UNIVERSITY OF EDUCATION WINNEBA

EFFECT OF DIFFERENT COMPOSITION OF GROWTH MEDIA ON THE GROWTH OF COCOA (*Theobroma cacao*) SEEDLINGS IN THE NURSERY

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MASTER OF EDUCATION (M. ED) IN AGRICULTURE

(CROP SCIENCE)

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A DISSERTATION IN THE DEPARTMENT OF CROP AND SOIL SCIENCES EDUCATION, FACULTY OF AGRICULTURE EDUCATION, SUBMTTED TO THE SCHOOL OF GRADUTE STUDIES, UNIVERSITY OF EDUCATION WINNEBA, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF EDUCATION (M.ED) IN AGRICULTURE (CROP SCIENCE)

MAY, 2023

DECLARATION

I, Apiu, Amos Songyekutu, hereby declare that except for the references to other people's work which have been duly cited, this is the result of my original findings and that this dissertation has neither in part nor in whole been presented for a degree or Master's in Ghana or elsewhere.

Name: Apiu, Amos Songyekutu

Signature…………………………………….

Date………………………………………

SUPERVISORS' DECLARATION

I hereby declare that the preparation of this dissertation was supervised in accordance with the guidelines on supervision of dissertation laid down by the Akenten -Appiah Menka University of Skills, Training and Entrepreneurial Development.

Mr. Emmanuel Kwasi Asiedu

Signature…………………………………….

Date………………………………………

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DEDICATION

This dissertation is dedicated to Almighty God for his protection and guidance through my study and to all my family.

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LIST OF ABBREVIATIONS

AAMUSTED	-	Akenten -Appiah Menka University of Skills, Training and Entrepreneurial Development.
ANOVA	-	Analysis of Variance
LSD	-	Least significant difference
RCBD	-	Randomized complete block design
CV	-	Coefficient of variation
SPD	-	Seed Production Division
pH	-	Power of hydrogen
EC	-	Electrical conductivity
CEC	-	Cation Exchange capacity
GDP	-	Gross Domestic Product
TS	-	Topsoil
RS	-	River Sand
NPK	-	Nitrogen, Phosphorus, Potassium
UNCTAD	-	United Nations Conference on Trade and Development

ABSTRACT

The Experiment was conducted at the Multi-Purpose Crop Nursery of Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED**)** formerly University of Education Winneba, Mampong –Ashanti (UEW - M). Experimental Design used was Randomized Complete Block Design (RCBD) with five treatments. The five treatments used in the experiment wereT_1= 100% topsoil, $T_{2\,=}$ 75% topsoil+ 25% river, T_3=50%topsoil +50%river sand,T_4 25%topsoil +75%river sand and T_5 =100%River sand. These treatments were replicated three times with twenty polybags per treatment. Morphological growth measurements such as plant height, width, number of leaves, were recorded to evaluate treatment effects. In addition, plant canopy, stem diameter and area of leaves were also collected The data collected was analyzed by using Analysis of Variance (ANOVA) using Genstat statistical package, version 9.2 (Genstat 2012). The least significance difference (LSD) at p= 0.05 was used to separate the means where significant differences were observed. From the results of the study,100% topsoil(T1) gave the best seedling growth followed by T3 and T2, T4 and T5 gave the poorest results. T1 is therefore recommended followed by T3 and T2.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

The potential production of cocoa in Ghana is threatened by over-aged and unproductive trees. Rehabilitating these aged farms will require raising millions of seedlings for transplanting. Large quantities of topsoil will be required for these nursery works. The use of topsoil only as potting medium will destroy the ecosystem of the areas where the topsoil is collected (Siregar *et al.*, 2002). Its use will also require additional inorganic fertilizer to supplement the seedlings nutrient demand. The compactness of topsoil restricts seedlings root growth and makes nursery polybags too heavy for conveyance over long distances for field transplanting The substrates (i.e., the propagation media in which plants grow), which provide anchorage for the plant roots, air spaces to enhance aeration and retain sufficient available water are known as the growth media. Growth media affect plant performance in bare roots and container nursery production.

The inherent nutrients and soil factor determine the productivity of crops. Mostly, nursery or propagation media influence the emergence and growth of seedlings. Thus, suitable media that could enhance the vigour of seedlings is crucial for continual cocoa production. Family *Sterculiaceae* / *Malvaceae* and genus *Theobroma* is where cocoa tree belongs. The original habitat of it is the evergreen rainforest, native to the deep tropical regions of Central and South America. Cocoa contains important nutrient elements and several minerals including phosphorus, potassium, calcium, copper, magnesium, sodium and zinc. Cocoapowder and chocolate are made from its seeds. Cocoa trees grow best in humid areas at temperatures ranging between 18-32℃ and this is due to the fact that they are tropical plants. Cocoa trees normally grow in areas where humidity range between 70-80% and the daytime humidity extend up to 100%. Cocoa plants require deep, well-drained and fertile soil with a pH of 5.0-7.5 for optimum growth. Cocoa seeds obtained from ripe, healthy pods stay viable for three weeks and are normally planted directly after harvest to generate new seedlings. Cocoa seeds are planted in plastic bags or fibre baskets filled with fresh soil and situated in a shaded location shielded away from the scorching sun. Meanwhile, cocoa cultivation can also be propagated vegetatively through marcotting, budding and cuttings. After 4-6 months, the seedlings grow quickly and are set to be transplanted. Seedlings are normally planted in the soil when they are 4-6 months old. The young cocoa trees are fragile, and they need some protection against direct sun rays and strong winds. Cocoa is Ghana's most important export and remains a critical livelihood activity for many Ghanaians, providing employment for over 30% of the population. As international demand for cocoa remains high, it is necessary to ensure a sustainable future supply.

In Ghana, plantations of cocoa have been established through seedlings raised in the nursery with only topsoil as the growth medium and these soils are either suitable or moderately suitable. Meanwhile, the topsoil at Kacheibi has lost its fertility through erosion. Consequently, the cocoa farmers always used expensive inorganic fertilizers to amend these soils often increases the cost of production of cocoa and unsafe for the environment or health. Again, the current directive from Ghana Cocoa Board to the Seed Production Division (SPU) is to raise 20 million seedlings each year. As a result of the new emphasis on cocoa rehabilitation in the country, there will be the need to increase cocoa seedling production, and this will require large quantities of soil for nursery work. However, excessive scraping of the topsoil to meet this demand will eventually result in serious degradation of productive farmlands since suitable land is limited as a result of misused of our natural resources.

1.2 Problem Statement and Justification

There has been a decline in cocoa productivity over the years owing to over aged cocoa farms and the black pod disease. Therefore, farmers in Kacheibi in Nkwanta South Municipality of the Oti Region need good cocoa seedlings for replanting their plantations. As a result, Government has intervened by rehabilitating the unproductive farms and replacing the diseased cocoa plants across the cocoa production zones with over 60 million hybrid cocoa seedlings tolerant to drought, diseases and of great yield. Yet, cocoa nurseries face a lot of challenges in cocoa growing areas of which, lack of suitable growth medium for propagation of hybrid cocoa seedlings is a typical example. More so, Topsoil for nursery is usually conveyed from long distances to nursery sites and its scarcity hinders the attainment of the government and COCOBOD goals of raising healthy hybrid cocoa seedlings for effective and efficient distribution to farmers. The major problem associated with the use of topsoil as seedling medium is scarcity. This scarcity has led to use of various alternatives and mixtures of other media with topsoil for nursing seedlings of other crops such as coconut. Nevertheless, some studies on the germination and early seedling growth of cocoa have been carried out. The focus of this study is to find out whether the mixture of 50% topsoil (TS) and 50% river sand (RS), 75% topsoil (TS) and 25% river sand (RS), 100% topsoil (TS), 75% river sand (RS) 25% topsoil (TS), 100% river sand (RS) + NPK fertilizer will support the growth of cocoa hybrid seeds in order to get a substitute medium in cocoa nursery management. The objective of this study was to determine the effect of the soil amendments on the germination of the cocoa hybrid seeds and also survival rate of cocoa hybrid seedlings in the different media.

1.3 Objectives of the Study

The main objective of this study is to find out whether the mixture of topsoil and river sand in various ratios will support the growth of cocoa hybrid seeds in order to get a substitute medium in cocoa nursery management.

1.3.1 Specific Objectives

The specific objectives of this study were to:

1. determine the effect of the soil amendments (mixture of 50% topsoil and 50% river sand, 75% topsoil and 25%river sand, 100%topsoil, 75%river sand 25%topsoil, 100%river sand + NPK fertilizer) on the germination of the cocoa hybrid seeds
2. find out the survival rate of cocoa hybrid seedlings in the different media and
3. find out the seedling growth performance of hybrid cocoa raised in the different media (plant height, leaf number, stem diameter etc.)

CHARPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution

The Latin name for cocoa is "*Theobroma*" which literally means 'food of the Gods (https://www.barry-callebaut.com/en/group/media/press-kit/theobroma-cacao-food-gods).' Cocoa (*Theobroma cacao*) belongs to the family *Sterculiaceae* / *Malvaceae* which is known for having flowering plants that are entomophilous and are bisexual. It consists of about 200 genera and close to 2,300 species distributed throughout the world and particularly abundant in the tropics (APG, 2009). Cocoa beans come from cacao trees, which reside in the genus *Theobroma* and originated several years ago in South America, east of the Andes. There are 22 species of Theobroma amongst which T. cacao is the most common. Archaeological evidence suggests that the Mayan people drank cacao as early as 400 B.C. Schwartzkopf, S. (2021).

