus, 2.5% Nitrogen, 0.9% potassium, 3.61% ash and 24.0% moisture. The pH of the material is near neutral (7.76 in H_2O). However the physiochemical properties of the exhausted soil used showed that it contained 2.1% organic carbon, 19.0ppm available phosphorus, 0.51% Nitrogen, 1.03 Meq /100g soil potassium and pH (KCl) of 6.20 (Table 4.6)

The physiochemical properties of uncomposted CPH are shown in Table 4.6. It contained 31.8% Organic Carbon, 2.7% Nitrogen, 0.1% Phosphorous, 3.1% Potassium, 11.7% Ash and 29.0% moisture. The pH in H2O is 7.2. However, the composting systems set up in this study which comprised of composted CPH + GD (1:1v/v)

Fig. 4.7. Sources of labour for clearing of cocoa plantation by participants

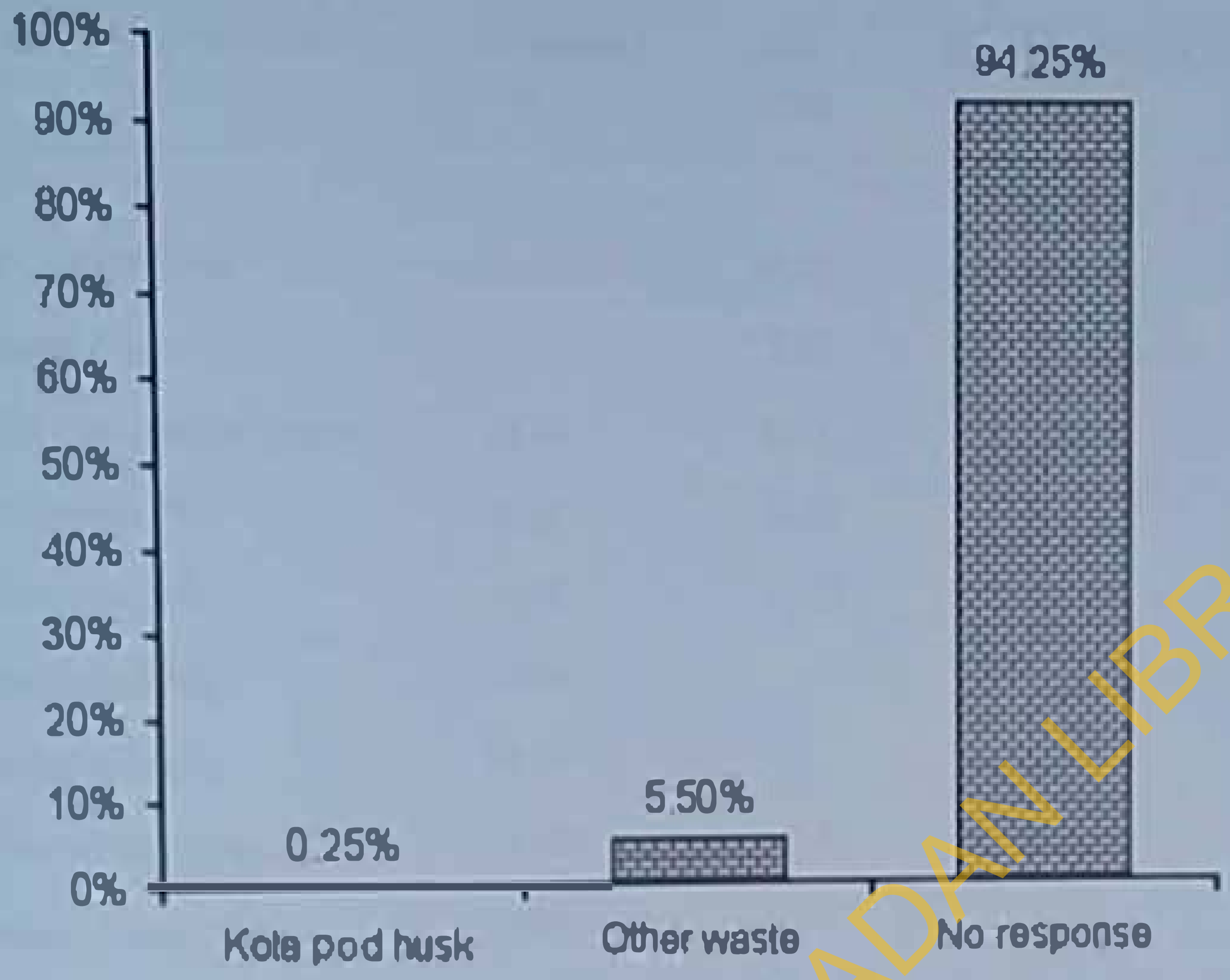

Fig. 4.8 Other waste requiring management on participants farm

Table 4.6: Physical and chemical properties of exhausted soil and organic materials used

