EFFECT OF WATERING REGIME AND COCOA POD HUSK ON SOIL FERTILITY AND GROWTH OF HYBRID COCOA SEEDLINGS IN THE SEMI - DECIDUOUS FOREST ZONE OF GHANA

By

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DECLARATION

I hereby declare that this submission is my own work towards the Master of Science degree (Soil and Water Engineering) and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgment has been made in the text.

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DEDICATION

TO GOD ALMIGHTY AND JESUS CHRIST HIS ONLY BEGOTTEN SON, FOR NOTHING IS IMPOSSIBLE WITH GOD AND TO MY DEAREST MOTHER THERESA NUAKO.

ABSTRACT

The establishment and rehabilitation of smallholder cocoa farms, aimed at replacing over 42 % ageing and non productive stock using seedlings is limited by poor soil fertility and inadequate water application resulted in the less vigorous cocoa seedlings. The experiment was conducted in two planting seasons (November, 2010 and February, 2011) at Buako Cocoa Station in the semi-deciduous forest zone of Ghana to determine the effect of watering regime and cocoa pod husks on soil fertility and growth of hybrid cocoa seedlings in nursery using clone 42 and 85 to replace the old stock in the field. The experimental design used was factorial with three replications. The analysis showed that the soils in the study areas were sandy clay, deficient in magnesium, potassium, phosphorous, calcium and nitrogen which have the potential of negatively influencing the soil fertility status. Application of cocoa pod husks improved significantly ($P<0.05$) soil water holding capacity, soil organic matter content, magnesium, nitrogen, phosphorus, potassium, hydrogen, calcium concentration and reduced soil bulk density. The study revealed that watering regimes II (0.18 l/seedling) and III (0.36 l/seedling) were the most effective treatments in improving leaf minerals and growth parameters of seedlings in both seasons and could be adopted as water requirement for hybrid cocoa seedlings. Leaf mineral concentrations in cocoa seedlings nursed in soil + cocoa pod husks composite increased significantly ($P<0.05$) compared to cocoa seedling nursed separately in only soil and cocoa pod husks. Also soil + cocoa pod husk composite influenced the plant height, leaf area, stem girth, number of leaves and root length growths compared to samples from cocoa pod husks and soil. Finally, results showed that statistically, there were no differences in leaf mineral and growth parameters among the seedlings nursed in the water sachets, COCOBOD, and IITA poly bags and that water sachets could be effectively adopted in raising hybrid cocoa seedlings up to five months.

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CHAPTER ONE

1.1. INTRODUCTION

Most cocoa (*Theobroma cacao L.)* production in Africa is by smallholder farmers, who over the years have been practicing slash and burn. However, increased human population and the quest to increase food production have led to intensive cultivation on arable lands without adequately replenishing soil nutrients. The result has been a declining trend in yields and depletion of the fertile lands (Tisdale and Nelson, 1996). In the tropics an average of 400,000 ha of agricultural land is lost annually (Omotoso, 1975; Alfred, 2009), of which 25% is degraded by water and wind erosion, more than 20% by salinization and almost 50% by other sources. On smallholder farms, soil fertility depletion has been recognized as one of the major biophysical constraint, limiting agricultural production, particularly nitrogen and phosphorus deficiencies (Ahenkorah, 1981; Mokwunye *et al*., 1996). Soil fertility has seldom been considered as a critical issue by the developing countries who until recently have focused primarily on other biophysical constraint, such as soil erosion, drought, and the environment, especially in Africa (Eicher, 1982; Davis and Schimer, 1987). These authors concluded that soil fertility depletion in smallholder farms is the fundamental root cause of declining per capita food production in West and Central Africa and that soil fertility replenishment strategies should be considered as an investment in natural resource capital. They further observed that, no matter how effectively other conditions are remedied, per capita food production in Africa would continue to decline unless the problem of soil fertility depletion is adequately addressed.

Generally, most Ghanaian soils are of low inherent fertility and therefore require an integrated soil fertility management approval for improvement (Ofori and Fianu, 1996; Anim-Kwapong, 2006; Tisdale and Nelson, 1996).

Cocoa production in Ghana is limited by soil nutrient depletion (Anim-Kwapong, 2006; Alfred, 2009). Hybrid cocoa seedlings are raised in nursery using soils and most these soils are deficient in P, K, Ca, Mg, Na, and ECEC (Rhodes, 1995).

The use of mineral fertilizers is the most effective and convenient way to improve soil fertility. However, mineral fertilizer use in Ghana has declined from 21.9 kg/ ha in 1978 to 7.3kg /ha in 1993 (MOFA, 1998) and to the current estimated average of 5kg/ha due mainly to the high cost and acute scarcity at farmers level (Bumb, 1994; Germer *et* al., 1995; Moyin-Jesu, 2004).

Consequently, there is presently a serious negative balance in nutrient budgets of soils posing a major limitation to sustainable soil management for increasing cocoa production and other food crops. Figures show that there is a negative nutrients balance of approximately 27 kg N ha^{-1}, 4kg P ha^{-1} and 21 kg K ha^{-1} annually in Ghana (Hartemink, 2005). Ironically, there are large amount of agro-industrial wastes that could be efficiently utilized as organic fertilizers at affordable cost to farmers, which are extremely sustainable and environmentally friendly in restoring and maintaining productivity of the soil (Agbeniyi *et al*., 2001). . In Ashanti, Bong Ahafo and Western regions for example, an estimated 6,800,000 tons of cocoa pod husks are generated annually and these are allowed to go moldy on the farm harbouring fungus (*phytophtora palmivora*) which are the causal organism of black pod disease (Odedina *et al*., 2007; Moyin-Jesu, 2004; Ofori-Frimpong *et al*., 2003).

Complementary and supplementary to mineral fertilizer is the organic materials, which contain substantial amounts of organic matter with the potential of improving soil nutrient level and crop yields (Titilayo, 1982; Agboola and Adeoye, 1990; Rayer and Chiroma, 1990; Adu- Dapaah *et al.*, 1994 and Folorunso, 1999).

The use of agro-wastes such as cocoa pod husks has great potential for improving soil productivity and crop yield through improvement of the physical, chemical and microbiological properties of the soils (Tandon, 1992; Odedina *et al*., 2007; Moyin-Jesu, 2007; Ayeni *et al*., 2008a; Ofori-Frimpong,*et al*.,2003; Ayeni, 2009).

Apart from soil fertility depletion, other production constraints currently limiting the establishment and rehabilitation of smallholder cocoa farms in Ghana are the scarcity of early bearing and high yielding hybrid cocoa planting seedlings, inadequate knowledge on require water quantity of water required for optimum growth of hybrid cocoa seedlings, inadequate irrigation facilities for nursing seedlings and non availability of standard COCOBOD polythene bags. For sustainable cocoa production in Ghana to be realized, practices and strategies which seek to address constraints affecting the establishment and rehabilitation of smallholder farms must be cautiously explored and adopted.

1.2: Justification

The extent to which cocoa pod husks could be exploited in restoring and maintaining soil fertility and crop production has not received much research attention in Ghana. Though, there are studies reported on utilization of cocoa pod ash for crop production (Obatolu, 1995; Moyin-Jesu and Atoyosoye, 2002; Odedina *et al*., 2007; Moyin-Jesu and Ojeniyi, 2006; Odedina et al., 2007; Ayeni, 2008; Ofori-Frimpong,*et al*.,2003) there is no research information on the optimum level at which cocoa pod husk can effectively be utilized in raising hybrid cocoa seedlings under suitable watering regime in Ghana.

It is within this context that this study was initiated to investigate the effect of watering regimes and cocoa pod husks on the soil fertility, leaf nutrient and physical growth performance of hybrid cocoa planting seedlings in the semi-deciduous forest zone of Ghana.

Research objectives

The main objective of the study was to determine the optimum watering regime and cocoa pod husks on the soil fertility, leaf mineral composition and physical growth parameters of hybrid cocoa seedlings in the semi-deciduous environment of Ghana.

The specific objectives of the study were:

- To determine the impact of cocoa pod husks on soil fertility.
- To determine the effect of watering regimes on the leaf nutrient and physical growth performance of hybrid cocoa planting seedlings.
- To determine the effect of cocoa pod husks only and cocoa pod husks soil mixture on the leaf nutrients and physical growth performance of hybrid cocoa seedlings.
- To determine the effect of water sachets as nursery potting bags on growth of hybrid cocoa seedlings.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Human settlement is found to start first in areas with fertile soils, adequate rainfall and mild temperature regimes. As populations grow, soil nutrient capacity is slowly depleted because farmers are unable to sufficiently compensate losses by replenishing or restoring nutrients to the soil using organic manures and inorganic fertilizers (Agbeniyi et al., 2010).

Increasing pressures on agricultural lands for high production level result in much higher nutrient uptake/absorption by plants. The traditional fertility maintenance strategies such as fallowing, intercropping cereals with legume crops and manure production have not been replaced by an effective fertilizer supply (Agboola and Unamena, 1989; Agbeniyi, 2010).

The bulk of cocoa in Africa is produced on smallholder farms (Asare and David, 2010). One of the major factors limiting cocoa production in Africa is the rapid depletion of nutrients in smallholder farms (Badiane and Delgado, 1995). This is because the smallholder farmers are poorly resourced and unable to invest in soil fertility inputs, particularly mineral fertilizers (Omoti, 1991).This is not surprising since about half of Africa's population is classified as "absolute poor" subsisting on per capita incomes of less than 1 U$$ per day (Badiane and Delgado, 1995).The situation is critical especially when the poor farmer has to bear the full cost of production owing to the removal of subsides on mineral fertilizers. The major effect of soil fertility decline is the food production in most African countries, including Ghana. In order to sustain soil and crop productivity, it is necessary to explore alternative soil fertility replenishment strategies, which are effective and affordable to farmers especially the smallholder farmers

2.2: Soil Nutrient Depletion in Africa

The magnitude of nutrient depletion in Africa's agricultural land is enormous. Stoorvogel and Smaling (1990) indicated that an average of 660kg Nha^{-1}, 75kg Pha^{-1} and 450kg Kha^{-1} have been lost during the last 30 years from about 200 million hectares of cultivated lands in 37 countries of Sub-Saharan Africa, excluding South Africa .This is equivalent to 1.4 tons of urea, 375 $kgha^{-1}$ of triple superphosphate (TSP) or 0.9 tons of phosphate rock (PR) and 896$kgha^{-1}$ of potassium chloride (KCL) during the stated period (Omotoso,1975). These figures represent the balance between nutrient inputs (fertilizers, manure, atmospheric deposition, biological nitrogen fixation (BNF) and sedimentation) and nutrient outputs (harvested products, crop residue removals, leaching, gaseous losses, surface runoff and erosion (Stoorvogel and Smaling, 1990).

Food production influences ''nutrient mining'' since very small amounts of nutrients are returned through fertilizer application (Ofori and Fianu, 1996). In a study commissioned by FAO, Stoorvogel and Smiling (1990) found negative N-P-K budgets in 1983 for all West African countries. Figures show that in Ghana there is a negative nutrient balance of approximately 27kg $ha^{-1}N$, 4$kgha^{-1}P$ and 21kg ha^{-1} K annually.

Rhodes (1995) estimated the rates of total crop nutrients uptake in Ghana at 428,700 tons of N, 73,100 tons of P and 414,900 tons of K over 10 years.

Production of the main food crops in Ghana removes almost 70, 00 tons of N and 25,00 tons of P_2O_5 from the soil annually (MOFA, 1998). To compensate for this nutrient uptake, a fertilizer consumption of about 400,000 tons, assuming a use efficiency of 50%, will be required. Ghana's annual fertilizer consumption is approximately 35,000 tons, about 10 times less than what is required.

According to Rhodes (1995) and Agbeniyi (2010) as much as 44 % of N, 42 % of P and 56 % of K taken up are found in crop residues. However, the use of crop residues as sources of nutrients and soil organic matter has long been a major component of many farming systems in Africa. In Ghana, the use of plant residues is low. Ogunrinde (2006) showed in a farm survey results that as much as 70% of crop residue produced by farmers in the Ashanti region of Ghana served no useful agricultural purpose.

2.3. Climatic Requirement for Cocoa

Cocoa is highly susceptible to drought and its production is related to rainfall distribution (Charter, 1947; Ahenkorah, 1981; Anim-Kwapong and Frimpong, 2009; Ogunrinde, 2006).

The variations in the yield of cocoa from year to year are affected more by rainfall than by any other climatic factor (Wessel, 1971; Ahenkorah, 1981). Cocoa seedlings are very sensitive to a soil water deficiency (Ogunrinde, 2006). An annual rainfall level between 1,500mm and 3,000mm per year is generally preferred.

It is well established that, in general, where soil nutrients, water and temperature are not limiting and losses from pests and diseases can be avoided, and that cocoa growth and yield are dependent on the total solar radiation intercepted during the growing season (Anim-Kwapong and Frimpong, 2009; Okali and Owusu,1975).

Cocoa has a low light saturation point (LSP) of 400 μ E m^{-2} s^{-1} and a low maximum photosynthetic rate (7 mg dm^{-1} h^{-1}) at light saturation (Hutcheon 1977; Anim-Kwapong and Frimpong 2009). The photosynthetic rate of the crop decreases if the photosynthetic apparatus is exposed to light intensities exceeding 60% of full sunlight that is 1800 μ mol m^{-2} s^{-1} while prolonged exposure to high light intensities damages the photosynthetic mechanism of the leaves (Raja Harun and Hardwick, 1988). Low light intensities however suppress flower production with light levels less than 1800 hours year^{-1} (Asomaning *et al*, 1971; Olaniran, 1977; Owusu, 1978). Cocoa as a tropical crop can only be profitably grown under temperatures ranging between 30-32^{o}C mean maximum and 18-21 ^{o}C mean minimum and absolute minimum of 10^{o}C (Wood and Lass, 1985). Temperatures below 10^{o}C cause inhibition of the photosynthesis rate. Leaf temperature affects stomatal resistance, decreasing the resistance upon increasing temperatures. However, since the increases in temperature may often go together with higher vapour pressure deficits (VPD), the effect of VPD may override the effect of temperature (Raja Harun and Hardwick, 1986). Hot and humid atmosphere is essential for the optimum development with relative humidity as much as 100% during the day, falling to 70-80% during the night (Ogunrinde, 2006). The overnight exposure of cacao seedlings to chilling temperatures between 4.7 and 15.8^{o}C reduced net CO_2 assimilation rate and stomata1 resistance to water vapor with temperatures below 10^{o}C causing severe inhibition. The mean monthly minimum temperature of 15^{o}C and an absolute minimum of 10^{o}C defined the lower limits for cocoa cultivation.

Wood and Lass (1985), Anim-Kwapong and Frimpong (2005) and Ogunrinde (2006) reported that temperatures below 10^{o}C for several consecutive days, reduced yields of cacao by approximately 50%. Cocoa is under-storey plants and therefore shading is indispensable (Asare and David, 2010).Shade serves as sun protection, reduces wind exposure and provides an excellent microclimate (Raja Harun and Kamariah, 1983). Cocoa prefers protected conditions and does not perform well in excessive sunlight, or in strong or unrelenting wind. In a guide to nursery practice Sheperd, (1976) recommended a light regime of 20 percent full sunlight (80 percent shade) during the first two months with the light gradually increasing (decreasing shade) to match the final shade.

2.4. Water and Soil Fertility Management for Smallholder Cocoa Farms

2.4.1 Soil

Charter (1947) Wood and Lass (1985) reported that good soil moisture, satisfactory aeration, good drainage and satisfactory supply of main nutrients such as potassium, phosphorus, calcium and magnesium are the main soil requirement for cocoa. According to Shepherd (1976), soil for cocoa should be rich in nutrients and contain appropriate physical and chemical properties that are favorable for rapid growth.

2.4.2. Soil physical properties

Soils for cocoa production should have good water retaining capacity, well- aerated and good drainage to support growth **(**Charter, 1947; Mossu, 1992; Sobulo and Osiname, 1981).

Wood and Lass (1985) proposed available water holding capacity, bulk density, infiltration, soil structure and macrospores as physical indicators in assessing quality soils for cocoa production. Cocoa needs a soil containing coarse particles to leave free space for roots and with a reasonable quantity of nutrients to a depth of 1.5m to allow the development of a good root system. Below that depth it is desirable not to have impermeable material so that excess water can drain away. Cocoa will withstand water logging for short periods but excess water should not linger. The cocoa tree is sensitive to lack of water so the soil must have both good water retention properties and drainage (Ogunrinde, 2006)**.**

Organic matter has a high capacity to retain moisture, nutrients and improve the structure of the surface layer. The organic matter in soils is a potential source of N, P and S for seedling growth. A minimum requirement of 3.5 % of organic matter about 2 % carbons in the top 15cm has been suggested by Wessel (1971) for cocoa seedlings. Wood and Lass (1985) reported that if soil is eroded or lost their layer of organic matter and humus, it will be very difficult to establish cocoa

2.4.3. Soil chemical properties

The chemical properties of top soil required for the optimum growth and development of cocoa seedlings include soil pH, Base Exchange capacity (CEC), C: N ratio (Carbon to Nitrogen) and base saturation.

Ahenkorah *et al*.(1981) and Brady and Weil (1999) reported that the best chemical soils properties for cocoa production tend to have an average pH of 5.6 -7.2 , C/N ratio between 10-12, organic carbon not less than 3%, base exchange capacity of 3-15 me/100g, soil available P greater than 20ppm in the 0-5cm and 15ppm in 0-20cm layer, exchangeable K not less than 0.25 me/100g soil, (Ca + Mg) about 8-13 me/100g soil.

Soil pH: Several studies (Wood and Less, 1985; Mossu, 1992) have found that the optimum pH for cocoa is 6.5. According to Ogunrinde (2006), cocoa seedlings can also be raised in soils with pH range of 5.0-7.5, but excessive acidity (pH 4.0 and below) or alkalinity (pH 8.0 and above) must be avoided. Soil pH <6.0 results in an increase in Aluminum which is toxic to cocoa.

Base Exchange capacity: This is alternatively known as cation exchange capacity (CEC).

It is a measure of the quantity of cations that can be adsorbed and held by a soil. These cations are in the soil solution and are in dynamic equilibrium with the cations adsorbed on the surface of clay. Soil with CEC level of 12-15 *me* per 100g is desirable for cocoa production (Wood and Lass, 1985).

Base saturation is a measure of the extent to which the CEC is taken up by the basic cations - potassium, calcium, magnesium, and sodium. It has been said that soil for cocoa should not have base saturation less than 30% within 50cm of soil surface (Wood and Lass, 1985) and the minimum saturation level of the exchangeable bases must be more than 60 % (Mossu, 1992).

Smyth (1966) indicated that lower level of base saturation poses nutritional troubles, especially a shortage of calcium, and magnesium.

Table 1: Classification of chemical properties of soils for cocoa production

Chemical properties	Nutrient status					
	Units	**Very low**	**Low**	**Moderate**	**High**	**Very high**
pH		<4.5	4.5-5.0	5.0-5.5	5.5-6.5	>6.5
Organic carbon	%	<1.0	1.0-1.5	1.5-3.0	3.0-4.0	>4.0
Total N	%	<0.10	0.10-0.15	0.15-0.25	0.25-0.40	>0.40
Total P	μgg^{-1}	<150	150-250	250-300	380-350	>380
Available P	μgg^{-1}	<10	10-15	15-25	25-35	>35
Exchangeable K	$cmolkg^{-1}$	<0.15	0.15-0.25	0.95-0.30	0.30-0.45	>0.45
Exchangeable Mg	cmol kg^{-1}	<0.15	0.15-0.25	0.25-0.40	0.40-3.00	>3.0
CEC	cmol $kg-^{1}$	<8	8-12	12-15	12-25	>25

Source: Omotoso (1975), Thong and Ng (1978), Wessel (1987) in Paramananthan, (2006)

Table 2: Classification of soil minerals

Chemical properties	Nutrient status			
	Units	Low	Moderate	High
pH		<1.5	-	5.5-6.5
Organic matter	%	<1.5	1.6 - 3.0	>3.0
Total N	%	<0.10	0.1- 0.2	>0.2
Available P	*ppm*	<10	15-20	>20
Available K	*ppm*	<50	50-100	>100
Exchangeable P	cmol(+)kg^{-1}	<0.2	0.2-0.40	>0.45
Exchangeable Ca	cmol(+) kg^{-1}	<5	5.0-10.0	>10
CEC	cmol (+)kg^{-1}	<10	10-20	>20

Source: Ling (1990)

2.4.4. Water Quality

According to Bauder el at (2010), soil scientists used the following categories to describe water effects on crop production and soil quality:

- Salinity hazard - total soluble salt content
- Sodium hazard - relative proportion of sodium (Na^+) to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions
- pH
- Alkalinity - carbonate and bicarbonate

- Specific ions: chloride (Cl), sulfate (SO_4^{2-}), boron (B), and nitrate-nitrogen (NO_3-N). Other potential irrigation water contaminants that may affect suitability for agricultural use include heavy metals and microbial contaminants.

Salinity hazard:

The most influential water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity (EC_w). The primary effect of high EC_w water on crop productivity is the inability of the plant to compete with ions in the soil solution for water (physiological drought). The higher the EC, the less water is available to plants, even though the soil may appear wet. Because plants can only transpire "pure" water, usable plant water in the soil solution decreases dramatically as EC increases

Table 3: Criteria for water use based upon conductivity

Classes of water	Electrical Conductivity(dS/m)
Class 1, Excellent	≤0.25
Class 2, Good	0.25 - 0.75
Class 3, Permissible	0.76 - 2.00
Class 4, Doubtful	2.01 - 3.00
Class 5, Unsuitable	≥3.00

Source: Bauder el at, (2010)

Sodium Hazard:

While EC_w is an assessment of all soluble salts in water, sodium hazard is defined separately because of sodium's specific detrimental effects on soil physical properties. The sodium hazard is typically expressed as the sodium adsorption ratio (SAR). This index quantifies the proportion of sodium (Na^+) to calcium (Ca^{++}) and magnesium (Mg^{++}) ions in water. Calcium will flocculate (hold together), while sodium disperses (pushes apart) soil particles. This dispersed soil will readily crust and have water infiltration and permeability problems. Additionally, at the same SAR, water with low EC_w (salinity) has a greater dispersion potential than water with high EC_w. Sodium in irrigation water can also cause toxicity problems for young cocoa seedlings

Table 4: General Classification of sodium hazard based on SAR values

SAR values	Sodium hazard of water
1-9	Low
10-17	Medium
18-25	High
>26	Very High

Source: Bauder el at, (2010)

Water pH:

The acidity or basicity of irrigation water is expressed as pH (< 7.0 = acidic and > 7.0 = basic). The normal pH range for irrigation water is from 6.5 to 8.4. High pH's above 8.5 are often caused by high bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) concentrations, known as alkalinity. High carbonates cause calcium and magnesium ions to form insoluble minerals leaving sodium as the dominant ion in solution.