The Aztecs prized the bean as well. Christopher Columbus was the first foreigner to drink chocolate when he sailed to Nicaragua in 1502 but it was not until Hernan Cortes, the leader of a 1519 expedition to the Aztec empire, that chocolate made its way back to Spain. Aztec xocoatl (chocolate drink) was not initially received favorably until the addition of sugar sometime later whereupon the drink became popular in the Spanish courts. The popularity of the new drink incited attempts to grow cacao in the Spanish territories of the Dominican Republic, Trinidad, and Haiti with little success. Some measure of success was eventually found in Ecuador in 1635 when Spanish Capuchin friars managed to cultivate cacao. By the seventeenth century, all of Europe was mad about cocoa and rushed to lay claim to lands suited to cacao production. As more and more cacao plantations came into being, the cost of the bean became more affordable and, thus, there was an increased demand. The Dutch and Swiss began establishing cocoa plantations in Africa during this time. (Primis Player Placeholder). Today, cocoa is produced in countries between 10 degrees North and 10 degrees south of the Equator. The largest producers are Cote-d'Ivoire, Ghana, and Indonesia. In 1870 Tetteh Quarshie introduced the cocoa crops to Ghana (a pre-independence Ghanaian) which today constitute one of the major export crops of the Ghanaian economy. In Ghana, cocoa is grown in the forest areas of the country such as Ashanti, Bono, Bono East, Ahafo, Eastern, Western, Central and Volta where the annual rainfall is between 1000 and 1500 mm. It was introduced into the Southern regions of the Gold Coast in the mid-19th century (Opoku *et al.,* 2010). In 2019/2020, Ghana is estimated to have produced about 800 thousand tons of cocoa beans, a decrease from approximately 812 thousand tons in 2018/2019. Although cocoa beans originated from South America, the majority of cocoa beans production is attributed to Africa. In 2017/2018, Africa's cocoa bean production amounted to around 3.5 million tons. On a country level, the top two producers of cocoa beans are Côte d'Ivoire and Ghana, with Côte d'Ivoire producing more than twice the volume of cocoa beans of Ghana Schwartzkopf, S. (2020).

2.2 Botany of Cocoa

Cacao trees can live for up to 100 years but are considered productive for only around 60. When the tree grows naturally from cocoa tree seeds, it has a long, deep taproot. For commercial cultivation, vegetative reproduction via cuttings is more commonly utilized and results in a tree lacking a taproot. In the wild, the tree may reach over 50 feet (15.24 m.) in height, but they are generally pruned to half that under cultivation. The leaves emerge a reddish hue and turn to glossy green as they grow up to two feet long (Prabhakaran, 2010).

2.2.1 Roots

Cocoa has a dimorphous root, orthotropic taproot and plagiotropic lateral root. The taproot which grows predominately downward with only few branches serves as anchorage for the cocoa tree. The tap root grows very deep when the soil is deep and there are favourable weather conditions. The roots that arise from the tap root and grow laterally are the main feeding roots which are mostly concentrated just below the soil surface up to a depth of 15 - 20 cm (Prabhakaran, 2010).

2.2.2 Stem

The cocoa plant grows in tiers. The shoot of the seedling grows upwards, and this is called chupon. The growth of the chupon ceases after it grows to a height of 1 – 1.5 m, then three to five lateral branches arise. These lateral branches are called fan or fan branches. The point at which fans arise is called jorquette and the process of the formation of fans from jorquette is called jorquetting. Therefore, a layer of fans may be called a tier. When the cocoa plant is allowed to grow unchecked, new chupon buds arise on the main stem above the first jorquette and grow up to jorquette again. The difference between a chupon and a fan are that chupon leaves will have longer petioles than those of fans and fan growth is predominantly to the sides whereas chupons grow vertically up. Additionally, the leaf arrangement of the chupons is spiral with a phyllotaxy of three to eight whiles leaves of the fans are arranged in one plane and are alternate (Prabhakaran, 2010).

2.2.3 Flowers

Small pink or white flowers cluster on the tree's trunk or lower branches during the spring and summer. The cocoa flowers have five sepals and five petals. The male flower consists of five double stamens with each stamen bearing up to four anthers. The female flowers consist of five united carpels, each containing 4 - 12 locules (cavities). Among the ten stamens, five of the outer whorls are sterile and five of the inner whorls, which occur opposite the petals, are fertile. These fertile stamens occur concealed in the pouched portions of petals. The ovary is simple and five-lobed which contains 40 - 60 ovules per flower. The style has five stigmatic lobes. The flowers open at dawn and the pollen is released from the anthers just before sunrise. The stigma is receptive to pollination only from sunrise to sun set on the day that the flower opens. Cocoa flowers are produced in large numbers but only a few of them develop into fruits whiles those that are not fertilized fall off within 24 hours.

In every 500 flowers, 10% are successfully pollinated and 2% grow into mature fruits. Pollination of the flowers is carried by insects, but higher rates of pollination can be achieved by hand. However, cherelle wilt prevents much higher rates of fruits set from being obtained. (Prabhakaran, 2010). Cherelle wilt is a natural fruit thinning mechanism whereby the young fruit called cherelle stop growing, turn black and shrivel but do not fall off the tree. Therefore, cherelle wilt is not a disease. In view of this, boron has been found to increase pod set and reduce cherelle wilt. Hence, in some places boron is applied to trees as an annual foliar spray (Prabhakaran, 2010). Once pollinated, the flowers become ridged pods up to 14 inches (35.5 cm.) long, filled with beans.

2.2.4 Fruits

The cocoa fruit is botanically a drupe, often called a pod. The mature pod consists of a thick husk containing 30-50 seeds. The seeds are held in position with the help of a placenta. The pods can be of green or reddish colour when immature. The green pods change to yellow when mature and the reddish pods change to orange or yellow in colour. The husk (pericarp) is fleshy and thick (Prabhakaran, 2010).

2.2.5 Seeds

The seeds, which are called beans, form the economic part of the crop. The number of beans per pod ranges from 30-60 seeds; each seed contains two convoluted cotyledons, a small embryo and a thin membrane, the remains of the endosperm and a leathery testa (shell). The seeds contain a significant amount of fat (40 - 50%) as cocoa butter and are the main ingredient of chocolate, while the pulp is used in making juices, smoothies, and jellies (Prabhakaran, 2010). The pulp covering the seed contains about 10-15% sugar and is sweet, tangy with its flavor reminiscent of mango. The pulp plays central role in the fermentation of cocoa beans and during fermentation, yeast grows on the sweet pulp and converts sugar to alcohol. The alcohol is oxidized by bacteria, a process that ultimately produces carbon dioxide, water, and heat. After fermentation, the cocoa beans must be dried to halt fermentation, reduce water content in the bean and to drive out acetic acid which was formed during fermentation. The drying of cocoa beans by sunlight takes one to two weeks with the beans being turned about four times a day and if not adequately dried, they are likely to become moldy. The cocoa beans are put into sacks after fermentation and drying and are transported to a central location for grading. After grading, the cocoa beans are packed into 60kg sacks for storage ((Prabhakaran, 2010).

2.3 How to Grow Cocoa Beans

Cacao trees are quite finicky. They need protection from sun and wind, which is why they thrive in the understory of warm rainforests. Growing cacao trees requires mimicking these conditions. In the United States, that means the tree can only be grown in USDA zones 11-13 – Hawaii, parts of southern Florida and southern California as well as tropical Puerto Rico. If you do not live in these tropical climates, it may be grown under warm and humid conditions in a greenhouse but may require more vigilant cocoa tree care (Prabhakaran, 2010). To start a tree, you will need seeds that are still in the pod or have been kept moist since their removed from the pod. If they dry out, they lose their viability. It is not unusual for the seeds to begin sprouting from the pod.

If your seeds have no roots yet, they should be placed between the damp paper towels or wetted cocoa sac in a warm (over 26 ℃.) area until they begin to root. The rooted beans should be put in individual 4-inch (10 cm.) pots filled with damp seed starter. The seed should be placed vertically with the root end down and cover with soil just to the top of the seed and the pot should be covered with dried organic material (palm leaves) or wrapped with plastic and should be placed on a germination mat to maintain their temperature at 27℃. In 5-10 days, the seed should sprout. At this point, the wrap or dried organic material (palm leaves) should be removed, and the seedlings should be kept on a partially shaded environment or under the end of a grow light (Prabhakaran, 2010).

2.4 Cocoa Tree Care

The seedling should be kept under a shade and at temperatures between 18-29 ℃. When the plants are not under shade, NPK fertilizer should be applied to the soil depending on the fertility of the soil. NPK may be applied at the rate of 15kg/ha. If you live in a tropical region, seedlings should be planted when it is two feet (61 cm.) tall. Humus rich, well-draining area with a pH near 6.5 should be chosen. The cacao seedling should be planted 10 feet away from a taller evergreen that can provide partial shade and wind protection. Planting hole should be three times deep as width of the tree's root ball. Two thirds of the loose soil should be put back into the hole and put the tree on top the mound at the same level it grew in its pot. The soil should be gathered around the base of the tree and water it well. The surrounding ground should be covered with 2- to 6-inch (5 to 15 cm) layer of mulch but should be kept at least eight inches (20.3 cm.) away from the trunk.

Depending upon rainfall, the cacao will need between 1-2 inches (2.5-5 cm.) of water per week. The plants should be fertilized with 1/8 pound (57 gr.) of 6-6-6 NPK every two weeks and then increase to 1 pound (454 gr.) of fertilizer every two months until the tree is a year old. The tree should flower when it is 3-4 years old and about five feet (1.5 m.) tall. Hand pollination can be done early in the morning. Never mind if some of the resulting pods drop. It is natural for some pods to shrivel, leaving no more than two on each cushion. (Prabhakaran, 2010).

2.5 Food of the Gods

For many South American cultures' cocoa was very valuable. The Aztecs used cocoa beans as a stimulant; in addition to the cocoa bean they added ingredients to it, to improve its taste. Just as we now add ingredients to make chocolate from cocoa. The Mayans used cocoa to create a drink which could be shared during bethrothal and marriage (Shahbandeh, 2020). In 1519 the Europeans first encountered cocoa, when they met the Aztec society. The Conquistadores brought the cocoa to King Philip the second of Spain. Spanish monks enriched the cocoa with honey, vanilla, and later sugar. This would be the foundation for the sweet chocolate drink as we now know it today (Shahbandeh, 2020). Linnaeus (father of modern-day taxonomic plant classification) gave the cocoa tree its first official botanic name: *Theobroma cocoa*. Which stood for 'food of the gods? In 1700 AC Spain held a monopoly position in the cocoa trade, Italy, The Netherlands, and Portugal started their own cocoa-crops in Venezuela, Chocolate was imported to the USA in 1765 and Doret built the first automatic machine which grinds cocoa beans Prinz *et al.*, 2013.