Physiochemical properties	Exhausted Soil	Goat Dung	Uncomposted CPH
Moisture content (%)	-	24.00	29.03
Ash content (%)	-	3.61	11.66
Available phosphorus (ppm)	18.99	0.61	0.09
Organic carbon (%)	2.12	54.17	31.82
Total Nitrogen (%)	0.51	2.45	2.66
Calcium (meq/100g)	1.52	-	-
Sodium (meq/100g)	24.00	-	-
Potassium (meq/100g)	1.03	0.85	3.04
Magnesium (meq/100g)	0.01	-	-
Acidity (meq/100g)	0.40	-	-
CEC (meq/100g)	3.21	-	-
Clay (%)	5.20	-	-
Silt (%)	3.40	-	-
Sand %	91.40	-	-
pH in water	7.01	7.76	7.20
pH in KCl	6.20	-	-

and composted CPH only as shown in Table 4.7 revealed that composted CPH + GD (1: 1 v/v) contained organic carbon which ranged between 35.9% and 48.2% for first and last day of composting respectively.

The increase observed in organic carbon was 34.2%. The Nitrogen content ranged between 5.25 and 5.89% for the first and last day of composting respectively. The increase observed in the Nitrogen and Potassium contents was 12.19 and 12.88% respectively. The Phosphorus, ash and moisture contents showed an inconsistent trend during the composting. Phosphorus and Potassium contents of the composted CPH only increased with time during composting by 141.7 and 38.2% respectively. Nitrogen, Carbon, ash and moisture contents also showed an inconsistent increase during the composting. (Table 4.7).

During this study, a whole lot of cocoa plantations across Ado Ekiti Local Government area were visited. Plate 4.1 shows two cocoa pod husk dumps in a plantation undergoing natural decomposition. Again, the two composting systems employed in this study after a composite was made are shown in Plate 4.2 where two composting systems were made to undergo an open aeration composting process.

During composting, the highest temperature measured was 43°C in the second day of composting. This temperature arose from the compost made up of CPH + GD 1:1 v/v. The composting of CPH only, gave the highest temperature of 35.6°C which was recorded in the second day of composting. (Figure 4.9).

4.3 Growth Variables of Cocoa Seedlings

4.3.1 Stem Girth

The effect of the three sources of fertilizer materials on the stem girth of cocoa seedlings is shown in Table 4.8. There was a significant difference between the fertilizer materials throughout the period of observation. The trend in stem girth of seedlings was in the following order: CPH+GD > CPH only > uncomposted CPH.

Table 4.7. Physicochemical Properties of the Composting Systems during maturation at different days of composting

Properties	CPH + GD (1:1v/v)					CPH ONLY				
	1	8	15	36	54	1	8	15	36	54
Moisture content (%)	11.35	11.03	11.27	11.32	22.00	10.02	10.14	10.06	9.94	17.00
Dry matter (%)	88.65	88.77	88.73	88.68		89.97	89.86	89.97	90.06	
Organic carbon (%)	35.92	36.93	38.69	42.57	48.20	33.14	33.35	34.66	33.13	33.30
Phosphorus (%)	0.43	0.46	0.49	0.47	0.49	0.24	0.35	0.40	0.51	0.58
Nitrogen (%)	5.25	5.67	5.88	5.88	5.89	4.18	4.45	4.67	4.66	4.88
Potassium (%)	3.65	3.74	3.91	3.97	4.12	2.59	3.03	3.05	3.09	3.58
Ash content (%)	7.08	6.95	7.11	6.98		9.75	9.83	9.78	9.88	
pH in water					9.45					9.71