Chloride:

Chloride is a common ion in water. Although chloride is essential to plants in very low amounts, it can cause toxicity to cocoa seedlings at high concentrations. Like sodium, high chloride concentrations cause more problems when applied on seedlings.

Table 5: Chloride classification of irrigation water

Chloride (ppm)	**Effect on Crops**
Below 70	Generally safe for all plants.
70-140	Sensitive plants show injury.
141-350	Moderately tolerant plants show injury.
Above 350	Can cause severe problems.

Source: Bauder el at (2010)

Boron:

Boron is another element that is essential in low amounts, but toxic at higher concentrations. Toxicity occurs in cocoa at concentrations less than 1.0ppm.

Sulfate:

The sulfate ion is a major contributor to salinity in many of waters. However, toxicity is rarely a problem, except at very high concentrations where high sulfate may interfere with uptake of other nutrients. As with boron, sulfate in irrigation water has fertility benefits, and irrigation water is enough for maximum production. Exceptions are sandy fields with <1 percent organic matter and <10 ppm (Bauder el at, 2010).

2.5.0 Mineral Requirement of Cocoa

Gockowski *et al*. (2004) indicated that cocoa seedling leaves need nutrients (nitrogen, phosphorous, potassium, etc.) and metabolites (proteins, lipids, carbohydrates) for their growth and thus it is important that young nursery seedlings and transplanted seedlings are in optimal condition as far as their nutrient and energy status are concerned.

Ogunride (2006) grouped macronutrients into primary and secondary; the primary nutrients are nitrogen (N), phosphorus (P), and potassium (K), while the secondary nutrients are calcium (Ca), magnesium (Mg), and sulfur (S). According to Moyin-Jesu (2007) the optimum total nitrogen /total phosphorous ratio for cocoa should be 1.5, with the phosphorus content at least equal to 180 ppm of P or 0.229 % and exchangeable bases balanced at 8 % potassium (K), 68 % calcium (Ca) and 24 % magnesium (Mg).

Wessel (1971) suggested standards referred to as “limits of adequacy” for optimum growth and development of cocoa based on his extensive knowledge in soil.

Table 6: Limits of adequacy for optimum growth of cocoa plant

Nutrient	Limit of adequacy	Unit
Calcium	8.0	me per 100g soil
Magnesium	2.0	me per 100g soil
Potassium	0.24	me per 100g soil
Phosphorus available	40	ppm

Wessel (1971) and Paramananthan (2006) reported concentrations of major elements for normal and deficient for 5 months cocoa seedling leaves.

Table 7: Classifications of nutrient level for 5 months cocoa seedlings.

Nutrient	**% On Dry Matter**		
	Severely Deficient	**Moderately Deficient**	**Normal**
Nitrogen (N)	<1.80	1.80-2.00	2.35-2.50
Phosphorous (P)	0.08-0.10	0.10-0.13	>0.13
Potassium (K)	<1.00	1.00 -1.20	>1.20

Source: Wessel, 1971

Table 8: Classifications of nutrient level for 5 months cocoa seedlings

Nutrient	**% On Dry Matter**		
	Deficient	**Low**	**Normal**
Nitrogen (N)	<1.80	1.8-2.0	>2.00
Phosphorous (P)	<0.13-0.15	0.13-0.20	>0.20
Potassium (K)	<1.20-1.40	1.40-2.00	>2.00
Calcium (Ca)	<0.30	0.30-0.40	>0.50
Magnesium (Mg)	<0.20	0.20-0.45	>0.45

Source: Paramananthan (2006) and ling (1990)

Nitrogen is a vitally important plant nutrient, the supply of which can be controlled by (Pidwimy, 2002). In cocoa production, it is a major yield - determining factor and its availability in sufficient quantity throughout the growing year is essential for optimum cocoa production (Pidwimy, 2002; Norgrove and Hauser, 2000).

In the soil, N found in decomposing organic matter may be converted into ammonium N ($NH4^+$) by soil microorganisms through mineralization (Pidwimy, 2002).

Nitrogen is absorbed by plants in the form of nitrate (NO3-) and ammonium ($NH4^+$) ions and as urea**.** In plant nutrition, nitrogen is part of all living cells and involved in the composition of all amino acids, proteins, enzymes and metabolic processes involved in the synthesis and transfer of energy .Nitrogen is also part of the puric and pyrimidic bases, and therefore is a constituent of nucleic acids (Mills and Jones,1996). Nitrogen is an integral part of chlorophyll, the green pigment of the plant which is the primary absorber of light energy responsible for photosynthesis and finally helps in stimulation of rapid and vigorous vegetative growth, increasing seedlings height and dark green color seedling leaves (Mills and Jones, 1996; Ogunrinde, 2006.)**.**

Deficiencies of nitrogen in the hybrid cocoa seedling are: stunted growth, yellow in appearance, poor root development, loss of leaves and chlorosis (Mills and Jones, 1996)**.**

Phosphorous (P) is the most important nutrient element after nitrogen limiting agricultural production in most regions of the world (Holford, 1997). It is absorbed by roots as phosphate ions ($H_2PO^-_4$, $HPO_4^{2-)}$. It is a structural component of DNA and RNA, the two genetic entities that are essential for the growth and reproduction of living organisms. Living organisms whether plants or humans, also derive their internal energy from P- containing compounds, mainly adenosine diphosphate (ADP) and adenosine triphosphate (ATP); this means that inadequate P supply will result in a decreased synthesis of RNA, the protein maker, leading to depressed growth.

The role of phosphorus in cocoa includes:

- Promotion of the development of roots, especially fibrous and lateral rootlets
- Makes the stems stronger and prevents logging

- Vital for seed germination and leaf development
- Essential for photosynthesis.
- Effects seedlings rapid growth
- Encourages leaf blooming and root growth and development.

Deficiencies of phosphorus in cocoa seedling include; stunted growth, thin stem growth, poor development of flowers and roots, limited development of leaf and stem and the spindly appearance. Also, leaf length, leaf size and girth diameter of cocoa seedlings are all reduced (Ogunrinde, 2006).

According to Hue (1997), potassium is absorbed by cocoa in larger amounts than any other mineral element except nitrogen and, in some cases, calcium. In soils, potassium is quite mobile as compared to phosphate. It exists as K^+ in soil solution and is absorbed by roots in that form. Although K^+ can be retained to some extent by negative charges on clay surfaces, Ca^{2+} or Mg^{2+} can displace it into the soil solution, when gypsum or dolomite is added .Thus if K is not taken by plant, it might be lost by leaching (Bergmann, 1992; Perrenoud, 1993). It is required for maintaining the osmotic potential of cells and turgidity of plants. Since K regulates the osmotic potential of cells, and closure or opening conditions of stomata, it plays an important role in water relations in the plant. Potassium is involved in water uptake from the soil, water retention in the plant tissue, and long distance transport of water in the xylem and of photosynthesis in the phloem (Marschner, 1995).

It functions in building of protein; aids in the development of cell expansion, roots and leaves .With adequate potassium, cells are thicker, thereby improving plant resistance to logging, pest and diseases and strengthening of the stem (Bergmann, 1992).

Deficiencies of potassium include low resistance to diseases (Perrenoud, 1993).The most visual K deficiency symptom is the scorching or firing along leaf tips and margin (Bergmann, 1992; Perrenoud, 1993)., mottling and curling of lower leaves of seedlings, chlorosis of leaves and poor development of roots.

Thong and Ng (1978) reported that calcium is absorbed by cocoa plants in Ca^{2+} ions and it is essential for growth of roots, root hairs and root tips. Wessel (1971) proposed that toxicity of aluminum, sodium, manganese and magnesium ions are controlled by calcium and provide normal transport and retention of other elements as well as strength in the plant.

According Wessel (1971), deficiencies of calcium in plants include stunted root tips, stunted growth and chlorosis.

Cocoa absorbs magnesium from the soil in the form of Mg^{2+} ions .It is part of the chlorophyll and essential for photosynthesis. The deficiencies include chlorosis and stunted growth.

It may be absorbed in a number of ionic forms including $B_4O_7^{2-}$, H_2BO_3 or BO_3^{2}. It helps in the use of nutrients and regulates other nutrients (de Geus, 1973), aids production of sugar and carbohydrates, essential for seed and fruit development.

Deficiencies in boron include retarded growth of young seedlings, poor root development and leaves are misshapen, wrinkled, brittle, and dark green in color. Others are: "blind leaf", "crinkle leaf", " hook leaf and “fishbone leaf" (Ogunrinde, 2006)

Copper (Cu) is important for reproductive growth (de Geus, 1973), aids in root metabolism and utilization of proteins. Deficiencies are severe stunted growth and chlorosis (Ogunrinde, 2006).

Manganese (Mn) is essential in the formation of chlorophyll (de Geus, 1973) and influences photosynthesis. It functions with enzyme systems and involves in breakdown of carbohydrates and nitrogen metabolism. Deficiency results in stunted seedling growth and chlorosis of seedling leaves.

Zinc (Zn) is essential for chlorophyll formation, stems and normal root development Essential for the transformation of carbohydrates, regulates consumption of sugars, and part of the enzyme systems which regulate plant growth. Deficiency consists of foliar malformation such as sickle leaf or long, narrow, and sometimes twisted leaves (de Geus, 1973).

Chloride (Cl) aids plant metabolism

Iron (Fe) is essential for formation of chlorophyll (de Geus, 1973).

Table 9: Classification of minor elements (ppm) in cocoa seedlings leaves

Nutrient	**Normal range**	**Deficiency range**
Iron (Fe),	65-175	50
Zinc (Zn)	30-65	15-20
Boron (B),	25-75	8.5-11

Source: Wessel, 1971

Table 10: Classification of minor nutrients (ppm) in cocoa seedlings leaves

Nutrient	**Critical level**	**Deficient level**
Mn	30	15
Fe	50	30
Zn	30	20
Cu	6	4
B	25	15

Source: Paramananthan (2006)

2. 6: The Role of Cocoa Pod Husks in Plant Growth

As part of the efforts to utilize cocoa by-products and in search for suitable potting material for nursing cocoa as soil depletion issue increasingly becomes a global concern (Agbeniyi et al, 2010; Ajayi *et al*., 2007a, 2007b), conducted a study to develop a method of composting cocoa pod husk for growth of cocoa seedlings at the nursery. They indicated that the C, N, P contents were significantly higher in cocoa pod husk compost developed over 12 months and that a mixture of cocoa pod husk and top soil also contained significantly higher C, N and P. The root / shoot ratios of cocoa seedlings grown in compost developed from cocoa pod husk and top soil alone contained significantly higher nutrients, suggesting better cocoa root growth in the potting medium.

Ofori - Frimpong *at al.* (2003) further concluded that cocoa pod husk based compost could be a suitable potting medium for nursing cocoa seedlings when mixed in smaller ratios.

Application of cocoa pod ash, NPK 20:10:10 fertilizer and their combinations increased soil organic matter and major nutrients such as N, P and K status as well as agronomic parameters of maize (Ayeni, 2007).

Ayeni *et al*.(2008a) found that cocoa pod ash contained plant nutrients as N, P, K Ca and Mg and micronutrients are good for tomato production (Odedina *et al*., 2007). Egunjobi (1976) also observed that ground cocoa husk applied to soil increased maize yield by 124%, and also increased uptake of P, K, and Mg. In the studies by Ajayi *et al*., (2007a, 2007b), it was found that cocoa pod husk increased growth and nutrient uptake of Kola seedlings and soil P, K, Ca and Mg, and that cocoa pod husk and its ash, at 2, 4, 6, 8 and 10t ha^{-1} increased root N, P, K, Ca, and Mg which increased with level .

Ojeniyi *et al*., (2007) investigated the effect of animal manure amended cocoa pod husk on tomato. Amended husk significantly increased growth and yield of tomato by 397%. Cocoa husk ash which is a plant derived material has great potential for ameliorating soil acidity as well as supplying plant nutrient elements, and therefore gives the optimum value for almost all soil chemical properties and plant parameters **(**Onwuka et al, 2007).

Moyin-Jesu (2008) indicated that the sole and amended forms of wood ash, cocoa pod husk and rice bran with poultry, duck and turkey manures applied at 8t/ha (40g /poly bag) increased the soil, leaf N, P, K, Ca, Mg, soil pH and O.M of coffee seedling. It also increased plant height, stem girth, leaf number, leaf area and fresh shoot weight of coffee seedling.

2.7. Factors Affecting Physical Growth of Cocoa Seedlings

According to Opeke (2006), 80 percent of seedlings today are poly bags-grown and have greater chances of survival and establishment after transplanting. Opeke (2003, 2006) found that the best sowing method used in raising cocoa seedlings is sowing in polythene bag. It favored tap root development and showed a significantly higher mean difference of tap root length and girth over other sowing methods. Famuwagun and Agele (2010) observed that poly bags enhance rooting, leave 80% of roots intact during transplanting, and make harvesting easier, save labor and time. Famuwagun and Agele (2010) observed that longer taproot length in the seedlings sown in polythene bag is due to the downward movement of water and nutrients in the polythene during watering because of the shape of the polythene bag which does not allow horizontal water flow. Diver and Greer (2001) also observed that sowing in polythene bags positively affects cocoa seedling height compared to sowing in groves and by broadcasting. According to studies (Diver and Greer, 2001), the color, depth, and size of poly bags used in raising seedlings determine the rate of shoot growth and root development. Diver and Greer (2001) and Adenikinju el at (1989) asserted that the black color of the poly bag enhances soil temperature in the root zone of the poly bags which facilitates seed germination and is responsible for the downward growth of the root.

A study by Famuwagun and Agele (2010) revealed that roots of seedlings raised in short-sized polythene bags are associated with more coiling and recoiling of roots in the pots and that coiling of roots in the bag causes the seedlings to be root-bound which is detrimental to establishment and rapid development of cocoa seedlings after transplanting on the field.

Table 11: Classification of physical growth parameters of hybrid cocoa seedlings for 4-5 months cocoa seedlings in the nursery

Growth parameters	Optimum value	Minimum value	Critical value
Mean height (cm)	>35	30 - 35	<25
Mean stem girth (cm)	>2.5	2.0	<1.5
Mean leaf area (cm^2)	>250	150-250	<90
Length of tap –root(cm)	>15	10 -15	<10
Number of leaves	>15	10-15	<10

Source: Sheperd (1976)

CHAPTER THREE

3.0. MATERIALS AND METHOD

3.1: Location of the study area

The study was conducted at the Buako Cocoa Station, about 40 km from Sefwi Wiawso. The area lies between latitudes 6’ 00" and 6’30"North and longitudes 2'15" and 2'45"West of the Greenwich meridian.

3.2: **Climate of the study area**

The area falls within the moist semi-deciduous forest zone of Ghana. This zone is characterized by two rainy seasons and two dry seasons in a year. The major rainy season starts from March to early July and the minor season starts from August to November. There is a short dry period in July. The major dry season occurs between the end of the minor wet season and the next major wet season (November to March) and is dominated by the hot and dry hammatan wind from Sahara - desert. The long term annual average precipitation is about 1400 mm.

Temperatures are generally high and uniform throughout the year. The mean monthly maximum in the hottest month (Feb – March) is 31-33^{o}C and the mean monthly minimum in the coldest month (Dec-Jan) varies between 19 and 21^{o}C.

Relative humidity is generally high in the mornings, about 90 % at 0600 hours and falling to between 60 and 70 % in the afternoon (1500 hours). Generally, in the wet season relative humidity is high (about 94 %) while it is low (about 40 %) in the dry season.

3.3: Soil sampling and cocoa pod husks compost preparation.

Soils used for the experiment were developed mainly from very old, pre-cambrian and volcanic rocks. In order to characterize the soil of the experimental field, samples were taken across the field to a depth of 45cm and bulked for laboratory analysis. In the laboratory, the soil samples were air-dried and crushed using a wooden mortar and pestle and then sieved through a 2 mm mesh. The sieved samples were stored in polythene bags for chemical and physical analysis at the Soil Research Institute, Kwadaso-Kumasi.

The samples of cocoa pod husks for the experiment were taken from 20 - 30 years old cocoa farms along River Tano basin in Sefwi Wiawso. The compost was prepared at Anhiwam.

Figure 1: Cocoa Pod Husks used

Figure 2: Sample of soil used

Composting procedure for Cocoa Pod Husk

1. 150 kg of milled cocoa pod husk was weighed into a wooden box (Figure 3)
2. The cocoa pod husk in wooden box was placed under a shade to prevent excess evaporation
3. Twenty Seven litres of water were added to the cocoa pod husk in the wooden box at the start of composting
4. The wooden box was covered to prevent other foreign materials from entering the setup
5. Thirteen and half litres of water was added every two week to the sample
6. Turning of compost was done weekly for the first two weeks after setting up the compost and fortnightly for the rest of the composting period.
7. Temperature of the compost was monitored weekly. The temperature increased to 50-60^{0}C within the first 24-72 hours. This was maintained for several weeks.

Composting procedure for Soil - Cocoa Pod Husk Mixture

1. 75 kg of sand and 75 kg of milled raw cocoa pod husk was weighed into a wooden box (Figure 4)
2. The soil - cocoa pod husk mixture in wooden box was placed under shade to prevent excess evaporation
3. Twenty Seven litres of water was added to the soil - cocoa pod husk mixture in the wooden box at the start of composting
4. The wooden box was covered to prevent other foreign material from entering the setup
5. Thirteen and half of water was added every two week to the sample
6. Turning of compost was done weekly for the first two weeks after setting up the compost and fortnightly for the rest of the composting period.

Figure 3: Composting of cocoa pod husks for the experiment

Figure 4: Composting of soil +cocoa pod husks for the experiment.

3.4. Soil and cocoa pod husks compost chemical analysis

3.4.1. Soil pH

Soil pH was measured in a solution of 1:1 soil-water ratio using a glass electrode (H19017 Microprocessor) pH meter. Approximately 25 g of soil were weighed into a 50 ml beaker and 25 ml of distilled water was added to the soil. The soil-water solution was stirred thoroughly and allowed to stand for 30 minutes. After calibrating the pH meter with buffers of pH 4.01 and 7.00, the pH was read by immersing the electrode into the upper part of the solution and the pH value recorded.

3.4.2. Soil organic carbon (modified Walkley-Black method)

Soil organic carbon was determined by the modified Walkley-Black method as described by Nelson and Sommers (1982). The procedure involved a wet combustion of the organic matter with a mixture of potassium dichromate and sulphuric acid. After the reaction, the excess dichromate was titrated against ferrous sulphate. Approximately 1.0 g of air-dried soil was weighed into a clean and dry 250 ml Erlenmeyer flask. A reference sample and a blank were included. Ten ml of 0.1667*M* potassium dichromate ($K_2Cr_2O_7$) solution was accurately dispensed into the flask using the custom laboratory dispenser; the flask was swirled gently so that the sample was made wet. Then using an automatic pipette, 20 ml of concentrated sulphuric acid (H_2SO_4) was dispensed rapidly into the soil suspension and swirled vigorously for 1 minute and allowed to stand on a porcelain sheet for about 30 minutes, after which 100 ml of distilled water was added and mixed well. Ten ml of ortho-phosphoric acid and one ml of diphenylamine indicator were added and titrated by adding 1.0 *M* ferrous sulphate from a burette until the solution turned dark green at end-point from an initial purple colour. About 0.5 ml of 0.1667 *M* $K_2Cr_2O_7$ was added to restore excess $K_2Cr_2O_7$ and the titration completed by adding $FeSO_4$ dropwise to attain a stable end-point. The volume of $FeSO_4$ solution used was recorded and % C calculated using the equation below

$$OC = M \times 0.39 \times Mcf \times \frac{(v_1 - v_2)}{s} \qquad [1]$$

Where

OC = organic matter (%)

M = molarity of ferrous sulphate solution.

V_1 =volume (ml) of ferrous sulphate solution required for blank.

V_2 = volume (ml) of ferrous sulphate solution required for sample.

s = weight of air-dry sample in grams.

Mcf = moisture correcting factor $\frac{(100 + \%\ \text{moisture})}{100}$

One point three = a compensation factor for the incomplete combustion of the organic carbon.

3.4.3. Total nitrogen (Kjeldahl method)

Total nitrogen was determined by the Kjeldahl digestion and distillation procedure described in Soil Laboratory Staff in 1984. Approximately 0.2 g of soil was weighed into a Kjeldahl digestion flask and 5 ml distilled water added. After 30 minutes a tablet of selenium and 5 ml of concentrated H_2SO_4 were added to the soil and the flask placed on a Kjeldahl digestion apparatus and heated initially gently and later vigorously for at least 3 hours. The flask was removed after a clear mixture was obtained and then allowed to cool. About 40 ml of distilled water was added to the digested material and transferred into 100ml distillation tube. 20 ml of 40 % NaOH was also added to the solution and then distilled using the Tecator Kjeltec distiller. The digested material was distilled for 4 minutes and distillate received into flask containing 20 ml of 4 % boric acid (H_3BO_3) prepared with PT5 (bromocresol green) indicator producing approximately 75 ml of the distillate. The colour change was from pink to green after distillation, after which the content of the flask was titrated with 0.02 M HCI from a burette. At the end-point when the solution changed from weak green to pink, the volume of 0.02 M HCl used was recorded and % N calculated. A blank distillation and titration was also carried out to take care of traces of nitrogen in the reagents as well as the water used.

The percentage nitrogen in the sample is expressed as:

$$N = \frac{(M \times (a - b) \times 1.4 \times Mcf)}{s} \qquad [2]$$

Where

N = Nitrogen concentration (%)

M = concentration of hydrochloric acid used in titration.

a = volume of hydrochloric acid used in sample titration.

b = volume of hydrochloric acid used in blank titration.

s = weight of air-dry sample in gram.

Mcf = moisture correcting factor $\frac{(100+\%\ \text{moisture})}{100}$

One point four (1.4) = 14 x 0.001 x 100 % (14 = atomic weight of nitrogen)

3.4.4. Bray's No. 1 Phosphorus (available phosphorus)

The readily acid-soluble forms of phosphorus were extracted with a HCI: NH_4F mixture called the Bray's no.1 extract as described by Bray and Kurtz (1945)

Phosphorus in the extract was determined on a spectrophotometer by the blue ammonium molybdate method with ascorbic acid as reducing agent. Approximately 5.0 g of soil was weighed into100 ml extraction bottle and 35 ml of

Extracting solution of Bray's no. 1 (0.03*M* NH_4F 0.025 m =M HCI) was added. The bottle was placed in a reciprocal shaker and shaken for 10 minutes after which the content was filtered through no.42 filter paper. The resulting clear solution was collected into a 100 ml volumetric flask.

An aliquot of about 5 ml of the clear supernatant solution was pipette into 25 ml test tube and 10ml colouring reagent (ammonium paramolybdate) was added as well as a pinch of ascorbic acid and then mixed very well. The mixture was allowed to stand for 15 minutes to develop a blue colour to its maximum. The colour was measured photometrically using a spectroinc 21D spectrophotometer at 660 nm wavelengths. Available phosphorus was extrapolated from the absorbance read.