2.6 Economic Importance of Cocoa

The significant role of cocoa as a driver of economic growth has gained overall acceptance in all cocoa growing economies. According to the United Nations Conference on Trade and Development, UNCTAD (2004), cocoa is a highly competitive and lucrative economic cash crop ranked highest in terms of income generation amongst other agricultural activities in the global smarkets. Cocoa is the economic mainstay of countries such as Cameroon, Ivory Coast and Ghana. It also plays an important role in the development of many African countries by generating foreign exchange earnings, government revenues and household incomes (UNCTAD, 2005). Cocoa has been the mainstay of the economy and provides the largest source of export earnings representing about 30% of Ghana's total export earnings and is still the main economic activity of small holders and ranks among one of the highest income generating cash crop to the GDP of Ghana. Cocoa directly or indirectly employs about two million people and offers livelihoods for over 700,000 farmers. It feeds, shelters, clothes, and takes care of the livelihood needs of farmers. In households where cocoa is an important source of income, it contributes roughly one third of their revenue (Mckay et al., 2004). The nutritional value of cocoa to man (health supportive) with regards to its constituent elements like butter (54%), protein (11%), cellulose (9%), pentosan (7.5%), tannin (6%), water (5%), theobromin (1.3%), sugar (11%) and caffeine (0.2%) have made it a more dependable cash crop which is encouraged worldwide.

Due to its nutritional value millions of people around the world enjoy consuming chocolate whether as part of snack drink or desert (ICCO, 2009). Cocoa is a source of dietary Magnesium shown to be effective in treating diabetes, epilepsy, sleeplessness arthritis and migraine. It also contains minerals such as copper, magnesium, potassium, and calcium that may help support a healthy cardiovascular system. Cocoa helps stimulate the nervous system to calm those who are hyperactive or to improve digestion and kidney function. It also reduces the risk of heart diseases and strokes. The cocoa butter produced from cocoa is rich in stearic, palmitic, and oleic acid, which is used in the manufacture of chocolate, chocolate products, cosmetics as well as used in the pharmaceuticals (Adomako *et al.*, 2006).

2.7 Growing Media and their Role in Raising Seedlings

A growing medium is any substance (peat, sand, cocopeat, vermiculite or other material) that provides nutrients, water, and air as well as provides support for the growing plants. A potting/growing medium must provide the necessary conditions that will enhance seedling growth for successful transplanting to the field (Miller and Jones, 1995). The most important aspect of seedling production is the quality of the growing media which is determined by the growth rate of the plants grown in them (Chen *et al.,* 1988; Verdonck and Gabriels, 1988). The quality of a potting medium is based on its physical and chemical properties. Argo (1997) stated that a good quality potting medium must have physical and chemical properties that can result in increasing plant growth rates, improving yields and enhancing tremendous plant quality. Reis *et al.* (2007), also, reported that a good quality potting medium must enhance the development of healthy, fibrous root system to provide support as well as supply nutrients to the plant for the plants growth and development.

In seedling production, one of the most important aspects is the quality of the growth media (Argo, 1997). The growing media must serve four main functions to facilitate proper shoot and root growth, and these includes, providing water, supplying nutrients, permitting gas exchange to and from the roots and providing support for the plant (Nelson, 1991). Thus, a good quality growing medium must have acceptable physical and chemical properties to perform these functions to enhance seedling growth and development. However, there is no one growing medium that works best in all situations therefore the grower must choose the growth medium with the optimum physical and chemical properties (Argo, 1997). The physical properties include the distribution of air, water and solid volume in the media and it's dependent on factors such as pore space, particle size distribution, container height and media settling in the growth media (Argo, 1997). These factors determine the bulk density, water holding capacity and porosity of the growth media (Awad, 2010). The chemical properties of a medium directly affect nutrient solubility and retention, in other words the nutrient availability for plant uptake. It therefore ensures the movement of nutrients through mass flow and diffusion for plant uptake. The components that contribute to a medium's chemical make-up is pH, cation exchange capacity (CEC) and electrical conductivity (EC).

2.8 The Physical Properties of Growing Media

Studies by Spiers and Percy (2007) shows that the physical makeup of the soil or soilless media can be divided into four parts. The four parts are the solid volume (20 - 30%), air space (10 – 30%), available water (10 - 25%) and residual water (15 - 45%). The essential parts are the air space and the available water, which depend mainly on the particle size and shape of the media components. The physical property of a growing medium is regarded as one of the most important factors that affect plant performance in a potting media. The air, water and solid volume in a potting media affects factors such as bulk density, water holding capacity and porosity (Richard, 2007). Bulk density is an indicator of the degree of compaction of a growing media, and it is expressed as the dry weight of the growing medium divided by its volume. Generally, loose porous growing media that are rich in organic matter have lower bulk density and when mixed with a growing media that has a higher bulk density such as soil, it decreases the bulk density of the soil (Arshad *et al.*, 1996). Thus, amendment of soil with enough organic matter alleviates compaction and provides a favourable environment for root growth. Hence, the lighter the soil, the easier it is for the seedling to emerge up through the soil to reach light as well as to extend its delicate new roots through the media to establish an effective feeding mechanism. Savvas and Passam (2002) reported that, increasing the bulk density of a growing medium with soil provides support to the plant in light weight growth media and prevents container instability. The bulk density of a growing medium is essential as it affects the growth of roots and shoots. The air space, also referred to as air filled porosity is the volume of air in a mix after it has been watered heavily and then allowed to drain. This can be defined as the amount of water retained by the growing medium which is made available for the plants. A growing medium appropriate for plant growth is one that allows water to be held without water logging and does not need regular irrigation (Awad, 2010). It must also permit gaseous exchange to provide aeration for the root as well as to permit water infiltration and movement (Larson, 1980).

Water retention capacity can be defined as the amount of water retained by the growing media to be made available for the plant. The plant available water is defined as the volume of water removed from a just-drained mix by a suction of 10 kPa or a metre column of water and this represents the available water to the plant roots. Although plants can extract more than the available water, they must exert extra energy to do so, and this restricts growth (Spiers and Percy, 2007). Porosity is defined as the total volume of pore space in a growing medium this controls the movement of water through the soil profile (Richard, 2006). The amount of total pore space in a root medium is inversely proportional to the bulk density (Bunt, 1983). Therefore, as the bulk density decreases, total pore space increases linearly. The total porosity of a medium controls the movement of water through the soil profile

(Richard, 2006). Harris *et al.* (1966) found that media aggregation increases growing media porosity and decreases its bulk density. This agrees with Chan *et al.* (2007) who showed that biochar application had improved some physical soil properties such as increased soil aggregation, water holding capacity and decreased soil strength. Thus, media aggregation in turn increases total porosity and at the same time increases the water retention of the growing medium (Sharma and Uehara, 1968). Hence, since water retention in micro pores (equal to a matrix potential of –15 MPa) is relatively constant, this process will increase the available growing media water. Particle size and pore space distribution influence the water to air ratio held in the root media. According to Spiers and Percy (2007), the balance between the plant available and the air space depends on the size and shape of the particles in the soilless mix or the pores between the solid particles. Large particles (0.5 mm or more) which have more air space between the pores contribute air space to the mix.

Medium- sized particles (0.1 mm- 0.5 mm) contribute to the available water. Fine particles (less than 0.1 mm) will hold some water, but this water is unavailable to the plant. For fine particle mixes, very little air is held in it. Therefore, the ideal mix must have a balance between medium and coarse particles with a small number of fine particles. A higher percentage of large particles are suitable for a mix that will be watered regularly in order to have lower available water level. On the other hand, a mix that will be watered once a week will need to have a higher proportion of medium sized particles. Generally, a good balance is achieved with two thirds to three quarters of coarse particles and the remainder being medium particles with a minimal volume of fine particles (less than 5%). Particle size also affects the amount of air space or available water since a more fibrous material has more available water than a less fibrous material (Spiers and Percy, 2007). There are two types of pore space within a root medium the capillary and non-capillary pores. The capillary pores are smaller (less than 0.3mm) pores which retain much of water after watering whiles the non-capillary pores are larger (greater than 0.3mm) pores that provide aeration for the roots. The water held in a root medium that is available to the plant is held at a tension between 1kPa and 10kPa (DeBoodt and Verdonck, 1971). Thus, the smaller the particle size, the greater percentage of smaller pore spaces and the greater amount of water held in the root media after irrigation. A suitable growing medium should maintain a balance between capillary and non-capillary pores in order to enhance optimal root growth. The size of the media container also affects the percentage water retention and aeration of a medium. As an example, a tall pot will have drier mix in the top layers than a wider, shallower container of the same volume. According to Argo (1997), for every 1cm increase in height above the bottom of the pot, there is a 0.1kPa increase in moisture tension resulting in less water held.

In view of this, additives such as water-holding gel example are crystal rain or surfactants example, slippery water). Milks et al. (1989) showed that the percent moisture held in a 17cm tall pot decreased from 69% at the bottom of the pot to 32% at the top of the pot. Nelson (1998) also reported that as container size becomes shorter, there was a decrease in percentage air and an increase in percentage water. Root- medium settling affects the physical properties of a root media by decreasing column height and altering the distribution between capillary and non-capillary pores. Settling occurs when the small particles settle into the large non capillary pores located between the larger particles (Nash and Pokorny, 1990). Nash and Pokorny (1990) found that excess settling occurred in a two component root media when there was a large difference in the particle size of the two components. The greatest amount of settling occurred when the components were mixed in equal volumes (50% each by volume), (Argo, 1997). The use of similar size components in a root medium could reduce or eliminate settling in a root medium (Nash and Pokorny, 1990). The state of decomposition of organic material may affect the ability to rewet after drying. For example, peats in a greater state of degradation have a greater amount of humic acid and this humic acid plays an important role in cation exchange capacity of peat-based root media. When the peat dries, the humic acid may form hard granules that have lost their initial capacity to absorb water and nutrients and this result in adverse effect on the structure of the peat (Argo, 1997).