Plate 4.1. Cocoa Pod Husk dump in a plantation undergoing natural decomposition

Plate 4.2. Composts made from cocoa pods

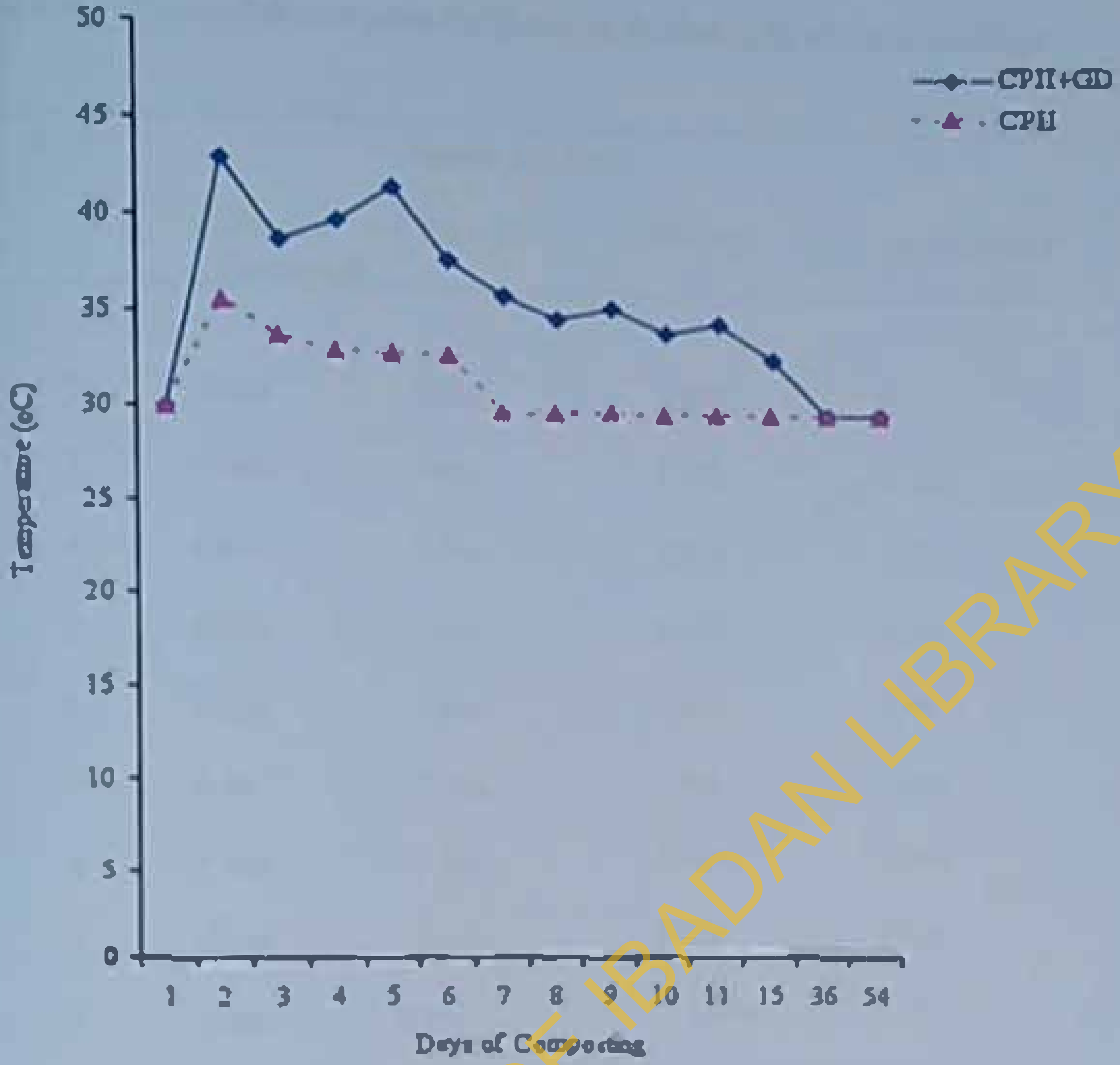

Fig 4.9. Change in temperature of the composting systems

Table 4.8. Effect of three organic fertilizers on the stem girth of cocoa seedlings

WAP	Organic fertilizers			
	Exhausted Soil(control)	CPH + GD	CPH only	uncomposted CPH
2	0.00d	0.91a	0.51b	0.19c
3	0.00d	1.08a	0.70b	0.20c
4	0.00d	1.21a	0.82b	0.37c
5	0.00d	1.33a	0.88b	0.50c
6	0.00d	1.68a	1.04b	0.68c
7	0.00d	2.33a	1.40b	1.24c
8	0.00d	2.41a	1.46b	1.28c
9	0.00d	2.52a	1.51b	1.31c
10	0.00d	2.64a	1.60b	1.35c

Means with the same letters in each row are not statistically significant by Duncan multiple range rate at 5% level of significance.

The addition of GD during composting contributed between 47.56 to 78.73% to stem girth at 4 and 2 weeks after planting respectively.