A standard series of 0, 1.2, 2.4, 3.6, 4.8 and 6 mg/l of Phosphorous was prepared from a 12 mg/1 stock solution by diluting 0, 10, 20, 30, 40 and 50 ml of 12 mg/l of Potassium in 100 ml volumetric flask and made to volume with distilled water. Aliquots of 0, 1, 2, 3, 4, 5 and 6 ml of the 100 mg/l of Phosphorous of the standard solution were put in 100 ml volumetric flasks and made to the 100 ml mark with distilled water

The amount of phosphorus was calculated using the equation

$$P = \frac{(a - b) \times 35 \times 15 \times Mcf}{s} \qquad [3]$$

Where
P = phosphorous (mg/kg)
a = mg/1 P in sample extract.
b = mg/1 P in blank.

s = sample weight in gram

Mcf = moisture correcting factor

Thirty -five = volume of extracting solution

Fifteen = final volume of sample solution

3.4.5 Determination of available Potassium

Available potassium extracted using the Bray's no. 1 solution was determined directly using the Gallenkamp flame analyzer. Available potassium concentration was determined from the standard curve. Potassium standard solutions were prepared with the following concentrations: 0, 10, 20, 30, and 50 µg K per liter of solution. The emission values were read on the flame analyzer. A standard curve was obtained by plotting emission values against their respective concentrations.

Calculation:

$$K = \frac{(a - b) \times 35 \times 15 \times Mcf}{s}$$

[4]

Where
K= Potassium (mg/kg)

a = mg/1 P in sample extract.

b = mg/1 P in blank.

Thirty -five = volume of extracting solution

Mcf = moisture correcting factor

3.4.6 Exchangeable cations

Exchangeable bases (calcium, magnesium, potassium and sodium) in the soil were determined in 1.0 *M* ammonium acetate (NH_4OAc) extract (Black, 1986) and the exchangeable acidity (hydrogen and aluminum) was determined in 1.0 *M* KCI extract.

3.4.7 Extraction of the exchangeable bases

A 5 g sample was transferred into a leaching tube and leached with 100 ml of buffered 1.0 M ammonium acetate (NH_4AOAc) solution at pH 7.

3.4.8. Determination of calcium and magnesium (EDTA Titrametric Method)

For the determination of the calcium and magnesium, a 25 ml of the extract was transferred into an Erlenmeyer flask. A 1.0ml portion of hydroxylamine hydrochloride, 1.0 ml of 2.0 percent potassium cyanide buffer (from a burette), 1.0 ml of 2.0 per cent potassium Ferro cyanide, 10.0 ml ethanolamine buffer and 0.2mlEriochrome Black T solution were added. The solution was titrated with 0.01*M* EDTA (ethylene diaminetetraacetic acid) to a pure turquoise blue colour. A 20 ml 0.01*M* magnesium chloride solution was also titrated with 0.01*M* EDTA in the presence of 25 ml of 1.0*M* ammonium acetate solution to provide to standard blue colour for the titration.

3.4.9. Determination of calcium

A 25 ml portion of the extract was transferred to an Erlenmeyer flask. Hydroxylamine hydrochloride (1.0 ml), potassium cyanide (1.0 ml of 2 % solution) and potassium Ferro cyanide (1.0 ml of 2 %) were added. After a few minutes, 4 ml of 8 *M* potassium hydroxide and a spatula of murexide indicator were added. The solution obtained was titrated with 0.01*M* EDTA solution to a pure blue colour. Twenty milliliters of 0.01*M* calcium chloride solution was titrated with 0.01*M* EDTA in the presence of 25 ml 1.0*M* ammonium acetate solution to provide standard pure blue colour. The titre value for calcium was subtracted from that of calcium plus magnesium to obtain the liter value for magnesium. The titre value was again recorded

The calculation of the concentration of calcium and magnesium follows the equation:

$$Ca = \frac{0.01 \times (Va - Vb) \times 100 \times Mcf}{10 \times 20.04 \times s} \qquad [5]$$

$$Mg = \frac{0.01 \times (Va - Vb) \times 100 \times Mcf}{10 \times 12.15 \times s} \qquad [6]$$

Where

C = Calcium (cmol(+)/kg soil)

Mg = Magnesium (cmol(+)/kg soil)

s = air-dried sample weight in grams

V_a = ml of 0.01 *M* EDTA used in the titration

V_b = ml of 0.01 *M* EDTA used in blank titration

Zero point Zero One (0.01) = concentration of EDTA used

Mcf = moisture correcting factor

3.4.10. Exchangeable potassium and sodium determination

Potassium and sodium in the percolate were determined by flame photometry. A standard series of potassium and sodium were prepared by diluting both 1000 mg/l potassium and sodium to 100 mg/l. this was done by taking a 25 ml portion of each into one 250 ml volumetric flask and made to volume with water. Portions of 0, 5, 10, 15 and 20 ml of the 100 mg/l standard solution were put into 200 ml volumetric flasks and made to volume with distilled water. The standard series obtained was 0, 2.5, 5.0, 7.5, 10.0 mg/l for potassium and sodium. Potassium and sodium were measured directly in the percolate by flame photometry at wavelength of 766.5 and 589.0 nm respectively.

$$K = \frac{(a - b) \times 250 \times Mcf}{10 \times 39.1 \times s} \quad [7]$$

$$Na = \frac{(a - b) \times 250 \times Mcf}{10 \times 23 \times s} \quad [8]$$

Where

K = Exchangeable Potassium (cmol/kg soil)

Na = Exchangeable Sodium (cmol/kg soil)

a = Concentration (mg/l) K or Na in the diluted sample percolate

b = Concentration (mg/l) K or Na in the diluted blank percolate

s = air-dried sample weight of soil in gram

Mcf = moisture correcting factor

3.4.11 Exchangeable acidity

Exchangeable acidity is defined as the sum of Al +H. The soil sample was extracted with unbuffered 1.0 *M* KCI and sum of Al + H was determined by titration. Ten grams of soil sample was put in a 100 ml bottle and 50 ml of 1.0 *M* KCI solution added. The bottle was capped and shaken for 1.0 hour and then filtered. Twenty five milliliters portion of the filtrate was added with a pipette into a 250 ml Erlenmeyer flask and 2- 3 drops of phenolphthalein indicator solution added. The solution was titrated with 0.1 *M* NaOH until the colour just turned /became permanently pink. A blank was included in the titration.

$$Ac = \frac{(a - b) \times M \times 2 \times Mcf}{s} \qquad [9]$$

Where:

Ac =Exchangeable acidity (cmol/kg soil)

a =Volume (ml) NaOH used to titrate with sample

b = Volume (ml) NaOH used to titrate with blank

M = Molarity of NaOH solution

s = air-dried soil sample weight in gram

Two = 50/25 (filtrate /pipette volume)

mcf = moistures correction factor [(100 + % moistures) / 100]

3.4.12. Determination of Organic matter and Organic Carbon (Dry Ashing Method)

One gram of sample was placed into already weighed silica crucible.

The sample was placed in a muffle furnace for 4 hours at temperature of 450^{o}C

The ash sample was removed and weighed with silica crucible.

Organic matter was calculated as

Percentage organic matter (% O.M) =100 - % ash

3.4.13. Effective cation exchange capacity (ECEC)

Effective cation exchange capacity was determined by summing the exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) and exchangeable acidity (Al_3^{+} H^{+})

3.6.0 Soil physical analysis

3.6.1 Soil texture

The soil texture was determined by the hydrometer method. Approximately 40 g of soil was weighed into 250 ml beaker and oven dried at 105°C over night. The sample was removed from the oven and then placed in a desiccator to cool, after, which it was weighed and the oven dry weight taken. A 100 ml of dispersing agent commonly known as Calgon (Sodium Bicarbonate and Sodium Hexa -met phosphate) was measured and added to the soil. It was then placed on a hot plate and heated until the first sign of boiling was observed. The content in the beaker was washed completely into a shaking cup and then fitted to a shaking machine and shaken for 5 minutes. The sample was sieved through a 50 microns sieve mesh into 1.0l cylinder. The sand portion was separated by this method while the silt and clay went through the sieve into the cylinder. The sand portion was dried and further separated using graded sieves of varying sizes into coarse, medium and fine sand. These were weighed and their weights taken. The 1.0litre cylinder containing the dispersed sample was placed on a vibration less bench in the night. The hydrometer method was used to determine the silt and the clay contents. The cylinder with its contents was agitated to allow the particles to be in suspension, it was then placed on the bench and hydrometer reading taken at 30 seconds, 4 minutes, for 4 hours and 24 hours intervals. At each hydrometer reading the temperature was also taken. Coarse silt, medium silt, fine silt and clay portion were then calculated graphically. The various portions were expressed in percentage and using the textural triangle the texture was determined

3.6.2 Bulk density

Bulk density of soil in the field at 0-15 cm depth was determined by the core method described by Blake and Hartge (1986). A cylindrical metal sampler of 5cm diameter and 15cm long was used to sample undisturbed soil. The core was driven to the desired depth (0 – 15cm) and the soil sample was carefully removed to preserve the known soil volume as existed in situ. Three samples were taken from different sites. The soil was then weighed, dried at 105^{o}C for two days and reweighed. Bulk density was computed as:

$$\rho b = \frac{Ms}{Vt} \qquad [10]$$

Where
ρb = Soil bulk density (gcm^{-3})
Ms = mass of the oven dry soil (g)

Vt = total volume of soil (cm^{3})

3.5.3 Field capacity

The field capacity of soil was determined by placing the pots with soil sample in tank containing water and saturating through the bottom. Pots were removed from the tank after saturation and covered with transparent polythene sheet to prevent evaporation. They were allowed to drain freely for 48 hours to achieve field capacity status. The amount of water at field capacity was calculated as the difference in the amount of water used for saturation less the amount freely drained after 48 hours. The percentage field capacity was calculated as:

$$FC = \left[\frac{(a-b)}{b}\right] \times 100 \qquad [11]$$

Where
FC = field capacity (%)
a = weight of moist sample (g)
b = weight of dry sample at 105^{o} (g)

3.6.0 Field experiment

3.6.1 Field layout

Field experiments were conducted concurrently in November, 2010 and repeated in February 2011 at Buako cocoa station experimental field

There were 54 treatments each in both experiments involving three watering regimes (WRI - 0.06 l/seedlings, WRII - 0.18 l/seedlings and 0.36 l/seedling), three potting media (Soil, Cocoa pod husks and Soil + Cocoa pod husks composite),three potting bags (Cocobod, IITA and Water sachets) and two clones (C42 and C85). The treatments were replicated three times and arranged 3×3×3×2 Factorial Design in an area of 16m x 40m (640m^2) with each block separated from each other by 1.5m.

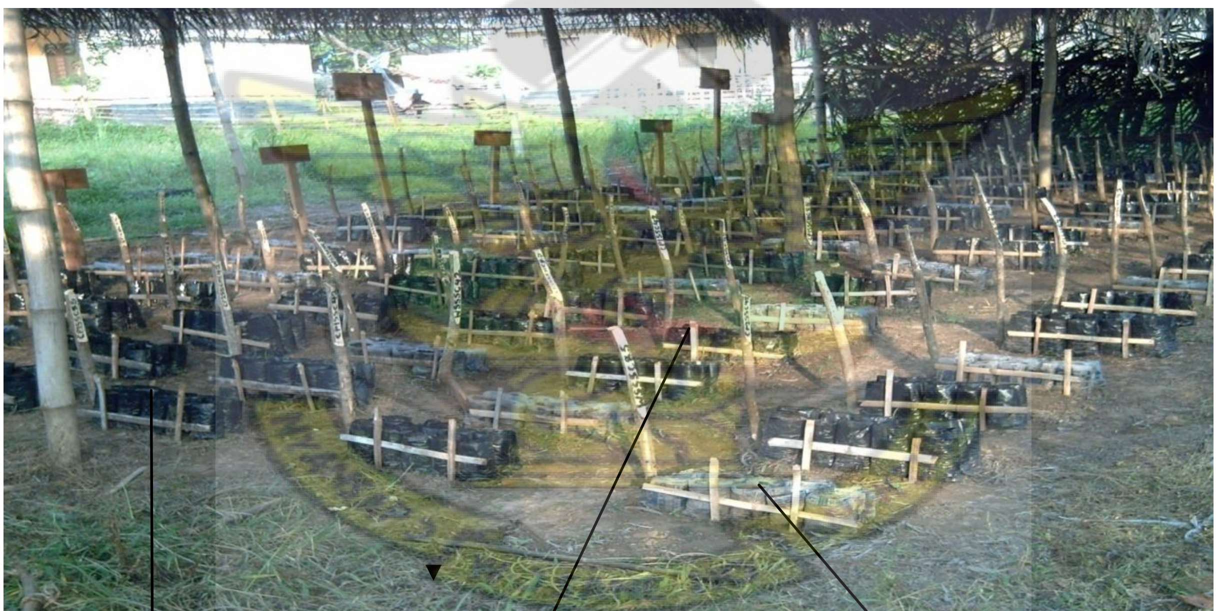

Figure 5: Experimental set up

Water Sachets (WS)

IITA poly bags (IITA) COCOBOD poly bags (CP1)

3.6.2 Planting and watering

The planting was done on 6th December 2010 and 28th February, 2011 for the first and second seasons respectively.

Figure 6a: Clone 42 hybrid cocoa pods **Figure 6b:** Clone 85 hybrid cocoa pods

Crop water requirement

$$CWR = \frac{f \times E \times A}{D} \qquad \text{(Ogunride, 2006)} \qquad [12]$$

Where
CWR= Crop water requirement of cocoa seedlings (l/day)
f = Water loss factor of 1.3

E = Monthly Evapo-transpiration (m)

A= Area of pot/bags (m^2)
D = Number of days in months
The Monthly Evapo-traspiration was estimated as 0.2m in the area.

Calculations:

Watering regime II

$$\text{Crop water requirement of cocoa seedling(litres/day)} = \frac{f \times E \times A}{D} \quad [13]$$

f = 1.3
E = 0.2 m
A = $0.021 m^2$
D = 30

$$\text{Crop water requirement (l/day)} = \frac{1.3 \times 0.2 \text{ m} \times 0.021 \text{ m}^2}{30} = 0.18$$

Watering regime III

$$\textit{Crop water requirement of cocoa seedling(litres/day)} = \frac{f \times E \times A}{D} \quad [14]$$

f = 1.3
E = 0.2 m
A = $0.043 m^2$
D = 30

$$\text{Crop water requirement (l/day)} = \frac{1.3 \times 0.2 \text{ m} \times 0.042 \text{ m}^2}{30} = 0.36$$

The watering was done every day around (except rainy days) in the morning (7:00 am) with 0.06 l/seedling (estimation based on farmers application rate) for watering regime I and 0.18 l/seedlings for both watering regime II&III. In the evening around (5:00 pm) 0.18 l/seedlings again for watering regime III only for the entire experimental period (20 weeks) using watering can. A 6.5m tall bamboo shade was provided to prevent excessive evapo-transpiration and scorching by sun.

3.7.0 Data collection

3.7.1 Growth parameters

The growth parameters such as plant height, leaf area, number of leaves and stem girth were recorded every two weeks starting from 4 weeks after planting (WAP) until 20 weeks in the nursery. Six cocoa seedlings were selected at random from each block and tagged for growth measurements.

Plant height and leaf area were measured using a measuring ruler. The plant height was taken from the soil surface to the apical tip of the plant. The leaf length and breadth were measured to obtain the leaf area. The leaf area was estimated as its length multiplied by its maximum width multiplied by 0.666 + 0.73 (cocoa leaf calibration factor). The plant stem girths were measured using veneer calipers and rope. At 12 WAP, root lengths were taken and finally at 20 WAP in the nursery, the seedlings were carefully removed from the polythene for the measurement of fresh shoot weight.

3.7.2 Plant analysis

3.7.2 Plant sampling and preparation

At 20 WAP, leaf samples of hybrid cocoa seedlings from various treatments were taken, dried at 60 ^{O}C for 48 hours and analyzed for N, P, K, Ca and Mg and micronutrients at SRI, Kwadaso

3.7.3 Water quality analysis

Samples of water from stream and borehole at Buako cocoa station were taken to Soil Research Institute, Kwadaso-Kumasi for laboratory analysis.

3.7.4 Statistical analysis

Data collected in both experiments were subjected to statistical analysis using statistical package for social science (SPSS).

The average data had for plant height, leaf area, stem girth, number of leaves , root length, and percentage of leaf mineral such as N, P, K, Ca, Mg , Cu, Mn, and Fe of cocoa seedlings were analyzed using an ANOVA.

The treatments' means were separated and compared using Duncan Multiple Range Test (DMRT) and Least Significant Difference (LSD) both at 5% level (Steel et al., 1997).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1: Chemical Properties of Water from Stream and Borehole used for the Experiment.

Table 12 presents the chemical properties of water from both the stream and borehole used for the experiment

Table 12: Selected chemical properties of Stream and Borehole water used for the experiment

	STREAM		BOREHOLE	
PROPERTIES	**MEAN**	**CV%**	**MEAN**	**CV%**
pH(H_2O)	6.9	7.6	6.3	0.4
Electrical Conductivity (μ/m)	125.8	0.1	96.9	8.0
Total Dissolved Solid (ppm)	121.9	0.2	94.3	8.5
Potassium (me/l)	0.1	0.0	0.1	10.0
Sodium Adsorption ratio (me/l)	0.6	0.0	0.5	2.8
Chlorine (me/l)	65.5	3.5	54.9	3.2
Sulfate (mg/l)	0.1	0.0	0.1	23.1
Calcium + Magnesium (me/l)	1.2	0.0	0.6	0.0

Hydrogen concentration of stream samples ranged between 6.5 and 6.7 with a mean value of 6.6. Samples from borehole recorded similar values ranging from 5.7 - 6.7 with a mean value of 6.3. The average value obtained from the stream was normal pH range for irrigation water from 6.5 - 8.4 (Bauder el at, 2010) while samples from the borehole were found within the normal range. Chloride concentration in stream samples ranged between 63.2ppm and 67.7 ppm with a mean value of 65.5 ppm. Borehole samples also recorded concentration between 53.0 ppm and 56.40ppm with a mean value of 54.9 ppm.

The average concentration obtained in both stream and boreholes were generally safe for plant use. The electrical conductivity (µs/m) and total dissolved solid (ppm) mean values had been found to be safe for the cocoa (Bauder el at, 2010).

4.2: Physical Properties of Soils, Cocoa Pod Husks and Soil Cocoa Pod Husks Mixture

Table 13a presents the physical properties of potting media used for both experiments

Table 13a: Physical properties of potting media

	1st Season			2nd Season		
	SS	CH	SSCH	SS	CH	SSCH
Bulk density (kg/cm3)	1.8	0.5	0.9	1.7	0.6	0.9
Field capacity (%)	11.6	98.7	71.7	14.4	88.2	92.8
Net Irrigation R.(mm)	6.12	35.9	45.3	8.9	37.1	44.3

The field capacity and Net Irrigation requirement in both experiments indicated that soil - cocoa pod husks mixture and cocoa pod husks had higher field capacity compared to soil samples (Table and Appendix A). This observation confirms the higher moisture content often recorded for soils with greater amount of organic matter content which sustained crop growth during periods of moisture stress. The mean bulk density of the soils was higher than soil - cocoa pod husks mixture and cocoa pod husks in both experiments which could influence aeration, infiltration, and seedling emergence and root elongation of the soil.

The relative proportions of mineral particles observed in soils in the experiments were 57.0 % sand, 13.7 % silt, 29.3 % clay and 60.6 % sand, 12.7 % silt, 26.7 % clay respectively (Table 13). Analysis showed that the soils were sandy clay loam and the low field capacity and NIR of the soil could be attributed to high fractions of sand and clay had in the experiments.

Table 13b: Soil particle size distribution (%)

	1st season			2nd season			
	SAND	SILT	CLAY	SAND	SILT	CLAY	TEXTURAL CLASS
SOIL SAMPLE I	57.5	12.5	30.0	60.5	11.5	28.0	Sandy Clay Loam
SOIL SAMPLE II	56.1	13.9	30.0	62.8	12.5	24.7	Sandy Clay Loam
SOIL SAMPLE III	57.4	14.6	28.0	58.5	14.2	27.3	Sandy Clay Loam
MEAN	57.0	13.7	29.3	60.6	12.7	26.7	

4.3. Assessment of Soil, Cocoa Pod Husk and Soil - Cocoa Pod Husks Mixture as Potting Media for Cocoa Seedlings Production

The mean organic matter content for experiments I and II are presented in Figure 7.

Cocoa pod husks and cocoa pod husks – soil mixture had the highest mean organic matter content in both experiments (Figure 7).

Soils in the first season recorded the least mean organic matter contents slightly below the critical level of 3 % (Wood and Lass, 1985). Cocoa pod husks and soil - cocoa pod husks mixture had a mean organic matter contents considerably above maximum organic matter content of 25 % (Figure 7) recommended to be ideal for optimum cocoa production (Mossu, 1992; Opeke, 2005)

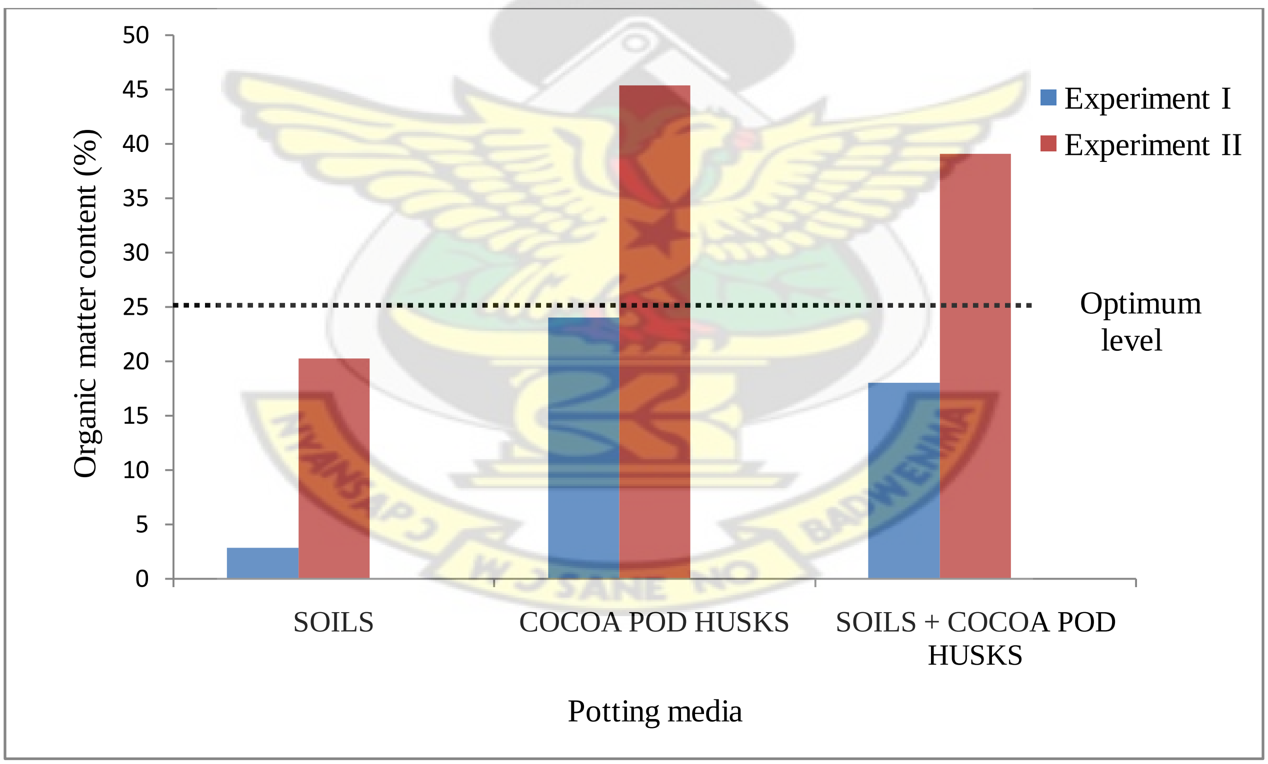

Figure 7: Organic matter content in the samples

Figure 8 presents mean pH for both experiments I and II. The pH of cocoa pod husks had the highest means followed by soil - cocoa pod husks mixture.