Irrigation method also affects water absorption. Argo and Biernnbaum (1994) found that with the same media, an average of 0.5 L was absorbed with top watering, 0.38 L was absorbed with drip irrigation and 0.19 L was absorbed with flood irrigation. Under the conditions of the experiment, a maximum of 0.60 L was needed to be absorbed by the medium to reach the air/water ratio which was measured in the laboratory with standard physical property testing methods. The volume of water applied to the medium influences water absorption. Many growers apply only small quantities of water to the medium at any one time in order to control shoot growth and with this, the air/water ratio never gets close to that of the minimum value measured in the laboratory. Water that is held in the root medium after irrigation can be divided into two; namely, water available to plant and water that remains in the root medium even when the plant is wilted, this is the unavailable water (Bunt, 1998; Milks *et al.*, 1989).

2.9 The Chemical Properties of a Growing Medium

The chemical properties are determined by the pH, the cation exchange capacity (CEC) and the electrical conductivity (EC) of the media. The pH of a medium is the measure of the concentration of hydrogen ions in a media/ water solution. The practical definition of soil pH however is the negative logarithm of the active hydrogen ion (H+) concentration in the soil solution. Since pH is measured using a logarithmic scale, a decrease of 1 unit of pH means that the acidity increases by a factor of 10, so small changes in pH values can have important consequences (Fernandez and Hoeft, 2009). The pH affects the availability of nutrients to plant roots, and this is influenced by the lime concentration, the plant species, plant uptake of nutrients and water alkalinity (Richard, 2006).

When the soil pH falls below 5.5, the major plant nutrients required for growth (N, P, K, S, Ca, and Mg) become significantly less available to plants resulting in aluminum toxicity and pH above 7.5, causes micronutrients (Fe, Mn, B, Cu, and Zn) to become less available (Mathers, 2003). According to Pawuk (1981), soil mixes must have a pH of 4.5 to 6.0 to promote seedling growth and reduce disease occurrence. Bunt (1988) also reported that organic media must have an optimal pH range of 5.2- 6.3 and Hartman *et al.* (1997), reported that for soilless media the pH must be between 5.4 -6.0 whiles for soil –based media the pH must be between 6.2 – 6.8. The cation exchange capacity is the capacity for a mix to hold nutrients or it is a measure of the plant available nutrient exchange capacity (Spiers and Percy, 2007). According to Hartman *et al.* (2002) root media components such as peat moss, vermiculite and bark have a negative electrical charge which attracts positively charged ions in the medium water solution. The cation exchange capacity indicates the strength of the electrical charge for a medium as well as determines the capacity of the medium to hold positively charged nutrient ions. Plants available nutrients are either held on exchange sites on the media particles by adsorption or dissolved in the media water. (Spiers and Percy, 2007). Loss of nutrients can occur when this water drains out of the container, and this can be minimized by avoiding over-watering or using additives such as zeolite which increases the CEC and thereby allows the media to hold more nutrients in plant available form. The CEC varies between different types of media. A higher CEC is desirable as it ensures an even supply of nutrients to the roots and causes fewer nutrients to be lost through over- watering. A higher CEC can be attained by increasing the surface area of the media. Hartman *et al.* (2002), reported that the CEC is based on the volume of the soilless media, and this must be high to allow the medium to retain nutrients for the plant.

The plant nutrient ions are cations (NH4 +, K+, Ca++, Mg++, Zn++, Cu++, Mn++, and Fe++) and anions (H_2PO_4 -, NO_3 -, SO_4 - and Cl-) of which SO_4 - and Cl- are not in limited supply. Media components with high CEC include soil, peat moss and vermiculite and components with low CEC include perlite, Styrofoam, and sand (Hartman *et al.*, 2002). The unit of measure for CEC can also be defined as the sum of exchangeable cations (bases) per weight of soil. Cation exchange capacity is usually expressed as milligram equivalents per 100 g (meq.100 g -1) but currently it is expressed as cmolkg-1. The CEC of a media mix depends on the individual components in the media mix. Composted or decayed organic components have higher CEC than fresh organic materials. Electrical conductivity (EC) is the measure of salt content of water based on the flow of electrical current. The electrical conductivity is measured by the amount of soluble salt in the media thus it is related to the quantity of dissolved ions (obtained from fertilizer salts) in solution. In effect, the more salts present, the higher the soluble salt level and this provides a general indication of soil fertility. Organic media supply small amounts of available nutrients to plants thus the need to apply fertilizers (Richard, 2006). The acceptable EC for seedlings is 1.0 – 2.0 dS/m and 2.0- 3.0 for established plants. Plant growth rates decrease when EC is high and sensitive plants may be damaged. Soils with high exchangeable sodium are characterized by poor tilth and lead to low permeability resulting in poor plant growth (Corwin and Lesch, 2005) Soil electrical conductivity is influenced by the amount of clay, soil water, bulk density, organic matter, soil temperature and the cation exchange capacity (Corwin and Lesch, 2005). Electrical conductivity is influenced by soil moisture and texture, especially in most saline soils (Brevik and Fenton, 2002). Excessive soluble salt levels are caused by over fertilization, poor drainage inadequate watering and leaching. Soluble salt damage may show up as root injury, leaf chlorosis, burning of leaf margins and /or wilting.

Seedlings, transplants, and crops grown in media containing more than 20% field soil are less tolerant to higher soluble salts. Leaching regulates electrical conductivity in soils by displacing salt ions into solution and subsequently flushes the soil water out of the pot. Another way of regulating electrical conductivity in soils is by stratification, which involves the movement of nutrient salts to the upper top (1cm) of the medium. Some examples of salt tolerant crops are barley, canola, cotton, beetroot soybean, wheat, olives, and sorghum. Moderately salt tolerant crops include lucerne, tomato, cabbage, potato, and carrots while some low salt tolerant crops include maize, sugarcane, celery, lettuce, and pumpkin (Corwin and Lesch, 2005).

2.10 Types of Growing Media

There are two types of growing media namely, a soilless medium which refers to a potting medium that contains peat, usually perlite or vermiculite and/or any organic material without soil. This is sometimes referred to as sterile mix. The second type is termed a soil-based medium mix which refers to a potting media which contains some percentage of soil (Spiers and Percy, 2007). The media must meet the entire basic plant requirements to facilitate proper shoot and root growth. The growing medium must supply plants with a means of support, good drainage, nutrients, adequate air circulation and water (Nelson, 1991).

2.10.1 Soilless Media

Soilless mixes as their name implies do not contain any soil mineral particle, thus they are extremely lightweight, nutrient retentive and sterilized (heated to kill microorganism and weed seeds). Soilless media are generally kept at a pH between 5.5 – 6.0 whiles the mixes that contain soil are best maintained at a pH ranging from 6 - 6.5 (Wander, 2010). Soilless mixes are made up of different organic ingredients including peat moss, shredded bark, sawdust, vermiculite, perlite, etc. Some alternative materials that are being used recently include shredded coconut husk, rice husk, other crop husks (cocoa pod, kola nut, and cowpea) and peanut hulls. The soilless mixes are typically lightweight as well as weed and disease free. The soilless media must be porous enough for root aeration, have good drainage to prevent waterlogging as well as being capable of retaining water and nutrients (Wander, 2010). A coarse mineral component is used to improve drainage and aeration by increasing the proportion of large air-filled pores. Sand is used to promote good drainage and its substitutes include perlite and polystyrene. Some examples of mineral components include sand, perlite, vermiculite, clay granules and rockwool (Hartman *et al.,* 1997). Quality soilless mixes should be low in soluble salts with pH of 5 – 6.5. Molson (2008) recommended one part perlite, one part peat moss and one part ground or milled sphagnum moss for a soilless mix. Until the 1970s, seedlings or potted plants were grown in potting mixes which were based on soil amended with coarse sand and peat (Spiers and Percy, 2007). Currently, many seedlings or container plants whether in nursery or greenhouse are grown in soilless media where the soil is replaced by other materials and they provide the physical and chemical properties needed for plant growth. This is a way to prevent soil-borne organism and weed seeds present in soils. The use of soilless media is relatively inexpensive and environmentally friendly. Some materials used for soilless media are peat, rock wool, sand as well as organic materials such as rice husk, sawdust, bark, coconut fibre, cocoa pod husk, kola nut husk. Kambooh (1984) reported that organic matter content of the planting medium has effect on the biological, chemical and physical properties. As the organic matter decomposes, the chemical elements become available to the plants.

2.10.2 Soil Based Media Mix

A soil-based media mix refers to a potting medium which contains some percentage of soil (Spiers and Percy, 2007). Soil mixes have the same characteristics as soil itself, except that the bulk density is reduced and aeration is increased by adding perlite, peat moss, washed river sand or sea sand and organic residues. A medium is considered soil based if it contains at least 25% soil (Fonteno, 1996). The soil in soil-based media provides buffering capacity to withstand pH changes and provides support as well as nutrients to the plant. One advantage of soil-based media over soilless media is the high CEC soil contributes to the mix. The high CEC of soil-based mix increases the difficulty of reducing high soluble salts or micronutrients level before leaching. Additionally, nutrient retention is increased, and this makes soil-based media mix useful for long term crops such as stock plants (Hartman et al., 1997). Soil mixes are considered to be important and necessary for the growth and development of seedlings as it provides the basic necessities required by the plant throughout its life. Soil based mixes contain equal parts of loamy soil, concrete-grade sand and sphagnum peat moss (Wang et al., 2002). For a seed soil-based mix, one part loam, one part leaf mould or peat moss and one part sand was recommended (Molson, 2008).

