

**EVALUATION OF GROWING MEDIA AND FIELD PERFORMANCE OF TWO
GRASSES FOR SOD PRODUCTION IN GHANA**

BY

BERVELYN OKYERE

(10340688)

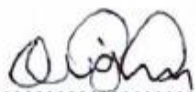
THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF PHD IN
CROP SCIENCE DEGREE



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DECLARATION

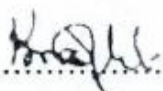
I affirm that apart from the references to studies, which I have cited, this study, “**EVALUATION OF GROWING MEDIA AND FIELD PERFORMANCE OF TWO GRASSES FOR SOD PRODUCTION IN GHANA**” was carried out by me in the Department of Crop Science, School of Agriculture, University of Ghana, Legon. No part of the study has been submitted for the award of a degree elsewhere.



Bervelyn Okyere
(Candidate)

28/10/2025

Date



Prof. G.K. Ofosu Budu
(Principal Supervisor)

28/10/2025

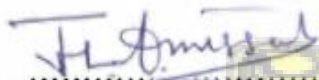
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Prof. Essie Blay
(Supervisor)

28/10/2025

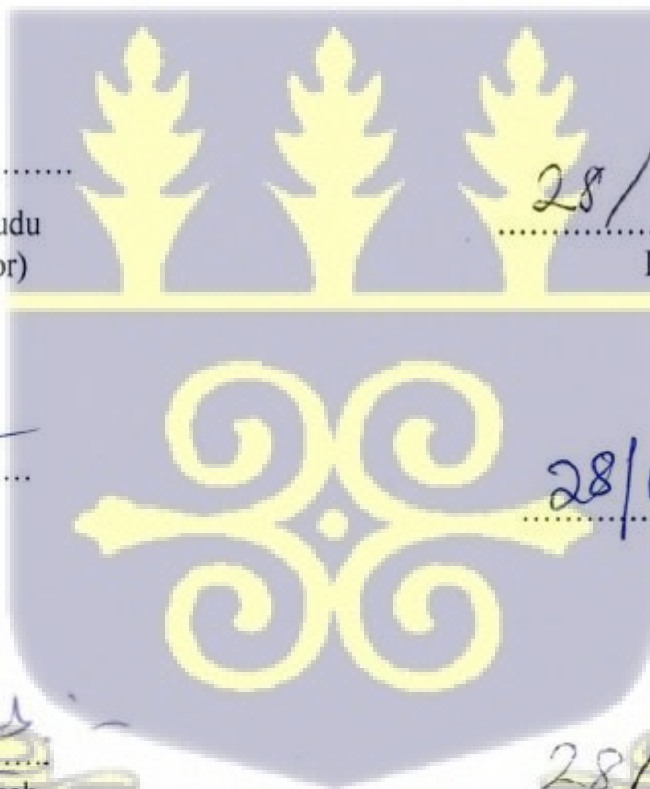
Date



Dr. Naalamle Amissah
(Supervisor)

28/10/2025

Date



ABSTRACT

Sustainable sod production is crucial for erosion control, enhancing aesthetics, and mitigating climate change. Growing media plays a key role in providing the suitable environment for the rooting and establishment of grasses. This study was conducted to evaluate the effect of growing media on the performance of Bermuda and St. Augustine's grasses for sod production in Ghana. A factorial experiment arranged in a RCBD with three replications was used for the study.

Local materials including poultry manure, biochar and sawdust were used in different proportions in the formulation of five different growing media. The growing media were; Topsoil only (M1), Topsoil, poultry manure, rice husk biochar, clay (60:20:15:5 v/v) (M2); Topsoil, poultry manure, rice husk biochar, clay (50:30:15:5 v/v) (M3); Topsoil, poultry manure, sawdust, clay (60:20:15:5 v/v) (M4); Topsoil, poultry manure, sawdust, clay (50:30:15:5 v/v) (M5). The physical and chemical properties differed significantly among the growing media formulated. Generally, the physical properties of the growing medium with sawdust were higher than the corresponding treatment where the sawdust component was replaced with rice husk biochar. The bulk density, porosity of M4 (60 % topsoil+ 30 % poultry manure + 15 % Sawdust + 5 % clay soil) and M5 (50 % topsoil+ 20 % poultry manure + 15 % Sawdust + 5 % clay soil) were higher than that of M2 (60 % topsoil+ 20 %poultry manure + 15 % rice husk biochar + 5 % clay soil), and M3 (50 % topsoil+ 30 % poultry manure + 15 % rice husk biochar + 5 % clay soil). A marginal increase in CEC in M3, M4 and M5 but a decrease in M2 was observed compared with M1 (soil only). Increases in organic carbon, Ca, Mg, were observed in all the mixtures.

Bermuda grass recorded the highest emergence (95.3%) whilst soil only recorded the lowest (91.3%). Saint Augustine's grass recorded the highest emergence (41.3%) in M1, and lowest in M3 (12.6%). Bermuda grass recorded the longest stolon length (145.6 cm) in M5, while the

shortest was recorded in M1 (90.6 cm) at the 13th week. Similarly, St. Augustine's grass recorded the longest stolon length (132.5 cm) in M5 and the shortest in M1 (30.7 cm). The biggest stolon girth for both St. Augustine's and Bermuda grasses was induced by the topsoil (M1) only treatment. The highest number of tillers in the Bermuda grass was observed in M5, while that for St. Augustine's, was observed in M4 treatment.

The highest dry matter production by Bermuda grass was recorded in M5 (4.67 g/cm²), while the lowest was observed in M1 (0.87 g/cm²). Similarly, the highest dry matter production by St. Augustine grass was recorded in M2 (3.33 g/cm²) whilst the lowest was observed in M3 (1.40 g/cm²). The results showed that dibble (T2) planting density favored quick establishment of Bermuda grass. In the case of planting depth 2.5 cm was the optimum depth. Regarding planting density, P3: 15 dibble/m² took longer time for grass establishment. Sod (Bermuda) produced the highest dry weight of 384.5 g/m², in the coastal savanna whereas Stolon (Bermuda) produced 211 g/m². Similarly, sod (St. Augustine's) produced dry matter of 243.8 g/m², whilst Stolon (St. Augustine's) produced 175.8 g/m². In the forest zone, however, Sod (Bermuda) produced dry weight of 166.8 g/m², whilst Stolon (Bermuda) produced 216 g/m² dry matter. Moreover, sod (St. Augustine's) produced 230.5 g/m² dry weight whilst Stolon (St. Augustine's) produced 177.5 g/m² dry weight.

Additionally, Stolon (Bermuda) recorded the highest weed dry weight of 92 g/m² and 142 g/m² in the coastal and forest regions respectively whereas Stolon (St. Augustine's) recorded (83 g/m², 97 g/m²). However, Sod effect on weed infestation was low compared to that of stolon. Planting materials (sod and stolons) performed differently within the two ecological zones due to the differences in the soil type, rainfall and temperature regimes.

DEDICATION

This thesis is primarily dedicated to the Late Prof. Allison Howell and my Late parents for their support and prayers. I also dedicate it to my children, Adepa and Nhyiraba and friends who supported my education. The Almighty God bless and keep you. A special dedication to my husband, Apostle Solomon Wireko Junior, whose diligence inspired me to have a positive attitude to work and life.



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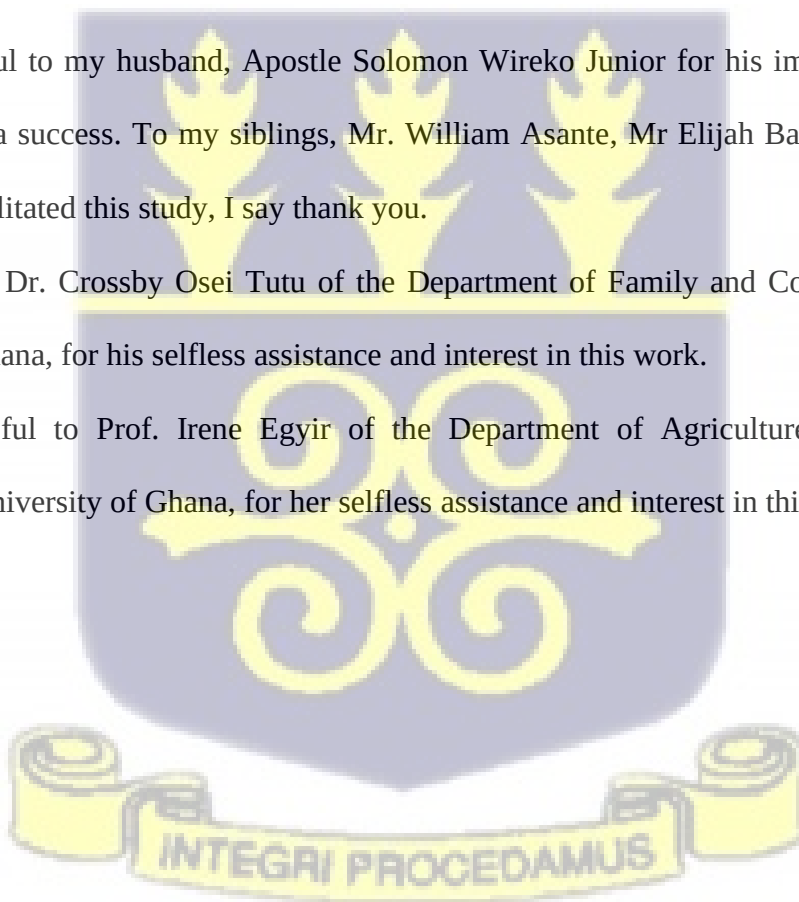


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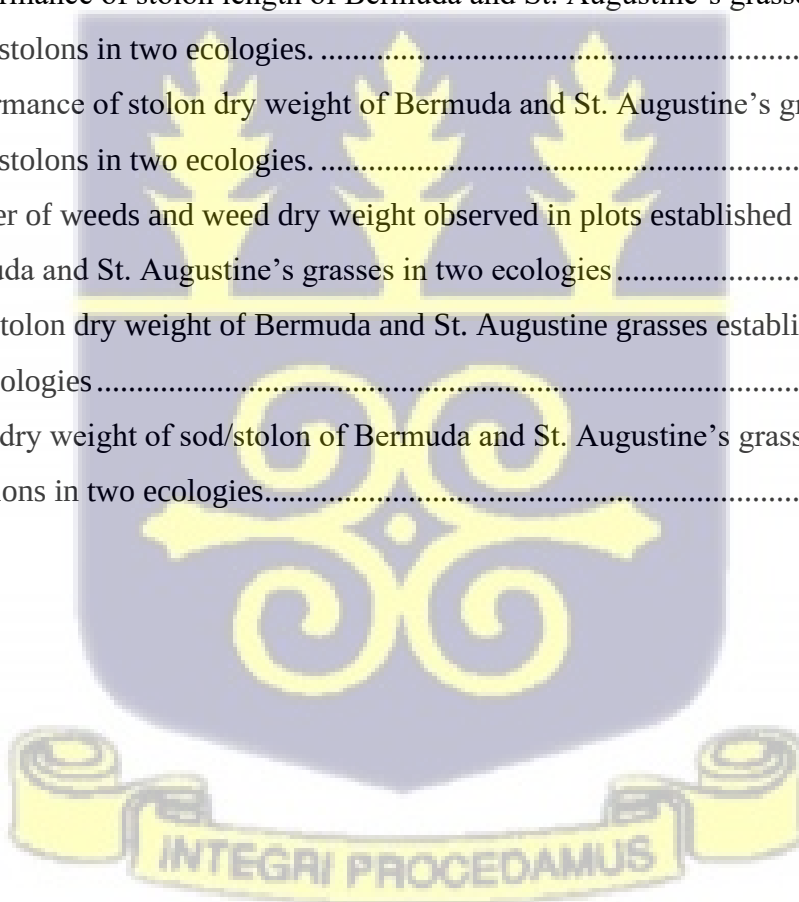
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LIST OF ACRONYMS

BD	Bulk Density
M	Media
P	Porosity
RHB	Rice husk biochar
SD	Sawdust
WHC	Water holding capacity
PM	Poultry manure
Cl	Clay



CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Climate change is causing extreme temperatures, drought and unpredictable rainfall patterns globally. Erosion is a global challenge due to the changing climate especially in developing countries. Developing countries must put in place measures to solve erosion problems for environmental protection. Developing countries must adopt landscaping strategies to mitigate erosion problem and to improve the livelihood of people.

Consequently, it is imperative to adapt sod production systems by promoting climate resilient grasses. While sod may not entirely be new to many communities, sod production needs to be promoted and its utilization extended especially in urban centers where expensive structures are being built and natural vegetation is being destroyed. Studies have showed the prospects of sod (Tomaškin *et al.*, 2012; Kaiser *et al.*, 2019) for fast establishment, immediate erosion control, weed control and carbon dioxide sequestration.

Bermuda grass (*Cynodon dactylon*) and St. Augustine's grass (*Stenotaphrum secundatum*) are warm season grasses which are locally available in Ghana and can be utilized for sod production for erosion control. Studies have shown the potential of these grasses in sod production (including drought tolerance, weeds suppression, erosion control) (Hanna *et al.*, 2013; Badawy, El-Khateeb & Salem, 2018; Quesenberry, Ocumpaugh & Ruelke, 2019).

Selection of suitable method appropriate for selected grass species is of superior rank in growing of turf. Yet, establishment is made based on the growth pattern of turf grass (Dhanasekaran, 2018). Even though grass species can be propagated by seed, grasses are classically planted vegetatively

(Kumar *et al.*, 2023). The method of establishment of grasses includes seeding, sodding, sprigging, stolonizing, plugging, dibbling and hydro-mulching.

Planting density and depth are factors to be considered in the establishment and spread of turf grasses. Plant density defines the number of plants per square meter. Grasses compete for growth resources such as water, light and nutrients (Helios *et al.*, 2021) and may therefore determine the available growth resource for individual plants, (Al-Suhaibani, Hendawy & Schmidhalter, 2013) for resource acquisition and use. Planting density may also affect the maintenance of turf since weed infestation may increase with lower densities. Planting depth can increase stolon survival, emergence, ground cover, and dry matter production, vigor, and establishment for it can alter biotic and abiotic conditions.

Topsoil is highly used for sod production but it is expensive and is causing sand winning problems in Ghana such as land degradation. The successful alternative of topsoil (partially or wholly) amended with locally available organic materials (including poultry manure, sawdust and rice husk biochar) in sod production will have tremendous implications for erosion control, environmental sustainability and as well as improving the local economy. The ecological sustainability of grasses is an increasingly vital subject and it involves both a restriction of management inputs and a careful evaluation of grasses and cultivars that are best adapted to low-maintenance requirements, for instance weed control.

Performance of grasses is different under different environment, that is in the coastal and forest zone. Factors which vary such as rainfall, soil bulk density and soil texture affect the performance of different grasses. Coastal soil and forest soil differ in terms of soil texture, CEC, aeration, bulk density and this study investigated the performance of these grasses under two different ecologies. Elsewhere, in North America, McGrath & Henry (2016) in Canada studied on soil type and saw

that it affected the yield or biomass production because of high bulk density. In the same vein, this study would like to see the performance of these grasses in the forest zone where the clay or bulk density is high than that of the coastal savanna.

This study investigated the performance of Bermuda and St. Augustine's grasses as warm season grasses for sod production using soil amended growth media with poultry manure, sawdust and rice husk biochar and with appropriate planting methods such as sodding and stolonizing.

1.2 Rational

Changes in the climate have demanded exploring the potential of grasses for sod production to ensure erosion and weed control and carbon dioxide sequestration in developing countries. Bermuda and St. Augustine's grasses are locally available for sod production. They form dense cover for erosion and weed control and have aesthetic value. Sod has relatively higher potential in erosion control compared to other alternative plants. Traditionally, soil has been used for the establishment of sod. However, soil is low in organic matter content, water retention and is acidic which requires many fertilizers for adequate support for growth and is relatively bulky. It is also not uniform in texture and has high level of weed seeds bank resulting in weed infestation which causes high cost of lawn maintenance. As soil is being depleted with the changing climate, there is the need to amend soil with organic substances (poultry manure, sawdust, rice husk biochar) which are locally available and cheap to replace the use of soil in totality for sod production. Commercial sod production will be challenging without understanding the physiochemical properties of such organic materials. Understanding the characteristics of sod and amended growing substrate can help address erosion problems, especially in the urban centers where more buildings are being put up. It could also provide sod producers with suitable growing media

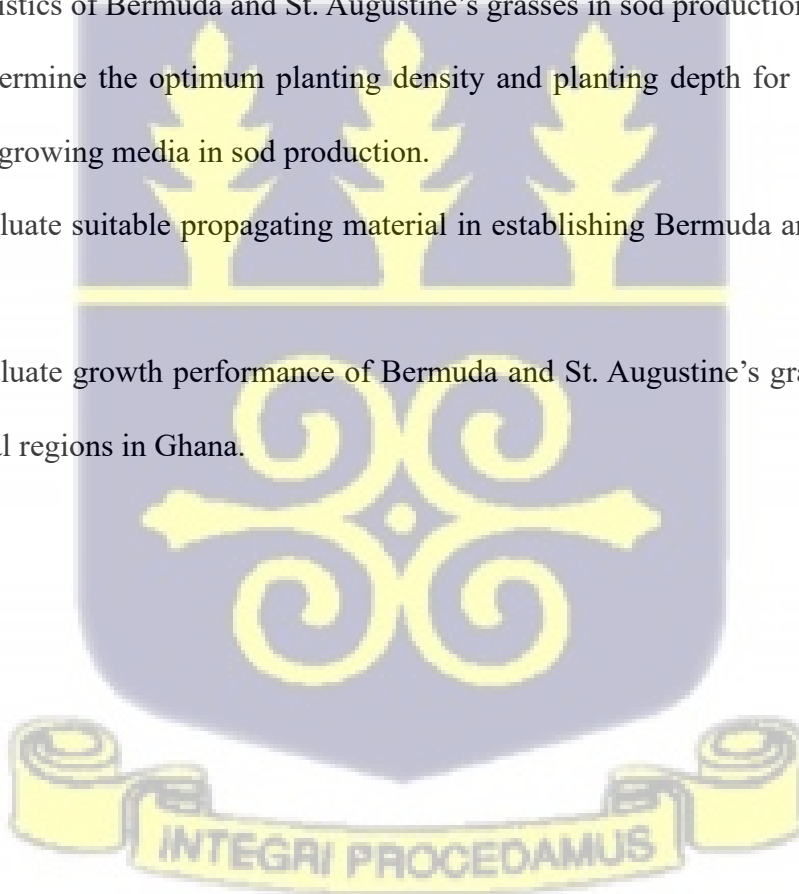
alternative to soil only. Considering the benefits of sod and growing media, the study will formulate and characterize growing media for sod production in Ghana.

1.3 Main objective of study

The main objective of this study was to evaluate the effect of growing media and performance of two grasses for sod production in Ghana.

1.4 Specific objectives

1. To evaluate the effect of growing media on emergence and some morphological characteristics of Bermuda and St. Augustine's grasses in sod production.
2. To determine the optimum planting density and planting depth for Bermuda grass in different growing media in sod production.
3. To evaluate suitable propagating material in establishing Bermuda and St. Augustine's grasses.
4. To evaluate growth performance of Bermuda and St. Augustine's grasses in two agro-ecological regions in Ghana.



CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Growing Media

A growing medium can be described as a material that can support plant growth by providing air, water and nutrients (Baiyeri & Mbah, 2006). Growing media are designed to attain high porosity and water retention while providing adequate aeration. Growing media offer a root setting that is originally devoid of plant pathogens and guarantees an adequate air, water, and nutrient supplies. In the horticultural business, usually, mixes of growing media elements and additives are utilized. Organic or inorganic resources can be used as constituents, while additives comprise fertilizers, liming materials, and bio-control or wetting agents. The growing media quality, effects of growing media characteristics on water and nutrient management, media column height and containers, handling growing media and growing media components all affect plants growth and yield (Bunt, 2012).

A lot of materials can be applied for growing media formulation, such as biochar, sawdust, poultry manure and topsoil. However, their preparation depends on media features that may be connected to agronomical functions, for instance the aptitude to sustain plant growth (Villego, 2016). Therefore, the main objective regarding the identification of suitable growing media for sod production is the cause of an effective and balanced development of the plants (Petrucelli *et al.*, 2022). In order to produce quality sod, growing media with appropriate physical and chemical characteristics are required.

Generally, plants grown in containers, have shallow volume to develop their root system. This creates an unbalanced relationship in growing stem and root. Also, under field conditions, a

superior consideration for water, air, and nutrients plant consume must be paid. Under greenhouse condition, the ideal growing medium must physically sustain the plants. It must promote oxygen transfer for root respiration via better porosity. It must also, permit drainage of water well and avoid waterlogging by extreme WHC. Moreover, growing media able to adsorb cations will by all means provide nutritional requirements for the plants. Actually, plant nutrients which are mostly electrically charged ions, such as NH_4^+ , K^+ , Ca^{+2} , Mg^{+2} , in growing media are essential for fast growth of ornamentals. Furthermore, pH is likewise an essential chemical characteristic of a suitable growing media. This affects nutrient availability.

The physical structure of growing media must be stable in time. It must be in good shape for physio-chemical features mutually in the time and in the space. It must promote resistance to the compaction and to volume decrease during the dehydration stage. Obviously, the materials for growing media formulation must be easily, locally and readily available. They must be cheap in order to satisfy requirements for sustainability. Effective growing media is guaranteed by the entire absence of pathogens (bacteria, nematodes, fungi, and insects). Moreover, the media must be devoid of chemical remains (pesticides) and from potentially phytotoxic materials and weed seeds.

2.2 Growing Media Components

The physiochemical characteristics and ratios of poultry manure, sawdust and rice husk biochar were considered for growing media constituents. Poultry manure, sawdust and rice husk biochar are locally available to amend soil in growing media formulations. These materials are environmentally friendly and the best options under the changing climate currently compared to inorganic fertilizers. The characteristics of poultry manure, biochar, sawdust and conventional soil and their proportions in growth media will touch the function of the media. The ratios of the

components will also affect the functions of the media such as WHC, BD, porosity, pH, EC etc. Therefore, it is important to evaluate the materials available and the ideal proportions in the establishment of the sod.

2.2.1 Poultry Manure (PM)

Nutrients in poultry manure are readily available. Nutrients high in poultry manure include nitrogen, phosphorus but these have not been evaluated for sod production. Nitrogen fertilization is one of the greatest significant managements applied in turf culture. Poultry manure is perceived to contain a large quantity of plant nutrients especially N (Appiah, 2015). According to Appiah (2015), essential nutrients for instance P and K also are found in poultry manure. The physiochemical properties of poultry manure are reliant on features such as moisture content, age, feed and manure to litter ratio as reported by Masud *et al.*, (2023). Meena *et al.*, (2023)

reported that uric acid abundant in new excretory product represented about 40 – 70% of the whole nitrogen whereas urea and NH_4^+ were in small amounts. Sajid *et al.*, (2023) also reported that diverse kinds of PM possess diverse physiochemical properties. The content of N in poultry is the best compared to the other animal manures, ranging from 2.0 %-3.0 % (Chadwick *et al.*, 2015). Although poultry is a rich basis of N, its accessibility to crops depends on conditions for instance; volatilization, denitrification, immobilization, mineralization, leaching and plant uptake (Shafreen *et al.*, 2021). They further stated that soil nitrogen quantity rest on N_2 fixing via microorganisms, extinct from leakage and crop elimination, volatilization and release of N_2O and N_2 .

2.2.1.1 Importance of poultry manure as component in a growing media

Basically, poultry provides organic matter, N, P, K, and these materials are readily available to mediated by soil microbes. Poultry manure is a great basis of nitrogen. It is needed for continuous cultivation of crops as it comparably checks microbial degradation. Poultry manure is generally

accepted to be efficient in providing enough of organic matter to the growing media. It amends the physical properties and improves plant growth (Akpalu *et al.*, 2020). Amending soil with organic fertilizer like poultry improves the physiochemical properties of the soil. Poultry manure enhances the biological materials of the soil resulting in low bulk density. It increases porosity and stability (Shah *et al.*, 2017). This improves water holding capacity, aeration and easy root penetration. According to Lal (2020), when organic material is added to the soil, it enhances the soil structure and WHC. This depicts that PM play a vital role in amending the physical properties of the soil. Research have publicized that amending soil with PM improves the CEC for more available nutrients to plant and improves P availability in acidic soils (Zolfi-Bavariani *et al.*, 2016; Johan *et al.*, 2021; Muñoz-Cerro *et al.*, 2023). Rodríguez-Ortiz *et al.*, (2022), reported that organic fertilizers give trace elements that are rarely found in conservative farming structures which rest exclusively on non-natural sources of N, P and K. Also, Gooding & Shewry (2022), discovered that OM can supply about 90% – 99% N, P and K when added to conventional soil. The research further reported that OM increased WHC of soils and minimized soil run-off thereby enhancing cohesion and malleability. Akuamoah-Boateng (2016), showed that the applying PM to acidic soil enhanced the soil pH from 5.7 to 6.1. This might be due to presence of more Ca in the PM provided brought by the oyster shells mixed with the poultry feed. Ozores-Hampton, (2021) and Inderbitzin *et al.*, (2018), noticed a rise in soil pH and a decrease of transferrable acidity in the soil when organic fertilizer was added. Organic fertilizers can reduce the concentration of Al^{3+} and Fe^{2+} in the soil. In the study conducted by Hariharan *et al.*, (2022) and Tokula *et al.*, (2023) on cassava, high soil pH was observed to be the addition of PM which brought about an increase in OM and Ca ions. These elements released into the soil mix in microbial decarboxylation of manure as buffer alteration in soil pH. Oyedeji *et al.*, (2014) studied on effect of poultry manure on Amaranths and

found that poultry manure at 30 Kg ha⁻¹ rate significantly increased plant height, stem girth, number of leaves, leaf area, and number of branches. Also, poultry compost applied at rates of 6.6 and 9.9 t/ha increased vine length and leaf number of watermelon (Adekiya & Agbede, 2017). Baiyeri & Mbah. (2006) reported that growth of African breadfruit seedlings was improved in potting media amended with poultry manure than those in the soil medium. Chang *et al.*, (2019) researched on the consequence of pig and horse compost on growth of *Acacia confuse* seedlings and reported that 10% application of pig manure enhanced seedling survival to 97% over the control (soil) with 92%. However, higher applications (30% and 40%) reduced seedling survival to 87% and 38% respectively. Whereas all rate of application produced less seedlings with horse manure.

2.2.2 Sawdust (SD)

Organic wastes from agricultural industries and Municipal solid waste could serve as growing media. These materials are cheap and readily available. For example, wood shavings, sawdust, rice husk, river sand, and coconut fiber are locally and readily available. Mixtures of these resources have been verified useful media for crop production (Saeed *et al.*, 2020).

Sawdust is the unused produce of crushing, cutting, grinding or piercing wood with a saw or other appliance. The usage of sawdust as a straw and soil modification has been considered. It has been utilized for growing seedlings and vegetables in several states (Setak, 2018). Sawdust is shaped in numerous assortments of dimensions, thicknesses and wood categories. In Ghana, forest trees for instance white and black odum (*Milicia excelsa*), ofram (*Terminalia superba*) mahogany (*Swietenia macrophylla*), wawa (*Triplochiton scleroxylon*) and onyina (*Ceiba pentandra*) are employed in making. Sawdust totals to approximately 1/3 of wood product exports (Agyen, 2013).

2.2.2.1 Effect of Sawdust on Physiochemical Properties of soil

The benefits of sawdust are achieved through the ability of wood debris to boost the physiochemical features of the soil. It improves the WHC of the soil and prevents quick fluctuations in moisture and temperature. Sawdust is made up of around 40% lignin and approximately 60% cellulose together with slight quantities of waxes, gums and fats (Singh & Vaishnav, 2022). It is low in nutrient. The small particles of sawdust promote microbial activities in soils. This brings about a faster breakdown of the wood. Sawdust that has been decomposed to humus, advances soil structure, upsurges air and soil WHC. Sawdust has an increased C: N ratio and can bring nutrient disparity. A soil modification is any substance added to soil to enhance its physical characteristics, fertility, or building. Soil modifications are commonly used in gardening, agriculture, and landscaping to enhance soil quality and promote healthy plant growth. These materials can comprise organic matter for example compost, manure, or peat moss, along with inorganic substances like lime, gypsum, or perlite.

Soil amendments can serve various purposes. They advance soil structure by increasing its ability to hold water and nutrients, in addition to improving aeration and drainage. They adjusted pH levels by making it more appropriate for specific types of plants that thrive in acidic or alkaline conditions.

Soil amendments enhance fertility by providing essential nutrients to the soil, promoting healthier plant growth and increasing yields. They reduce compaction by loosening compacted soil, improving root penetration and overall soil health. They also suppress pests and diseases by controlling weed growth or reducing the incidence of certain soil-borne pests and diseases.

Generally, soil amendments play a vital role in maintaining and improving soil vigor, which is essential for sustainable agriculture and gardening practices for plants. Yet, it can be a helpful soil

modification. Agricultural professionals have been hesitant to admit sawdust as a necessary organic matter due to the problems it causes when added to the soil. It slows down the rate of decomposition. Likewise, sawdust absorbs nitrogen from the soil and develops hydrophobic once dry, hard to soak and may prevent water. However, once sawdust is used in mixes, it oxidizes promptly and condensed readily. Compositing the sawdust before use will eliminate such constraints incorporated with manure. In spite of all the challenges, the benefits from the usage of sawdust to improve the physical characteristics of the soil cannot be ignored. As said by Rominiyi *et al.*, (2017), the compost becomes more useful when it makes up less than 50% sawdust based on the kind of plant that will be established. He designated that sawdust used alone does not possess the required properties for potting mixture.

Saeed *et al.*, (2020) stated that microbial action increased significantly with increasing amounts of sawdust in a soil + sawdust mix. Christoulaki *et al.*, (2014) recommended sawdust as the ideal growing medium for the greenhouse for numerous decenniums. This is for its little price and comparatively increased crop productivity. Yet, sawdust is liable to slow decomposition, which brings undesirable media physical characteristics.

2.2.3 Rice Husk Biochar (RHB)

According to Mehmood *et al.*, (2021), RHB is a unique carbon-rich produce gained when organic materials such as rice husk, shells and leaves are kept in a covered vessel with slight or no oxygen. It is formed by pyrolysis or gasification (heating system the biomass with little or no oxygen) in a procedure close to how charcoal is produced. Yet, the main use of biochar is for soil reformer. Adding biochar to the growing mix increases the amount of nutrients in seedlings, because plants could harness more accessible nutrients. According to Lashari *et al.*, (2018), RHB can decrease salinity strain in crops with significant environmental, agronomic, and economic use.

Also, RHB addition can decrease N and P usage from the plants which will require more fertilization for successful plant growth (Ali *et al.*, 2020). Also, the impact of biochar on plant growth varies among plant species. This is because diverse plants may possess dissimilar growing conditions or different resistance to some pressures. Not too many studies have been conducted to investigate the influences of biochar on diverse plant growth features to move yield, for instance seed germination and the building of shoots or roots (Chrysargyris, *et al.*, 2020; Liu *et al.*, 2021; Jabborova *et al.*, 2021). A few papers have applied low rates of biochar at 1–15% to peat (Solaiman, Murphy & Abbott, 2012; Hilioti, *et al.*, 2017; Bachmann, *et al.*, 2018; Gu, *et al.*, 2018) and have found a positive response on fresh and dry weight, morphological and physiological changes of plant leaves (Viger, *et al.*, 2015).

Rice husk biochar proportion affects appreciably growing media properties {EC, organic matter, organic carbon, N, K, Mg, Na, SO₄, Fe, Zn, and Mn at $p < 0.001$; P and B at $p < 0.01$ } and plant growth {Fv/Fm, MDA, CAT, POD, N, K, Ca, Mg, Cu, and Zn at $p < 0.001$ }. Fertilizer impacted substantially growing media properties {EC, organic matter, organic carbon, N, K, P, SO₄, and Cu at $p < 0.001$; Ca, Fe at $p < 0.05$ } and plant-related parameters (height, fresh weight, dry weight, H₂O₂, POD, P, Ca, Mg, Na, and Cu at $p < 0.01$; chlorophyll a, entire chlorophyll, CAT, Fe, and Zn at $p < 0.05$). In conclusion, according to Chrysargyris *et al.*, (2020), biochar increases crop growth (biomass, height) at a little proportion (7.5%). It decreased the appearance of lettuce and crop height at 15%. Increasing biochar increased nutrients in the seedlings, as the plants might take additional accessible nutrients.

2.2.3.1 The role of Biochar in growing media

Currently, biochar has proved to be a potential component of growing media. The benefits of biochar include sequestration of carbon (Zimmermann & Ouyang 2019), retention of soil moisture

(Hernandez-Soriano *et al.*, 2018) and restraining soil pathogens (Elad *et al.*, 2012). It generally improves soil health (Nan *et al.*, 2022). Biochar may also affect important physical and chemical properties of soil. For example, soil structure, liberation of soluble C and making micronutrient available to plants. Therefore, biochar is a potential material that could be incorporated into sod media. Biochar improves BD, particle size distribution and WHC of growing media (Kaudal *et al.*, 2016). Trupiano *et al.*, (2017) researched on the biochar effects on lettuce (*Lactuca sativa* L.) growth, and reported that compost modification had positive impact on plant growth and yield. It also enhances retention of nutrients for instance N and P (Werdin *et al.*, 2021; Reza *et al.*, 2020). It improves disease resistance and water retention of growing media (Zwart & Kim, 2012; Harel *et al.*, 2012). Mulcahy, Mulcahy, & Dietz, (2013), reported that, in sandy soil, 30% (v/v) biochar, concentrated in tomato seedling root regions, significantly improved seedling resistance to drying for over 4000 tomato seedlings. Prasad *et al.*, (2019) stated that applying 25% pelletized biochar to peat enhanced hydraulic conductivity in the medium as well as water availability. Although biochar has good properties as a growing medium, other factors may affect its use in horticultural production. Blok *et al.*, (2017) reported that Biochar from vegetable debris contained undesirable elements such as Na, Cl, SO₄ and HCO₃. These were in high amounts to decrease growth at doses exceeding 10% v/v. Vaughn *et al.*, (2015) evaluated biochar composition in the growing media and reported that at higher levels above 15% decreased plant growth. This phenomenon was attributed to excessively high pH values. The authors proposed that, if pH standards of biochar were less, then higher proportions of biochar could be used. Altland & Locke, (2012) and Jahromi (2018) discovered that washing biochar with water before use reduced pH. Altland & Locke (2012) studied Gasified Rice Hull Biochar on nutrient availability and showed that GRHB offers adequate P and K to sustain a production of geranium. However, it needed the right equilibrium of

micronutrients for vigorous development of geranium. Lu, Sun, & Zong (2014) studied the effect of RHB and detected that, addition of RHB increased soil aggregate stability. It influenced WHC, root dispersion and seedling appearance. It was also recorded that, addition of a 6% RHB to growing media reduced the percentage of micro aggregates from 70.9% to 50.4%. According to Korai (2021), adding biochar to soil increases cation exchange capacity (CEC) under favorable conditions. The authors stated that, the BD of the soil utilized in the experiment decreased by approximately one-third with 150 g/ kg biochar. This was in sync with results that a 10% biochar modification significantly reduced BD of soil. It was concluded that, RHB used at rates between 50–150 g/ kg in pot experiments brought an extremely positive impact on lettuce and cabbage growth. Altland & Locke (2012) suggested that future research would need to explore the impact of biochar properties and their possible usage in glasshouse and nursery container farming. Production of biochar is cost effective and can be practiced by smallholder farmers (Huang, 2023). Biochar prevents leaching of nutrients from growing media. Mineral nitrogen (N^- , NO_3^-) is the most frequently leached nutrient in media. This is because of the small anion-holding capacity of maximum growing media utilized in crop production (Matysiak & Nogowska, 2016). Xie *et al.*, (2019) stated that leaching of nutrients particularly nitrogen (N) and phosphorus (P), is a challenge with media formulation. There are factors which affect the extent of leaching from growing media. These include media components, plant species, volume of water applied and frequency of watering, (Shober, Wiese, Denny, Stanley, & Harbaugh, 2011). Zheng, Cayan, & Dixon, (2010) found that up to 50–60% of the nitrogen applied to greenhouse roses was lost due to leakage. This increased to 2000 kg/ha per year. Breš & Trelka, (2015) reported an entire decline to 231 kg $N^-NO_3^-$ per month/ha for greenhouse growth schemes. Soilless culture in exposed fertigation system was used. Different workers recorded $N^-NO_3^-$ concentrations in runoff water up to 7.2 - 12

(Colangelo & Brand, 2019), 2.8 - 29.9 mg/l (Wilson *et al.*, 2010) and 0.7 - 26.3 mg/l (Wilson, Rosen, & Moncrief, 2010). Bilderback *et al.*, (2013), stated that, growing media modifications that could quickly reduce leakage of N and P would preserve these nutrients for future utilization by plants. This will abate their effects on the atmosphere. According to Novak *et al.*, (2019), switchgrass stolon and root yields significantly increase in soil amended with compost in blend with cattle manure, RHB or poultry litter. Five percent cattle manure biochar with 5% compost decreased in total Cd and Zn absorptions calculated in switchgrass stolons and roots associated to the additional two factors. Switchgrass advance was markedly enhanced afterward treatment with the compost in blend with biochar from cattle manure. This may be clarified by the improved soil pH that encouraged Zn and Cd, water absorption that lessened soil-available heavy metal absorptions.

2.2.4 The importance of Topsoil on Growing Media

Topsoil is depleted or not available and so new options are needed to be evaluated. Soil erosion has reduced water quality and instigated land filth. The continuous digging of soil for establishing lawns is not environmentally sustainable (Danso *et al.*, 2010; Alireza and Mohammad, 2019)). The continuous use of topsoil for sod production and other agricultural activities have led to its scarcity. Most sod growers have resorted to the use of infertile soils, resulting in poor sod production, and poor field establishment. Over 3000-3500 tons of soil is dug annually from farmlands for horticultural activities in Ghana (Danso *et al.*, 2010).

Topsoil is the uppermost layer of natural soil of about 10.16cm-30.48cm in thickness which vary from environment to environment (Ogunrotimi and Kayode, 2018). Among soil layers, topsoil contains the highest amount of organic matter. This is because it contains high volumes of dead plant twigs, leaves, dead insects, fungi, and microorganisms which add essential nutrients to the

layer. Topsoil plays important role in sod production. It contains all of the nutrients that grasses need to survive and grow. It holds nutrients, absorbs water and provides anchorage (Ogunrotimi and Kayode, 2018). According to Regassa *et al.*, (2023) pore spaces, CEC, WHC, BD, pH, soluble salts and delivery of the elements size are essential physical and chemical characteristics which need to be considered before choosing a medium. However, the conventional topsoil mostly used for sod production is unable to provide these properties without amendments (Olle *et al.*, 2012; Ogunrotimi and Kayode, 2018). Also, topsoil is currently expensive in Ghana (GHS 3500 per 20m³) and becoming scarce (Mr. Acheampong, 2023; personal communication). This is as a result of erosion and extensive use of mass grading to remove topsoil during construction (Brown, Mahoney, & Sprenger, 2014). The amount of clay as inorganic material to growing media improves K, P and micronutrients, pH-buffering, improvement of re-wettability, and solidity of growing media (Dultz *et al.*, 2010).

2.2.5 Clay and its importance

Clay is a mineral component to growing media to change their chemical and physical properties. Several kinds of clay vary in CEC dependent on their mineral arrangement (Meisl *et al.*, 2013). Clay particles possess a high CEC and are usually more fertile and hold more H₂O (Bartholomew and Williams 2010). Clay helps to enhance soil structure by binding soil particles together. This can prevent soil erosion and improve water retention. Clay contains nutrients that are vital for plant development, such as potassium and Ca. Clay also helps to buffer pH levels in growing media for maintaining the right conditions for plant growth. Thus, clay plays a vital role in the fertility and health of growing media.

Adding clay to growing media increases preservation of nutrients and reduces leaching. It promotes nutrition of planted crops (Binner, 2014). However, clay quantity can lessen the accessible phosphorus amount in growing media.

The CEC of clays is predisposed by the amount of clay minerals. For example, montmorillonite has the maximum CEC 0.7–1.3 mmol (+) g⁻¹, CEC of illite arrays from 0.2 to 0.5 mmol (+) g⁻¹ and kaolinite has the bottommost CEC 0.03–0.05 mmol (+) g⁻¹. High CEC of natural clays is > 0.3 mmol (+) g⁻¹ (Meisl *et al.*, 2013). After mineral apparatuses zeolites have the uppermost CEC, it arrays from 1 to 2 mmol+g⁻¹ (Figueiredo *et al.*, 2018).

Atzori *et al.*, (2021) noticed that clay addition to the peat-coir blend improved H₂O capacity at 1 kPa H₂O tension, EAW and accessible H₂O. It however, reduced entire aperture space and oxygen volume.

In man-made biological growing media with mineral constituents the proportion of clay ranges from 30 to 200 kgm⁻³ of growing media. The proportion 200 kgm⁻³ roughly agrees to 20% vol. The producers of woody plants for landscape gardening use blends with an extreme content (equal to 50% vol.) of mineral constituents (soil loam). Shortcomings comprise high BD and typically little oxygen content in such growing media (Carlile, Cattivello & Zaccheo, 2015).

Clay modification had a substantial consequence on cultivation of Thuja plants. Grown in the media with clay, they were fewer and had minimize fresh and dry masses. Meisl *et al.*, (2013) and Virrarreal-Sanchez (2022) reported that the source could be shoddier phosphorus obtainability besides minor size of essential agricultural variables (EAV) in media with clay.

Clay addition altered physical and chemical features of the verified media. The consequence hinge on scaling and on the degree of the clay produce. Clay count reduced the available nitrogen,

potassium and phosphorus in media before establishing. In cooperation clay products augmented element density and BD and reduced entire aperture volume. Clay products altered water holding features, the consequence of fine clay was far sturdier. It only reduced WBC and AS. Coarse clay limited substrate shrinkage. They concluded that, Thuja planted in the media modified with clay were petite and were lesser in fresh weight and dry weight than ornamentals in the rheostat media.

2.3 The need to evaluate different materials for sod production

Evaluating different materials for sod production, apart from traditional soil, is important for several reasons. These alternative materials are often referred to as growing media or substrates. Their selection can have a significant impact on the success of sod cultivation. Here are some reasons why it is necessary to consider and evaluate different materials:

2.3.1 Optimized growth conditions

Sod requires specific growing conditions for optimal development (Braun *et al.*, 2020). Traditional soils may not always provide the ideal environment. Evaluating alternative materials allows producers to customize growing media. This will help them to meet the specific needs of the grass species being cultivated. This can include factors such as texture, nutrient content, and pH levels.

2.3.2 Consistency and uniformity

Different materials can be mixed to make growing media. These materials, however, possess consistent and even characteristics.

This is necessary for producing sod with uniform quality and appearance across the entire field. Consistency in growing media ensures that each piece of sod harvested has similar root development, nutrient content, and moisture retention (Bunt 2012).

2.3.3 Improved drainage and aeration

Many alternative materials improve drainage and aeration properties compared to native soils. This is crucial for preventing waterlogged conditions (Qamar, Shafaat & Javeed, 2023). Waterlogged conditions can lead to root diseases and poor grass health. Thus, well-draining growing media promote healthy root development and overall turf quality.

2.3.4 Disease management

Traditional soils may carry soil-borne pathogens and pests. Incidents of soil-borne pathogens and pests can affect the health of the sod (Sulaiman & Bello, 2023). Evaluating and selecting alternative materials can help mitigate the risk of diseases and pests. Thus, contributing to a healthier and more resilient turf.

2.3.5 Control over nutrient levels

Growing media can be formulated to provide specific nutrient levels required for optimal grass growth. This allows for better control over nutrient availability (Barrett, Alexander, Robinson & Bragg, 2016). It can also promote healthy and vigorous root and shoot development. Nutrient-rich growing media can improve the quality of the sod.

2.3.6 Conservation of resources

Alternative materials used in growing media may be sourced sustainably or recycled from other industries (Gruda 2019). Evaluating and adopting such materials can contribute to resource conservation. This is in conformity with environmentally friendly practices in sod production.

2.4 Growing Media Physical Properties

Sod media must possess well-proportioned physical and chemical features. These properties are pH, EC, C/N ratio, BD, water holding capacity, air occupied porosity, and stability. A good sod growing media may possess qualities such as; to hold enough moisture for plant growth, to enhance

exchange of gases to and from the roots, anchorage for root growth, and to serve as good store for nutrients (Hussain, Younis, Riaz, Tariq, & Ali, 2016). Growing media mixtures of different ratios have significant effect on plant biomass. For example: height, leaf number, chlorophyll content, fresh and dry weights (Younis, Rayit, & Riaz, 2015). Alam *et al.*, (2022) reported that nearly all the genotypes tested in media composted with rice husk and poultry manure turned out to be superior to that of sawdust and poultry manure.

Grasses require support, nutrients, and moisture from growing media for optimum performance (Gruda, 2023). Physical properties of growing media are most important parameters that affect grass performance in sod production (Awad *et al.*, 2017). Growing media physical properties describes how much water it can hold, available air spaces, texture and its weight per volume (Abu-hashim *et al.*, 2023). Physical properties of growing media for sod production have been determined. This is to give sod producers an impression of resources that could be employed as constituents for growing media. Yeager *et al.*, (2010) suggested that for desired physical properties for growing media air space of 10 - 30%, WHC of 45 - 65%, entire porosity of 50 - 80%, and bulk density of 0.19 - 0.70 g/cm³ are considerable.

2.4.1 Bulk Density

The BD is the oven- dried mass/ unit volume of the growing media which includes pore space. Mathematically, $\rho_b = M_s / V_t$ (Phogat *et al.*, 2018). It reflects how much the growing media is compacted. Factors that affect BD of a particular medium are the types of mineral particles, texture, organic matter content and compaction of the medium. Therefore, adding an appreciable quantity of organic matter to growing media of high bulk density reduces bulkiness and offers conducive atmosphere for root development. It means, the barge the growing medium, the freely grasses can sprout, develop roots and extend through the media to build a productive feeding apparatus. The

bulk density of growing media is of greater importance in understanding the physical performance of media and is used for calculating the weight of a furrow slice of growing media (Phogat *et al.*, 2018). Bulk density $< 1.5 \text{ g/cm}^3$ gives a good indication of the suitability of growing media. It helps in root growth, soil penetrability and is extremely significant for the media-plant-atmosphere scheme (Brogowski *et al.*, 2014; Miransari *et al.*, 2011). Lower bulk density of growing media increases penetration, rooting depth, obtainable water capacity, soil porosity, plant nutrient accessibility, and soil micro-organism action, which affect key soil procedures and output (Bartholomew and Willi, 2010). Bulk density usually declines with increases in organic matter content and also with fineness of soil texture. In most cases, growing media rich in organic matter that is loose and porous have a lower bulk density (Dal Ferro *et al.*, 2023). Advanced principles of bulk density are a pointer of soil compaction.

BD can therefore be achieved, using procedures that limit hardness and incorporate soil organic matter. Some of the management practices are incessant no-till, cover crops, compost usage, varied rotations with extreme residue crops, perennial legumes or grass. Increased bulk density reduces total porosity in the substrate which causes increased difficulty of root penetration. This is because growing media with a BD more than 1.6 g/cm^3 incline to limit root growth (Wang *et al.*, 2018). According to Bartholomew *et al.*, (2010) grasses display sluggish growth and lessen pasturage harvest due to changes in BD amid cultivated and uncultivated ground.

2.4.2 Porosity

The entire capacity of pore space in a medium is known as porosity. Porosity determines the flow of H_2O via the media profile (Fu *et al.*, 2019). The sum of entire pore space in a rooting substrate is inversely proportionate to the BD (Macagno & Bigi., 2017). It is a guide of comparative pore volume in soil (Phogat *et al.*, 2018). Thus, once the BD declines, entire pore space rises vertically.

The entire permeability of growing media determines water flow by the soil profile (Fu *et al.*, 2019). Porosity value ranges from 30% to 60%. Growing media aggregation increases total porosity and therefore increases the quantity of H₂O detained by the medium. The proportion of H₂O to air maintained in a medium is influenced by particle size and pore space dispensation. Large particles of growing media (0.5 mm) contain greater air space within the pores while particle size < 0.5 mm may hold available water (Kato *et al.*, 2013). Therefore, porosity decreases in coarse textured substrates than in the fine textured media. However, the size of discrete apertures is larger in the coarse featured media than in the fine textured growing media. Both Buol *et al.*, (2011) and Pardossi *et al.*, (2011) designated that porosity declined with snowballing BD and moistness of growing media. Their results showed that the permeability of their soilless substrate reduced from 93.0% to 87.0% as the BD augmented from 125.8 - 119.7 kg m⁻³ with declining wetness from 32.5 to 26.8 percent.

