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GROWTH PERFORMANCE OF COCOA *(THEOBROMA CACAO)* HYBRID SEEDS IN DIFFERENT MEDIA

ANING ISAAC

MASTER OF EDUCATION (AGRICULTURE)

MARCH, 2022

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UNIVERSITY OF EDUCATION, WINNEBA

FACULTY OF AGRICULTURE EDUCATION

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GROWTH PERFORMANCE OF COCOA *(THEOBROMA CACAO)* HYBRID SEEDS IN DIFFERENT MEDIA

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DECLARATION

STUDENT'S DECLARATION

I, ANING ISAAC, declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE……………………………..

DATE……………………………………..

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this project work were supervised following the guidelines for supervision of Dissertation as laid down by the University.

SUPERVISOR'S NAME: PROF. KOFI AGYAKO

SIGNATURE……………………………..

DATE……………………………………..

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DEDICATION

I, Aning Isaac, dedicate this work first to the immortal God, for the strength, wisdom, and favor upon me throughout the whole academic work.

Secondly, to my parents, Mr & Mrs. Isaac Aning Afriyie, and the entire family members. May God replenish all they have lost on me.

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ABSTRACT

The study was conducted to determine the growth performance of cocoa (*Theobroma cacao*) hybrid seeds in different media. The study was carried out at the multipurpose crop nursery, college of Agriculture Education, Akenten-Appiah Menkah University Of Skills Training And Entrepreneurial Development. The experiment was laid out in a randomized complete block design with three replication and four treatments. The treatments were Topsoil , 50 % Topsoil + 50 % cocoa Husk , 50 % Topsoil + 50 % Rice Husk ,and 50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk. 80 polybags were filled for each replication, making a total of 240 filled polybags and a seed was sown per polybag. 80 seeds were used for each replication making a total of 240 seeds for the study. The variables observed were plant height, number of leaves, canopy spread, leaf area, and stem diameter. The results showed no significant difference among most of the treatments. 50 % Topsoil + 25 % Rice husk + 25 % Cocoa Husk showed a better effect in improving the growth of cocoa seedlings among the treatment. It could be concluded that the 50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk can support the growth of the hybrid cocoa (*Theobroma Cacao*) seedlings and could be used as a substitute for the topsoil.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Cocoa (*Theobroma cacao*) is one of the most important agricultural export commodities in Ghana. It is one of the most modeled commodities internationally and attracts premium prices globally due to its great nutritional and health benefits derived from its consumption. In Ghana, it is the highest export crop, accounting for 8.2 % of the country's GDP, 30 % of total export earnings in 2010 (Zakaria, 2017), and employing over 30 % of the population. Cocoa is the most important cash crop cultivated in Ghana and it is established on about 1,600.00 hectares (Amon-Armah *et al.*, 2021). It is a major raw material used in the production of cocoa powder (for beverage drinks, chocolate, and various chocolate-based products, biscuits, and confectioners). The processed cocoa bean is also used to make sweets, sweetening products, cocoa butter, and cosmetics and is used in pharmaceuticals.

The cocoa pod husk is used in making soap locally (Lu *et al.*, 2018). The production of cocoa in Ghana is threatened by unproductive trees on over-aged farms. Rehabilitating these old farms will require raising millions of seedlings for transplanting and this will also require large quantities of topsoil for the nursery works. The use of topsoil only as a potting medium will destroy the ecosystem of the areas where the topsoil is collected (Quaye *et al.,* 2019). The use of topsoil alone will also require additional inorganic fertilizers to supplement the seedling's nutrient demand. The compactness of topsoil restricts seedlings' root growth and makes nursery polybags too heavy for conveyance over long distances for field transplanting (Davis & Pinto, 2021).

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A growth media is a substrate on which plants grow. It is an integral part of crop production that provides anchorage for the plant roots, and air spaces to enhance aeration and retain sufficient available water (Pereira *et al.,* 2020). Growing media affect plants' performance in the nursery bed and container nursery production. The inherent nutrients and soil factors determine the productivity of crops. Mostly, nursery or propagation media influence the emergence and growth of seedlings (Eigenbrod & Gruda, 2015). Thus, suitable media that could enhance the vigor of seedlings is crucial for continual cocoa production.

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. As a result, the 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 and diseases (Anthonio *et al.,* 2018). Therefore, farmers need good cocoa seedlings for replanting their plantations. Yet, cocoa nurseries face a lot of challenges in cocoa growing areas of which, the lack of suitable growth media for propagation of hybrid cocoa seedlings is a typical example. More so, Topsoil for nurseries is usually conveyed from scarcity which hinders the attainment of the government and COCOBOD goals of raising healthy hybrid cocoa seedlings for effective and efficient distribution to farmers (Anthonio *et al.,* 2018). Fortunately, different growth media are available, which are economical and could be a suitable alternative to this already known Topsoil. Some agro-industrial waste materials such as sawdust, rice husk, and coconut fiber have been successfully used as alternatives to the topsoil for potting plants (Amoah-Antwi *et al.,* 2020). The use of these organic materials as potting media provides environmental benefits as ecosystem damage caused by soil extraction can be avoided and environmental problems associated with their disposal are mitigated. The use of agricultural waste such as rice husk and cocoa pod husk could be investigated.

1.3 The hypothesis of the study

The study was conducted based on the hypothesis that amending the Bediese soil with rice husk or cocoa pod biochar can enhance its quality and improve the growth performance of cocoa seedlings.

1.4 Objectives of the study

1.4.1 Main objective

The main objective of the study was to determine the impact of rice husk and cocoa pod husk on the growth performance of cocoa seedlings.

1.4.2 Specific objectives

The specific objectives of the study were to;

1. Evaluate the effects of rice husk, cocoa pod husk, and rice husk + cocoa pod husk as soil amendments on seedling emergence of cocoa at the nursery.
2. Evaluate the growth performance of hybrid cocoa seedlings in soil amended rice husk, cocoa pod husk, and rice husk + cocoa pod husk.

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CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Description of Cocoa

Cocoa belongs to the family *Malvaceae* which is acknowledged for having flowering plants that are entomophilous and bisexual. It is made up of about 200 genera and close to 2,300 species disseminated all over the globe and predominantly copious in the tropics (Cook *et al.*, 2021). Cocoa is one of the 22 species of the genus Theobroma and the only species of economic importance (Huda-Shakirah *et al.*, 2022). The plant is a local species of tropical humid forests on the lower eastern equatorial slopes of the Andes in South America. Nowadays, cocoa is cultivated worldwide, and it is grown in the tropical rainforest of Africa, Asia, and Latin America. In Ghana, cocoa is cultivated in the forest areas of the country (Ashanti, Brong Ahafo, Eastern, Western, Central, and Volta) where the rainfall is sandwiched between 1000 and 1500 mm per year. It was introduced into the Southern region of the Gold coast in the mid-19th century (Darfour, 2019).

2.2 Constraints to Cocoa Production in Ghana

Cocoa is an important cash crop in Ghana and its cultivation has a lot of challenges which include poor soil fertility which results from continuous cropping of farmlands. Relative to other continents in the world, most of the soils in Africa are naturally not very fertile (Onyutha, 2019). They are typically low in available nitrogen and commonly deficient in Sulphur, Magnesium, and Zinc (Wortmann *et al.*, 2019). Healthy and vigorous cocoa seedlings are essential to boosting the productivity of the cocoa tree. Poor fertility of seedling propagating medium is a major constraint to the development of vigorous cocoa seedlings. According to (Njonjo *et al.*, 2019) poor soil nutrients and poor seedlings vigor are major production constraints in Ghana.

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Based on their economic importance, the diseases of cocoa in Ghana can be categorized into two groups thus, the major and the minor ones. The major ones are the cocoa swollen shoot virus disease and the Phytophthora pod rot diseases. The minor ones include pink disease, thread blight, mealy pods, root rot, cushion gall, charcoal pod rot, warty pods, and damping off disease of nursery plants (Tiwari *et al.*, 2020).