2.10.3 Media Mixes

There are two types of growing medium, these are the soil-based mixes (contain a portion of field soil) and the soilless mixes (contain no field soil). Farms and nurseries use various potting media in the production of seedlings, container plants and greenhouse crops (Kuepper and Everett, 2010). A typical medium mix consists of two or three components. Ideally, organic, and inorganic components are used due to their opposite and complementary, physical and chemical properties. Some organic components used include cocoa pod husk, cola nut husk, cocopeat, peat moss, compost, rice hulls, and sawdust. These materials are usually low in weight with high water holding capacity, high CEC and highly resistant to compaction. Additionally, they contain significant quantities of nutrients. Inorganic components such as gravel, sand, vermiculite, perlite improves physical properties of the media by increasing aeration, pore space and enhancing drainage (Jacobs *et al.,* 2009). Rice husk, cocoa pod husk, sawdust and cocopeat are mixed with the soil to serve as an organic matter to the soil so as to increase the nutrient retention, water holding capacity and aeration of the soil.

2.10.4 Soil

Soil is the heaviest of all growing media and is usually low in organic matter which reduces its ability to hold water (Khan *et al.*, 2002). Soil is a mixture of minerals, organic matter, gases, liquids, and organisms that serves as a medium support for plant growth. Soils supply plants with mineral nutrients held in place by the clay and humus content of the soil. The soil texture is determined by the relative proportions of sand, silt, and clay in the soil. The presence of organic matter, water, gases cause the soil of a certain texture to develop into a larger soil structure called aggregates. The presence of soil pores determines the ability of the soil to absorb and hold water and making it readily available for plant uptake. This is vital for plant survival. The pore space allows for the infiltration and movement of air and water and is critical for life in the soil.

The most influential factor in stabilizing soil fertility are the soil colloidal particles, clay, and humus, which behave as repositories of nutrients and moisture and acts to buffer the variations of soil solution ions and moisture. They act to store nutrients that might otherwise be leached from the soil or to release the ions in response to changes of soil pH as well as to make them available to plants. The greatest influence on plant nutrient availability is soil pH, which is the measure of the hydrogen ion (acid-forming) soil reactivity and is in turn a function of the soil materials, precipitation level and plant root behaviour. Soil pH strongly affects the availability of nutrients (Khan *et al.*, 2002). Cation exchange, between colloids and soil water buffers (moderates) soil pH, alters soil structure and purifies percolating water by adsorbing cations of all types. The negative charges on a colloid make it able to hold cations to its surface. Cations held to the negatively charged colloids resist being washed downward by water and out of reach of plant roots, thereby preserving the fertility of soils. Cation exchange capacity is the soil‘s ability to remove cations from the soil water solution and sequester those to be exchanged later as the plant roots release hydrogen ions to the solution. Sixteen nutrients are essential for plant growth and reproduction. They are carbon, hydrogen, oxygen, nitrogen, phosphorous, potassium, sulphur, calcium, magnesium, iron, boron, manganese, copper, zinc, molybdenum, and chlorine (Hartley, 1988). A wide variety of soils have been successfully used in different countries. These include sandy soil partially sterilised by heating over a fire; deep friable topsoil, overlying alluvial clay mixed with a small proportion of coarse river sand in the proportion 3:2; peat and sand mixed in equal proportions; sandy soil; inland clay-loam topsoil and silted forest topsoil (Hartley, 1988). In general, fertile topsoil, sufficiently free draining to prevent puddling or sealing of the surface has been recommended (Hartley, 1988).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The Experiment was conducted at the Multi-Purpose Crop Nursery of Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED**)** formerly University of Education Winneba, Mampong –Ashanti (UEW - M). Mampong is in the Ashanti region and about 57.6 km North of Kumasi. Mampong-Ashanti lies at the transitional zone between the forest and northern savanna zones of Ghana and lies on latitude7.08^0 N and longitude 1.40^{0}W of the equator and it is 457.5 m above sea level (Meteorological Department., 1094.4, 2008).

3.2 Climate

Mampong has a bimodal rainfall pattern with annual mean rainfall between 1094.4mm and 1200 mm and the monthly mean rainfall of about 91.2 mm. The major rainy season starts from March to July whereas the minor rainy season occurs from September to November (Meteorological Department, 2008). Mampong has a daily temperature of about 30.5^0 C and night temperature of 26^0 C. The experiment lasted for fourteen (14) weeks (86 days) and was commenced on 1st April 2021 to 25th June 2021.

3.3 Experimental Materials

The materials used in the study were topsoil, river sand and poly bags of sizes 18 cm diameter x 25 cm length. The river sand was collected from the stream near the

AAMUSTED cocoa farm, and the topsoil was also collected from the Multi-Purpose Nursery Crop Farm, at a depth of 0-15 cm, and sun dried.

3.4 Experimental Design and Treatments

Experimental Design used was Randomized Complete Block Design (RCBD) using five treatments. The five treatments used in the experiment were: T_1= 100% topsoil, 100% river sand T_2 = 75% topsoil, 25% river sand, T_3 = 50% topsoil ,50%river sand, T_4 = 25% topsoil and 75%river sand T_5 100% river sand and their mixtures T_1 (100%TS),T_2 (75% TS+25% RS), T_3 (50% TS+50% RS), T_4 (25% TS+75% RS) and T_5 (100% RS). These treatments were replicated three times with twenty polybags per treatment.

3.5 Field Operations

3.5.1 Nursery Establishment

The polybags used for the experiment were black and were initially perforated at the base with a perforator 70 creating a 0.25 mm^2 holes to facilitate aeration and drainage. The polybags were filled with the growth media and their mixtures. The bags were arranged under a shed and the cocoa seeds sown directly into the bags and watered two times daily when necessary. All the media constituents were thoroughly mixed to obtain a uniform mixture. Polybags filled with the different potting media were watered 24 hours before cocoa seeds were sown. The seeds were obtained from the AAMUSTED cocoa farm. The Clone 16 cocoa variety was used for the experiment. The seeds were sown at a seeding rate of two seeds per poly bag which were thinned to one seedling per bag. The seedlings were kept under a shed to reduce the light intensity. The seedlings were kept at the nursery for three months and were watered when necessary. Weeds in the polybags were handpicked regularly to prevent weeds from serving as host to pests and competing with the seedlings for nutrients.

Figure 3.1 Nursery layout for the experiment

3.6 Data collected on seedlings

Morphological growth measurements such as plant height, number of leaves, were recorded to evaluate treatment effects. In addition, plant canopy width, stem diameter, length of the leaves and breadth (leaf Area) of the leaves were also collected.

3.6.1 Plant height

Plant height was determined using a meter rule by measuring from the base (soil surface) to the tip of the apical leaf at every two weeks intervals.

3.6.2 Number of leaves

The number of fully developed leaves was counted on each plant and recorded in every two weeks.

3.6.3 Diameter of the stem (cm)

The diameter of the stem of the plants was recorded by using garden line to tire around the stem and later placed on the measuring rule and measured and recorded the results in every two weeks intervals.

3.6.4 Leaf Area (cm^2)

The area of the leaves was taken by using the Montgomery equation of leaf area coefficient of 0.69 multiplied the length of the leaf by the breadth of the leaf (Peppe *et al.,* 2011).

3.6.5 Canopy width

The canopy width was measured from the midst-spread with the help of a meter rule and recorded in centimeters.

3.7 Statistical analysis

The data collected was analyzed by using Analysis of Variance (ANOVA) using Genstat statistical package, version 9.2 (Genstat 2012). The least significance difference (LSD) at p= 0.05 was used to separate the means where significant differences were observed.

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

This chapter consists of data presentation, analysis and summary of the findings. The main objective of this study is to find out whether the mixture of topsoil and river sand in various ratios will support the growth of cocoa hybrid seeds in order to get a substitute media in cocoa nursery management. The researcher discusses the results collected at five (5) different times, using tools which include descriptive statistics presentation and the one-way analysis of variance.

Table 4.1: Average Values of Variables for First Round of Results Collection (23/04/2021)

Treatment	Plant Height (cm)	Number of Leaves	Stem Diameter(cm)	Canopy Width(cm)	Leave Area(cm^2)
T1 =100% TS	14.13	4.6	0.35	18.60	24.22
T2 =75% TS + 25% RS	14.40	4.5	0.32	17.80	22.81
T3 =50% TS+50%RS	14.73	4.5	0.36	18.69	25.46
T4 =25%TS+75%RS	15.33	4.7	0.35	17.60	22.07
T5 =100% RS	14.27	4.6	0.30	16.80	19.40
LSD	0.367	0.145	0.014	0.601	1.66
CV (%)	3.3	1.8	7.5	4.3	10.1

To determine the growth of the cocoa hybrid seeds, five variables were considered. These variables are plant height, number of leaves, plant stem diameter, canopy, and area of the leaves. The table above shows the average values obtained for each of the treatments and the five variables under consideration during the first data collection period (23/04/2021). It is clearly observed from the table that treatment 4 had the highest average value for plant height, followed by treatment 3. With regard to number of leaves, on the average, all the treatments had approximately equal numbers. Treatment 3 had the largest stem diameter of 0.36cm, followed by treatment 1 and treatment 4 when plant stem diameter is considered.

Treatment 5 had the least plant canopy of 16.80, while treatment 1 had the highest value of 18.60. Finally, area of the leaves was taken into consideration, and it was computed using the Montgomery equation of leaf area coefficient of 0.69 multiplied by the length times the breadth (Peppe *et al.,* 2011). It was observed that treatment 3 had the highest value of 25.46cm^2, followed by treatment 4, while treatment 5 had the lowest value of 19.4cm^2. Although there were obvious differences in the values obtained for each of the five variables for the five treatments, the researcher wanted to determine which of the differences was statistically significant. To do this, the one-way analysis of variance (ANOVA) test was carried out and the result obtained is as presented in the table below.