2.4.3 Water Holding Capacity

Water holding capacity is the quantity of H₂O that growing media can contain for crop use. It is the change amid the quantity of H₂O in the media at field capacity and the quantity of H₂O at wilting point. Water holding capacity is measured in inches/foot or inches/inch. Growing media that can contain a lot of H₂O can yield additional plant growth (Aduhene-Chinbuah, 2018). They are low-prone to forfeiture of nutrients and chemicals via leaching. Field capacity is the limit where the soil WHC has attained its supreme for the whole field. The ideal water holding capacity is between 40 to 65% and this complements a water retention of 25 to 35% (Gascó *et al.*, 2018). When there is a deficit in the quantity of H₂O in the media, it must stay irrigated. Understanding the dynamics of water holding capacity of growing media will help prevent drought. Growing media that can hold more water promote crop growth, less prone to nutrients loss and chemicals

through leaching. Water stress affects grass color as it causes browning and discoloration (Grass, 2021). According to Van Acker *et al.*, (2023), growing media conditioners such as sawdust increases moisture retention and facilitates cohesive interaction of its particles. Growing media water holding capacity is affected by soil erosion. According to Shelton (2015), erosion generally reduces water holding capacity of substrates. In research of Kentucky Maury and Crider soils, WHC declined from 29% to 24% in the Maury soil and from 24% to 20% in the Crider soil due to soil run off. This reduction in water holding capacity was caused by shallower medium and more undesirable media properties. In a substrate sample, as clay increases and organic matter decreases, the amount of water it can make available to the plant also decreases.

2.5 Growing Media Chemical Properties

Growing media chemical properties are essential for successful sod growth and development (Akinde 2020). Chemical affects nutrient solubility and retention of a growing medium by the flow of nutrients for plant uptake (Fu *et al.*, 2019). The main chemical components of growing media are pH, EC and CEC (Dickson *et al.*, 2016). These chemical components are reflected through total dissolved salts (TDS) (Mirsoleimani, Najafi-Ghiri, Boostani, & Farrokhzadeh, 2023).

2.5.1 pH

Growing media pH is a degree of the acidity or alkalinity of the media (Pagani and Mallarino, 2012). Practically, pH is the adverse log of the vigorous H ion (H^+) amount in the substrate solution. Measurement of pH is done deploying logarithmic measure. Thus, a reduction of 1 unit of pH indicates that the acidity upsurges by a feature of 10, therefore little fluctuates in pH standards can have significant effects (Farmaha, Fernández, & Nafziger, 2012). The pH of a growing medium should be in a range from 5.8 to 7.2 for optimum performance of sod (Alabdallah *et al.*, 2024). The pH of the media controls the availability of plant nutrients. This happens by the

regulation of the chemical forms and also change the chemical reactions (Pagani and Mallarino, 2012). The pH of the media changes often throughout the growing period. This depends on the kind of fertilizers used, especially those high in ammonium-N. It also hinges on soil moisture and biological activities of the media (Brown *et al.*, 2022). However, the optimum pH for high nutrient absorption varies significantly among plant species (Rengel, 2015). Dickson *et al.*, (2016) indicated that the pH of the substrates changes weekly or monthly through the growing period depending on the type of fertilizers used, especially those high in ammonium-N. It also includes precipitation and biological activities in the growing media. When the growing media pH is less than 5½ (five and half), the main plant nutrients [N, P, K, S, Ca, and Mg] required for growth develop considerably low obtainable to plants. This brings about aluminum poisonousness (Fageria, 2016). Because of this, acidic growing media are often unsuitable for sod production (Fageria, 2016). A pH greater than 7½ (seven and half), makes minor nutrients (Fe, Mn, B, Cu, and Zn) less available toward plants (Rengel, 2015). Work done by (Dickson *et al.*, 2016), plant species have different capacity for nutrients absorption at a given pH. For example, Geranium and Marigold efficiently accumulate Fe and Mn under high media pH of 6.5. But Petunia had difficulty taking up Fe under the same media pH condition and so required pH < 5.5 (Dickson *et al.*, 2016). Optimum pH for Bermuda or St. Augustine's which makes nutrients available improves color, (darker green, more chlorophyll), density, root and shoot growth, stress tolerance, recuperative potential, drought tolerance, water use efficiency, and seedling establishment. Thus, optimum pH affects turfgrass biomass production. Ow and Yusif (2018) studied about the consequences of localized liquid fertilization of N, P, K and Ca and concluded that exposed parts of the roots to nitrate deficiency instigated a localized delay of root start and expansion, coupled with a significant depression in foliar growth, likened with regions getting the complete stock of nutrients.

2.5.2 Electrical Conductivity (EC)

Electrical conductivity is an indicator of salt concentration and an index of electrolyte concentration of the growing media regime (Ding *et al.*, 2018). The growing media has the ability to convey an electrical current. This aids as a degree of the soil brininess (Hayat *et al.*, 2020). The electrical conductivity of a nutrient regime is connected to the number of ions accessible to crops at the root zone (Alem *et al.*, 2015). EC levels ranging from 0.5-1.0 dS/m are considered as the acceptable range for most plants in organic soils. However, the EC ranging from 0.2-0.5 dS/m are considered the optimum range for inorganic soils. Higher EC prevents nutrient uptake by plants. This, however, increases osmotic pressure of the nutrient regime (Ding *et al.*, 2018). Salt affects the osmotic ability of the soil solution by reduces it and intend decreases plant available water. Salt also affects the physical structure of the media for degeneration. This however reduces soil water penetration and air movement within the media. Also, salt affects the concentration of certain ions by increasing them in soil solution. This increment might be toxic to plants or causes other nutrients to become unavailable to plants (Khursheda, *et al.*, 2015). Salt stress hinders sprouting or germination of seed. It causes changes in physiological characteristics of the plant (Akram *et al.*, 2019). Highly concentrated salt may damage roots of plants and reduces plant growth. It also causes wilting of plants or total crop failure (Aslam *et al.*, 2017).

2.5.3 Cation Exchange Capacity (CEC)

Cation exchange capacity is the aptitude of an element to alter positive bases within the growing medium (Aprile & Lorandi, 2012). CEC promotes retention of positively charged ions and prevents them from leaching. This however, supplies nutrients to plant roots by an exchange of ions. The most essential exchangeable cations in growing media are ammonia (NH_4^+), Calcium (Ca^+), Potassium (K^+), Magnesium (Mg^{++}), Sodium (Na^+), Aluminum (Al^{3+}) and Hydrogen (H^+) (Aprile & Lorandi, 2012). CEC has the capacity to influence soil pH directly. For instance,

when clay particles trap cations, releases H^+ and Al^{3+} ions. This in high concentrations causes soil acidity. The CEC changes with different types of media. CEC of organic residues are low and tend to increase as the residues change into humus. A high CEC is advantageous in a way. This is because it provides nutrients to plant roots and reduce nutrient loss under frequent watering. High CEC causes the growing media to retain more cations. CEC of clay varies from 4 to 100 meq per 100g. whereas, humus has an average CEC of 2 00meq per 100g.

2.5.4 Nutrient Requirement of Sod Production

2.5.4.1 Nitrogen (N)

In sod production, fertilizer plays a key role. Nitrogen is the most significant element in most fertilization programs (León-Burgos, *et al.*, 2022). It is especially critical in sod production where rapid vegetative growth occurs (Melgar *et al.*, 2010). Grasses absorb nitrogen as nitrate (NO_3^-), ammonium (NH_4^+) ions and urea. Nitrogen is part of all living cells. It is in the configuration of all amino acids, proteins, enzymes and metabolic procedures included in the synthesis and transmission of energy (Sainju *et al.*, 2019). Grasses need N for the production of proteins, nucleic acids (DNA and RNA) and chlorophyll. Generally, N deficiency indications in worse cases are chlorosis of lower leaves, stunted growth and necrosis of older leaves (Brown *et al.*, 2022). Grasses depends on N for photosynthesis. It also aids in stimulus of fast and dynamic vegetative growth of grasses. It increases grass length and gives dark green coloration of leaves (Bassi, Menossi, & Mattiello, 2018). Application of organic matter with high carbon content such as sawdust to the growing media can cause nitrogen deficiency in plants. This is because, organisms in the growing media use any N to break down carbon sources and so make N unavailable to plants. Lima *et al.*, 2014 reported that increasing nitrogen level of 249.31 kg ha⁻¹ to 422.9 kg ha⁻¹ significantly increased plant height and stem diameter.

2.5.4.2 Potassium (K)

Grasses absorb potassium in greater quantities (Khan & AlZuaibr, 2022). Grasses use K in the stimulation of enzymes, photosynthesis, protein construction and sugar conveyance (Johnson *et al.*, 2022). In grass, potassium is needed to maintain the osmotic ability of cells. It is also needed for turgidity as well as closure and opening of stomata. Potassium takes part in H₂O absorption from the growing media and H₂O holding in crop tissues. A typical example is the transport of water from xylem to phloem for photosynthesis (White & Ding 2023). The common K deficiency symptoms are chlorosis along the leaf margins. There is also a reduction of growth rate due to poorly developed rooting system (Johnson *et al.*, 2022). The infested older herbage demonstrates local spotted parts with leaf scorch at borders. The signs of chlorosis mostly start on the leaf apex. This however, advances by the leaf borders to the bottom, parting the midvein active and green. As the lack advances, the entire leaf turns yellowish. Insignificant white or yellow necrotic areas might also grow, starting with leaf borders (Brown, Zhao & Dobermann, 2022).

2.5.4.3 Phosphorus (P)

Phosphorus is needed in sod for the growth of Adenosine Triphosphate (ATP energy), sugars and nucleic acids. Young grasses have relatively, greater demand for P than more mature ones. This is because, P deficiency signs are generally very obvious in young crops (Das, Avasthe & Yadav, 2017). Grass with P insufficiency mainly brings dark green (both leaves /stolons). Mature leaves are infested first, and this assumes a purplish discoloration. There is also building up of sugars, which promotes the synthesis of anthocyanin. This causes browning of leaf tips and death. Grasses affected by P deficiency grow weak and delay in establishment. Leaf growth and surface area could be reduced. This causes herbages to twist and become very light. Light grains with P lack incline to be strained and prone to root rot infections, and some varieties will change color from red or purple (Brown, Zhao & Dobermann, 2022). In sod production, phosphorus is involved in seed

germination, sprouting, root development, and strong stolons development. Deficiencies of phosphorus causes underdeveloped growth, tinny stolons, reduced growth of flowers and roots, inadequate development of leaf and skinny appearance of leaves. In addition, there is a reduction in leaf span, leaf scope and girth diameter of grass (León-Burgos, Unigarro, & Balaguera-López 2022).

2.5.4.4 Calcium (Ca)

Calcium is a constituent of crop cell walls. It controls cell wall building. Ca is

Needed in roots growth, root hairs and root tips (Ghosh *et al.*, 2022). Calcium deficiency may bring new leaves to develop slanted and become unusually dark green. Grass stolons develop weak. Leaf apex frequently turns dry and may finally wilt and die. Mohammed *et al.*, (2020) stated that calcium is sometimes required in higher concentrations when grass is young.

2.5.4.5 Magnesium (Mg)

Magnesium is the vital molecule in chlorophyll. It is essential for photosynthesis in grasses. Mg is also a significant co-factor for the manufacture of ATP. Interveinal chlorosis and leaf borders turning yellow or reddish-purple whereas the midrib maintains green are typical symptoms of magnesium deficiency (Tanoi & Kobayashi, 2015).

2.5.4.6 Trace elements (Zn, Cl)

Zinc (Zn) is required by grasses for the production of growth hormones. Zn performs a substantial function in photosynthesis, resistance of plants to diseases, cell membrane stability, protein synthesis and pollen formation (Rudani, Patel, & Prajapati, 2018). Zn has intermediate movement in grasses and signs are mostly seen in mid leaves. Zn undersupplied leaves exhibit interveinal chlorosis, particularly halfway amid the border and midvein. Leaves produce a striping outcome as well as streaking. Chlorotic parts often turn light green, yellow, and may be white. Severe Zn

deficit in grasses make leaves show grey-white, dry up or perish (Hossain, Haque & Rahman, 2015). Since Zn performs a profound function in internode elongation, Zn undersupplied stolons largely display plain stunting (Brown *et al.*, 2022).

Chlorine (Cl) concentration in the plant decides yield and quality composition. Grasses require Cl for leaf turgor and photosynthesis. Cl deficiency eventually leads to metabolic problems that obstruct grass growth (Geilfus, 2018). The deficiency also shows chlorotic and necrotic spotting on leaves with sudden margins amid deceased and live tissues. Leaves begin to wilt on borders with extremely divided root structures. This is mostly found in grasses. Cl deficits are extremely cultivar precise and are simply confused with leaf sicknesses (Brown *et al.*, 2022).

To attain a suitable level in terms of sod establishment, the quality of the growing media formulated should meet some criteria, which includes improved media physical/ chemical features, boost plant nutrient obtainability and associated growth and establishment, increased bacterial population and activity and decrease glasshouse air releases via carbon seizure improve soil physical and chemical properties (Mukherjee & Lal, 2013; Biederman & Stanley Harpole, 2013; Jaafar, Clode, & Abbott, 2014; Crombie *et al.*, 2015). A successful establishment of sod is achieved by a mixture of high rates of emergence and tillering, and vital plant development. Thus, a good establishment phase will enhance the probabilities of more sod output and sustainability.

2.6 Bermuda and St. Augustine's grasses

Among the factors that affect the growth and establishment of Bermuda and St. Augustine's grasses in Ghana is depleted soil richness and hostile soil physical properties (Augustine, 2018). Over the years, nutrient exhaustion as a consequence of unjustifiable sand winning practices have changed initially rich soils into infertile ones (Osman 2018). Orthodox soil fertility preservation

approaches for instance, the use of inorganic fertilizers have been espoused by sod growers over the years. These outdated approaches have proven to be unmaintainable in sod production as a result of the residual effect of inorganic fertilizers and its associated environmental pollution. Bermuda and St. Augustine are quality nutrient- seeking grasses which need to be provided by the soil being the elementary environment and provider of the nutrients.



PLATE 1: a) Bermuda grass b) St Augustine's grass

2.6.1 Characteristics of Bermuda and St. Augustine grasses

Bermuda and St. Augustine's grass are characterized under species, tillering, stolon size, drought tolerance, rooting habits. Bermuda and St. Augustine's grasses are grass species found in tropical and subtropical areas (Sollenberger & Wallau, 2020). In tillering, Bermuda grasses produce more tillers than St. Augustine's grass and are relatively taller. According to Ribeiro *et al.*, (2023), a satisfactory establishment grass is attained by a mixture of high levels of field establishment and

tillering, and dynamic plant development. Bermuda grass stolons spread quickly, as long as 2m, but are usually 0.5-1.5 m. Bermuda grass produce several (8-40) culms. Face down but blossoming culms usually are vertical or geniculated and can be 10-90cm in height. Leaf blades of Bermuda grass are blue- green, 02-20 cm in length, and 2-6mm in width, smooth on the lower exterior but pubescent at the superior one (McCarty, 2018). On the other hand, Saint Augustine's grass is a stoloniferous and creeping perennial which develops quickly and forms dense leafy sods. Stems are branched from numerous nodes and may be up to 50 cm tall. The leaves of St. Augustine's grass are glabrous, blue-gray rounded blades, 3-15cm long and 3-12 mm wide. Inflorescences are 4-15 cm long with spike-like panicles (Chamberlain, 2018). Bermuda grass stolons are thinner (0.3 mm-2 mm) than the stolons of St. Augustine's grass ranging from 1mm to 4.5 mm (Nelson & Moore, 2020). Bermuda grass is a good drought tolerant grasses, whereas St. Augustine's grass tolerates drought moderately. According to Mandal *et al.*, (2017), Bermuda grass can survive up to seven months drought and several weeks under water because of its deep rhizome and deep rooting system (15.24 cm). St Augustine grass can withstand temporary flooding and waterlogging and does not tolerate a prolonged dry season (Giolo *et al.*, 2023).

2.6.2 Origin and climatic conditions of Bermuda and St. Augustine grasses

Both grasses are indigenous to the coastal region of West Africa in the *Poaceae* family (Baxter *et al.*, 2022). Especially, it is a commercially significant kind for sod production (Quesenberry, Ocumpaugh & Ruelke, 2019). They are warm-season perennial species with a C4 photosynthetic pathway. The temperature requirements vary from 20 °C to 30 °C, with the lowest temperature for development being 10 °C (Krishnan *et al.*, 2011). Mostly, Bermuda and St. Augustine grasses grow vigorously when temperatures are sufficiently high with adequate moisture. Generally, Bermuda and St. Augustine perform better in annual rainfall zones, ranging between 1000 mm-2000 mm with moderate drought tolerance (Krishnan *et al.*, 2011; Stier, Horgan & Bonos, 2020).

Studies have shown that these grasses are able to tolerate long seasons of drought but resumes growth and recover greenness when moisture is reestablished (Colmer, 2011; Ewing, 2020).

2.6.3 Soil requirements of Bermuda and St. Augustine grasses

Bermuda and St. Augustine grasses may be grown on several diverse soils. However, a well-drained soil rich in organic matter and nutrients is utmost appropriate. Bermuda and St. Augustine grasses thrive well in soils with pH between 4.5 and 8.5 and they grow across a range of soil textures (Ewing, 2020). They grow well on sandy loams to light clays, ranging in pH from 4.5 to 8.5 (Stier, Horgan & Bonos, 2020).

2.6.4 Nutrient requirement of Bermuda and St. Augustine grasses

Bermuda and St. Augustine grasses averagely require both major and minor nutrients for growth and establishment. Nitrogen, Potassium Phosphorus and Calcium are mostly very significant in sod production in soil-field structures. Various micronutrients have been explicitly studied and found to be very significant for Bermuda and St. Augustine grasses. These include, iron and zinc. Micronutrient deficits are rare but on very sandy soils, high pH soils, or in cases of imbalances due to key element extremes, such as Phosphorus. These micronutrients, if not in their appropriate concentration level in the growing medium or plant, may end in a deficit or poisonousness. Therefore, addition of a micronutrient to the soil must be based on a soil examination and/or plant analysis-based endorsement (Jones, 2013).

2.6.5 Sources of nutrients for Bermuda and St. Augustine grasses

Various constituents may serve as bases of plant nutrients. Such materials may be natural, artificial, secondhand wastes or a range of biological goods such as microbial inoculants. Nutrient bases are generally categorized under organic, mineral and biological. Minerals, as well as organic nutrient are existing in soils, but they must frequently be enhanced with outside materials for improved plant growth (Hansen *et al.*, 2019). Badawy, El-Khateeb & Salem, (2018) applied NPK, at once-

a-month rate of 5 g/ tray to all plants under their study and recorded that the shade of Bermuda grass distinctly improved in clay or its combination with sand. Pompeiano, Grossi & Volterrani, (2012) studied on “the vegetative establishment rate and stolon growth characteristics of ten Zoysia grasses in Southern Europe” and recorded that addition of N fertilizer [20N–2.2P– 6.6K–1.2Mg], 10 gm–2 and diammonium phosphate [18N–20.1P–0K–2S], 25 gm–2, to the soil significantly improved stolon growth frequency, establishment rates, biometric traits, and winter color retaining of Zoysia grasses.

2.6.6 Factors that affect growth and establishment of Bermuda and St. Augustine grasses

Generally, Bermuda grass is established by seeds. However, cross variations are unable to produce seeds and are proliferated vegetatively by sprigs (pieces of rhizomes) planted in the soil on a 90 cm grid. St Augustine’s grass produces very few viable seeds and is usually propagated vegetatively. The growth and establishment of Bermuda and St. Augustine grasses are affected by physical, ecological and social factors, including growing media, water, nutrition and climatic factors. Barrett *et al.*, (2016) detected that part of the factors that contribute to slow growth and development of plants is little soil productiveness and unfavorable soil physical characteristics like bulk density. Little soil fertility and physical restrictions distress sod production particularly in Ghana, known for her often restraints of compaction, surface deepness, high temperature and nutrient deficit of soil (Mensah, 2015). Moreover, environmental factors such as soil type, temperature, rainfall and relative humidity can cause severe consequence on growth and establishment of grass (February *et al.*, 2013) Ground managing practices also have effect on turfgrass quality. Sod that has been strained due to high or low watering may result in high level of nitrogen and mechanical damage seen as brown patches in lawns (Hempson *et al.*, 2015).

2.6.7 Effect of organic and inorganic manure on the establishment of Bermuda and St. Augustine's grasses

Sod/turfgrass cultivators, particularly marketable ones, hang on either chemical manures and/or biological manure to enhance plant development and establishment. Incorporation is the method used to improve the nutrients of soils to meet turfgrass and is for the upkeep of soil fertility to increase production. Fertilization may have both adverse and helpful effects on the condition of the soil. It also has the capacity to offer the sound ecological conditions essential for growth and establishment of Bermuda and St. Augustine's grasses. Kering *et al.*, (2011) in their publication on effects of nitrogen (N) fertilization rate reported that nitrogen fertilizers increased forage quality of Bermuda grass. In the same vein, work done by Nematollahi *et al.*, (2018) "Improving early growing stage of *Festuca arundinacea* Schreb, using media amendments under water stress conditions" recorded that Using municipal solid waste and fertilizer vermicompost as soil modifications could sustain soil moistness and water supplement for the enhancement of morphological, physiological and visual value of the ecotype of *Festuca arundinacea* Schreb.

2.6.8 Growth and establishment of Bermuda and St. Augustine's grasses

Turfgrass growth and establishment may be well-defined as the advanced development and covering of the grass (Fan *et al.*, 2020). Normally, the term growth and establishment are stated as the quantity of biomass in the plant or plant part. Too much of nitrogen manures like Ammonium sulphate or Ammonium nitrate may result in toxicity in plants, retarding the growth of the plants consequently (Grzebisz *et al.*, 2022). Chen Chen (2020) researched on the effect of pig and horse manure compost on growth of *Acacia confuse* seedlings and stated that 10% addition of pig manure enhanced seedling survival of 97% than the control (soil) 92%. However, higher applications (30% and 40%) reduced seedling survival (87% and 38%) respectively. Whereas all rate of application produced less seedlings with horse manure.

2.7 Growing media required for Bermuda grass

A growing medium is a constituent through which plant roots grow and draw water and nutrients. It is specifically formulated to provide optimal conditions for plant growth.

Growing media are made to attain high porosity and water retaining capacity while providing satisfactory aeration. Media “substrates” or “plant substrates” offer a root setting that is primarily free of plant pathogens and features that guarantee an adequate aeration, water, and nutrient supply. Growing media could differ depending on the type of crop/plant. In horticulture, largely, combinations of media elements and flavors are used. Organic or inorganic resources can be used as constituents, while flavors include fertilizers, liming materials, and bio-control or moistening agents. The growing media quality, effects of growing media characteristics on water and nutrient management, media column height and containers, handling growing media and growing media components affect grasses growth and yield (Nguyen, 2022).

A lot of materials can be used to prepare growing media, such as biochar, sawdust, poultry manure, topsoil. However, their preparation depends on media properties that may be interrelated with agronomical purposes, such as the capacity to maintain grasses growth (Gruda 2019). So, the key objective regarding the identification of an appropriate growing media for turf/sod production is the cause of an effective and balanced development of the turf (Hull, Alm, & Jackson, 2020). These grasses have been established in a substrate apart from soil. Owusu *et al.*, (2024) researched on “sustainable commercial sod production of *Cynodon dactylon* (Bermuda Grass) in Ghana: assessing growth, visual, and physical quality” and concluded that application of chicken manure to soil visibly enhanced the growth, visual display, and physical strength of both seeded and sprigged sod, meeting commercial ethics. Similarly, Owusu *et al.*, (2023) studied “evaluation of *Chrysopogon aciculatus* (Ritz.) Trin. seed for sod production in Ghana: an assessment of growth

performance and post-harvest quality” and recorded that chicken manure with soil had pointedly higher clipping fresh and dry weights, higher sod tensile strength, long-lasting, and handling quality of sod.

Generally, grasses grown in containers, have shallow volume to develop their root system. This creates an unstable association between growing stem and root. Also, under field settings, more attentiveness to the water, air, and nutrients grasses consume must be paid. The reason is that an extreme buildup of salts, insufficient drainage and poor aeration could be harmful for sod growth. Under greenhouse condition, the perfect medium must physically help the turf. It must enhance oxygen exchange for root breathing through good porosity. It must also support well drainage of surpassing water and avoid waterlogs by a high water-holding capacity. Moreover, media that is able to adsorb cations will by all means provide nutritional requirements for the turfgrass. Actually, plant nutrients which are mostly electrically charged ions, like NH_4^+ , K^+ , Ca^{+2} , Mg^{+2} , in growing media is essential for quick development of ornamentals. Furthermore, pH is also an essential chemical feature of an appropriate media. This is because it touches nutrient accessibility.

The physical make-up of growing media should be steady with time. It must be in good shape for physio-chemical properties together in the time and in the space. It must promote resilience to the compaction and to capacity decrease during the lack of moisture phase. Obviously, the materials for media formation should be easily, locally and readily available. They must be cheap in order to satisfy requirements for sustainability. Effective growing media is safeguarded by the absolute nonappearance of both human and plant pathogens (bacteria, nematodes, fungi, and insects). Moreover, the substrata must be free from chemical deposits (pesticides) and from other possibly phytotoxic constituents and weed seeds.

According to Nematollah *et al.*, (2018), one of the keys to reduce scarcity stress in diverse growth phases of grasses is the addition of soil modifications (Increasing the organic matter content of the medium) to the media. One way of amending soil is the use of organic materials. Examples of locally available organic materials are: poultry manure, rice husk biochar and sawdust (Ravindran *et al.*, 2022). These organic constituents affect the development of turf grasses. For instance, turf grasses grown in bio solid-amended soils covered faster and showed advances in density, color and the ability to resist foliar diseases (Khaple *et al.*, 2012; Nematollahi *et al.*, 2018; Kazemi *et al.*, 2021). Talbott (2022) also specified that poultry manure had positive effect on the growth of *Festuca arundinacea* Schreb and *Poa pratensis* L. growth. He established that poultry manure can be an appropriate source of manure for grassland renovation and manufacture if applied in a suitable measure. Ongun *et al.*, (2023) also showed that manure sludge improved development and green color in lofty fescue, perennial ryegrass and Kentucky bluegrass. Moreover, manures and crop residues restored productivity in eroded soils (Zhou *et al.*, (2015). Parallel outcomes were given concerning the use of yard trimmings on *Cynodon dactylon* and *Paspalum notatum* (Vance, 2019).

In order to achieve a successful sod production, the grass to be used must have adaptation, ease of establishment, suitability in erosion control, well suited to use as cover crops to suppress weeds by hindering light and outcompeting weeds for water and nutrients. Not only that, suitable growth media is also required for growth and establishment of sod as it has the ability to retain water and nutrients for root uptake, make available sufficient root aeration, and ensure structural support to the plant (Quesenberry, Ocumpaugh & Ruelke, 2019; Criscione, 2021; Gruda & Bragg, 2021; Sahoo *et al.*, 2023).

2.7.1 Origin and Botany of *Cynodon dactylon*

Cynodon dactylon (Bermuda grass) is native to southeast Africa. It is widely distributed in India, Australia and New South Wales.

Cynodon dactylon (Bermuda grass) is a warm-season grasses in the *Poaceae* family. It is deep-seated, sod-forming and covers by stolons and rhizomes which grows to a height of 37 to 60 cm. Its stems spread laterally below-ground by rhizomes and above ground by stolons.

2.7.2 Uses of *Cynodon dactylon*

Cynodon dactylon is habitually used for home grasses, athletic pitches, golf course roughs, and utility turf zones (Liu *et al.*, 2021). Bermuda grass yields a widespread root system. This enhances some deficiency tolerance. It responds well to nitrogen fixation. This in turn yields a huge quantity of dry matter for either grazing or hay production.

Bermudagrass (*Cynodon* spp.) is mostly grown by stolons. However, the planting proportion needed for effective development fluctuates under diverse soil condition. Dryness of planting material can happen quickly even under moistened environments because of adjustable on-farm irrigation management. Few studies have assessed stolon planting frequency effects under such settings. According to Baseggio *et al.*, (2015), the effect of stolon thicknesses affects the development of Tifton 85. Their study showed treatments of 5 planting rates with 1120, 1570, 2020, 2470, and 2920 kg/ha organised in four copies of a randomised complete block design. The three greatest planting density attained 80% frequency at 40 days after planting equated with 68 days after planting. In the sand of the U.S. Gulf Course, planting densities enhanced bermudagrass rate of recurrence, ground cover, and dry matter harvested and reduced weed spread. All treatments had more than 80% bermudagrass frequency of occurrence and ground cover after planting in 2011 kg/ha.

2.7.3 Climatic requirement of *Cynodon dactylon* rowing media soil vs. new growing media

Cynodon dactylon grows best under temperature between 30–38 °C with soil temperature between 24–35 °C. It requires minimum air temperature of 13 °C for growth. *Cynodon dactylon* needs high sunlight intensity for best growth. At least 6 hours of full sunlight is a daily requirement for growth. Enclosed environments limit photosynthesis, and therefore reduce yield. Excessive shade brings about tinny and etiolate leaves. It also leads to increased internode length with reduced tiller density and rooting. *Cynodon dactylon* thrives on well- infiltrated topsoil with pH between 6 and 7. Topsoil pH > 7.5 can lead to nutrient deficiencies such as nitrogen, potassium and phosphorus (Liu *et al.*, 2021).

2.7.4 Effect of planting depth of stolon on root development/ tillering

Among several production features which limit sod establishment, planting density is the utmost significant agronomic practice which needs critical consideration (Baloch *et al.*, 2023). The density which brings extreme yield rest on temperature, solar radiation, moisture and soil fertility. The performance of individual grasses increases with wider spacing. This is because wider space promotes more extraction of nutrients and more absorption of solar radiation for improved photosynthetic development as single plant (Asmamaw, 2017). When plant population is increased beyond the optimal density will result to unnecessary stress on grasses which will affect tiller formation, sun light interception, nutrient uptake, rate of photosynthesis and will eventually affect the growth and establishment of sod (Bozorgi *et al.*, 2011). Asmamaw 2017, investigated on “the effect of planting density on the growth, yield and yield attributes of rice” and revealed that “growing plant density from 16.7 to 50 hills m⁻² panicle length and stem diameter decreases by 12 % and 29.2%, respectively”. Instead, a reduction in density led to a substantial increase in spikelet number/ panicle over the previous population density. “Spikelet number/panicle increase of 44%, 32%, 26% and 9% were attained in 16.7 hills m⁻² over 50, 33.3, 25 and 22.2 hills m⁻², respectively”

(Asmamaw 2017). Also, Solanki *et al.*, (2021) researched on “Turf establishment quality as affected by planting density and variety of *Cynodon dactylon* L.” and showed that planting densities of “P1: 100.00 dibble/m², P2: 44.44 dibble/m² and P3: 25.00 dibble/m²” affected grass growth and establishment. They found that, 100.00 dibble/m² planting density had rapid development of turf, suitable growing practice for less regularity of lawn mowing and a reduced amount of weed growth.

Vulnerability to dryness is more for stolons than inactive rhizomes and little survival of stolons has been described when they were visible to lower relative humidity (Anisiobi, 2018). When grasses are installed in rough sands, stolons may die. Their instalment can also fail if soil water is insufficient. Due to the prospect of dryness, additional substances may be needed to recompense for possible loss of stolons. Moreover, there is the need to add to the number of plants that become developed before the beginning of cold temperatures. Suggested stolon planting densities cover a big variety. Vendramini *et al.* (2021) recommended the ideal “rate for planting bermudagrass stolons in Florida at about 1500 kg/ ha”. Baseggio *et al.* (2015) detected an “satisfactory stand at 176 d after planting hybrid bermudagrass at a rate of 2000 kg/ha”. However, 1000 kg/ha caused increase in weed control and a sparse stand, demanding extra time for canopy closure. Moreover, a “rate of 2500 kg/ha” lowered growth establishment since more plant material prevented sufficient incorporation of stolons into the growing media. Since there are a wide range of proposed planting densities across locations, additional research is needed to regulate optimum planting densities in the deeper sandy soil settings.

2.7.5 Effect of Planting Depth on Sod Production

Planting depth is another factor that has a significant effect on the capacity of plants to rise or sprout and allows to make a suitable setting for growth. It is a crucial factor for plants to have

suitable depths in order to obtain appropriate percentage germination/sprouting, sustaining emergence/sprouting and high plant number and on-farm irrigation management. Planting depth significantly impacts on crops ability to emerge and establish an even stand (Baye, 2020). Since the period used by plant to sprout is determined by depth of sowing, size of seed, that is to say reserve food material (Singh, Bharat, Chandra & Dimree, 2010). Planting depth performs vital function in establishment of stolons so that stolon numbers and eventually, the yield itself will be enhanced by planting tubers depth (up to approximately 20 cm; depending on cropping conditions) (Merga & Dechassa, 2019). Planting depth of stolons impacts the period of shoot emergence, vigour, and development (Mangoale & Afolayan, 2020). Planting too shallow can cause sprouting due to inappropriate soil moisture in the topsoil deposit. Because deep settlement of plants/seeds in the soil helps better rooting of the plant, which reduces lodging vulnerability and hence, more efficient use of available soil moisture (Helios *et al.*, 2021). Planting too deep and too shallow causes the danger of growing poor yield and irregular emergence/sprouting. However, sowing plants either too shallow or too deep will result in irregular germination/sprouting, growth performance, growth reduction, as well as losses. According to Wato (2019), planting depth at 5cm of maize seeds showed high plant germination, number of leaves, leaf size, and seedling vigor as compared to 10cm, 15cm and 20cm. However, the planting depth at 15cm and 20cm produced shorter leaf size, a small number of leaf and low germination percentage and hence, poor growth performance of plants.

Stolons length and depth were discovered to impact the formation of *M. giganteus* (Mangoale & Afolayan, 2020; Christian & Haase, 2001) likewise stated that planting depth of stolons was an imperative feature in influencing produce in this grass. Planting of the stolons may significantly touch the establishment and growth of grass remains since it might alter biotic and abiotic

environments. The establishment and growth of grass remains planted in profound media might typically depend on the use of reserved in plant tissues when carbohydrates cannot be comprehended via photosynthesis (Ievinsh, 2023). Nevertheless, if remains stored in the plant tissues are utilized before fresh shoots sprout from the stem, fragments may die Dong *et al.*, (2010).

Rise in establishing depth meaningfully abridged the emergence degree of *A. amatymbica*. At 2.5 cm depth, the appearance was seen to be advanced than at 5 and 7.5 cm depths irrespective of stolons lengths. Earlier research on *Alternanthera philxeroides* (Mart) Standl. and *Physalis viscosa* L. equally stated that profound burial depth reduced the degree of appearance of shoots (Zhai *et al.*, 2022; Chen, Lei & Dong, (2010). This result was likewise in pact with Masilamani *et al.*, (2023), who presented that shoot had advanced emergence (%) in low planting depths. Therefore, it is obvious that sowing depth is a significant feature that impact the degree of germination.

A successful sod production depends on planting density and planting depth of grass stolons for growth and establishment of turfgrass/sod for erosion control and climate change mitigation (Stratton & Rechcigl, 2020; Ng, Ni & Leung, 2020).

2.8 Turfgrasses

The greatest available turfgrass types propagated from sod comprise bermudagrass (*Cynodon dactylon.*), centipede grass (*Eremochloa ophiuroides*), fine fescue, St. Augustine's grass (*Stenotaphrum secundatum*), tall fescue, and zoysia grass (*Zoysia* spp.) (Liu *et al.*, 2021). Currently, in Ghana, Bermuda and St. Augustine are the utmost prevalent turf species in

marketable and housing landscapes in the cities. These types are mostly grown as gardeners' knowledge with its planting. Both grasses develop a solid turfgrass lawn with outstanding color. They mow most neatly than other varieties, for instance tall fescue. Also, the widespread rhizome of Bermuda grass and St. Augustine's grass produce lawns that are vigorous and established (Satognon, 2024; Arikilla, 2023; Kazemi *et al.*, 2024).

Both Bermuda grass and St. Augustine's grass require a higher number of inputs and have elevated conservational apprehensions. These concerns are, latent freshwater pollution from manures and insecticides (Stier *et al.*, 2013; Stier, Horgan & Bonos, 2020). But sod growers consider planting the same species, regardless of how to plant, the cultural performance and reserves connected to each type, and the influence on farm productivity.

2.8.1 Selection of grass

Selection of grass depends on the use of the field for both sodding and seeding. For instance, baseball and softball fields require grasses that can survive in cooler environments. A mixture of bluegrass and ryegrass can produce a good quality turf. These grasses are not heavy thatch producers and hence require minimum management work. Selecting a smaller wild grass might likewise aid suppress grass accumulation.

Conversely, football fields require more aggressive grasses for heavier thatch layer. One advantage is, heavier grass sheet shields the lawn well from the pressures of performance and headrest falls. well. Also, when it rains, a heavier grass saves people outside the mud. Bermuda grass is considered a sports turf and it is a hot spell grass. However, cold lenient cultivars such as Kentucky is also recommendable. Theses varieties are considered "low-maintenance" grasses because they can be cut as high as 3.8cm to 5.1cm for less mowing, watering, fertilization and pest control.

2.8.2 Installation

Both sod and stolons require soggy earth to evade dryness. In a warm dry atmosphere, planting materials may perish in seconds (Raja Hussian, 2017). Mostly in the tropics, using stolons maintains the key technique of establishing bermudagrass (Baxter *et al.*, 2024). In Ghana, there is classically satisfactory precipitation for turfgrass growth in the months of June through September, mainly in the Eastern region (Braun, 2017), and the mean yearly precipitation for Ghana is 2,160 millimeter (Nkrumah, 2014). Consequently, establishing in Ghana may happen for a quite extended period with high probability of successful establishment. High susceptibility to dryness and little existence of runners have remained specified once they remained bare to little proportional moisture (Baseggio *et al.*, 2015). Yu (2020) recommended the ideal density for establishing bermudagrass runners remained around 1500 kg/ha on the ground. Baseggio *et al.*, (2015) experiential a suitable stance at one hundred and seventy-six days after establishing bermudagrass stolons at a density of 2,000 kg per ha, whereas 1,000 kg per ha brought about an increased in weed rivalry and a scant stance. This requires extra period for cover closing. Moreover, a density of 2,500 kg per ha reduced growing of grasses.

Sod planting might be done anytime the media is practicable when the temperatures are low. In laying sod, care must be taken to keep the seams tight. Pulling the turf well in such a manner that widening must be avoided. Overextended turf may ultimately pull back to its original scope, leaving wearisome openings. Liberal watering is done for the first two weeks to prevent shrinkage.

2.8.3 Establishment

Newly planted stolons need light watering but frequent to maintain the top 0.64cm of the earth soggy until the stolons sprout (Christians *et al.*, 2016). When sprouting happens, you slowly decrease watering rate but rather increase the amount of H₂O given each period. Cutting can start once you see the 1/3 rule (Calvache *et al.*, 2017). It means cutting off the top third of the grass.

Ryegrass and fescues use around 4 months to develop resolutely grown. Hot spell arenas established with Bermuda might take 4 to 6 weeks after sprouting, provided the turf is substantially watered (Leinauer & Devitt, 2013). Sandor (2018) performed glasshouse research to “examine the effect of three irrigation amounts (50, 75, and 100% reference evapotranspiration [ET_o]) and three frequencies (daily, every 2 days, and every 3 days) on establishment of perennial ryegrass (*Lolium perenne* L.) (PR), tall fescue (*Schedonorus arundinaceus* (Schreb.) Dumort (TF), and Kentucky bluegrass (*Poa pratensis* L.) (KBG)”. Other researchers investigated watering rates required to plant TF together with the type that uses a straight slope irrigation scheme (Ashraf, 2018) and ace performed utilizing a volley out housing (Sandor *et al.*, 2021).

2.8.4 Weed Control

Weed-infested lawns will reduce the esthetic touch of the site. Weeds are controlled when they are actively growing (Rana & Rana, 2016; Scavo & Mauromicale, 2020). Weeds are mostly introduced through irrigation water from open canals, ditches or ponds (Abouzienna *et al.*, 2013). Untreated soil from different site introduces weed seeds during land preparation. Moreover, birds, wind, soil erosion and humans also deposit weed seeds into production field (Osman, 2018; Palai, 2010; Prats *et al.*, 2014). Weeds are controlled when ditches and fence rows are kept clean and by washing equipment before entering a weed-free field. Weeds can be picked manually. Once the grass is established, weeds can be managed through: proper mowing, cultural practices that promote turf competition and use of herbicides (Watschke, Dernoeden, & Shetlar, 2013). Broadleaf weeds can be controlled effectively by continuous mowing (Hahn, Sallenave, Pornaro & Leinauer, 2020). For example; ragweed (*Ambrosia artemisiifolia*), pigweed (*Amaranthus spinosus*) and cocklebur (*Xanthium strumarium*).

Mowing must be done before seedheads emergence. This is to help prevent reinfestation from seed. Examples of grassy weeds in sod production include annual blue grass, crab grass, goose grass, vasey-grass, signal grass, sprangle top, torpedo grass and Bermuda grass. Weed seedlings are most susceptible to herbicides. Usually, turf grass can be damaged when air temperatures exceed 27 °C to 30 °C at the time of herbicide application (Balogh & Anderson, 2020). Therefore, turf should not be under moisture or mowing stress when treated with herbicide. The environmentally friendly of sod is an ever more crucial subject and it includes equally a limit of management aids and a careful valuation of grasses that require low maintenance.

2.9.5 Mowing

Mowing is another important cultural practice for maintaining lawns. Mowing controls turfgrass growth. The '1/3 rule of cut' for mowing is used (Smith & Fellowes, 2014). This method ensures that not over one third of the leaf expanse is detached at a one cutting. It ensures grass is normally mowed at a height of 2.5cm. The types of mowers usually used are reel, rotary and flail. A reel mower is most desirable. This is because it gives highest possible mowing quality, helps smoothens the sod field for easier, and more uniform harvesting. However, rotary mowers are acceptable for St. Augustine grass production if blades are properly sharpened and balanced. Flail mowers can be used when sod is not yet uniformly dense. Mowing frequency depends on the fertility level, season of year and grass species. Established Bermuda grass is typically mowed every 3 to 4 days whereas St. Augustine grass is mowed once every 7 to 10 days. Ideally, grass clippings must be picked up to prevent them from filtering down into the turf stand and turning brown (Smith & Fellowes, 2014).

2.8.6 Soil and Climatic Requirement of Bermuda and St. Augustine's grasses

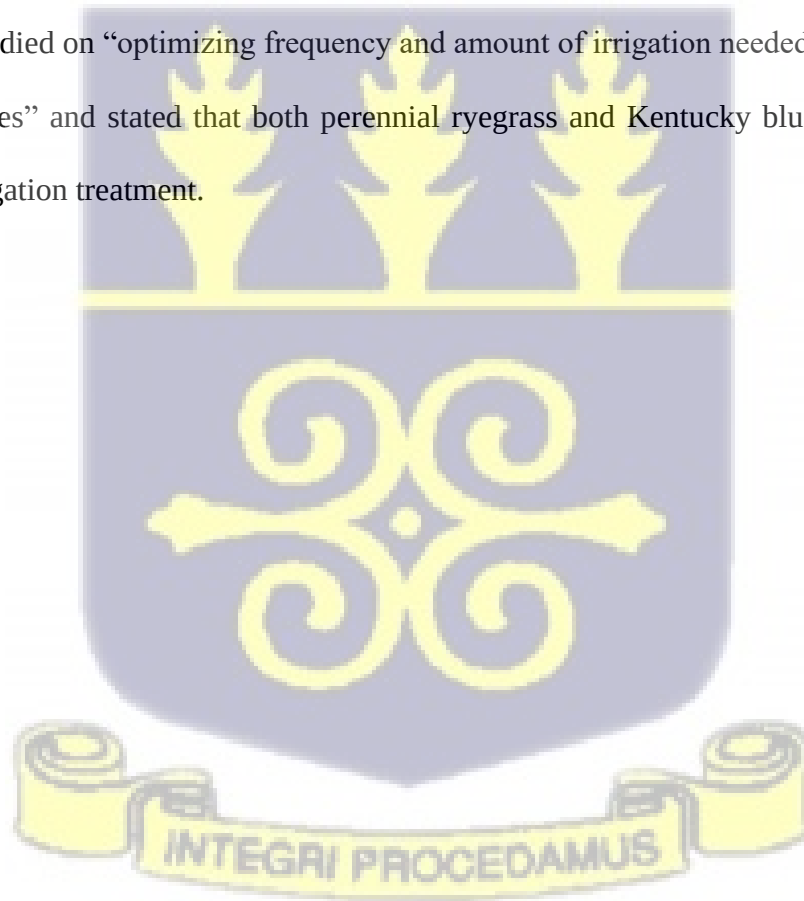
St. Augustine's grass is a perennial grass. It is a hot-period grass with a C4 photosynthetic pathway. The temperature requirements for growth and establishment vary amid 20 °C - 30 °C, with a least

temperature for development being 10 °C (Egan *et al.*, 2017). Mostly St. Augustine's grass grows vigorously when temperatures are sufficiently high with adequate moisture. It grows year-round in lower-altitude equatorial climates. Generally, St. Augustine's grass performs well in areas of annual rainfall between 1000 mm-2000 mm with drought tolerance (Otiso, 2016; Egan *et al.*, 2017). Studies have shown that St. Augustine has the ability to stand lengthy periods of drought and resumes growth and recover freshness once moisture is reinstated (Ewing, 2020; Jordan, 2022). Polyploid cultivars are more drought tolerant than diploids, vary greatly between cultivars (Tossi *et al.*, 2022). St. Augustine's grass thrives well in soils with pH between 5.0 and 7.0 and it may develop across a series of soil feels (Spaeth Jr, 2020). It develops well on sand, loam and humic earths, oscillating in pH between 4.5 - 8.5 (Tossi *et al.*, 2022).

Bermuda grass grows best under temperature between 30–38 °C with soil temperature between 24–35 °C (Chhetri, 2017). It requires minimum air temperature of 13 °C for growth. Bermuda needs complete sunlight for optimum performance. At least a minimum of six hours. of complete sun is obligatory every day for growth. Cool conditions limit photosynthesis, and therefore reduce growth. Excessive shade brings about thin and etiolated leaves. It also leads to increased internode length with reduced tiller density and rooting. Bermuda grass thrives in healthy loose earths with pH between six and seven. Media pH > 7.5 can lead to nutrient deficiencies such as nitrogen, potassium and phosphorus (Jana *et al.*, 2022).

Changes in growth of sod is not merely attributed to the weather, but the combination of weather per different environmental conditions such as organic matter, fertility, run-off, watering, manure, and biotic pressures (Hatfield, 2017). Biotic strains are insects, diseases, and weeds. The integration of climatic conditions is able to increase the susceptibility of grasses to climatic conditions for the soil H₂O accessibility and nutrient revolution (Hatfield, 2014).

Research done by Hatfield *et al.*, (2011) and Izaurralde *et al.*, (2011) of weather effects on farming and gardening plants and on pasture and rangeland presented heat and rain as main issues impacting crop growth and sod establishment. All ornamentals need warmth for growth and establishment. Each grass thrives well in a specific temperature range. Cool-season turfgrasses grow well between temperatures of 15 °C and 24 °C, while hot-period turf grows amid twenty - seven and thirty- five-degree celcius (Flournoy, 2017). This temperature array controls wherever these turfs are grown; yet, development depends on periodic rainfall. The aptitude of soils to offer suitable soil H₂O and nutrients to plants is the basis for weather pliability. The incorporation of weather and soil determines the thriving and pecuniary feasibility of sod (Hatfield, 2017). Serena *et al.*, (2022) studied on “optimizing frequency and amount of irrigation needed to establish cool-season turfgrasses” and stated that both perennial ryegrass and Kentucky bluegrass established faster under irrigation treatment.



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CHAPTER THREE

3.0 DEVELOPING GROWING MEDIA FOR SOD PRODUCTION IN GHANA

Abstract

The use of top soil has been the traditional method of establishing sod. The increased interest in establishing sod is putting a lot of pressure on the environment. Sustainable sod production calls for the identification and use of organic materials that are easily available and suitable for use to substitute part of the soil. Growing media was formulated using soil, poultry manure, biochar, sawdust and clay in different proportions and compared with soil only. The treatments for the study were as follows; topsoil only (M1); (60% soil; 20% poultry manure; 15% rice husk biochar and 5% clay) M2; (50% topsoil+ 30% poultry manure + 15% rice husk biochar + 5% clay) M3; (60% topsoil+ 30% poultry manure + 15% sawdust + 5% clay soil) M4 and (50% topsoil+ 20% poultry manure + 15% sawdust + 5% clay soil) M5 v/v. The physical and chemical properties of the different formulations were determined. The results showed that the addition of poultry manure, sawdust and rice husk biochar to the soil reduced the bulk density, increased the water holding capacity, Electrical conductivity and increased the pH compared to the soil only treatment. A decrease in the total nitrogen and a marginal increase in potassium and phosphorus contents of the formulated growing media were observed compared to the topsoil. A marginal increase in CEC in M3, M4 and M5 but a decrease in M2 was observed compared with soil only. Increases in organic carbon, Ca, Mg, were observed in all the mixtures. The C/N ratio increased in all formulated growing media during the trial. The physicochemical properties such as bulk density, porosity of M4 (60% topsoil+ 30% poultry manure + 15% sawdust + 5% clay soil) and M5 (50% topsoil+ 20% poultry manure + 15% sawdust + 5% clay soil) were significantly higher than that of M2

(60% topsoil+ 20% poultry manure + 15% rice husk biochar + 5% clay soil) and M3 (50% topsoil+ 30% poultry manure + 15% rice husk biochar + 5% clay soil).