2.3 Growth Requirements of Cocoa

Cocoa thrives best in soils that are moist, nutrient-rich, well-drained, and aerated. Cultivation of cocoa requires adequately drained, properly aerated soil with a fine crumb structure and adequate supplies of water and nutrients. Cocoa seedlings require sufficient nutrients such as nitrogen, phosphorous, potassium, and other metabolites (proteins, lipids, carbohydrates) for their growth and development (Tiwari *et al.*, 2020). Cocoa can grow in soils with a pH range of 5.0 - 7.5. It can therefore cope with both acidic and alkaline soils, but excessive acidity (pH 4.0 and below) or pH 8.0 and above must be avoided. Cocoa is tolerant to acidic soil, provided the nutrient content is high enough (Snoeck *et al.*, 2016).

Cocoa can successfully be grown in areas having rainfall between 1100 mm and 3000 mm per annum. For optimum production, areas with annual rainfall between 1500 - 2000 mm and a dry season of not more than three months with not less than 100 mm of rain per month are preferred. The average annual temperature should be around 25 °C. In Ghana, cocoa is grown in areas with temperatures between 25 °C and 26 °C. The relative humidity is generally high in cocoa-producing regions ranging from 70 to 80 %(Asigbaase *et al.*, 2021)

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2.4 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 (Tambi & Lum, 2020), cocoa is a highly competitive and lucrative economic cash crop ranked highest in terms of income generation among other agricultural activities in the global markets. 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 (Indah *et al.*, 2022).

Cocoa is the main raw material used in the production of cocoa products such as beverage drinks, chocolate, and various chocolate-based products, biscuits, and confectioneries. The processed cocoa bean is also used to make sweets, sweetening products, cocoa butter, and cosmetics and is used in pharmaceuticals. The cocoa pod husk is used in making soap locally (Cook *et al.*, 2021).

The sugar obtained from fresh cocoa pulp juice "sweatings" varies from 10 - 15 % (w/v). The pulp juice is used for the production of alcoholic beverages such as the local gin (akpeteshie), wine, gin, and brandy. Fat extracted from discarded beans is used in the production of soap and cosmetics for household and commercial purposes (Cook *et al.,* 2021). Cocoa pod husk contains a very high nutritional value and can be used to feed animals but their use is restricted by the "Theobromine" which is toxic to livestock up to certain levels. Cocoa pod husk has a high polysaccharide content of about 42 % on a dry weight basis, a crude fiber content of 24 – 35 %, and a crude protein content of 6.35 %. The potash obtained from cocoa pod husk can be used as fertilizer but the majority of it is used for soap production (Cook *et al.,* 2021).

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2.5 The Physical Properties of a Growing Media

Studies show (Tan *et al.,* 2021) that the physical make-up of the 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 media 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 affect factors such as bulk density, water holding capacity, and porosity (Sarmah & Karak, 2020). Porosity is defined as the total volume of pore space in a growing medium that controls the movement of water through the soil profile (Siedt *et al.*, 2021). Therefore, as the bulk density decreases, total pore space increases linearly. The total porosity of a media controls the movement of water through the soil profile (Siedt *et al.*, 2021).

Particle size and pore space distribution influence the water to air ratio held in the root media. According to (Caron & Michel, 2021), 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 to have a lower available water level. On the other hand, a mix that will be watered once a week will need to have

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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 (Ramlee *et al.*, 2019). There are two types of pore space within a root media; capillary and non-capillary pores. The capillary pores are smaller (less than 0.3 mm) pores that retain much water after watering whiles the non-capillary pores are larger (greater than 0.3 mm) pores that provide aeration for the roots.

2.6 Types of Growing Media

There exist two main growing media namely, soil-based and soilless media. A soil-based media mix refers to a potting media which contains some percentage of soil (Medyńska-Juraszek & Ćwieląg-Piasecka, 2021). Soil mixes are considered to be important and necessary for the growth and development of seedlings as it provides the necessities required by the plant throughout its life. Soil-based mixes contain equal parts of loamy soil, concrete-grade sand, and sphagnum peat moss (Pereira, 2020). For a seed soil-based mix, one part loam, one part leaf mold or peat moss, and one part sand are recommended (Gruda & Bragg, 2021). Soilless media refers to a potting media that contains any organic material without soil. This is sometimes referred to as sterile mix (Gruda et al., 2021). They are extremely lightweight, nutrient retentive, and sterilized (heated to kill microorganisms 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 (Maucieri *et al.*, 2019). Quality soilless mixes should be low in soluble salts with a pH of 5 –6.5 (Bar-Tal *et al.*, 2019). (Yasin *et al.*, 2020) recommended one part perlite, one part peat moss, and one part ground or milled sphagnum moss for a soilless mix. Until the

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1970s, seedlings or potted plants were grown in potting mixes which were based on soil amended with coarse sand and peat (Agarwal *et al.*, 2021).

2.7 The use of Soil as a Growth Medium in Nurseries

Soil is the heaviest of all growing media and is usually low in organic matter which reduces its ability to hold water (Gondek *et al.*, 2020). Soil is a mixture of minerals, organic matter, gases, liquids, and organisms that serves as 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 (Villas-Boas *et al.*, 2016). The presence of organic matter, water, and 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 make 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 (Siedt *et al.*, 2021).

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 in 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 behavior. Soil pH strongly affects the availability of nutrients. Cation exchange, between colloids and soil water buffers (moderates) soil pH, alters soil structure, and purifies

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percolating water by adsorbing cations of all types (Siedt *et al.*, 2021). 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 into the solution. Sixteen nutrients are essential for plant growth and reproduction (Mengel & Kirkby, 2012). A wide variety of soils have been successfully used in different countries. These include sandy soil partially sterilized by heating over a fire; deep friable topsoil, overlying alluvial clay mixed with a small proportion of coarse river sand in the proportion of 3:2; peat and sand mixed in equal proportions; sandy soil; inland clay-loam topsoil and silted forest topsoil (Siedt *et al.*, 2021). In general, fertile topsoil, sufficiently free-draining to prevent sealing of the surface has been recommended (Siedt *et al.*, *2*021).

2.8 The Use of Agricultural Residues as Growth Medium in Nurseries

The global annual production of agricultural residues is estimated to be more than 500 million tonnes (Molina-Guerrero *et al.*, 2020). Ghana's agricultural sector is characterized by a large number of dispersed small-scale producers, employing manual cultivation techniques, and dependent on rain-fed with little or no purchased inputs (Siedt *et al.*, 2021). Major crop residues generated in Ghana include straw or stalk of cereals such as rice, maize/corn, sorghum and millet, kola pod husk, and cocoa pod husk, while agro-industrial by-products include maize cob, cocoa husk, Coconut shell and husk, rice husk, oil seed cake, sugarcane bagasse and oil palm empty fruit bunch. It is estimated that about 41590 tonnes of agricultural crop residues were generated in the country in 2008 (Quaye *et al.*, 2019). The agricultural and agro-industrial residues, if

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managed properly, can be beneficial to agriculture, since these contain important plant nutrients such as nitrogen, phosphorus, potassium, magnesium, and other nutrients. (Nduka *et al.*, 2015) reported that cocoa pod husk manure contains Ca, P, K, and also a sizeable amount of useful organic constituents. (Siedt *et al.*, 2021) observed that cocoa pod husk manure is effective in raising cocoa seedlings in the nursery. Grounded cocoa pod husk when applied to soil, as reported by (Adejobi *et al.*, 2011) increased maize yield by 12.4% and the uptake of P, K, and Mg by the crops. (Siedt *et al.*, 2021) reported that agricultural residues can be properly managed by using them as soil amendments (compost or biochar) to enrich the degraded soils with very low organic matter content. One of the technologies that have been practiced for raising seedlings in many countries is the use of alternative growing media such as the use of sawdust and rice husk (Ravindran *et al.*, 2022).