Table 4.2: P-values from the Analysis of Variance

ANOVA	P-VALUE
PLANT HEIGHT	0.048
NUMBER OF LEAVES	0.036
STEM DIAMETER	0.021
CANOPY WIDTH	0.042
LEAF AREA	0.044

The test was performed at a significant level of 5%. The hypotheses were that there was no significant difference in the values obtained for the five variables with regards to the five treatments. From the table, it is observed that all the tests were significant and had p-values which were less than the 0.05 alpha levels. This means that, the differences in the mean values of all the variables were statistically significant with reference to the various treatments. That is, in each of the five variables, there was at least one treatment whose mean value was significantly different from the rest. Thus, a post-hoc test was conducted to determine which treatments were significantly different from the others. The LSD was used to determine which of the treatments were significantly different, which is a pairwise comparison for all the treatments. The LSD for plant height was obtained to be 0.367. A pairwise comparison was done, and it occurred that treatment 4 had a difference which was greater than 0.367 with all other treatments.

This implies that treatment 4 was significantly different from all the other treatments in terms of plant height. Also, treatment 3 was found to be significantly different from treatment 1 and treatment 5 with mean differences of 0.6 and 0.46 respectively. With regards to number of leaves, the LSD obtained was 0.145. From the pairwise comparisons, it was clearly seen that treatment 4 was significantly different from treatment 2 and treatment 3 with a mean difference of 0.2 in both cases. Treatment 3, treatment 1 and treatment 4 were significantly different from the remaining treatments with regards to plant stem diameter, with pairwise differences which were greater than the LSD of 0.014. Considering plant canopy, the LSD obtained was 0.601 and treatment 1 was significantly different from all the others with the exception of treatment 3. Also, treatment 3 was significantly different from treatment 2 and treatment 5. Moreover, treatment 2 was also significantly different from treatment 5. It can therefore be inferred from the foregoing that treatment 3 outperformed the rest with regard to plant canopy, which was followed by treatment 1. The LSD obtained for the area of leaves was 1.66 and it was observed from pairwise comparisons that treatment 3 was significantly different from treatments 2, 4and 5. Also, treatment 1 was found to be significantly different from treatments 4 and 5. It can be said therefore that treatment 3 performed better than the rest when area of leave is considered. The coefficient of variation was also employed to determine the spread of the data points around the mean. It is obviously observed that number of leaves had the least spread of 1.8%, which was followed by plant height (3.3%) and then plant canopy (4.3%). On the contrary, the area of plant leaves had the highest value of 10.1%, followed by plant stem diameter with a spread of 7.5%. The second period of data collection occurred on the 7th May, 2021. The data collected at this time is as analyzed in the table below for the various treatments and the variables of interest.

Table 4.3: Average Values of Variables for Second Round of Data Collection (07/05/2021).

Treatment	**Plant Height (cm)**	**Number of Leaves**	**Stem Diameter(cm)**	**Canopy Width(cm)**	**Leave Area(cm^2)**
T1 =100% TS	15.07	8.3	0.42	18.60	26.88
T2 =75% TS + 25% RS	16.53	5.5	0.37	18.93	26.95
T3 =50% TS+50%RS	15.88	5.8	0.39	18.69	29.56
T4 =25%TS+75%RS	16.13	6	0.41	17.60	28.48
T5 =100% RS	15.21	5.6	0.39	16.80	22.36
LSD	0.979	0.815	0.056	0.993	1.35
CV (%)	3.9	18.7	2.3	5.0	4.4

From the data presented above, it is clearly observed that on the average, treatment 2 had the highest value of 16.53cm for plant height whiles treatment 1 had the lowest value of 15.07cm. Treatment 1 had the highest average value for both the number of leaves and the stem diameter (8.3, 0.42) at this point, while treatment 2 had the lowest (5.5, 0.37) in both situations. For plant canopy, treatment 2 had the highest which is 18.93 whiles treatment 5 had the least value of 16.80. Treatment 3 had the highest value for the area of leaves ($29.56cm^2$) while treatment 5 had the lowest value ($22.36cm^2$). Once again, there were obvious differences in the values obtain, and the researcher wanted to determine which of the differences was statistically significant. To do this, the one-way analysis of variance (ANOVA) test was carried out and the results obtained is as presented in the table below.

Table 4.4: P-values from the Analysis of Variance

ANOVA	**SIGNIFICANT VALUE**
PLANT HEIGHT	0.040
NUMBER OF LEAVES	0.000
STEM DIAMETER	0.198
CANOPY WIDTH	0.030
LEAF AREA	0.010

The test was performed at a significant level of 5%. The hypotheses were that there was no significant difference in the values obtained for the five variables with regards to the five treatments. It is observed that only two of the variables, had p-values which were more than the 0.05 alpha level. This means that, the differences in the other variables were statistically significant with reference to the various treatments.

A post-hoc test was conducted to determine which treatments were significantly different from the others with reference to plant height, number of leaves, plant canopy and area of plant leaves. The Fisher's LSD was used to determine which of the treatments were significantly different. The pairwise comparison for all the treatments was carried out and it was observed that treatment 2 was significantly different from treatment 1 and treatment 5 with respect to the plant height, since it had differences greater than the LSD of 0.979. Also, the LSD for number of leaves was obtained to be 0.815 and after the pairwise comparison, it was found out that treatment 1 was significantly different from all the others. With regards to plant canopy, treatment 2, treatment 3 and treatment 1 were all significantly different from treatments 4 and 5, since the differences were greater than the LSD value of 0.993. Finally, the LSD for area of leaves was 1.35 and treatments 3 and 4 were found to be significantly different from the other treatments. Also, treatments 1 and 2 were both significantly different from treatment 5.

The coefficient of variation was also employed to determine the spread of the data points around the mean. It is obviously observed that plant diameter had the least spread of 2.3%, which was followed by plant height (3.9%) and then area of leaves (4.4%). On the contrary, number of leaves had the highest spread of 18.7% which was followed by plant canopy (5.0%). Data collection for the third period occurred on the 21st May, 2021. The data collected from the field was analyzed for the various treatments and the variables of interest. The result obtained is presented in the table below.

Table 4.5: Average Values of Variables for Third Round of Results Collection (21/05/2021)

Treatment	Plant Height (cm)	Number of Leaves	Stem Diameter(cm)	Canopy Width(cm)	Leave Area(cm^2)
T1 =100% TS	16.73	9.7	0.42	20.40	33.01
T2 =75% TS + 25% RS	16.33	6.5	0.39	19.27	28.54
T3 =50% TS+50%RS	16.47	7.8	0.41	21.87	32.60
T4 =25%TS+75%RS	16.60	7.2	0.41	21.87	33.45
T5 =100% RS	16.33	7.7	0.39	18.67	26.37
LSD	0.51	0.90	0.02	0.81	2.35
CV (%)	1.1	15.3	3.3	7.2	10.3

The lowest average height was 16.33, which was jointly obtained from treatment 5 and treatment 2, while treatment 1 had the highest value of 16.73. Concerning the number of leaves, it was observed that treatment 1 still had the highest average value of 9.7, while treatment 2 recorded the lowest average of 6.5. All the treatments had the same average value of 0.39 for plant diameter, with the exception of treatment 3, which recorded a slightly higher value of 0.41. Treatment 5 recorded the lowest average value for plant canopy, which is 18.67, while treatment 3 and treatment 4 jointly had the highest value of 21.87. With respect to the area of leaves, treatment 4 had the highest values of 33.45cm^2 which was followed by treatment 1 with a value of 33.01cm^2 the lowest value for the area of leaves was recorded for treatment 5, with an average value of 26.37cm^2.

Table 4.6: P-values for the Analysis of Variance

ANOVA	SIGNIFICANT VALUE
PLANT HEIGHT	0.979
NUMBER OF LEAVES	0.011
STEM DIAMETER	0.910
CANOPY WIDTH	0.032
LEAF AREA	0.016

The ANOVA table showed that there was no significant difference in three of the variables under consideration, namely, plant height, stem diameter and the areas of plant leaves for all the treatments. This implies that all the treatments were equally good at this period. However, there was a significant difference in the number of leaves, plant canopy and the area of plant leaves. This means that at least one of the treatments was significantly different from the others. To find out the treatments which brought about the significant difference, the Fisher's LSD was used. The LSD obtained for number of leaves was 0.903 and the comparison showed that treatment 1 was significantly different from all the other treatments.

Also, the pairwise comparison for plant canopy showed that treatments 3 and 4 were significantly different from treatments 1, 2 and 5 since the differences were greater than the LSD value of 0.811. Treatment 1 was also significantly different from treatments 2 and 5. With respect to area of leaves, treatments 1, 3 and 4 were found to be significantly different from the rest of the treatments with pairwise differences greater than the LSD value of 2.35.
Here again, the coefficient of variation was also employed to determine the spread of the data points around the mean. It is obviously observed that plant height had the least spread of 1.1%, which was followed by plant diameter (3.3%). On the contrary, number of leaves

had the highest spread of 15.3% which was followed by area of leaves (10.3%). The last but one data collection took place on 4th June, 2021. The data collected at this time is as analyzed in the table below for the various treatments and the variables of interest.

Table 4.7: Average Values of Variables for Fourth Round of Results Collection (04/06/2021)

Treatment	**Plant Height (cm)**	**Number of Leaves**	**Stem Diameter(cm)**	**Canopy Width(cm)**	**Leave Area(cm^2)**
T1 =100% TS	18.01	14.5	0.52	23.47	40.02
T2 =75% TS + 25% RS	17.07	8.1	0.52	23.13	33.33
T3 =50% TS+50%RS	17.87	12.9	0.51	23.47	38.64
T4 =25%TS+75%RS	17.27	12.6	0.47	24.07	38.88
T5 =100% RS	17.80	9.9	0.51	20.20	29.14
LSD	0.97	0.84	0.02	1.15	3.31
CV (%)	2.4	3.7	4.1	6.7	12.9

It is clearly observed from the table that the lowest average height and number of leaves corresponding to17.07 and 8.1 respectively, were both for treatment 2, while treatment 1 had the highest values on both occasions with values 18.01 and 14.5 respectively. The lowest value for the stem diameter was 0.47, for treatment 4 while the highest value was 0.52 jointly for treatment 1 and treatment 2. Treatment 4 had the highest value in terms of plant canopy with a value corresponding to 24.07, whereas treatment 5 had the lowest value of 20.20. The lowest value for the area of leaves was obtained by treatment 5 (29.14cm^2), while the highest value for area of leaves was obtained by treatment 1 (40.02cm^2).