3.1 Introduction

A growing medium may be well-defined as a substance in which crop roots develop and extract H₂O and nutrients (Villego, 2016) for growth and development. It is a hard medium that substitute the usual earth for crop growth (Jia *et al.*, 2023). Primarily, media have the ability to contain H₂O and manure for root uptake, provide adequate root aeration, and ensure structural support to the grass (Sahoo *et al.*, 2023; El Haddadi *et al.*, 2022; Gruda & Bragg, 2021; Criscione, 2021; Gallegos *et al.*, 2020).

Selecting a good medium is fundamental to good nursery management and is the basis of a vigorous root system. A media may be soil based or organic based or mixtures of the two. The literature is replete with various types of growing media, organic inorganic or mixes that has been developed for various plants such as vegetables (Ngxabi, 2020); ornamentals (Chaudhary, 2022; Nath *et al.*, 2016), and medicinal plants medicinal plants (Xego, 2017).

Organic substances, for example, rice husk, sawdust, biochar, poultry manure, mulch, pine tree howl, coco-fiber and cacao shell or inorganic substances such as mineral wool, vermiculite, perlite and clay can be used in formulating growing media (Ogunrotimi & Kayode, 2018; Dalila *et al.*, 2017; Shaju, *et al.*, 2018; Jayakrishna, 2017). These substances in growing media improve soil physical and chemical properties (Sohi *et al.*, 2010; Mukherjee & Lal, 2013), improve plant nutrient availability and correlated growth and establishment (Biederman & Stanley Harpole,

2013; Jeffery *et al.*, 2011), increase microbial population and activities [Jaafar, Clode, & Abbott, 2014) and decrease glasshouse gas releases through carbon sequestration (Crombie *et al.*, 2015).

Growing media require sufficient biological substance to hold soil moisture which help to maintain its physicochemical properties. Diverse kinds of organic growing media are the key part of most production system in professional and ornamental sectors of horticulture for the fact that they offer healthier root environment to the floras, hold moisture, offer anchorage to the crop and ease the gaseous exchange of CO₂ and O₂ for respiration.

The physical and chemical properties of the growing media are very significant factors that determine the suitability of the media for the specific plant growth. The proportions of the materials used in the formulation affects the physical and chemical properties of the medium. In addition to the methods used in nutrient management, determines the biomass and quantity of the crops that are produced (Jayakrishna, 2017). These properties inform the nursery operator in the selection of the kind of medium suitable for specific growing conditions. Such chemical properties for instance are nutrient, pH level, organic matter content, and physical properties like texture and structure.

The physical properties may have a direct or indirect effect on the output of plant, as it affects the porosity and aeration, nutrient uptake (Olle, Ngouajio, & Siomos, 2012). Suitable particle size mixture is crucial for a friable medium to promote quick seed germination, robust root growth and adequate drainage. In this regard, it is important to use different proportions of easily available materials and assess their effect on the physical and chemical properties of the media and the growth of the plant. In Ghana, biological waste such as biochar, poultry manure and sawdust are generated continuously, are environmentally friendly, and cheap, and it is proper that these are evaluated for suitability to replace part or the topsoil in the establishment of sod. The different proportions of

the locally available materials such as sawdust, poultry manure and rice husk biochar could affect the physical and chemical properties and the growth of the plants.

Raw materials used for growing media differ depending on local availability (Barrett *et al.*, 2016). These materials may be inorganic or organic, but growing medium is generally formulated from a mixture of diverse raw materials so as to attain the right balance of air and WHC for plant development and for the lasting stability of the medium (Barrett *et al.*, 2016). Globally, about 88% of the hydroponic industry are known for the use of inorganic media for instance rockwool, silt, perlite, vermiculite, pumice, soils, extended polystyrene and urea formaldehydes (Abeena *et al.*, 2016; Shaju *et al.*, 2018; Putra & Yuliando, 2015; McCartney & Lefsrud, 2018), whereas only about 12% use organic growing media (Osman *et al.*, 2023) such as moss, leaf mold, sawdust, poultry manure, barks, coir, bagasse, rice hulls and biochar. All these materials usually resist possible pests, diseases, unwanted plant seeds and may be watered regularly. They enhance free drainage and can therefore be managed to offer an optimal ratio of air and water for plant production during the growing period (Fields & Gruda, 2021).

Characterization of a growing media is important in identifying the potential of the media in meeting the plant growth requirements such as nutrients, pH, moisture retention, aeration, and physical structure (Gohardoust *et al.*, 2020). Biochar kind, proportion, and nutrient levels in growing media influences seedling production and plant performance. The proportion of biochar in the growing media in the range of 7.5% and 15% biochar positively influenced the chemical features including rise in pH, nutrient retention and promoted the performance of lettuce seedlings (Chrysargyris *et al.*, (2020). Application of low rates of biochar improved the microbial population with high proportion of Gram-negative bacteria dominating, while increased biochar levels (i.e., 49 t ha⁻¹) lowered microbial activity (Gomez *et al.*, 2014) and extractable phospholipid fatty acid

(Ameloot, *et al.*, 2014). Thus, effect of biochar amendment on growing media or soil depends to a greater extent on biochar properties, soil characteristics and biochar-microbial interaction.

The use of topsoil and inorganic fertilizers have been the conventional method for sod production (Ihtisham *et al* 2018; Ogunrotimi & Kayode, 2018; Olle, Ngouajio & Siomos, (2012). The physicochemical properties influence the value of the turf raised as well as its establishment in the field (Xiao, 2016 and Cattin, (2022). The physical properties of the soil should be taken into consideration as black loamy soil has been reported to retain adequate amount of H₂O and nutrients for sod growth and health. (Koudahe, Allen & Djaman, 2022). Loamy soil which contains 95% pure black topsoil, as well as, 5% peat moss (Osman, 2018) provides better drainage than clayey soil, and could be why it is commonly used for sod production. The use of topsoil is not environmentally friendly and is easily depleted. The continuous use of topsoil for sod production promotes erosion, and causes land degradations. (Danso *et al.*, 2013; Alireza and Mohammad, 2019) and has increased in demand. Due to lack of fertile topsoil, most sod growers have resorted to the use of poor soils, that is reflected in the slow growth of sod, and poor field establishment. According to Danso (2013), over 3000-3500 tons of soil is dug annually from farmlands for horticultural activities in Ghana. The main objective of sod producers is to produce quality sod, exhibiting the preferred morphological and physiological features, and establishes fast after transplanting. Using topsoil alone for sod production, Mathew (2021), observed poor field performance. Furthermore, it was observed that sod raised in topsoil was so heavy that, growers had to remove some of the soil around the root system that disturbed the roots and caused shock before transplanting. Over-reliance on topsoil for sod is a key limitation to marketable production. Therefore, usage of a very good growing media that can produce high quality, healthy and dense sod is important to the industry. Thus, finding sustainable appropriate alternative growing media

aimed at sod production is quite urgent. The characteristic of such a growing media should include its availability, light weight, healthy for sod production. Using locally available agricultural waste: (rice husk biochar, sawdust and poultry manure) look promising as it can reduce cost and is sustainable. The use of soil-amended with organic waste as growing media for production of horticultural plants like ornamentals and vegetables have been reported in the literature (Younis, Rayit & Riaz, (2015); Villecco, (2016); Trupiano et al., 2017). The suitability of the use of agricultural waste as component in growing media for sod production will enhance its use for recycling for sustainable use, as it will be environmentally friendly and reduce cost. Information on the use of agricultural waste soil-amended medium for sod is scarce. The significance of growing medium option, comparative to other production factors, should be assessed for sod production. Therefore, the objective of the present study was to develop growing media for sod production in Ghana

3.2 Methodology

3.2.1 Growing media formulation and analysis

The composition of the different growing media was as follows; M1 = Topsoil (100%); M2(TS + PM + RHB + CS) = 60:20:15:5; M3 (TS + PM + RHB + CS) = 50:30:15:5; M4 (TS + PM + SD + CS) = 60:20:15:5; M5 (TS + PM + SD + CS) = 50:30:15:5.



Table 1 Growing media formulation

Treatment code	Treatment details	Proportion v/v
M1	Topsoil only	100%
M2 (TS + PM+ RHB+ CS)	Topsoil, poultry manure, rice husk biochar, clay	60:20:15:5
M3 (TS + PM + RHB + CS)	Topsoil, poultry manure, rice husk biochar, clay	50:30:15:5
M4 (TS + PM + SD + CS)	Topsoil, poultry manure, sawdust, clay	60:20:15:5
M5 (TS + PM + SD + CS)	Topsoil, poultry manure, sawdust, clay	50:30:15:5

An analysis was done to characterize and formulate growing media developed from locally available materials for sod production.

3.2.2 Physicochemical properties analysis determination

Samples were taken from top soil, clay and decomposed sawdust, poultry manure, rice husk biochar, to determine the physical and chemical features.

Physical properties considered included: bulk density, porosity and water holding capacity;

and chemical properties included: pH, nitrogen(N), Potassium (K), Phosphorus (Avail. P), Calcium (Ca), Magnesium (Mg), Electrical conductivity (EC), Cation Exchange Capacity (CEC), Organic carbon (OC) and Carbon/Nitrogen (CN) ratio. These physical and chemical properties were assessed at the Soil Science Department, University of Ghana in October, 2022.

Analysis was conducted at Soil Science Department, University of Ghana.

3.2.3 The Soil

The top soil and clay used for the experiment were collected from the same site (University of Ghana farms). These soils are classified as Luvisol (Ayalew *et al.*, 2015) which was developed from weathered parent materials. The soil was sandy within the top horizon of 0-30 cm depth

(Borden *et al.*, 2021). These soils are inherently poor in nutrient, low organic matter content, low buffering ability and cation exchange ability. They are mostly deficient in nutrients such as nitrogen and phosphorus (Ayalew *et al.*, 2015).

3.2.3.1 Soil Analysis

Soil samples were fetched and analyzed at Soil Science and Ecological laboratories of University of Ghana. The soil bulk density was (BD) was determined using core method (Reichert *et al.*, 2021) and water holding capacity (WHC) was determined according to Malińska & Zabochnicka-Świątek (2013). Soil chemical analysis: pH and EC were calculated by 1:1 soil- water ratio using pH meter and EC meter (Hanna Instrument (HI) Combo 99301. Romania). Soil OC and Nitrogen were detected with the TruMac CNS analyser, (Model: LECOTruMac CNS analyzer, manufactured by LECO Corporation in St. Joseph, Michigan, USA).

Total and available phosphorus were determined using the digestion method (Pote & Daniel, 2000). Potassium, Magnesium and Calcium were determined using Jenway flame photometer (PFP7). Transferable bases were detected with Atomic Absorption Spectrometer (AAS).

3.2.4 Preparation of Growing Media Formulation

The growing media were prepared at Plant Genetic Resources and Research Institute (PGRRI) of the Centre for Scientific and Industrial Research (CSIR) at Bunso in the Eastern Region of Ghana. Different proportions of the biochar, poultry manure, sawdust and soil were bulked together and covered with a polyethylene sheet, under shade. Biochar proved its potential for addition in growing media, combined with dissimilar constituents such as peat, compost, coir, and vermicompost (Abrishamkesh *et al.*, 2015).

Biochar was combined with sawdust and poultry manure in different proportions as heaps. These materials were weighed and placed on a black polyethene sheet under a shed (Table 1). The

materials were moistened with water to attain a moisture content of 60%, and was turned regularly when the temperature dropped. Adequate water was added to attain a moisture content of about 65% moisture content. It was mixed thoroughly and heaped. Turning of the composting feedstock was done weekly up to 12 weeks until the composting process was completed. The composted growing media were then allowed to dry under shade before used.



PLATE 2: Formulations from sawdust, poultry manure, rice husk biochar, top soil and clay.

Table 2: Composition of Growing Media Used for the Experiment

Media	Composition	Ratio (%)
M ₁	Top soil	100%
M ₂	Top soil + poultry manure + rice husk biochar + clay	60:20:15:5
M ₃	Top soil + poultry manure + rice husk biochar + clay	50:30:15:5
M ₄	Top soil + poultry manure + sawdust + clay	60:20:15:5
M ₅	Top soil + poultry manure + sawdust + clay	50:30:15:5

3.2.6 Parameters considered for a suitable growing media

The parameters considered or functions of a suitable growing media for sod production include; bulk density, porosity, water retention capacity, pH, EC, OC, total nitrogen, available phosphorus,

exchangeable calcium, magnesium, potassium, carbon/nitrogen ratio and cation exchange capacity.

3.2.7 Determination of physical properties of the growing media

The physical properties of the growing media analyzed at the Soil Science department were bulk density (BD), porosity (P) and water holding capacity (WHC).

3.2.7.1 Determination of bulk density (BD)

Samples of the growing media (50g) for each treatment were oven dried at 85 °C for 48 hours. The dried samples were filled into a container. Afterwards, the growing media were lightly compressed to get rid of large spaces within the mixtures. The samples were weighed. BD was determined by dividing the mass of the sample by the volume of the growing media in the vessel. Thus, BD (ρ) = Mass/volume

3.2.7.2 Porosity

The porosity was calculated using the equation:

$$\text{Porosity} = 1 - \frac{P_{wb} (MC + DM \times OM + DM \times (1-OM))}{P_w} \times 10$$

P_{wb} POM P_{ash}

P_{wb} = wet bulk density (kg m⁻³)

MC = moisture content

DM = dry matter

OM = organic matter

P_w = density of water (kg m⁻³)

POM = density of organic matter (kg m⁻³)

Pash = density of ash (kg m^{-3})

3.2.7.3 Determination of water holding capacity (WHC)

A 10 ml of water was poured unto the different growing media samples to saturation. The weight of the saturated samples was recorded. Then, the saturated samples were left to drain for one or two days. The weight of samples after draining was recorded. The difference in weight reflected water held by the media. The volume of H_2O suspended by the various media was calculated.

3.2.8 Determination of physical properties of the growing media

3.2.8.1 Determination of pH of growing media

Samples of air-dried growing media was used for the determination of the pH. The samples were filtered in a 2mm mesh. The resultant mass was used for the pH determination. Ten (10g) each of the sample that passed through the 2 mm mesh size was put into a beaker. Ten (10 ml) distilled water was added making a 1:1 suspension. The samples were stirred vigorously for ten minutes and left to settle within 30 minutes. pH meter (Hanna Instrument (HI) Combo 99301. Romania) was calibrated with standards at 4.05 and 7.5 before being used to determine the pH of the respective samples.

3.2.8.2 Determination of electrical conductivity of growing media

The EC meter was calibrated before using it to measure the EC values. Ten grams (10g) of air-dried samples each of the growing media was combined with 50ml of purified water. Mixtures were mixed thoroughly in 20 min at room temperature. Each mixture was left to settle in 10 minutes. EC probe was then inserted into the supernatant of each suspension. The values on the EC meter (Hanna Instrument (HI) Combo 99301. Romania) were recorded. This process was repeated for all the various samples.

3.2.8.3 Determination of organic carbon

A 0.5grams growing media was sieved through a 2mm and 5-micron sieves. The samples were weighed into 500ml conical flask. 10ml of 1N Potassium dichromate was added, then 20ml of concentrated sulphuric acid. It was then allowed to stay for 45 minutes before stopping reaction with 200ml of purified H₂O. 10ml of 85% orthophosphoric acid was then poured in, followed by 1ml barium dipylamine 4-sulphonate indicator. Solution was titrated with freshly prepared 0.2M Ammonium ferrous sulphate to a green end point coloration. Blank was also prepared in the same manner.

Calculation:

$$\%C = 0.3(10 - (XN)) * 1.33 / 0.5$$

Where;

0.3= factor

1.33= factor

X= titre

N= normality of blank

0.5= weight of sample

3.2.8.4 Total nitrogen determination

One gram (1g) of soil and 0.5g of compost were weighed into 250ml kjeldahl digestion flask. Nitrogen catalyst, CuSO₄ and K₂SO₄ were added followed by 5ml of H₂SO₄. The moisture was digested for about 1 hour and digest after cooling transferred into 50ml volumetric flask and filled to the mark with purified H₂O. 5ml aliquot was then pipetted into 500ml distillation flask and 5ml

of 40% NaOH included. 5ml of boric acid indicator was pipetted into a 100ml conical flask to trap ammonia liberated by heating. The concentrate was also back titrated with 0.01M HCL.

So, amount of nitrogen was determined using the formula below:

$$A * 0.01 * 0.014 * 50 * 100 / B \times C$$

Where A= titre

0.01M = concentration of HCL used for titration

0.014= Factor for Nitrogen

100= %

B= Aliquot 5ml

C=wt of sample taken 0.10g

3.2.8.5 Determination of available phosphorus

Phosphorus content of the media was achieved by adopting (Pote & Daniel, 2000) formula. Five (5g) of growing media sieved through a 2mm sieve was weighed into 100 ml extraction bottle. 50ml of Bray mixture was put together and placed on a mechanical shaker and shaken for five minutes. The supernatant was sieved via No.42 Whatman filter paper. Soluble aliquots of abstract were used for the detection of phosphorous using ascorbic acid and Ammonium molybdate to developed color. Readings were measured using the UV spectrophotometer at 712 wave length. Phosphorous levels were determined using the formula as showed below:

$$(\text{Mg/kg}) (\text{ppm}) \text{ SOIL} = \text{spec reading} * \text{vol of extraction} / \text{wt}$$

3.2.8.6 Determination of exchangeable Calcium, Magnesium and Potassium

Five grams of growing media was sieved through a 2mm sieve and weighed into 100ml extraction bottle. Fifty (50ml) of 1N NHOAc mixture buffed at pH 7 was included. The bottle and contents were put on a mechanical shaker and stirred for 30minutes. The supernatant was sieved via No.42 Whatman filter paper. Soluble aliquots of abstract were used to determine exchangeable (Ca, Mg,).

Calcium (Ca) was detected from the sieved mixture using atomic absorption spectrophotometer (AAS). AAS was standardized with standard solution of calcium comprising 2,4 and 10 ug/ml at wave length 422.7Lamda. A slit limit of 0.07 and a current of 10A.

Magnesium (Mg) was determined from filtered solution using a standard solution of magnesium comprising 0.2,0.6, and 1.0ug/ml, a wavelength of 422.7 lambda, a slit limit of 0.07 and current of 10A.

Sodium (Na) and Potassium (K) were similarly standardized.

The outcome was used to calculate the quantity of calcium, magnesium, sodium and potassium found in the growing media showed below.

$X = \frac{Ca \cdot Mg \cdot Na \cdot K}{A}$

A= AAS reading ug/ml

B=charge of Ca, Mg, Na and K

C=Atomic mass of Ca, Mg, Na and K



3.3 Results

Table 3.1 Climatic data at the experimental site from October 2022 to January 2023

Months	Total rainfall (mm)	Maximum temperature (°C)	air Minimum temperature (°C)	air Mean relative humidity (%)
October 2022	113.1	31.3	23.6	87.9
November 2022	77.3	32.3	23.9	88.3
December 2022	2.0	33.1	23.7	82.2
January 2023	29.5	33.9	23.8	81.1

Source: Ghana Meteorological Services

Physical and chemical properties of organic constituents used in the formulation of the growing media.

Table 3.2 Physical properties of soil used before formulation

Soil Samples	BD (g/cm ³)	Porosity (%)	WHC (%)
Top Soil	1.4	83.8	39.5
Clay	1.6	83.0	44.7

BD = Bulk density WHC = Water holding capacity

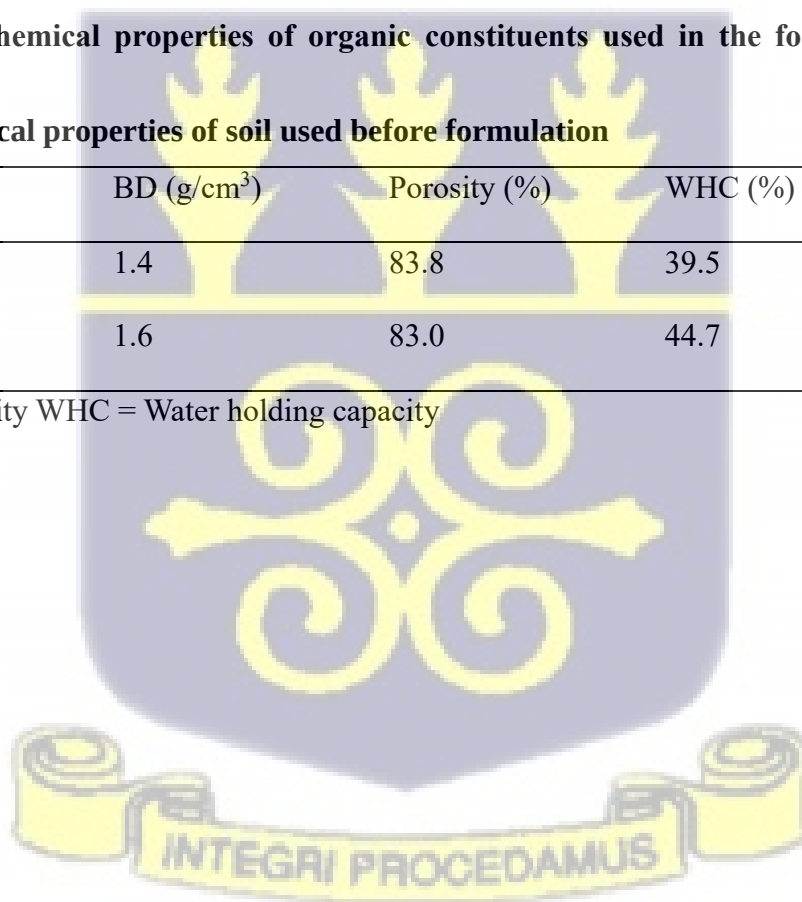


Table 3.3 Chemical properties of soil and organic materials used in the growing media formulation

Material	pH	N%	K%	Avail. P mg/kg	Ca cmol/kg	Mg cmol/kg	EC dS/m	CEC Cmol ⁺ /kg	OC%	CN Ratio
TS	6.5	0.01	1.12	5.9	0.29	0.08	0.23	9.14	0.22	22
CS	4.1	0.2	0.27	20.64	1.54	1.05	0.14	9.72	2.1	2.1
RHB	7.5	0.1	3.06	324.5	2.68	7.30	0.66	39.08	49.37	493.7
SD	5.6	1.2	1.96	3.88	6.33	5.66	0.28	31.31	42.52	35.4
PM	8.1	2.31	26.1	129.3	9.29	23.1	0.81	52.5	55.6	24.2

TS = Topsoil, CS = Clay soil, RHB = Rice husk biochar, SD = Sawdust, PM = Poultry manure

Table 3.4 Physical properties of growing media after formulation

Media Samples	Bulk Density (g/cm ³)	Porosity (%)	Water holding Capacity (%)
M1	1.4	53.8	44.7
M2	0.6	59.3	56.1
M3	0.4	62.2	54.3
M4	0.7	60.6	56.4
M5	0.5	66.4	51.3

M1 = Topsoil (100%); M2= Top soil + poultry manure + rice husk biochar + clay (60:20:15:5); M3= Top soil + poultry manure + rice husk biochar + clay (50:30:15:5); M4=Top soil + poultry manure + sawdust + clay (60:20:15:5); M5= Top soil + poultry manure + sawdust + clay (50:30:15:5).

Table 3.5 Chemical Properties of Growing Media after Formulation

Material	pH	N%	K%	Avail. P mg/kg	Ca cmol/kg	Mg cmol/kg	EC dS/m	CEC c mol ⁺ /kg	OC%	C/N Ratio
M1	6.5	0.01	1.12	5.9	0.29	0.08	0.27	9.14	0.22	22
M2	7.5	0.01	2.81	810.5	3.31	1.16	0.54	18.32	14.43	6.1
M3	8.2	0.02	11.0	109.4	5.83	3.13	0.39	21.99	14.22	9.6
M4	7.4	0.02	3.39	570.5	3.96	1.78	0.40	17.04	13.89	5.1
M5	7.3	0.02	10.1	1817	4.74	2.04	0.11	18.91	14.28	6.2

M1 = *Topsoil (100%)*; M2= *Top soil + poultry manure + rice husk biochar + clay (60:20:15:5)*;
M3= *Top soil + poultry manure + rice husk biochar + clay (50:30:15:5)*; M4=*Top soil + poultry manure + sawdust + clay (60:20:15:5)*; M5= *Top soil + poultry manure + sawdust + clay (50:30:15:5)*.



3.4 Discussion

3.4.1 General changes in the physical and chemical properties of the formulated growing media as affected by the addition of the organic materials

Topsoil recorded high bulk density, low porosity and water holding capacity; physiochemical properties like porosity and water holding capacity compared to the amended soil. Poor physical properties water holding capacity and porosity and low nutrients state of the most topsoil may be credited to intensive and continuous farming of the land deprived of adequate application of soil amendments to replenish missing soil nutrients (Eifediyi *et al.*, 2022). The addition of PM, biochar and sawdust increased the WHC, reduced the bulk density but increased porosity. However, these changes were dependent on the ratios of the materials used. There was a general decrease in bulk density with the addition of the organic materials. The highest bulk density was observed in the soil only (1.4 gcm⁻³) and the lowest in M3 (0.4 gcm⁻³). Replacing RHB with sawdust increased the bulk density (comparing M2 and M4 and M3 vrs M5). This agrees with earlier report by Mosharrof *et al.*, (2022), that addition of organic materials decreases bulk density. Similarly, adding organic materials improved the WHC of the media, compared to the soil. According to Blanco-Canqui (2017), biochar can increase soil porosity by reducing soil BD, increasing soil aggregation and/or reducing soil packing, and interacting with mineral soil particles. These effects are attributed to the highly porous internal structure of biochar, its large particle surface area and its very low BD.

The cause of this difference might also be due to a reduction of soil compaction with increased organic matter from the amendments to provide conducive environment for plant growth, Phogat *et al.*, (2018) and Dal Ferro *et al.*, (2023) both stated that bulk density usually declines with increase in organic matter content and also with fineness of soil texture. Bulk density of growing

substrate will increase infiltration, porosity, rooting depth, available water, and plant available nutrients for plant growth (Bartholomew *et al.*, 2010). Moreover, amending the substrate with poultry manure, sawdust and biochar enhanced both the porosity and WHC of the media. There was a general increase in porosity with the addition of the organic materials. The highest porosity was observed in M5 (66.4%) and the lowest in soil only (53.8%). Replacing RHB with sawdust increased the porosity (comparing M2 vrs M3 and M4 vrs M5). This is in agreement with earlier report by Agboola *et al.*, (2018), that addition of sawdust increased porosity. There was also a general increase in WHC with the addition of the organic materials. The highest WHC was observed in M4 (56.1%) and the lowest in soil only (44.7%). Replacing RHB with sawdust increased the water holding capacity (comparing M3 and M4), being in agreement with report by Van Acker *et al.*, (2023), that addition of sawdust increases WHC of topsoil.

Results are similar with Shah *et al.*, (2017) and Lal (2020) who reported that organic substances such as sawdust and poultry manure increased porosity, soil structure and WHC for plant growing and development. Earlier work done by Kaudal *et al.*, (2016) also reported that biochar decreases BD, particle size dispersal and WHC of growing media. The results in the present study agrees with the work done by Oyedeleji *et al.*, (2014) on “The effect of poultry manure on growth, yield, and proximate composition of three Amaranths”, which recorded that poultry manure at 30 Kg/ ha rate significantly increased crop height, stalk girth, sum of leaves, leaf area, and number of branches. Also, work done by Nematollahi *et al.*, (2018) on “Improving early growing stage of *Festuca arundinacea* Schreb. using media amendments under water stress conditions” reported that using municipal solid waste and manure vermicompost as soil modifications could sustain soil moistness and water enhancement for the development of morphological, physiological and visual quality of *Festuca arundinacea* Schreb. The current results are also in line with Adekiya & Agbede,

(2017) who testified that poultry manure added to soil at rates of 6.6 and 9.9 t/ha increased vine length and leaf number of watermelon. The addition of poultry manure, sawdust and rice husk biochar to the substrate in the medium mix reduced the BD, improved porosity and WHC in the media for better plant growth. On the contrary, Agboola *et al.*, (2018) following a trial on “The effect of the use of sawdust as a growing medium on the growth and yield of tomato” and concluded that sawdust may be employed as a substitute growing medium for tomato even though “plant height, number of leaves, leaf length, leaf width and number of fruits were delayed as compared to those planted on the soil”. Similarly, Ogunrotimi & Kayode (2018) did a study on “influence of potting media on growth and development of *Solanum macrocarpon* L.” and reported that crops grown-up in topsoil (100%) showed maximum yield in the leaf area, plant height, stem diameter and leaf number compared with topsoil and sawdust (50%:50%).

In the current research, adding poultry manure, sawdust and biochar to the soil improved pH, nitrogen, potassium, phosphorus, calcium, Magnesium, EC, cation exchange capacity, OC and C/N ratio in all amended growing media (Table 4). The introduction of PM, biochar and sawdust also increased the WHC, reduced the bulk density but increased porosity. However, these changes were dependent on the ratios of the materials used. There seemed to be a general increase in pH with the addition of the organic materials. The highest pH was observed in M3 (8.2) and the lowest in the soil only (6.5). Replacing RHB with sawdust increased the pH (comparing M2 vrs M3 and M4 vrs M5). This is in agreement with a report by Yu *et al.*, (2019), that addition of organic materials increases pH. Similarly, adding organic materials improved the pH of the media, compared with the topsoil only. According to Fahreza, Marliah & Karmil, (2019), sawdust biochar function for soil was as soil ameliorant because it has a comparatively high pH and CEC. Also, carbon in sawdust biochar can increase the content of C in soil. The lower organic content of C in the

treatment of soil likened to other treatments (M2, M3, M4, M5) revealed that the C was further used by soil microorganisms as a basis of energy. The amount of pore space on sawdust biochar can provide suitable habitats for the growth of soil microorganisms, so that soil microorganisms may function effectively. Earlier, work done by Akuamoah-Boateng (2016), showed that applying PM to acidic topsoil improved the topsoil pH from 5.7 to 6.1 and Gooding & Shewry (2022) also reported that organic manure can supply about 90% – 99% N, P and K when added to conventional topsoil. Similarly, Tokula *et al.*, (2023) and Hariharan *et al.*, (2022) suggested that, increased soil pH may be credited to the addition of PM leading to an increase in organic matter and Ca ions. Owusu, *et al.*, (2024), studied “sustainable commercial sod production of *Cynodon dactylon* (Bermuda grass) in Ghana: assessing growth, visual, and physical quality” and recorded that, nutrients in poultry manure, like nitrogen, phosphorus, and potassium contributed to the improved coverage of sod by providing the necessary resources for seed germination and growth allowing for quick spread of vegetative parts of the sod. Zolfi-Bavariani *et al.*, (2016), Johan *et al.* (2021), and Muñoz-Cerro *et al.*, (2023) also reported that amending soil with poultry manure improved the CEC for more available nutrients to plants and improved P availability in acidic soils. Lima *et al.*, (2018) found that the application of nitrogen fertilizer increased the percentage of ground cover of Zoysia grass, with 400 kg ha⁻¹ N providing the fastest turfgrass closure.

Studies have also shown that sawdust acts as a reservoir for plant nutrients, particularly N, P, K and micronutrients and has nutrient retention capabilities (Eifediyi *et al.*, 2022; Purakayastha *et al.*, 2019). Saeed *et al.*, (2020) equally stated that microbial activity improved pointedly with growing proportions of sawdust in a soil+ sawdust mixture. Earlier work done by Paunović, Milinković & Pešaković, (2020) on “effect of sawdust and foil mulches on soil properties, growth and yield of black currant”, reported that soil covered with sawdust had enhancing consequence

on nutrient composition such as humus, N, P, K and microbial count in the soil. Thus, sawdust covering favored the amendment of soil microclimate through temperature decrease and maintenance of moderate soil moisture through the growing season.

3.4.2 Changes in the physical and chemical properties when biochar was substituted with sawdust

Differences observed in physicochemical properties in biochar amended growing media and sawdust amended growing media may be attributed to the fact that sawdust and biochar amendments impact greatly depend on sawdust and biochar properties, as well as soil characteristics (Chrysargyris *et al.*, 2020).

In the present study, differences in physical and chemical properties were observed when biochar was substituted with sawdust. Bulk density decreased in amended growing media whereas porosity and water holding capacity increased in growing media M4 (TS + PM + SD + CS) = 60:20:15:5 and M5 (TS + PM + SD + CS) = 50:30:15:5 compared with M2(TS + PM + RHB + CS) = 60:20:15:5 and M3 (TS + PM + RHB + CS) = 50:30:15:5, when biochar was substituted with sawdust (Table 4). A decreasing bulk density may be caused by particle size distribution of the growing media. Generally, BD reduces as particle size increases because the volume of spaces between particles increases. Ahn *et al.*, (2020) studied “Characteristics of sawdust, wood shavings and their mixture from different pine species as bedding materials” and concluded that a mixture of sawdust and Wood shavings (1:1 in volume) is a better choice for effectual application of bedding materials. Moreover, particle size distribution is an important feature inducing the WHC. The water holding capacity of substance differs largely due to variations in the degree of decomposition, altering the particle size distribution and surface area. Therefore, sawdust containing fine particles drew additional H₂O than biochar in the formulated growing media. Also,

porosity increased when sawdust was substituted for rice husk biochar in the formulated growing media because of the amount of space within the media particles. With respect to the chemical properties, only the pH decreased when sawdust was substituted with RHB. This could be due to the alkaline nature of biochar. This is in agreement with Yu *et al.*, (2019), who reported that biochar can reduce soil acidity, hence the capacity of crops to draw nutrients from growing media is enhanced.

Moreover, results from the present study are in line with several searches that have considered the consequence of biochar on growing media properties. Trupiano *et al.*, (2017) did a trial on “The effects of biochar and its combination with compost on lettuce (*Lactuca sativa* L.) growth, soil properties, and soil microbial activity and abundance” and reported that compost amendment had significant effect on plants and biomass and on soil chemical properties. Chrysargyris *et al.*, (2020) studied on “How biochar type, ratio, and nutrient levels in growing media affect seedling production and plant performance” and reported that adding biochar to growing media enhanced the content of nutrients in seedlings, as plants could draw more available nutrients. Also, the present study aligns with trial done by Mosharrof *et al.*, (2022) on the “Influence of rice husk biochar and lime in reducing phosphorus application rate in acid soil: A field trial with maize”, which reported that combination of biochar and lime, regardless of the proportions of P, pointedly improved soil nutrient such as N and P availability, whereas Al and Fe concentrations in soil decreased. Additionally, biochar combined with a lower amount of lime, improved maize production by 62.38% equated with the control. This was in conformity with earlier work done by Masulili, Utomo & Syechfani, (2010), on “rice husk biochar for rice-based cropping system in acid soil: the characteristics of rice husk biochar and its influence on the properties of acid sulfate soils and rice growth” and recorded that addition of biochar reduced soil BD, soil strength,

exchangeable Al, and soluble Fe and improved porosity, available soil water content, C-organic, soil pH, available P, CEC, exchangeable K, and Ca. Thus, soil carbon, phosphorus, exchangeable Al, soluble Fe, and soil strength directly affected rice biomass. Similarly, Abrishamkesh *et al.*, (2015) researched on the “Effects of rice husk biochar application on the properties of alkaline soil and lentil growth” and reported that biochar application pointedly improved soil organic carbon, CEC, available potassium and decreased soil bulk density. These results suggest that using conventional soil alone as growing media may not support crop growth because of low nutrients, Shamshudeen, (2010), and requires an amendment to support sod production, Rosenani *et al.*, (2016).

Moreover, RHB-amended media had lower EC compared to that of the topsoil. This was linked to the degree of applying with the higher rate (30%) to be more effective than lower rates such as 5%. This is in accordance with previous report by Prasad, Tzortzakis & McDaniel, (2018). From this study, amending conventional soil with poultry manure improved cation exchange capacity which in turn increased the available P. This agrees to the findings by Zolfi-Bavariani *et al.*, (2016); Johan *et al.*, (2021) and Muñoz-Cerro *et al.*, (2023) that, “poultry manure improves cation exchange capacity to make more nutrients available to plant and improves P availability in acidic soils”. Also, leaching of some macronutrients such as P and Mg was reduced in rice husk biochar-based media, Laird *et al.*, (2010). Rice husk biochar addition enhanced the media porosity and WHC in the formulated growing media. This reduction in bulk density of the amended-based growing media could be attributed to the permeable nature of the biochar and sawdust incorporated to the topsoil. This finding confirmed the recording by Zaini *et al.*, (2017) that conditioners such as sawdust increases moisture retention and enables cohesive interaction of growing media particles.

3.5 Conclusion

In conclusion, this study justified that amending soil with poultry manure, rice husk biochar and sawdust had effect on media BD, WHC, CEC, porosity, organic matter content, pH, available P, OC and exchangeable K, Ca and C/N ratio. It was also obvious that these proportions of organic material for soil amendment affected the physicochemical properties of the formulated growing media. Conventional soil only was usually low in nutrients as well as physical properties such as BD, porosity and WHC. The media developed however, were used for sod production in the subsequent studies.

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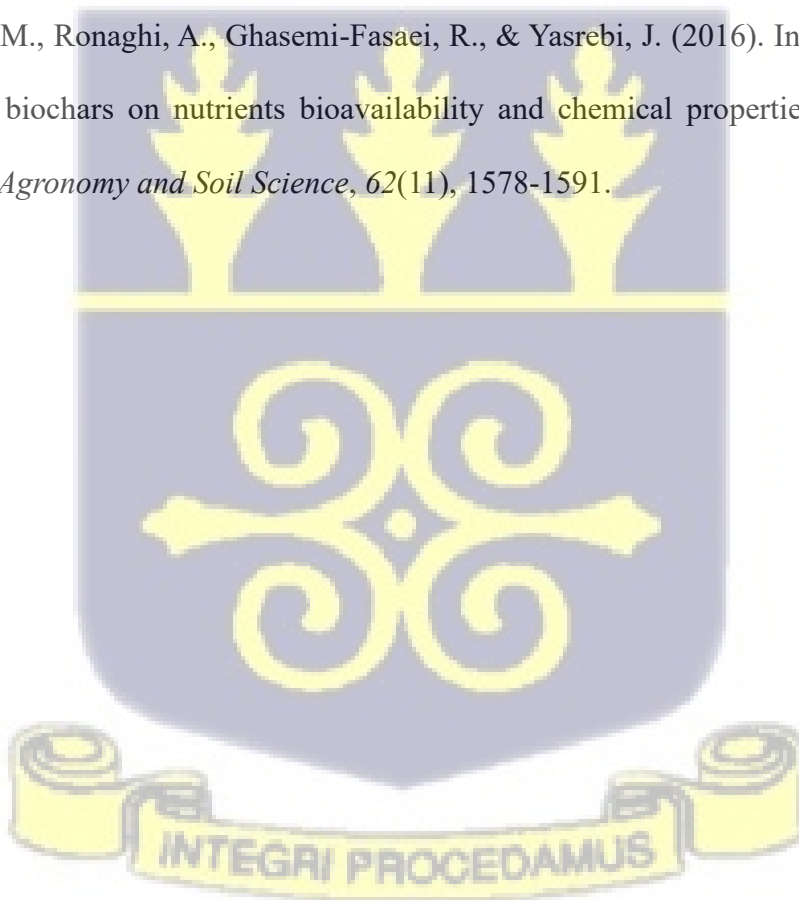
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CHAPTER FOUR

4.0 EFFECT OF GROWING MEDIA ON EMERGENCE AND SOME MORPHOLOGICAL CHARACTERISTICS OF BERMUDA AND ST. AUGUSTINE'S GRASSES IN SOD PRODUCTION

Abstract

Sustainable and quality sod production is essential in erosion control and climate change mitigation. Growing media plays a key role in providing an environment for the rooting of grasses and its establishment in the field. This study was conducted to evaluate the effect of growing media on the establishment and growth of Bermuda and St. Augustine's grasses in sod production in the University of Ghana, Legon-Accra. The factors considered were 1) substrate (5 levels) and grass type (2 levels). The experiment was set up using a (2 x 5) factorial arrangements in a randomized complete block design (RCBD) with three replications per treatment for grass and amended growing media applied at different rates. The treatments were; M1G1, M2G1, M3G1, M4G1, M5G1, M1G2, M2G2, M3G2, M4G2, M5G2, where; M1 = *Topsoil (100%)*; M2= *TS + PM + RHB + clay (60:20:15:5)*; M3= *TS +PM + RHB + clay (50:30:15:5)*; M4=*Top soil + poultry manure + sawdust + clay (60:20:15:5)*; M5= *Top soil + poultry manure + sawdust + clay (50:30:15:5)*, Bermuda and G1= St. Augustine's grass and G2=Bermuda grass.

Plots without amendments served as control. Data were collected on emergence (%), shoot length, number of tillers/plants, chlorophyll content, stem girth, and dry matter production. The interaction effect on grass and growing media had influence on the above parameters. Generally, the two grasses performed better in the formulated growing media than topsoil only.

Bermuda grass recorded the highest emergence (95.3%) in M3G2, whereas soil only (M1G2) recorded the lowest shoots (91.3%). Saint Augustine's grass recorded the highest emergence (41.3%) in M1G1, whereas M3G1 growing media recorded the lowest emergence (12.6%).

Treatment M5G2 recorded the longest (145.6 cm) while the shortest stolon length was observed in treatment M1G2 in Bermuda grass. The longest stolon length in St. Augustine grass was observed in the M5G1. The biggest stem girth in St. Augustine's was observed in the topsoil (M1G1), while that of Bermuda grass was also detected in topsoil only (M1G2). The maximum number of tillers in the Bermuda grass was observed in M5G2, while for the St. Augustine's, this was observed in M4G1 grass topsoil only treatment. The highest dry matter in Bermuda grass was documented in M2G2, whereas the lowest was detected in M1G2. The highest dry matter in grass was chronicled in M2, whereas the lowermost was seen in M1.

Saint Augustine's grass recorded the highest chlorophyll content (32.2 spad) in M5G1. Bermuda grass recorded more tillers (14.2 spad) in Topsoil 50%: PM 30%: SD15%: Clay5% v/v growing media. The highest dry matter was recorded for Bermuda grass (20kg/ha) in Topsoil60%: PM20%: RHB15%: CS5% v/v growing media. The highest root dry matter was recorded for Bermuda grass (2.1 kg/ ha) in M4G2, whereas the highest root volume was recorded for St. Augustine's grass (0.73cm³) in M5G1 growing media. It is therefore recommended that amended growing media has influence on the establishment and growth of turfgrass/sod. However, Bermuda grass performed better in M3 [Topsoil (50%) + PM (30%) + RHB (15%) + Clay (5%)] and M5 [Topsoil (50%) + PM (30%) + SD (15%) + Clay (5%)] whereas St. Augustine's grass performed well in M4 [Topsoil(60%) + PM(20%) + SD(15%) + Clay(5%)] and M5 [Topsoil (50%) + PM (30%) + SD (15%) + Clay (5%)]. Thus, M5 is highly recommended for sod production.

4.1 Introduction

Sod is a solid grass stand of high quality, that is harvested along with roots and a thin layer of topsoil, transported and installed at the landscaping site (Kaiser *et al.* 2019). Sodding is the planting or the installation of a sod. Establishing sod using already prepared sod material at the nursery is recommended because of its several benefits, including, fast establishment, immediate erosion control, flexibility in time of establishment (Goatley, 2016) and weed controls (Owusu *et al.*, 2023).

Bermuda and St. Augustine's grasses are warm-season grasses which belong to the family *Poaceae*, subfamily *Panicoideae*, and tribe *Andropogoneae* (Owusu *et al.*, 2024). These turf grasses are used in establishment of lawns and sports fields.

Unlike in the advanced countries, they are classified in many developing countries as noxious weeds due to their quick-spreading growth and invasive seed-forming inflorescence (Owusu *et al.*, 2024). Consequently, they have been largely ignored in the commercial sod production industry in most developing countries where sod is produced.

Growing a good sod mostly requires the addition of organic or inorganic fertilizers to improve soil nutrient levels. Organic fertilizers are preferred due to their positive impact on soil physicochemical properties, lower hostile impact on the environment, and availability. Poultry manure is a type of organic fertilizer high in nitrogen and phosphorus compared to other bulky organic manure and is relatively affordable and accessible in Ghana (Akpalu *et al.*, 2020). In turf production, sawdust and biochar are also regularly used, and they can be essential when the soil conditions are not optimal or favorable for roots to absorb nutrients (Chakanyuka *et al.*, 2019).

Sod used widely in the site of urban centers, recourses touristic communities and individual home gardens for artistic value enhances the microclimate of these areas, where establishment and growth largely depend primarily on soil (Badawy, El-Khateeb & Salem, 2018). Many authors have used soil for turfgrass establishment and have concluded that soil effect on grass performance was not encouraging (“Trupiano *et al.*, 2017; Nematollahi *et al.*, 2018”). It has been stated by Mathew (2021) that when topsoil is used as the sole source of growing medium for producing sod, the performance is very poor, hence an application of organic waste will reduce bulk density, add manure (organic substance and plant nutrients) to media, improve microbial activity and soil health. This can reduce the dependency on inorganic fertilizers. Other authors have used organic materials like biochar, poultry manure and various degrees of success have been reported (Akpalu *et al.*, 2020; Barrett *et al.*, 2016; Chrysargyris *et al.*, 2020).

The continuous use of topsoil for raising sods has been criticized by environmentalist with also complaints about sustainability (Moulick *et al.*, 2024). The detrimental effects of topsoil on turfgrass include depletion or unavailability and so new options are needed to be evaluated. The continuous practice of digging soil for establishing lawns increases erosion and is non environmentally sustainable because it destroys the site at where the soil was collected (Danso *et al.*, 2013; Alireza & Mohammad, 2019). The continuous use of topsoil for growth and establishment of turfgrasses is expensive and limited in supply. As a result, stakeholders have resorted to use unfertile soils, resulting in poor sod production, and poor turf establishment. In Ghana, over 3000-3500 tons of soil is dug annually from farmlands for horticultural activities (Danso *et al.*, 2013). Xiao, 2016 and Cattin, (2022) reported that growing media physicochemical properties influence the value of the turf raised as well as its establishment in the field (Cattin, 2022). In addition, sod raised in topsoil is so heavy that, growers remove some of the soil around

the root system which in turn disturbs roots causing too much shock to sod before transplanting. Using farm land topsoil for turfgrass establishment is a major limitation to commercial production. Hereafter, it has become necessary to discover appropriate alternative growing substrate that is easy to convey, readily available and sustainable for raising healthy sod. The use of locally available agricultural waste for instance RHB, sawdust and PM look promising. The use of plants and animal waste is going to help sod growers decrease the use of inorganic fertilizer and topsoil in raising healthy sod/turf leading to a reduction in production expenses.

Soil amendments resulted in drastic improvements in the production period of sod (Owusu *et al.*, 2023) when compared to the regular conventional methods requiring up to 2 years after planting. It is therefore very essential to evaluate the performance of turfgrass species, that are capable of maintaining quality and appearance in soils amended with organic elements such as poultry manure, sawdust and RHB (Nematollahi *et al.*, 2018; Pornaro *et al.*, 2019). These organic substances are locally and readily available, easy to convey and sustainable for raising healthy turfgrasses/sod. Moreover, the use of plants and animal waste is going to help sod growers reduce the use of inorganic fertilizers and topsoil in raising healthy sod/turf leading to a reduction in production cost. This is because poultry manure, sawdust and biochar have been proven to enhance physicochemical properties of soil which include BD, porosity, WHC, pH, CEC and soil nutrients (Chrysargyris *et al.*, 2020; Montgomery, 2018; Gohardoust *et al.*, 2020; Cattin, 2022).

Bermuda and St. Augustine's grasses are usually planted with sprigs/stolons on topsoil, which is sometimes mixed with composted manure (Asiedu *et al.*, 2012). The sprigs of these grasses are very prominent, easily accessible, and mostly viable but are usually mown together with the leaf clippings and discarded, completely disregarding their potential as good propagation material if saved. Its creeping or spreading growth style, resistance to heat, drought, and trampling/traffic

could also make it ideal for sod production as they easily spread and form a mat-like growth over soil. Moreover, propagating Bermuda and St. Augustine's grasses using seed is generally more cost-effective and easier to manage, however, sprigs/stolons may offer the advantage of faster establishment and can potentially yield more vigorous sod.

Although there have been many studies on the soil amended media for the production of several ornamentals such as roses, marigolds and vegetables such as tomato, cucurbits, and pepper, literature on Bermuda and St. Augustine's turfgrasses sod production is limited. Sod producers rely on inorganic fertilizers, particularly through foliar application, to enhance soil quality (Zuza *et al.*, 2023). Powlen & Bigelow, (2024) concluded that, the application of 2.0 to 3.0 "lb N 1,000 ft⁻²" during the first sixty days after planting Bermuda grass seeds was sufficient to maximize seedling establishment on a silt-loam soil. In a corresponding study, Ow & Yusof, (2018) studied the "Effects of localized liquid fertilization of N, P, K and Ca on root development in *Zoysia matrella*, *Cynodon dactylon* and *Stenotaphrum secundatum*". The study concluded that fertility rates influence turf quality characteristics differently and the external concentrations of N, P, K and C are needed by the root system in varying quantities for optimal growth of roots. Moreover, Owusu *et al.*, (2024) studied "Sustainable commercial sod production of *Cynodon dactylon* (Bermuda grass) in Ghana" and concluded that using chicken compost and foliar manure with window netting significantly enhanced the growth, graphic scene, and physical strength of both seeded and sprigged turf, meeting marketable standards. To bridge this knowledge gap, the current study, evaluated the establishment and growth of *Cynodon dactylon* and *Stenotaphrum secundatum* grasses produced using stolons on different growing media formulated from topsoil, PM, RHB and clay.