Organic components used include peat, soft and hardwood barks, or sphagnum moss. Recent studies have shown that leaf mulch, rice husk as well as other agricultural wastes such as peat, cocoa pod husk, and kola pod husk has been used as a medium for supporting seedling growth (Ravindran *et al.*, 2022). Organic matter either fresh or composted plays a critical role in maintaining nutrient availability and thus enhancing plant productivity (Ravindran *et al.*, 2022). It has, however, been shown to be of greatest value in soils with low fertility where large fertility improvements occur (Ravindran *et al.*, 2022). Organic matter improves the physical, chemical, and biological properties of soil. It also supplies plants with essential nutrients and soil organisms with energy (Ravindran *et al.*, 2022).

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2.9 Rice husk

Rice husks also known as rice hulls are the outermost covering of the paddy grain rice which is separated from the brown rice during rice milling. It is one of the most widely available agricultural by-products in the world (Ravindran *et al.*, 2022). Globally, approximately, 600 million tonnes of rice paddy are produced every year and an average of 20 % of the paddy rice is the husk. Rice husk contains 75 – 90 % organic matter such as cellulose, and lignin and the rest is mineral components such as silica, alkalis, and trace elements (Ravindran *et al.*, 2022). Rice husk biochar improves nitrogen content and soil biomass. (Ravindran *et al.,* 2022). It is an agricultural waste that can cause serious environmental problems but it had been used as a soil amendment (Ravindran *et al.,* 2022).

Studies have shown that rice husks have been used in media trials as an alternative to peat and peat/perlite mixes (Ravindran *et al.*, 2022). Rice husk had been used as a medium for hydro phonic gardening and has been found to have the same properties as sand or rock wool. It also has similar properties as peat moss and could be used as a substitute for peat. (Ravindran *et al.,* 2022) reported that the best organic way to amend clay soil was to use rice husk. Rice husk is an organic material that can be used as a mulching material or in compost or mixed with soil to improve the aeration and water holding capacity of the soil. It is effective in loosening heavy soil and providing organic matter to the soil which enables the soil to retain water and nutrients and this will encourage plant growth and development (Sosu, 2014). Studies have shown that decomposition and nitrogen depletion do not occur in rice husk thus it is best used with compost or soil as a soil amendment (Ravindran *et al.*, 2022). In Thailand, carbonated rice husks have exhibited alkaline properties and large water absorption capacity which

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functioned as a suitable soil conditioner for acid sandy soils (Pode, 2016). The use of rice husk as an organic fertilizer is essential as it plays the role of improving soil's physical properties, nutrition, and water use efficiency (Demir & Gülser, 2021).

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CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental location

The field experiment was carried out at the multipurpose crop nursery, College of Agriculture Education, Akenten-Appiah Menkah University of Skills Training and Entrepreneurial Development, Asante Mampong campus from April to June 2021 and August to October 2021. Asante Mampong is in the transitional zone located between the Southern Rainforest belt and the Guinea Savannah belt and at an elevation of 457.5 m above sea level and latitude 07°, 04'N, and longitude 01°, 24'W of the equator (Osae *et al.*, 2020).

3.2 The climatic condition of the study area

The area has an average annual rainfall of 1270 mm to 1524 mm which occurs in a bimodal pattern, with the major rainy season from March to July and the minor season from September to November. A short dry spell usually occurs in August (Gyekye et al., 2020). A long dry season that occurs from December to February separates the two main seasons. During this period, the average monthly temperature rises to about 29 – 31°C (Gyekye *et al.*, 2020).

3.3 Vegetation and soil type of the study area

The vegetation of the area is described as the forest-savannah transition type. The common trees and shrubs in the area include wawa, odum, sapele, mahogany, neem tree, acacia, and mango. The vegetation also supports crops such as cocoa, coffee, oil palm, plantain, banana, citrus, cocoyam, and cereals such as maize and rice. Cyperus, spear grass, and elephant grass are common weeds found in the area.

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The soil is derived from the voltaic sandstone of Afram plains belonging to the savannah Ochrosol class (Osae *et al.,* 2020). It is Chromic Luvisol and locally as Bediesi series. Apart from being deep sandy loam and free from pebbles, it is also well-drained soil containing a moderate amount of organic matter with a pH of 6.0 to 6.5 (Gyekye *et al.*, 2020).

3.4 Growth media preparation

Dried rice husks and dried broken decomposed cocoa pod husks were obtained from Ejura farms and the University research farm respectively. These were pounded to obtain a finer texture compost. The topsoil used was sieved with a sieve of mesh size of 2 mm to get rid of unwanted materials. The rice husk and the cocoa pod husk were mixed with the topsoil at different ratios into polybags of 15.7 cm high and 13.2 cm wide, where the polybags represented the various plots.

3.5 Experimental design, field layout, and treatment

The experiment was laid out in Randomized Complete Block Design (RCBD) with the four levels of root media as the treatments. This was replicated three times.

A total volume of 10500 cm^3 was used in the determination of the mixing ratios per treatment.

Treatments

T_1 – (Control) – 100 % topsoil (10500 cm^3) with no rice husk and cocoa pod husk

T_2 – 50 % volume of topsoil (5250 cm^3) with 50 % rice husks (5250 cm^3)

T_3 – 50 % volume of topsoil (5250 cm^3) with 50 % cocoa pod husks (5250 cm^3)

T_4 – 50 % volume of topsoil (5250 cm^3) with 25 % rice husk (2625 cm^3) and 25 % cocoa pod husk (2625 cm^3)

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3.5.1 Field Layout

The experimental area measured 2.5 m x 1.75 m and each treatment plot around with its polybags measured 0.5 m x 0.25 m with a spacing of 0.25 m between treatment plots and 0.5 m among the replications. The spacing between polybags on treatment potions was 0.10 m by width and 0.10 m by length. Each treatment plot had two rows of polybags with five plants per row in a polybag for each cocoa pod husk treatment and the control (Figure 3.1).

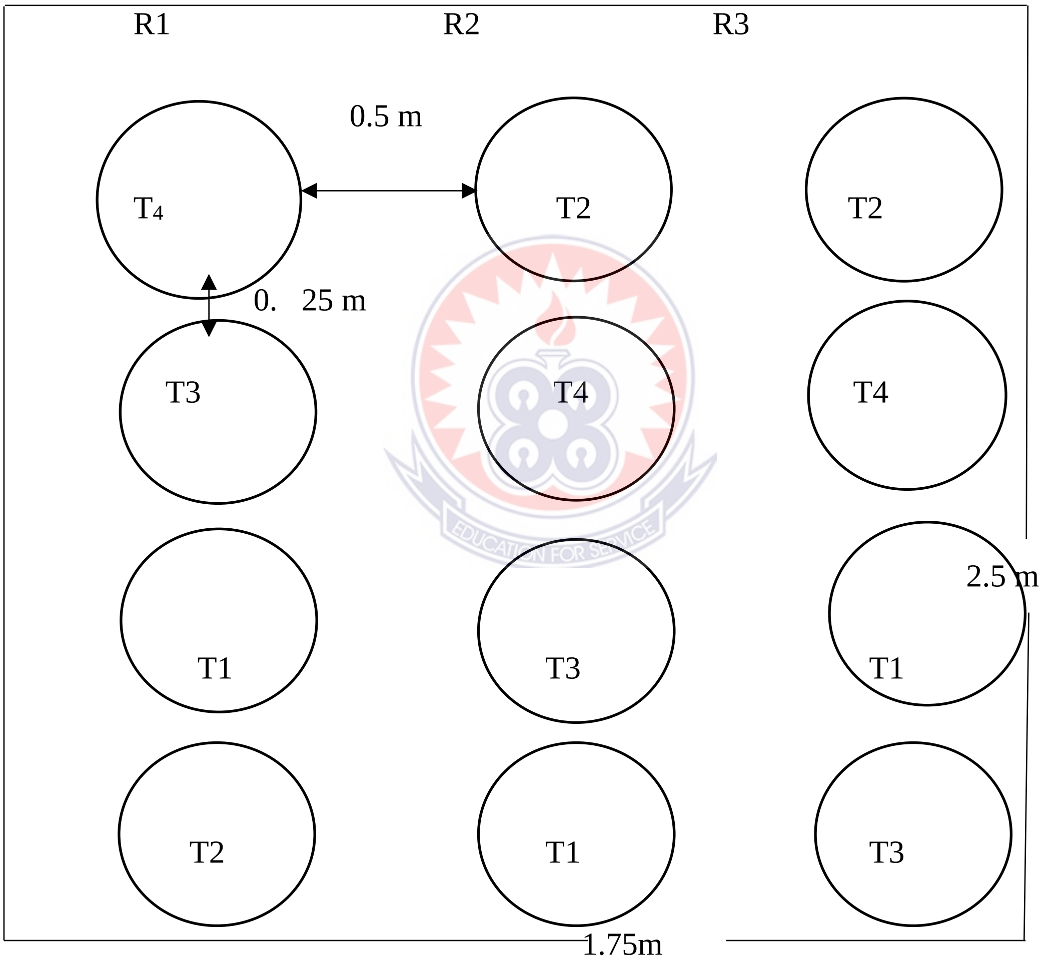

Figure 3.1:Nursery layout for the experiment

3.6 Sowing and management of plants

The research was carried out under a nursery shade. The cacao seeds used were a Clone 67 hybrid variety. Seeds were nursed on 16/02/2021. Twenty (20) seeds were planted for