Table 4.8: P-values from the Analysis of Variance

ANOVA	SIGNIFICANT VALUE
PLANT HEIGHT	0.717
NUMBER OF LEAVES	0.000
STEM DIAMETER	0.026
CANOPY WIDTH	0.016
LEAF AREA	0.019

The ANOVA test was performed at a significant level of 5%. The hypotheses were that there was no significant difference in the values obtained for the five variables with regards to the five treatments. From the table, it is observed that three of the variables (number of leaves, stem diameter and canopy) had p-values which were less than the 0.05 alpha level. The p-values for number of leaves, plant diameter and canopy were 0.000, 0.026 and 0.016 respectively. This means that, the differences in the other variables were not statistically significant with reference to the various treatments.

Also, a post-hoc test was conducted to determine which treatments were significantly different from the others with regards to the number of leaves, plant stem diameter and canopy. The Fisher's LSD was used to determine which of the treatments were significantly different. The pairwise comparison for all the treatments, revealed that with respect to the number of leaves, treatment 1 was significantly different from all the other treatments with differences greater than the LSD value of 0.844, while treatments 3 and 4 were also significantly different from treatment 2 and treatment 5. Also, with respect to plant stem diameter the pairwise differences showed that treatments 1, 2, 3, and 5 were all significantly different from treatment 4 with the difference greater than the LSD of 0.019. When the canopy was taken into consideration, treatments 1, 2, 3 and 4 were all significantly higher treatment 5 with pairwise differences greater than the LSD value of 1.155. Finally, the pairwise comparison also shows that treatments 1, 3 and 4 were significantly different from treatments 2 and 5 while treatments 2 was significantly different from treatments 5 in terms of area of leaves with the LSD value of 3.31. Once more, the coefficient of variation was also employed to determine the spread of the data points around the mean. It is obviously observed that plant height had the least spread of 2.4%, which was followed by number of leaves (3.7%) and then plant stem diameter (4.1%). On the contrary, area of leaves had the highest spread of 12.9% which was followed by plant canopy (6.7%).

The last phase of data collection occurred on the 25th June, 2021. It is clearly observed from the table that treatment 1 had the highest average value when it comes to plant height, followed by treatment 4, with corresponding values of 19.13 and 18.93 respectively. With regards to number of leaves, on the average, treatment 1 had the highest value of 15, while treatment 2 obtained the lowest value of 9. Treatment 1 had the largest diameter of 0.59, while treatment 5 had the smallest value of 0.52. Treatment 1 had the least plant canopy of 23.67, while treatment 1 had the highest value of 27.13. Finally, the area of the plant leaves was taken into consideration, and in this case, treatment 1 had the highest value of 49.38 while treatment 5 had the least value of 35.91.

Table 4.9: Average Values of Variables for Fifth Round of Results Collection (25/06/2021)

Treatment	**Plant Height (cm)**	**Number of Leaves**	**Stem Diameter (cm)**	**Canopy Width(cm)**	**Leave Area(cm^2)**
T1 =100% TS	19.13	15	0.59	27.13	49.38
T2 =75% TS + 25% RS	17.67	9	0.58	23.67	35.22
T3 =50% TS+50%RS	18.07	14	0.55	26.33	47.23
T4 =25%TS+75%RS	18.93	12	0.56	25.80	45.20
T5 =100% RS	18.33	11	0.52	23.67	35.91
LSD	0.87	0.919	0.09	1.37	4.69
CV (%)	3.3	19.5	4.9	6.2	15.5

The difference in the data values of all the treatments was tested again to see whether they are statistically significant. The analysis of variance test was employed, and the result obtained is presented in the table below.

Table 4.10: P-values from the Analysis of Variance

ANOVA	SIGNIFICANT VALUE
PLANT HEIGHT	0.026
NUMBER OF LEAVES	0.000
STEM DIAMETER	0.282
CANOPY WIDTH	0.023
LEAF AREA	0.012

It can be observed that for diameter, the differences in the data values for all the treatments were not statistically significant. This is because they all had p-values which were greater than 0.05. This means that, all the treatments were good to support the growth of the cocoa seeds. On the contrary, there was a significant difference in the average values of the remaining treatments. That is, at least one of the treatments was significantly different from the rest in terms of the variables afore mentioned. To determine which of the treatments that was significant, the Fisher's LSD post hoc analysis was carried out. The pairwise comparison of the treatments on plant height indicated that, treatment 1 was significantly different from treatments 2 and 3 with differences more than the LSD value of 0.873. Also, treatment 4 was found to be significantly higher than treatment 2, with pairwise difference greater than 0.873. With regard to the number of leaves, it was observed that treatment 1 was significantly different from all the other treatments with pairwise differences greater than the LSD value of 0.919. Treatment 4 was found to be higher than treatments 3, 5 and 2 respectively.

Also, treatment 3 was significantly different from treatments 2 and 5. Lastly, the pairwise comparison shows that treatment 5 was significantly higher than treatment 2. The LSD value for plant canopy was 1.372 and the pairwise comparison shows that treatment 1 was significantly different from treatments 2 and 5. Likewise, treatment 3 and treatment 4 were each found to be significantly different from both treatments 2 and 5respectively. For the area of leaves, the LSD value was 4.69 and it was observed from pairwise comparison that treatments 1, 3 and 4 were all significantly different from treatments 2 and 5. To measure the spread of the data values around the mean value of each of the variables, the coefficient of variation was used. Plant height had the least spread with a percentage of 3.3%, followed by plant stem diameter having a value of 4.9%. Number of leaves was the variable with the greatest spread, accounting for 19.5%, followed by area of leaves with a spread of 15.5%

The researcher finally considered the various variables one after the other over the study period in order to assess the performance of the treatments.

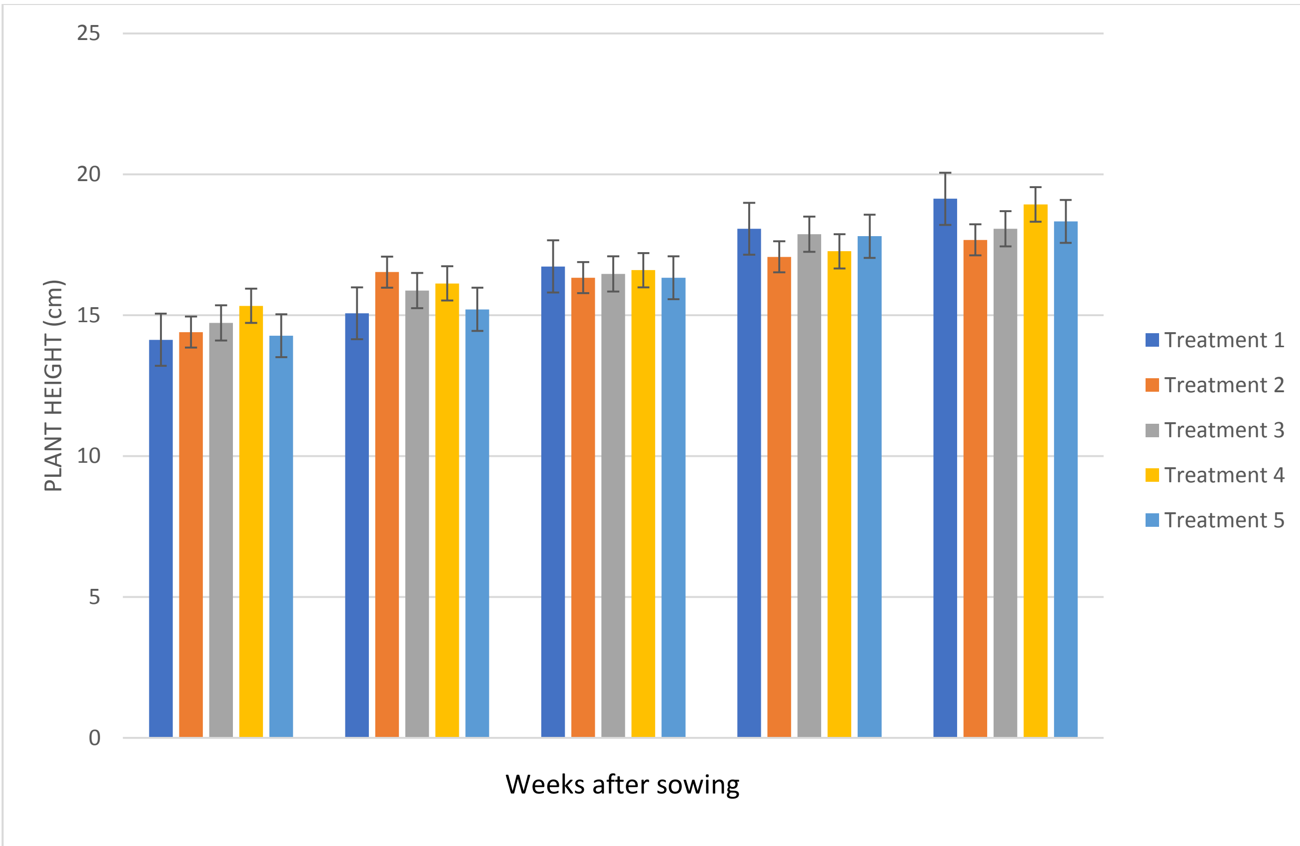

Figure 4.1 Effect of different growth media on average plant height of cocoa seedlings