4.2 Methodology

4.2.1 Experimental Site

This experiment was carried out at the Greenhouse, Sinna's Garden-Department of Crop Science, 0.50 39 N1, 000 10 W0, 69m above sea level. Average rainfall for this zone ranges from 74.1mm to 95 mm and annual and minimum temperature means are 31 °C and 24.3 °C respectively.

4.2.2 Experimental materials and layout

An experiment was carried out between October and December 2022 to investigate the effect of growing type viz different combinations of SD: PM: RHB, clay and soil as the control on grasses for sod. After media formulations, two different grasses were planted in the various growing media looking at the interactions between the factors that would support growth of grasses in making sod. Biochar was obtained from the Forest and Horticulture Research Centre (FOHCREC), Kade. Sawdust was obtained from Bunso CSIR. Bermuda and St. Augustine's grasses stolons were obtained from Benoras Horticultural services Ltd. at Abokobi, Ga East District and Poultry manure was obtained from A.K. Farms at Abokobi, Ga East District. Top soil and clay soil were obtained from the University of Ghana Experimental farm.

4.2.3 Experimental Design

Treatments had factorial arrangements in the Randomized Complete Block Design consisting of two factors. Factor one was the growing media (prepared from top soil, poultry manure, rice husk biochar, saw dust and clay). Factor two was the two different grasses [Saint Augustine's grass (*Stenotaphrum secundatum*), and Bermuda grass (*Cynodon dactylon*). The growing media had five (5) level treatments, i.e. M1 M2 M3 M4 and M5. M1=Topsoil (100%), M2= (60%TS + 20%PM + 15%RHB + 5CS), M3= (50%TS + 30PM + 15RHB + 5CS), M4= (60%TS + 20PM + 15SD + 5CS), M5 (50TS + 30PM + 15SD + 5CS). These formulations performed best in our earlier trials.

Grasses also had two (2) level treatments i.e., G1= St. Augustine's grass and G2= Bermuda grass. The treatments include; M1xG1, M2xG1, M3xG1, M4xG1, M5xG1, M1xG2, M2xG2, M3xG2, M4xG2, M5xG2. Thus, the total treatments for the experiment were ten (10), with three (3) replicates. These growing media were selected because they performed well from earlier trials conducted.

4.2.4. Treatment

Table 4.1: Materials and formulation ratios of Growing Media

Media	Composition	Ratio (%)
M ₁	Topsoil	100%
M ₂	Topsoil + poultry manure + rice husk biochar + clay	60:20:15:5
M ₃	Topsoil + poultry manure + rice husk biochar + clay	50:30:15:5
M ₄	Topsoil + poultry manure + sawdust + clay	60:20:15:5
M ₅	Topsoil + poultry manure + sawdust + clay	50:30:15:5
G ₁	Saint Augustine's grass (<i>Stenotaphrum secundatum</i>),	
G ₂	Bermuda grass (<i>Cynodon dactylon</i>)	

4.2.5 Experiment conducted for the two grasses

The experiment was performed from October 2022 to January 2023 at the Crop Science Department, University of Ghana. Wood box (40cm*20cm) and 6cm depth was lined with a net on perforated poly sheet at the bottom and filled with samples of the various growing media. Topsoil that was used as the control was taken from soil belonging to the Adenta series classified as Lixisols. The topsoil was taken to a depth of 0 – 10 cm, air- dried and passed through a sieve of 5mm net to eliminate all debris, soil clods and stones. The wood boxes with the various treatments

were arranged according to the complete randomized block design (CRBD). The boxes were left to stand for 48 hours for the growing media in each box to settle. Grass stolons were planted at a density of 50 per box and watered when necessary. Runners/ stolons cut from the basal portion of grass (10cm long) was used for propagation. Planting was done by dibbling. The planting distance was 4cm * 4cm between and within grass and thus, 50 cuttings of grass was used per box. Planting depth used was 2.5cm, and this depth was selected based on a preliminary study, that showed that the depth of 2.5 cm was the optimum planting depth. Grasses used for the experiment were Bermuda grass (*Cynodon dactylon*) and St. Augustine's grass (*Stenotaphrum secundatum*). The space between stolons planted was 4cm. Watering was administered twofold daily. Five hundred, 500mls in mornings and 500mls in the evening.



PLATE 3: Boxes filled with growth media (Left); Stolons shoot in growth media(Right)

4.2.6 Data Collection for 13 weeks after planting

Information on the morphological parameters and performance of Bermuda and St. Augustine's grass were recorded during the trial period of three (3) months. Morphological parameters including, emergence that was expressed as (%), stolon length, number of tillers/plants,

chlorophyll content, stolon girth, and yield were calculated as the mean obtained from 18 plants that were randomly sampled from the mid row per plot. Data was taken at 3, 5, 7, 9, 11 and 13 weeks after planting. Harvesting/trimming was done by hand using a pair of shears, at a height of 10 cm at 5, 9 and 13 weeks after planting respectively. Freshly trimmed yield of the grass after trimming was weighed using a weighing balance. The dried samples were determined after-labelling and dried in oven at 70 °C for 72 hours. Morphological yields of the 1st and 2nd trimmings were taken on the 7th and 13th weeks after planting. All data was taken around 10 am in the morning.

4.2.6.1 Emergence percentage

A stolon was determined by way of “emerged” if the above-ground portion of new stolon sprouting from the original stolon exceeded 1 cm long. Emergence was assessed by the number of fresh stolons in a 1- by- 1 cm “quadrat” positioned in a point at the center of the plot. Stolons were totaled every two weeks for seven weeks. Emergence was assessed as labelled in “Baseggio *et al.*, (2015)”.

$RE = \sum S/t$ (Baseggio *et al.* (2015).

S is the number of grasses stolons at two weeks interval and “t” is the whole period of emergence.

RE is relative emergence.

“Emergence (%)” = $\frac{\text{“Total number of stolons shoots”}}{\text{“Total number of stolons staked”}} \times 100$

4.2.6.2 Number of tillers

Number of tillers was evaluated as an average count from ten stolons that were randomly selected in central rows of individual plots at 3, 5, 7, 9 11 and 13 weeks after planting. Number of tillers was evaluated as described by Adnew & Asmare (2023).

4.2.6.3 Stolon length

Stolon length was calculated on ten stolons that were randomly selected from the mid rows of the plots at 3, 5, 7, 9, 11 and 13 weeks after planting. Stolon length was determined as described by Adnew & Asmare (2023). Data was taken on the longest stolon and was measured in centimeters.

4.2.6.4 Stolon Girth

Stolon girth (per stolon) was also measured from ten stolons that were randomly selected from the central rows of plots at 3, 5, 7, 9, 11 and 13 weeks after planting. Stolon girth was measured at the point where the cotyledons detached from the shoot using electronic calliper. It was measured in millimetres (mm).

4.2.6.5 Chlorophyll

Chlorophyll content scores “(0-100 unit)” were performed at 3, 5, 7, 9, 11 and 13 weeks after planting with a chlorophyll meter “(Minolta SPAD-501, Spectrum Technologies, Inc., Illinois, U.S.A)”. This calculation was dependent on the variation amid light reduction at “430 and 750 nm”, with nope diffusion. One complete expanded blade from a box was assessed as samples for chlorophyll measurement. Four leaves were sampled. The time for data collection was 10am in the morning. To safeguard the same leaf sampled, four selected samples before cutting were highlighted with plastic tags. The “relative increase rate” (RIR) of “chlorophyll meter reading” (CMR) through third to thirteenth weeks was measured as ratio of thirteenth week “CMR” medium first week CMR to first week CMR. Chlorophyll was evaluated as described by Kuo (2015).

4.2.6.6 Root Volume

The root volumes of Bermuda and St. Augustine’s grasses were determined destructively. Each root volume was determined using the displacement method. The roots were cut and washed to get rid of debris. The roots were placed in a 100 ml graduated cylinder, which was filled with water to

the brim. Then, the chopped roots were immersed in the water. The displaced water that was collected was used as an estimate of the root volume (Akpalu *et al.*, 2020).

4.2.6.7 Weed number and dry matter determination

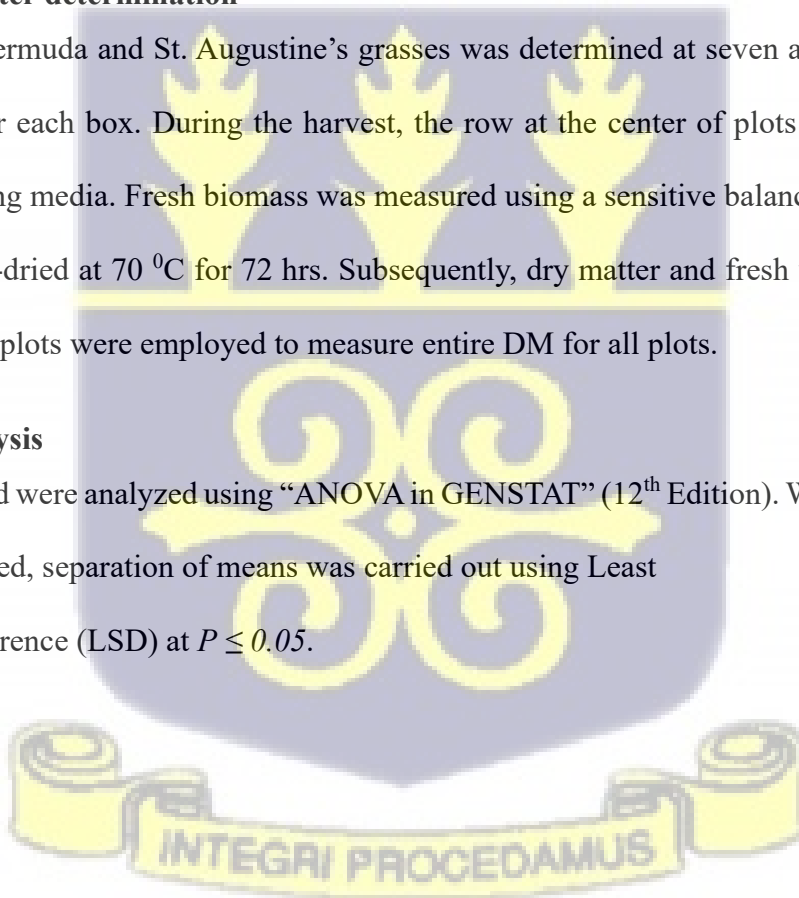
The number of weeds that grew during the experimental period on each treatment box was determined by counting. The uprooted weeds / roots were thoroughly cleaned to remove remnants of the growing media. The weeds were then separated into leaves, stems and root, and dried in oven at a temperature of 70 °C for 72 hrs. The dry matter of the weeds was determined after drying, using a scale. And the weights recorded accordingly.

4.2.6.8 Dry Matter determination

Dry matter of Bermuda and St. Augustine's grasses was determined at seven and thirteen weeks after planting for each box. During the harvest, the row at the center of plots was cut at 10 cm above the growing media. Fresh biomass was measured using a sensitive balance. After that fresh grass were oven-dried at 70 °C for 72 hrs. Subsequently, dry matter and fresh vegetative harvest from the sample plots were employed to measure entire DM for all plots.

4.2.7 Data Analysis

The data obtained were analyzed using “ANOVA in GENSTAT” (12th Edition). Where a significant *f* test was observed, separation of means was carried out using Least Significant Difference (LSD) at $P \leq 0.05$.



4.3 Results

Table 4.3: Climatic data at the experimental site, University of Ghana from October 2022 to January 2023

Months	Total rainfall (mm)	Maximum temperature (°C)	air Minimum temperature (°C)	air Mean relative humidity (%)
October 2022	113.1	31.3	23.6	87.9
November 2022	77.3	32.3	23.9	88.3
December 2022	2.0	33.1	23.7	82.2
January 2023	29.5	33.9	23.8	81.1

Source: Ghana Meteorological Service

4.3.1 Bud Emergence of Bermuda and St. Augustine's grasses

Differences in the emergence of St. Augustine's (G1) and Bermuda (G2) grasses were observed over the experimental period. Emergence (%) was significantly higher in ($P \leq 0.05$) Bermuda grass compared to the St. Augustine's grass at 3 weeks after planting. Bermuda grass recorded more emergence (75.7%, 91.2% and 93.4%) at 3, 5 and 7 weeks after planting respectively. However, lower number of stolons were observed in the St. Augustine's grass G1 (24.9%, 38.5% and 26.8%) at 3, 5 and 7 weeks after planting respectively (Figure 4.1a).

Bermuda grass exhibited, increase in buds at the nodes, indicating higher rate of emergence during the study period. However, in the case of St. Augustine's grass, there was a decrease in emergence after 5 weeks, indicating differences in the peak for grass emergence among the two grasses.

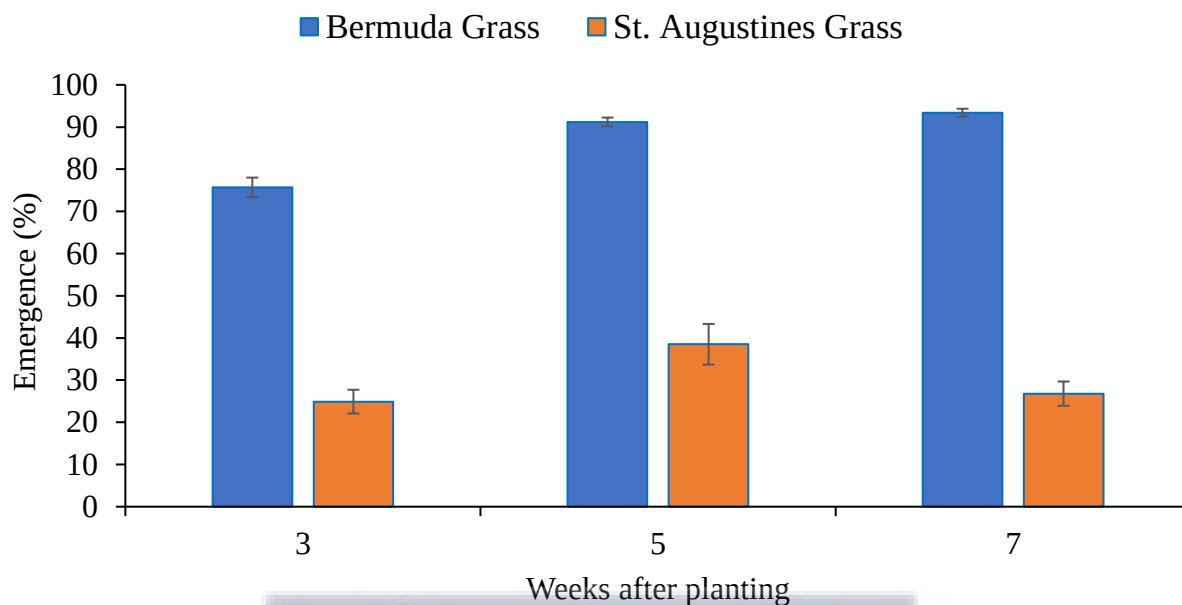


Figure 4.1a: Percentage Emergence of Bermuda Grass and St. Augustine's Grass at 3,5 and 7WAP

4.3.1.1 Growing media effect on stolon emergence

Treatment M5 [Topsoil (50%) + PM (30%) + SD (15%) + Clay (5%)] recorded higher stolon emergence (55.8%) while the least number of stolons emergence was observed in treatment M3 [Topsoil (50%) + PM (30%) + RHB (15%) + Clay (5%)] for both grasses (G1 and G2) at 3 WAP. At 5 weeks after planting, treatment M1 (topsoil) significantly recorded higher stolon emergence (79%) while the least number of stolon emergence was observed in treatment M3 for both grasses (G1 and G2). Moreover, treatment M1 (topsoil) recorded significantly higher number of emergence (66%) whereas, M3 recorded the smallest number of emergence (54%) at 7 weeks after planting in G1 (St. Augustine's) and G2 (Bermuda grass). Growing media had a significant effect on emergence in G1 and G2, with treatment M5 (50:30:15:5) Top soil + poultry manure + sawdust + clay v/v growing media recording the highest emergence (55.8%) and the lowest stolon

emergence being observed in treatment M3 (50:30:15:5) *Top soil + poultry manure + rice husk biochar + clay* (44.8%), when biochar was substituted for sawdust at 3 weeks after planting (WAP), whereas M3 (50:30:15:5) *Top soil + poultry manure + rice husk biochar + clay* v/v growing media recorded the lowest emergence (44.8%). However, at 7 weeks after planting topsoil recorded significantly more emergence (79%), than the other treatments (M2, M3, M4, M5). A similar trend was observed with the emergence (%) at 5 and 7 weeks after planting (Figure 4.1b). However, there was an average emergence across all growing media which means the performance of the two grasses on emergence does not depend on growing media used.

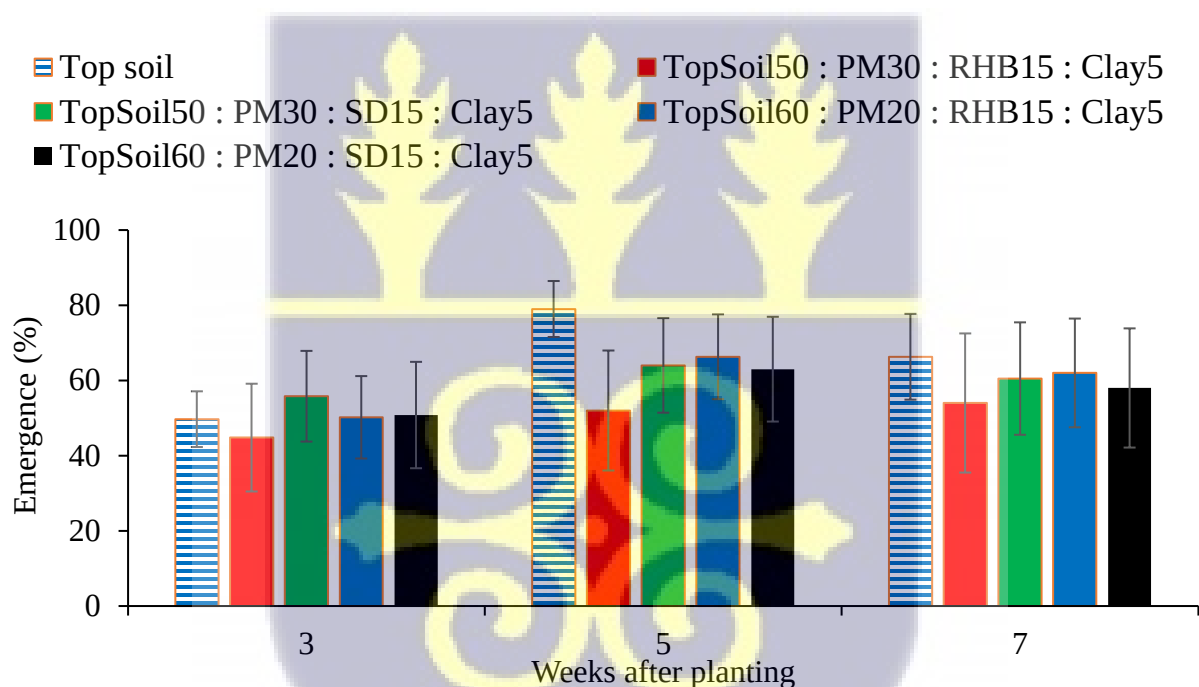


Figure 4.1b: Growing media effect on percentage emergence of Bermuda and St. Augustine's grasses

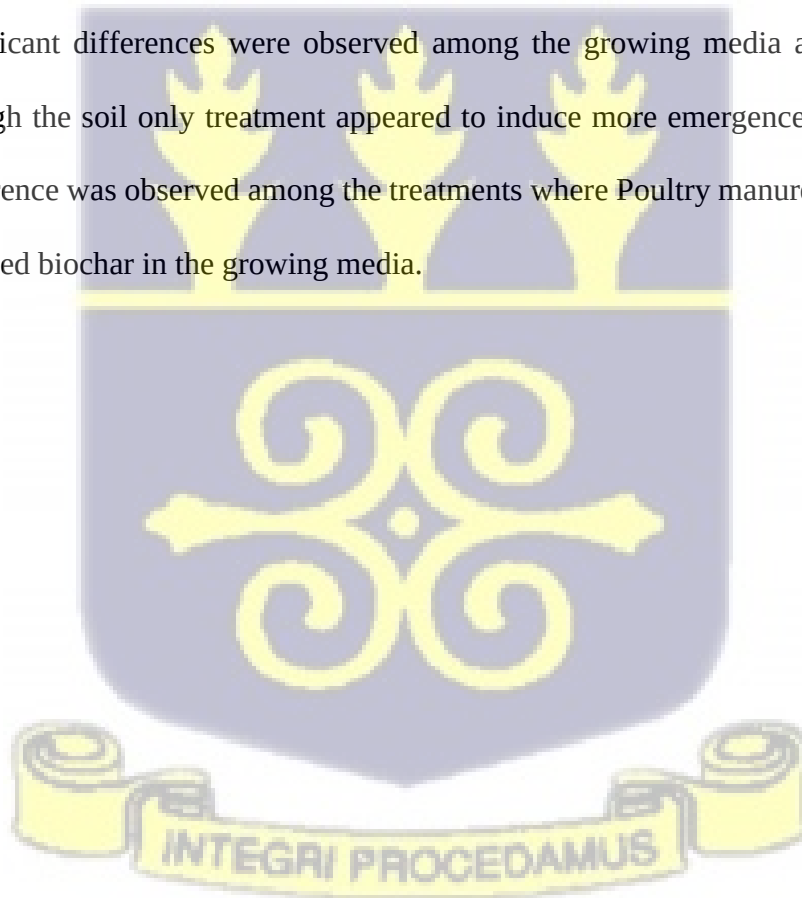
4.3.1.2 Effect of growing media and grass type on emergence

Differences in the effect of the growing media on the different grasses were observed with time. Growing media M4 recorded the highest number of emergence (82.3%) whilst the lowest number was observed in treatment M1 (64.7%) in Bermuda grass at 3WAP. The highest number of stolons

in Bermuda grass was observed in the M4 (94%) whilst the least was observed in M3 (87.3%) at 5WAP. Growing media M3 recorded the highest number of stolons (95.3%) whilst the lowest number was observed in treatment M1 (91.3%) in Bermuda grass at 7WAP. No significant differences in the emergence of Bermuda grass were detected at 3 and 7 weeks after planting (WAP) in different growing media. There was no significant ($P \leq 0.05$) difference in emergence among growing media. *M3 (50:30:15:5) Top soil + poultry manure + rice husk biochar + clay* v/v growing media recorded the highest (95.3%) emergence, whereas topsoil recorded the lowest emergence (91.3%) in Bermuda grass at 7 weeks after planting. When RHB was replaced with SD, *M4 (60:20:15:5) Top soil + poultry manure + sawdust + clay* recorded significantly more emergence (82.3%) at 3 weeks after planting. Therefore, change in treatment had effect on the emergence of Bermuda and St. Augustine's grasses.

Treatment M1 recorded the highest emergence (34.7%) while the least was recorded in treatment M3(13.3%) in St. Augustine's grass at 3WAP. The highest emergence in St. Augustine's grass was observed in the M1 (65.3%) at 5WAP whereas M3 recording the least emergence (16.7%). Treatment M1 recorded the highest emergence (41.3%) whereas the smallest was observed in treatment M3(12.6%) in Bermuda grass at 7WAP. Differences in the emergence of St. Augustine's grass was observed from 3 weeks after planting (WAP) onwards in the different growing media. There was significant ($P \leq 0.05$) difference in emergence amongst growing media. Topsoil (M1) recorded the highest stolons emergence (65.3%, 41.3%) while, *M3 (50:30:15:5) Top soil + poultry manure + rice husk biochar + v/v* growing media recorded the least stolons (16.7%, 12.6%) in St. Augustine's grass at 5 and 7 WAP respectively (Figure 4.1c). It is therefore, evident that topsoil seems to do better than amended growing media with regards to emergence for St. Augustine. However, Bermuda grass performed better for emergence in amended growing media than topsoil.

The effect of growing media on emergence cumulatively differed among the treatments. It was noted that the difference between 5 and 7 weeks was a decrease for topsoil only and while there was increase for the emergence (%) for treatment M3 (50/30/15/5) for Bermuda grass. No significant difference was observed at 7 WAP for Bermuda grass. At 7 WAP the percentage emergence ranged between 91.3 for topsoil and 95.3 for topsoil 50; PM 30; RHB15; clay 5 v/v. however no significant difference was observed. The topsoil only treatment recorded the highest bud emergence, while the treatment topsoil M3 (50; PM 30; RHB 15, clay) 5 recorded the lowest. In the present state, it seems the peak for the bud emergence for the topsoil among other treatments was highest and reached the peak in 5 WAP after which there was a decrease for St. Augustine's grass. No significant differences were observed among the growing media at the weeks after planting, although the soil only treatment appeared to induce more emergence. Furthermore, no significant difference was observed among the treatments where Poultry manure was increased or where SD replaced biochar in the growing media.



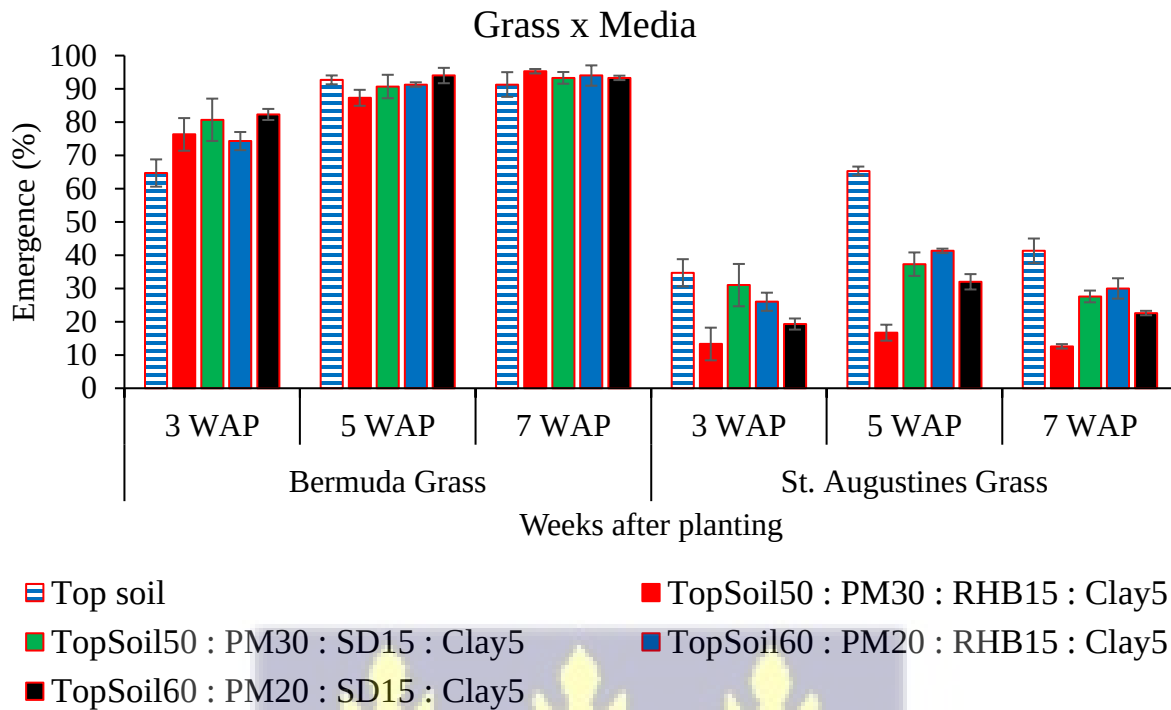


Figure 4.1c: Effect of growing media on percentage emergence of Bermuda and St. Augustine's grass

4.3.2 Performance of stolon length of Bermuda and St. Augustine's grass

Differences in stolon length of Bermuda and St. Augustine's grasses was observed at 3 weeks after planting (WAP). Bermuda stolon was significantly ($P \leq 0.05$) longer compared with that of the St. Augustine's stolon at 3 weeks after planting. Similar trend was observed with the stolon length at 5, 7, 9, 11, and 13 weeks after planting. Bermuda grass recorded the longest stolons (37.1 cm, 44.8 cm, 58.6 cm, 68.1 cm, 99.9 cm and 119.6 cm) at all sampling period. Whereas, St. Augustine's grass recorded shortest stolons (8.8 cm, 10.7 cm, 29.2 cm, 35.8 cm, 78.4 cm and 96.2 cm) at the sampling period (Figure 4.2a). The stolon length ranged between 17.1 and 119.8 cm for Bermuda grass, while St Augustine's 8.8 and 96.2 cm within the 7 weeks period. Significant differences between Bermuda grass and St Augustine's as observed at all the sampling periods at 7 WAP.

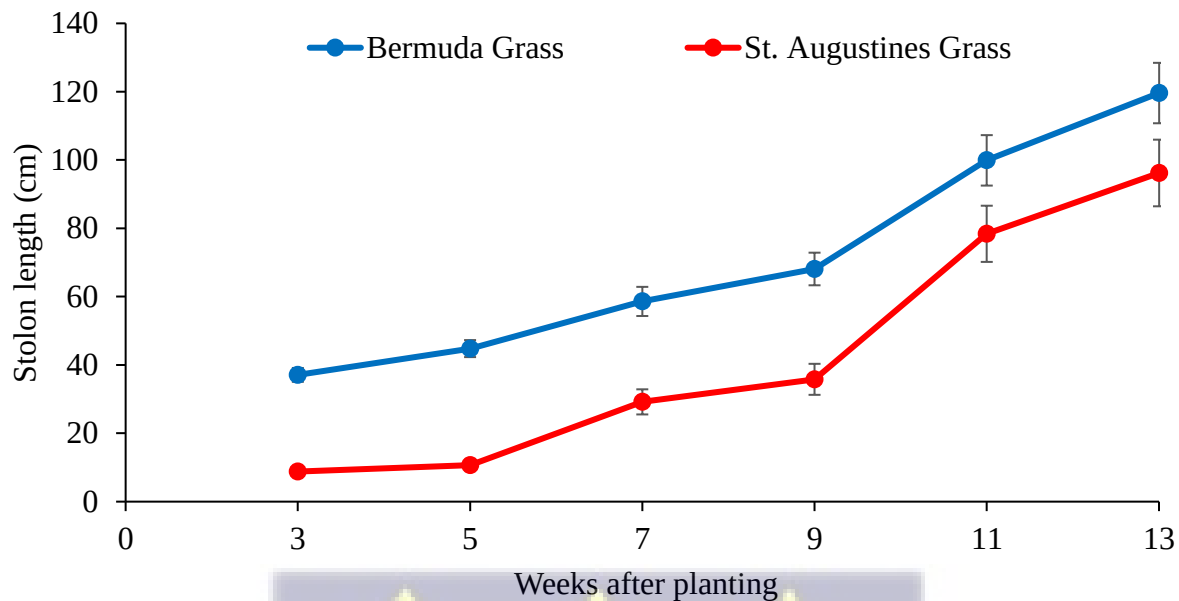


Figure 4.2a: Mean stolon length of Bermuda and St. Augustine's grasses at 2 weeks intervals over 13-week period

4.3.2.1 Growing media effect on stolon length

Growing media had significant ($P \leq 0.05$) effect on stolon length in both grasses. M5 (50:30:15:5) Top soil + poultry manure + sawdust + clay v/v growth media recorded the longest stolons (27.8 cm, 33.6 cm, 56.5 cm, 69 cm, 116.1 cm and 139 cm) when biochar was substituted for sawdust at 3,5,7,9,11 and 13 weeks after planting respectively, whereas topsoil recorded the shortest stolons (14.6 cm, 17.4 cm, 22.8 cm, 27.7 cm, 50.6 cm and 60.7 cm) at all sampling period (Figure 4.2b). The treatment with the lowest effect on stolon length was topsoil while the highest was M5.

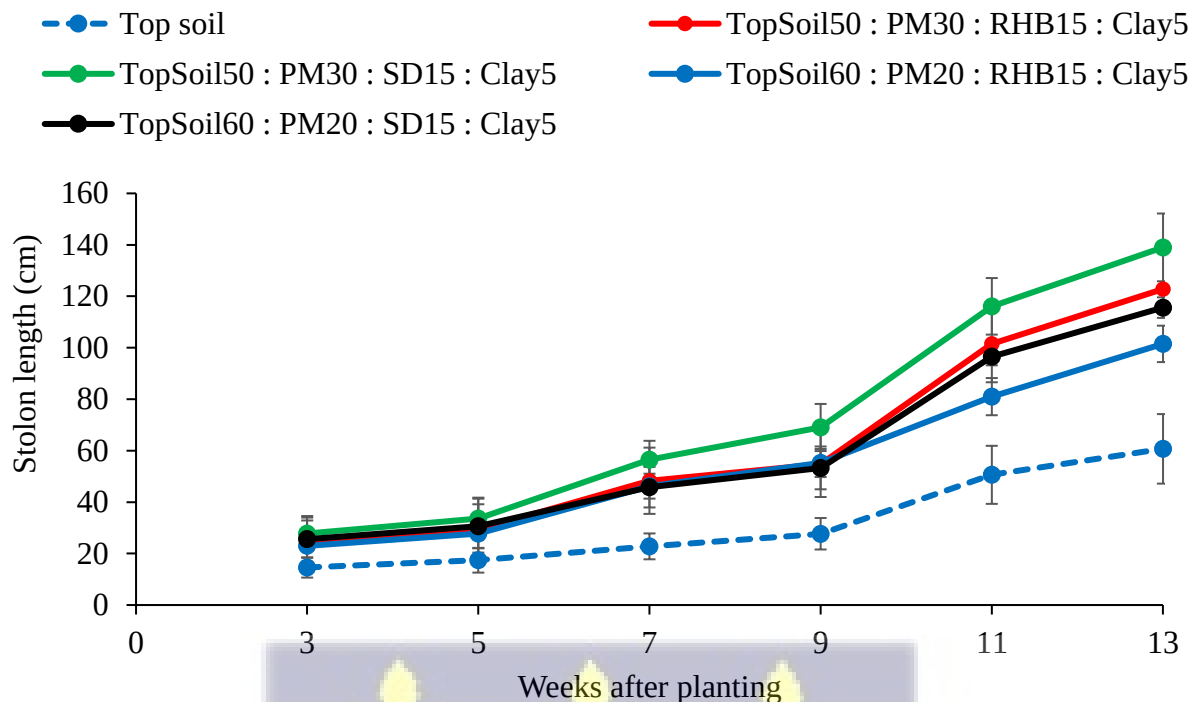
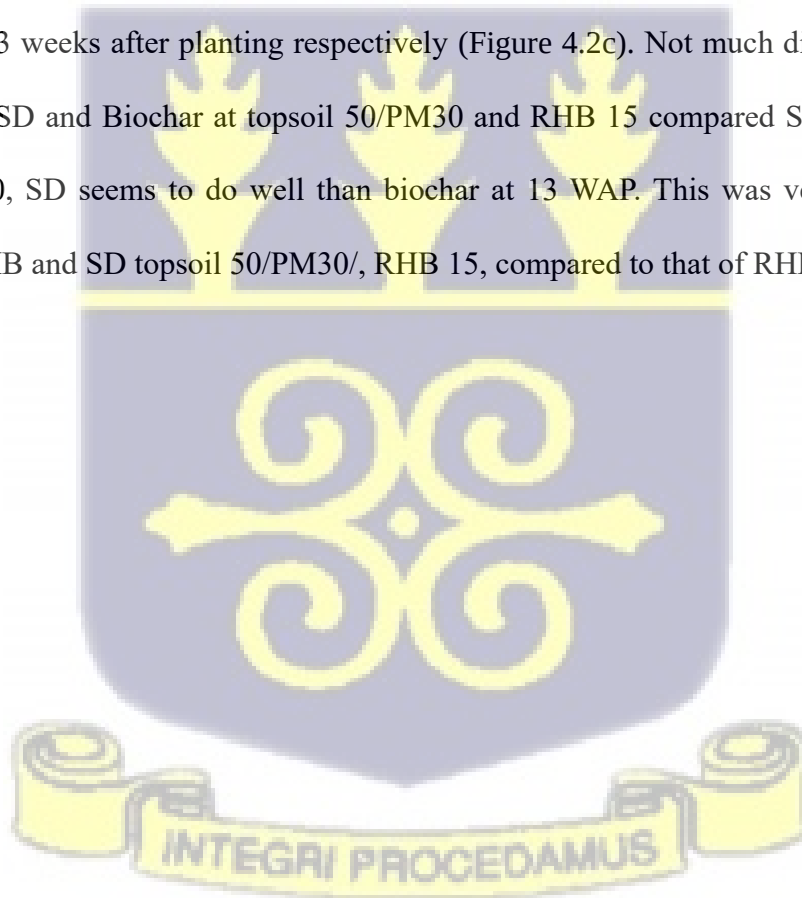


Figure 4.2b: Growing media effect on stolon length at 3-13 WAP

4.3.2.2 Effect of growing media and grass type on stolon length

Treatment M5 recorded the longest stolon (42.1 cm) while the shortest stolon was observed in treatment M1(23.2 cm) in Bermuda grass at 3WAP. The longest stolon in Bermuda grass was observed in the M5 (145.6 cm) at 13WAP whereas M1 recorded the shortest stolon (90.6 cm). Differences in stolon length of Bermuda grass was observed at 3 weeks after planting (WAP) in different growing media. There was significant ($P \leq 0.05$) difference in stolon length in the amended growing media at 3 and 5 weeks after planting. M5 (50:30:15:5) *Top soil + poultry manure + sawdust + clay* v/v growing media recorded the longest stolons (42.1cm, 50.6cm, 69.1cm, 84cm, 121.6cm and 145.6cm) when biochar was substituted for sawdust at 3,5,7,9,11 and 13 weeks after planting. Topsoil recorded the shortest stolons (23.2cm, 28cm, 34cm, 41.2cm, 75.6 cm and 90.6 cm) at 3,5,7,9,11 and 13 weeks after planting respectively. Therefore, growing media performed better when RHB was replaced with SD for Bermuda grass.

Treatment M5 recorded the longest stolon (13.5 cm) while the shortest stolon was observed in treatment M3(5.9 cm) in the St. Augustine's grass at 3WAP. The longest stolon in St. Augustine's grass was observed in the M5 (132.5 cm) at 13WAP whereas M1 recorded the shortest stolon (30.7 cm). Differences in stolon length of St. Augustine's grass was observed at 3 weeks after planting (WAP) in different growing media. There was significant ($P \leq 0.05$) difference in stolon length at 3 and 5 weeks after planting among growing media. M5 (50:30:15:5) Top soil + poultry manure + sawdust + clay v/v growing media recorded the longest stolons (13.5 cm, 6.6 cm, 43.8 cm, 53.9 cm, 110.6 cm and 132.5 cm) when biochar was substituted for sawdust at all recording period. Topsoil recorded the shortest stolons (5.9 cm, 6.9 cm, 11.7 cm, 14.1 cm, 25.6 cm and 30.7 cm) at 3,5,7,9,11 and 13 weeks after planting respectively (Figure 4.2c). Not much difference in stolon length between SD and Biochar at topsoil 50/PM30 and RHB 15 compared SD15. However, at topsoil 60/PM20, SD seems to do well than biochar at 13 WAP. This was very evident for St Augustine at RHB and SD topsoil 50/PM30/, RHB 15, compared to that of RHB at same ratio.



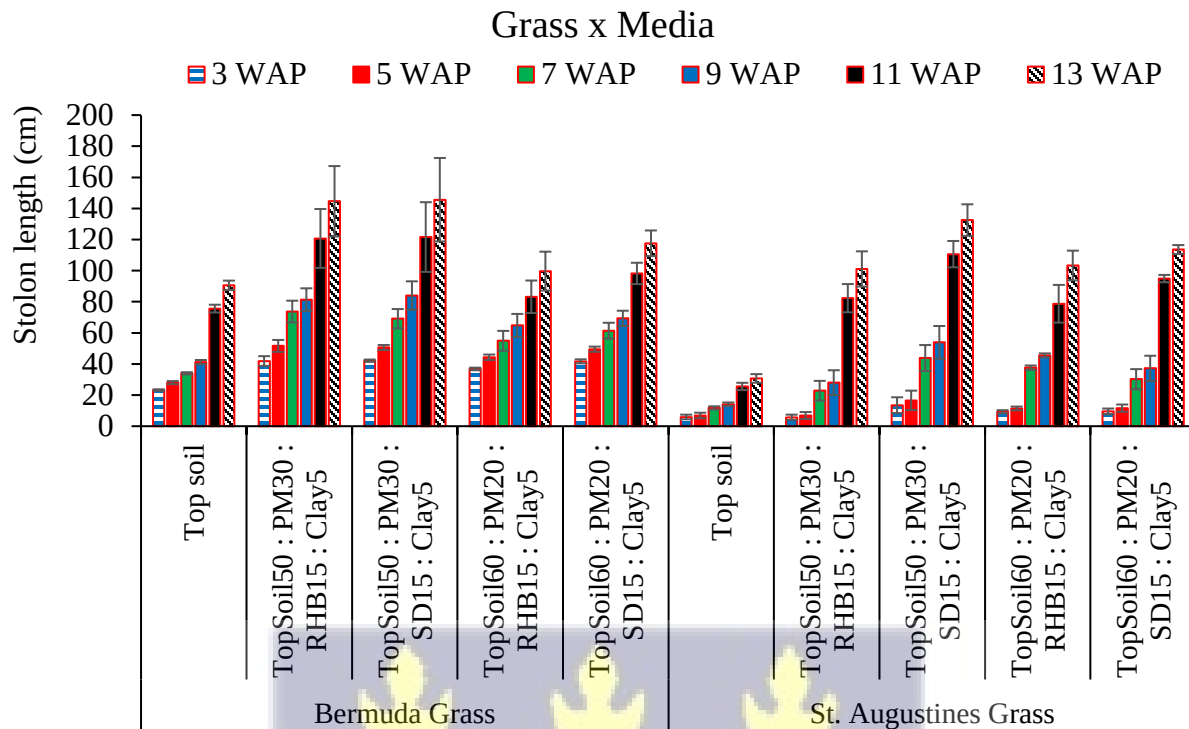


Figure 4.2c: Effect of growing media and grass type on shoot length at 3-13 WAP

4.3.2.3 Difference between final and initial stolon lengths

The stolon length of Bermuda grass in the different growing media differed significantly. The longest stolon was observed in treatment M5 (50:30:15SD: 5 clay) (103.5 cm) and the shortest was observed in topsoil (67.4 cm). Replacing the sawdust with rice husk biochar reduced stolon length (comparing 50:30: SD15:5 clay and 50:30: RHB15:5 clay), while increasing the topsoil component reduced the stolon length comparing (TS60: PM30: SD15 :5 clay and 50:30: SD15:5 clay). This growth trend was similar for both Bermuda and St. Augustine's. Genetically, the Bermuda grass growth is faster than that of St. Augustine's grass (Table 4.4).

Table 4.4 Difference between final and initial stolon lengths (cm)

	Bermuda & GM			St. Augustine's & GM		
	Final	Initial	Diff	Final	Initial	Diff
M1 (Topsoil)	90.6	23.2	67.4	30.7	5.9	24.8
M2 (TS60: PM20: RHB15: 5 clay)	99.7	36.8	62.9	103.3	9.3	94.0
M3 (TS50:PM30: RHB15:5 clay)	144.6	41.9	102.7	101.1	5.7	95.4
M4 (TS60: PM20: SD15 :5 clay)	117.6	36.8	80.8	113.6	9.5	104.1
M5 (TS50: PM30: SD15 :5 clay)	145.6	42.1	103.5	132.5	13.5	119.0

4.3.3 Stolon girth of Bermuda and St. Augustine's grass across all growing media

Differences in stolon girth of Bermuda and St. Augustine's grasses was observed at 3 weeks after planting (WAP). St. Augustine's grass was significantly ($P \leq 0.05$) bigger than Bermuda grass. St. Augustine's grass recorded the biggest stolon (1.9 mm, 2.1 mm, 2.4 mm, 2.7 mm, 3.0 mm and 3.4 mm) at all sampling periods, as Bermuda grass recorded smallest stolon (0.7 mm, 0.8 mm, 1.1 mm, 1.2 mm, 1.4 mm and 1.6 mm) (Figure 4.3a). It was noted, that in the case of both grasses, there was consistently an increase in size as a reflection of growth with time.

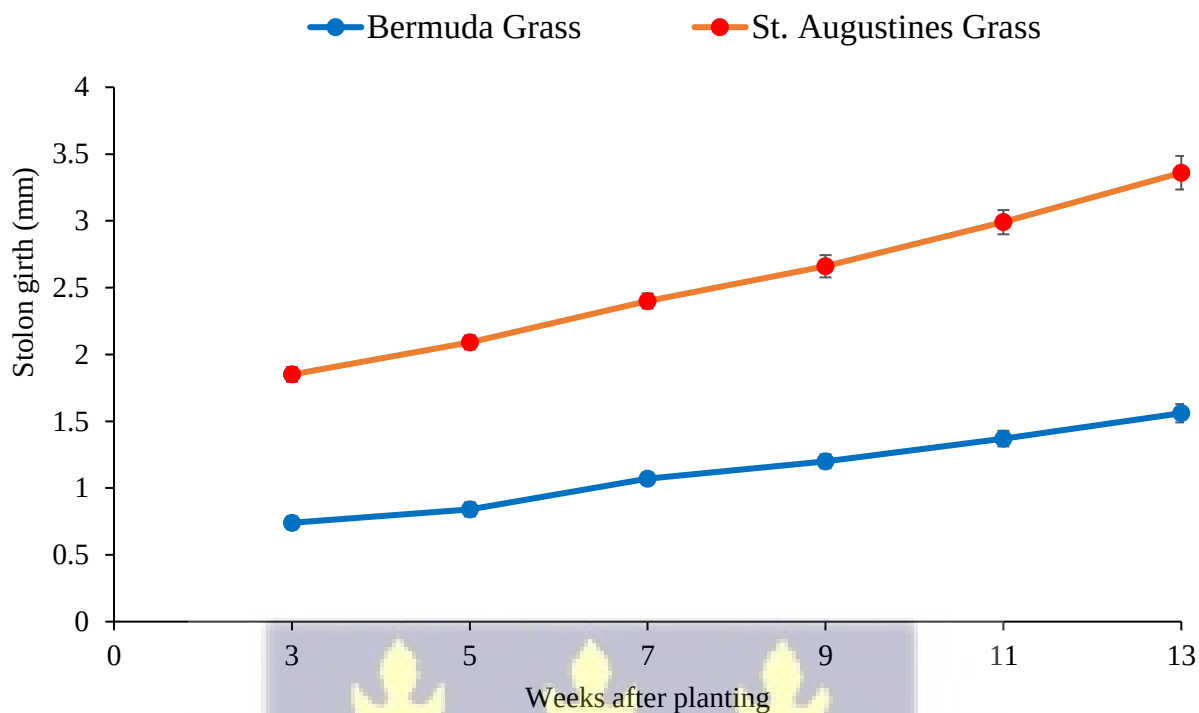


Figure 4.3a: Stolon girth of Bermuda and St. Augustine's grass over 13 weeks planting duration

4.3.3.1 Growing media effect on stolon girth of Bermuda and St. Augustine's grasses

Growing media had significant ($P \leq 0.05$) impact on stolon girth in Bermuda and St. Augustine's grasses. Topsoil recorded the largest girth (1.0 mm, 1.2 mm, 1.9 mm, 2.3 mm, 2.5 mm and 2.9 mm) at all sampling period, whereas M4 (TopSoil60 : PM20 : SD15 : Clay5 v/v) growing media recorded the smallest girth (1.4 mm, 1.5 mm, 1.7 mm, 1.8 mm, 2.1 mm and 2.3 mm) when biochar was substituted for sawdust at 3,5,7,9,11 and 13 weeks after planting respectively (Figure 4.3b). Suggesting the treatment with the lowest effect on stolon girth was M4 while the highest was topsoil.