Soil samples recorded the least pH concentration (Figure 8). Generally, the soil samples were slightly acidic and classified as having low pH for cocoa cultivation (Wood, 1989)

The mean values of cocoa pod husks and soil - cocoa pod husks composite were slightly above the optimum value of 6.5 recommended as ideal hydrogen concentration for cocoa production (Thong and Ng, 1978; Wood, 1989; Ogunrinde, 2006).

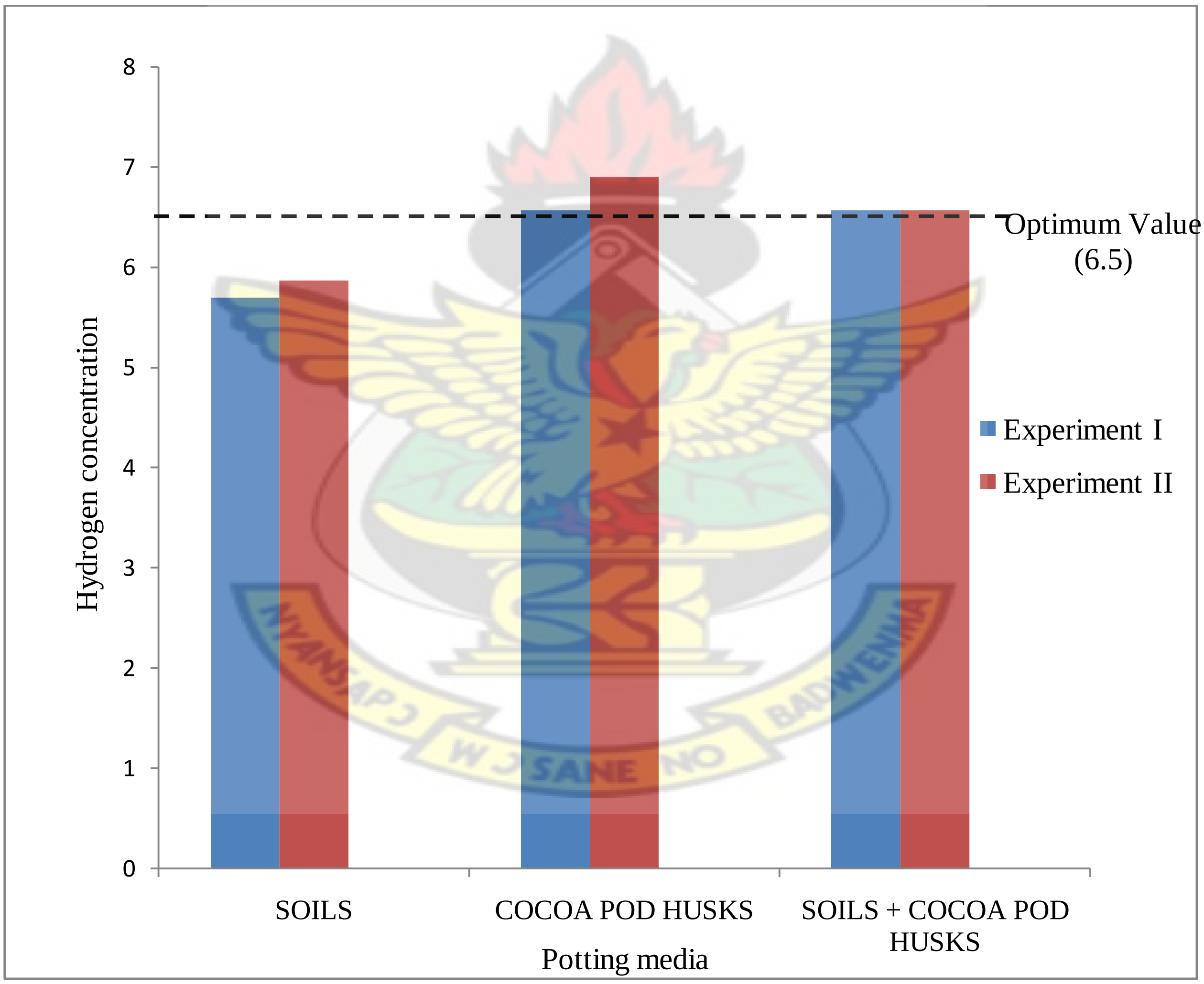

Figure 8: Soil pH of potting media

Mean nitrogen concentration had in both experiments I and II are presented in Figure 9. Cocoa pod husks recorded the highest nitrogen concentration followed by cocoa pod husk + soil mixture.

Soil samples recorded the least nitrogen concentration (Figure 9). Nitrogen content of all the samples was adequate for cocoa production since all the values recorded were substantially higher than the critical level of 0.09 % required for cocoa cultivation (Thong and Ng, 1978; Egbe *et al.*, 1989; Aikpokpodion et al., 2010).

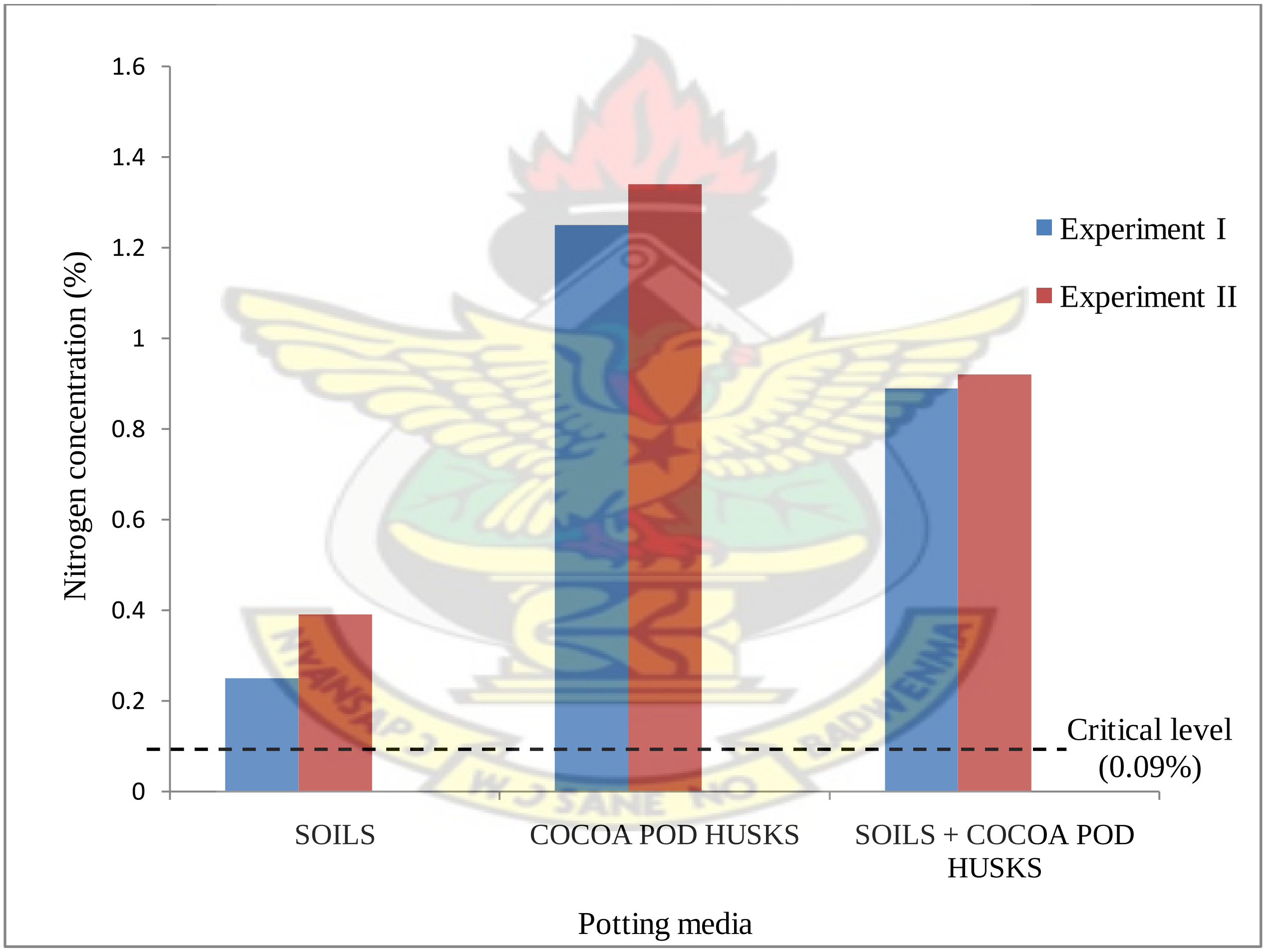

Figure 9: Nitrogen concentration in the potting media

Potassium concentration had in both experiments I and II are presented in Figure 10. Cocoa pod husks had the highest mean potassium concentration in both experiments followed by soils - cocoa pod husks mixture.

Soil samples recorded the least mean potassium concentration and slightly above the critical level of 100 ppm of potassium required for cocoa cultivation. The cocoa pod husks and soil - cocoa pod husks composite had mean potassium concentration above the maximum concentration required for optimum cocoa production.

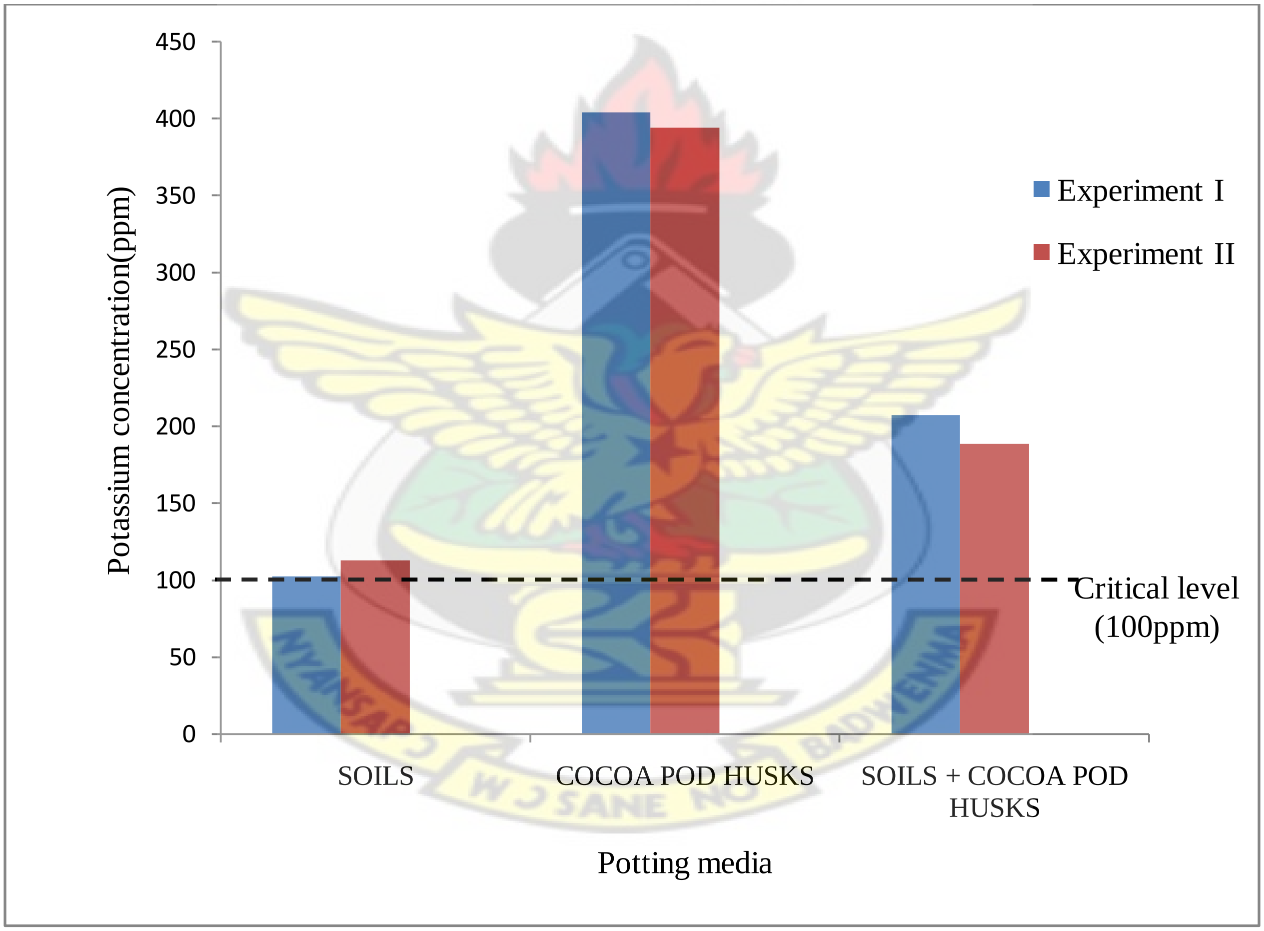

Figure 10: Potassium concentration in potting media

Phosphorous content had in both experiments I and II are presented in Figure 11. Soil had the least mean phosphorous concentration and was grossly lower than the optimum level of 35 ppm required for cocoa cultivation (Agboola, 1982; Wood, 1989; Egbe et al. 1989; Ogunlade *et al*. 2006; Thong and Ng, 1978; Aikpokpodion et al, 2010).

The cocoa pod husks and soil - cocoa pod husks mixture had mean phosphorous concentration appreciably greater than the required maximum concentration level of 35 ppm required for optimum cocoa production

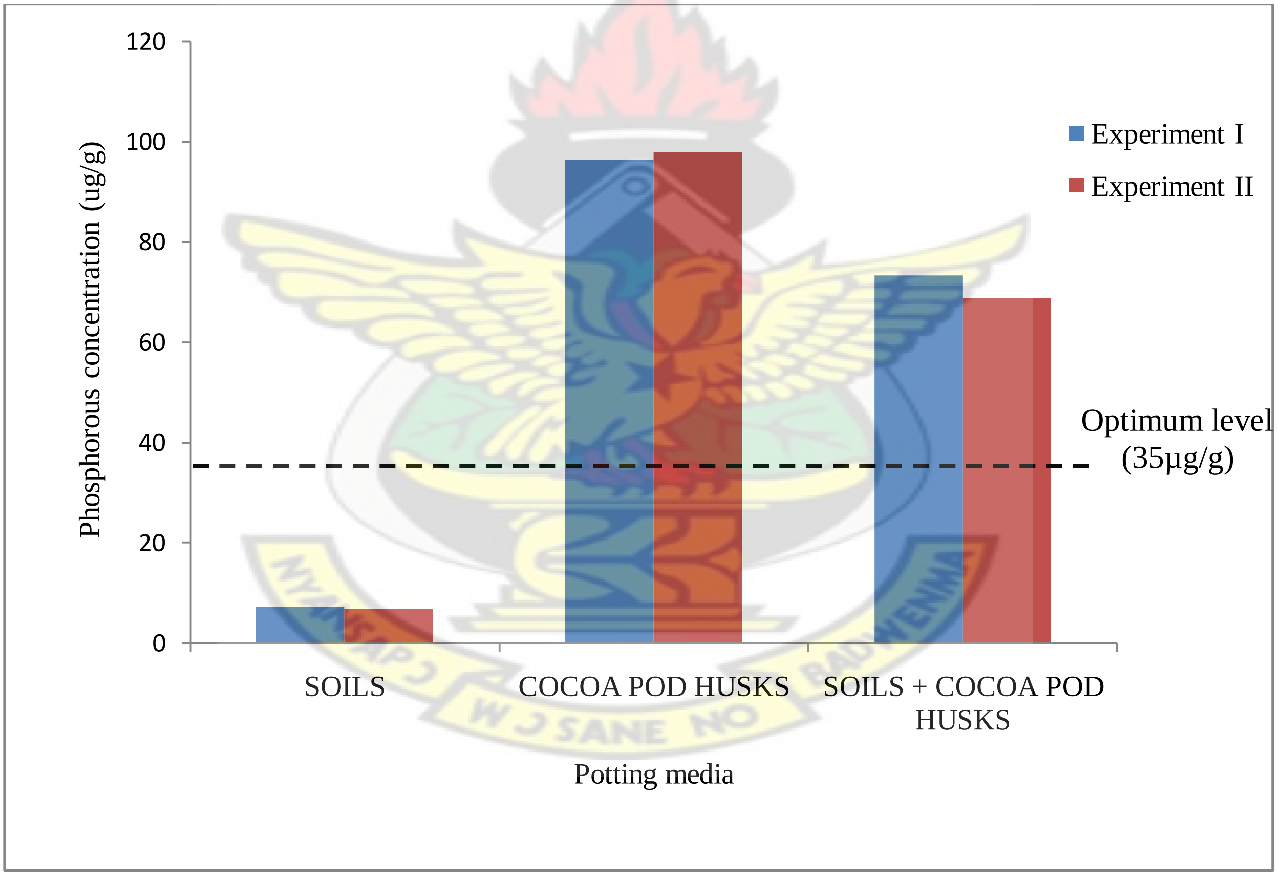

Figure 11: Phosphorous concentrations in the potting media

Cation Exchange capacity (CEC) content of the potting media in the two experiments is presented in Figure 12. Soil samples obtained the least mean CEC concentration and were lower compared to the minimum level of 20cmol/kg required for cocoa cultivation. The cocoa pod husks and soil cocoa pod husks mixture had mean CEC concentration considerably above the minimum concentration required for optimum cocoa production (Thong and Ng, 1978; Aikpokpodion et al, 2010) indicating CEC in the soil is adequate for cocoa cultivation.

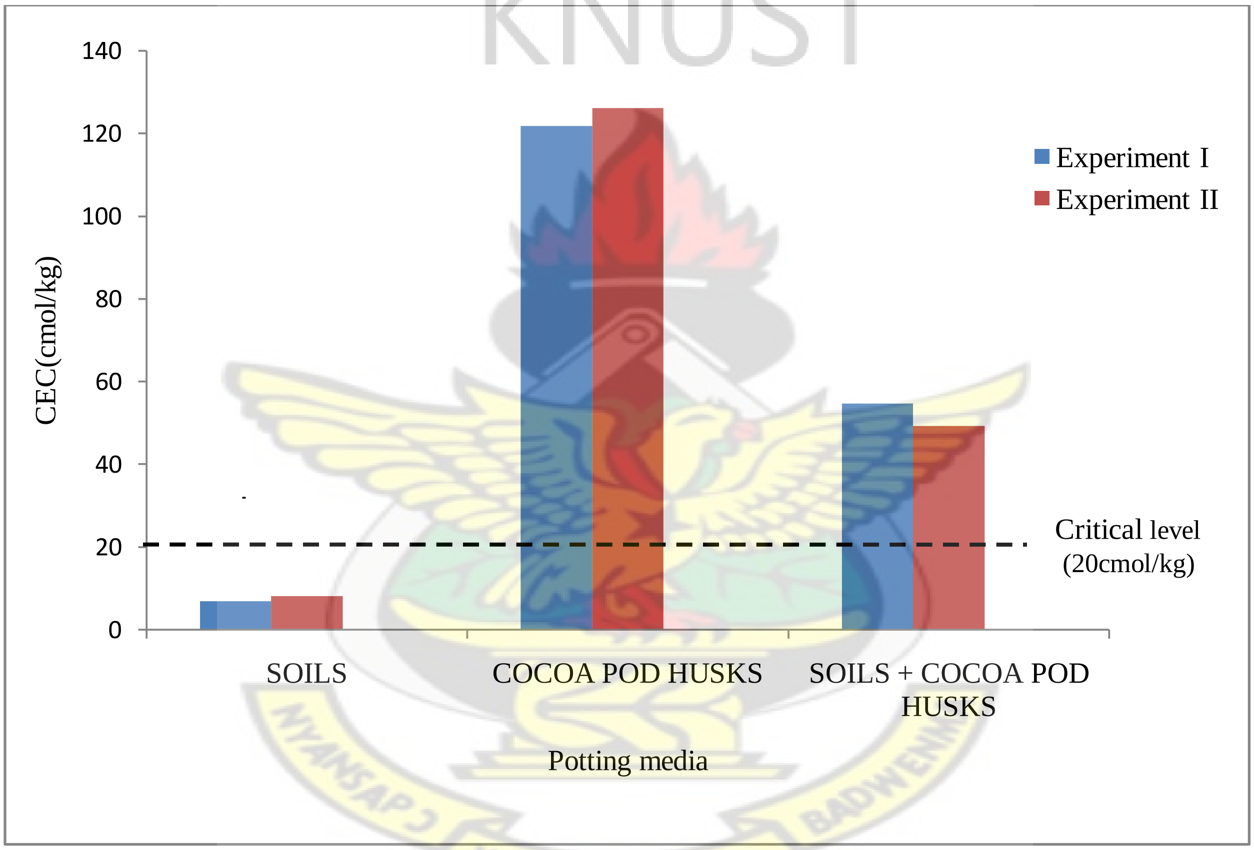

Figure 12: ECEC concentration in the potting media

Magnesium content of the potting media in the two experiments is presented in Figure 13.

Cocoa pod husks had the highest mean magnesium concentration followed by soil - cocoa pod husks mixture.

Soils recorded the least mean magnesium concentration which was slightly above the critical value of 0.8cmol/kg for cocoa production (Ipinmoroti *et al*, 2009; Aikpokpodion, 2010).

The cocoa pod husks and soil - cocoa pod husks mixture in both experiments recorded mean magnesium contents significantly above the maximum concentration level of 3cmol/kg required for optimum cocoa production (Thong and Ng, 1978).

This indicated that the magnesium content in the soil is adequate for cocoa cultivation in the area.