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each plot consisting of 20 polybags about 2 cm in depth. Nursed seeds were watered once every day with 250 ml of water per polybag.

3.7 Agronomic practices

During the research, weeds were controlled by handpicking and seedlings were watered when necessary.

3.8 Data collection

3.8.1 Number of days to seedling emergence

The initial planting date was noted and the date of seedling emergence from each treatment was also noted. The difference between the date of planting and seedling emergence for each treatment was calculated to determine the number of days for seedling emergence on each treatment.

3.8.2 Germination count

The number of seeds developing into new plants was counted per treatment.

3.8.3 Plant height (cm)

Five randomly selected seedlings of each treatment were tagged. Their heights were measured at 29, 43, 57, 71, 85, and 99 days after planting (DAP). Seedling height was measured from the base of the stem to the tip using a ruler. The mean height of the five plants was recorded to represent each treatment.

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3.8.4 Leaf area (cm^2)

Three leaflets from the tagged plants in each treatment were taken for the exercise. The length (L) was taken along the midrib of the leaf from the point of attachment to the petiole to the tip of the leaf. The breadth (B) was taken by measuring the maximum width of the leaf (Khaembah *et al.*, 2020). The leaf area (LA) was estimated and the mean from the five tagged plants was used to represent the leaf area.

3.8.5 Number of leaves

Five randomly selected seedlings of each treatment were tagged. Their leaves were counted at 29, 43, 57, 71, 85, and 99 days after planting (DAP). The number of leaves was counted from the bottom to the top. The mean leaves of the five seedlings were recorded to represent each treatment.

3.8.6 Stem girth (mm)

Five randomly selected seedlings of each treatment were tagged. Their girths were measured at 29, 43, 57, 71, 85, and 99 days after planting (DAP). The seedling girth was measured at 5 cm above the soil surface using a vernier caliper. The mean girth of the five seedlings was recorded to represent each treatment.

3.9 Data Analysis

All data collected were subjected to one–a way analysis of variance (ANOVA) using the GenStat 18th Edition Computer Package. Means were separated by multiple comparison tests using Turkey's Least Significance Difference (LSD) at $P \leq 0.05$.

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CHAPTER FOUR

4.0 RESULTS

4.1 Plant height

Table 4.1 shows that there were no significant (P < 0.05) differences among the treatments at 29 DAP

However, 50% Topsoil + 25 % Rice Husk + 25 % Cocoa Husk recorded the highest mean value (14.27 cm) of plant height at 29 DAP. Topsoil (control) recorded the least mean value (12.22 cm) at 29 DAP.

Table 4.1 Effect of different media on the plant height of cocoa seedlings

Treatment	Plant height (cm)					
	29DAP	43DAP	**57DAP**	71DAP	85DAP	**99 DAP**
Topsoil	12.22a	13.47a	14.40a	15.07a	16.27a	18.60a
50 % Topsoil + 50 % Rice Husk	13.20a	14.40ab	14.80a	15.73ab	17.20ab	19.00a
50 % Topsoil + 50 % Cocoa Husk	12.97a	14.32ab	14.90a	15.67ab	16.87ab	18.33a
50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk	14.27	15.60b	16.13a	17.73b	18.60b	19.53a
LSD	2.45	1.51	1.76	2.20	2.23	2.85
CV (%)	9.3	5.2	5.8	6.8	6.5	7.5

The same letter (a) means no significant difference while the different letter (a, b) means a significant difference at p = 0.05.

Table 4.1 shows that there were no significant (P < 0.05) differences among the treatments at 29 DAP. However, 50% Topsoil + 25 % Rice Husk + 25 % Cocoa Husk recorded the highest mean value (14.27 cm) of plant height at 29 DAP. Topsoil (control)

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recorded the least mean value (12.22 cm) at 29 DAP. There were significant (P > 0.05) differences among the treatments at 43 DAP. However, 50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk recorded the highest mean plant height value (15.60 cm) at 43 DAP while the Topsoil recorded the least mean value (13.47 cm) at 43 DAP. There were no significant (P < 0.05) differences among the treatments at 57 DAP (Table 4.1). However, 50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk recorded the highest mean value (16.13 cm) at 57 DAP.The Topsoil recorded the lowest mean value (14.40 cm) at 57 DAP. There were significant (P > 0.05) differences among the treatments at 71 DAP. The 50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk recorded the highest mean plant height value (17.73 cm) at 71 DAP.

The Topsoil recorded the least mean value (15.07 cm) at 71 DAP. There were significant (P > 0.05) differences among the treatments at 85 DAP. The 50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk recorded the highest mean plant height value (18.60 cm) at 85 DAP. The Topsoil recorded the least mean value (16.27 cm) at 85 DAP. There were no significant (P < 0.05) differences among the treatments at 99 DAP. However , 50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk recorded the highest mean value (19.53 cm) at 99 DAP . The 50 % Topsoil + 50 % Cocoa Husk recorded the least mean value (18.33 cm) at 99 DAP. Among all the treatment mean values for plant height, there was consistency where the 50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk recorded the highest mean value from 29 DAP to 99 DAP and the Topsoil also recorded the least mean value from 29 DAP to 85 DAP.

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4.2 Number of leaves per plant

Table 4.2 shows tha there weret no significant (P < 0.05) differences in the number of leaves among the various treatments at 29 DAP.

Table 4.2 Effect of different media on the number of leaves of cocoa seedlings

Treatment	Number of leaves per plant					
	29DAP	43DAP	**57DAP**	71DAP	85DAP	**99DAP**
Topsoil	5.02a	6.13a	6.87a	8.47a	10.47a	11.40a
50 % Topsoil + 50 % Rice Husk	5.40a	6.13a	6.93a	8.87a	11.13a	11.00a
50 % Topsoil + 50 % Cocoa Husk	5.07a	6.40a	7.07a	9.27a	10.20a	11.33a
50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk	5.53a	7.27a	7.00a	9.53a	10.73a	11.80a
LSD	1.16	2.32	3.62	2.49	4.05	1.81
CV (%)	11.1	17.9	26.0	13.8	19.0	7.9

The same letter (a) means no significant difference while the different letter (a, b) means significant differences at p=0.05.

The 50 % Topsoil + 25 % Rice Husk + 25% Cocoa Husk recorded a higher number of leaves than the rest of the treatment from 29 days (5.53), 43 days (7.27), 71 days (9.53) and 99 days whiles the Topsoil recorded the least mean value at 29 DAP (5.02), 43 DAP (6.13), 57 DAP (6.87) and 71 DAP (8.47).

4.3 Canopy Spread

Table 4.3 shows that there were no significant (P < 0.05) differences among the treatments at 29 DAP. However, the 50 % Topsoil +25 % Rice Husk+25 % Cocoa Husk

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recorded the highest mean value (14.47 cm) while Topsoil (control) recorded the least mean value (11.20 cm) at 29 DAP.