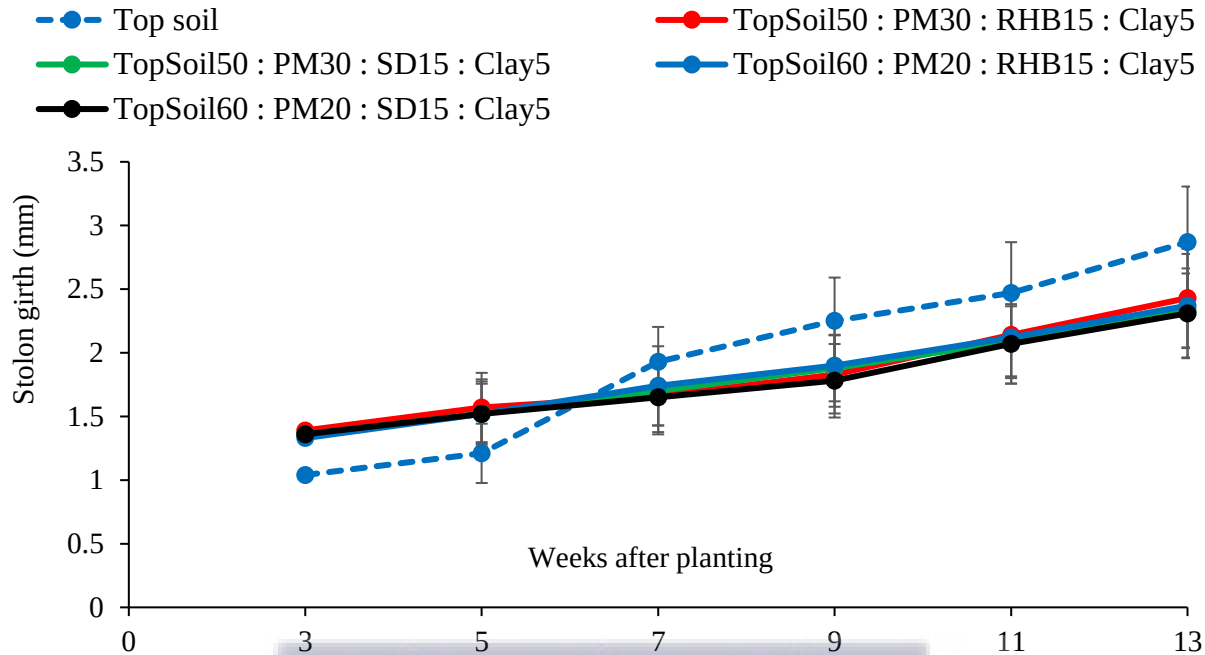


Figure 4.3b: Effect of Growing media effect on stolon girth over the experimental period

4.3.3.2 Effect of growing media and grass type on stolon girth of Bermuda and St. Augustine's grasses

Treatment M4 recorded the biggest stolon girth (0.84 mm) while the smallest stolon girth was observed in topsoil, M1(0.54 mm) in Bermuda grass at 3WAP. However, the biggest stolon girth in Bermuda grass was observed in topsoil (1.75 mm) at 13WAP, whereas M3 recorded the smallest stolon girth (1.40 mm).

Differences in stolon girth of Bermuda grass was observed at 3 weeks after planting (WAP) in different growing media, however there was no significant ($P \leq 0.05$) difference in stolon girth of Bermuda grass in growing media. Topsoil recorded the largest/biggest stolon girth (0.5 mm, 0.6 mm, 1.2 mm, 1.4 mm, 1.5 mm and 1.8 mm) at 3, 5, 7, 9, 11 and 13 weeks after planting. M2 (60:20:15:5) Top soil + poultry manure + rice husk biochar + clay v/v growing media recorded

the smallest girth (0.7 mm, 0.8 mm, 1.0 mm, 1.1 mm, 1.3 mm and 1.4 mm) at 3,5,7,9,11 and 13 weeks after planting respectively. Topsoil clearly performed better compared to the formulated growing media with respect to stolon girth in Bermuda grass. When RHB was replaced with SD, *M5 (50:30:15:5) Top soil + poultry manure + sawdust + clay* recorded the largest stolon girth (0.8 mm, 0.9 mm, 1.1 mm, 1.3 mm, 1.5 mm and 1.7 mm at 3,5,7,9,11 and 13 weeks after planting respectively.

Therefore, change in treatment had an effect on the stolon girth examined even though the change was insignificant. Also, there were differences in stolon girth with time in Bermuda grass.

Treatment M3 recorded the biggest stolon (1.98 mm) while the smallest stolon was observed in treatment M1(topsoil) (1.53 mm) in the St. Augustine's grass at 3WAP. However, the biggest stolon in St. Augustine's grass was observed in the M1 (3.99 mm) at 13WAP, whereas M5 recording the smallest stolon (2.99 mm). Differences in stolon girth of St. Augustine's grass was observed at 3 weeks after planting (WAP) in different growing media. There was no significant ($P \leq 0.05$) difference in stolon girth of St. Augustine's in growing media. Topsoil only recorded the largest stolon (1.5 mm, 1.8 mm, 2.7 mm, 3.1 mm, 3.4 mm and 4 mm) at 3,5,7,9,11 and 13 weeks after planting, while *M5 (50:30:15:5) Top soil + poultry manure + sawdust + clay* v/v growing media recorded the smallest stolon girth (1.9mm, 2.1mm, 2.3mm, 2.5mm, 2.7mm and 3.0mm) at 3,5,7,9,11 and 13 weeks after planting (Figure 4.3c). Topsoil clearly performed better compared to the formulated growing media with respect to stolon girth in St. Augustine's grass. When RHB was replaced with SD, *M4 (60:20:15:5) Top soil + poultry manure + sawdust + clay* recorded the largest stolon girth (1.9 mm, 2.1 mm, 2.3 mm, 2.5 mm, 2.9 mm and 3.1 mm at 3,5,7,9,11 and 13 weeks after planting respectively. Therefore, change in treatment had any effect on the stolon girth

examined even though the change was insignificant. Also, there were differences in stolon girth with time in the St. Augustine's grass.

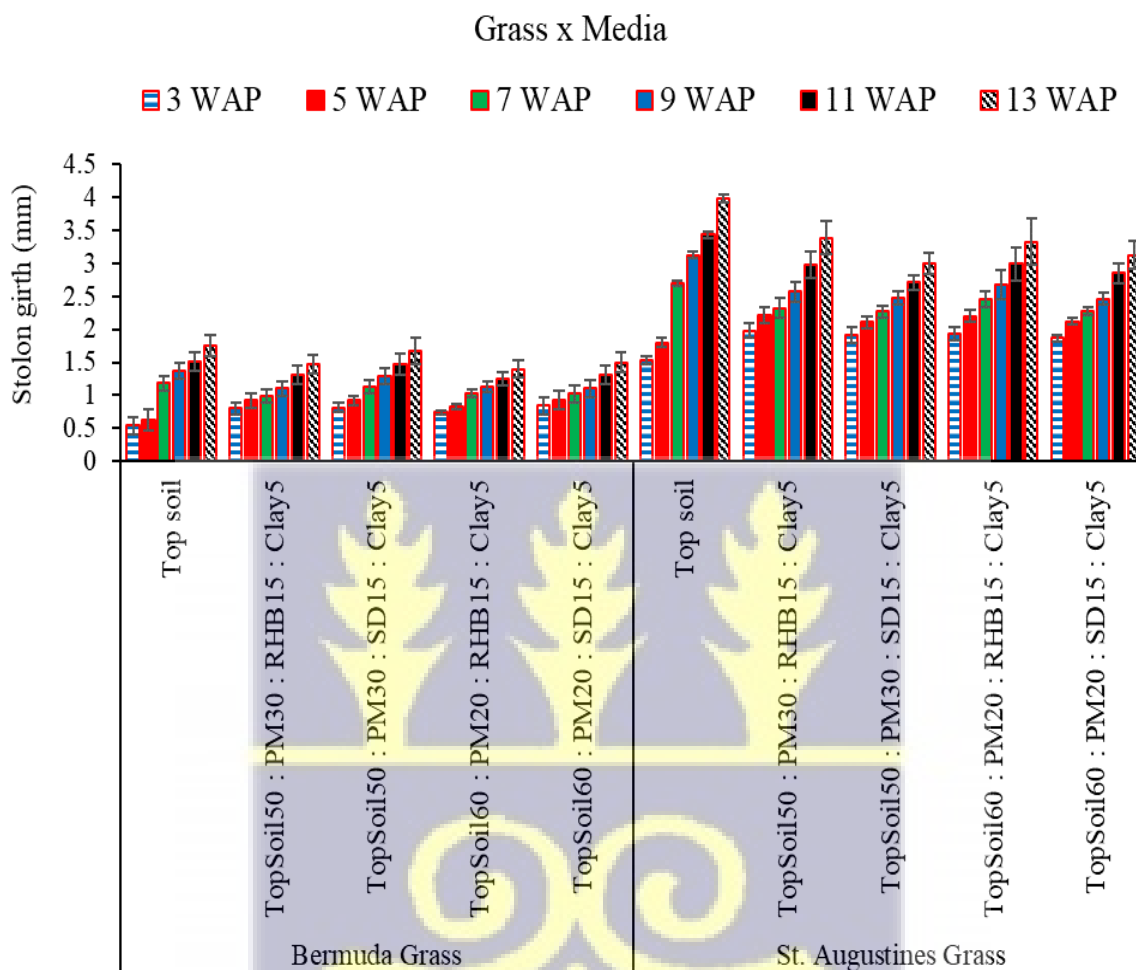


Figure 4.3c: Effect of growing media and grass type on stolon girth over the experimental period



Table 4.5 Difference between final and initial stolon girth (mm)

	Bermuda &GM			%Over	St. Augustines's & GM				%Over
	Final	Initial	Diff	Initial	Final	Initial	Diff	Initial	
M1 (Topsoil)	1.75	0.54	1.21	224.10	3.99	1.53	2.46	160.78	
M2 (TS60: PM20: RHB15: clay5)	1.40	0.74	0.66	89.19	3.33	1.93	1.40	72.54	
M3 (TS50:PM30: RHB15: clay5)	1.47	0.80	0.67	83.75	3.39	1.98	1.41	71.21	
M4 (TS60: PM20: SD15: clay5)	1.50	0.84	0.66	78.57	3.13	1.87	1.26	67.38	
M5 (TS50: PM30: SD15: 5clay)	1.67	0.81	0.86	106.17	2.99	1.91	1.08	56.54	

From the above table, it could be noticed that the variance between the former stolon girth and the latter were influenced by the treatments. Treatment M5 produced the biggest girth amongst the formulated growing media in Bermuda grass. The percentage increase over the initial girth of M5 is higher than the rest of the formulated growing media indicating that sawdust amended growing media performed better than RHB in Bermuda grass. Also, increased PM with sawdust yielded better performance of growing media in Bermuda grass. However, the percentage increase over the initial girth of M2 is higher than the rest of the formulated growing media indicating that RHB amended growing media performed better than sawdust in the St. Augustine's grass. Moreover,

decreased PM with RHB yielded better performance of growing media in the St. Augustine's grass. In conclusion, replacing RHB for sawdust, and also decreasing topsoil composition from 60 to 50% increased stolon girth in Bermuda grass, whereas replacing sawdust for RHB, and also increasing topsoil composition from 50 to 60% increased stolon girth in the St. Augustine's grass. The difference in stolon girth may be due to genetic factors as Bermuda has a smaller girth compared to St Augustine's grass. However, it seems the media had effect on the stem girth (Table 4.5).

4.3.4 Chlorophyll content in Bermuda and St. Augustine grass

Generally, the chlorophyll content of St. Augustine's was consistently higher than Bermuda grass. Significant differences were observed at all sampling periods except at 7 and 9 weeks after planting (Fig. 4.4a) St. Augustine's grass recorded higher chlorophyll (SPAD values) (30, 29.8, 26.7, 27, 29.2 and 30.1) at all sampling periods, while Bermuda grass recorded low chlorophyll content (26.9, 26.3, 24.1, 24.4, 25.9 and 27.2).

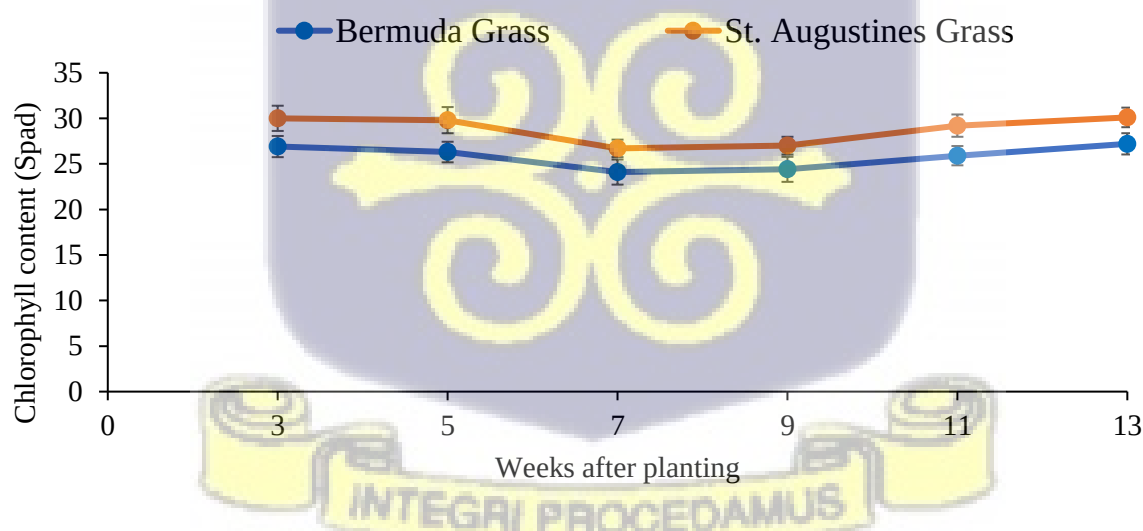


Figure 4.4a: Chlorophyll content of Bermuda and St. Augustine's grass over the growing period

4.3.4.1 Effect of growing media on chlorophyll content of Bermuda and St. Augustine's grasses

The highest chlorophyll content at initial stages of the experiment was recorded in M2: Top soil 60: PM20; RHB 15 and clay5 v/v, but decreased and at the 13th week chlorophyll content was significantly lower than Topsoil 50: PM 30: RHB 15: clay 5. The chlorophyll content of treatment M3: Topsoil 50: PM30: RHB 15: clay 5 increased consistently throughout the experimental period, that culminated in that treatment recording the highest SPAD value among the treatments. M3: Treatment Topsoil 50: PM 30: RHB 15: clay 5, recorded the highest while M1: topsoil recorded the lowest SPAD value, and the difference was statistically significant (Fig. 4.4b).

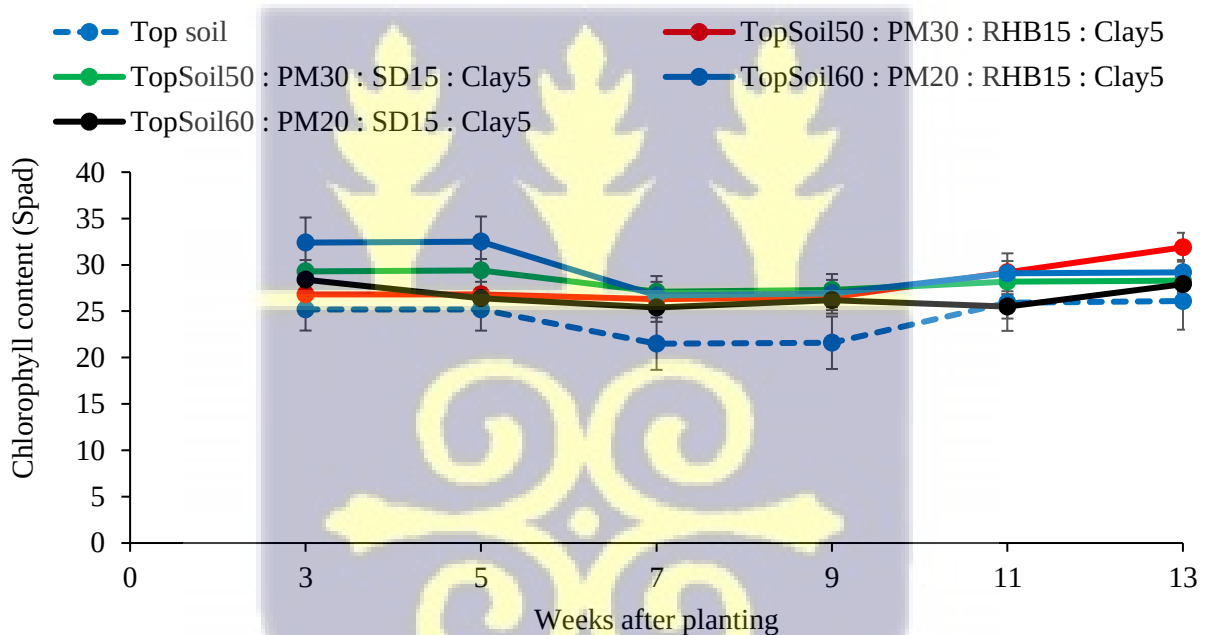
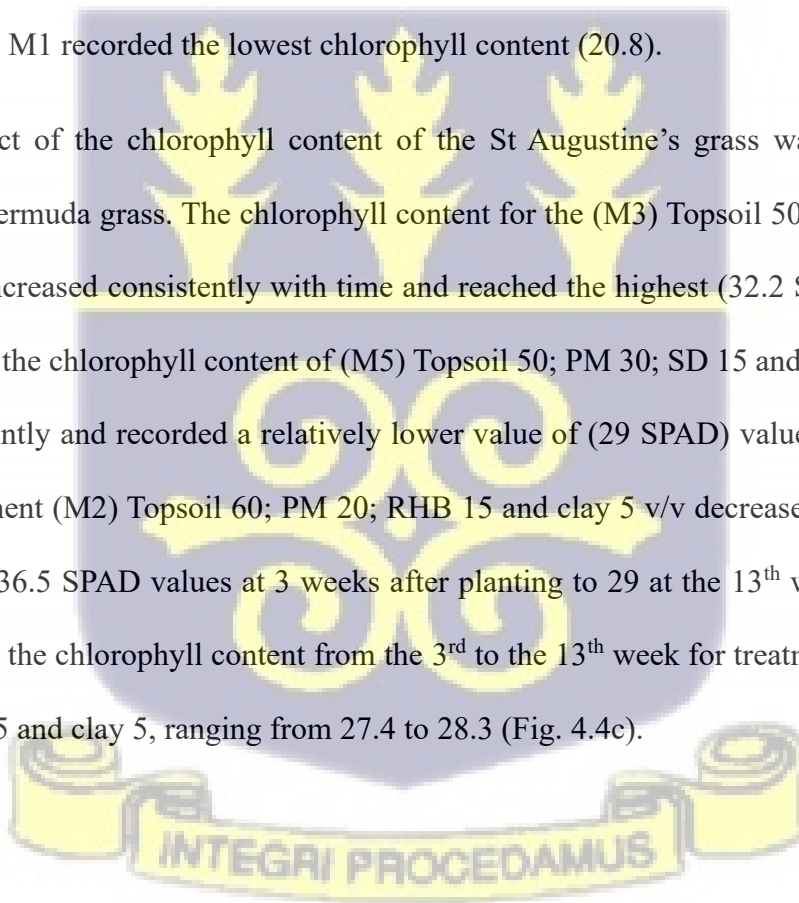


Figure 4.4b: Effect of growing media on chlorophyll content of Bermuda and St. Augustine's grasses

4.3.4.2 Chlorophyll content Bermuda and St. Augustine's grasses over time as influenced by growing media

The chlorophyll content of Bermuda grass for (M3)Topsoil 50; PM 30; RHB 15 and clay 5 v/v at 13th week 31.5 SPAD value was higher than that of (M5)Topsoil 50; PM 30; SD 15 and clay 5 v/v (27.6 SPAD value); Similarly, chlorophyll content of (M2) Topsoil 60; PM 20; RHB 15 and clay 5 v/v at the 13th week (28.7) was slightly higher than treatment Topsoil 60; PM 20; SD 15 and clay 5 v/v that recorded (27.5 SPAD value). These results show that replacing sawdust with RHB on the media consistently improved chlorophyll composition, suggesting a role of biochar in increasing the chlorophyll content. Treatment M3 and M4 recorded the highest chlorophyll content (29.4) while the smallest stolon girth was observed in topsoil, M1(20.3mm) in Bermuda grass at 3WAP. However, the highest chlorophyll content (31.5) in Bermuda grass was observed in M3 at 13WAP, whereas M1 recorded the lowest chlorophyll content (20.8).

The topsoil effect of the chlorophyll content of the St Augustine's grass was higher than its counterpart of Bermuda grass. The chlorophyll content for the (M3) Topsoil 50; PM 30; RHB 15 and clay 5 v/v increased consistently with time and reached the highest (32.2 SPAD value at the 13th week, while the chlorophyll content of (M5) Topsoil 50; PM 30; SD 15 and clay 5 v/v did not increase consistently and recorded a relatively lower value of (29 SPAD) value. The chlorophyll content of treatment (M2) Topsoil 60; PM 20; RHB 15 and clay 5 v/v decreased with time, from initial values of 36.5 SPAD values at 3 weeks after planting to 29 at the 13th week. There was a small increase in the chlorophyll content from the 3rd to the 13th week for treatment (M4) Topsoil 60; PM 20; SD15 and clay 5, ranging from 27.4 to 28.3 (Fig. 4.4c).



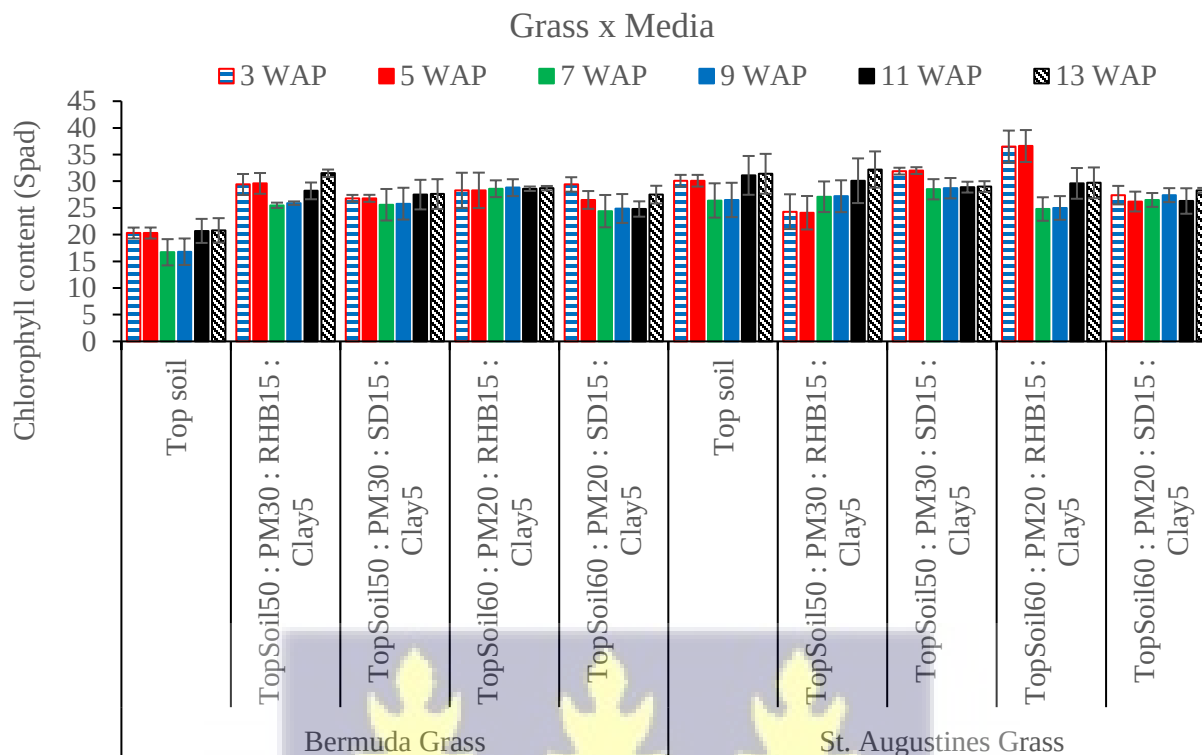


Figure 4.4c: Effect of growing media and grass type on chlorophyll content

4.3.5 Tillering in Bermuda and St. Augustine's grasses

Generally, tiller number of Bermuda grass was consistently higher than that of St. Augustine's grass. Significant differences were observed at all sampling periods (Fig. 4.5a). Bermuda grass recorded more tillers (4.9, 5.7, 6.9, 7.6, 9.3 and 11) at all sampling periods, as St. Augustine's grass recorded least number of tillers (1.8, 1.9, 3.1, 3.6, 4.8 and 5.8). In percentage wise, there was 222.22 % increase in tiller number for Bermuda grass at the 13th week after planting, compared to 124.49 % increase in tiller number for the St. Augustine's grass. This may be due to genetic factors. Bermuda grass may have a higher tillering ability than St. Augustine's grass.

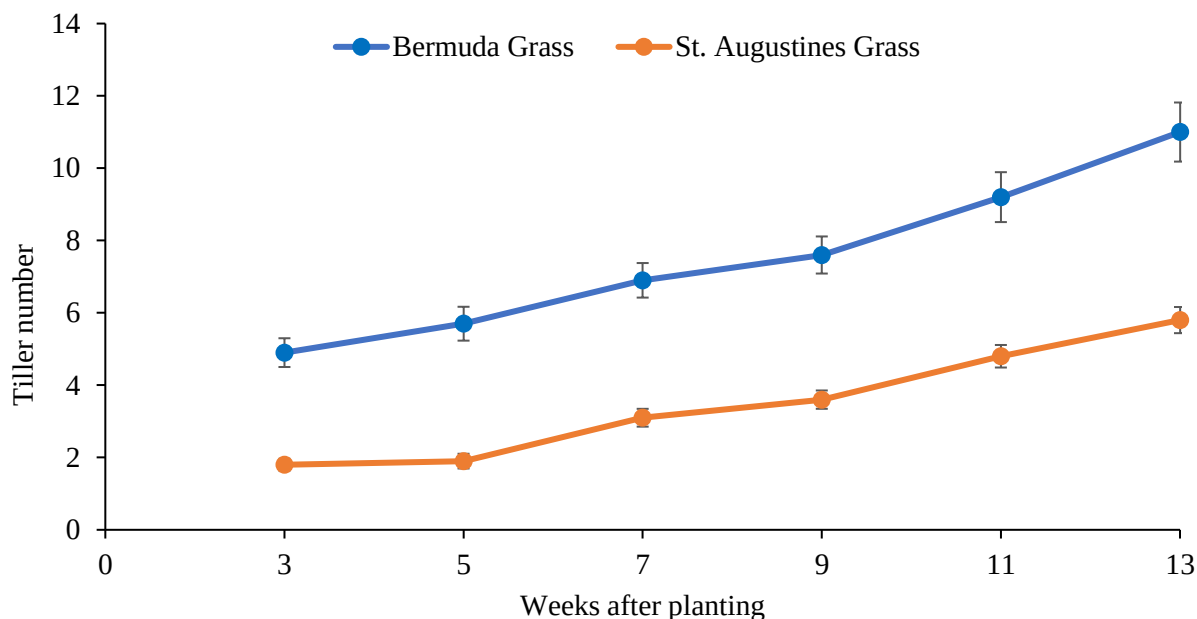


Figure 4.5a: Tillering in Bermuda and St. Augustine's grasses

4.3.5.1 Effect of growing media on tillering of Bermuda and St. Augustine's grasses

The growing media affected the number of tillers produced by the grasses. At the end of the study, the highest number of tillers was observed in the growing media (M5) TopSoil50: PM30: SD15: Clay5 v/v, and the least in topsoil only. It was observed that treatments with SD consistently produced higher number of tillers than the corresponding treatment with RHB. For example, treatment (M5) TopSoil50: PM30: SD15: Clay5 produced 10.2, while (M3) TopSoil50: PM30: RHB15: Clay5 recorded 9.7 tillers. Similarly, differences in number of tillers between (M4) TopSoil60: PM20: SD15: Clay 5 v/v and (M2) TopSoil60: PM20: RHB15: Clay 5 v/v were observed, recording 9.0 and 8.2 tillers respectively (Fig. 4.5b).

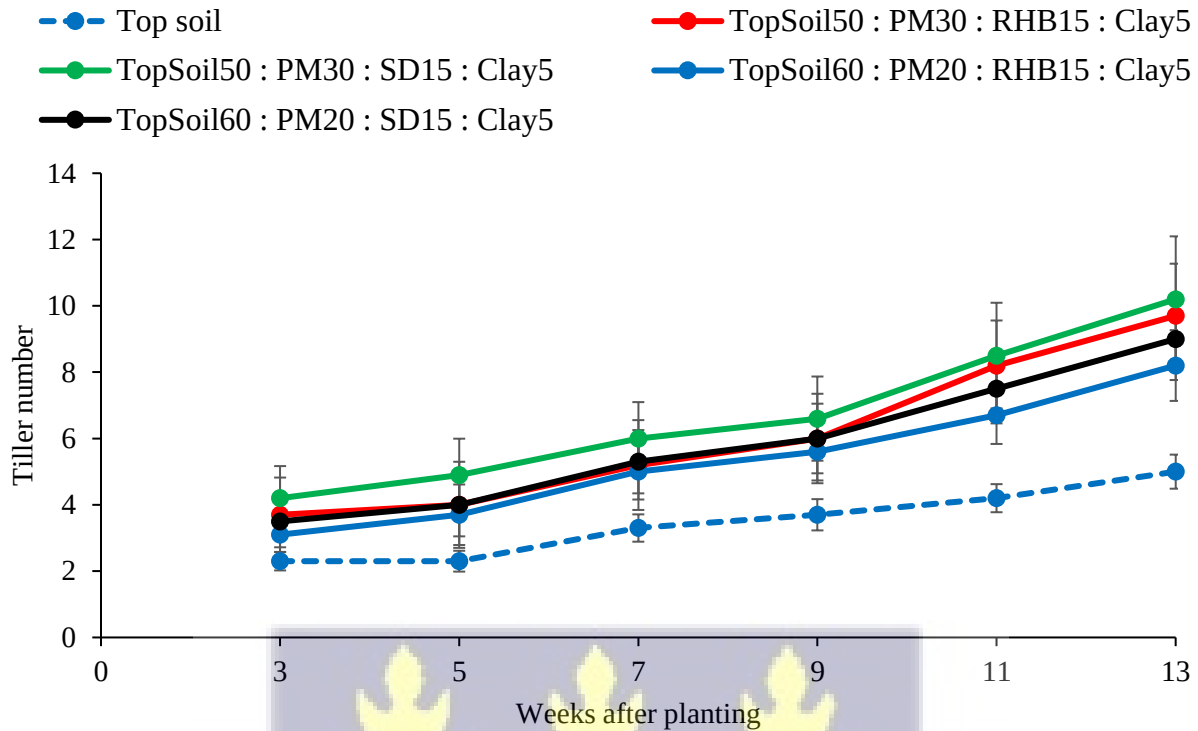


Figure 4.5b: Effect of growing media on tillering of Bermuda and St. Augustine's grasses

4.3.5.2 Effect of growing media on tillering ability of the two grasses

The tiller number of treatment (M3) topsoil 50; PM30; RHB15; clay 5 v/v increased consistently from 3 week (6 tillers) to 13 tillers at 13th week. Similar trend in tiller number production was observed for topsoil 50; PM30; SD15; clay 5 v/v treatment, however at 13th week the tiller number was higher than the (M5) RHB counterpart, recording 14.3 compared to 13 tillers for Bermuda grass. A significant reduction in tiller number was observed when the percentage of topsoil was increased, and the PM proportion was reduced in treatment (M2) topsoil 60; PM20; RHB15; clay 5 v/v, increasing from 4.5 in the 3rd week to 10.5 tillers at 13th week. Similarly, the tiller number for treatment (M4) topsoil 60; PM20; SD15; clay 5 v/v. increased in number from 5.1 to 11.5 tillers. This tiller number is slightly higher than treatment (M2) topsoil 60; PM20; RHB15; clay 5 v/v (Fig. 4.5c).

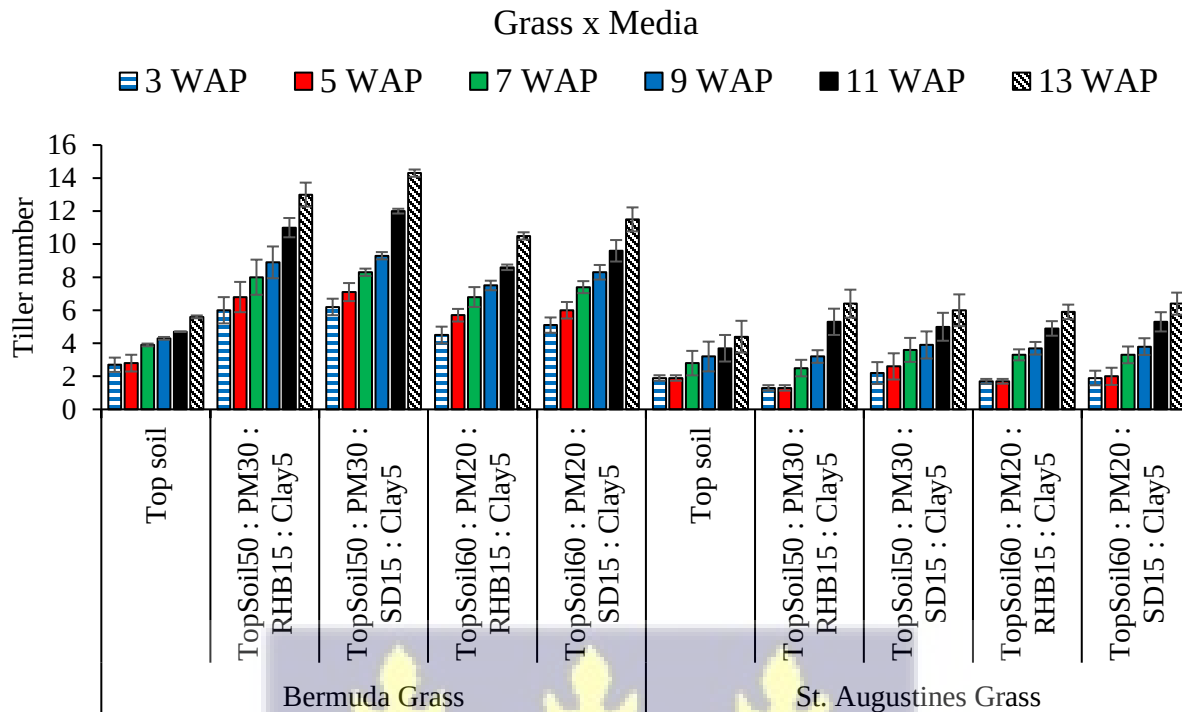


Figure 4.5c: Effect of the growing media on tillering ability of the two grasses

4.3.6 Effect of grass and growing media on shoot dry matter

Interaction between growing media and grasses had effect on shoot dry matter production. The highest dry matter at 7 weeks after planting was recorded in (M2) TopSoil60: PM 20: RHB 15: CS 5 v/v growing media x Bermuda grass, followed by (M5) TopSoil50: PM 30: RHB 15: CS 5 v/v growing media x Bermuda grass as 2.33 g/cm² and 2.00 g/cm² respectively. In St. Augustine's grass, both treatment M2) TopSoil60: PM 20: RHB 15: CS 5 v/v growing media x St. Augustine's grass and (M4) TopSoil60: PM 20: SD 15: CS 5 v/v growing media x St. Augustine's produced the highest dry matter (1.63 g/cm²), followed (M5) TopSoil50: PM 30: SD 15: CS 5 v/v growing media x St. Augustine's grass, 1.33 g/cm². For the same growing media treatment, compositions with rice husk biochar (RHB) produced higher dry matter compared to sawdust (SD) at 7 weeks after planting.

Moreover, the highest dry matter at 13 weeks after planting was recorded for (M5) TopSoil50: PM 30: SD15: CS 5 v/v growing media x Bermuda grass, (4.67g/ cm²) followed by (M2) TopSoil60: PM 20: RHB 15: CS 5 v/v growing media x Bermuda grass as 4.67g/ cm² and 4.63g/ cm² respectively. In St. Augustine's grass (M2) TopSoil60 + PM 20 + RHB 15 + CS 5 v/v growing media x St. Augustine's grass produced the highest dry matter (3.33g/ cm²).

followed by (M4) TopSoil60 + PM 20 + RHB 15 + CS 5 v/v growing media x St. Augustine's grass, 1.97g/ cm². It was obvious that Bermuda grass produced the highest dry matter in growing media amended with sawdust compared with that of biochar. However, the reverse was observed for St. Augustine's grass at 13 WAP (Table 4.6).

Table 4.6 Effect of grass type and growing media on shoot dry weight (g)

Media	7 WAP		Mean	13 WAP		Mean
	Bermuda	St. Augustine's		Bermuda	St. Augustine's	
M1	0.66 a	1.33 bc	1.00 a	0.87 a	1.93 ab	1.40 a
M2	2.33 e	1.63 cd	1.98 c	4.63 c	3.33 bc	3.98 c
M3	2.00 de	1.10 ab	1.55 b	3.77 c	1.40 a	2.58 ab
M4	1.50 bc	1.63 cd	1.56 b	3.70 c	1.97 ab	2.83 bc
M5	1.63 cd	1.33 bc	1.48 b	4.67 c	1.67 ab	3.17 bc
Mean	1.62 b	1.40 a		3.53 b	2.06 a	

“LSD (P ≤ 0.05)”; Grass variety = 0.21
Media = 0.34
Grass Variety x Media = 0.48

M1 - Top soil
M2 - TopSoil 60 : PM20 : RHB15 : Clay5
M3 - TopSoil 50 : PM30 : RHB15 : Clay5
M4 - TopSoil60 : PM20 : SD15 : Clay5
M5 - TopSoil50 : PM30 : SD15 : Clay5

* Means with the same letters are not significantly different from each other.

4.3.6.1 Type of grass and growing media on rate of shoot dry weight production (g/ week).

Shoot dry weight production was specific to grass and media interaction. For example, the rate of shoot dry weight production for Bermuda grass was highest in M5 (0.51 g/ week), whilst that for St. Augustine's was highest in M2 (0.28 g/ week). M2 that contained RHB was not significantly different from M4, thus irrespective of sawdust or RHB, for Bermuda grass it was suitable. But for M3 and M5 differences in growth rate was observed. Thus, sawdust in the ratio was better than RHB in that proportion for Bermuda grass. However, no significant difference was observed for St Augustine's. These results suggest differences in growth conditions, nutrient uptake and growth for these two grasses (Table 4.7).

Table 4.7 Type of grass and growing media effect on the rate of shoot dry weight production (g/ week)

Media	Bermuda grass	St. Augustine's grass
M1	0.04	0.10
M2	0.38	0.28
M3	0.30	0.05
M4	0.37	0.06
M5	0.51	0.06

M1 = Topsoil (100%); M2= Top soil + poultry manure + rice husk biochar + clay (60:20:15:5); M3= Top soil + poultry manure + rice husk biochar + clay (50:30:15:5); M4=Top soil + poultry manure + sawdust + clay (60:20:15:5); M5= Top soil + poultry manure + sawdust + clay (50:30:15:5).

4.3.7 Effect of grass and growing media on root dry weight (g)

Contact between media and grasses had effect on root dry matter. Variation was observed among the tested treatments for dry matter in kg per hectare. The highest dry matter at 7 weeks after planting was recorded in (M4) TopSoil60 + PM 20 + SD 15 + CS 5 v/v growing media x Bermuda

grass, followed by (M5) TopSoil50+ PM 30 + SD 15 + CS 5 v/v growing media x Bermuda grass as 0.21g/ cm² and 0.18g/ cm² respectively. In St. Augustine's grass (M4) TopSoil60 + PM 20 + SD 15 + CS 5 v/v growing media x St. Augustine's grass produced the highest dry matter (0.09 g/ cm²), followed by (M2) TopSoil60 + PM 20 + RHB 15 + CS 5 v/v growing media x St. Augustine's grass, 0.08 g/ cm².

Moreover, the highest dry matter at 13 weeks after planting was recorded in (M5) TopSoil50 + PM 30 + SD15 + CS 5 v/v growing media x Bermuda grass, followed by (M3) TopSoil50+ PM 30 + RHB 15 + CS 5 v/v growing media x Bermuda grass as 0.62 g/ cm² and 0.42 g/ cm² respectively. In St. Augustine's grass (M5) TopSoil50 + PM 30 + SD 15 + CS 5 v/v growing media x St. Augustine's grass produced the highest dry matter (0.27 g/ cm²), followed by (M2) TopSoil60 + PM 20 + RHB 15 + CS 5 v/v growing media x St. Augustine's grass, 0.26 g/ cm². It was important to note that both Bermuda and St Augustine's grasses produced higher root dry matter in growing media amended with sawdust than with biochar at 7 and 13 WAP respectively (Table 4.8).

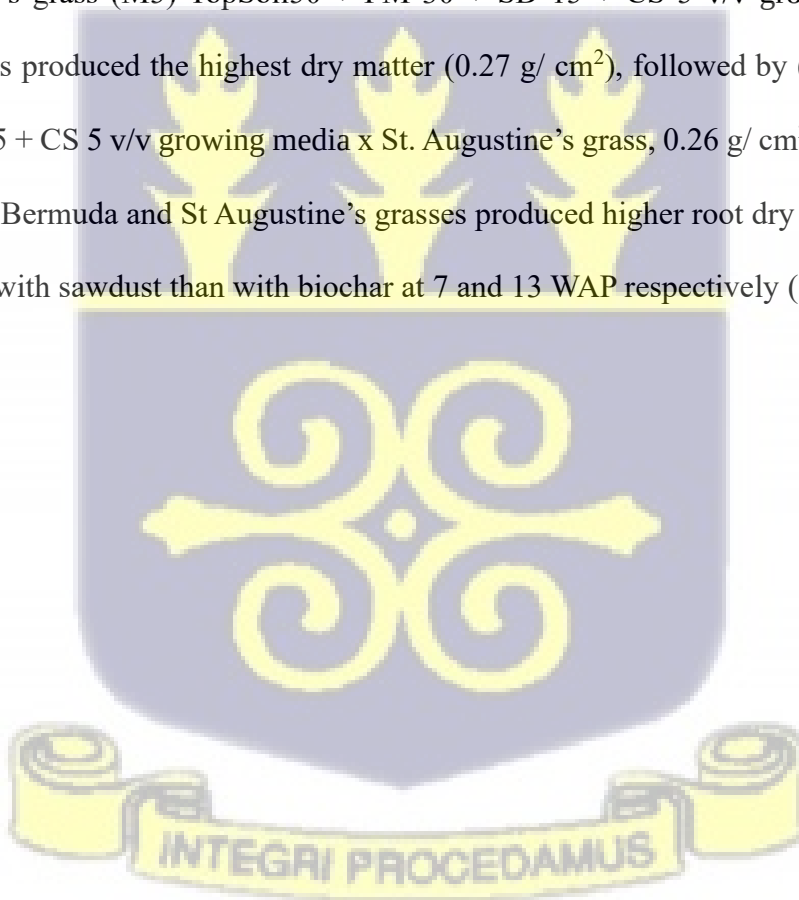


Table 4.8: Effect of grass and growing media on root dry weight (g/cm²)

Media	7 WAP		Mean	13 WAP		Mean
	Bermuda	St. Augustine's		Bermuda	St. Augustine's	
M1	0.06 a	0.07 ns	0.06 ns	0.16 a	0.17 a	0.16 a
M2	0.12 ab	0.08 ns	0.10 ns	0.28 ab	0.23 ab	0.25 ab
M3	0.14 ab	0.05 ns	0.09 ns	0.42 bc	0.26 ab	0.34 b
M4	0.21 b	0.09 ns	0.15 ns	0.29 ab	0.27 ab	0.28 ab
M5	0.18 ab	0.06 ns	0.12 ns	0.62 c	0.20 ab	0.41 b
Mean	0.14 b	0.07 a		0.35 b	0.23 a	
“LSD (P ≤ 0.05)”; Grass variety = 0.04				0.10		
Media = 0.07 NS				0.17NS		
Grass Variety x Media = 0.11 NS				0.24 NS		

M1 - Top soil

M2 – TopSoil60 : PM20 : RHB15 : Clay5

M3 - TopSoil50 : PM30 : RHB15 : Clay5 M4 - TopSoil60 : PM20 : SD15 : Clay5

M5 – TopSoil50 : PM30 : SD15 : Clay5

* Means with the same letters are significantly not different.

4.3.7.1 Grass type and media on root dry weight per week (root dry weight/week)

Root DW production was specific to grass and media interaction. For example, the rate of root dry weight production for Bermuda grass was highest in M5 (0.07 g/ week), whilst that for St. Augustine's was highest in M3 (0.04 g/ week). M5 that contained sawdust was not significantly different from M3, thus irrespective of sawdust or RHB, for Bermuda grass it was suitable. These results suggest differences in root growth conditions, nutrient uptake and growth for these two grasses (Table 4.9).

Table 4.9: Grass type and media on root dry weight per week (root dry weight/ week)

Media	Bermuda grass	St. Augustine grass
M1	0.02	0.02
M2	0.03	0.03
M3	0.05	0.04
M4	0.01	0.03
M5	0.07	0.02

M1 = Topsoil (100%); M2= Top soil + poultry manure + rice husk biochar + clay (60:20:15:5); M3= Top soil + poultry manure + rice husk biochar + clay (50:30:15:5); M4=Top soil + poultry manure + sawdust + clay (60:20:15:5); M5= Top soil + poultry manure + sawdust + clay (50:30:15:5).

4.3.7.2 Total dry weight (DW) of grass (root + shoot)/week as affected by growing media for Bermuda and St. Augustine's grasses

Total root and shoot dry weight production was specific to grass and media interaction. For instance, the rate of root and shoot dry weight production for Bermuda grass was highest in M5 (0.58 g/ week), whilst that for St. Augustine's was highest in M2 (0.31 g/ week). M5 that contained sawdust was not significantly different from M2, thus irrespective of sawdust or RHB, for Bermuda grass it was suitable. But for M5 and M2 differences in growth rate was observed (Table 4.10). Moreover, no significant difference was observed for St Augustine's. These results suggest differences in root and shoot growth conditions, nutrient uptake and growth for these two grasses.

Table 4.10 Total dry weight of grass (root + shoot)/week as affected by growing media for Bermuda and St. Augustine's grasses

Media	Bermuda (g)			St. Augustine's (g)		
	Root DW	Shoot DW	Total DW	Root DW	Shoot DW	Total DW
M1	0.02	0.04	0.22	0.02	0.10	0.12
M2	0.03	0.38	0.41	0.03	0.28	0.31
M3	0.05	0.30	0.35	0.04	0.05	0.09
M4	0.01	0.37	0.38	0.03	0.06	0.09
M5	0.07	0.51	0.58	0.02	0.06	0.08

4.3.8 Effect of grass and growing media on root volume (cm³)

Interaction between growing media and grasses had effect on grass root volume. Disparity was noticed amongst the confirmed treatments of roots volume. Thus, highest root volume at 7 weeks after planting was recorded for (M4) TopSoil60 + PM 20 + SD 15 + CS 5 v/v growing media x Bermuda grass, followed by (M3) TopSoil50+ PM 30 + RHB 15 + CS 5 v/v growing media x Bermuda grass as 0.36 cm³ and 0.30 cm³ respectively. In St. Augustine's grass (M3) TopSoil50 + PM 30 + RHB 15 + CS 5 v/v growing media x St. Augustine's grass produced the highest root volume (0.28 cm³), followed by (M2) TopSoil60 + PM 20 + RHB 15 + CS 5 v/v growing media x St. Augustine's grass as well as (M4) TopSoil60 + PM 20 + SD 15 + CS 5 v/v growing media x St. Augustine's grass (0.26 cm³).

Moreover, the highest root volume at 13 weeks after planting was recorded for (M3) TopSoil50 + PM 30 + RHB15 + CS 5 v/v growing media x Bermuda grass, followed by (M4) TopSoil60+ PM 20 + SD 15 + CS 5 v/v growing media x Bermuda grass as 1.16 cm³ and 0.73 cm³ respectively. In St. Augustine's grass (M2) TopSoil60 + PM 20 + RHB 15 + CS 5 v/v growing media x St.

Augustine's grass produced the highest root volume (0.73 cm^3), followed by (M4) TopSoil60 + PM 20 + SD 15 + CS 5 v/v growing media x St. Augustine's grass, (0.70 cm^3). It was important to note that both Bermuda and St Augustine's grasses produced higher root volume in growing media amended with sawdust than with biochar at 7 WAP. However, biochar amended growing media recorded the highest root volume at 13 WAP, even though the difference was small in the St. Augustine's grass (Tab. 4.11).

Table 4.11 Effect of grass and growing media on root volume (m^3)

Media	7 WAP		Mean	13 WAP		Mean
	Bermuda	St. Augustines		Bermuda	St. Augustine's	
M1	0.15a	0.18a	0.16a	0.50ab	0.46ab	0.48a
M2	0.21ab	0.26ab	0.24ab	0.50ab	0.73b	0.61ab
M3	0.30ab	0.28ab	0.29b	1.16c	0.48ab	0.82b
M4	0.36b	0.26ab	0.31b	0.73b	0.70b	0.71ab
M5	0.20ab	0.20ab	0.20ab	0.66ab	0.33a	0.50a
Mean	0.24a	0.23a		0.71b	0.54a	
“LSD ($P \leq 0.05$)”; Grass variety = 0.08 NS				0.15		
Media = 0.13 NS				0.24		
Grass Variety x Media = 0.18 NS				0.34		

M1 - Top soil

M2 – TopSoil60 : PM20 : RHB15 : Clay5

M3 - TopSoil50 : PM30 : RHB15 : Clay5

M4 - TopSoil60 : PM20 : SD15 : Clay5

M5 – TopSoil50 : PM30 : SD15 : Clay5

* Means with the same letters are significantly not different.