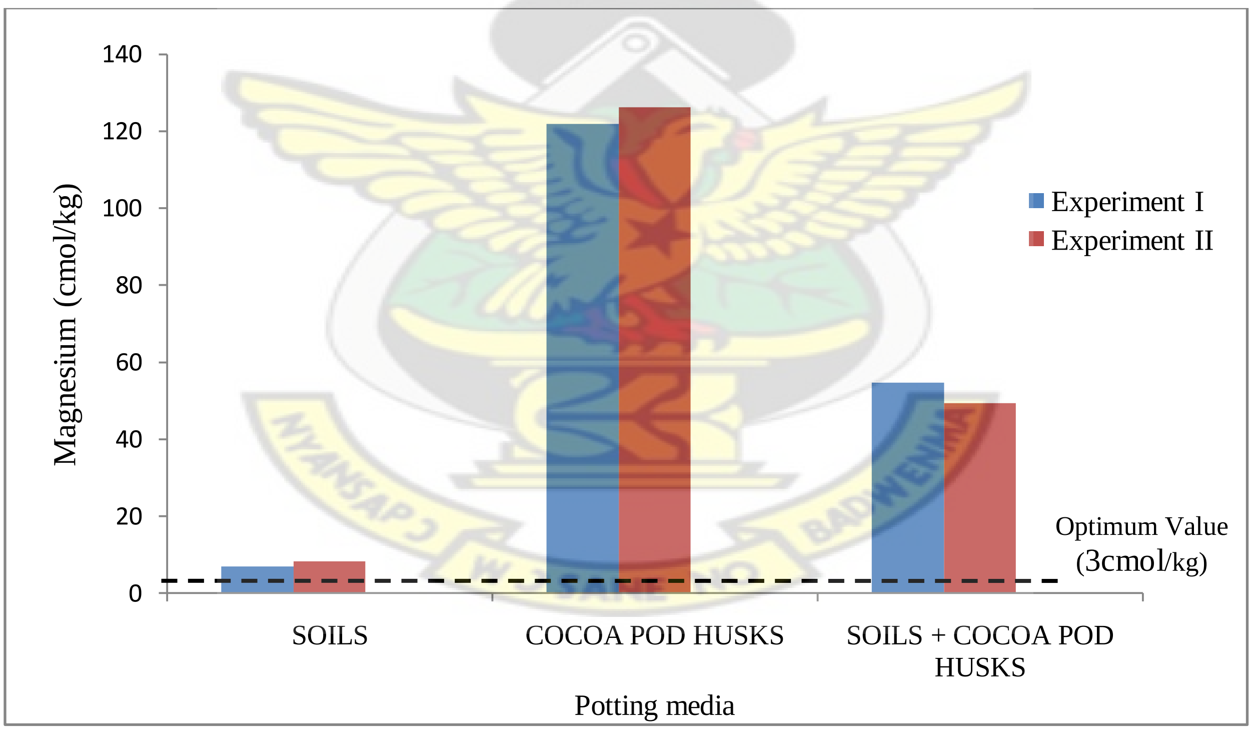

Figure 13: Magnesium content in the potting media.

The calcium content of the potting media in the two experiments are presented in Figure 14 Cocoa pod husks recorded the highest mean calcium concentration followed by soil +cocoa pod husk composite.

Soil obtained the least mean calcium concentration which was below the critical the value of 5.0 cmol/kg. Cocoa pod husks and soil + cocoa pod husks mixture had mean calcium concentrations above the optimum concentration of 10coml/kg required for cocoa production (Thong and Ng, 1978; Aikpokpodion et al., 2010).

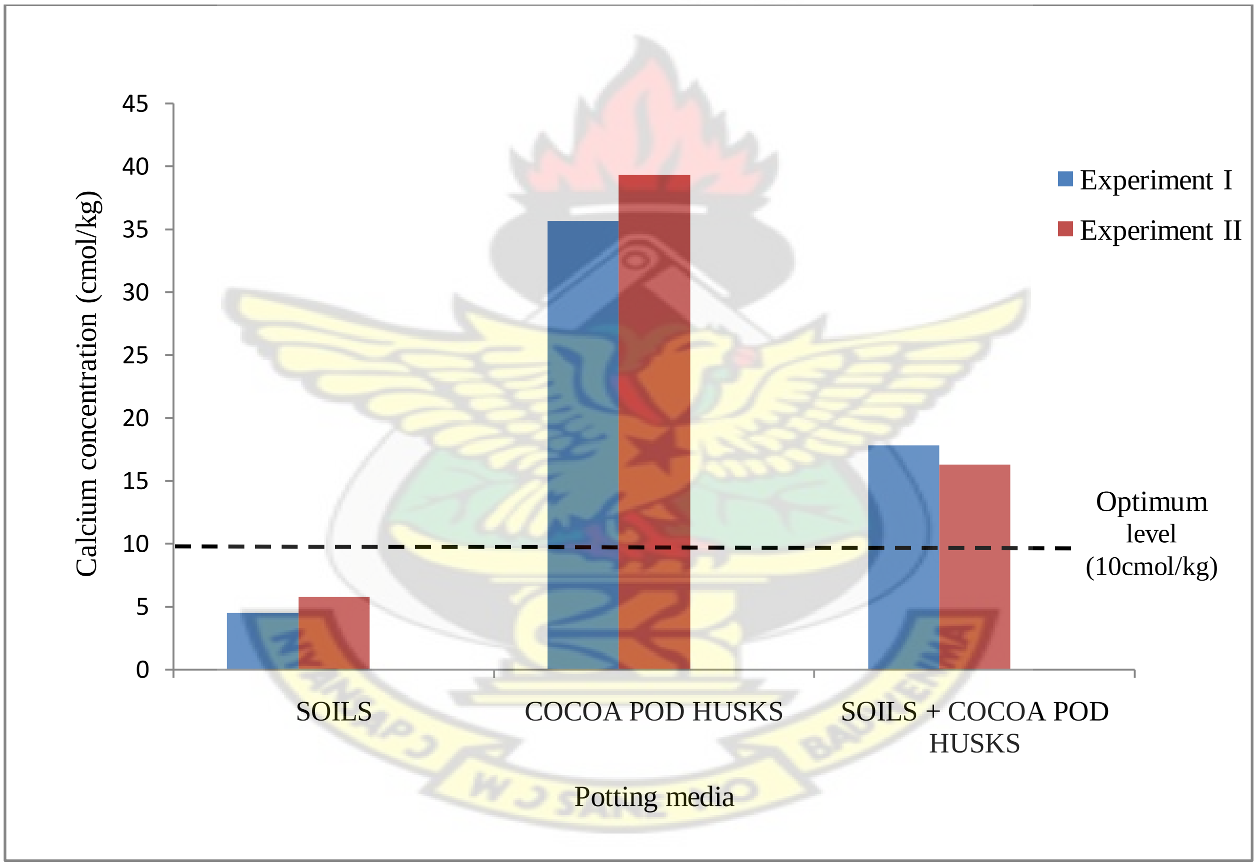

Figure 14. Calcium content in the potting media

4.4: Changes in Some Properties of the Soil, Cocoa Pod Husks and Soil + Cocoa Pod Husks at the 5 month.

Table 14: Changes in soil (SS), cocoa pod husk (CH) and soil + cocoa pod husks (SSCH) at 5 MAP

	Season I			Season II		
Properties	SS	CH	SSCH	SS	CH	SSCH
pH (H2O)	-1.2	-1.1	-0.6	-1.4	0.4	-0.4
Organic matter %	-0.7	0.7	-6.9	-2.3	3.3	-6.9
Total N %	-0.2	0.2	-0.3	-0.2	0.1	-0.4
Available P mg kg-1	-0.4	-64.8	-22.5	-0.6	-60.3	-21.2
Available K mg k/g	-32.3	298.7	378.6	-32.3	135.7	31.2
% Base saturation	-4.8	-7.4	0.2	-6.1	-7.4	0.3
ECEC	-1.8	-62.7	-18.2	-3.0	-94.7	-16.4

(+) =increased in mean concentration, (-) = decreased in mean concentration

Table 14 shows that chemical properties such as pH, organic matter, nitrogen, phosphorous and cation exchange capacity is reduced at end of both experiment for soil and soil + cocoa pod husks which were due to nutrient uptake by cocoa plant.

However the results indicated that the drops in the nutrient concentration that occurred in the soil and soil + cocoa pod husks in both experiments after the experimental period were not significantly different from each other and that the reduction in the nutrient level was due to nutrient uptake requirement of cocoa.

It was also observed that the organic matter, nitrogen and phosphorous concentration in the cocoa pod husks increased and this was due to the continuous decomposition and mineralization of cocoa pod husks. Also the drop in the pH in both experiments under the soil and soil cocoa pod husks mixture treatments indicating an increased in soil acidity

4.5: Effect of Potting Media on Leaf Macronutrients composition of Hybrid Cocoa Seedlings.

Table 15 presents the effects of potting media on leaf macronutrients composition of hybrid cocoa seedlings

Table 15: Effect of potting media on leaf macronutrients (%) composition of hybrid cocoa seedlings at 5MAP

	1st Season					2nd Season				
Treatment	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Soil	2.7b	0.2b	1.1c	0.7a	0.5c	2.9c	0.2c	1.2a	0.7b	0.7b
Cocoa pod husks	3.1a	0.3b	1.5a	0.4b	0.7b	3.1b	0.4a	1.8a	0.5c	0.7b
Soil +cocoa pod husks	3.5a	0.4a	1.4b	0.8a	0.8a	4.4a	0.4a	1.8a	0.9a	0.8a
LSD(0.05)	0.2	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.3	NS

Treatment means having the same letters along the column are not significantly different from each other at 5 % level

Cocoa leaves from soil - cocoa pod husks mixture and cocoa pod husks had the highest nitrogen concentrations in both seasons. However, there were significant higher ($P<0.05$) nitrogen concentration for cocoa pod husks and soil + cocoa pod husk compared to soil (Table 15). Nitrogen contents of leaves in cocoa pod husks and soil - cocoa pod husks mixture were sufficient for optimum cocoa seedlings growth (Wessel 1971; Egbe et al, 1989; Paramananthan, 2006; Aikpokpodion, 2010).

The adequate nitrogen content obtained in the leaves of seedlings planted in cocoa pod husks and soil - cocoa pod husks mixture were a reflection of high nitrogen contents recorded in cocoa pod husk and soil - cocoa pod husks mixture compared to the soil.

Cocoa leaves nursed in soil - cocoa pod husks mixture had the highest phosphorous concentration in both seasons (Table 15). Phosphorus content of cocoa leaves from soil sample recorded the lowest phosphorous concentration and was lower than the critical value of 0.18 % (Wessel 1971; Paramananthan, 2006). There were significant differences ($P<0.05$) in the phosphorous concentration among the treatments in both experiment. The high values obtained in cocoa pod husks and soil + cocoa pod husks composite may be attributed to the nutrient phosphorous content in the soil and may facilitates the leaves formation.

Cocoa leaves of plants on soil - cocoa pod husks mixture and cocoa pod husks obtained the highest mean potassium concentration in both seasons and found within the optimum value of 0.2%

The low level of potassium observed in the leaves under soil in both experiments reflected the low potassium content recorded in the soil (Wessel, 1971; Paramananthan, 2006) which may affect plant metabolism, carbohydrate formation and translocation of starch to all parts of the seedlings.

Leaves under soils + cocoa pod husks mixture had the highest mean calcium content in both seasons compared to cocoa pod husks and soil (Appendix B & Table.15). Statistical analysis of the results indicated that there were differences ($P<0.05$) in the calcium contents among the treatments in both seasons (Table 15).

The calcium content of leaves obtained under soil and soil - cocoa pod husks were higher than the critical nutrient level of 0.6 % (Wessel, 1971; Egbe et al, 1989) which may facilitates flowering and strengthen the stem girth of the seedlings.

Leaves of plants on soil - cocoa pod husks mixture and cocoa pod husks had the highest magnesium content in both experiment.

However there were no significant differences (P<0.05) in the magnesium concentration among the treatments in the second experiment (Table 15). Magnesium concentration in cocoa leaves under all the treatments in both seasons was above the critical value of 0.5 % (Wessel, 1971; Egbe et al., 1989; Paramananthan, 2006).

However the higher nitrogen, phosphorous, potassium, calcium and magnesium concentrations in cocoa seedlings leaves planted on soil - cocoa pod husk composite were higher than soil and cocoa pod husk may be due to the good physical properties and adequate nutrient composition in the soil - cocoa pod husks composite.

Also the low magnesium, potassium, phosphorous, nitrogen, calcium concentration in the cocoa leaves plants on soil may be due to nutrient deficiency in the soil.

This observation is in line with Charter (1947) that good soil moisture, satisfactory aeration, good drainage and satisfactory supply of main nutrients such as potassium, phosphorus, calcium and magnesium are the main soil requirement for cocoa.

4.6: Effect of Potting Media on Leaf Micronutrients composition of Hybrid Cocoa Seedlings

Based on Table 16 is the effect of potting media on the micronutrients composition of leaf of cocoa seedlings at 5MAP

Table 16: Effect of potting media on the micronutrients (ppm) composition of cocoa seedlings leaves at 5 MAP

	1st Seasons				2nd Season			
Treatment	Fe	Cu	Zn	Mn	Fe	Cu	Zn	Mn
Soil	73.0c	27.0b	53.3b	32.7c	75.0c	30.0b	57.7b	34.0b
Cocoa pod husks	88.0b	25.3c	53.4b	36.7b	94.0b	26.0c	56.7b	36.7b
Soil - cocoa pod husks	103.7a	31.0a	71.7a	67.0a	112.3a	34.3a	73.7a	78.7a
LSD(0.05)	3.7	1.1	3.6	1.9	2.0	1.0	3.2	1.4

Treatment means having the same letters along the column are not significantly different from each other at 5% level

Leaves of cocoa seedlings planted on soil - cocoa pod husks mixture had the highest iron concentration in both experiments compared to seedlings planted on cocoa pod husks and soils. The statistical analysis indicated significant differences ($P<0.05$) in the iron concentration among the treatment means (Table 16).

The iron content of leaves obtained from all the treatments was appreciably higher than the deficiency level of 50 ppm.

Cocoa leaves planted on soil - cocoa pod husks mixture recorded the highest copper content than soil and cocoa pod husks. There was significant differences ($P<0.05$) in the copper content among the treatments means (Table 16).

The copper content of leaves obtained under all the treatments was considerably above the deficiency level of 4 ppm and the critical level of 6.0 ppm (Egbe et al., 1989; Paramananthan, 2006).

Leaves of cocoa seedlings planted on soil - cocoa pod husks mixture contained the highest zinc content in both seasons. There were significant differences ($P<0.05$) in the zinc contents among all the treatments as depicted in Table 16. The zinc content of leaves obtained under all the treatment means was higher than the deficiency level of 20 % and within the normal range of 30.0 - 65.0% (Wessel, 1971; Paramananthan, 2006)

Cocoa leaves nursed on soil - cocoa pod husks mixture had the highest manganese content in both season. However, there were significant differences ($P<0.05$) in zinc content among treatments as indicated in the Table 16.

The leaves of seedlings planted on cocoa pod husks and cocoa pod husks - soil mixture was considerably above the deficiency level of 15ppm and the critical level of 30 ppm (Wessel, 1971; Paramananthan, 2006)

However the higher iron, copper, zinc and manganese concentration obtained in cocoa leaves planted on soil – cocoa pod husk mixture compared to soil and cocoa pod husk may be due to the good physical properties and adequate nutrient composition in the soil - cocoa pod husks mixture.

4.7: Effect of Watering Regimes on the Leaf Macronutrients composition of Hybrid Cocoa Seedlings

The Table 17 presents results of macronutrients composition of leaf of cocoa seedlings under the influence of different watering application rates

Table 17: Effects of watering regime on the macronutrients (%) composition of hybrid cocoa seedlings at 5MAP

	1st Season					2nd Season				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Watering regime I(0.06l)	2.0c	0.1c	0.6c	0.1b	0.4c	2.4c	0.2c	0.8c	0.2c	0.4b
Watering regime II(0.18l)	3.4a	0.3b	1.1a	0.3a	0.8a	3.9a	0.3a	1.2b	0.3a	0.9a
Watering regime III(0.36l)	3.1b	0.3a	1.0 b	0.3a	0.7a	3.9a	0.3a	1.3a	0.3a	0.8a
LSD(0.05)	0.2	0.0	0.06	0.1	0.1	0.1	0.1	0.1	0.2	0.1

Treatment means having the same letters along the column are not significantly different from each other at 5 % level

Cocoa seedlings leaves nursed in watering regime II & III in both experiments resulted in higher nitrogen concentration compared to watering regime I.

However, statistical analysis of the results depicted that, there was significant differences ($P<0.05$) in the nitrogen concentration among all the watering regimes (Table 17) and was considerably higher than the deficiency level of 1.8 % and the critical level of 2 % (Paramananthan, 2006).

Cocoa leaves nursed under watering regime II &III gave higher mean phosphorous concentration compared to watering regime I in both experiments. There were significant differences ($P<0.05$) in the phosphorous concentration among all the watering regimes.

The phosphorous concentration of leaves planted under all the watering regime was above the deficiency level of 0.13 % and critical level of 0.20 % (Wessel 1989; Egbe et al.1989; Paramananthan, 2006; Aikpokpodion, 2010) which is essential for root development, flowering and strengthen the stem girth of cocoa plant thereby preventing lodging during transplanting on the field (Ling, 1990). These observations also confirm early study by Ogunlade and Aikpokpodion (2006) that the phosphorous concentration in the leaf at specific growth stage is related to the performance of crop.

The leaves of cocoa seedlings planted under watering regimes II&III had higher potassium concentration than watering regime I in both seasons (Appendix B).

Statistical analysis of results indicated that there were differences ($P<0.05$) in potassium concentration among watering regimes (Table 17 and Appendix B). All the values obtained were lower than the critical value of 2.0% (Egbe *et a.l*, 1989) which may affect plant metabolism, carbohydrate formation and translocation of starch to all parts of the seedlings.

Cocoa leaves planted under watering regimes II&III recorded higher calcium concentration than watering regime I in both seasons. The calcium content of the leaves obtained in all watering regimes was below the critical level of 0.6 % (Egbe *et al*., 1989).

Cocoa leaves under watering regime II &III recorded higher mean magnesium concentration than watering regime I (Appendix B). Cocoa leaves under watering regime I obtained the lowest amount of magnesium concentration which is below the critical level of 0.5 %.

Analysis of results indicated that there were differences ($P<0.05$) in the magnesium concentration among all the watering regimes in both experiments. The magnesium content of leaves obtained under watering regimes II&III was considerably above the critical level of 0.5 % (Egbe et al. 1989) which constitute an essential component of chlorophyll molecule without which photosynthesis cannot take place (Ogunrinde, 2006; Aikpokpodion, 2010). Also low magnesium concentration of seedlings under watering regime I may be responsible for chlorosis along the leaf veins and stunted growth observed in the growing period.

The higher magnesium, potassium, phosphorous, nitrogen, calcium concentration obtained in cocoa leaves planted under watering regime II & III compared to watering regime I may be due to the application of 0.18 l/seedlings and 0.36 l/seedling which are adequate for the optimum growth of the seedlings. This observation agreed with Asare and David (2010) that hybrid cocoa seedlings may use an average of 0.18 liters of water (0.18 liter/ seedling) a day if there is no additional water.

4.8: Effect of Watering Regimes on the Leaf Micronutrients composition of Hybrid Cocoa Seedlings

Table 18 presents results of micronutrients composition of leaf of cocoa seedlings leaves under the influence of different watering application rates

Table 18: Effect of watering regimes on leaf micronutrients of hybrid cocoa seedlings at 5MAP

	1st Season				2nd Season			
	Fe	Cu	Zn	Mn	Fe	Cu	Zn	Mn
Watering regime I(0.06l)	13.3c	25.0c	35.3c	23.0c	17.7c	25.0c	37.7c	27.3c
Watering regime II(0.18l)	22.0b	38.7b	50.3b	38.5b	23.7b	44.3b	53.3b	41.7b
Watering regime III(0.36l)	89.0a	48.3a	71.7a	49.7a	91.3a	46.0a	74.0a	54.7a
LSD(0.05)	2.50	3.8	2.3	4.5	2.07	3.1	1.8	3.6

Treatment means having the same letters along the column are not significantly different from each other at 5% level.

Cocoa leaves from seedling planted under watering regime III gave the highest iron concentration among the watering regimes in both seasons (Appendix C). There were significant differences (P<0.05) in the iron concentration among all watering regimes (Table 18). The iron content of cocoa leaves obtained under watering regime I & II were below the deficiency range of 30.0 - 50.0 ppm while that of watering regimes III was found to be within the normal range of 65.0 - 175.0 % (Paramananthan, 2006).

Leaves under watering regime II & III recorded higher copper concentration compared to watering regime I. Analysis of results indicated that there were significant differences (P<0.05) in the copper concentration among watering regimes (Table 18). The copper content of leaves for all the watering regimes was above both the deficiency level of 4.0 ppm and the critical level of 6.0 ppm (Wessel, 1971; Paramananthan, 2006).

Cocoa leaves under watering regimes II & III recorded higher mean zinc content compared to watering regime I (Appendix C). The zinc content of leaves for all the watering regimes were found above the optimum level of 65.0ppm.

Analysis of the results indicated that there were differences (P<0.05) in the manganese concentration among all the watering regimes. The manganese content of the leaves obtained under all watering regimes was above the critical level of 30.0 ppm. The higher iron, copper, zinc and manganese concentration obtained in cocoa leaves planted under watering regimes III followed by watering regime III &I may be due to the higher water application which are adequate for growth of the seedlings. This observation agrees with Asare and David (2010) that hybrid cocoa seedlings may use an average of 0.18 liters of water (0.18 liter/ seedling) a day if there is no rain. This observation confirms Ogunrinde, (2006) findings that cocoa seedlings are very sensitive to a soil water deficiency.

4.9: Effect of Potting Bags on the Leaf Macronutrients composition of Hybrid Cocoa Seedlings

The Table 19 presents the effect of poly bags on macronutrients (%) composition of cocoa seedlings at 5MAP

Table 19: Effect of poly bags on macronutrients (%) composition of cocoa seedlings at 5MAP

	1st Season					2nd Season				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
COCOBOD bags	3.1	0.2	0.5	0.5	0.5	4.3	0.3	1.2	0.6	0.5
ITTA poly bags	2.9	0.2	1.4	0.7	0.6	3.0	0.2	1.4	0.8	0.9
Water sachets	2.7	0.2	0.9	0.6	0.6	2.8	0.3	1.2	0.8	0.6
LSD(0.05)	0.0	NS	0.3	NS	0.1	0.0	NS	NS	NS	0.1

Treatment means having the same letters along the column are not significantly different from each other at 5% level

The results indicated that there was significant difference ($P < 0.05$) in the nitrogen concentration among the treatment in both seasons (Table 19 and Appendix D). The nitrogen content of leaves in the three different types of potting bags were above the deficiency level of 1.8 % and critical level of 2.0% (Paramananthan, 2006).

Analysis of the results indicated that there were no significant differences ($P>0.05$) in the phosphorous concentration among the treatments means in the two experiments. The phosphorous content of leaves recorded in all the treatments was above the deficiency level of 0.13 % and the critical level of 0.2 % (Egbe et al. 1989; Paramananthan, 2006). However, there were no significant differences ($P>0.05$) in the potassium concentration among the treatment.