Table 4.3 Effects of different media on the canopy spread of cocoa seedlings

Treatment	Canopy Spread (cm)					
	29DAP	43DAP	**57DAP**	71DAP	85DAP	**99DAP**
Topsoil	11.20a	16.47a	17.47a	22.40a	23.20a	29.60ab
50 % Topsoil + 50 % Rice Husk	11.73a	18.33a	18.33ab	22.40a	22.13a	25.07a
50 % Topsoil + 50 % Cocoa Husk	12.07a	17.07a	20.73b	23.53a	24.73a	33.67b
50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk	14.47a	19.00a	20.27ab	23.27a	25.33a	28.40ab
LSD	4.85	2.67	3.15	3.40	6.70	4.45
CV (%)	19.6	7.5	8.2	7.4	14.1	7.6

The same letter (a) means no significant difference while the different letter (a, b) means significant differences at p=0.05.

There were no significant differences among the treatments at 43 DAP. However, the 50 % Topsoil +25 % Rice Husk + 25 % Cocoa Husk recorded the highest mean value (19.00 cm) while the Topsoil recorded the least mean value (16.47 cm) at 43 DAP. There were significant ($P > 0.05$) differences among the treatments at 57 DAP. However, the 50 % Topsoil + 50 % Cocoa Husk recorded the highest mean value (20.73 cm) at 57 DAP while the Topsoil recorded the lowest mean value (17.47 cm) at 57 DAP. There were no significant ($P < 0.05$) differences among the treatments at 71 DAP. However, the 50 % Topsoil + 50 % Cocoa Husk recorded the highest mean value (23.53 cm) at 71 DAP. The least mean value was both the Topsoil and the 50 % Topsoil + 50 % Rice

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Husk with a mean value of (22.40 cm) at 71 DAP. There were no significant (P < 0.05) differences among the treatments at 85 DAP. However, the 50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk recorded the highest mean value (25.33 cm) at 85 DAP while the 50 % Topsoil + 50 % Rice Husk recorded the least mean value(22.13 cm) at 85 DAP. There were significant (P > 0.05) differences among the treatments at 99 DAP. However, the 50 % Topsoil + 50 % Cocoa Husk recorded the highest mean value (33.67 cm) at 99 DAP whiles the 50 % Topsoil + 50 % Rice Husk recorded the least mean value (25.07 cm) at 99 DAP.

4.4 Leaf Area

Table 4.4 shows that there were no significant (P < 0.05) differences among the treatment means for the Leaf Area of cocoa seedlings from 29 DAP – 99 DAP.

Table 4.4 Effect of different media on the leaf area of cocoa seedlings

Treatment	**Leaf Area (cm^2)**					
	29DAP	**43DAP**	**57DAP**	**71DAP**	**85DAP**	**99DAP**
Topsoil	9.9a	10.25a	11.11a	15.33a	17.66a	20.35a
50 % Topsoil + 50 % Rice Husk	9.8a	11.32a	11.09a	14.43a	15.30a	16.78a
50 % Topsoil + 50 % Cocoa Husk	6.9a	10.88a	11.77a	16.11a	16.82a	19.79a
50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk	9.6a	13.31a	12.07a	14.90a	17.25a	19.43a
LSD	7.08	3.48	2.78	2.51	2.94	3.70
CV (%)	39.2	15.2	12.1	8.3	8.8	9.7

The same letter (a) means no significant difference while the different letter (a, b) means significant differences at p=0.05.

The highest means at 29 DAP (9.9 cm^2), 85 DAP (17.66 cm^2), and 99 DAP (20.35 cm^2) were recorded by the Topsoil whiles at 43 DAP (13.31 cm^2) and 57 DAP (12.07 cm^2) the

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highest were recorded by 50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk and at 71 DAP (16.11 cm^2) the highest was recorded by 50 % Topsoil + 50 % Cocoa Husk. The lowest means at 29 DAP (6.9 cm^2) was recorded by 50 % Topsoil + 50 % Cocoa Husk and 43 DAP (10.25 cm^2) was also recorded by Topsoil while 71 DAP (14.43 cm^2), 85 DAP (15.30 cm^2), and 99 DAP (16.78 cm^2) were recorded by 50 % Topsoil + 50 % Rice Husk.

4.5 Stem diameter

Table 4.5 shows that there were no significant (P < 0.05) differences among the treatments at 29 DAP. However, the 50 % Topsoil + 50 % Rice Husk recorded the highest mean value (0.33 cm) while both the Topsoil and the 50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk recorded the least mean value(0.31 cm) at 29 DAP

Table 4.5 Effect of different media on the stem diameter of cocoa seedlings

Treatment	Stem Diameter (cm)					
	29DAP	43DAP	**57DAP**	71DAP	85DAP	**99DAP**
Topsoil	0.31a	0.41a	0.46a	0.46a	0.49a	0.57ab
50 % Topsoil + 50 % Rice Husk	0.33a	0.39a	0.44a	0.47a	0.50a	0.55a
50 % Topsoil + 50 % Cocoa Husk	0.32a	0.42a	0.45a	0.48a	0.50a	0.55a
50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk	0.31a	0.43a	0.47a	0.53a	0.55a	0.61b
LSD	0.08	0.04	0.07	0.08	0.07	0.04
CV (%)	13.1	5.2	7.5	7.9	7.1	3.7

The same letter (a) means no significant difference while the different letter (a, b) means significant differences at p=0.05.

There were no significant (P < 0.05) differences among the treatments at 43 DAP. However the 50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk recorded the highest

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mean value (0.43 cm) whiles the 50 % Topsoil + 50 % Rice Husk recorded the least mean value (0.39 cm) at 43 DAP. There were no significant ($P < 0.05$) differences among the treatments at 57 DAP. However, the 50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk recorded the highest mean value (0.47 cm) whiles the 50 % Topsoil + 50 % Rice Husk recorded the least mean value (0.44 cm) at 57 DAP. There were no significant ($P < 0.05$) differences among the treatments at 71 DAP.

However, the 50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk recorded the highest mean value(0.53 cm) whiles the Topsoil (control) recorded the least mean value (0.46 cm) at 71 DAP. AT 85 DAP, there were no significant ($P < 0.05$) differences among the treatments. However, the 50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk recorded the highest mean value (0.55 cm) whiles the Topsoil recorded the least mean value (0.49 cm). There were significant ($P > 0.05$) differences among the treatments at 99 DAP. The 50 % Topsoil + 25 % Rice Husk + 25 % Cocoa Husk recorded the highest mean value(0.61 cm) whiles both the 50 % Topsoil + 50 % Rice Husk and the 50 % Topsoil + 50 % Cocoa Husk (0.55 cm) recorded the least mean value at 99 DAP.

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CHAPTER FIVE

5.0 DISCUSSION

The use of agricultural wastes in the preparation of potting media can support seedlings' growth in the nursery and their survival after transplanting (Mariotti *et al.*, 2020). The positive impacts of media types and or their combinations with cocoa pod husk and rice husk on the growth and nutrient uptake of cocoa seedlings in this current study confirms the observations made in other studies (Quaye *et al.*, 2019). During the study, there were no significant differences among the various treatments for some of the days of the experiment. The soil-based mixes produced the highest mean canopy spread, leaf area, plant height, and the number of leaves and stem diameter of cocoa seedlings compared to soil only. The increase in these parameters is an indication of higher growth. Growth is measured as an increase in length, width, volume, and fresh and dry weight of a plant.