4.3.9 Effect of grass and growing media on trimmed grass biomass (g) at 13 WAP

Interaction among growing media and grasses had effect on dry matter at 13 weeks after planting.

Difference was noticed amongst the verified treatments of dry matter kg /Ha. Thus, highest dry matter at 13 weeks after planting was recorded for (M5) TopSoil50 + PM 30 + SD 15 + CS 5 v/v

growing media x Bermuda grass, followed by (M3) TopSoil50+ PM 30 + RHB 15 + CS 5 v/v growing media x Bermuda grass as 66.8 g/ cm² and 55.5g/cm² respectively. Moreover, in St. Augustine's grass, (M5) Topsoil50 : PM 30 : SD 15 : CS 5 v/v growing media x St. Augustine's grass produced the highest dry matter (104.1g/ cm²), followed by (M3) TopSoil50 : PM 30 : RHB 15 : CS 5 v/v growing media x St. Augustine's grass, 85.5g/ cm². At the end of 13 WAP, both grasses were trimmed and sawdust amended growing media performed better than rice husk biochar growing media with respect to dry matter of trimmed grasses (Table 4.12).

Table 4.12 Effect of grass and growing media on trimmed grass dry weight (g)

Media	Trimmed grass dry weight (g)		Mean
	Bermuda	St. Augustine's	
M1	34.7 ab	68.0 bcd	51.3 ab
M2	21.8 a	43.2 abc	32.5 a
M3	55.5bcd	85.5 de	70.5 bc
M4	21.8 a	75.9 cde	48.9 ab
M5	66.8 bcd	104.1 e	85.5 c
Mean	40.1 a	75.3 b	
LSD (P ≤ 0.05); Grass variety = 17.15			14.90
Media = 27.12			23.56
Grass Variety x Media = 38.36			33.32

M1 - Top soil

M2 – TopSoil60 : PM20 : RHB15 : Clay5

M3 - TopSoil50 : PM30 : RHB15 : Clay5 M4 - TopSoil60 : PM20 : SD15 : Clay5

M5 – TopSoil50 : PM30 : SD15 : Clay5

* Means with the same alphabets are significantly not different from each other.

4.3.10 Effect of grass and growing media on weed dry weight (g/ cm²)

Interaction between media and grasses had effect on weed dry matter. Variation was observed among the tested treatments for dry matter in kg per hectare. The highest weed dry matter at was recorded for (M4) TopSoil60 + PM 20 + SD 15 + CS 5 v/v growing media x Bermuda grass, followed by (M2) TopSoil60+ PM 20 + RHB 15 + CS 5 v/v growing media x Bermuda grass as 20.3g/ cm² and 14g/ cm² respectively. In St. Augustine's grass (M2) TopSoil60 + PM 20 + RHB 15 + CS 5 v/v growing media x St. Augustine's grass produced the highest weed dry matter (16.5g/ cm²), followed by (M3) TopSoil50 + PM 30 + RHB 15 + CS 5 v/v growing media x St. Augustine's grass, 12.1g/ cm² (Tab. 4.13).

Table 4.13 Effect of type of grass and growing media on weed dry weight (g)

Media	Weeds dry weight (g)		Mean
	Bermuda	St. Augustine's	
M1	10.8 ns	10.9 ns	10.9 ns
M2	14.0 ns	16.5 ns	15.2 ns
M3	6.1 ns	12.1 ns	9.1 ns
M4	20.3 ns	11.4 ns	15.9 ns
M5	7.4 ns	4.0 ns	5.7 ns
Mean	11.7 a	11.0 a	
LSD (P ≤ 0.05); Grass variety = 19.78			9.05
Media = 31.27			14.31
Grass Variety x Media = 44.22			20.24

M1 - Top soil

M2 – TopSoil60 : PM20 : RHB15 : Clay5

M3 - TopSoil50 : PM30 : RHB15 : Clay5

M4 - TopSoil60 : PM20 : SD15 : Clay5

M5 – TopSoil50 : PM30 : SD15 : Clay5

* Means with the same letters are significantly not different from each other.

4.3.11 Effect of type of grass and growing media on number of weeds

The interaction between growing media and grasses had effect on number of weeds. Differences were observed among the tested treatments for number of weeds. The highest number of weeds was recorded for (M2) TopSoil60 + PM 20 + RHB 15 + CS 5 v/v growing media x Bermuda grass, whereas (M3) TopSoil50+ PM 30 + RHB 15 + CS 5 v/v growing media x Bermuda grass recorded the lowest number of weeds as 3.0 and 2.0 respectively. In St. Augustine's grass, (M4) TopSoil60 + PM 20 + SD 15 + CS 5 v/v growing media x St. Augustine's grass produced the highest number of weeds (3.6), whereas (M5) TopSoil50 + PM 30 + SD 15 + CS 5 v/v growing media x St. Augustine's grass recorded the lowest number of weeds (1.3) (Tab. 4.14).

Table 4.14 Effect of type of grass and growing media on number of weeds harvested

Media	Number of weeds		Mean
	Bermuda	St. Augustine's	
M1	2 ab	3 ab	3 a
M2	3 ab	3 ab	3 a
M3	2 ab	2 ab	2 a
M4	2 ab	4 b	3 a
M5	2 ab	1 a	2 a
Mean	2 a	3 a	

LSD ($P \leq 0.05$); Grass variety = 1

Media = 2

Grass Variety x Media = 2

M1 - Top soil

M2 – TopSoil60 : PM20 : RHB15 : Clay5

M3 - TopSoil50 : PM30 : RHB15 : Clay5

M4 - TopSoil60 : PM20 : SD15 : Clay5

M5 – TopSoil50 : PM30 : SD15 : Clay5

* Means with the same alphabets are significantly not different from each other.

4.4 Discussion

4.4.1 Effect of growing media and grass type on emergence

Formulated growing media documented higher values in parameters calculated at various treatment levels than the control treatment (topsoil). Increasing in the proportion of PM (20%-30%) or decreasing of topsoil (60%-50%), improved growth parameters. PM, sawdust and RHB incorporated in the topsoil affected the texture, structure, and composition of the soil to play a significant role. The organic materials promoted aeration which was ideal for the emergence of stolons in Bermuda and St. Augustine's grasses and rhizomes. Compacted or heavy growing media may have restricted their emergence. The finding is consistent with that of Linde & Hepner (2005), who studied "turfgrass seed and sod establishment on soil amended with biosolid compost" and stated that the biosolid compost performed well as a soil amendment for sod.

The amended growing media had a high rate of emergence and used lesser weeks to attain 50% emergence; which could be due to their WHC and lower BD compared with the topsoil. The high-water holding capacity might have reduced the imbibition duration. This allows grasses to shoot at a quicker rate. However, lower water holding capacity can upsurge the imbibing period and so increase the weeks to reach the 50% emergence. And so, in such situations, a reduction of topsoil in growing media probably increased the emergence in both grasses.

Increased BD could have also led to compaction of the growing media. This creates resistance during watering to grass emergence and also causes some grass stolons to choke and perish. This observation resonates with Bartholomew *et al.*, (2010) who reasoned that "grasses exhibit slower establishment and lower herbage yield due to the frequent watering required by the grass causing

soil compaction”. Differences in shoot emergence is probably due to bulk density differences. Differences in BD may have influenced the shoot emergence of the grasses.

Nkurunziza, (2022) also published a similar result of poor germination of rice in growing media of high percentage of topsoil (40%). The amended/formulated growing media chemical properties affected emergence of grasses. Grass emergence was early and high in the topsoil even though pH and EC were lower and more acidic than the amended growing media. According to Burton and Hanna, (1995), Bermuda species grow on both acidic and basic soil, but grow optimum on soils with “a pH of 5.5” and above. However, as weeks progresses, grasses raised in topsoil grew weaker and died. This is in line with the findings of (Díaz-Pérez & Camacho-Ferre, (2010), who recorded the highest grass seedling emergence rate when media pH and EC were low (5.2 and 4.6) respectively. Emergence at this stage may well be controlled by physical properties of media rather than chemical. The presence of essential nutrients like nitrogen, phosphorus, and potassium in the growing media can influence the growth and spread of stolons.

On the contrary, Pérez-Fernández et al., (2006) researched on “Seed germination in response to chemicals effect in growing media” and stated that pH in growing media had no effect in the final level of germination of all species studied. The negative effect of high pH on emergence might depend on the grass species. The EC values recorded for the growing media were within the optimum range (0.5-1.0 dS/m) for good grass emergence recommend by (Alem *et al.*, 2015) and (Rauter, (2022). The emergence of stolons of Bermuda and St. Augustine’s after planting in growing media may also be influenced by Genetic Factors. Certain grass species and varieties are genetically predisposed to produce stolons. For example, grasses like Bermuda grass produce more stolons, than St. Augustine’s grass. This agrees with Pompeiano, Grossi & Volterrani, (2012), who researched on “Vegetative establishment rate and stolon growth characteristics of 10 Zoysia

grasses” and stated that Zoysia grass genetic constitution significantly affected grass coverage during the formation because of fast emergence. Environmental conditions may also affect the emergence of Bermuda and St. Augustine’s grasses. Grass stolons require optimal temperatures to grow. Adequate light levels are essential for photosynthesis, which supports the emergence of stolons. Sufficient growing media moisture is critical for the emergence of stolons. Too little moisture can prevent their emergence, while overly saturated conditions can lead to poor aeration and root rot, inhibiting their development. e delle Produzioni, (2009), studied on “Performance of perennial tropical grasses in different Mediterranean environments” and noted that all species, except the perennial sorghums, encountered emergence difficulties and established gradually due to temperature fluctuations with inadequate moisture supply. Plant Hormones for example; auxins and cytokinins also regulate the growth and development of stolons. The balance of hormones within the stolons can significantly influence the emergence and growth of Bermuda and St. Augustine’s grasses.

These factors work together, and optimal conditions for one grass species may differ for another. Ensuring a favorable environment for the specific grass being cultivated is key to promoting the emergence of stolons.

4.4.2 Effect of growing media and grass type on stolon length

Stolon length was enhanced by growing media. The results showed increased stolon length for soil amended treatments compared to that of topsoil only. This finding could be due to increased nutrient availability and other growth resources such as improved water retention that promoted growth and dry matter production of the grasses compared to that of topsoil only. Different proportions among the treatments also had influence on stolon length. For example, when the proportion of PM was increased (from 20% to 30%), the treatment increased stolon length and

also when sawdust replaced RHB, an increase in stolon length was realized. This was because the amended growing media might have provided macro and micronutrients vital for plant growth.

These findings agree with the reports of Akpalu *et al.*, (2020) on cocoa seedlings who observed that amending soil with organic substances improves the physicochemical properties of the media resulted in enhancing shoot length. The Bermuda grass displayed vigorous growth habit than the St. Augustine's grass. The Bermuda grass increased in stolon length by 103.5% over the initial, compared to that of St. Augustine's. The treatment that resulted in higher percentage increase over the initials was different for that of St. Augustine's. Therefore, it can be suggested that the nutrient and growth resources required for the two grasses are different.

The Bermuda grass had the longest stolon length. This may account for the differences in the stolon dry weight when the composition of the growing media was varied. Especially when the RHB and Sawdust was interchanged. There was a response to growing media depending on the grass type. M2 with RHB gave more stolon dry weight than sawdust. The percentage increases among treatments could be attributed to their different physical and chemical properties.

However, both grasses increased in length with increasing weeks after planting. This may be as a result of differences in percentage increase over the initial of treatments with high amount of pm (30%). The proportion of pm affect the dry weight production as nitrogen application increased dry weight production of grasses. Moreover, M2 that contained RHB was not significantly different from M4, thus irrespective of sawdust or RHB, for Bermuda grass it was suitable. But for M3 and M5 differences in growth rate was observed. Thus, sawdust in the ratio was better than RHB in that proportion for Bermuda grass. However, no significant difference was observed for St Augustine's. These results suggest differences in growth conditions, nutrient uptake and growth for these two grasses.

Variances in stolon length may be ascribed to grass species, growing media, and weather conditions (Mustaring *et al.*, 2014). According to Bantihun, Asmare & Mekuriaw, (2022), this variation might come from environmental factors, genetic make-up of grasses, and inherent capabilities of grasses to absorb nutrients. Again, they published that variations may also arise from the heredities of the grasses, media and fertility, and management scheme in the zone wherever the trials were performed. This may be for the well-developed roots and nutrient imbibition ability of turf which may result in the increment in stolon length (Bantihun, Asmare & Mekuriaw, 2022).

In this study, the proportion of the media affected the dry weight when the PM proportion was increased and sawdust replaced RHB condition promoted stolon growth and dry matter production, suggesting that improved nutrient availability improves stolon dry weight. Sawdust has a better WHC than RHB, thus this situation could have provided a better medium for supplying nutrients to the grasses. This confirms earlier reports where fertilizer application or improved nutrient supply affected dry weight production in grasses. Kefyalew *et al.*, (2020) reported an increased dry matter production of Desho grass with fertilizer application that shoot length of “Desho grass increased from a lower level of 37.19 cm at 90 days of age to a significantly higher value of 45.43 cm at the age of 150 days”.

4.4.3 Effect of growing media and grass type on stolon girth

Growing media had effect on stolon girth of Bermuda and St. Augustine’s grasses. However, St. Augustine’s grass developed bigger stolon girth. Turf having broader leaves possess larger superficial area which increases photosynthetic action, thus manufacturing extra carbohydrates to stimulate growth of stolon width (Bantihun, Asmare & Mekuriaw, 2022). It is attributable to cell division, elongation and maturing regions taking place consecutively along the base of the growing

stem. However, M1 (topsoil) developed the highest stolon girth (2.9mm). This is consistent with findings by Ogunrotimi and Kayode (2018), who researched on the “influence of potting media on growth and development of *Solanum marocarpum L.*” and found out that topsoil had the highest performance in stem diameter among other parameters.

4.4.4 Effect of the growing media on tillering ability of the two grasses

In this case, tiller number and number of leaves per plant were pointedly affected by the fertilizer type.

Tiller production was observed to be more in Bermuda grass than St. Augustine’s grass. The percentage increase in tiller number between 3 and 13 WAP differed among the grasses and also the growing media. In the case of Bermuda grass, there was an increase of just over onefold (110%) in tiller number between 3 and 13 WAP, while that for the soil amended recorded percentage increases of between 1.2fold and 1.3fold for topsoil50: PM30: RHB15 and clay5 and topsoil50: PM30: SD15 and clay5 respectively. On the other hand, there was an increase in tiller number of 1.3fold for topsoil60: PM20: RHB 15 and clay5 and 1.25fold for topsoil60: PM20:SD 15 and clay5 between the same period. These results suggest that the amended soil treatments provided better growing conditions that provided more tillers compared to the topsoil. The results of St. Augustine’s were even more pronounced. An increase of 1.3fold increase in tiller number was observed for the topsoil only treatment, while for the topsoil amended treatments, tiller number increased by almost 4-fold for the topsoil50: PM30: RHB15: clay5 v/v treatment, while that for topsoil50: PM30: SD15: clay5 v/v recorded 1.7fold increase. The difference in tiller number for topsoil60: PM20: RHB15: clay5 v/v and topsoil60: PM20: SD15: clay5 v/v was 2.5fold and 2.4fold respectively.

This variation could be as a result of genetic differences, compatibility, and the environment. Moreover, this amended growing media generally produced more tillers than St. Augustine's grass. This might be due to high content of nitrogen and phosphorus present in the amended growing media. Assuero & Tognetti (2010) indicated that "nitrogen has a high mediatory role over tiller production through cytokinin production by roots, since production of this hormone is mediated by root nitrogen concentration which is a function of nitrogen absorption from the amended growing media and seasonal reallocation of tissue nitrogen".

4.4.5 Effect of growing media and grass type on chlorophyll content

The insignificant variations in plant chlorophyll content among the growing media treatment after planting was not essentially a factor for development of grasses. This is in line with Balasimha *et al.*, (2013), who pointed out that chlorophyll content of grass leaf is indicators of adaptation to shade conditions. The lack of differences might be due to the growing media conditions under which they were growing. Chlorophyll content is influenced by nutrients in growing media. Also, the physical and chemical characteristics of the substrate or growing media influence the chlorophyll content (Nerlich & Dannehl, 2021). The substrate nutrient content might have not differed enough to induce significant variation in their chlorophyll content. Moreover, the plant chlorophyll component of the treatments improved per time depicting the required growth of the photosynthetic apparatus to meet high demand for assimilates as the shoot grows and develops. (Akpalu *et al.*, 2020). The low chlorophyll content observed at the beginning of the M3 (topsoil50 : PM30 : RHB15 : Clay5) growing media might be due to the high pH compared to other amended media. High pH can decrease the availability of nutrients to turfgrass and this is in agreement with (Mathers, Lowe, & Scagel, 2007) who specified that "above pH of 7.5, minor nutrients such as "Fe, Mn, B, Cu, and Zn become less available". Increased RHB also affects nutrient availability.

Altland & Locke, (2012) detected that nitrate levels reduced to 1% in biochar amended media but increasing biochar level to 5% and 10% boosted nitrite levels in the growing media.

4.4.6 Effect of grass and growing media on shoot dry matter

High bulk density affects root growth. Matthieu *et al.*, (2011) reported that subsurface compaction decreased roots form for 2 grasses and prevented deep root development, with the greatest decrease occurring between 1.7 and 1.8 g cm⁻³. The outcomes showed that the dry weight of the biomass formed from the Bermuda grass was significantly lower. This grass establishment has been approved of with orthodox ways and with current study apparatuses. For instance, Caturegli *et al.*, (2016), realized the growth parameters such as plant growth (cm) and dry weight as vital parameters in tall fescue grass research and used unmanned medium to study the reflectance and correlated the N needed for 3 turf grasses; Bermuda, Paspalum and Korean. The emergence of stolons of both St. Augustine and Bermuda turf and the establishment of the stolons of the turfs were studied on five different media namely; M1-topsoil, (100%), M2- topsoil 60: PM20: RHB15: Clay5, M3 - topsoil50: PM30: RHB15: Clay5, M4 – topsoil 60: PM20: SD15: Clay5, M5 – topsoil50: PM30: SD15: Clay After one week of watering stolons, the emergence commenced. Amended growing media has many advantages viz.; ease in handling, high WHC, more accurate control of nutrients and optimum aeration (Sengar *et al.*, 2014). The amended substrates presented significantly highest WHC among all examined growing media by Dannehl *et al.*, (2015). The use of amended growing medium is gaining more attention. In the current study, the dry weight of the St. Augustine and Bermuda trimmed grasses ranged from 21.8 g/cm² to 104.1g/cm². An actual significant difference might be seen in the dry weight calculated. The maximum dry weight of biomass (104.1g/cm²) was observed in the St Augustine's grass grown from M5 – topsoil50 : PM30 : SD15 : Clay 5 as a substrate followed by M3 - topsoil50 : PM30 : RHB15 : (85.8 g/cm²). The

general results showed that the St. Augustine's grass was found with a higher percentage for dry weight of biomass than Bermuda grass. However, Bermuda grass grew taller than St. Augustine. This may be due to varietal differences among the two grasses as they were all growing in the same formulated media. On the contrary, the rapid growth rate of Bermuda grass may be due to the increase in the availability of vital nutrients, particularly N and P and have the benefit of improving the growth rate (Tesfamariam *et al.*, 2009). In this study, diverse parameters of the growth of grass such as emergence (%), stolon length, tiller number, plant girth, chlorophyll content, fresh weight and dry weight were examined on five different types of growing media. Many advantages make amended growing media a specific practice for plant biology researches. In plant study, amended growing media allows scholars manage nutrients and control pH, EC, major and minor elements concentrations in media substrates (Torabi *et al.*, 2012).

Weed emergence in amended growing media was due to the presence of weed seeds in the soil mixed with the organic materials. Research has shown that broad leaf weeds growing in sod reduce the aesthetic value of the turfgrass sod (Barker, 2001). Weeds also compete with grass in response to improved fertility given by the amended growing media (Barker, 2001).

The significant performance of the growing media containing poultry manure may be attributed to dynamic nutrient associated with high photosynthesis consequently promoting the growth of root and shoot. This observation agrees with study by Havlin, Beaton, Tisdale, & Nelson (2005). Lowest plant height, tiller number and chlorophyll content documented for the medium M1 (topsoil) showed the poor quality of top soil, thus the incapability to support turfgrass growth. This finding is in line with Salem (2015), who stated that conventional topsoil mostly used for plant production is unable to provide the physicochemical properties for plants growth and development without amendments (Olle *et al.*, 2012). In their study, they planted tomato plants in soil, perlite,

peat, sand, pumice and diverse mixtures as well. Their outcomes revealed that “the highest total and consumable produce was obtained from a mixture of 80% pumice + 10% perlite + 10% peat medium”. This provided about 30% additional yield compared to the conventional topsoil.

In this study, M4 (topsoil 60 : PM20 : SD15 : Clay5) did not increase chlorophyll content as well as stem girth. The pH and EC values were not high for this substrate M4 (topsoil 60 : PM20 : SD15 : Clay5). However, this might be due to the high proportion of sawdust that could have brought about N immobilization. The reverse was noticed in substrate M3 (topsoil50 : PM30 : RHB15 : Clay5), which recorded outstandingly higher turfgrass growth parameters. Typically, significant growth parameters recorded for the growing media containing rice husk biochar + poultry manure treatment over sawdust might be attributed to the fact that PM contained a reasonable amount of Ca and Mg which might have increased the essential nutrient content of the growing media. Also, sawdust used did not contain sufficient N and other elements which could have improved the medium for optimum growth of turfgrass. Ogunrotimi & Kayode (2018) found out that substrate mix of sand and sawdust (50% + 50%) could not support plant growth. The high C:N ratios of sawdust results in nitrogen immobilization since microorganisms may actively be using available mineral nitrogen for their protein synthesis (Verdonck, 1988).

The improved root development noticed for medium M5 may be due to the lower BD, which boosts root growth. Also, the growth of larger trimmed grass weight in this growing medium might cause the production of high nutrients which were segregated to the root. This outcome resonates with (Argo, 1998), who established that “type of media used in potting plant dictates rate of shoot and root development”. The lower root developed in the M2 may be due to the high BD, which promotes media compaction and thus, restricting root development. The higher trimmed dry weight showed by the media containing PM may be due to their comparatively high N and organic

matter content with low C:N ratio that caused the production of more leaves of these substrates. The significantly bigger plant girth produced by the growing M2 resulted in a higher grass dry matter. When rice husk biochar (RHB) + poultry manure (PM) was increased grass dry weight in both grasses, while increasing RHB+PM increased grass dry weight once more showing the positive effect of RHB and PM amendment on turfgrass growth. The higher dry matter produced by media with PM might be to the production of more leaves and bigger stem girth, this again confirms the fact that PM support grass growth (the differences between genotypes, growth analysis has evidenced that high stolon growth rate of quick establishing genotypes is due to a higher proportion of dry weight partitioned to stems instead of leaves (Patton, 2006). Akpalu *et al.*, (2020) stated that “application of poultry manure at the rate of 6t/ha contributed to the production of more leaf number and stem girth which led to higher fresh and dry weight of *Telfaria*”. Again, production of higher shoot growth and high biomass of plants hinge on the accessibility of nutrients in the growing media (Zhang *et al.*, 2014). Turfgrass established in amended growing media containing biochar and poultry manure exhibited improved quality and suitability for sodding than conventional topsoil. For sod to resist transplanting stress, it would largely depend on their dry matter content for easier establishment at the field (Pimpini, Giardini, Borin, & Gianquinto, 1992).

4.5 Conclusion

Based on the nursery experiments, the following conclusions were drawn.

Addition of soil amendment reduced BD and increase porosity, WHC and other physical and chemical properties of the media compared to the top soil only (control).

SD+PM as components of the media promoted grass growth and DM production than RHB + PM.

This could be due to the differences in physical and chemical properties.

Bud Emergence (%) in St. Augustine's grass was highest in topsoil, while no differences were observed among the growing media for Bermuda grass.

The observed differences in emergence could be attributed to the differences in the physical and chemical properties of the media used in the study.

Application of soil amendments increased the pH and other properties of the growing media compared to top soil.

Increasing PM decreased the BD and increased porosity for both RHB and SD based growing media.

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CHAPTER FIVE

5.0 DETERMINATION OF OPTIMUM PLANTING DENSITY AND PLANTING DEPTH FOR BERMUDA GRASS IN SOD PRODUCTION

Abstract

Planting density and depth are essential factors in sod production as they influence the establishment of turfgrasses. Compared to rhizomes, planting density of stolons is essential for successful growth of Bermuda grass. Planting depth is a critical feature to be taken into consideration when establishing stolons in growing media with little water. Surface depth can upsurge emergence; but if stolons are placed too shallow, they could dry out without watering. The study was conducted to determine the optimum planting density and planting depth for Bermuda grass (*Cynodon dactylon*) in sod production. The experiment was 3×3 factorial experiments arranged in RCBD with 3 replications. Treatments were two factors namely, factor 1- plant densities (P1: 98 dibble/m², P2: 28 dibble/m², P3: 15 dibble/m²) and factor 2 planting depth (D1: 1.5cm, D2: 2.5cm, D3: 3.5cm). The treatments included : P1: 98 dibble/m² x D1: 1.5cm (T1), P1: 98 dibble/m² x D2: 2.5cm (T2), P1: 98 dibble/m² x D3: 3.5cm (T3), P2: 28 dibble/m² x D1: 1.5cm (T4), P2: 28 dibble/m² x D2: 2.5cm (T5), P2: 28 dibble/m² x D3: 3.5cm (T6), P3: 15 dibble/m² x D1: 1.5cm (T7), P3: 15 dibble/m² x D2: 2.5cm (T8), P3: 15 dibble/m² x D3: 3.5cm (T9). The interaction effect of plant density and planting depth were observed on parameters namely; emergence (%), tiller number, stolon length, stolon girth, chlorophyll content, stolon biomass and weed biomass. T6 recorded the highest shoots in Bermuda of 75.3%. T8 recorded the tallest shoot (263.5cm). T8 recorded the widest stolon girth of 1.68mm. T7 produced the highest chlorophyll of 42.7. T5 showed the maximum number of tillers (15.7). T2 recorded the highest stolon dry matter of 65g/cm². The highest weed dry matter was recorded for T7 (18.1g/ cm²). However, T6

recorded maximum number of weeds (6). From the results it was observed that dibble T2 planting depth favored quick establishment of Bermuda grass. Depth 2.5 was the optimum depth regime and density P3: 15 dibble/m² took longer time for grass establishment. It is therefore recommended that planting density and depth have influence on the establishment and growth of turfgrass/sod.

5.1 Introduction

Over the past years, Bermuda grass (*Cynodon dactylon*) has gained popularity as one of the most extensively cultivated and utilized grass species globally, primarily owing to its remarkable tolerance for drought, resilience, and rapid growth (Owusu *et al.*, 2024). Planting density of stolons is a necessary factor for successful establishment. Higher planting density classically results in faster establishment of grasses (Baseggio *et al.*, 2015)¹, also planting density is frequently related to forage production in the early planting stage. Suggested stolon planting densities range from 1.7 - 3.5 m³ ha⁻¹, but such densities were established on sandy-clay loam soils with good irrigation and nutrient retention (Baseggio *et al.*, 2015; Zhang *et al.*, 2021; Gao *et al.*, 2022). However, data on appropriate planting densities under these circumstances is required. Another significant aspect of establishment of Bermuda grass using stolons, is planting depth. Shallow planting may enhance stolons survival, emergence, ground cover, and dry matter production (Baseggio *et al.*, 2015; Christians, Patton & Law, 2016). Planted too shallow, however, the stolons may dry out without irrigation (Baseggio *et al.*, 2015). Although deep planting helps in high temperature and soil water retention, if placed too deep the new sprouts may perish before emerging (Baseggio *et al.*, 2015). Bermuda grass is a widely planted warm season grass that has adequately adapted to the environmental conditions in Ghana and is propagated by stolons or sprigs (Macolino *et al.*, 2010; Mutlu *et al.*, 2015; Pornaro, Macolino, & Richardson, 2019; Burgin *et al.*, 2022). The increase

interest in establishing lawns in real estates and recreational areas stems from the fact that lawns add esthetic value, and create the environment that can absorb carbon dioxide in the atmosphere to mitigate climate change. Hitherto, the establishment of lawns have depended excessively on the use of soil, which is not environmentally friendly. Furthermore, the quality of topsoil for plant propagating purposes has reduced significantly due to over exploitation (Owusu *et al.*, 2024). In addition, there is the need to prepare sod materials that can be used to establish lawns at any point in time, especially in the tropics where temperature for establishing plants is not a constraint. It is important to explore the potential for developing commercial sod production to establish lawns at any time of the year. Sod for lawn establishment should be available at any time, and it should establish early to meet the expectations of users. This objective can be achieved if sod is raised in a growing media, that can provide the anchorage and supply nutrients for its growth in the nursery and under the field conditions. Increasing the soil organic carbon content through the recycling of organic materials, has become attractive to scientists. Recycling of organic waste into compost and biochar and using these as components in growing media have been used for several crops and ornamentals, but information on its use for lawns is scanty. Furthermore, the development of the appropriate growing media for lawns will be contributing to mitigating effects on climate change. Bermuda grass turf is a stoloniferous type of grass. A dynamic system of stolons warrants durability and quality of sod under low-maintenance conditions. The success of establishing lawns depends mainly on the selection of a suitable grass that is adaptable to the environment and the development of suitable cultural practices and management skills. A proper planting method that ensures a rapid grass cover within a short period is ideally preferred. The best material and method for establishing a lawn very fast could be grass-specific. Hence, selection of suitable method appropriate for selected grass species is of great importance in establishment of turf. However,

early establishment of grass is dependent on the growth pattern of the grass species and fertility of the growing media. Since, Bermuda is a stoloniferous type of grass, the spread and cover are more rapid. The faster covering is largely dependent on the distance between sprigs planted and tillering ability of the grass. Dhanasekaran (2018) reported that closer spacing of Bermuda sprigs at 10 cm x 10 cm resulted in the earliest spread and ground cover for Bermuda grass. This is the reason why spreading and establishment rate is more rapid. However, the faster spread is largely dependent on the planting density and depth (Lane, Watkins & Spivak, 2019).

Planting density and depth are factors that have to be considered in the establishment and spread of grasses. Planting density defines the number of plants per square meter. Grasses compete for growth resources such as water, light and nutrients (Helios *et al.*, 2021). The planting density therefore determines the available growth resource available to individual plants, (Naser, Hendawy & Schmidhalter, 2013) for resource acquisition and use.

Authors have published that planting density affects the absorption and utilization of radiation, water, and nutrients in plants by changing the canopy and root system architecture (Zhang *et al.*, 2021; Gao *et al.*, 2022; Jia *et al.*, 2021 and Fahad *et al.*, 2022). According to Hernández-Ordoñez *et al.*, (2024), increased planting density enhances the intercepted photosynthetically active radiation through fast canopy closure and improves the “leaf area index” (LAI). Different planting factors constrain sod production. Planting density is the most important agronomic practice which must be duly considered (Asmamaw, 2017). The spreading of grasses increases with an increase planting density to some optimum value. The spacing of grass plants in the sod production field can influence spread as well. Higher planting densities can lead to more competition among individual grass plants for resources such as sunlight, water, and nutrients. This competition may result in slower lateral spread as the grass plants invest more energy in vertical growth to access

resources. Conversely, lower planting densities can allow for faster lateral spread as there is less competition and more resources available per plant. Optimal planting density varies depending on factors such as the species of grass being cultivated, soil conditions, climate, and intended use of the sod. Balancing planting density to promote both quick establishment and efficient lateral spread is essential for successful sod production.

The depth at which grass is planted can impact its root development and subsequent spread (Ng & Leung, 2020). Planting grass too shallow may result in weak root systems, which can limit the ability of the grass to establish and spread effectively due to inadequate moisture content (Christians, Patton & Law, 2016). Conversely, planting too deep can hinder germination and initial growth, also affect spread because of heat build-up (Finch-Savage & Bassel, 2016). Generally, following recommended planting depths for the specific type of grass being cultivated is crucial for optimal spread. Planting depth has significant impact on the ability of grass to sprout. Oxygen and soil moisture are environmental factors that affect emergence of grasses (Egley, 2017), and planting too deep may deny roots of adequate oxygen and moisture for optimum performance. The grass could be affected by planting depth. Emergence is affected by planting depth. It helps form suitable environs for the sod (Baye *et al.*, 2020). It is important to plant grass at the appropriate depth. Planting of grass stolons in the growing media contributes to better rooting system, thereby reducing its susceptibility to lodging (Ali & Idris, 2015). The depth of planting positively impacted on emergence and growth of plants (Baye *et al.*, 2020).

The increasing demand for quality sod for the establishment of sports fields, recreational areas, urban landscaping and erosion control necessitates for a novel method of grass establishment, especially when stolons are being used for propagation. Understanding how Bermuda grass adapts to the factors both as plant density and depth is also critical for devising successful sod production

strategies tailored to local conditions. The objective of this study was to determine appropriate planting density and depth of Bermuda grass for sod production.

5.2 Methodology

5.2.1 Experimental site

The experiment was carried out at the Greenhouse, Sinna's Garden-Department of Crop Science, 0.50 39 N1, 000 10 W0, 69 m above sea level. The rainfall for this area ranges from 74.1mm to 95 mm and annual maximum and minimum temperatures means are 31 °C and 24.3 °C respectively.

5.2.2 Experimental materials and layout

The experiment was carried out between October and December 2022 to determine appropriate planting density and depth for establishing sod. M2 (Top soil + poultry manure + rice husk biochar + clay 60:20:15:5) growing media established from the previous experiment was used. Bermuda grass was planted in the growing media. Plots were 20cm by 40cm and alleyways between plots were 2.4cm wide. Planting densities and depth were selected based on earlier experiment done and

at rates adopted by growers in Ghana. Based on the recommended density on reference, the lower and higher densities were to assess the effect of densities on Bermuda grass establishment. Bermuda grass stolons were obtained from Benoras Horticultural services Ltd. at Abokobi, Ga East District.

5.2.3 Experimental design

The design for this study was 3×3 factorial experiments arranged in RCBD with 3 replications. Factor one was planting density; while factor two was planting depth. P: planting density and D: Planting depth. Planting density has three (3) treatment levels, i.e. P_1 , P_2 , and P_3 (P_1 : 98 dibble/ 0.8 m^2 ; P_2 : 28 dibble/ 0.8 m^2 ; P_3 : 15 dibble/ 0.8 m^2) and planting depth had three (3) treatment levels, i.e. D_1 , D_2 and D_3 (D_1 : 1.5cm deep; D_2 : 2.5cm deep; D_3 : 3.5cm deep). Experimental treatments include: P_1 : 98 dibble/ m^2 x D_1 : 1.5cm, P_1 : 98 dibble/ m^2 x D_2 : 2.5cm, P_1 : 98 dibble/ m^2 x D_3 : 3.5cm, P_2 : 28 dibble/ m^2 x D_1 : 1.5cm, P_2 : 28 dibble/ m^2 x D_2 : 2.5cm, P_2 : 28 dibble/ m^2 x D_3 : 3.5cm, P_3 : 15 dibble/ m^2 x D_1 : 1.5cm, P_3 : 15 dibble/ m^2 x D_2 : 2.5cm, P_3 : 15 dibble/ m^2 x D_3 : 3.5cm. Thus, the total treatments for the experiment were nine (9), with three (3) replicates.

5.2.3.1 Treatments

Factor one treatment: Planting Density

Factor two treatment: Planting Depth

Table 5.1 Planting Density and Planting Depth

A. Planting density	B. Planting depth
P_1 : 98 dibble/ 0.8 m^2 Spacing: 3cm*3cm	D_1 : 1.5cm deep
P_2 : 28 dibble/ 0.8 m^2 Spacing: 6cm*6cm	D_2 : 2.5cm deep

P ₃ :15 dibble/0.8 m ²	D ₃ : 3.5cm deep
Spacing: 9cm*9cm	



PLATE 4: Planting density and depth of experimental set-up.

5.2.4 Experiment

The experiment was conducted from October 2022 to January 2023 at the Crop Science Department, University of Ghana. Wooden box (40 cm*20 cm) with a height of 6 cm, lined with a net on perforated poly sheet at the bottom, filled with samples of the growing media. The growing media was formulated as described earlier on, and air dried. The growing media was air dried and passed through a sieve of 5 mm mesh size to remove all plant debris, clogs and stones. The wood boxes filled with the media were arranged and set up for the experiment. The boxes were left to stand for 48 hours for the growing media in each box to settle. Cuttings were made at the basal portion of grass (10 cm) and dibbling method was used for planting at depth of 1.5 cm, 2.5 cm and 3.5 cm, and watered when necessary. Runners/ stolons cut from the basal portion of grass (10 cm) was used for propagation. Planting was done by dibbling method. Wood box (40 cm*20 cm), 6 cm high lined with a net on perforated poly sheet was used for the propagation of grass. Substrates were mixed properly by dividing each plot into smaller sections to ensure uniform spread. The

distance between grass stolons was 4cm. Planting was done at depth of 1.5 cm, 2.5 cm and 3.5 cm. Saw dust, rice husk biochar, poultry manure and clay were used to amend top soil. The substrate was 6 cm deep. Grass used for the experiment was Bermuda grass (*Cynodon dactylon*). Grass stolon of 10cm length was used for the experiment.

Substrate prepared from top soil mixed with poultry manure, rice husk biochar, saw dust and clay at a ratio of 60: 20: 15: 5 (top soil, poultry manure, biochar and clay respectively) was used as rooting/growing medium for the emergence of the grass stolons. Stolons were at the basal portion of grass (10 cm) and dibbling method was used. Planting at depths of 1.5 cm, 2.5 cm and 3.5 cm were employed. The spaces used were 3 cm x 3 cm (9.0×10^{-8} /ha); 6 cm x 6 cm (3.6×10^{-7} /ha) and 9 cm x 9 cm (9.9×10^{-8} /ha), resulting in planting materials per box being fifteen (15), twenty-eight (28), and ninety-eight (98) respectively. Thus, the total planting materials was thousand two hundred and sixty-nine (1,269). 1.5 cm depth, (3 cm x 3 cm; 6 cm x 6 cm; and 9 cm x 9 cm) 2.5 cm depth (3 cm x 3 cm; 6 cm x 6 cm; and 9 cm x 9 cm) 3.5 cm depth (3 cm x 3 cm; 6 cm x 6 cm; and 9 cm x 9 cm). Watering was done twice daily at 500 mLs two times daily, morning and evening.

5.2.5 Data Collection

Data for morphological parameters and yield of Bermuda grass were collected over the three (3) months experimental period. Morphological parameters such as emergence (%), stolon length, number of tillers, chlorophyll content, stolon girth, and dry weight were calculated as the mean of sums obtained from 18 stolons that were randomly chosen from the mid row of plots at 3, 5,7,9,11 and 13 weeks after planting. Data was taken at 10am in the day throughout the sampling period. Harvesting/trimming was done by hand using a pair of shears, leaving a growth height of 10 cm at 13 weeks after planting. Fresh trimmed yield of the grass was measured as soon as harvested and

weighed using a weighing balance. Following that, turf samples from respective plots were weighed, branded, and oven-dried at 70 °C for 72 hours and kept in separate dry matter and fresh biomass yield from each plot to estimate full dry matter produced for respective plots.

5.2.5.1 Emergence (%)

A stolon was determined as “emerged” if the above-ground part of new stolon emerging from the original stolon exceeded 1 cm long. Emergence was assessed by the quantity of new stolons in a 1 x 1cm quadrat positioned in a secure position in the middle of the plot. Stolons were totaled every other week for seven weeks. Emergence was assessed as labelled in Baseggio *et al.*, (2015).

$RE = \sum S/t$ (Baseggio *et al.*, (2015).

RE is relative emergence. S is the number of grasses stolons at two weeks interval and t is the total time of emergence.

$$\text{Emergence (\%)} = \frac{\text{Total number of stolons shoots}}{\text{Total number of stolons staked}} \times 100$$

(Baseggio *et al.*, 2015).

5.2.5.2 Number of tillers

Number of tillers was “calculated as mean count from 10 stolons that were randomly selected from the mid rows of each plot at 3, 5, 7, 9 11 and 13 weeks after planting”. Number of tillers was evaluated as described in Adnew & Asmare (2023).

5.2.5.3 Stolon Length

Stolon length was “measured from 10 stolons that were randomly selected from the middle rows of each plot at 3, 5, 7, 9, 11 and 13 weeks after planting”. Stolon length was determined as described in Adnew & Asmare (2023).

5.2.5.4 Stolon Girth

Stolon girth per stolon was also measured from 10 stolons which were randomly picked from the central rows of each plot at 3, 5, 7, 9, 11 and 13 weeks after planting. Stolon girth was measured at the point where the cotyledons detached from the shoot using electronic calliper. It was measured in millimetres (mm).

5.2.5.5 Chlorophyll

Chlorophyll content ratings (0-100 unit) were performed at 3, 5, 7, 9, 11 and 13 weeks after planting with a chlorophyll meter (Minolta SPAD-501, Spectrum Technologies, Inc., Illinois, U.S.A). This measurement was based on the difference between light attenuation at 430 and 750 nm, with no transmittance. One fully expanded blade from each box was used as samples for chlorophyll measurement. Four leaves in all were sampled. The time for data collection was 10am in the morning. To ensure the same leaf from each plant was sampled, four selected samples before trimming were marked with rubber tags. The relative increase rate (RIR) of chlorophyll meter reading (CMR) through third to thirteenth week was calculated. Chlorophyll was evaluated as described in Kuo (2015).

5.2.5.6 Weed number and dry matter determination

The number of weed that grew during the experimental period on each treatment plot was determined by counting. The uprooted weeds / roots were thoroughly cleaned to remove remnants of the growing media. The weeds were then separated into leaves, stems and root, and dried in the oven at a temperature of 70 °C for 72 hrs. The dry matter of the weeds was determined after drying, using a scale. And the weights recorded accordingly.

5.2.5.7 Dry matter determination

Dry matter of Bermuda and St. Augustine's grasses was determined at seven and thirteen weeks after planting for each plot. During the harvest, the row at the center of plots was cut at ten cm above the growing media. Fresh biomass was measured using a sensitive balance. After that fresh grass were over-dried at 70 °C for 72 hrs. Subsequently, dry matter and fresh vegetative harvest from the plots were employed to measure entire DM for all plots.

5.2.6 Data Analysis

The data obtained were analyzed using “ANOVA in GENSTAT” (12th Edition). Where a significant *f* test was observed, separation of means was carried out using Least Significant Difference (LSD) at $P \leq 0.05$.

5.3 Results

Table 5.2 Climatic data during the experimental period from October 2022 to January 2023.

Months	Total rainfall (mm)	Maximum temperature (°C)	air Minimum temperature (°C)	air Mean relative humidity (%)
October 2022	113.1	31.3	23.6	87.9
November 2022	77.3	32.3	23.9	88.3
December 2022	2.0	33.1	23.7	82.2
January 2023	29.5	33.9	23.8	81.1

Source: Ghana Meteorological Service

5.3.1 Effect of planting density on emergence (%) of Bermuda grass in a growing media.

Emergence was assessed in the sampling period and was affected by the density treatments. First stolons started emerging earlier than 3 WAP. There was no significant difference among treatments at all the sampling periods. At 3 WAP, the highest rate planted (density 98) showed the highest emergence (67.1 %); other factors did not differ. At 7 WAP, the same factors still displayed the highest emergence, trailed by the lowest rate (Figure 5.1 a).

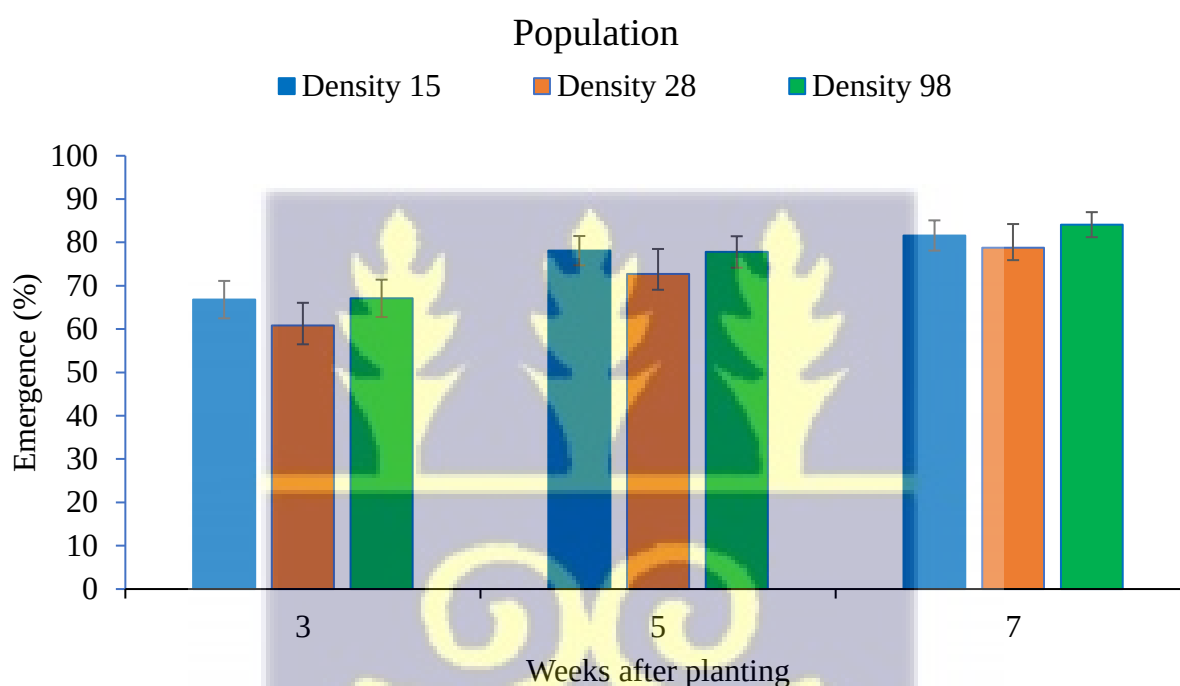


Figure 5.1a: Effect of planting density on emergence (%) of grass at 3 WAP, 5 WAP and 7WAP

5.3.1.1 Effect of planting depth on emergence (%) of grass at 3 WAP, 5 WAP and 7WAP

Differences in the emergence of the stolons was observed at 3 WAP, with the planting depth at 3.5 cm and 2.5 cm recording the highest and lowest percentage stolons respectively. Similar differences were observed at 5 WAP and 7 WAP. At 7 WAP, the highest depth (3.5 cm) presented the greatest emergence (85.8 %), and it was significantly different from the medium depth at (2.5 cm) (Figure 5.1b).

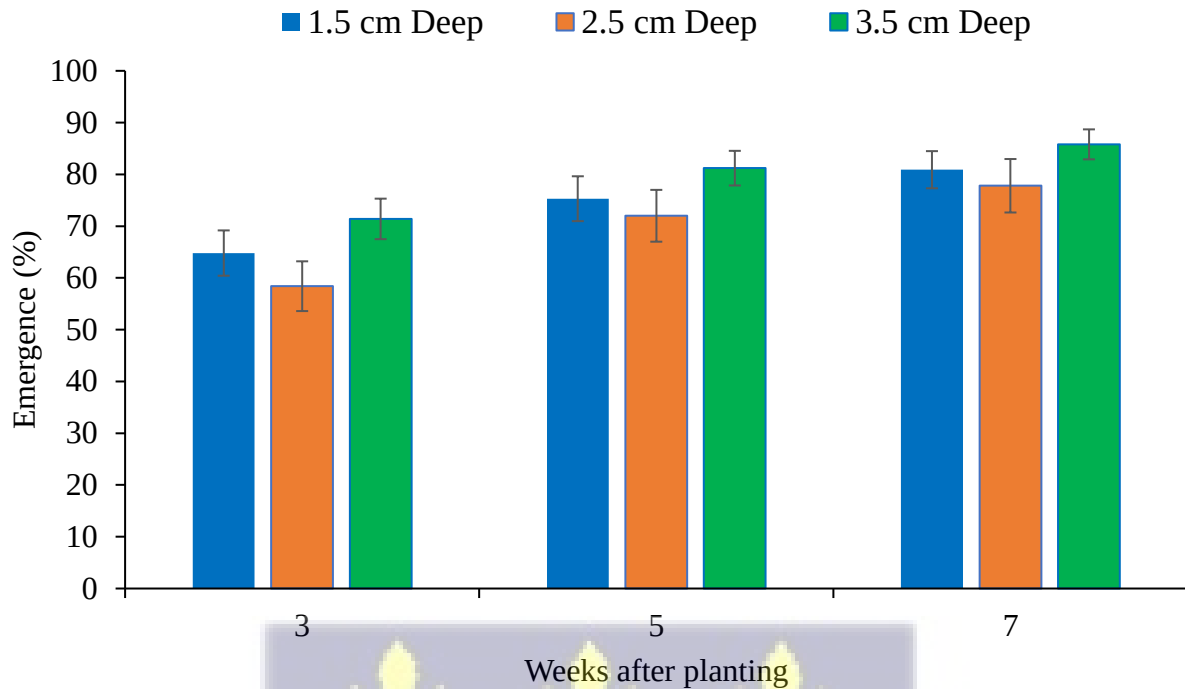


Figure 5.1b: Effect of planting depth on emergence (%) of grass at 3 WAP, 5 WAP and 7WAP

5.3.1.2 Effect of planting density x depth on emergence (%) of Bermuda grass

Emergence was assessed in the sampling period and was influenced by the interaction of WAP and treatments depth. Stolons began to emerge earlier than 3 WAP. Baseggio *et al.*, (2015) reported emergence earlier than 30 DAP when using Bermuda rhizome fragments. There was no significant difference among treatments at all the sampling period. At 3 WAP, the medium rate planted (density 28) at 3.5 cm showed the highest emergence (75.3 %); other treatments did not vary. At 7 WAP, the equivalent treatment still showed the “highest emergence, trailed by the highest rate at 3.5 cm and the lowest rate at 3.5 cm (Figure 5.1 c).