The potassium content of cocoa leaves obtained in the COCOBOD bags and water sachets were below the deficiency level of 1.2 % (Wessel, 1971; Paramananthan, 2006).

The results showed that there were no statistical differences ($P<0.05$) in the calcium concentration between water sachets, COCOBOD and IITA poly bags in the two experiment. Calcium content of cocoa leaves obtained from all the bags was above the deficiency level of 0.3 % and the normal level of > 0.5 % (Wessel, 1989; Ling, 1990; Paramananthan, 2006).

The magnesium content of leaves obtained from all the bags was statistically different ($P<0.05$) in both experiments. The magnesium content of leaves obtained in all the bags was above the deficiency level of 0.20 % and normal level of > 0.45 % (Paramananthan, 2006). The similar macronutrient recorded in the leaves of cocoa seedlings planted in water sachets, COCOBOD and IITA poly bags in both season was due to adequate nutrient composite and quantity of water applied. It may also attribute to sizes of potting bags. This observation agrees with Diver and Greer (2001) findings that 80 percent of seedlings today are poly bags - grown and have greater chances of survival and establishment after transplanting.

4.10: Effect of Potting Bags on the Leaf Micronutrients composition of Hybrid Cocoa Seedlings.

The Table 20 presents effect of different poly bags on leaf macronutrients composition of hybrid cocoa seedlings.

Table 20: Effect of poly bags on the leaf micronutrients composition of cocoa seedlings at 5MAP

	1st Season				2nd Season			
	Fe	Cu	Zn	Mn	Fe	Cu	Zn	Mn
COCOBOD bags	102.a	28.6c	68.0b	57.3b	88.0a	30.3c	88.7a	58.3b
ITTA POLY bags	71.33b	48.3a	66.6b	37.3c	75.3b	48.3a	66.7c	39.3c
Water sachets	61.3c	40.3b	73.6a	73.0a	64.7c	43.3b	76.3b	73.0a
LSD(0.05)	3.2	1.3	2.2	3.6	1.9	3.4	2.3	3.8

Treatment means having the same letters along the column are not significantly different from each other at 5 % level

The statistical analysis of the results (Table 20) showed that there were significant differences (P<0.05) in the iron content between water sachets, COCOBOD and IITA poly bags in both experiment. The iron content of leaves obtained under all the poly bags were considerably higher than the deficiency level of 50 ppm, and are within the normal range of 65-175ppm (de Genus, 1973, Paramananthan, 2006). However, there were significantly differences (P<0.05) in the copper content between water sachets, COCOBOD and IITA poly bags. The copper content of leaves obtained under all the bags was considerably above the critical level of 6 % (de Genus, 1973; Paramananthan, 2006). The results indicated that, there were significantly differences (P<0.05) in the zinc content among the treatments. The zinc content of leaves obtained in all the poly bags were above the deficiency level of 20.0 ppm, and the normal range of 30.0-65.0ppm (de Genus, 1973; Paraananthan, 2008)

4.11: Effect of Watering Regimes and Potting Media on the Growth parameters of Hybrid Cocoa Seedlings

Table 21 presents the results of effects of combined treatments of watering regimes and potting media on plant height of clone 42 hybrid cocoa seedlings.

Table 21: Effect of watering regimes and potting media on plant height (cm) of clone 42 hybrid cocoa seedlings

		Mean plant height per seedlings(cm)				
Watering regime (WR)	Potting media	1MA	2MAP	3MAP	4MAP	5MAP
I	SS	15.5 b	17.6 c	19.2 e	24.2 d	24.9 e
	CH	15.7 b	18.1 b	19.9e	24.1 d	28.1 d
	SSCH	15.9 b	18.4 b	20.3e	24.3 d	28.7 d
II	SS	15.5 b	19.1 b	24.1 c	27.6 c	31.1 c
	CH	18.0 a	20.9 a	26.6 b	31.4 b	39.9 ab
	SSCH	18.2 a	21.1 a	27.5d	32.9 a	42.9 a
III	SS	15.8 b	18.9 b	23.6 c	27.5 c	31.3 c
	CH	18.0 a	20.7 a	26.2 b	32.1 ab	37.3 b
	SSCH	18.5 a	21.6 a	27.3 a	33.1 a	42.7 a
LSD(0.05)		1.1	0.9	1.1	1.7	2.6

Plant height of hybrid cocoa seedlings planted under all the treatments in both experiments increased progressively with time throughout the entire experimental period.

There was significant increase ($P<0.05$) in plant height of clone 42 hybrid cocoa seedlings under the combined treatments (Table 21).The treatment of soil - cocoa pod husks mixture under watering regime II (WRIISSCH) and III (WRIIISSCH) promoted significantly ($P<0.05$) higher plant height than the other treatments which were found within optimum value of > 35cm (Sheperd, 1976).

The table 22 presents the results of effects of combined treatments of watering regimes and potting media on leaf area of clone 42 hybrid cocoa seedlings

Table 22: Effects of combined treatment of watering regimes and potting media on plant leaf area (cm^2) of clone 42 hybrid cocoa seedlings

		Mean plant leaf area per seedlings(cm^2)				
Watering regime (WR)	Potting media	1MAP	2MAP	3MAP	4MAP	5MAP
I	SS	41.7d	56.6c	62.6e	96.9d	104.2e
	CH	45.6c	52.2d	85.0 c	96.9d	128.2d
	SSCH	47.9c	54.7c	87.8 c	93.6e	127.9d
II	SS	50.1b	66.4a	77.1d	113.4c	154.5c
	CH	50.1b	66.9a	107.8b	144.3b	212.6b
	SSCH	57.6a	67.1a	11 2.2a	146.2b	219.3a
III	SS	49.7b	63.8b	86.76c	142.3b	164.8c
	CH	49.3b	65.4a	102.2b	184.8a	213.6b
	SSCH	55.7a	64.7a	115.3a	186.3a	222.4a
LSD(0.05)		4.5	8.15	9.57	15.8	21.1

Treatment means having the same letters along the column are not significantly different from each other at 5 % level

Plant leaf area of hybrid cocoa seedlings nursed in soil, cocoa pod husks and soil - cocoa pod husks mixture under watering regimes increased considerably with time (Table 22).The plant leaf area of clone 42 hybrid cocoa seedlings was influenced significantly by treatments of potting media and watering regime. Analysis of the results indicated that the treatment of soil + cocoa pod husks mixture under watering regime III (WRIIISSCH) and II (WRIISSCH), cocoa pod husks under watering regime II (WRIICH) and III (WRIIICH) gave significantly ($P<0.05$) higher plant leaf area than the other combined treatments at 5 MAP which were found above the minimum range of 90 -150cm^2 in both experiment at 5 MAP (Sheperd, 1976).

Table 23: Effects of combine treatment of watering regimes and potting media on plant number of leaves of clone 42 hybrid cocoa seedlings

		Mean number of leaves per seedling				
Watering regime (WR)	Potting media	1MAP	2MAP	3MAP	4MAP	5MAP
I	SS	2.9c	4.8c	4.9d	5.8c	8.3e
	CH	2.8c	4.6c	4.8d	5.5c	8.6d
	SSCH	2.7c	5.3bc	5.4d	5.8c	9.5d
II	SS	3.2b	5.5b	7.1c	9.8b	13.3c
	CH	3.7a	5.5b	8.0b	10.8b	14.3b
	SSCH	3.9a	5.8b	8.9a	11.4a	17.2a
III	SS	3.1b	5.6b	7.1c	9.7b	13.4c
	CH	3.9a	5.5b	7.6b	10.2b	14.9b
	SSCH	3.5ab	6.7a	9.1a	11.5a	17.8a
LSD(0.05)		0.35	0.6	1.0	0.8	1.3

The number of plant leaf of clone 42 hybrid cocoa seedlings influences significantly under combined treatments (Table 23).The results showed significant difference (P<0.05) in the plant number of leaves among the treatments from two to five months after planting (5MAP).

The treatment of soil + cocoa pod husks under watering regime III (WRIIISSCH), soil + cocoa pod husks under watering regime II (WRIISSCH) produced significantly (P<0.05) higher plant number of leaves than the other combine treatment which were found within the optimum value of >15 (Sheperd, 1976). The increase in the number of leaves could positively affect the photosynthetic activity of the plant since it is a growth index that could enhance crop yield.

Table 24: Effects of combine treatment of watering regimes and potting media on plant root length (cm) of clone 42 hybrid cocoa seedlings

		Mean plant root length per seedling(cm)			
Watering regime (WR)	Potting media	2MAP	3MAP	4MAP	5MAP
I	SS	11.8 b	9.4 c	10.9 d	13.3a
	CH	11.3 b	6.0 e	7.4 e	9.6 d
	SSCH	10.6 c	7.2 d	8.3 e	10.8 c
II	SS	12.6 a	13.5a	12.4bc	12.9 a
	CH	12.9 a	9.6 c	13.7 b	13.3 a
	SSCH	12.6 a	10.8 c	11.5 c	11.0 c
III	SS	11.2 b	13.4 a	15.2 a	12.8 a
	CH	10.1 c	10.1 c	11.8c	12.7 a
	SSCH	10.1 c	11.2b	9.9 d	12.8 a
LSD(0.05)		2.9	3.3	3.9	3.2

There were significant increase ($P<0.05$) in the plant root length of clone 42 hybrid cocoa seedlings during the five months after planting under different treatment (Table 24).

Analysis of results indicated that all the treatment means show significantly higher ($P<0.05$) plant root length for different potting media under watering regime II and III except for soil + cocoa pod husks media under water regime II. The mean tap root length of all the treatments recorded was found within minimum range of 10-12 cm (Sheperd, 1976) in both experiments for 5 MAP.

Table 25: Effect of combined treatments of watering regimes and potting media on plant height (cm) of clone 85 hybrid cocoa seedlings

		Mean plant height per seedling(cm)				
Watering regime (WR)	Potting media	1MAP	2MAP	3MAP	4MAP	5MAP
I	SS	14.7 d	16.9 d	18.8 e	23.8 e	25.3 e
	CH	14.6 d	18.0 c	20.5 d	26.6 d	28.7 d
	SSCH	16.2 b	18.0 c	20.8 d	24.5 e	28.5 d
II	SS	15.1 c	18.9 bc	24.4 c	27.9 c	32.3 c
	CH	16.9 b	19.9 b	26.5f	31.8 b	37.0 b
	SSCH	18.2 a	21.1 a	27.2 a	33.6 a	42.0 a
III	SS	15.2 c	19.4b	23.9 c	27.9 c	32.4 c
	CH	17.6 b	20.3 ab	25.9 b	32.1a	36.4 b
	SSCH	18.8 a	21.2 a	27.6 a	33.6 a	43.5 a
LSD(0.05)		0.91	0.7	1.2	2.34	2.9

Plant height of hybrid cocoa seedlings nursed under all the potting media under watering regimes gradually increased with time and followed the normal growth curve of tree crops.

There were significant difference increased (P<0.05) in plant height of clone 85 of hybrid cocoa seedlings under combined treatments of potting media and water regime (Table 25).

The treatment of soil + cocoa pod husks under watering regime III (WRIIISSCH) and II (WRIISSCH), cocoa pod husk under watering regime III (WRIIICH) and II (WRIICH) gave significantly (P<0.05) higher plant height found within optimum value of >35 (Sheperd, 1976) compared to other combine treatment. Soil under watering regime I (ISS) recorded the lowest plant.

Table 26: Effect of combined treatment of watering regimes and potting media on plant leaf area (cm^2) of clone 85 hybrid cocoa seedlings

		Mean plant leaf area per seedling(cm)				
Watering regime (WR)	Potting media	1MAP	2MAP	3MAP	4MAP	5MAP
I	SS	42.6 d	52.7 e	67.3 e	83.3 f	110.0 d
	CH	44.2c	50.9 e	83.7 d	90.1 e	122.4 e
	SSCH	45.2 c	62.0 d	87.7 d	89.7 e	142.1 d
II	SS	49.4 b	62.5 d	78.7 e	109.7d	170.7 c
	CH	47.1 b	66.6 c	103.9b	143.3b	210.3 a
	SSCH	57.1 a	88.1 a	106.7b	155.3 a	213.4 a
III	SS	48.5 b	61.7 d	90.3 c	104.9 d	166.9 c
	CH	48.6 b	66.0 c	101.3 b	118.2 c	201.5 b
	SSCH	56.9a	70.1 b	119.6 a	121.8 c	220.4 a
LSD(0.05)		3.7	15.7	9.9	18.7	20.7

The plant leaf area of clone 85 of hybrid cocoa seedlings under combine treatments is presented in Table 26.

Analysis of the results showed significant difference ($P<0.05$) in the plant leaf area among the treatments. The treatment of soil + cocoa pod husks under watering regime III (WRIII SSCH) and II (WRIISSCH), cocoa pod husks under watering regime II (WRIICH) and III (WRIIISSCH) gave significantly ($P<0.05$) higher plant leaf area compared to the other treatments which were found to be close to the optimum value of >250 (Sheperd, 1976) than the other combine treatments.

Table 27: Effect combined treatment of watering regimes and potting media on number of plant leaves (cm) of clone 85 hybrid cocoa seedlings

		Mean number of plant leaves per seedling (cm)				
Watering regime (WR)	Potting media	1MAP	2MAP	3MAP	4MAP	5MAP
I	SS	2.9c	5.0 c	4.8 f	5.6 c	8.7 f
	CH	2.7d	4.5 d	4.9 f	6.0cc	9.2e
	SSCH	2.5e	4.7 d	5.2 e	5.7 c	10.0d
II	SS	2.9c	5.6 b	6.9 d	10.4b	14.3c
	CH	3.5b	6.1 a	7.8 c	10.9b	14.9c
	SSCH	3.9a	5.8 a	9.3 a	11.7a	17.9b
III	SS	3.2b	3.5 e	7.6 c	10.8b	13.1c
	CH	3.6a	6.0a	8.1 b	10.9b	14.9c
	SSCH	3.9a	5.1 c	9.4 a	11.4 a	18.1a
LSD(0.05)		0.7	0.61	1.3	0.96	1.22

The results in Table 27 shows significantly difference ($P<0.05$) in the number of leaves among the treatments. The treatment of soil + cocoa pod husks under watering regime III (WRIII SSCH) and II (WRIISSCH), cocoa pod husks under watering regime III (WRIIICH) and II (WRIISSCH) produced significantly ($P<0.05$) higher plant number of leaves than the other treatment which also different from one another.

Table 28: Effect of combined treatment of watering regimes and potting media on plant root length (cm) of clone 85 hybrid cocoa seedlings

		Mean plant root length per seedling (cm)				
Watering regime (WR)	Potting media	1MAP	2MAP	3MAP	4MAP	5MAP
I	SS		10.7c	8.5c	9.8 e	12.8 b
	CH		11.9 a	5.9 e	9.1e	11.8 c
	SSCH		11.2 c	7.5d	8.4f	9.16 d
II	SS		14.3 a	12.9a	12.9b	12.8 b
	CH		10.1c	11.7b	10.4d	13.2 a
	SSCH		12.9 a	8.9 c	11.5c	12.6 b
III	SS		13.8 a	12.3a	13.7a	10.7 d
	CH		8.7 d	9.0 c	11.4 c	11.7 c
	SSCH		10.4c	12.8a	11.6 c	12.4 b
LSD(0.05)			3.1	3.1	2.9	3.3

There were significant difference (P<0.05) in the plant root length of clone 85 hybrid cocoa seedling under the treatments (Table 28). Analysis of results indicated that all the treatments increased significantly (P<0.05) in fibrous plant root length.

4. 12: Effect of Poly Bags on the Physical Growth Performance of Hybrid Cocoa Seedlings

Statistically, the monthly mean plant height recorded in both experiments showed no significant differences (P<0.05) among the means of all the treatments of different potting bags (Figure 15 and Appendix O, G & M). Generally, the water sachets, IITA poly bags and COCOBOD poly bags in both seasons produced hybrid seedling heights within the optimum value of >35cm (Sheperd, 1976) and results agree with observations made by Diver and Greer (2001), that sowing in polythene bags positively affects cocoa seedling height compared to sowing in groves and by broadcasting.

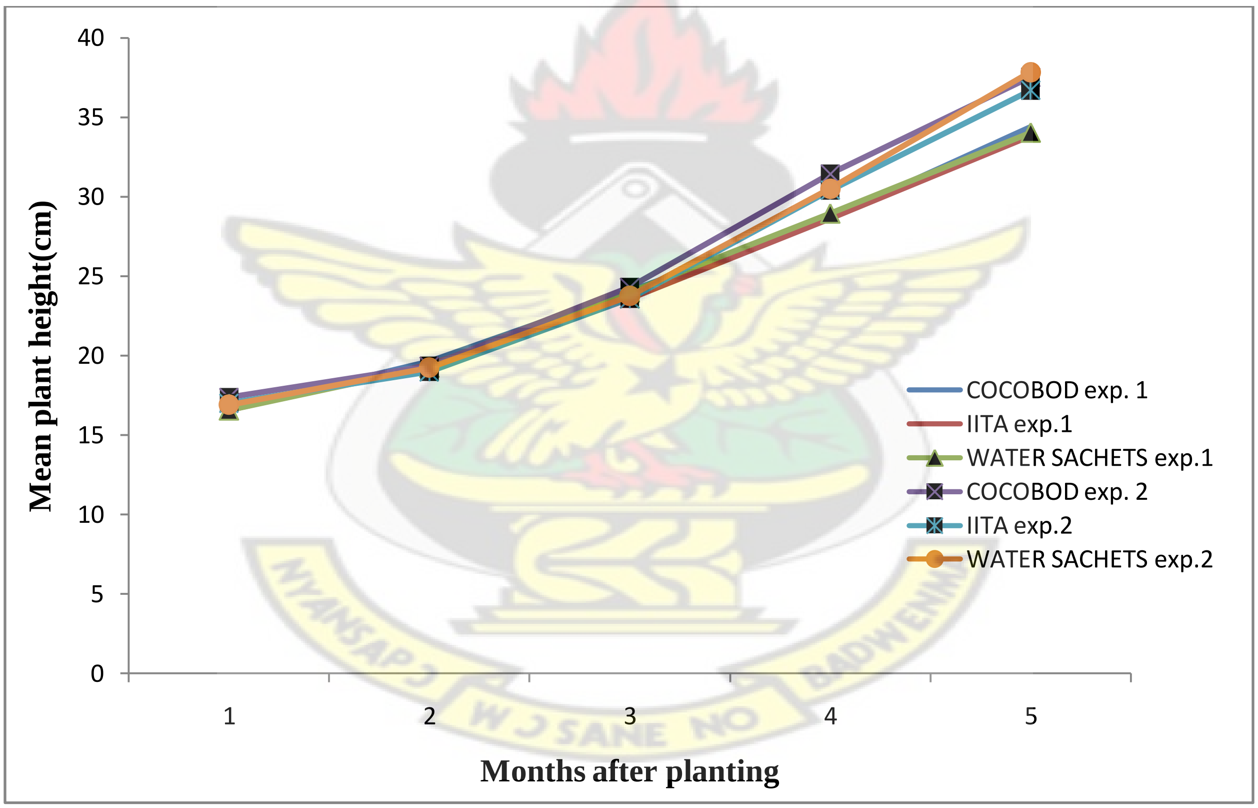

Figure 15: Effect of poly bags on the height of hybrid cocoa seedlings

Plant leaf area also showed considerable increase with time for all hybrid cocoa seedlings planted in the COCOBOD poly bags, IITA poly bags and water sachets as indicated in Figure 16. The results (Appendix G & M) showed that there were no significant differences ($P<0.05$) among the monthly means of all the treatments. Generally the seedlings under water sachets, IITA and COCOBOD poly bags recorded in the second season produced broader leaves than the first season as depicted Figure 16 and this may be due to additional rains observed in the months.

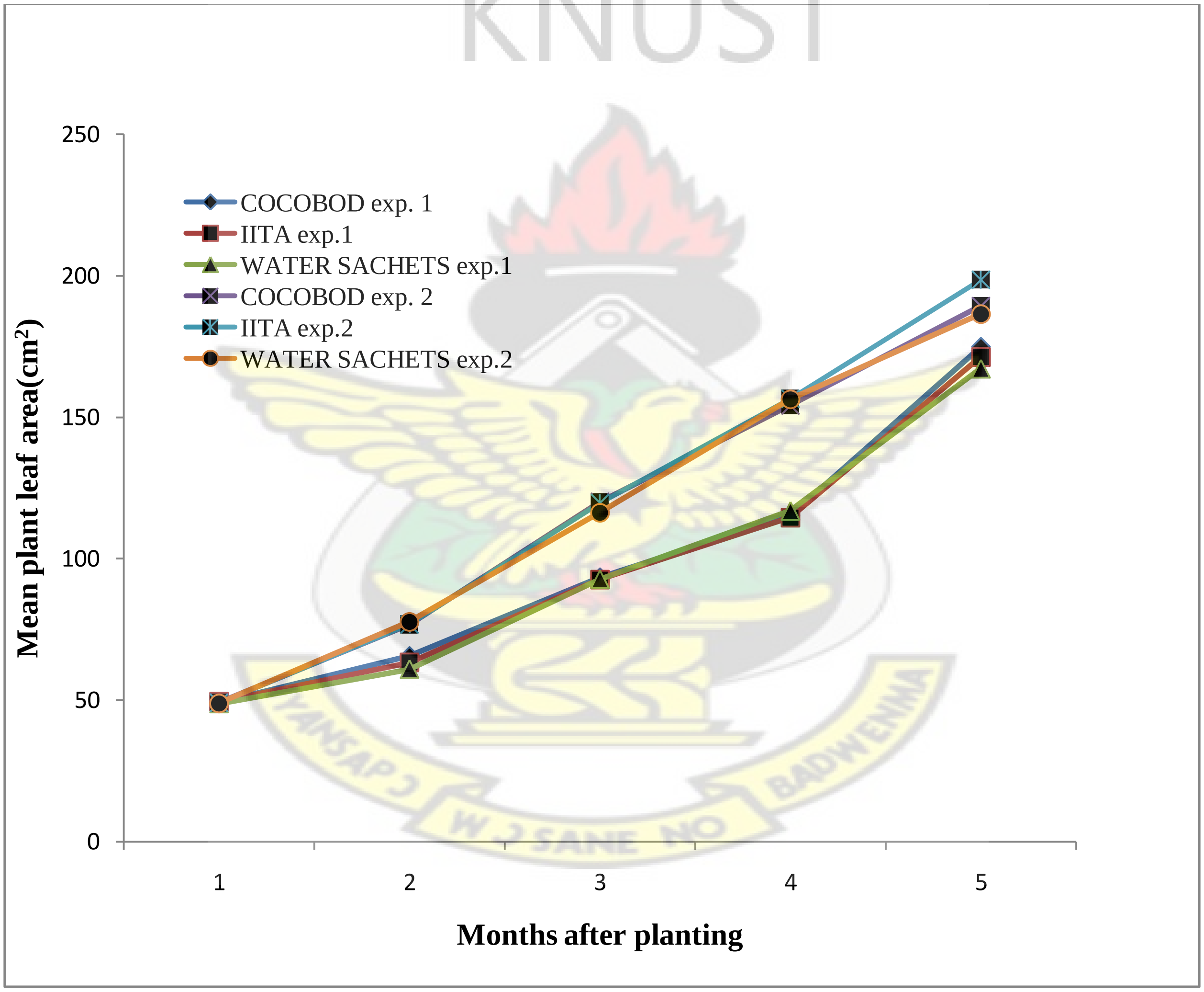

Figure 16: Effect of poly bags on leaf area of hybrid cocoa seedlings

Plant stem girth of hybrid cocoa seedlings under all the treatments statistically showed no significant differences ($P<0.05$) among the treatment means (Figure 17 and Appendix G & M) in both experiments. Generally, the seedlings in the water sachets, IITA and COCOBOD poly bags recorded in the second season more vigorous stem girth than the first experiment as depicted in Figure 17. This may be due to additional rains observed in the months.