The results agree with those (Medina-Vega *et al.*, 2021) who reported that plants of greater heights with larger leaf areas intercept more sunlight faster which is required for photosynthesis to take place to promote growth than plants with smaller leaf areas. This may be because the soil mixes had soil environmental conditions such as ideal pH and electrical conductivity that supported the growth and development of the seedlings. The addition of rice husk and cocoa pod husk had a significant influence on the physical and chemical properties of the topsoil (Jakpa *et al.*, 2020). In the present study, the results show that seedlings grown in the soil and rice husk and or cocoa pod husk media mix recorded the highest plant height, girth, leaf area, and stem diameter as compared to the cocoa seedlings grown in soil only and soilless media. The cause of the difference in the 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,

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cation exchange capacity (CEC), porosity, organic matter content, pH, total phosphorous, soluble Fe, exchangeable al and exchangeable K and Ca. (Demir, 2019). (Chen et al., 2020)reported that the addition of organic matter increases CEC and soil pH and decreases soil bulk density. The rice husk significantly reduced the bulk density of the soil due to its lighter weight. This is in agreement with the findings of (Are, 2019) who showed that the application of biochar improved soil properties such as bulk density, soil strength, and increased soil water retention. Thus, the addition of rice husk or cocoa pod husk to the soil in the media mix decreased the bulk density and increased the organic matter in the media which bound the soil particles together to retain water for better plant growth. The application of organic wastes improves soil structure and soil fertility which provides favorable conditions for plant growth and development.

This can be attributed to the fact that the organic residues that were added to the soil reduced the bulk density of the soil which loosened the soil and thereby increased the air space of the media mix. This is in agreement with the observation of (Omar *et al.*, 2021) that organic matter such as rice hulls loosens the soil and increases the amount of pore space to support root growth. . The increase in soil porosity and soil water retention enhances the absorption of mineral nutrients, water, and air by roots for their development (Abid *et al.*, 2020). Carbonated rice husk acts as a soil conditioner by supplying and retaining nutrients which in turn improves the physical and chemical properties of the soil (Purakayastha *et al.*, 2019). The observation in this study is similar to that of (Abanum *et al.*, 2022) who reported that the addition of organic materials such as cocoa pod husk and kola pod husk as nutrient sources produced a positive effect on cocoa seedlings. (Manirakiza & Şeker, 2020) reported that the use of organic residues helps in increasing and balancing soil nutrients with a consequential increase in crop

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performance. Thus, adding cocoa pod husk to the soil will improve soil structure which will provide a favorable environment for better plant growth. This is in agreement with (Usharani *et al.,* 2019), who reported that the application of organic matter alters the physical properties of the soil such as increasing soil aggregation, aeration, and water holding capacity. The incorporation of organic residues into soils significantly improves some properties of the soil namely: decreasing soil bulk density, soil strength as well as exchangeable aluminum and soluble iron and increasing soil pH, soil organic matter, total phosphorous, exchangeable potassium, and calcium as well as the cation exchange capacity (Muindi, 2019).

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CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

At the end of the experiment, it can be concluded that the topsoil amended treatments, Cocoa pod husk, and Rice husk can support the growth of hybrid cocoa seedlings and could be used as substitutes for topsoil. The soil-based media mixes significantly supported better growth of cocoa seedlings than the topsoil (control) thus the Canopy Spread, Number of Leaves, Leaf Area, Plant Height, and Plant Girth.

6.2 Recommendations

Based on the performance of the cocoa seedlings at the nursery in this experiment, nursery operators could add cocoa pod husk and/or rice husk to the topsoil for the raising of cocoa seedlings. However, considering that cocoa pod husk is more readily available on cocoa farms, the soil and cocoa pod husk mix is recommended as a growth media for raising cocoa seedlings at the nursery.

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REFERENCES

Abanum, N. B., Ede, O. M., Olufemi, A.D., & Arinze, O. V. (2022). Cashew seedlings nursery production in University of Abuja Nigeria and its response to different organic amendments. *Food Science*, *5*(2), 1–15.

Abid, M., Batool, T., Siddique, G., Ali, S., Binyamin, R., Shahid, M. J., Rizwan, M., Alsahli, A. A., & Alyemeni, M. N. (2020). Integrated nutrient management enhances soil quality and crop productivity in maize-based cropping system. *Sustainability*, *12*(23), 10214.

Adejobi, K. B., Famaye, A. O., Adeniyi, D. O., Orisajo, S. B., & Adeyemi, E. A. (2011). Effect of cocoa pod husk ash and goat dung on nutrient content and growth performance of cashew (Anacardium occidentale). *Advances in Environmental Biology*, *5*(7), 1536–1542.

Agarwal, P., Saha, S., & Hariprasad, P. (2021). Agro-industrial-residues as potting media: Physicochemical and biological characters and their influence on plant growth. *Biomass Conversion and Biorefinery*, 1–24.

Amoah-Antwi, C., Kwiatkowska-Malina, J., Thornton, S. F., Fenton, O., Malina, G., & Szara, E. (2020). Restoration of soil quality using biochar and brown coal waste: A review. *Science of The Total Environment*, *722*, 137852.

Amon-Armah, F., Domfeh, O., Baah, F., & Dzahini-Obiatey, H. K. (2021). Effectiveness of the eradication campaign of cocoa swollen shoot virus disease in Ghana: The extension and implementation problem. *International Journal of Pest Management*. https://doi.org/10.1080/09670874.2021.1943049

Anthonio, M. M., Boampong, E. Y., Coleman, F. N., & Anthonio, F. A. (2018). The impact of different growth media on cocoa (Theobroma cacao L.) seedling. *Journal of Energy and Natural Resource Management*, *5*(1).

University of Education,Winneba http://ir.uew.edu.gh

Are, K. S. (2019). Biochar and soil physical health. *An Imperative Amendment for Soil and the Environment; Abrol, V., Sharma, P., Eds*, 21–33.

Asigbaase, M., Dawoe, E., Lomax, B. H., & Sjogersten, S. (2021). Biomass and carbon stocks of organic and conventional cocoa agroforests, Ghana. *Agriculture, Ecosystems & Environment, 306*, 107192.

Bar-Tal, A., Saha, U. K., Raviv, M., & Tuller, M. (2019). Inorganic and synthetic organic components of soilless culture and potting mixtures. In *Soilless culture* (pp. 259–301). Elsevier.

Caron, J., & Michel, J.C. (2021). Understanding and optimizing the physical properties of growing media for soilless cultivation. In *Advances in horticultural soilless culture* (pp. 107–137). Burleigh Dodds Science Publishing.

Chen, X., Yaa, O.K., & Wu, J. (2020). Effects of different organic materials application on soil physicochemical properties in a primary saline-alkali soil. *Eurasian Soil Science*, *53*(6), 798–808.

Cook, A. M., Berry, N., Milner, K. V., & Leigh, A. (2021). Water availability influences thermal safety margins for leaves. *Functional Ecology*, *35*(10), 2179–2189.

Darfour, B. (2019). *Controlling the deterioration of harvested grain/seed to improve food security* [PhD Thesis]. Lowa State University.

Davis, A. S., & Pinto, J. R. (2021). The scientific basis of the Target Plant Concept: An overview. *Forests*, *12*(9), 1293.

Demir, Z. (2019). Effects of vermicompost on soil physicochemical properties and lettuce (Lactuca sativa Var. Crispa) yield in greenhouse under different soil water regimes. *Communications in Soil Science and Plant Analysis*, *50*(17), 2151–2168.

Demir, Z., & Gülser, C. (2021). Effects of rice husk compost on some soil properties, water use efficiency and tomato (Solanum lycopersicum L.) yield under

University of Education,Winneba http://ir.uew.edu.gh

greenhouse and field conditions. *Communications in Soil Science and Plant Analysis*, *52*(9), 1051–1068.

Eigenbrod, C., & Gruda, N. (2015). Urban vegetable for food security in cities. A review. *Agronomy for Sustainable Development*, *35*(2), 483–498.

Gondek, M., Weindorf, D. C., Thiel, C., & Kleinheinz, G. (2020). Soluble salts in compost and their effects on soil and plants: A review. *Compost Science & Utilization*, *28*(2), 59–75.

Gruda, N. S., & Bragg, N. (2021). Developments in alternative organic materials for growing media in soilless culture systems. In *Advances in horticultural soilless culture* (pp. 73–106). Burleigh Dodds Science Publishing.

Gyekye, P. M., Boateng, E., Sadick, A., Baffoe, J. A., Kabutey, B. T., & Mensah, S. O. (2020). *Soil and land Suitability Assessments towards Sustainable Rice Production in the Northern Zone of Ghana*.