Furthermore, composting contributed between 12.90 to 250.00% to stem girth at 7 and 2 weeks after planting respectively. The effect of the rates of fertilizer application on the stem girth is shown in Table 4.9; the addition of 200kg^{-1} ha of fertilizer application was different significantly from other lower rates throughout the period of observation, however there was no significant difference among 100, 50 and 25kg^{-1} ha rates in the first 5 weeks of observation. Again, 100 and 50kg^{-1} ha rates of fertilizer application were not significantly different from themselves between 7 and 10 weeks after planting (Table 4.9).

4.3.2 Number of Leaves

The effect of the three sources of fertilizer materials on the number of leaves is shown in Table 4.10. CPH + GD 1:1 v/v was significantly different from CPH only and uncomposted CPH throughout the period of observation. The addition of GD during composting contributed between 9.76 and 77.36% to number of leaves at 4 and 10 weeks after planting respectively. However, composting contributed between 26.73 and 38.89% to number of leaves at 5 and 3 weeks after planting. Composting process did not significantly enhance the number of leaves of cocoa seedlings between 6 and 10 weeks after planting.

Cocoa seedlings receiving 200 kg^{-1} ha rate consistently had the highest number of leaves which was significantly different ($P<0.05$) from other rates throughout the period of observation (Table 4.11). Also, 100, 50 and 25 kg^{-1} ha rates of fertilizer application were significantly different from themselves except at 6 and 7 weeks after planting.

4.3.3 Stem Length

The effect of the three sources of fertilizer application on the stem length is shown in Table 4.12. There was significant difference between CPH + GD 1:1 v/v other sources throughout the period of observation. Beyond 4 weeks after planting, there was no significant difference between CPH only and uncomposted CPH treated cocoa seedlings. The addition of GD

Table 4.9. Effect of four rates of organic fertilizer application on the stem girth of cocoa seedlings.

WAP	Organic fertilizer rates (kg^{-1} ha)				
	0	25	50	100	200
2	0.00c	0.31b	0.46b	0.52b	0.86a
3	0.00c	0.44b	0.54b	0.63b	1.10a
4	0.00c	0.51b	0.63b	0.74b	1.30a
5	0.00c	0.56b	0.76b	0.84b	1.47a
6	0.00d	0.64c	0.92bc	1.08b	1.89a
7	0.00d	0.72c	1.53b	1.59b	2.79a
8	0.00d	0.76c	1.62b	1.62b	2.87a
9	0.00d	0.86c	1.66b	1.68b	2.96a
10	0.00d	0.84c	1.74b	1.81b	3.06a

Means with the same letters in each row are not statistically significant by Duncan multiple range rule at 5% level of significance.

Table 4.10. Effect of the fertilizers on number of leaves of cocoa seedlings.

WAP	Exhausted Soil (control)	Organic fertilizers		
		CPH + GD	CPH ONLY	uncomposted CPH
3	0.00c	1.67a	1.50ab	1.08b
4	0.00d	2.25a	2.05b	1.50c
5	0.00c	3.42a	2.75ab	2.17b
6	0.00c	4.58a	3.08b	2.75b
7	0.00c	7.33a	4.42b	3.92b
8	0.00c	8.67a	5.17b	4.75b
9	0.00c	9.58a	5.50b	5.00b
10	0.00c	10.50a	5.92b	5.58b

Means with the same letters in each row are not statistically significant by Duncan multiple range rate at 5% level of significance

Table 4.11. Effect of four rates of Organic Fertilizer Application on Number of Leaves of Cocoa Seedlings

WAP	Organic fertilizer rates (kg^{-1} ha) 0	25	50	100	200
3	0.00c	0.78b	1.44b	1.22b	2.22a
4	0.00c	1.11b	2.00ab	2.00ab	2.89a
5	0.00c	1.89b	2.89ab	2.56b	378a
6	0.00c	2.33b	3.33b	3.11b	5.11a
7	0.00c	3.33b	4.78b	5.00b	7.78a
8	0.00d	3.89c	6.11b	5.67bc	9.11a
9	0.00d	4.00c	6.78b	6.11c	9.89a
10	0.00d	4.33c	7.33b	6.67bc	11.00a

Means with the same letters in each row are not statistically significant by Duncan multiple range rate at 5% level of significance.