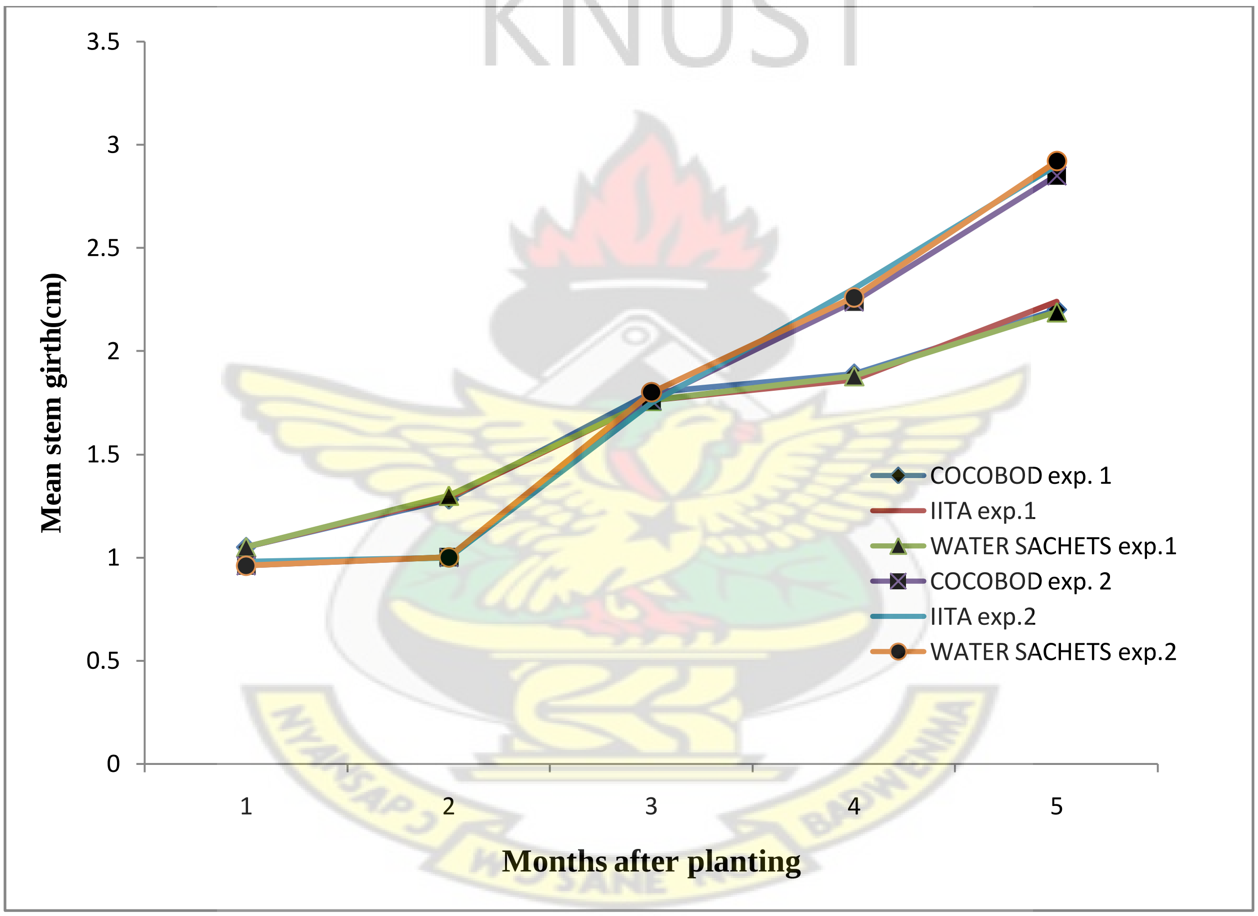

Figure 17: Effect of poly bags on the stem girth of hybrid cocoa seedlings

Plant number of leaves steadily increased with time for all hybrid cocoa seedlings nursed in the COCOBOD poly bags, IITA poly bags and water sachets (Figure 18 & Appendix O). Again the statistical analysis of the results (Appendix G & M) indicated no significant differences ($P<0.05$) among the monthly means of all the treatments in both experiments. Generally the seedlings in water sachets, IITA and COCOBOD poly bags in the second experiment produced more leaves than the first experiment and this may due to additional rains observed in the months.

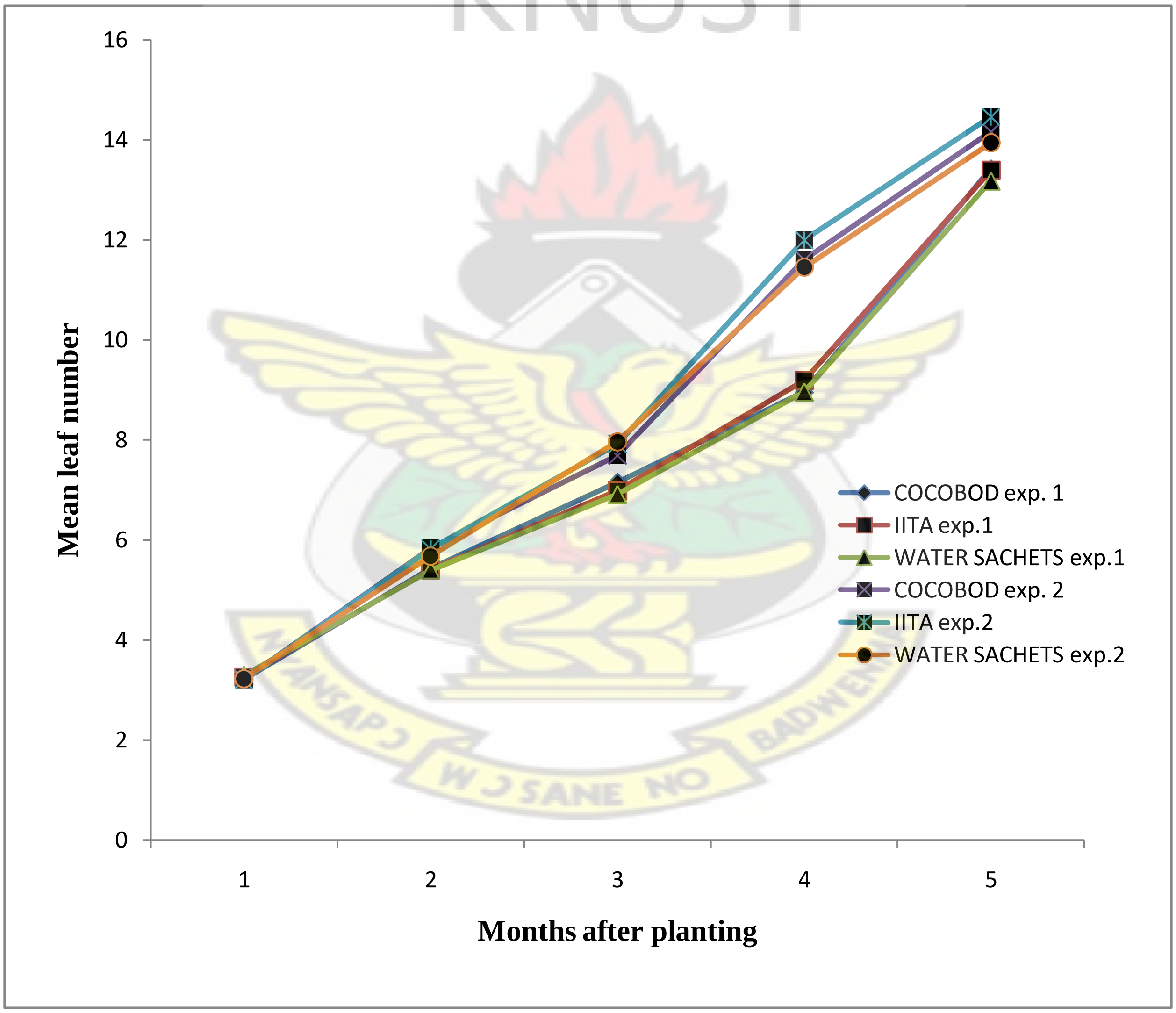

Figure 18: Effect of poly bags on the number of leaves of hybrid cocoa seedlings

Root length of hybrid cocoa seedlings recorded in both seasons progressively increased with time (Figure 19) under all the treatments. The results obtained (Appendix G & M) indicated that there were significant differences (P< 0.05) among the monthly means of all the treatments. Statistically the seedlings under IITA and COCOBOD poly bags and water sachets in the second experiment produced longer tap roots than the first experiment (Figure 19). Also, the seedlings planted in the water sachets in the first season gave the least tap root length. This

result attested to the past studies by Steve and Lane (2003) and Famuwagun and Agele, (2010) that roots of seedlings raised in short-sized polythene bags are associated with more coiling and recoiling of roots in the bags and that coiling of roots in the bag causes the seedlings to be root-bound which is detrimental to establishment and rapid development of cocoa seedlings after transplanting on the field.

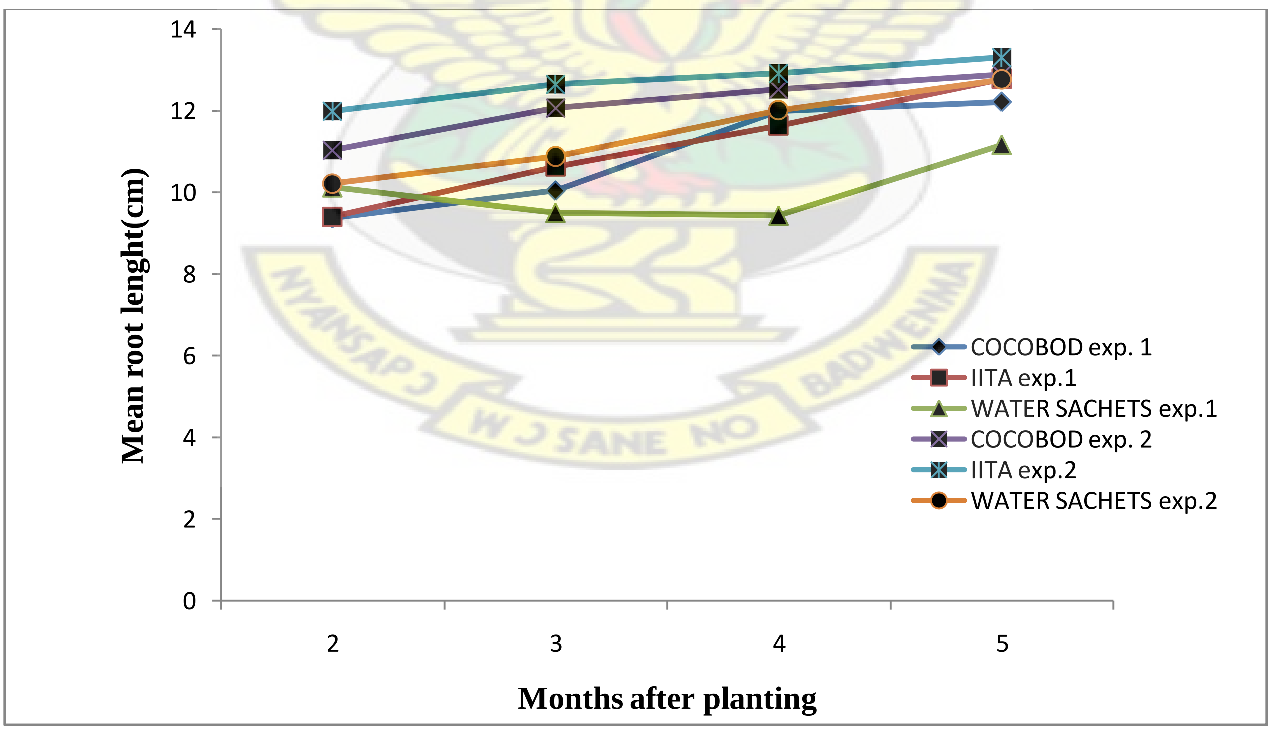

Figure 19: Effect of poly bags on the tap root length of hybrid cocoa seedlings

4.13: General Observations

The properties of cocoa pod husks and soil - cocoa pod husks mixture use for the experiments were found to be within the optimum nutrient requirement for cocoa production and this reflected in the leaf mineral composition and physical growth parameters of hybrid cocoa seedlings produced under soil + cocoa pod husks mixture and cocoa pod husks. This result confirms the earlier studies made by Ofori- frimpong (2008), that cocoa pod husk based compost could be a suitable potting medium for nursing cocoa seedlings when mixed in smaller ratios. The effectiveness of soil + cocoa pod husks mixture in improving the physical growth parameters and leaf mineral composition of hybrid cocoa seedlings compared with the treatments of soil or cocoa pod husks only was due to high nutrient composition contained in soil + cocoa pod husks mixture and good root - potting media contact. This finding was similar to that of Moyin-Jesu and Ojeniyi et al, (2007) who reported that the nutrient superiority of organically amended fertilizers compared to the ordinary forms of the materials. The higher value of root length of seedlings under soil + cocoa pod husks mixture was due to the fact that cocoa pod husks reduced soil bulk density, and thereby enhanced better root elongation. This observation is supported by Folorunso (1999) and Ojeniyi, *et al*, (2007) who reported that amended organic manure reduced soil bulk density and enhanced root elongation for better nutrient uptake. The results (Tables 20 to 27) showed that there were no significant ($P<0.05$) differences in the growth parameters among the treatment clones (i.e C42 and C85).

Table 15 to 20 indicated that there were difference in mineral composition and physical growth parameter between experiment I& II and may be due to the more rainfall had in experiment II.

5.0. CONCLUSION AND RECOMMENDATION

5.1: Conclusion

Soil in the study area was sandy clay loam that is deficient in calcium, magnesium, potassium and phosphorous concentration which is a consequence of continuous mining of nutrients from the soil by cocoa and other crops without any integrated soil fertility management. This had had negative influence on the soil's fertility status which is reflected in the low leaf mineral compositions and physical growth parameters of hybrid cocoa seedlings produced under the soil. The study revealed that application of raw cocoa pod husks in the soil in two experiments improved soil organic matter, soil water holding capacity, nitrogen, pH, calcium, magnesium, potassium, phosphorous concentrations and reduced the bulk density of the soil which resulted in the availability of nutrients in the soil needed for optimal plant yield.

Cocoa pod husks + soil mixture treatment produced significantly ($P<0.05$) the higher leaf mineral composition and optimum physical growth parameters of hybrid cocoa planting seedlings in the two experiments than soil and cocoa pod husks only. This is due to the nutrient's availability of organically amended cocoa pod husks composite compared to the ordinary form of the soil or cocoa pod husks only as a potting media.

Application of 0.18 l/seedling and 0.36 l/seedling on hybrid cocoa planting seedlings significantly ($P<0.05$) gave higher leaf calcium, magnesium, potassium, phosphorous, nitrogen, iron, zinc, copper, manganese as well as vigorous plant height, leaf area, plant stem girth, number of leaves and root length than 0.06 l/seedling in both experiments and therefore infer that hybrid cocoa planting seedlings required between 0.18 l/seedling and 0.36 l/seedling per day during the first five months in the nursery in semi-deciduous forest zone of Ghana if there is no rain.

Hybrid cocoa planting seedlings nursed in the water sachets (14cm high, 13cm diameter), produced vigorous plant height, broad leaf area, leaf number, healthy stem girth, fibrous root length and leaf mineral composition similar to hybrid cocoa seedlings planted in the COCOBOD (17.5cm high, 13.5cm diameter) and IITA (25cm high, 15cm diameter) poly bags and could therefore be suitable for raising hybrid cocoa planting seedling in the nursery during the first five months.

Finally, the study revealed that tap root of seedlings raised in water sachets and cocoa pod poly bags were associated with coiling of roots which may cause seedlings to be root - bound detrimental to establishment and rapid development of cocoa seedlings after transplanting on the field.

5.2: Recommendations

Based on the findings, it is hereby recommended that:

1. Further research be carried out into cocoa pod husk fertilizer technology in cocoa growing areas to assess its impact on cocoa production.
2. Farmers should be encouraged to adopt the use of the cocoa pod husks fertilizer on their farms for crop production rather than looking for inorganic fertilizer all the time.
3. Further research should also be carried out to determine the post transplanting practices among cocoa farmers in the cocoa growing areas in Ghana.

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APPENDIX A1

EFFECT OF COCOA POD HUSKS ON THE SOIL PHYSICAL AND CHEMICAL PROPERTIES

	Soil		**Soil + Cocoa pod husks**		**Increased Mean**	**%Mean**
	Range	**Mean**	**Range**	**Mean**		
Field capacity (FC)%	11.24-11.87	11.56	71.21-72.13	71.67	60.11	83.87
Field water content	7.9-8.21	8.07	23.24-23.66	23.62	15.55	65.83
Bulk density	1.17-1.79	1.76	0.92-0.97	0.94	0.82	87.23
pH (H_2O)	5.7	5.70	6.52-6.70	6.57	0.87	87.23
pH ($CaCl_2$)	5.22-5.40	5.27	6.1	6.10	0.83	13.60
Organic matter %	2.73-2.87	2.81	14.16-23.62	17.98	15.17	84.37
Orgainic carbon %	1.59-1.67	1.64	8.23-13.73	10.45	8.81	84.31
Total N %	0.18-0.34	0.25	0.88-0.89	0.89	0.64	71.91
Available P mg kg^{-1}	6.61-8.05	7.27	70.96-75.74	73.35	66.08	90.09
Available K mg k/g	100.44-104.17	102.60	204.22-210.91	207.28	104.68	50.50
Ex Ca cmol/kg	4.27-4.81	4.50	16.82-18.69	17.80	13.30	74.72
Ex. Mg cmol/kg	1.34-1.87	1.60	28.16-28.57	28.34	26.74	94.35
Ex. Na cmol/kg	0.07-0.08	0.08	0.23-0.28	0.26	0.18	69.23
Ex. acidity cmol/kg	0.45-0.5	0.47	0.08-0.1	0.09	0.38	422.22
Ex. K cmol/kg	0.35-0.38	0.37	8.5-8.77	8.62	8.25	95.70
% Base saturation	92.37-93.85	93.31	99.82-99.85	99.83	6.52	6.53
ECEC	5.55-7.32	7.01	52.81-56.2	54.78	47.77	87.20
Sand %	56.06-57.48	56.99				
Silt %	12.52-14.58	13.68				
clay	28-30	29				

APPENDIX A2

CHEMICAL PROPERTIES OF SAMPLES USED BEFORE AND AFTER THE EXPERIMENT I

	Before the experiment			After the experiment			Changes		
	SS	**CH**	**SSCH**	**SS**	**CH**	**SSCH**	**SS**	**CH**	**SSCH**
pH	5.70	6.57	6.57	4.20	5.80	6.00	-1.20	-1.07	-0.57
O.M (%)	2.81	24.00	17.98	1.04	24.75	11.07	-0.72	0.72	-6.91
O.C (%)	1.64	13.96	10.45	0.60	14.39	6.44	-1.04	0.43	-3.99
Total N	0.25	1.23	0.89	0.06	1.44	0.58	0.19	0.21	-0.30
Av. P	7.27	96.37	73.35	6.86	31.58	50.87	-0.41	-64.79	-22.48
Av. K	102.60	404.35	207.28	70.3	703.5	585.89	-32.3	298.72	378.61
Ex. Ca	4.50	35.67	17.80	4.20	20.83	14.42	-2.1	-14.84	-3.38
Ex. Mg	1.60	74.67	28.34	2.40	35.57	19.76	0.8	-39.07	-8.58
Ex. Na	0.08	0.35	0.26	0.18	0.67	0.48	0.1	0.32	0.22
Ex. Acidity	0.47	1.42	0.09	0.11	0.05	0.15	0.36	0.00	-0.06
Ex. K	0.37	11.20	8.62	0.18	2.11	1.55	-0.19	-9.09	-7.07
% Base	93.31	107.34	99.83	98.1	99.92	99.59	4.79	-7.42	0.24
ECEC	7.01	121.89	54.78	5.26	59.23	36.36	-1.75	-62.66	-18.18

SS=soil samples, CH =cocoa pod husks samples, SSCH = soil +cocoa pod husk samples
(-) = decrease, (+) = increase

APPENDIX A3

CHEMICAL PROPERTIES OF SAMPLES USED BEFORE AND AFTER THE EXPERIMENT II

	Before the experiment			After the experiment			Changes		
	SS	**CH**	**SSCH**	**SS**	**CH**	**SSCH**	**SS**	**CH**	**SSCH**
pH	5.87	6.90	6.57	4.50	6.16	6.22	-1.37	0.41	-0.35
O.M (%)	20.23	45.38	39.05	17.9	48.72	39.1	-2.33	3.34	-6.91
O.C (%)	10.74	16.78	13.94		18.32	14.30	-1.04	1.54	-3.99
Total N	0.39	0.37	0.92	0.22	0.41	0.57	-0.17	0.11	-0.35
Av.P	6.86	97.98	68.97	6.22	37.65	47.79	-0.64	-60.33	-21.18
Av.K	112.62	394.33	188.49	89.5	530	219.7	-32.3	135.67	31.21
Ex. Ca	5.73	39.33	16.31	3.18	25.1	12.32	-2.55	-14.18	-3.99
Ex.Mg	1.53	75.33	24.42	1.78	27.5	17.37	-0.25	-47.83	-8.58
Ex. Na	0.11	0.43	0.24	0.18	0.65	0.48	-0.07	0.22	0.22
% Base	93.31		97.15	99.2		96.34	-6.1	-7.42	
ECEC	8.24	126.19	49.35	5.26	31.5	32.97	-2.98	-94.69	-16.38