Huda-Shakirah, A. R., Mohamed Nor, N. M. I., Zakaria, L., Leong, Y. H., & Mohd, M. H. (2022). Lasiodiplodia theobromae as a causal pathogen of leaf blight, stem canker, and pod rot of Theobroma cacao in Malaysia. *Scientific Reports*, *12*(1), 1–14.

Indah, P. N., Putra, C. A., Edahwati, L., & Maulana, H. (2022). Interdisciplinary Diagnostic Study On Local Economic Through Sustainable Cocoa Development Program In East Java. *Educational Research (IJMCER)*, *4*(1), 43–50.

Jakpa, S., Nyarko, G., & Aidoo, A. E. (2020). The effect of decomposed sawdust and rice hull as growth media on the growth and yield of corchorus *OLITORIUS*.

Khaembah, E. N., Maley, S., George, M., Chakwizira, E., de Ruiter, J., Zyskowski, R., & Teixeira, E. (2020). Crop growth and development dynamics of two fodder beet

University of Education,Winneba http://ir.uew.edu.gh

(Beta vulgaris L.) cultivars sown on different dates in New Zealand. *New Zealand Journal of Agricultural Research*, *63*(3), 449–466.

Lu, F., Rodriguez-Garcia, J., Van Damme, I., Westwood, N. J., Shaw, L., Robinson, J. S., Warren, G., Chatzifragkou, A., Mason, S. M., & Gomez, L. (2018). Valorisation strategies for cocoa pod husk and its fractions. *Current Opinion in Green and Sustainable Chemistry*, *14*, 80–88.

Manirakiza, N., & Şeker, C. (2020). Effects of compost and biochar amendments on soil fertility and crop growth in a calcareous soil. *Journal of Plant Nutrition*, *43*(20), 3002–3019.

Mariotti, B., Martini, S., Raddi, S., Tani, A., Jacobs, D. F., Oliet, J. A., & Maltoni, A. (2020). Coconut coir as a sustainable nursery growing media for seedling production of the ecologically diverse Quercus species. *Forests*, *11*(5), 522.

Maucieri, C., Nicoletto, C., Van Os, E., Anseeuw, D., Van Havermaet, R., & Junge, R. (2019). Hydroponic technologies. *Aquaponics Food Production Systems*, *77*.

Medina-Vega, J. A., Bongers, F., Schnitzer, S. A., & Sterck, F. J. (2021). Lianas explore the forest canopy more effectively than trees under drier conditions. *Functional Ecology*, *35*(2), 318–329.

Medyńska-Juraszek, A., & Ćwieląg-Piasecka, I. (2021). Biochar as a growing media component. In *Biochar as a Renewable-Based Material: With Applications in Agriculture, the Environment and Energy* (pp. 85–104). World Scientific.

Mengel, K., & Kirkby, E. A. (2012). *Principles of plant nutrition*. Springer Science & Business Media.

Molina-Guerrero, C. E., Sanchez, A., & Vázquez-Núñez, E. (2020). Energy potential of agricultural residues generated in Mexico and their use for butanol and electricity production under a biorefinery configuration. *Environmental Science and*

University of Education,Winneba http://ir.uew.edu.gh

Pollution Research, *27*(23), 28607–28622. https://doi.org/10.1007/s11356-020-08430-y

Muindi, E. M. (2019). Understanding Soil Phosphorus. *International Journal of Plant & Soil Science*, *31*(2), 1–18.

Nduka, B. A., Adewale, D. B., Akanbi, O. S. O., & Adejobi, K. B. (2015). Nursery Soil Amendments for Cashew Seedling Production: A Comparative Analysis of Coffee Husk and NPK. *Journal of Agricultural Science*, *7*(3). https://doi.org/10.5539/jas.v7n3p111

Njonjo, M. W., Muthomi, J. W., & Mwang'ombe, A. W. (2019). Production practices, postharvest handling, and quality of cowpea seed used by farmers in Makueni and Taita Taveta Counties in Kenya. *International Journal of Agronomy*, *2019*.

Omar, L., Ahmed, O. H., Boyie Jalloh, M., & Abdul Majid, N. M. (2021). *Rice Husk Compost Production and Use in Mitigating Ammonia Volatilization from Urea. Sustainability 2021, 13, 1832*. s Note: MDPI stays neutral with regard to jurisdictional claims in published ….

Onyutha, C. (2019). African food insecurity in a changing climate: The roles of science and policy. *Food and Energy Security*, *8*(1), e00160.

Osae, R., Essilfie, G., Alolga, R. N., Bonah, E., Ma, H., & Zhou, C. (2020). Drying of ginger slices—Evaluation of quality attributes, energy consumption, and kinetics study. *Journal of Food Process Engineering*, *43*(2), e13348.

Pereira, V. M. (2020). *Landscape Performance of Annual Bedding Plants Following Foliar Application of Silicon and Titanium* [PhD Thesis]. Illinois State University.

Pode, R. (2016). *Potential applications of rice husk ash waste from rice husk biomass power plant. Renewable and Sustainable Energy Reviews, 53, 1468-1485.*

University of Education,Winneba http://ir.uew.edu.gh

Purakayastha, T. J., Bera, T., Bhaduri, D., Sarkar, B., Mandal, S., Wade, P., Kumari, S., Biswas, S., Menon, M., & Pathak, H. (2019). A review on biochar modulated soil condition improvements and nutrient dynamics concerning crop yields: Pathways to climate change mitigation and global food security. *Chemosphere*, *227*, 345–365.

Quaye, A., Konlan, S., Arthur, A., Pobee, P., & Dogbatse, J. A. (2019). Effect of media type and compost mixtures on nutrient uptake and growth of cocoa (Theobroma cacao L.) seedling in the nursery. *Ghana J. Hortic*, *14*, 11–21.

Ramlee, N. A., Jawaid, M., Zainudin, E. S., & Yamani, S. A. K. (2019). Tensile, physical and morphological properties of oil palm empty fruit bunch/sugarcane bagasse fibre reinforced phenolic hybrid composites. *Journal of Materials Research and Technology*, *8*(4), 3466–3474.

Ravindran, B., Awasthi, M. K., Karmegam, N., Chang, S. W., Chaudhary, D. K., Selvam, A., Nguyen, D. D., Milon, A. R., & Munuswamy-Ramanujam, G. (2022). Co-composting of food waste and swine manure augmenting biochar and salts: Nutrient dynamics, gaseous emissions and microbial activity. *Bioresource Technology*, *344*, 126300.

Sarmah, D., & Karak, N. (2020). Biodegradable superabsorbent hydrogel for water holding in soil and controlled-release fertilizer. *Journal of Applied Polymer Science*, *137*(13), 48495.

Siedt, M., Schäffer, A., Smith, K., E., Nabel, M., Roß-Nickoll, M., & Dongen, V., J., T. (2021). Comparing straw, compost, and biochar regarding their suitability as agricultural soil amendments to affect soil structure, nutrient leaching, microbial communities, and the fate of pesticides. *Science of The Total Environment*, *751*, 141607.

University of Education,Winneba http://ir.uew.edu.gh

Snoeck, D., Koko, L., Joffre, J., Bastide, P., & Jagoret, P. (2016). Cacao nutrition and fertilization. In *Sustainable agriculture reviews* (pp. 155–202). Springer.

Sosu, G. (2014). *Growth of cocoa seedlings as affected by different growth media and different polybag sizes* [PhD Thesis]. University of Ghana.

Tambi, M. D., & Lum, M. M. (2020). Effects of social capital on cocoa production in Cameroon. *International Journal of Business Economics (IJBE)*, *2*(1), 1–17.

Tan, J. K. N., Lee, J. T. E., Chiam, Z., Song, S., Arora, S., Tong, Y. W., & Tan, H. T. W. (2021). Applications of food waste-derived black soldier fly larval frass as incorporated compost, side-dress fertilizer and frass-tea drench for soilless cultivation of leafy vegetables in biochar-based growing media. *Waste Management*, *130*, 155–166.