Table 4.12. Effect of the organic fertilizers on stem length of cocoa seedlings

WAP	Exhausted soil	Organic fertilizers CPH + GD	CPH ONLY	uncomposted CPH
2	0.00b	3.67 a	2.53 a	3.36 a
3	0.00c	9.79 a	4.48 b	7.28 a
4	0.00c	14.56 a	6.54 b	8.03 b
6	0.00c	15.02 a	6.70 b	8.35 b
5	0.00c	13.84a	6.42b	7.87b
7	0.00c	15.53 a	7.18 b	8.56 b
8	0.00c	15.73 a	7.29 b	9.10 b
9	0.00c	15.89 a	7.43 b	9.33 b
10	0.00c	16.02 a	7.51 b	9.45 b

Means with the same letters in each row are not statistically significant by Duncan multiple range rate at 5% level of significance.

during composting contributed between 113.32 and 124.18% to stem length at 9 and 6 weeks after planting respectively. Composting process heightened stem length by between 22.59 and 62.50% at 4 and 3 weeks after planting respectively.

Optimum performance in terms of stem height was observed for seedlings raised on 200 kg^{-1} ha rate of fertilizer which was significantly different ($p<0.05$) from the lower rates (Table 4.13). From 4 weeks upward, the stem length of seedlings raised on 200 and 100 kg^{-1} ha fertilizer material did not differ significantly, but were significantly different from those seedlings that received 25 kg^{-1} ha.

4.1 Correlation between Variables

The correlation between rate of fertilizer application and the three agronomic variables were positive and significant during the 3, 6 and 10 weeks of observation (Table 4.14). Out of the three variables, stem girth had the highest correlation coefficient of 0.63 and 0.65 at 6 and 10 weeks after planting respectively, which were significantly different ($P<0.001$). The least coefficient (0.43) was between rate of fertilizer application and stem length at 6 weeks after planting ($P<0.01$).

During the monitoring of the growth of the cocoa seedlings under green house conditions, pictures taken in the fifth and tenth week after planting the cocoa seedlings are shown in Plate 4.3 and Plate 4.4.

Table 4.13. Effect of four rates of organic fertilizer application on the stem length of cocoa seedlings

WAP	Organic fertilizer rates (kg^{-1} ha)				
	0	25	50	100	200
2	0.00d	1.61c	3.34b	2.91bc	4.87a
3	0.00c	4.08b	6.50b	6.87b	11.29a
4	0.00d	5.16c	9.19b	9.28b	13.88a
5	0.00d	5.63c	9.62b	9.50b	14.08a
6	0.00d	5.97c	10.24b	9.67b	14.21a
7	0.00d	6.22c	10.71b	10.06b	14.69a
8	0.00d	6.34c	11.11b	10.41b	14.97a
9	0.00d	6.39c	11.21b	10.61b	15.32a
10	0.00d	6.42c	11.34b	10.70b	15.50a

Means with the same letters in each row are not statistically significant by Duncan multiple range rate at 5% level of significance.

Table 4.14. Pearson correlation coefficient between fertilizer application rates and agronomic variables of cocoa seedlings at different stages of growth.

	Weeks after planting		
	3	6	10
Stem girth	0.50**	0.63***	0.65***
Stem length	0.54**	0.43**	0.44**
Number of leaves	0.55**	0.40**	0.52**

Note: **, *** = Significant at 1% and 0.1% respectively and positive correlation

Plate 4.3. Cocoa Seedlings grown on (A) composted CPH + goat dung and (B) CPH only under greenhouse condition at 5 WAP