APPENDIX B

EFFECT OF POTTING MEDIA ON THE LEAF MINERAL COMPOSITION OF HYBRID COCOA SEEDLINGS FOR EXPERIMENT ONE

		Macronutrients/DM(%)					Micronutrients (ppm) Element/DM			
POTTING MEDIA		N	P	K	Ca	Mg	Fe	Cu	Zn	Mn
SS	1	2.87	0.24	1.01	0.72	0.55	72	28	56	30
	2	2.88	0.14	1.2	0.7	0.5	74	26	50	34
	3	2.76	0.13	1.01	0.71	0.52	73	27	54	34
CH	1	3.08	0.34	1.7	0.4	0.66	96	24	54	34
	2	3.1	0.32	1.4	0.42	0.74	84	25	48	37
	3	3.2	0.31	1.4	0.43	0.56	84	27	58	39
SS +CH	1	3.68	0.31	1.4	0.68	0.78	104	32	68	66
	2	3.69	0.3	1.5	0.71	0.7	104	30	74	67
	3	3.23	0.31	1.4	0.65	0.79	103	31	73	68

APPENDIX C

EFFECTS OF WATERING REGIMES ON THE LEAF MINERAL COMPOSITION OF HYBRID COCOA SEEDLINGS FOR EXPERIMENT ONE

	Macronutrients/DM(%)					Micronutrients (ppm) Element/DM			
	N	P	K	Ca	Mg	Fe	Cu	Zn	Mn
WR I 1	1.8	0.18	0.7	0.15	0.5	11	22	35	14
2	2.13	0.11	0.57	0.14	0.3	13	25	33	25
3	2.1	0.13	0.5	0.14	0.4	16	28	38	30
WRII 1	3.6	0.27	1.06	0.2	0.73	18	32	48	36
2	3.09	0.25	1.12	0.3	0.8	24	40	51	40
3	3.5	0.24	1.12	0.3	0.87	24	44	52	39
WRIII1	3.12	0.33	0.98	0.24	0.73	90	50	72	50
2	3.1	0.29	1.00	0.30	0.70	87	46	74	51
3	3.21	0.29	0.99	0.32	0.74	90	49	69	48

APPENDIX D

EFFECT OF POLY BAGS ON THE LEAF MINERAL COMPOSITION OF HYBRID COCOA SEEDLINGS FOR EXPERIMENT ONE

	Macronutrients/DM(%)					Micronutrients ppm Element/DM			
	N	P	K	Ca	Mg	Fe	Cu	Zn	Mn
CP 1	3.06	0.24	1.2	0.6	0.49	104	30	64	52
2	3.04	0.22	0.11	0.5	0.51	101	28	70	58
3	3.08	0.23	0.11	0.5	0.52	101	28	70	62
IITA 1	2.87	0.24	1.38	0.6	0.5	74	46	66	36
2	2.85	0.23	1.45	0.8	0.55	72	50	68	37
3	2.87	0.24	1.47	0.7	0.61	68	49	66	39
WS1	2.69	0.23	0.96	0.68	0.58	62	40	76	76
2	2.72	0.21	0.89	0.55	0.64	58	40	72	68
3	2.81	0.23	0.94	0.57	0.68	64	41	73	75

APPENDIX E1

EFFECTS OF WATERING REGIMES ON THE PHYSICAL GROWTH PARAMETERS OF HYBRIDCOCOA SEEDLINGS FOR EXPERIMENT ONE

a. Effect of watering regime on the height (cm) of hybrid cocoa seedlings

	Mean plant height per seedling (cm)				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
Watering regime I(0.06l/s)	15.3	17.85	19.9	24.5	27.4
Watering regime II(0.18l/s)	17.1	20.10	26.1	30.7	37.8
Watering regime III(0.36l/s)	17.2	20.33	25.8	31	37.2
LSD(0.05)	1.4	1.0	1.6	1.8	4.3

b. Effect of watering regime on the leaf area (cm^2) of hybrid cocoa seedlings

	Mean plant leaf area per seedling (cm^2)				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
Watering regime I(0.06l/s)	44.1	54.7	79.2	91.9	122.2
Watering regime II(0.18l/s)	51.6	69.7	97.9	134.3	198.4
Watering regime III(0.36l/s)	51.6	65.4	101.5	120.5	192.9
LSD(0.05)	4.9	13	14.4	19.3	26.9

APPENDIX E2

c. Effect of watering regime on the stem girth (cm) of hybrid cocoa seedlings

	Mean plant stem girth per seedling (cm)				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
Watering regime I(0.06l/s)	1.03	1.3	1.4	1.5	1.9
Watering regime II(0.18l/s)	1.06	1.3	2	2.2	2.3
Watering regime III(0.36l/s)	1.07	1.3	1.9	2.1	2.4
LSD(0.05)	NS	0.07	0.29	0.2	0.2

d. **Effect of watering regime on the leaf number of hybrid cocoa seedlings**

	Mean plant leaf number per seedling				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
Watering regime I(0.06l/s)	2.8	4.8	5	5.7	9.1
Watering regime II(0.18l/s)	3.5	5.7	8	10.8	15.2
Watering regime III(0.36l/s)	3.6	5.7	8.1	10.7	15.7
LSD(0.05)	0.4	0.6	1.3	0.9	1.7

APPENDIX E3

e. Effect of watering regime on the root length (cm) of hybrid cocoa seedlings

	Mean plant root length per seedling (cm)			
Treatment	2MAP	3MAP	4MAP	5MAP
Watering regime I(0.06l/s)	7.5	7.5	8.9	9.7
Watering regime II(0.18l/s)	9.7	11.3	11.9	10.8
Watering regime III(0.36l/s)	10.6	11.4	12.2	10.7
LSD(0.05)	3.00	3.30	3.40	3.20

APPENDIX F1

EFFECT OF POTTING MEDIA ON THE PHYSICAL GROWTH PARAMETERS OF HYBRID COCOA SEEDLINGS FOR THE EXPERIMENT ONE

a :Effect of potting media on the height (cm) of hybrid cocoa seedlings

	Mean plant height per seedling (cm)				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
Soil	15.3	18.4	22.3	26.3	29.4
Cocoa pod husks	16.9	19.6	24.3	29.7	34.7
Soil + cocoa pod husks	17.6	20.2	25.5	30.3	38.2
LSD(0.05)	1.32	1.31	2.87	3.47	5.17

b: Effect of potting media on the leaf area (cm^2) of hybrid cocoa seedlings

	Mean plant leaf area per seedling (cm^2)				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
Soil	44.6	60.4	76.7	75.4	142.9
Cocoa pod husks	47.4	61.5	97.2	92.47	182.9
Soil + cocoa pod husks	53.07	67.9	104.9	125.2	187.6
LSD(0.05)	5.20	6.0	12.9	21.73	37.64

APPENDIX F2

c: Effect of potting media on the stem girth (cm) of hybrid cocoa seedlings

	Mean plant stem per seedling(cm)				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
Soil	1.1	1.2	1.7	1.7	2.1
Cocoa pod husks	1.1	1.3	1.8	1.9	2.4
Soil + cocoa pod husks	1.1	1.3	1.9	1.9	2.5
LSD(0.05)	NS	NS	NS	NS	NS

d: Effect of potting media on the leaf number of hybrid cocoa seedlings

	Mean plant leaf number per seedling				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
Soil	3	5.3	6.3	8.5	12.1
Cocoa pod husks	3.4	5.3	6.9	9	13.0
Soil + cocoa pod husks	3.4	6	7.9	9.5	15.0
LSD(0.05)	NS	NS	1.8	0.9	2.6

APPENDIX F3

e: Effect of potting media on the root length (cm) of hybrid cocoa seedlings

	Mean plant root length per seedling (cm)			
Treatment	2MAP	3MAP	4MAP	5MAP
Soil	10.3	11.8	12.4	12.7
Cocoa pod husks	10.8	8.9	10.6	12
Soil + cocoa pod husks	10.8	9.8	11	11.5
LSD(0.05)	1.9	3.5	3.6	3.2

APPENDIX G1

EEFECT OF POLYBAGS ON THE PHYSICAL GROWTH PARAMETERS OF HYBRID COCOA SEEDLINGS FOR THE EXPERIMENT ONE

a. Effect of poly bags on the plant height (cm) of hybrid cocoa seedlings

	Mean plant height per seedling (cm)				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
COCOBOD poly bags	15.3	19.65	24.07	28.66	34.37
IITA poly bags	16.6	19.43	23.57	28.64	33.82
Water sachets	16.6	20.25	23.98	28.94	34.03
LSD(0.05)	NS	NS	NS	NS	NS

b. Effect of poly bags on the leaf area (cm^2) of hybrid cocoa seedlings

	Mean plant leaf area per seedling (cm^2)				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
COCOBOD poly bags	49.02	65.59	93.41	115.14	174.94
ITTA poly bags	49.39	63.32	92.62	114.59	171.36
Water sachets	48.72	60.88	92.69	116.88	167.19
LSD(0.05)	NS	NS	NS	NS	NS

APPENDIX G2

c: Effect of poly bags on the stem girth (cm) of hybrid cocoa seedlings

	Mean stem girth per seedling (cm)				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
COCOBOD poly bags	1.05	1.28	1.8	1.89	2.2
ITTA poly bags	1.05	1.29	1.76	1.86	2.24
Water sachets	1.05	1.3	1.76	1.88	2.19
LSD(0.05)	NS	NS	NS	NS	NS

d: Effect of poly bags on the leaf number of hybrid cocoa seedlings

	Mean plant leaf number per seedling (cm)				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
COCOBOD poly bags	3.27	5.43	7.15	8.95	13.42
ITTA poly bags	3.26	5.4	6.98	9.19	13.39
Water sachets	3.29	5.4	6.92	8.96	13.18
LSD(0.05)	NS	NS	NS	NS	NS

APPENDIX G3

e. **Effect of poly bags on the root length (cm) of hybrid cocoa seedlings**

	Mean plant root length per seedlings (cm)			
Treatment	2MAP	3MAP	4MAP	5MAP
COCOBOD poly bags	9.35	10.05	12	12.22
IITA poly bags	9.41	10.64	11.65	12.79
Water sachets	10.13	9.51	9.44	11.17
LSD(0.05)	NS	NS	NS	NS

APPENDIX H

EFFECTS OF WATERING REGIME ON THE LEAF MINERAL COMPOSITION OF HYBRID COCOA SEEDLINGS FOR EXPERIMENT TWO

	Macronutrients/DM					Micronutrients ppm Element/DM			
	% N	% P	% K	% Ca	% Mg	Fe	Cu	Zn	Mn
WR I 1	2.36	0.23	0.9	0.18	0.4	18	23	40	20
2	2.55	0.19	0.8	0.17	0.5	18	25	35	30
3	2.33	0.21	0.7	0.17	0.4	17	28	38	32
WRII 1	3.9	0.26	1.23	0.32	0.9	20	39	52	40
2	3.8	0.28	1.26	0.32	0.8	25	45	55	43
3	3.9	0.29	1.23	0.31	0.9	26	49	53	42
WRIII1	3.89	0.29	1.2	0.32	0.79	92	55	75	56
2	3.56	0.3	1.32	0.32	0.79	89	56	75	55
3	3.89	0.3	1.32	0.55	0.29	93	57	72	53

APPENDIX I

EFFECTS OF POLY BAGS ON THE LEAF MINERAL COMPOSITION OF HYBRID COCOA SEEDLINGS FOR EXPERIMENT TWO

		Macronutrients/DM					Micronutrients ppm Element/DM			
		% N	% P	% K	% Ca	% Mg	Fe	Cu	Zn	Mn
CP	1	4.32	0.26	01.25	0.6	0.5	88.23	32.0	64.0	52.0
	2	4.36	0.27	1.23	0.6	0.51	87.32	30.0	71.0	59.0
	3	4.32	0.28	1.11	0.6	0.52	88.47	29.0	71.0	63.0
IITA	1	2.98	0.23	1.38	0.7	0.96	73.0	69.0	66.0	39.0
	2	2.97	0.22	1.45	0.9	0.96	74.0	59.0	68.0	39.0
	3	2.97	0.26	1.47	0.8	0.62	79.0	58.0	66.0	39.0
WS	1	2.88	0.22	0.96	0.96	0.59	66.0	43.0	77.0	76.0
	2	2.87	0.23	1.35	0.67	0.67	63.0	44.0	75.0	68.0
	3	2.77	0.44	1.23	0.68	0.67	65.0	43.0	77.0	75.0

APPENDIX J

EFFECTS OF POTTING MEDIA ON THE LEAF MINERAL COMPOSITION OF HYBRID COCOA SEEDLINGS FOR EXPERIMENT TWO

		Macronutrients/DM					Micronutrients ppm/ Element/DM			
		% N	% P	% K	% Ca	% Mg	Fe	Cu	Zn	Mn
SS	1	2.95	0.25	1.02	0.81	0.56	75.0	31.0	62.0	32.0
	2	2.97	0.17	1.25	0.79	0.67	74.0	29.0	55.0	36.0
	3	2.76	0.15	1.28	0.75	0.76	76.0	30.0	56.0	34.0
CH	1	3.04	0.36	1.8	0.5	0.77	98.0	26.0	56.0	35.0
	2	3.05	0.39	1.7	0.5	0.74	91.0	25.0	54.0	38.0
	3	3.12	0.37	1.9	0.5	0.55	93.0	27.0	60.0	37.0
SSCH	1	4.23	0.46	1.8	0.89	0.87	112.0	35.0	70.0	79.0
	2	4.39	0.36	1.9	0.87	0.79	113.0	33.0	75.0	78.0
	3	4.56	0.39	1.8	0.87	0.79	112.0	35.0	76.0	79.0

APPENDIX K1

EFFECTS OF WATERING REGIMES ON THE PHYSICAL GROWTH PARAMETERS OF HYBRIDCOCOA SEEDLINGS

a. **Effect of watering regime on the height (cm) of hybrid cocoa seedlings**

	Mean plant height per seedling (cm)				
TREATMENT	1MAP	2MAP	3MAP	4MAP	5MAP
Watering regime I(0.06l/s)	15.4	17.9	19.4	24.6	29.1
Watering regime II(0.18l/s)	17.9	20.0	25.8	33.3	42.5
Watering regime III(0.36l/s)	17.0	19.7	26.5	34.6	40.4
LSD(0.05)	1.3	1.0	1.7	1.9	3.9

b.Effect of watering regime on the leaf area (cm^2) of hybrid cocoa seedlings

	Mean plant leaf area per seedling (cm^2)				
TREATMENT	1MAP	2MAP	3MAP	4MAP	5MAP
Watering regime I(0.06l/s)	44.1	54.7	101.5	120.8	131.2
Watering regime II(0.18l/s)	50.9	77.7	112.0	173.2	229.6
Watering regime III(0.36l/s)	52.2	99.0	145.4	173.3	240.4
LSD(0.05)	5.5	15	15.4	16.7	23.4

APPENDIX K2

c. Effect of watering regime on the stem girth (cm) of hybrid cocoa seedlings

	Mean plant stem girth per seedling (cm)				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
Watering regime I(0.06l/s)	1.0	1.0	1.4	2.1	2.9
Watering regime II(0.18l/s)	1.0	1.3	2.0	2.2	3.3
Watering regime III(0.36l/s)	1.0	1.5	1.9	2.4	3.4
LSD(0.05)	NS	0.07	0.29	0.3	0.2

d. **Effect of watering regime on the leaf number of hybrid cocoa seedlings**

	Mean plant leaf number per seedling				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
Watering regime I(0.06l/s)	2.8	4.9	5.6	7.6	10.2
Watering regime II(0.18l/s)	3.4	6.2	7.5	13.7	15.9
Watering regime III(0.36l/s)	3.4	6.3	10.1	13.8	16.5
LSD(0.05)	0.3	0.5	1.5	1.1	1.9

APPENDIX K3

e. Effect of watering regime on the root length (cm) of hybrid cocoa seedlings

	Mean plant root length per seedling (cm)			
Treatment	2MAP	3MAP	4MAP	5MAP
Watering regime I(0.06l/s)	11.1	11.3	11.7	12.8
Watering regime II(0.18l/s)	12.5	12.2	14.4	14.4
Watering regime III(0.36l/s)	12.6	12.9	14.4	14.4
LSD(0.05)	4.0	5.0	4.3	3.9

APPENDIX L1

EFFECT OF POTTING MEDIA ON THE PHYSICAL GROWTH PARAMETERS OF HYBRID COCOA SEEDLINGS FOR EXPERIMENT TWO

a :Effect of potting media on the height (cm) of hybrid cocoa seedlings

	Mean plant height per seedlings (cm)				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
Soil	15.9	18.6	22.9	28.9	33.3
Cocoa pod husks	17.4	19.2	22.9	30.1	37.4
Soil + cocoa pod husks	17.4	19.9	25.9	33.5	41.3
LSD(0.05)	17.8	1.7	3.7	4.1	6.4

b: Effect of potting media on the leaf area (cm^2) of hybrid cocoa seedlings

	Mean plant leaf area per seedlings (cm^2)				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
Soil	46.8	73.9	97.7	124.3	144.6
Cocoa pod husks	47.6	75.8	110.8	152.5	193.7
Soil + cocoa pod husks	52.9	81.8	148.4	152.5	183.7
LSD(0.05)	5.5	6.8	13.2	23.4	39.4

APPENDIX L2

c: Effect of potting media on the stem girth (cm) of hybrid cocoa seedlings

	Mean plant stem girth per seedlings(cm)				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
Soil	0.9	1.0	1.7	2.1	2.6
Cocoa pod husks	1.0	1.0	1.8	2.2	2.8
Soil + cocoa pod husks	1.0	1.0	1.8	2.5	2.8
LSD(0.05)	NS	NS	NS	NS	NS

d: Effect of potting media on the leaf number of hybrid cocoa seedlings

	Mean plant leaf number per seedlings				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
Soil	3.2	5.3	7.9	8.5	12.6
Cocoa pod husks	3.3	5.7	8.8	10.6	13.0
Soil + cocoa pod husks	3.5	6.4	10.8	13.6	17.0
LSD(0.05)	NS	NS	1.3	1.2	3.1

APPENDIX L3

e: Effect of potting media on the root length (cm) of hybrid cocoa seedlings

	Mean plant root length per seedlings (cm)			
Treatment	2MAP	3MAP	4MAP	5MAP
Soil	12.0	12.5	12.9	14.5
Cocoa pod husks	10.6	11.0	12.7	13.4
Soil + cocoa pod husks	12.0	11.7	12.9	13.9
LSD(0.05)	1.8	3.9	3.9	3.5

APPENDIX M1

EEFECT OF POLYBAGS ON THE PHYSICAL GROWTH PARAMETERS OF HYBRID COCOA SEEDLINGS

a. Effect of poly bags on the height (cm) of hybrid cocoa seedlings

	Mean height per seedling (cm)				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
COCOBOD poly bags	17.38	19.36	24.31	31.44	37.52
IITA poly bags	17.01	18.98	23.57	30.40	36.68
Water sachets	16.91	17.23	23.76	30.51	37.31
LSD(0.05)	NS	NS	NS	NS	NS

b. Effect of poly bags on the leaf area (cm^2) of hybrid cocoa seedlings

	Mean leaf area per seedling (cm^2)				
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
COCOBOD poly bags	49.2	76.8	120.06	154.28	189.37
ITTA poly bags	49.04	76.77	119.76	156.6	198.59
Water sachets	48.92	77.79	116.25	156.42	186.47
LSD(0.05)	NS	NS	NS	NS	NS

APPENDIX M2

c: Effect of poly bags on the stem girth (cm) of hybrid cocoa seedlings

	Mean stem girth per seedling (cm)				
TREATMENT	1MAP	2MAP	3MAP	4MAP	5MAP
COCOBOD poly bags	0.96	1.00	1.76	2.24	2.85
ITTA poly bags	0.96	1.00	1.75	2.3	2.9
Water sachets	0.97	1.0	1.8	2.26	2.92
LSD(0.05)	NS	NS	NS	NS	NS

d: Effect of poly bags on the leaf number of hybrid cocoa seedlings

		Mean plant number per seedling (cm)			
Treatment	1MAP	2MAP	3MAP	4MAP	5MAP
COCOBOD poly bags	3.21	5.83	7.69	11.6	14.16
ITTA poly bags	3.20	5.82	7.92	12.00	14.46
Water sachets	3.22	5.67	6.96	11.45	13.94
LSD(0.05)	NS	NS	NS	NS	NS

APPENDIX M3

e. **Effect of poly bags on the root length (cm) of hybrid cocoa seedlings**

	Mean plant root length per seedling(cm)			
Treatment	2MAP	3MAP	4MAP	5MAP
COCOBOD poly bags	11.04	12.07	12.53	12.89
IITA poly bags	12.00	12.66	12.92	13.31
Water sachets	10.32	10.89	12.02	12.77
LSD(0.05)	NS	NS	NS	NS

APPENDIX N

Effects of three combine treatments on the height of hybrid cocoa seedlings

			Mean plant height per seedlings(cm)				
Water	Media	Bags	1MAP	2MAP	3MAP	4MAP	5MAP
I	SS	CP	14.68	17.48	19.09	27.89	26.16
	SS	IITA	14.8	17.21	18.79	23.95	25.64
	SS	WS	15.42	17.08	19.03	24.28	23.44
	CH	CP	15.57	18.01	20.03	24.77	29.61
	CH	IITA	14.98	18.15	20.63	24.55	28.05
	CH	WS	14.87	18.05	20.03	26.69	28.09
	SSCH	CP	16.31	18.05	20.31	24.45	28.32
	SSCH	IITA	16.11	18.24	20.47	24.1	28.77
	SSCH	WS	15.62	18.37	20.94	24.69	28.67
II	SS	CP	15.22	18.92	24.12	28.48	32.05
	SS	IITA	14.83	19.45	24.33	28.04	31.41
	SS	WS	15.91	18.54	24.25	26.62	31.66
	CH	CP	18.15	20.84	27.7	31.91	39.28
	CH	IITA	18.25	20.27	25.69	31.75	37.49
	CH	WS	17.8	20.11	26.24	31.27	39.4
	SSCH	CP	18.58	21.27	26.99	32.62	43.16
	SSCH	IITA	18.19	21.05	27.23	32.61	42.52
	SSCH	WS	17.75	20.94	28.37	33.27	42.73
III	SS	CP	14.94	19.52	24.77	27.36	31.44
	SS	IITA	15.44	19.15	23.79	26.91	31.16
	SS	WS	16.11	18.89	23.29	28.14	31.3
	CH	CP	17.64	21.07	26.93	32.26	37.16
	CH	IITA	18.66	20.47	25.92	32.26	37.16
	CH	WS	17.66	19.83	25.92	31.85	36.27
	SSCH	CP	18.55	21.7	27.25	33.24	42.72
	SSCH	IITA	18.49	20.9	26.92	33.59	42.14
	SSCH	WS	18.61	21.4	28.21	33.67	44.71

APPENDIX O1

HYBRID COCOA SEEDLINGS ON THE FEILD

Figure 20: Hybrid cocoa seedlings at 2 WAP

Figure 21: Hybrid cocoa seedlings   at 1MAP

Figure 22: Hybrid cocoa seedlings at 2MAP

Figure 23: Hybrid cocoa seedlings at 3MAP

Figure 24: Hybrid cocoa seedlings at 4MAP

Figure 25: Hybrid cocoa seedlings at 5 MAP