Tiwari, S., Patel, A., Pandey, N., Raju, A., Singh, M., & Prasad, S. M. (2020). Deficiency of Essential Elements in Crop Plants. *Sustainable Solutions for Elemental Deficiency and Excess in Crop Plants*, 19–52. https://doi.org/10.1007/978-981-15-8636-1_2

Usharani, K. V., Roopashree, K. M., & Naik, D. (2019). Role of soil physical, chemical and biological properties for soil health improvement and sustainable agriculture. *Journal of Pharmacognosy and Phytochemistry*, *8*(5), 1256–1267.

Villas-Boas, P. R., Romano, R. A., de Menezes Franco, M. A., Ferreira, E. C., Ferreira, E. J., Crestana, S., & Milori, D. M. B. P. (2016). Laser-induced breakdown spectroscopy to determine soil texture: A fast analytical technique. *Geoderma*, *263*, 195–202. https://doi.org/10.1016/j.geoderma.2015.09.018

Wortmann, S., C., Kaizzi, C., K., Maman, Nouri, Cyamweshi, A., Dicko, M., Garba, M., Milner, M., Senkoro, C., Tarfa, B., Tettah, F., Kibunja, C., Munthali, M., Nalivata, P., Nkonde, D., Nabahungu, L., Ouattara, K., & Serme, I. (2019).

University of Education,Winneba http://ir.uew.edu.gh

Diagnosis of crop secondary and micro-nutrient deficiencies in sub-Saharan Africa. *Nutrient Cycling in Agroecosystems*, *113*(2), 127–140. https://doi.org/10.1007/S10705-018-09968-7

Yasin, M., Jabran, K., Afzal, I., Iqbal, S., Nawaz, M. A., Mahmood, A., Asif, M., Nadeem, M. A., Rahman, Z. U., & Adnan, M. (2020). Industrial sawdust waste: An alternative to soilless substrate for garlic (Allium sativum L.). *Journal of Applied Research on Medicinal and Aromatic Plants*, *18*, 100252.

Zakaria, H. (2017). The drivers of women farmers' participation in cash crop production: The case of women smallholder farmers in Northern Ghana. *The Journal of Agricultural Education and Extension*, *23*(2), 141–158.

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APPENDICES

APENDIX A (PLANT HEIGH)

29 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.016	0.008	0.01	
rep.*Units* stratum					
trt	3	6.461	2.154	1.43	0.324
Residual	6	9.049	1.508		
Total	11	15.526			

43 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.0504	0.0252	0.04	
rep.*Units* stratum					
trt	3	6.9290	2.3097	4.05	0.068
Residual	6	3.4179	0.5697		
Total	11	10.3973			

57 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.2817	0.1408	0.18	
rep.*Units* stratum					
trt	3	5.0425	1.6808	2.17	0.192
Residual	6	4.6450	0.7742		
Total	11	9.9692			

71 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	4.940	2.470	2.05	
rep.*Units* stratum					
trt	3	12.143	4.048	3.35	0.097
Residual	6	7.247	1.208		
Total	11	24.330			

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85 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	6.487	3.243	2.60	
rep.*Units* stratum					
trt	3	8.813	2.938	2.35	0.171
Residual	6	7.487	1.248		
Total	11	22.787			

99 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	6.847	3.423	1.69	
rep.*Units* stratum					
trt	3	2.453	0.818	0.40	0.756
Residual	6	12.167	2.028		
Total	11	21.467			

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APPENDIX B (NUMBER OF LEAVES)

29 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	1.3054	0.6527	1.93	
rep.*Units* stratum					
trt	3	0.5723	0.1908	0.56	0.658
Residual	6	2.0296	0.3383		
Total	11	3.9073			

43 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.827	0.413	0.31	
rep.*Units* stratum					
trt	3	2.597	0.866	0.64	0.614
Residual	6	8.053	1.342		
Total	11	11.477			

57 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.187	0.093	0.03	
rep.*Units* stratum					
trt	3	0.067	0.022	0.01	0.999
Residual	6	19.653	3.276		
Total	11	19.907			

71 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	4.687	2.343	1.51	
rep.*Units* stratum					
trt	3	1.960	0.653	0.42	0.746
Residual	6	9.340	1.557		
Total	11	15.987			

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85 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	12.607	6.303	1.54	
rep.*Units* stratum					
trt	3	1.427	0.476	0.12	0.947
Residual	6	24.593	4.099		
Total	11	38.627			

99 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.1667	0.0833	0.10	
rep.*Units* stratum					
trt	3	0.9700	0.3233	0.40	0.761
Residual	6	4.9000	0.8167		
Total	11	6.0367			

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APPENDIX C (CANOPY SPREAD)

29 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	1.627	0.813	0.14	
rep.*Units* stratum					
trt	3	18.787	6.262	1.06	0.432
Residual	6	35.333	5.889		
Total	11	55.747			

43 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	2.287	1.143	0.64	
rep.*Units* stratum					
trt	3	12.037	4.012	2.26	0.182
Residual	6	10.673	1.779		
Total	11	24.997			

57 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	7.340	3.670	1.48	
rep.*Units* stratum					
trt	3	21.733	7.244	2.91	0.123
Residual	6	14.927	2.488		
Total	11	44.000			

71 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	8.720	4.360	1.50	
rep.*Units* stratum					
trt	3	3.107	1.036	0.36	0.787
Residual	6	17.413	2.902		
Total	11	29.240			

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85 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	10.82	5.41	0.48	
rep.*Units* stratum					
trt	3	19.05	6.35	0.57	0.658
Residual	6	67.42	11.24		
Total	11	97.29			

99 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	6.407	3.203	0.65	
rep.*Units* stratum					
trt	3	113.503	37.834	7.64	0.018
Residual	6	29.727	4.954		
Total	11	149.637			

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APPENDIX D (LEAF AREA)

29 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	15.97	7.99	0.64	
rep.*Units* stratum					
trt	3	18.88	6.29	0.50	0.695
Residual	6	75.38	12.56		
Total	11	110.23			

43 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	13.838	6.919	2.29	
rep.*Units* stratum					
trt	3	15.667	5.222	1.73	0.260
Residual	6	18.149	3.025		
Total	11	47.654			

57 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.582	0.291	0.15	
rep.*Units* stratum					
trt	3	2.153	0.718	0.37	0.777
Residual	6	11.589	1.932		
Total	11	14.324			

71 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	19.989	9.995	6.33	
rep.*Units* stratum					
trt	3	4.583	1.528	0.97	0.467
Residual	6	9.468	1.578		
Total	11	34.040			

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85 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	8.583	4.291	1.98	
rep.*Units* stratum					
trt	3	9.611	3.204	1.48	0.312
Residual	6	13.008	2.168		
Total	11	31.201			

99 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	15.124	7.562	2.20	
rep.*Units* stratum					
trt	3	22.634	7.545	2.20	0.189
Residual	6	20.607	3.434		
Total	11	58.365			

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APPENDIX E (STEM DIAMETER)

29 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.001550	0.000775	0.45	
rep.*Units* stratum					
trt	3	0.000492	0.000164	0.09	0.960
Residual	6	0.010383	0.001731		
Total	11	0.012425			

43 DAYS

Variate: SDat43D

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.0016167	0.0008083	1.70	
rep.*Units* stratum					
trt	3	0.0026250	0.0008750	1.84	0.240
Residual	6	0.0028500	0.0004750		
Total	11	0.0070917			

57 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.002400	0.001200	1.04	
rep.*Units* stratum					
trt	3	0.001967	0.000656	0.57	0.657
Residual	6	0.006933	0.001156		
Total	11	0.011300			

71 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.003800	0.001900	1.31	
rep.*Units* stratum					
trt	3	0.007567	0.002522	1.73	0.259
Residual	6	0.008733	0.001456		
Total	11	0.020100			

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85 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.001400	0.000700	0.53	
rep.*Units* stratum					
trt	3	0.005467	0.001822	1.38	0.337
Residual	6	0.007933	0.001322		
Total	11	0.014800			

99 DAYS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.0056000	0.0028000	6.30	
rep.*Units* stratum					
trt	3	0.0065333	0.0021778	4.90	0.047
Residual	6	0.0026667	0.0004444		
Total	11	0.0148000			