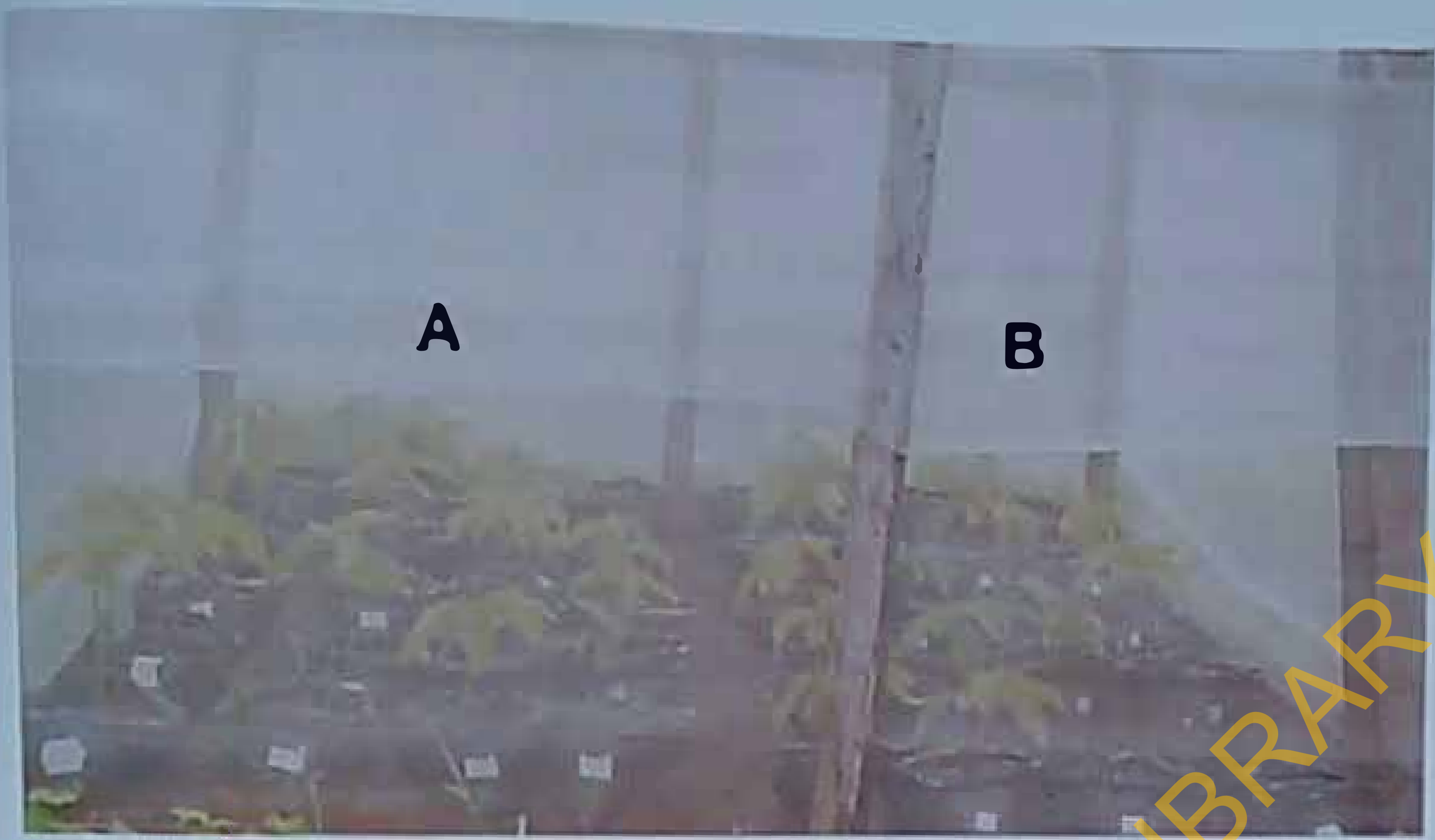

Plate 4.4. Cocoa Seedlings grown on (A) composted CPH + goat dung and (B) CPH only under greenhouse condition at 10WAP

CHAPTER FIVE

DISCUSSION

Majority of the participants in this study had no formal education therefore their level of understanding regarding the imminent effect of leaving CPH in heaps in their cocoa plantations is very low. All the participants interviewed in this study, responded to have seen a cocoa pod before. Their uniform response of seeing a cocoa pod before could be said to qualify all of them as cocoa farmers. All the participants took to leaving the cocoa pod husks as heaps in their plantations after they must have taken the cocoa beans in it. This again justifies the known traditional practice of leaving CPH as heaps after taking the cocoa beans from it in the cocoa plantations. This finding coincides with the report of Sobamiwa (1997) that millions of tonnes of CPH are produced and left as heaps inside cocoa plantations annually across the West Africa sub-region.

The perception of the participants on the consequence of leaving CPH in heaps on their farms indicated that majority of the participants believed such practice promotes black pod disease during the fruiting stage. This finding, justifies the claim of Opeke (1992) that CPH become a significant source of disease inoculums when used as mulching materials inside the plantation. Other participants believed that it only occupies space in their plantations and were completely ignorant of the use of CPH as organic fertilizer.

Majority of the participants admitted knowledge of CPH being used as herb that cures certain diseases such as Malaria, epilepsy and certain skin diseases while other participants admitted to knowing that CPH can be used in soap making. This finding again coincides with the submission of Oduwole and Arueya (1990) and Arueya (1991) that pod husk ash has been used to make soap in Ghana and Nigeria. The finding again corroborated the report of PRWeb (2006) that black soap is made from roasted cocoa pods, plantain skins' ashes mixed with palm oil. These uses to which CPH is put by the farmers although can be a way of managing the waste, the quantity utilized is not sufficient enough to rid the farms of the waste.