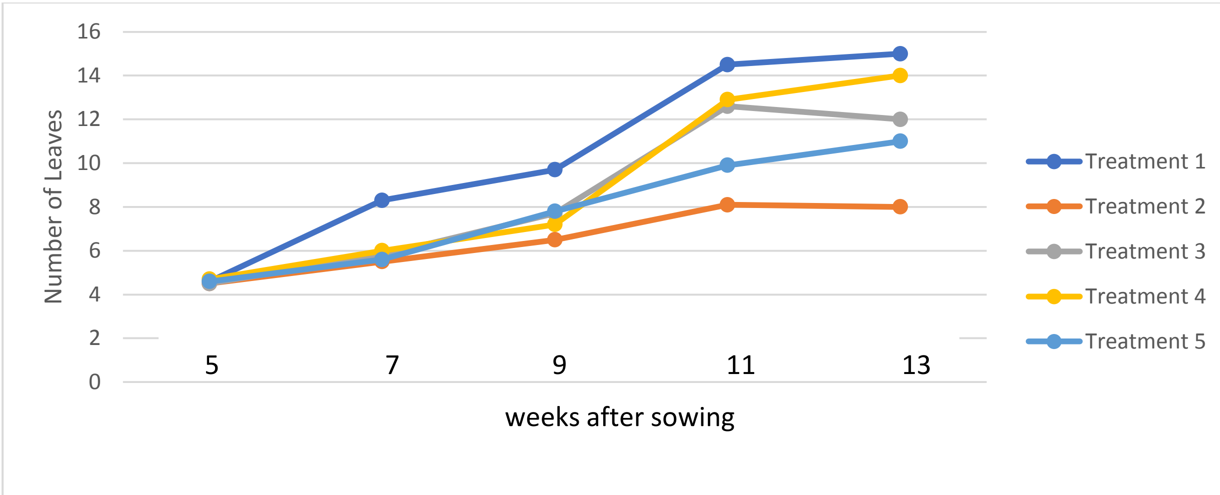

Figure 4.2 Effect of different growth media on average number of plant leaves of cocoa seedlings

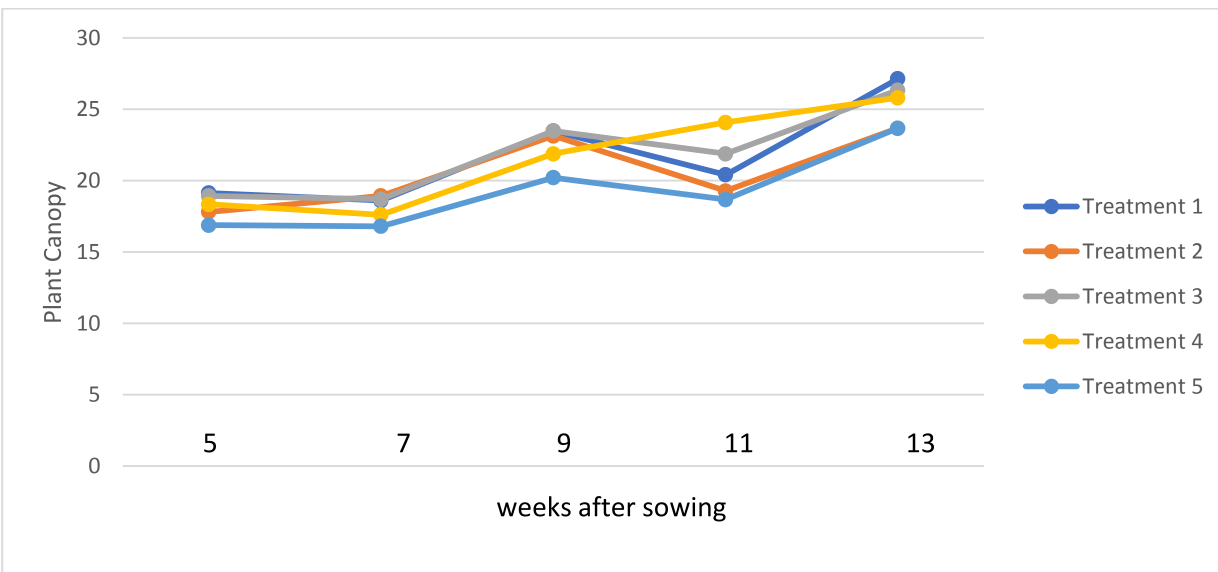

Figure 4.3 Effect of different growth media on average plant canopy width with cocoa seedlings

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of different composition media on the growth of cocoa seedlings

The topsoil produced the highest mean plant height, number of leaves, stem diameter, canopy and leaf area of cocoa seedlings as compared to other media compositions and river sand only. The increase in these parameters is an indication of higher growth. Growth is measured as an increase in height, number of leaves, stem diameter, canopy and leaf area of a plant. The results agree with Ogbodo (2009) who reported that plants of greater heights with larger leaf area intercept more sunlight faster which is required for photosynthesis to take place to promote growth than plants with smaller leaf area. The topsoil did not only have significant influence on the growth rate of the seedlings but also produced seedlings with a higher leaves and canopy. This may be due to the fact that, the topsoil is made up of mixtures of organic matter which had soil environmental conditions such as ideal pH and electrical conductivity that supported the growth and development of the seedlings.

The addition of other organic components to the topsoil had significant influence on the physical and chemical properties of the topsoil (Shamshuddin *et al.,* 2004). In the present study the results show that seedlings grown in the topsoil media (T1) recorded the highest plant height, girth, number of leaves, stem diameter and leaf area, follow by treatment three (T3), treatment two(T2) and four(T4) as compared to the cocoa seedlings grown in river sand (T5) only from second data collection to the last part of the data collection. The cause of the difference in growth of the seedlings may be due to the differences in the properties of the media. Some soil properties that enhance plant growth are bulk density, water holding capacity, cation exchange capacity (CEC), porosity, organic matter content From **Figure 4.1** above, it can be observed that treatment 1 outperformed the others over the study period when it comes to plant height which was followed by treatments, 4, 3 and 2. Thus treatment 1 is most preferred with respect to plant height. The differences in the plant height in the various media may be due to differences in leaf growth and supply of photosynthate to the roots (Adu-Berko *et al.,* 2011). It is also reported that better uptake of water and nutrients which enhanced vigorous plant growth was observed in seedlings raised in large bags (Abugre *et al.*, 2011).

5.2 Effect of different growth media on average number of plant leaves of cocoa seedlings

Figure 4.2 in chapter four above also portrays the average number of leaves over the study period for all the treatments under consideration. It is clearly observed that treatment 1 ranked first, which was keenly followed by treatment 4 while treatment 2 performed worst. Here, treatment 1 is recommended on the basis of number of leaves.

5.3 Effect of different growth media on average plant canopy width of cocoa seedlings

With respect to the average plant canopy width over the study period, treatment 1 still outperformed all the other treatments, but this time, which was followed by treatment 3. This is clearly seen in Figure 4.3 below. Thus, treatment 5 and treatment 2 are least preferred while treatment 1 is to be considered on the basis of plant canopy width.

5.4 Effect of different growth media on average stem diameter of cocoa seedlings.

It is clearly seen from table 4.9 that for the study period, treatment 1 performed best, which was followed by treatment 2, while treatment 5 had the worst performance. Thus, when it comes to the variable of Plant stem diameter, treatment 1 is preferred to the other treatments.

5.5 Effect of different growth media on average leave area of cocoa seedlings

The last variable to be considered by the researcher was the plant leaves area over the study period. Table 4.9 above shows that treatments 2 and 5 performed worst whereas treatment 1 outperforming all the others. Treatments 3 and 4 performed quite well, but in all, treatment 1 is to be considered when it comes to area of plant leaves. At the early stages, all the treatments were performing moderately good till the second period of the data collection to the last data collections period where treatment 1 outperforming all the others. Thus, raising cocoa seedlings by using the topsoil should be considered by cocoa farmers. Farmers are therefore recommended to use the mixture of 50% topsoil and 50% river sand if the topsoil is insufficient to raise cocoa seedlings for transplanting.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

The main objective of this study was to find out which of the mixture of topsoil and river sand in various ratios will support the growth of cocoa hybrid seeds in order to get substitute media in cocoa nursery management. To get a firm determination of that, the researcher decided to find the treatment with the maximum average of the parameters plant height, number of leaves, stem diameter, canopy, and leaf area. From the table 4.1, it is clearly seen that treatment 3 performed better during the early stages, followed by treatment 4, while treatment 5 performed poorly. However, from the time of second data collection (07/05/2021) to the last, treatment 1 consistently performed better than all the other treatments. From this, it can be concluded that treatment 1 will best support the growth of cocoa seeds. This was followed by treatment 3 and treatment 4. Thus, in the absence of treatment 1, treatment 3 or treatment 4 can also be suitable to support the cocoa seedlings. Treatment 5 performed badly from the early stages through to the last period. This implies that, it is the treatment that should be least considered to support the growth of the cocoa seedlings.

6.2 Conclusion

Treatment 1 (100%topsoil) positively influenced the growth performance of the cocoa seedlings based on plant height, stem girth and number of healthy leaves. Thus, in the absence of treatment 1 (100%topsoil), treatment 3 the mixture of 50% topsoil and 50%river sand (1:1) positively influenced the growth performance of the cocoa seedlings based on plant height, stem girth and number of healthy leaves. Or treatment 4 (75%topsoil+25%river sand) can also be suitable to support the growth of cocoa seedlings. Treatments 5 and 2 (100 %River sand) and (25%topsoil + 75%river sand) were ranked worst growth media because of their undesirable influence on growth performance of cocoa seedlings this could be due to some factors such as poor water holding capacity, soil particles size and low organic matter content. This implies that, it is the treatments that should be least considered to support the growth of the cocoa seedlings.

6.3 Recommendations

Though the control experiment (Topsoil) was rated the best medium, its continual use as a candidate growth medium could threaten the environment (i.e., soil degradation, non-sustainable, non-renewable).

- Since good morphological development of seedling enhances better field establishment, the use of treatment 3 though was rated second best medium to amend growth medium could be a promising alternative for raising cocoa seedlings.
- In a situation where topsoil is scarce, cocoa seedlings could be raised with treatment 3 which is 50%topsoil and 50%River Sand (1:1) mixture.

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