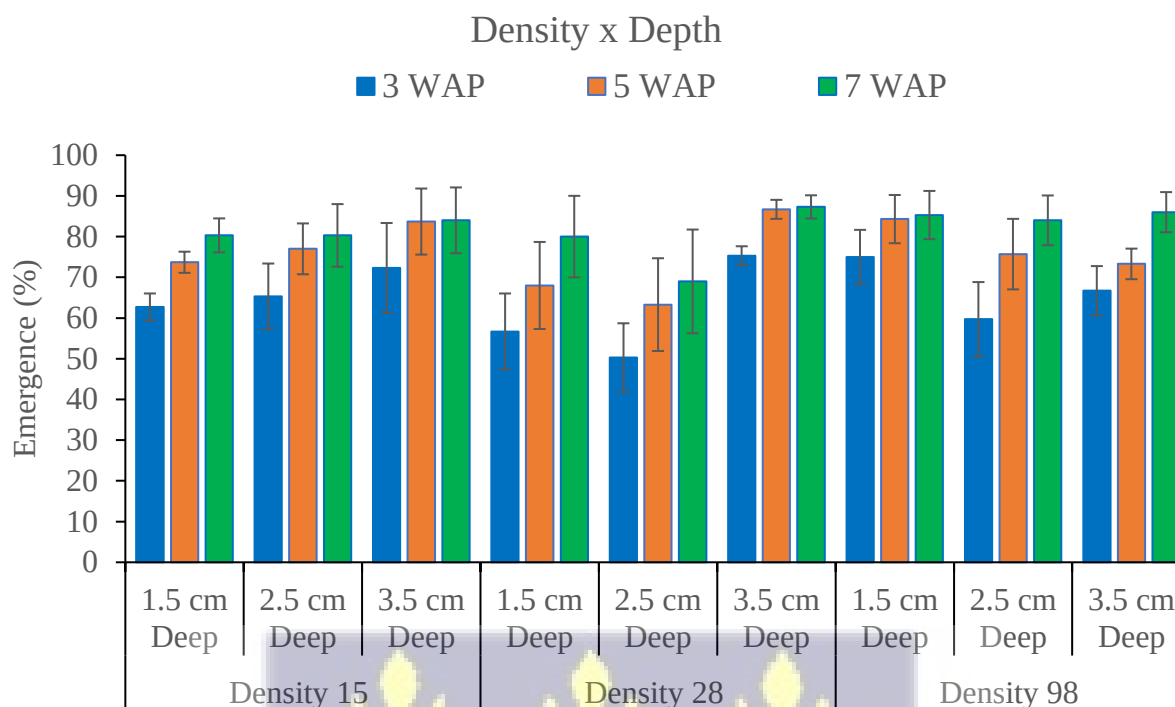


Figure 5.1c: Effect of planting density x depth interaction on emergence (%) at 3 WAP, 5WAP and 7WAP

5.3.2 Effect of planting density on stolon length of Bermuda grass

Stolon length was assessed in the sampling period and was affected by the density treatments. There was significant difference among treatments at 7 WAP to 13 WAP. At 7 WAP, the lowest rate planted (density 15) presented the longest stolon length (158 cm); other treatments significantly differed. At 9 WAP, 11 WAP and 13 WAP, similar treatment also revealed the highest emergence, trailed by the medium rate and highest rate (Figure 5.2 a).

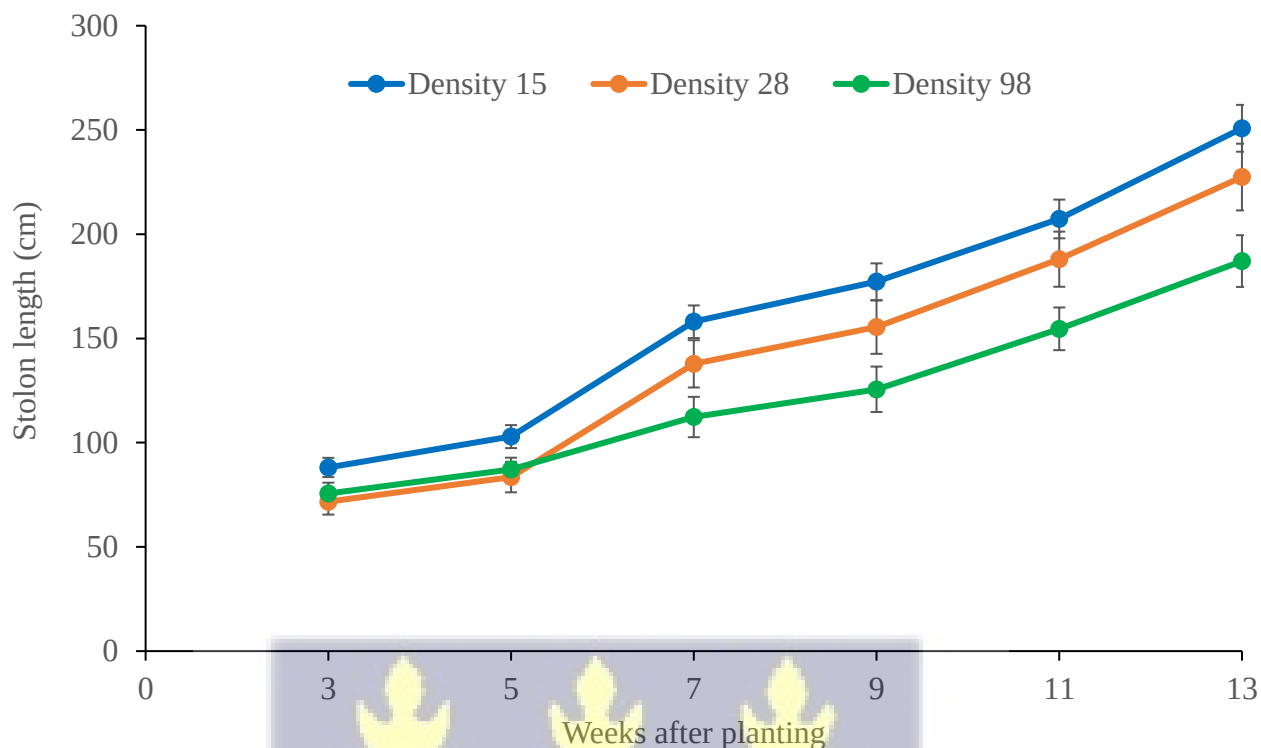


Figure 5.2a: Effect of planting density on stolon length of Bermuda grass

5.3.2.1 Effect of planting depth on stolon length Bermuda grass in the formulated growing media.

Stolon length was assessed in the sampling period and was affected by the planting depth treatments. There was no significant change among treatments through all the sampling periods. At 3 WAP, the moderate depth (2.5 cm) produced the longest stolon length (80.2 cm). At 13 WAP, the same treatment revealed the longest stolon length, followed the shallow rate and the greatest depth (Figure 5.2 b).

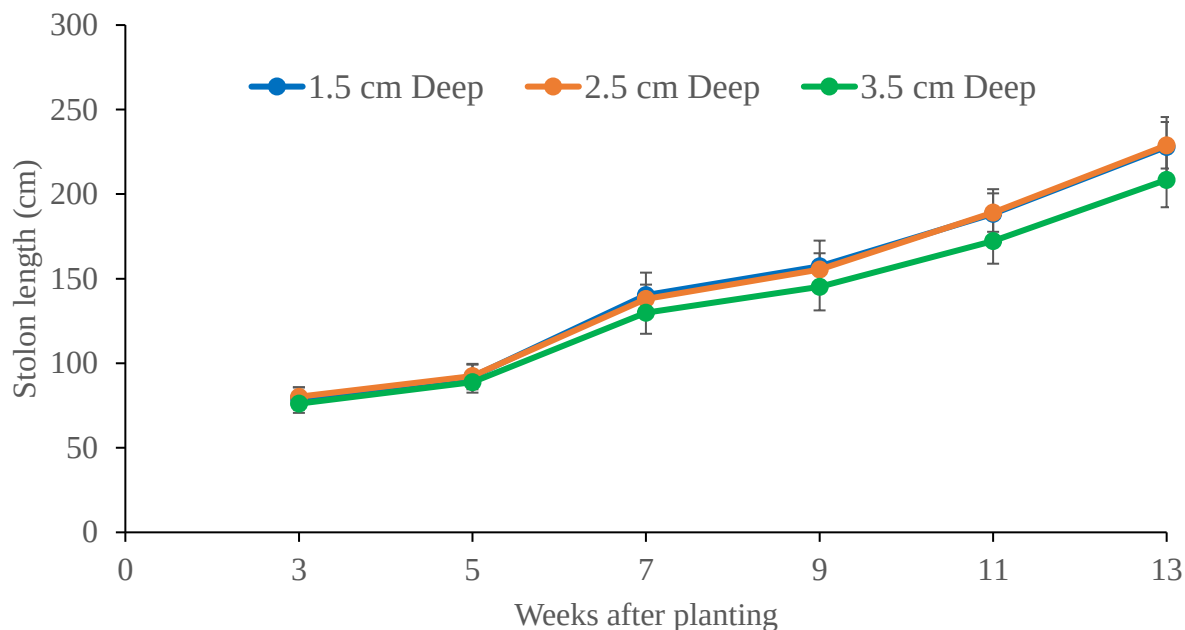


Figure 5.2b: Effect of planting depth on stolon length of Bermuda grass

5.3.2.2 Effect of planting density x depth on stolon length of Bermuda grass in the formulated growing media.

Stolon length was assessed in the sampling period and was influenced by the interaction between WAP and treatment put together. There was no difference among treatments at all the sampling period. At 3WAP, the low rate planted at 2.5 cm showed the longest stolon; other treatments did not change. At 13WAP, the same treatment presented the longest stolon, followed by the low rate at 3.5 cm and low rate at 1.5 cm (Figure 5.2 c).



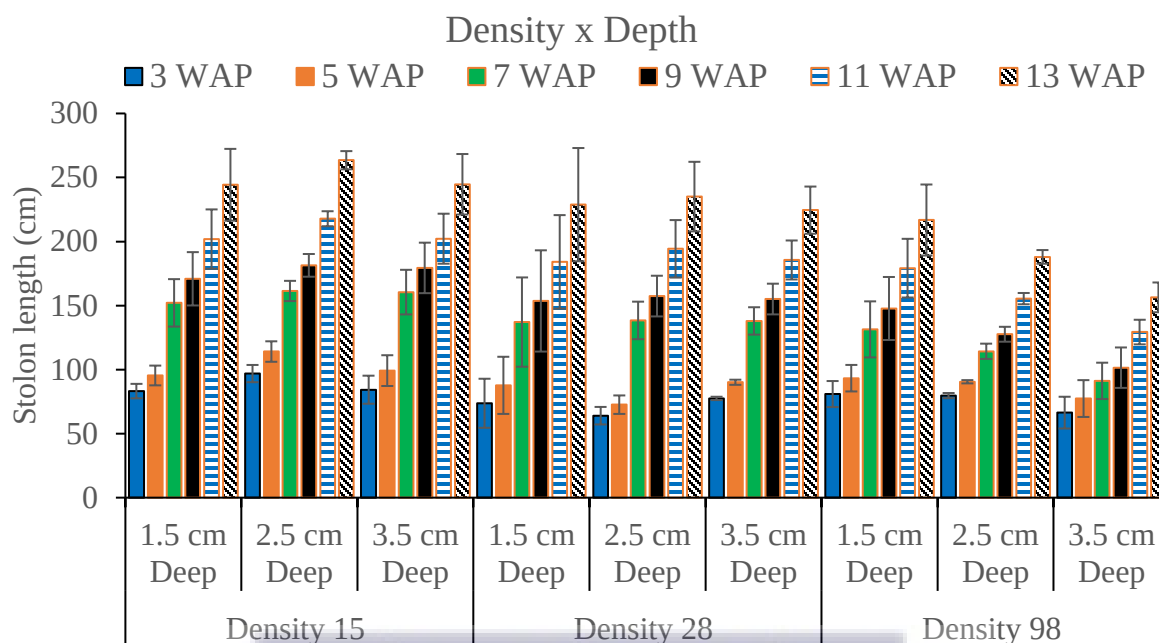


Figure 5.2c: Interactive effects of plant density and depth of planting on Bermuda grass stolon length

5.3.3 Effect of planting density on stolon girth of Bermuda grass.

The difference between plant densities had effect on the stolon girth in Bermuda grass. Rising from the initial growing phase (3 weeks) to latter growing phase (13 weeks), low population showed the largest stolon girth per stolon at all sampling periods. The smallest stolon girth was recorded for medium rate. All treatments increased in girth throughout the growing period. However, there was no significant change between treatment means (Figure 5.3 a).



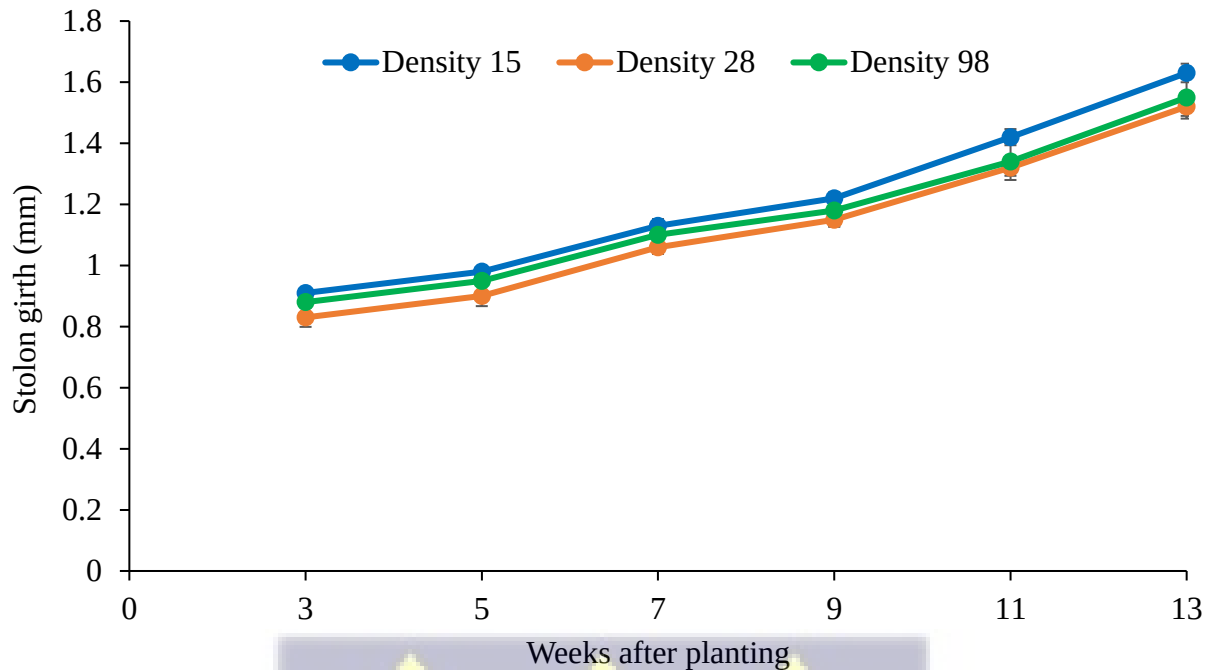


Figure 5.3a: Effect of planting density on stolon girth of Bermuda grass

5.3.3.1 Effect of planting depth on stolon girth of Bermuda grass

Stolon girth assessed in the sampling period was affected by the depth treatments. There was no significant difference among treatments at all the sampling period. At 3 WAP, the greatest depth (3.5 cm) presented the largest stolon girth (0.9 mm); other treatments did not significantly differ. At 13 WAP, the shallow depth (1.5 cm) presented the largest stolon girth, followed by the 3.5 cm and the 2.5 cm depth (Figure 5.3 b).

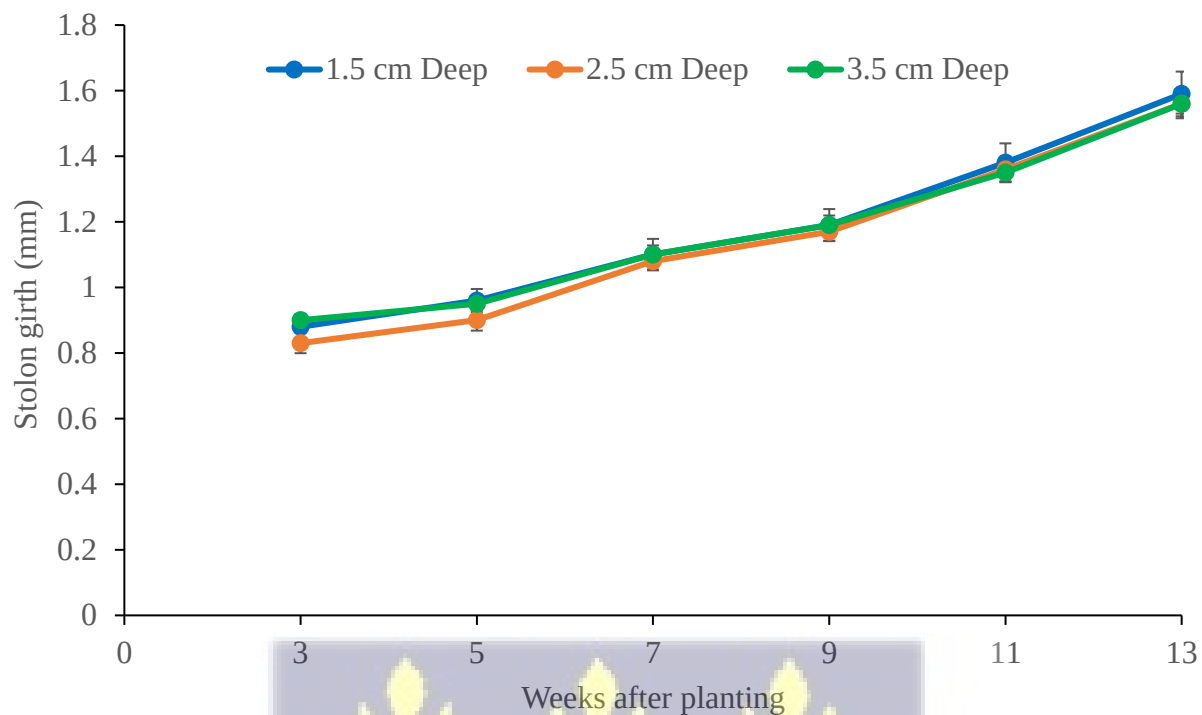


Figure 5.3b: Effect of planting density on stolon girth of grass

5.3.3.2 Effect of planting density x depth on stolon girth of Bermuda grass in the formulated growing media.

Stolon girth assessed throughout the sampling period and was influenced by the interaction between WAP and treatments. There was no difference among treatments at all the sampling period. At 3 WAP, the lower rate established at 2.5 cm showed the largest stolon girth; other treatments did not change significantly. At 13 WAP, the low rate at 2.5 cm recorded the largest stolon girth, followed by 1.5 cm and 3.5 cm (Figure 5.3 c).

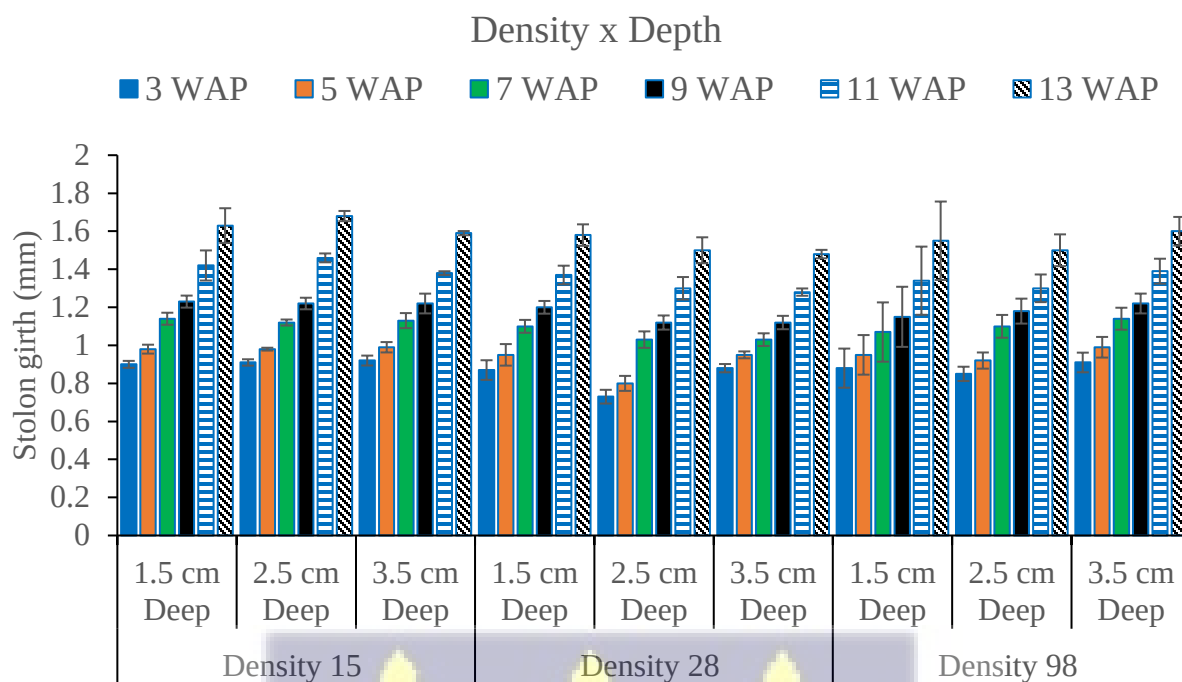


Figure 5.3c: Effect of planting density x depth interaction on stolon girth of *Cynodon dactylon*

5.3.4 Effect of planting density on chlorophyll content of Bermuda grass in the formulated growing media.

Chlorophyll content was assessed within the sampling period and was affected by the density treatments. There was significant difference among treatments. At 3 WAP, both the density 15 and the density 28 presented the highest chlorophyll content in Bermuda grass (26.6 Spad); with the higher population producing the lower chlorophyll content. However, at 13 WAP, the lower rate treatment showed the highest chlorophyll content, followed by the density 28 and the density 98 (Figure 5.4 a). Chlorophyll content declined in all planting population at 9 WAP and increased at 11 weeks after planting.

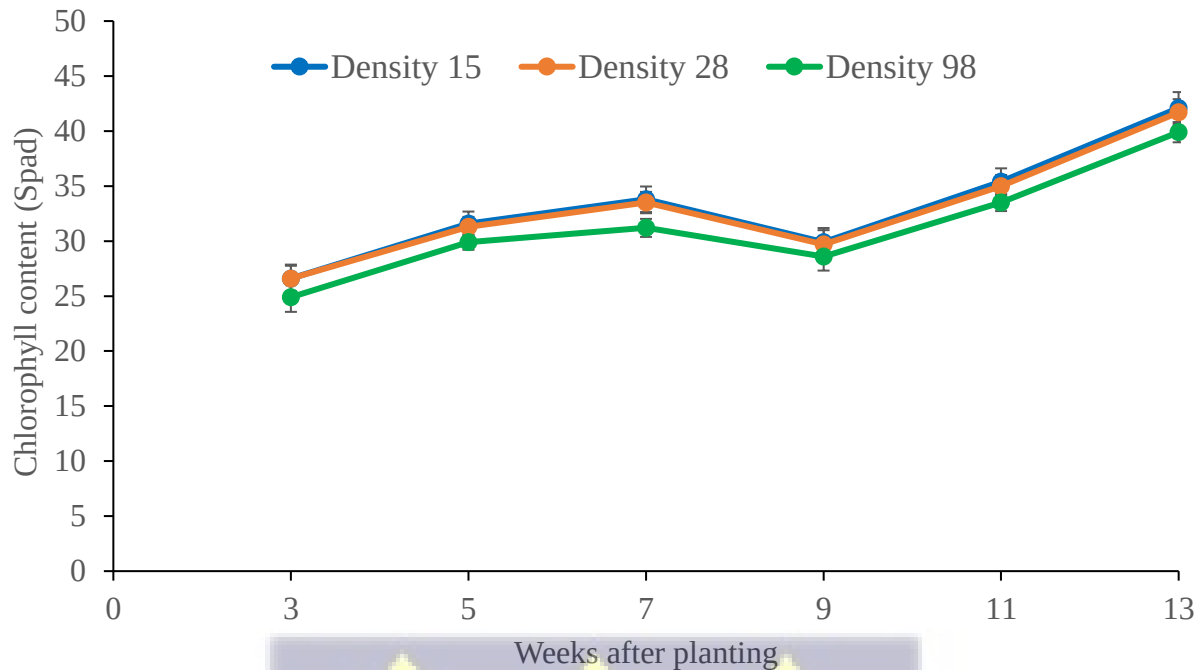


Figure 5.4a: Effect of planting density on chlorophyll content of grass

5.3.4.1 Effect of planting depth on chlorophyll content of Bermuda grass

Planting depths had no significant ($P \leq 0.05$) effect on the chlorophyll content of Bermuda grass.

The highest chlorophyll content was recorded in the medium depth at 3 weeks after planting. The shallow depth 1.5 cm presented the highest chlorophyll content at 5 WAP. At 13 WAP, the same treatment recorded the highest chlorophyll content followed by the 2.5 cm depth and the 3.5 cm depth (Fig. 5.4 b).



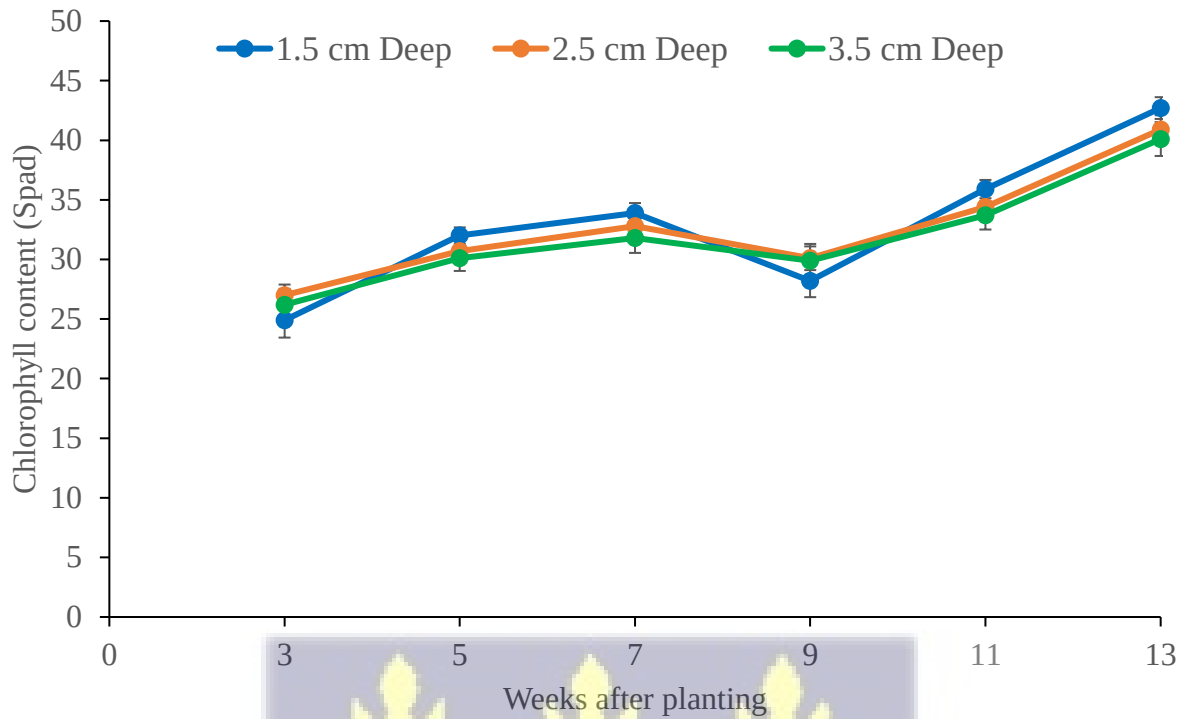


Figure 5.4b: Effect of planting depth on chlorophyll content of grass from 3 WAP to 13WAP.

5.3.4.2 Interactive effect of planting density x depth on chlorophyll content of Bermuda grass

Chlorophyll content assessed throughout the sampling period was influenced by the interaction of WAP and treatments. There was no significant difference among treatments at all the sampling period. At 3 WAP, the 15planting density at 1.5 cm showed the highest chlorophyll content; other treatments did not change significantly. At 13WAP, the low rate at 1.5 cm recorded the highest chlorophyll content, with high rate at 3.5 cm presenting the lowest chlorophyll content (Figure 5.4 c).



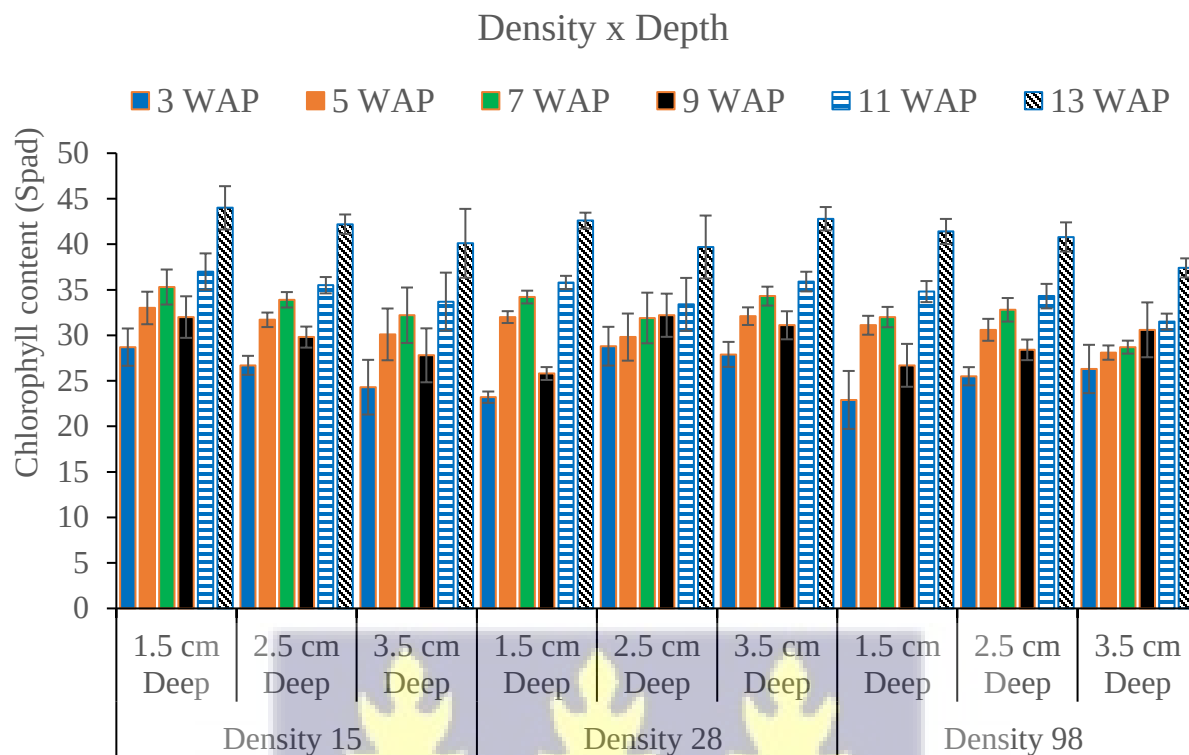


Figure 5.4c: Effect of planting density x depth on chlorophyll content of grass

5.3.5 Combined effect of plant density on number of tillers of Bermuda grass in the formulated growing media.

Tillering yield is a vital morphological factor to consider when selecting suitable grass types for sod establishment. No significant ($P \leq 0.05$) effect among planting densities on the number of tillers in Bermuda turf was observed. The highest quantity of tillers was reported for the low rate at all the sampling period, whereas the minimum number of tillers was recorded for the higher rate (Figure 5.5 a).



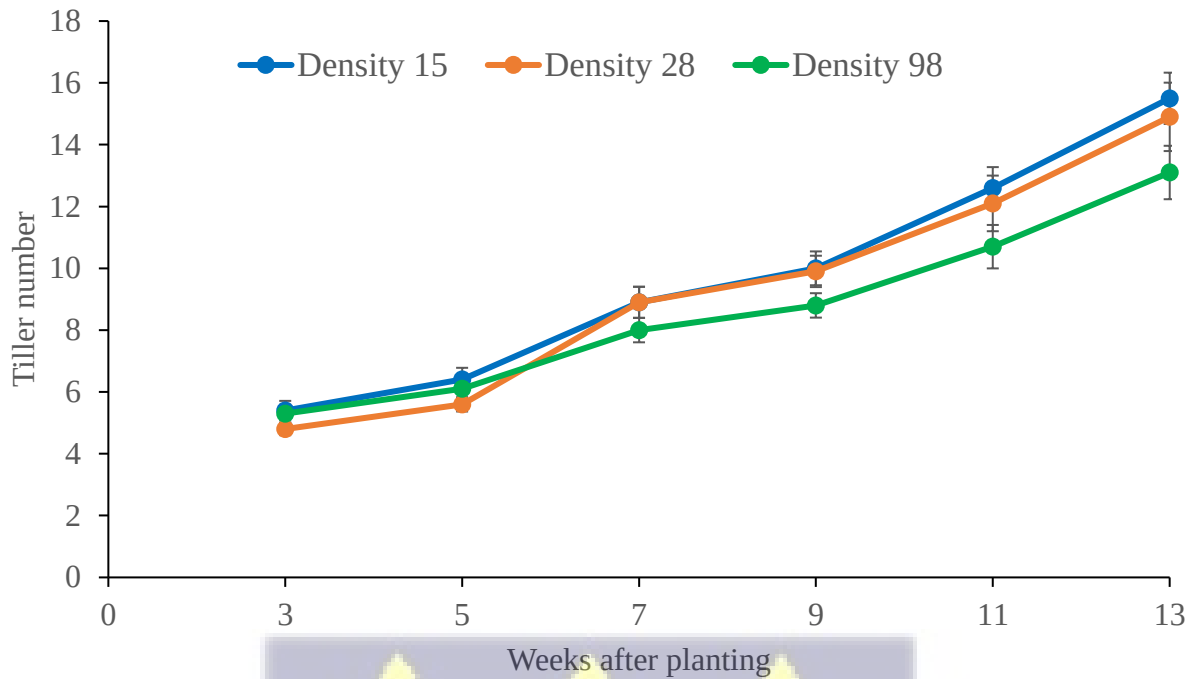


Figure 5.5a: Effect of plant density on number of tillers of *Bermuda* grass from 3 WAP to 13WAP.

5.3.5.1 Effect of planting depth on number of tillers of *Bermuda* grass

Number of tillers was assessed in the sampling period and was affected by the depth treatments. There was no significant difference among treatments at all the sampling period. At 3 WAP, the shallow and the moderate depth presented the highest number of tillers; other treatment did not differ. However, at 13 WAP, the 2.5 cm depth treatment showed the highest number of tillers, followed by the 3.5 cm depth and the shallow depth (Figure 5.5 b).



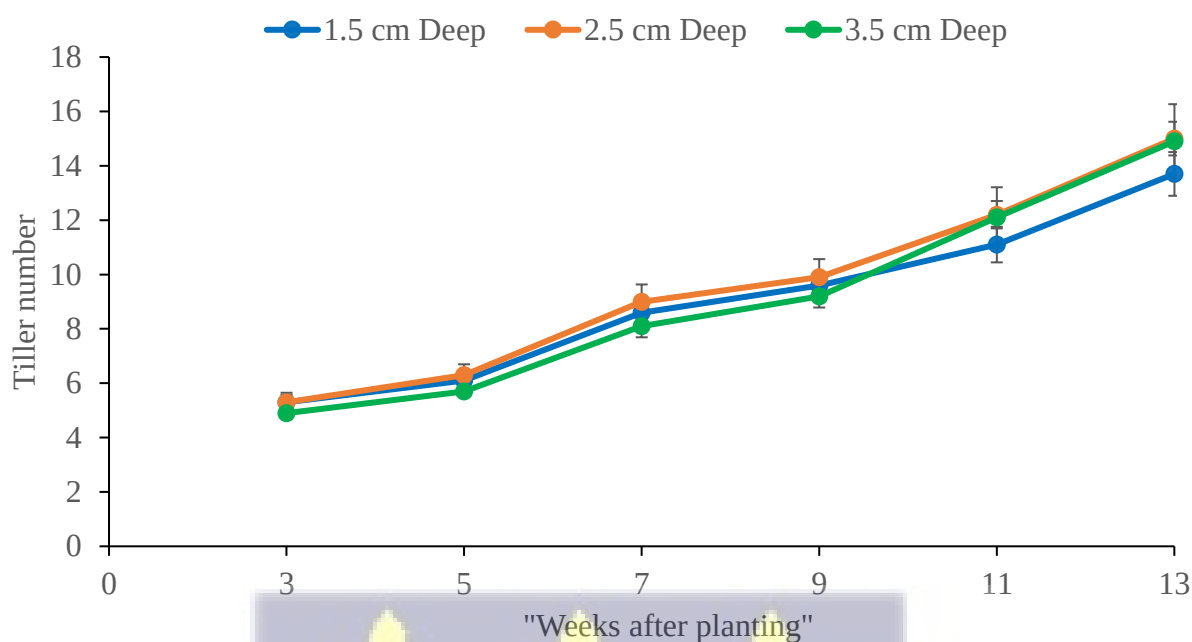


Figure 5.5b: Effect of plant density/spacing on number of tillers *Bermuda grass*

5.3.5.2 Effect of Plant density x depth on number of tillers of *Bermuda grass*

Number of tillers was evaluated in the sampling period and was influenced by the interaction of WAP and treatments. There was no significant difference among treatments at all the sampling period. At 3 WAP, both the 15 planting density installed at 1.5 cm and highest rate at 2.5 cm presented the highest number of tillers; other treatments did not differ significantly. At 13WAP, the low rate at 1.5 cm showed the highest number of tillers in the *Bermuda grass*, with higher rate at 1.5 cm recording the lowest number of tillers (Figure 5.5 c).

Plant density x depths had no significant effect on the number of tillers of *Bermuda grass*. The maximum tillers per plant (4.9, 5.8, 9.5, 10.51, 12.8 and 15.7) was recorded for planting density 28 (9 cm x 9 cm) x planting depth 2.5 cm at 3, 5, 7, 9, 11 and 13 weeks after planting respectively. The minimum number of tillers (5, 5.6, 7.9, 8.8, 10.5, and 13.3) was reported for density 98 x depth

3.5cm. All treatments progressed in plant height during the growing season. However, there was no significant differences between treatment means.

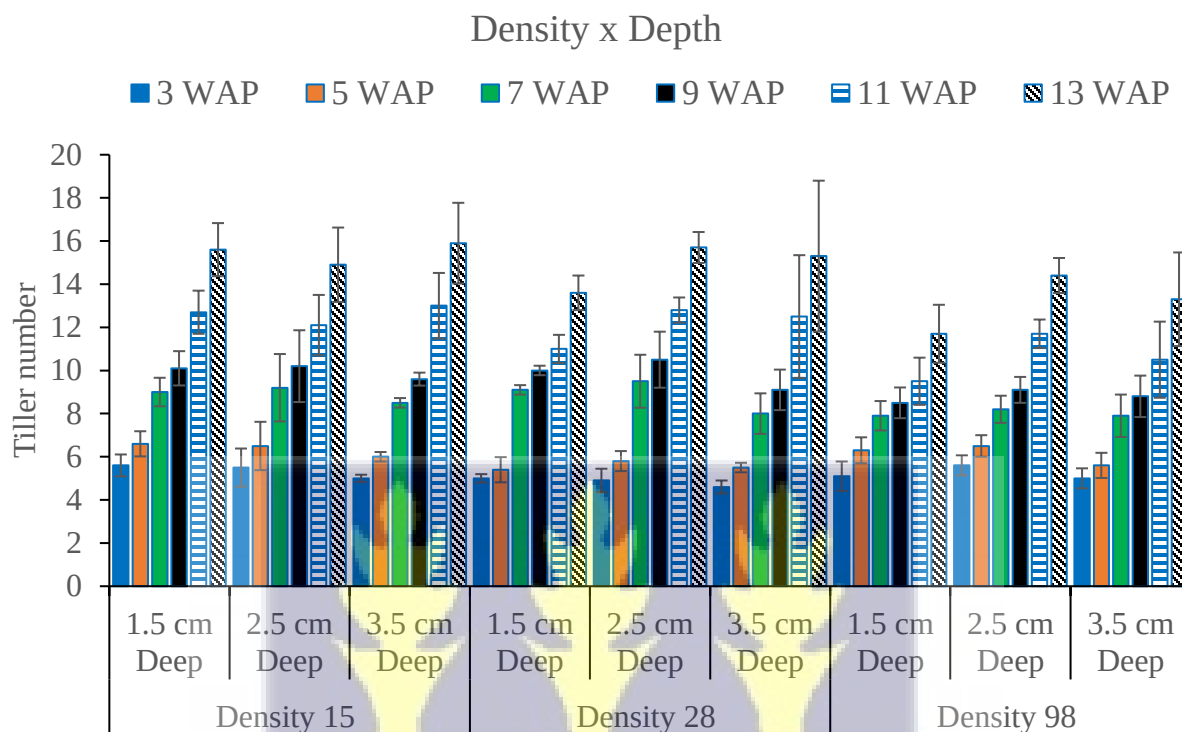


Figure 5.5c: Effect of planting density x density on number of tillers of Bermuda grass at 13WAP

5.3.6 Combined effect of planting density and depth on stolon biomass production at 13WAP

Planting density and depth interaction for DM and the main effect at 13 WAP was significant. Even though the DM showed generally was low at 13 WAP, treatments revealed a parallel pattern of output at 13 WAP. Planted at 1.5 cm, the high density had larger DM than both 28 and 15 planting densities, and the latter treatments did not change (Table 5). At 2.5 cm, there was insignificant difference among densities ($P > 0.05$); however, high density moved toward greater yield comparative to low ($P > 0.10$). At 3.5 cm, the high rate maintained the highest value of the dry matter. When comparing depths in each density, it was significant only for the density 28 planted at 1.5 cm, the density 98 yielded 61.6 g, while at 3.5 cm the DM for this treatment was only 58.4

g/ cm². Similar to emergence, when the planting rate was 98, there was no effect on planting depth. When planting density was 28, DM harvested increased at 98 vs. 2.5 cm. Using the 15density, nevertheless, there was no significant increase in DM when using the 2.5 cm depth, different from what was noticed for emergence (Table 5.3).

Table 5.3: Combined effect of planting density and depth on stolon biomass production at 13WAP

Density	Trimmed grass dry weight (g)			Mean
	1.5 cm Depth	2.5 cm Depth	3.5 cm Depth	
Density 15	54.5 a	52.1 a	46.6 a	51.0 a
Density 28	48.9 a	53.4 a	52.0 a	51.4 a
Density 98	61.6 a	65.0 a	58.4 a	61.7 a
Mean	55.0	56.8	52.3	
LSD ($P \leq 0.05$); Density = 27.62 ns		22.08		
Depth = 27.62 ns		22.08		
Density x Depth = 47.83 ns		38.25		

5.3.7 Combined effect of planting density and depth on weed dry matter

There was planting density and depth interaction for weed DM and the key effect of 13 WAP was significant. Even though the DM showed generally low at 13 WAP, treatments presented a similar pattern of yield at 13 WAP. At 1.5 cm, the 15density had higher DM than both 28 and 98 densities, and the latter treatments did not vary (Table 6). At 2.5 cm, there was no significant difference among densities ($P < 0.05$); however, 98density approached greater performance relative to 28density ($P < 0.10$). At 3.5 cm, the 15density maintained the highest value of the dry matter. When comparing depths within each density, it was significant only for the 15density. Planted at 1.5 cm, the 15density yielded 18.1 g/ cm², while at 2.5 cm the DM for this treatment was only 4.9 g/ cm² (Table 5.4).

Table 5.4 Combined effect of planting density and depth on weed dry matter

Density	Weeds dry weight (g/ cm ²)			Mean
	1.5 cm Depth	2.5 cm Depth	3.5 cm Depth	
Density 15	8.1 c	4.9 ab	7.3 b	10.1 b
Density 28	3.1 ab	2.8 a	3.3 a	3.1 a
Density 98	4.6 a b	5.6 a b	2.5 a	4.2 a
Mean	8.6 a	4.4 a	4.3 a	
LSD ($P \leq 0.05$); Density = 14.91		4.48		
Depth = 14.91		4.48		
Density x Depth = 25.83		7.76		

5.3.8 Combined effect of planting density and depth on number of weeds

The interaction between plant density and planting depth had effect on number of weeds grown. Differences were noticed amongst the tried treatments for the quantity of weeds. The maximum quantity of weeds was recorded for 28 density at 3.5 cm, followed by 15 density at 1.5 cm. Among densities, medium rate recorded the highest mean number of weeds, whereas among planting depth, 1.5cm produced the highest number of weeds (4.6) (Table 5.5).

Table 5.5 Combined effect of planting density and depth on number of weeds

Density	Number of weeds			Mean
	1.5 cm Depth	2.5 cm Depth	3.5 cm Depth	
Density 15	6 b	1 a	4 a	4 a
Density 28	3 a	2 a	6 b	4 a
Density 98	5 ab	4 a	3 a	4 a
Mean	5 a	2 a	4 a	
LSD ($P \leq 0.05$); Density = 2				
Depth = 2				
Density x Depth = 4				

5.4 Discussion

5.4.1 Effect of plant density on sod production

Higher planting density significantly increased the emergence (%) of Bermuda grass. At high density (98 dibbles), the emergence was higher than the 28 and 15 densities. Baseggio *et al.*, (2015) observed greatest emergence of Bermuda grass in the high rate planted. A later report on Bermuda grass by Wadekar *et al.*, (2018) and Undhad (2018) specified that increasing planting rate increased emergence percentage of stolons. The current result is in agreement with Agnihotri (2015) who reported that “stolons had higher emergence (%) in higher densities”. Therefore, it is obvious that density is one of the substantial parameters that impact on the rate of emergence in Bermuda grass. Qodliyadi *et al.*, (2018) and Johnson *et al.*, (1997) presented that “planting density was related to delay in emergence”. One likely reason is density has been the major environmental stress on the emergence of stolons because it could significantly change abiotic factors as temperature and active photosynthetic radiation (Mangoale & Afolayan, 2020). Closer planting rate will lead to a faster cover since low rate had a few numbers of individual stolons/ unit area. On the contrary, low planting rate may lead to poor lawn formation coverage, plain spots and patches (Qodliyadi *et al.*, 2018). The minimum weeks taken for grass establishment may also, be as a result of better performance and adaptability of Bermuda grass. Bermuda grass establishes faster under tropical climatic conditions by reason of their capacity to acclimatize in particular environment and by genetic make-up (Mangoale & Afolayan, 2020). These authors established that, the girth is attributed to genetic characters of Bermuda grass. Bermuda grass is found to be more vigorous for maximum girth and length.

The stolon length increased progressively with a decrease in planting rate but increasing depth in Bermuda grass. This could be due to enormous root, stem, and leaf growth and efficient nutrient

imbibition, letting the stolon to increase in length. A comparable outcome was reported by other scholars for *Brachiaria mutica* grass (Zemene, Mekuriaw & Asmare, 2020; Bantihun, Asmare, & Mekuriaw, 2022). The detected outcome of stolon length increment at 13 weeks after planting is in agreement with the results of “Tiruset (2019)” who detected that the average stolon length was small at 90 days of growth, nonetheless at gathering period of 120 days, improved growth was experienced in “Desho grass”. The differences in stolon length could be ascribed to variation in densities and depths, medial and climatic factors (Bantihun, Asmare, & Mekuriaw, 2022). Stolon length variations might also originate from the genetics of the Bermuda grass, media type and fertility, managing system, and trimming period in this study. Results however were consistent with that of Kefyalew *et al.*, (2020) who recorded that stolon length of “Desho grass” improved from a subordinate level of 37.19 cm at 90 days after planting to a substantially higher value of 45.43 cm at 150 days after planting. This might be attributable to the well-established root growth and nutrient imbibing attitude of Bermuda grass which subsequently may perhaps be displayed by the increase in stolon length.

Number of tillers decreased with increasing plant density. The production of tillers is believed to be associated with endogenous hormones and the availability of carbohydrates. Our observed reduction in tillers production at the higher planting density can probably be explained on a basis of low available carbohydrate supplies due to mutual shading. According to Assuero & Tognetti, (2010), plants that are capable of developing tillers can recompense for little sowing densities or seedling losses in early crop phases. Usually, deprived of much difference in maturity time when little seeding density results in more heads being fashioned through tillering from mainstems.