The more than three hectare farm size of over 60% of participants is a demonstration of their commitment to farming as means of livelihood despite the advanced ages of the cocoa farmers. This finding has again supported the report of Oladokun (1995) that Ondo State (Ekiti State inclusive then) produces above 70% of the cocoa production in Nigeria and that largely peasant farmers grow this.

It is pertinent to determine the nutritional status of media used in growing crops to guarantee a sustained growth of the crop being grown. In this study, the composition of Nitrogen and Phosphorous reported for goat dung is in line with the report of Salem (1975) that gave a range of 2-3% N and 0.4-0.7% P_2O_5 for these nutrients in goat dung. The submission of Wood and Lass (1985) that CPH contain 3 to 4% potassium on dry basis proved to be correct in the sense that the chemical composition of the processed CPH used in this study, gave 3.04%.

It can be seen from the results of the physicochemical properties of the composting systems that organic carbon, phosphorus, Nitrogen and potassium contents of the two composting systems increased with days of composting. These increments over time mean that nutrients were gradually released through mineralization of the composts; similar observation was made by Moyosore (2006). The compost of CPH+GD 1:1 v/v was observed to produce the higher contents of these nutrients when compared to the compost of CPH only.

It is observed from the result that composted CPH+GD 1:1 v/v produced the best performance in terms of stem girth, stem length and number of leaves throughout the period of observation. Although composted CPH only and uncomposted CPH produced appreciable performance on the agronomic variables but they could not be matched up with the result produced by composted CPH+GD 1:1 v/v. The optimum performance of composted CPH+GD 1:1 v/v could be linked with the addition of GD in the compost which presumable is an additional source of nutrients that promotes better performance.

The effect of high rate of fertilizer application on the stem girth of cocoa seedlings was tremendous. Even though 200 kg^{-1} ha rate of fertilizer application had the best performance throughout the experiment in term of stem girth, 100, 50 and 25 kg^{-1} ha rates of fertilizer application produced a non significant effect on the stem girth at 2, 3, 4 and 5WAP. This can be attributed to the fact that nutrients were slowly released from the added fertilizer materials. Again, the effect of 100 and 50 kg^{-1} ha rates of fertilizer application were not significant at 7WAP up to 10WAP. This result implies that cocoa seedlings during nursery need a substantial rate of fertilizer application with a view to producing a very good performance in terms of stem girth.

Composted CPH + GD 1:1 v/v again had the best performance out of the three fertilizer materials used in this study on the number of leaves produced throughout the period of the experiment in the green house. Composted CPH only and uncomposted CPH had a non significantly different effect on number of leaves from 6 to 10WAP. It was observed that 200 kg^{-1} ha rate of fertilizer application had the best performance in terms of number of leaves produced throughout the experiment whereas 100, 25 and 50 kg^{-1} ha rates of fertilizer application produced a non significantly different result at 6WAP and 7WAP. This trend was recorded at 4WAP between the two rates of fertilizer application on number of leaves produced.

It can be seen that composted CPH + GD 1:1 v/v had the best performance in terms of stem length when compared with composted CPH only and uncomposted CPH throughout the 10 weeks of monitoring in the green house. Although, uncomposted CPH was better than composted CPH only up to 4WAP with respect to stem length. This trend changed from the 5 WAP up to 10 WAP with composted CPH only being better. mineralization process can be implicated for this change. It can again be seen that 200 kg^{-1} ha rate of fertilizer application gave the best performance in terms of stem length of cocoa seedlings throughout the experiment. Lower rates of 100 and 50 kg^{-1} ha of fertilizer application had no significantly different effect on the stem length of cocoa seedlings from 3WAP to 10WAP. This result again suggests that a substantial rate of fertilizer application is needed during the nursery of cocoa seedlings so as to attain the best performance in terms of stem length.

Positive and significant correlation between rate of fertilizer application and the agronomic variable suggest higher rate of fertilizer application enhances the performance of the measured variable which further reiterates earlier submission in this work.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

The outcome of this study indicated that cocoa farmers in Ado – Ekiti Local Government Area are used to leaving CPH as heaps in their plantations after they must have taken the cocoa beans from it. Although these CPH are produced and left as heaps in their plantations annually, nothing is done to maximize the use.

Due to the results obtained from the effects of the three sources of organic fertilizer materials and their rate of application of the organic fertilizer materials on all the agronomic variables monitored in this study, it can be concluded that they all varied with rate of application of the organic fertilizer materials. Composted CPH + GD 1:1 v/v that had the best performance in all the agronomic variables monitored is believed to achieve this feat due to the addition of goat dung during the composting. Composted CPH only and uncomposted CPH were not significantly different from each other going by the results obtained from the agronomic variables monitored. It is advisable to add an organic waste to the composting of CPH as this will ultimately yield a very positive and productive result in improving soil fertility. Composted CPH only and uncomposted CPH are not totally advisable since their outcome on the growth of cocoa seedlings used in this study did not give the best performance.

Again, it is recommended that a substantial rate of fertilizer application that is more than 200 kg^{-1} ha that had the best performance on the monitored agronomic variables, be used in the nursery of cocoa seedlings with a view to bringing the best out of the growth of the seedlings.

The practice of using CPH as an organic fertilizer for farmers to appropriate the use of inorganic fertilizer that are becoming more expensive every day is highly recommended. This is because of the fact that the practice is environmentally friendly and CPHs are locally available annually in all the cocoa producing regions in the world over. Cocoa farmers that produce CPH without maximizing the availability need to be educated on the potentials of these agro-allied waste products being used in making organic fertilizer that can be used to improve soil fertility.

It is recommended that further experiment needs to be conducted to really ascertain the best organic waste that can be composted with CPH so as to attain the best outcome in terms of improving soil fertility.

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Appendix 1

QUESTIONNAIRE ON THE UTILIZATION OF COCOA POD HUSK (CPH) FOR THE PRODUCTION OF ORGANIC FERTILIZER AS A WASTE MANAGEMENT STRATEGY

Dear Respondent,

I am a postgraduate student of the Department of Epidemiology, Medical Statistics and Environmental Health (EMSEH), College of Medicine, University of Ibadan presently carrying out a research on the utilization of cocoa pod husk for the production of organic fertilizer as a waste management strategy. I wish to kindly request your voluntary participation by providing answers to the following questions honestly as this would increase the quality of the findings. Please, be rest assured that all information provided by you would be used for research purposes only and strict confidentiality would be ensured.

Thanks for your co-operation.

1. Serial No.........

SECTION A: SOCIO-DEMOGRAPHIC INFORMATION

2. Age.....................

3. Sex: 1. Male 2. Female ☐

4. Marital Status
   1. Married
   2. Single ☐
   3. Separated
   4. Widowed
   5. Divorced

5. Major Occupation................

6. Highest level of education attained
   1. None
   2. Quranic school ☐
   3. Primary school
   4. Secondary School
   5. Tertiary (Please specify e.g NCE, OND, HND, B.Sc, PhD.........

7. Ethnicity..........

1. Yoruba
2. Hausa
3. Ibo
4. Others (specify)...............

8. Religion

1. Christianity
2. Islam
3. Traditional
4. Others (specify).....

SECTION B: PERCEPTIONS AND PRACTICES CONCERNING COCOA POD HUSK

9. Have you seen a cocoa pod before?

1. Yes. 2. No

10. If yes, what do you do with the pod husk after taking the beans in it?

1. Bury
2. Burn
3. Leave as heap inside cocoa plantation
4. Dispose into a nearby bush
5. Others (specify)..........

11. Do you face any problems in disposing the cocoa pod husk?

1. Yes. 2. No

12. If yes, what kind of problem(s)

1..............................
2..............................

13. Do you know any economic importance of the cocoa pod husk?

1. Yes 2. No

14. If yes, specify it

1..............................
2..............................

15. If no, would you like to know?

1. Yes 2. No

SECTION C: AREA OF LAND OCCUPIED BY COCOA PLANTATION

16. How many cocoa plantation (s) do you have?

1. One
2. Two
3. Three
4. Four
5. Others (specify)............

17. How many hectares of land do your cocoa plantation(s) cover?

1. One
2. Two
3. Three
4. Four
5. Others (specify)...........

18. How do you manage you cocoa plantation(s) in terms of clearing.

1. Self clearing
2. Employment of laboureis
3. The use of weed killers (chemicals)
4. Others (specify)..........

SECTION D: MANAGEMENT OF ALTERNATIVE WASTE

19. Do you have any other waste that requires management on your farm?

1. Yes 2. No

20. If yes, what kind of waste

1.............................
2.............................
3.............................

20. Do/Does these/this waste(s) have/has any negative impacts on your farming activities?

1. Yes 2. No

22. If yes, what kind of problem(s)

1.............................
2.............................
3.............................