The number of tillers is an imperative quality of grasses, and it upsurges the probabilities of survival and the quantity of obtainable forage production as stated by Bantihun, Asmare, &

Mekuriaw (2022). Improved tillering is perhaps an adaptive feature to stand frequent defoliation by re-establishing the lost photosynthetic area and maintaining the basal area. Planting rate influenced the number of tillers in this present study.

High planting rate led to faster covering because it had a greater number of individual plant materials/unit area. Low rates increased stolon girth. It was anticipated that high rate may enhance the competition for vital growth nutrients amongst planting materials and hence decrease their ability to attain their normal size. Hence, optimum stolon length was noticed when grass rate was low. This may be a reduction competition between planting materials for nutrients, light, and H₂O to enhance growth (Gashaw and Haile, 2020). Similar pattern was reported by Mangoale & Afolayan, (2020) in Bermuda grass. The optimum trimmed grass dry weight at low density may relate to fast growth and production of high grass trimmed biomass.

The number of weeds and weed dry matter decreased with increasing density. Reduced weed totals may be ascribed to grass horizontal growth habit. This deprives weed seeds from substrate nutrients and light. Shading from the grass do not encourage weed to grow further, hence low weed growth and subsequently biomass. The result was in agreement with Agnihotri (2015) who reported that due to higher planting rate, growth of weeds reduced in little space which decreases the light dispersion to the weeds emerging from underneath the grass. Craft (2021) recorded that once established, zoysia grass will crowd out most weeds. Besides, denser planting density do not let weed grow.

Chlorophyll content among all planting rates and depths increased markedly in during the experimental period. Chlorophyll content characterizes the intensity of the greenness and is measurable quality parameter for turfgrass (Dhanalakshmi *et al.*, 2018). Chlorophyll content is

affected by genetic characteristics of grass species. It is also affected by biotic and abiotic stress along with adaptability to specific environment.

The interaction of different densities and Bermuda grass had insignificant result on total dry biomass at 13 weeks after planting owing to less vegetative growth of Bermuda grass at the months. After 13 weeks of planting, density 98 and depth 2.5 presented higher dry matter of Bermuda grass, as growth rate was observed in number of sprouts, number of tillers, stem girth, plant height etc. at closer plant density (98 dibble/m²). Improved biomass is also directly connected to larger photosynthetic activity of Bermuda grass (Solanki *et al.*, 2021).

5.4.2 Effect of planting depth on sod production

Planting depth significantly increased emergence (%) in Bermuda grass. At 3.5 cm depth, the emergence was realized to be advanced than at 1.5cm and 2.5 cm depths from the present study. It was anticipated that deep planting would slow the emergence and consequently keep the new stolons from hostile environmental conditions that may occur if grasses were to appear too early. Though, in this study, the result was truly the reverse, with the deep planting giving an optimum number of stolons earlier. Perhaps deep planting permitted for water conservation below inadequate watering, causing higher emergence of stolons planted deeply likened to a shallower planting (1.5 cm). Thus, planting at 3.5 cm would keep more H₂O around stolon and therefore promotes its rooting and emergence. Baseggio *et al.*, (2015) reported optimum emergence of Bermuda grass in deeper planting depth than shallow ones. This was in agreement with previous studies by Mangoale & Afolayan (2020) that deeper depth increased the degree of emergence of stolons of *Alepidea amatymbica*. Askari *et al.*, (2017) also presented that, stolons had advanced emergence (%) in moderate planting depths. Thus, it is obvious that planting depth is an important factor that influences emergence (%) of grass stolons. Mangoale & Afolayan, (2020) stated that

depth was linked to slowness in emergence in “*Mentha arvensis* (L) and *Calystegia sepium*”. Even with greater lengths, warm season grasses, emergence decreases with increasing planting depth (Berti & Johnson, 2013).

Results presented that buffalograss emergence reduced with increasing planting depth. “All cultivars had <10% total emergence at planting depths > 50 mm) (L.) R.Br”. (Moussa *et al.*, 2020). This is because, planting depth has been a key environmental stress on the of planting materials as it can potentially alter abiotic factors such as “temperature, active photosynthetic radiation, moisture and substrate organic matter” (Mangoale & Afolayan, 2020). This variation may arise from ecological influences, competition for nutrients in the media, genetic difference of grasses, and genetic potential of grasses to extract minerals as described by Bantihun, Asmare & Mekuriaw, (2022).

The existence and growth of grass stolons propagated in the deeper media may generally depend on the use of nutrients stored in the stolons when sugars cannot be given through photosynthesis (Ferraro *et al.*, 2023). The stolon length of Bermuda grass was reduced with the increase in depth, similar outcomes were also seen by Eldlgamony *et al.*, (2022) and “Kumar *et al.*, (2015)”. Yet, the increase in stolon length was accredited to the preceding emergence of grass and nutrients level of the growing media (Arslan & Qureshi, 2022).

Bermuda grass produced the largest chlorophyll at shallow and medium depths throughout the 2022 and 2023 periods, respectively. These may be attributed to the improved nutrient absorption period with the earlier start of climatic factors in both spells. Nonetheless, the optimum chlorophyll was at 2.5 cm. The general trend of chlorophyll content was significantly higher in the 1.5cm depth treatment. This may improve the plant's vegetative growth and produce of Bermuda grass.

The stolon length increased in all planting depths which could be attributed to enormous root and effective nutrient imbibition, allowing the grass to attain optimum length. A comparable outcome has also been established by other scientists for "*Brachiaria mutica* grass" (Bantihun, Asmare & Mekuriaw, 2022).

It has been stated that planting materials propagated in the deeper media may exhaust all reserved carbohydrates before emergence (Dong, Yu, Guo & Zhang, 2010).

The present trial presented that planting depth controlled the growth and development of tillers, as it was seen that deep planting depth improved the number of tillers. Usually, moderate and deep planting caused more tillers than 1.5 cm depth.

It has been stated that planting depth impact better use of nutrients and adequate ability to resort to favorable circumstances which brings about more fast plant growth (Zhang *et al.*, 2016). Comparable outcomes have been described for soybean (Li *et al.*, 2021). Number of tillers produced in the grass might be as a consequence of stolon length being positively related to levels of sugars, proteins and additional nutrients (Dong, Yu, Guo & Zhang, 2010). This work agreed with Weber (2011), who instituted that stolon length performs a significant part in stolon establishment.

Planting depth had significant effect on the production of the trimmed grass biomass. Shorter stolons in 2.5 cm had the highest dry weight. Depth at 2.5 cm enhanced crop's ability for making photosynthetic materials and improved dry grass weight by storing sugars in grass (Arab *et al.*, 2011). Similar records were made by Oudolf & Kingsbury, (2016) who reported that planting materials into short form need a reduced amount of stored energy to induce growth which render short planting materials to have additional fast growth than longer planting materials. This agrees

with Amatymbica (2017) who recorded that stolon length had effect on the dry weight of the stolons. The reduced trimmed grass biomass may be attributed to the number of leaves which may affect the amounts of nutrients being accrued by plants owing to reduced photosynthesis.

The highest trimmed grass dry weight detected in this study may be credited to the growth in plant height and a number of leaves which impact affect biomass. This work also authenticated the work of Inagaki, Fujii & Urakawa, (2022). The differences in biomass in Table 36b could be related to advanced emergence effectiveness.

5.4.3 Interaction

There was interaction of WAP x density x depth. Increase in planting density, DM was less at first, but was followed by a sharp and then a steady deceleration to reach 100%. When comparing each establishing density, depth of grassing was significantly dissimilar for 28 and 15 densities in all sampling period. By increasing the planting depth from 1.5 to 2.5 cm, the DM was enhanced when using both 15 and 28 planting densities. At the 2.5cm depth, the DM began to improve significantly earlier and got 65 % before the 2.5 cm depth. This may be attributed to adequate moisture supply for optimum performance. Depth 15 cm may have inadequate water supply whilst depth 3.5 cm may have heat build-up which is unfavorable for plant growth and development. Also, when using 15 densities at a 1.5 cm depth, the DM never surpassed 65% at 13WAP, even after 13 WAP. For the 98-planting density, though, variation between planting depths was less distinct. Both depths obtained similar DM at the sample date and touched 65%. This proposes that planting depth is significant only when higher densities are employed. If planting material is not readily available, a deeper planting depth should be used.

There was interaction of WAP X density x depth and parameters were examined by the nine mixtures of density and depth. Stolon length also established a keen outcome to WAP. Comparable

to emergence, planting depth was only significant for 28 and 15 densities. When established at a 3.5 cm depth, stolon length was not impressive apart from the first and second sampling dates (about 3 to 5 WAP) for density. The higher depth at 3.5 cm presented stolon length lower than 80cm, indicating that most of the material had not yet emerged. The subsequent week, 3.5 cm depth performed better, but yet had 77.4 cm stolon length while the same planting density at 1.5 cm displayed over 90 cm stolon length. With low planting though, no significant difference amid planting depths was detected at all sampling periods.

Stolon girth for the low density was similar for all depths across the sampling period to 1.6 mm at about 13 WAP. Treatments in the present trial took more than 11 weeks for chlorophyll content to reach 40 Spad. In general, low and medium planting densities presented greater number of tillers throughout the growing period. In some instances when less planting material was used but depth was greater, tillers were analogous when utilizing advanced densities. This happened at 5 WAP when 28 and 98 densities planted at a 3.5 cm depth presented comparable number of tillers. Thus, when material is not readily accessible, deep planting at 3.5 cm appears to advance establishment. The interaction of dissimilar plant depth and planting density has insignificant impact on chlorophyll content, tiller number and shoot girth due to genetic make-up of *Cynodon dactylon*. However, it showed maximum dry biomass due to growth in quantity of leaves, higher quantity of runners at high planting density (98 dibble/m²). Improved biomass is also directly linked to higher photosynthetic activity of the Bermuda grass (Kumar, 2012). The interaction of planting density and planting depth significantly influenced weed dry biomass. Morphological characteristics of Bermuda grass and its adaptability to the tropical environment enhanced the vegetative growth of grass. Moreover, closer planting do not permit weed to grow.

5.5 Conclusion

Bermuda grass at 3 x 3 cm planting density promoted quick establishment of grass and reduced weed growth. The highest trimmed grass dry weight observed could be due to increase plant density and improved growth resources at 2.5 cm depth. Planting depth at 2.5 cm promoted shoot growth of grass that resulted in the higher trimmed dry weight. Usage of the high stolon establishing density resulted in more stolons per unit area than 28 and 15 densities. Deep stolon planting enhanced the emergence for 28 planting density at 3 WAP. For bermudagrass occurrence and ground cover, planting depth had a consequence on all planting densities even though it happened per chance because the effect was not significant. Planting at 2.5 cm augmented the growth of ground cover and the planted area was totally covered more quickly. Using the high density, both 1.5cm and 3.5 cm depths performed likewise. When planted at a 2.5-cm depth, the 98density had greater DM harvested than 15 density and 28 rates, which did not differ significantly. The high rate seems to offer the best cooperation amid formation performance and expenses related to planting.

5.6 Reference

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CHAPTER SIX

6.0 TYPE OF PROPAGATING MATERIAL ON ESTABLISHMENT AND FIELD PERFORMANCE OF BERMUDA AND ST. AUGUSTINE'S GRASSES IN TWO AGRO-ECOLOGICAL REGIONS IN GHANA

Abstract

The establishment of turfgrasses, an essential component of landscaping in Africa, is sternly controlled by the method of establishment and the performance of grass species under field conditions. The use of stolon and/or sod in establishing the grasses could influence the rate of establishment and spread and its ability to control erosion and to enhance environmental beautification. Two field trials were conducted at Legon (coastal savanna) and Kade, (semi-deciduous forest) to assess the method of establishment of Bermuda and St. Augustine's grass in two ecological regions. The treatments comprised two grass varieties; Bermuda and St. Augustine's, and two planting materials; sod and stolon. A 2 x 2 factorial in randomized complete block design with three replications was used. Significant differences ($p < 0.05$) were observed between grasses, planting materials and their interaction effects on morphological characteristic, growth and dry matter of grasses at both locations. Results showed that the use of sod as planting material was superior to the use of stolon in establishment, spread and other parameters considered. The superiority of the sod treatments in both ecologies was likewise noticeable in the morphological data such as stolon length, number of nodes and stolon dry matter of the grasses giving them the comparative benefit to absorb additional photosynthates for partitioning to the stolons and trimmings. Sod from Bermuda grass produced the highest relative dry weight of 384.5 g/m², which was 14.2% higher than sod from St. Augustine's, 18.2% higher than Bermuda grass stolons and 21.8% higher than the stolon from St. Augustine's established at the coastal savanna.

Sod produced from St. Augustine's reported the highest relative dry weight (DW) of 230.5 g/m², which was 10.6 % higher than that from Bermuda stolons, 7.7% higher than stolon from St. Augustine's and 13.8% higher than the sod from Bermuda at the forest zone. Similarly, stolon (Bermuda) recorded the highest weed dry weight of 92 g/m² and 142 g/m² in the coastal and forest regions respectively whereas stolon (St. Augustine's) recorded (83 g/m², 97 g/m²).

Planting materials (sod and stolons) changed morphologically within the two agroecological zones due to the differences in the soil type, rainfall and temperature regimes.

6.1 INTRODUCTION

Turf grasses are considered as an essential part in landscaping. Turf grasses are extensively used in all agro-ecologies of Ghana (Owusu *et al.*, 2024). Turfgrass/sod has become increasingly important in today's society for recreation, comfort and conservation. Turfgrasses benefits that have been beforehand highlighted comprise useful, aesthetic, recreational, communal, and economic benefits as well as benefits connected to individuals mental and physical health (Ćwik, *et al.*, 2021). Turf grasses reduce warmth via evaporative cooling reflection and covering (Rahman *et al.*, 2021). Tan *et al.*, (2015) detected good relationships amid foliage evapotranspiration and cooling capacity. Aesthetically, turf functions as the edge that increases other factors. Turf provides space for recreation. Turf allows the penetrable, non-warmth, damage defensive, effect padding, inexpensive, open-space superficial desirable in athletics such as "golf, baseball, soccer or American football". Artificial grass, although pretty and popularly used in sport fields builds-up heat which might be harmful to field operators. Economic importance from the flora "(as reviewed by Brethour *et al.*, (2007))" stem from decreased heating and chilling expenses, the improved assets values, decreased maintenance expenses for the outdoor, and derivatives from

gardens, sport amenities and promotes tourism. A decreased heating system and cooling expenses relate to the previously stated restraint of city temperature excesses. Sociological and psychological aids of turf grasses (Beard and Green, 1994, Guerrero, 2016, Monteiro, 2017,) comprise, a reduced pressure with increased health, improved social well-being, improved self-esteem and promoting peaceful communities.

The attractiveness of any garden mainly hinges on the greenness of the turf. Well established turf mostly rests on the selection of suitable grasses appropriate to the climatical and soil conditions. Also, needed are suitable cultural practices and management (Dhanasekaran, 2018). Proper selection of turf grasses according to climatic conditions, cultural practices and its purpose and utility is essential for lasting turf success. It has various uses in landscaping. Ntoulas *et al.*, (2017) observed differences in GTC (Green Turf Cover) among the three turfgrass species indicating the importance of studying “the ability of each turfgrass species to adapt to different environments”. The solid grass cover of cut turf is real in set-up of H₂O and airborne particulate matter in addition to engrossing gassy contaminants. To sustain good and lush turf in sun and partial shade, shade tolerant grass such as Bermuda and St. Augustine’s grasses should be selected (Wadekar *et al.*, 2018). Bermuda grass is most prone (morphological and chemical response) to water shortage circumstances (Huang *et al.*, 2019). It is one of the most extensively utilized grass and is a drought and salt resilient type (Ajtahed, *et al.*, 2021). St Augustine’s grass is known as a valued fodder for sheltered, humid-tropical surroundings in developing republics (Wadekar *et al.*, 2018). Over the past years, Bermuda and St. Augustine’s grasses have gained popularity as the most extensively cultivated and utilized grass species globally because of their remarkable tolerance to drought, resilience, and rapid growth (Conley *et al.*, 2021; Owusu *et al.*, 2024). They find regular application as a turfgrass for swards, golf game developments, and they are the most common for

sports fields in arid and semi-arid regions (Owusu *et al.*, 2024). Moreover, they serve vital roles, for example, erosion control, livestock fodder, and land rehabilitation in these areas. Additionally, Bermuda and St. Augustine's grasses are readily available in Ghana making it possible to explore the potential for commercial production to curb the over reliance on artificial turfs. Wadekar *et al.* (2018) used both St. Augustine and Bermuda grasses in their study and recorded the highest grounds cover (100%) in Bermuda grass at 60 days after planting as well as significantly enhanced chlorophyll content "69.59 mg/100g". However, they recorded that both St. Augustine and Bermuda grasses exhibited medium green color.

Bermuda and St. Augustine's grasses possess numerous necessary features that contribute to their extensive popularity for use as turfgrasses (Christians & Engelke, 2020). These grass species may contribute to increasing the adaptive range to different ecologies needed by these relatively important turfgrasses. Climatic factors between different ecologies differ greatly and these could affect the establishment and management of Bermuda and St. Augustine's grasses (Pornaro, Macolino & Richardson, 2019). Climatic factors such as rainfall amount and distribution, temperature, relative humidity and solar radiation affect the establishment of grasses. The major ecological differences between semi deciduous forest and coastal savanna such as soil factors, rainfall amount and distribution and temperature could affect the establishment of grasses. Similarly, different grass species may respond to the ecological differences in their establishment. The coastal savannah and forest agro-ecological zones of Ghana differ in climatic factors such as rainfall distribution. Coastal savanna has mean annual rainfall of about 1000 mm and about 1500 mm to 2000 mm in the forest area (Yamba *et al.*, 2023). Therefore, these grasses necessitate to be verified in different agro-ecologies as per their usefulness; Performance of grasses under different environment that is in the coastal and forest zone. Mainly the factors are rainfall, soil bulk density

and soil texture. These could affect the performance of different grasses. Coastal soil and forest soil differ in terms of soil texture, CEC, aeration, bulk density. Elsewhere, in North America, McGrath & Henry (2016) in Canada studied on this soil type and saw that soil type affected the yield or biomass production because of high bulk density. In the same vein, this study was conducted to evaluate the performance of these grasses in the forest zone where the clay or soil bulk density is high than the coastal savanna.

Consequently, the type of planting material affects the spread and other morphological characteristics of grasses of grasses and control of weeds (Linder *et al.*, 2018). A good propagating material promotes grass spread within a small period. Hence, selection of suitable technique appropriate for designated grasses is of great importance in spread of turf. Yet, establishment of grass depends on the growth rate of turf species (Dhanasekaran, 2018). Though grasses can be propagated by seed, grasses are classically planted by vegetative means (Kumar, 2023). The method of establishment of grasses include; seeding, sodding, sprigging, stolonizing, plugging, dibbling and hydro-mulching. Seeding is when grass seeds are used for grass establishment. Seeds develop a carpet rapidly and roots outward at the bulges. Formation of turfgrass via seeds is the inexpensive technique of turf formation for big expanses (Janakiram *et al.*, 2015). Moreover, stress-free transport of establishing material and stress-free and quick method of grassing reduces labor work. Michael (2012) described that Bermuda grass cultivars “Dune, La Paloma and Yukon” documented 100 % sprouting after 6 days of planting.

Mathew *et al.* (2020), later confirmed that seed broadcasting at 10 g/m² of Bermuda grass var. ‘Tif dwarf’ recorded the lowest number of weeds (2.70 g/m²), lowest days to germination (6 days) and highest ground shelter 5%. Sodding is the method of planting grass by the use of sod. Sod is a mat-like piece of lawn comprising of grass with soil or growing media attached to its roots that allows

it to continue growing seamlessly when transplanted (Owusu *et al.*, 2023). Sodding is advantageous as a means of turfgrass establishment with relative ease all year round, and reduces wastage of planting material (Goatley, 2016). Sod is well known especially to the total installation or repair of smaller patches by producing almost instant results in football and soccer pitches as well as lawns (Yi, 2012). However, sodding is expensive as the cost that goes into land preparation, acquisition of high-quality sod, transplanting, and post-planting care steps in the establishment process for sod could be quite high (Kumar 2023). Sprigging is the method of using stolons and rhizomes for planting in minor pits and troughs. A grass sprig is a single stem or segment of stem devoid of soil add-on. Dhanasekaran (2018) reported that Bermuda grass planting sprigs recorded the earliest spread and ground cover at 7 and 15 days after planting. Stolonizing is the method of using the turf grass stolon for planting. This method may be favorable to grasses that are propagated through stolons, stoloniferous grasses to be planted in this manner, for example Bermuda and St. Augustine's grass (Kumar 2023). According to Dhanalekshmi *et al.* (2015), Bermuda grass grown via stolon reported highest ground shelter (96.03 %) at 120 days after planting. Plugging is the act of insertion blocks of sod with a width of between 5.1 cm – 10.2 cm at even intermissions. Comparing it to sprigging, plugging needs 3-10 times as much planting material which makes it much more expensive (Kumar 2023). Dibbling is the act of using grass vegetative materials to be dibbed ten to fifteen cm apart. Hydro-mulching/hydro-seeding Although relatively new, is becoming utilized more frequently. Hydro-seeding/hydro-mulching includes spraying the required area with a mix of the required grass seed, fresh wood mulch, and H₂O. Though the method is justly expensive, it is classically less expensive than sodding (Kumar 2023). It is highly recommended for large lawns, spaces with sharp slopes, or/and hard-to-reach areas. However, planting cost is somewhat larger than those of conventional techniques.

Factors which affect turfgrasses are its high cost of planting and up-keep, like cost of weed control, mowing, aeration etc. Weed management in an established lawn is very difficult owing to solid cover of grasses. Control of weeds and effective spread of grasses are key areas of research in turf grass production. Proper grassing and maintenance are vital for any turfgrass to be vigorous and to appear green (Mathew *et al.*, 2020). Weeds in turf are taken as nuisance as they disturb lawn uniformity and compete with required grasses for water, sunlight, and nutrients. A substantial weed invasion can reduce turfgrass color quality. Weeds are therefore, kept under control by avoidance (Susan *et al.*, 2016). Mathew *et al.*, (2020) reported that Bermuda grass var. ‘Tif dwarf’ recorded lowest number of weeds (2.70/m²), lowest days to germination “(6.17 days)” and higher ground cover. Weeds grow in every lawn, but they rarely become issues in well-managed, healthy growing turfgrass.

Various soils require to be modified with organic matter or nutrients to enhance drainage and water holding capacities. The ability of soils to drain water and concurrently hold sufficient water is largely significant in growing the turfgrass root system and keeping vigorous lawns.

Bermuda and St. Augustine’s grasses are most susceptible to drought (Wadekar *et al.*, 2018). Ideal watering can hold nutrients and improve chlorophyll content of turf. With this, the ideal growing medium for turf grass establishment should have a high-H₂O holding capacity and advanced aeration (Golestani *et al.*, 2014). Suitable moisture is obligatory not only to begin the seed germination process, but also to keep young grass seedlings before their root systems are completely developed. With sod, enough moisture is important to root down into the earth at the location. Too little water will render sod to dry off, which could bring in late development or death of grasses. However, excessive water can constrain germination, rooting and stolon growth, encourage disease problems (“damping-off”) and may enhance washing of grass seed and soil.

Turf grass species with poor survivability would result in poor nutrient uptake. Turf species that are healthy will provide the greatest benefit. So, choosing a turf species that will grow well in a particular location is highly encouraged. Moreover, early field establishment will lead to erosion control, aesthetic value to the building and reduction cost of maintenance.

Bermuda grass is one of the greatest extensively used turf. It is a drought and salt resilient grass (Wadekar *et al.*, 2018). St. Augustine's grass is preferred grass species for shade and humid-tropical surroundings in developed countries (Wadekar *et al.*, 2018]. Most of the research on turf grasses has been done in countries such as USA, Australia, Japan, Singapore, India etc. but these grass species may not be suitable for Ghana because of difference in the climatic conditions. The escalating demand for quality turf in the context of sports fields, recreational areas, and urban landscaping necessitates an in-depth examination at different ecological zones for growth, visual quality, and physical characteristics of sod/stolon and while stolon establishment is generally more cost-effective and easier to manage, sod planting may offer the advantage of faster establishment and can potentially yield more vigorous turf. Understanding how Bermuda and St. Augustine's grasses adapt to the factors such as sodding and stolonization is also critical for devising successful sod production strategies tailored to local conditions. According to Pfautsch *et al.*, (2013), different site conditions will require different lawn grass species to best suit the environment, including degree of sun/shade exposure.

Adnew & Asmare, (2023) researched on “agronomic performance, yield, and nutritional value of grasses affected by agroecological settings in Ethiopia” and reported that, in most agronomical and chemical composition treatments, there were significant interactions between elevations and gathering times for all verified grasses “(Mulato II, Napier, and Rhodes grasses)”. Similarly, Essilfie, Darkwa & Asamoah, (2024) studied “the growth and yield response of maize to integrated

nutrient management of chicken manure and inorganic fertilizer in different agroecological zones” and reported that treatments presented analogous response for vegetative characters whereas the combined application demonstrated greater for grain yield of maize crosswise the two agro-ecologies.

Moreover, the data accessible on the performance of diverse kinds of turf grasses with respect to initial and stable establishment with dissimilar turf establishment methods is very scanty. There will be variation in spread between sodding and stolonization on field establishment (scanty information on these in Ghana) other factors like cost and availability of planting resources. Hence the objective of this research was to evaluate the type of propagating material on establishment and field performance of Bermuda and St. Augustine’s grasses in two agro-ecological regions in Ghana

6.2 METHODOLOGY

6.2.1 Experimental Site

Two field experimentations were conducted in 2023. The foremost experiment was conducted at the University of Ghana Crop Science Experimental farm, from May, 2023 to August, 2023. The site which is located in the Greater Accra region, has the following geographical characteristics, on Latitude 5°38’45” N and Longitude 00°11’13” E, at an altitude of 300m above sea level. The climate of the site is characterized by an annual rainfall of 1000 mm mostly distributed from April to November and a mean annual temperature of 33.6°C and described as coastal savanna with bimodal rainfall distribution. The soils are mainly sandy to sandy loam with evapotranspiration.

The second experiment was also conducted at the University of Ghana's Forest and Horticultural Research Centre-Okumaning, (6°05'N; 0°05'W) near Kade from June to September, 2023. The center is located about 175 km from Accra and about 150 m above sea level. It is located in the Semi- Deciduous Forest zone. The soils at the experimental site belongs to the Kokofu series. The soils belong to forest Ochrosols which are well drained (Owusu-Bennoah *et al.*, 2000). The soils are generally classified as Acrisols (kokofu series) (IUSS - WRB, 2014). Acrisols are acidic, highly weathered soils that are low in nutrients and characterized by clay accumulation in the subsoil. They pose challenges for agricultural use due to their low fertility, high aluminum content, and nutrient leaching, but with proper management, they can be made productive for certain crops. The area experiences a bi-modal rainfall pattern that reaches its peak in June and October with a brief dry spell in August. The dry season starts from December till March. The location has a humid tropical climate with an annual rainfall of 1200 to 1800. The mean annual temperature is 30.9°C.

6.2.2 Soil and growing media analyses

A growing media prepared/formulated from well decomposed organic materials was applied at the experimental sites prior to planting 60% Top soil + 20% poultry manure + 15% rice husk biochar + 5% clay from an earlier trial.

Selected chemical properties of the growing media are shown in Table 1. "The data analyzed comprise soil pH on 1:1 (soil: distilled water) and 1:2 (soil: 0.01 M CaCl₂) mixtures and assessed on Germany)". "The Walkley and Black method" were employed for organic matter assessment (Nelson & Sommers, 1996). and total N established by means of the micro "Kjeldahl method (Horwitz & Latimer, 2005). Total carbon, organic carbon, and organic matter. Methods of soil analysis: Part 3 Chemical methods, 5, 961-1010. Obtainable P was measured calorimetrically after abstraction using the Bray method (Frank, Beegle, & Denning, 1998). Flame emission photometry

was applied for the resolve of exchangeable cations (Bray & Kutz, 1945). Calcium and Mg were measured with “atomic absorption spectrometry” after the removal of ammonium acetate and organic resources at pH 7.0. Outcomes of soil analysis of the trial locations are offered in Table 6.5 and Table 6.6. The climatic conditions of the research locations during the grass growing time for the two places are also obtainable in Table 6.1 and Table 6.2.

6.2.3 Experimental Design

The field experiment was set in a 2 x 2 factorial in randomized complete block design with three replications. This involved two grass species, Bermuda grass and St. Augustine’s grass. Bermuda grass leaves are thinner while St. Augustine’s grass possess broader leaves. Sod and stolons of Bermuda grass and St Augustine’s from a preliminary study were used in this study. The size of sod was 20cm x 20cm and the length of the stolons was 10centimetres. Bermuda grass and St. Augustine’s grass were planted with sod and stolons planting materials. 1. Bermuda sod 2. Bermuda Stolons 3. St. Augustine’s sod 4. St. Augustine’s Stolons and replicated 3 times. Sods were planted on 1m⁻² and were monitoring the spread of these to cover the 1 m⁻². Top soil60 + poultry manure20+ rice husk biochar 15+ clay 5 growing was given at the lowest of the groove to safeguard improved H₂O holding.

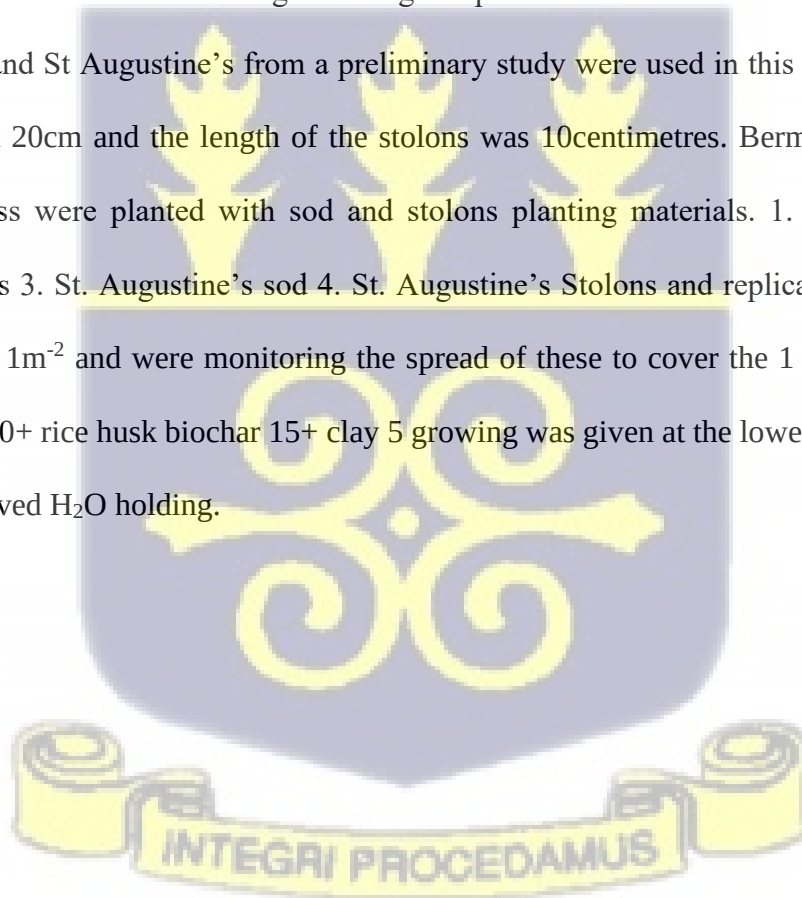




PLATE 5: Field experiment set-up at Kade(Left) and Legon (Right)

6.2.4 Land Preparation

The sites have been hitherto farmed to cowpea. Weeding was done by the use of cutlass. Thereafter, hoeing was done to clear all weeds to expose the bare land. Mattock was then used to dig the surface of the ground 20cm deep. Raking was done to gather all debris which were removed from sites when dried. Afterwards, the place was demarcated into blocks (3 blocks) with 3 replications which were furrowed and pegged.

6.2.4.1 Soil Sampling

Soil samples were taken at random at six different points in the field at both sites. An auger was used, at a depth of 0 – 10cm. The samples were moved to the research laboratory for analysis for chemical and physical characteristics.

6.2.5 Transplanting of sod

Four-month-old sods of Bermuda grass and St. Augustine's grass (20cm x 20cm) were used for this study. The materials were transported from the Crop Science Department Sinna's Garden,

University of Ghana to the University of Ghana to study the effect of the method of establishment and field performance of Bermuda and St. Augustine's grasses in two agroecological zones in Ghana. The sods were hardened by reducing the shade for 8 days before transplanting at both fields. The sods were planted in a 20 cm x20 cm area dug to a depth of 15cm. Nets were carefully removed in order not to lose the medium around the roots. The sods together with the growing media were placed in the dugout areas and covered firmly. Moreover, stolons of Bermuda and St. Augustine's grasses (10 cm long with approximately 4 nodes) were planted on 20 cm x 20 cm area in the middle of a m² plot of land. Each plot size measured 1m x 1m and contiguous to the other treatments plots and the distance between plots was 1m. Weeding was done when necessary. Thinning out was done by removing the dead stolons regularly to encourage strong and smooth turf with the right density. Watering was done regularly to keep the plots moist. Watering was done up to 60% moisture level.

6.2.8 Data Collection

Data on the morphological and biomass production of Bermuda and St. Augustine's grasses were taken during the trial time (3 months). Morphological data including canopy spread, number of nodes, internode length, chlorophyll content, trimmings dry matter, stolon length, type of weed and weed dry matter were taken at 3, 5, 7, 9, 11 and 13 weeks after planting. Harvesting/trimming was done by hand using a pair of shears, leaving a growth height of 10 cm at 9 and 13 weeks after planting respectively. Data on fresh trimmed weight was calculated instantly after cutting and weighed, by means of weighing balance. Dry weights of each plot were determined after oven drying at 70 °C for 72 hours. Thereafter, the results were converted to tons/ha.

6.2.8.1 Canopy spread (CS)

Canopy spread percentage was visually assessed based on the degree of spread by using a ruler and a scale of 1 - 5 “(1-less than 25 %, 2 - 25 %, 3 - 50 %, 4 - 75%, 5 - 100 % green vegetation cover)” It was done every two weeks through to 9 weeks after planting (Mathew *et al.*, 2020).

6.2.8.2 Number of nodes (NN)

Tiller number was determined as mean count from 18 stolons that were randomly designated from the mid rows of plots at 3, 5, 7, 9 11 and 13 weeks after planting. Number of nodes was evaluated as described in Adnew & Asmare (2023).

6.2.8.3 Internode length (IL)

Internode length was measured from 18 stolons that were randomly selected from the mid rows of plots at 3, 5, 7, 9, 11 and 13 weeks after planting. A meter rule was used to measure the internode length in cm. Internode length was determined as described in Adnew & Asmare (2023).

6.2.8.4 Chlorophyll content (CC)

Chlorophyll content ratings (0-100 unit) were performed at 3, 5, 7, 9, 11 and 13 weeks after planting with a chlorophyll meter (Minolta SPAD-501, Spectrum Technologies, Inc., Illinois, U.S.A). This measurement was based on the difference between light attenuation at 430 and 750 nm, with no transmittance. One fully expanded blade from each box was used as sample for chlorophyll measurement. Four leaves were sampled. The time for data collection was 10am in the morning. To ensure the same leaf from each plant was sampled, four selected samples before trimming were marked with rubber tags. The relative increase rate (RIR) of chlorophyll meter reading (CMR) through third to thirteenth week was calculated as the ratio of thirteenth week CMR substrate first week CMR to first week CMR. Chlorophyll was evaluated as described in Kuo (2015).

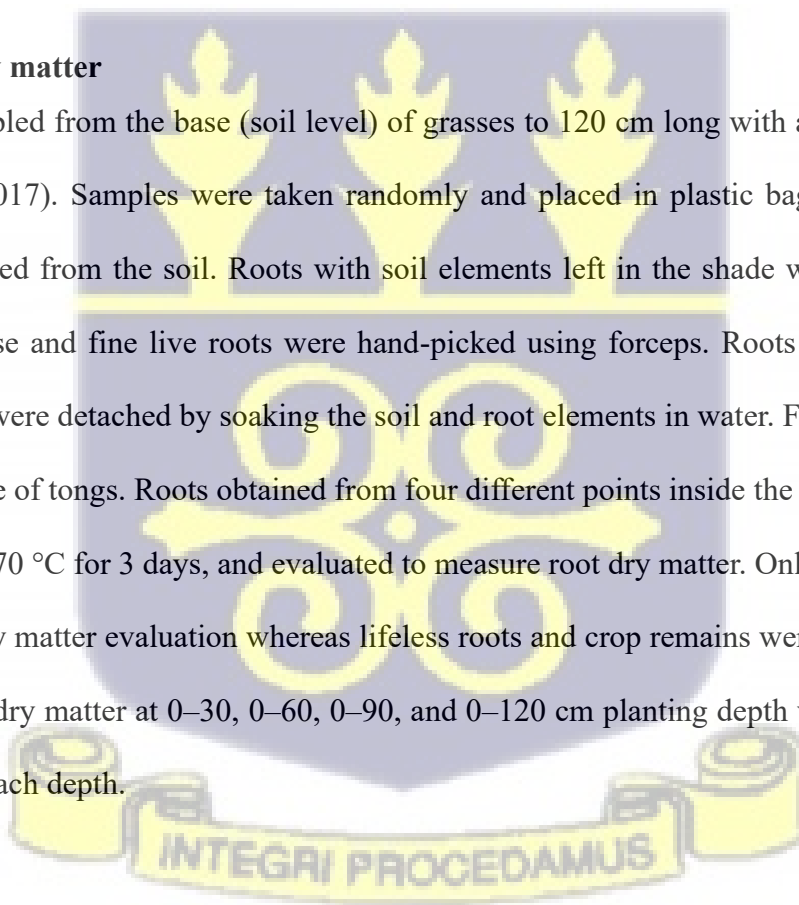
6.2.8.5 Stolon Dry matter (DM)

Biomass of the grasses was determined at thirteen weeks after planting on each plot. Harvesting was done at 10 cm above the soil surface of each plot. Fresh biomass was measured using a weighing scale. The DM was determined after oven drying at 70 °C for 72 hrs. Subsequently, dry matter and biomass from the taster zone of plots were employed to compute entire DM for the plots.

The dry mass of turf trimmings was chronicled at two harvests, the first being after 7 week of growth and the second being after 13week to determine relative growth rate.

6.2.8.6 Root dry matter

Roots were sampled from the base (soil level) of grasses to 120 cm long with a knife at 13 WAP (Sainju *et al.*, 2017). Samples were taken randomly and placed in plastic bags and roots were carefully separated from the soil. Roots with soil elements left in the shade were moved into a container. Coarse and fine live roots were hand-picked using forceps. Roots that could not be picked by hand were detached by soaking the soil and root elements in water. Floating roots were picked by the use of tongs. Roots obtained from four different points inside the plot were washed, dried in oven at 70 °C for 3 days, and evaluated to measure root dry matter. Only fresh roots were employed for dry matter evaluation whereas lifeless roots and crop remains were rejected. Where applicable, root dry matter at 0–30, 0–60, 0–90, and 0–120 cm planting depth were evaluated by totaling DM at each depth.



6.2.8.7 Stolon length (SL)

A recording of stolon length was done instantly after the period of biomass gathering, at the close of each cutting period. Data were taken on the longest stolon. From the entire three rows in the plots, one row was designated without the boundary rows on each sideways (assess the stolon length and afterwards eighteen tillers were randomly selected for the dimension of the stolon length at 7 weeks after planting and 13 weeks after planting respectively and then the average length was taken.

6.2.8.8 Determination of Weed dry matter

The number of weed seedlings that emerged from each plot during the experimental period were counted. The dry matter of weeds was determined by collecting all weeds from each plot, washed. The selected weeds uprooted and roots thoroughly washed to remove media particles. The weeds were thereafter detached into leaves, stems and roots, and dried at 70 °C for 72 hrs. The fresh weight and the dry weights were recorded.

6.2.8.9 Sod cutting (SC)

Three months after planting, plots picked at random were cut into a 40 cm x 1m sod to determine their yield. A sharp cutlass was used to do the cutting whereas a spade was used to do the lifting. Sod was cut to a depth of 6 cm to 8 cm. Sod samples from plot were evaluated, characterized, and oven-dried at 70 °C for 72 hours and kept in separate dry matter and fresh biomass yield from each plot to calculate total dry matter yields for each plot. Thereafter, the results were converted to metric tons per hectare.

6.2.9 Data Analysis

The data obtained were analyzed using “ANOVA in GENSTAT” (12th Edition). Where a significant *f* test was observed, separation of means was carried out using Least Significant Difference (LSD) at $P \leq 0.05$.

6.3 Results

Table 6.1: Climatic data at the study site (coastal savanna) during the experimental period from May to August 2023

Months	Total rainfall (mm)	Maximum air temperature (°C)	Minimum air temperature (°C)	Mean relative humidity (%)
May 2023	162.1	32.3	24.6	86.5
June 2023	154.5	33.2	24.3	87.5
July 2023	69.3	34.6	24.7	88.6
August 2023	71.5	34.3	24.8	93.8

Source: Ghana Meteorological Service

Table 6.2: Climatic data at the study site (forest zone) during the experimental period from June to September 2023

Months	Total rainfall (mm)	Maximum air temperature (°C)	Minimum air temperature (°C)	Mean relative humidity (%)	Total solar radiation (MJ/m ² /day)
June 2023	333.7	31.5	22.4	84.3	9.9
July 2023	145.7	31.0	22.9	85.6	9.8
August 2023	157.5	29.8	22.7	87.6	7.5
September 2023	211.0	31.4	22.6	85.1	9.3

Source: Ghana Meteorological Service

Table 6.3: Physical properties of growing media used for the study

Media Samples	Bulk Density (g/cm ³)	Porosity (%)	Water holding Capacity (%)
M2	0.6	89.3	66.1

M2 (TS + PM + RHB + CS) = 60:20:15:5; TS=Topsoil, PM= Poultry manure, RHB= Rice husk biochar and CS= Clay soil

Table 6.4: Some chemical properties of growing media used for the experiment

Organic material	pH	%N	%K	Avail. P mg/kg	Ca cmol/kg	Mg cmol/kg	EC dS/m ²	CEC Cmol ⁺ /kg g	%OC	%Na
M2	7.5	0.01	2.8	810.5	3.31	1.16	541.6	8.32	14.43	1.0

M2 (TS + PM + RHB + CS) = 60:20:15:5;

Table 6.5: Physical properties of the soil at the experimental research site in the Coastal Savanna and Forest Zones

Untreated soil sample		
Soil properties	Legon (Coastal Savanna)	Kade (Forest zone)
Bulk density (g/cm ³)	1.44	1.47
Porosity (%)	83.81	81.40
Water holding capacity (%)	44.77	47.37

Table 6.6: Chemical properties of the experimental soil at research sites

Soil samples		
Soil properties	Legon (Coastal Savannah)	Kade (Forest Area)
pH	4.20	6.71
Organic carbon (%)	0.22	0.57

Organic matter (%)	0.38	0.96
N%	0.16	0.17
Avail. P (mg/kg)	5.90	12.88
Available K (mg/kg)	0.12	0.07
Ca (Cmolc Kg-1)	0.29	0.92
Mg (Cmolc kg-1)	0.08	0.21
EC (dS/m ²)	0.01	0.46
CEC (Cmol ⁺ /kg)	9.14	12.01

6.3.1 Effect of method of establishment on the canopy spread of Bermuda and St.

Augustine's grasses

Canopy spread varied significantly ($p \leq 0.05$) for the grass species for the two places. The Bermuda grass spread faster than St. Augustine's grass at both locations (Figure 6.1). Canopy spread of sod (Bermuda) recorded 190.3 cm and 450 cm at 3 WAP and 13 WAP respectively indicating earlier spread in Bermuda grass as compared with St. Augustine's grass. However, canopy spread in Stolon (Bermuda) was slower (93 cm and 246 cm at 3 WAP and 13 WAP respectively) at the coastal savanna compared to that of the forest zone. The effect of sod treatments on canopy spread were significantly ($p \leq 0.05$) slower at both locations compared with stolon treatments. At both locations, Stolon (St. Augustine's) recorded slowest canopy spread among other treatments. The performance of the materials differed for both locations and within location. While there was no significant difference in the spread between stolon for Bermuda, sod for St Augustine's and stolon for St Augustine's for the coastal savanna, the spread for sod Bermuda was significant compared to the others at the coastal. Consistently the spread of sod for Bermuda was the highest and stolon for St. Augustine's was the least. Whilst there was no significant difference in the spread between

stolon sod for St Augustine's and stolon for Bermuda, this was different for the spread in the forest zone. For the same treatments the sod and stolon of Bermuda was greater than that of St. Augustine's. the least spread was observed in stolon for St. Augustine's sod seemed to be better than the use of stolon in the establishing turfgrass, but this differed depending on the ecology.

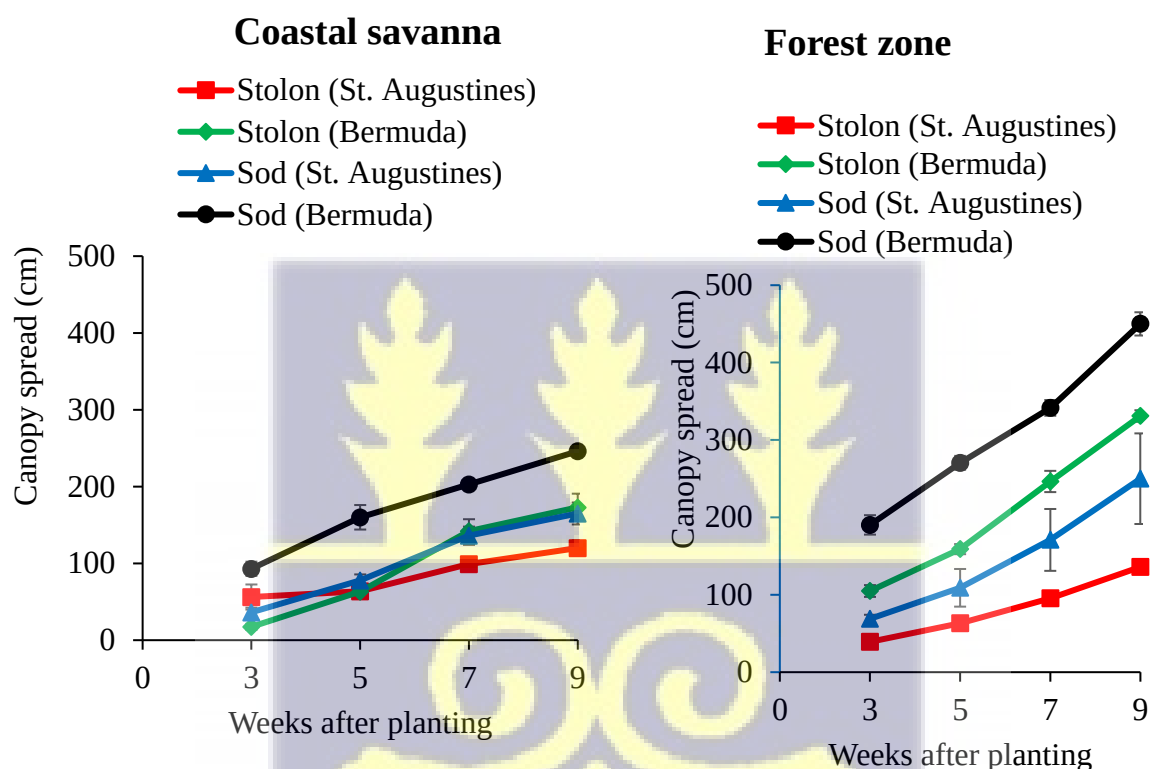


Figure 6.1 Effect of method of establishment on the canopy spread of sod and stolon of Bermuda and St. Augustine's grasses

6.3.2 Changes in leaf chlorophyll content of sod and stolons of Bermuda and St. Augustine's grasses during the experimental period

Significant variations ($P \leq 0.05$) were noticed for leaf chlorophyll content of the grasses with the planting methods throughout the sampling periods at both locations. Inversely, the impact of grasses and stolons and sod interaction was statistically significant for this parameter at coastal

savanna. For forest zone, the control of grass, stolon and sod interaction significantly impacted the leaf chlorophyll content of grass across the sampling periods, except for sod (Bermuda) and Stolon (Bermuda) (Fig. 6.2). Leaf chlorophyll content below the diverse planting methods largely augmented from 3 WAP to a topmost at 9 WAP. Stolon Bermuda and Sod (Bermuda) cultivated gave the minimum leaf chlorophyll content at both locations. The highest chlorophyll content of leaves was observed for both Stolon (St. Augustine's grass) and Sod (St. Augustine's grass), with Stolon (St. Augustine's grass) recording the highest chlorophyll content at the coastal savanna whereas Sod (St. Augustine's grass) recorded the highest chlorophyll content of leaves at the forest zone. Moreover, leaf chlorophyll content declined in Bermuda grass at 9 WAP in coastal savanna whereas at the forest zone, it was the reverse. Similarly, leaf chlorophyll content in St. Augustine's grass increased steadily at coastal savanna whereas at the forest zone, a sharp increase at 9 weeks after planting.



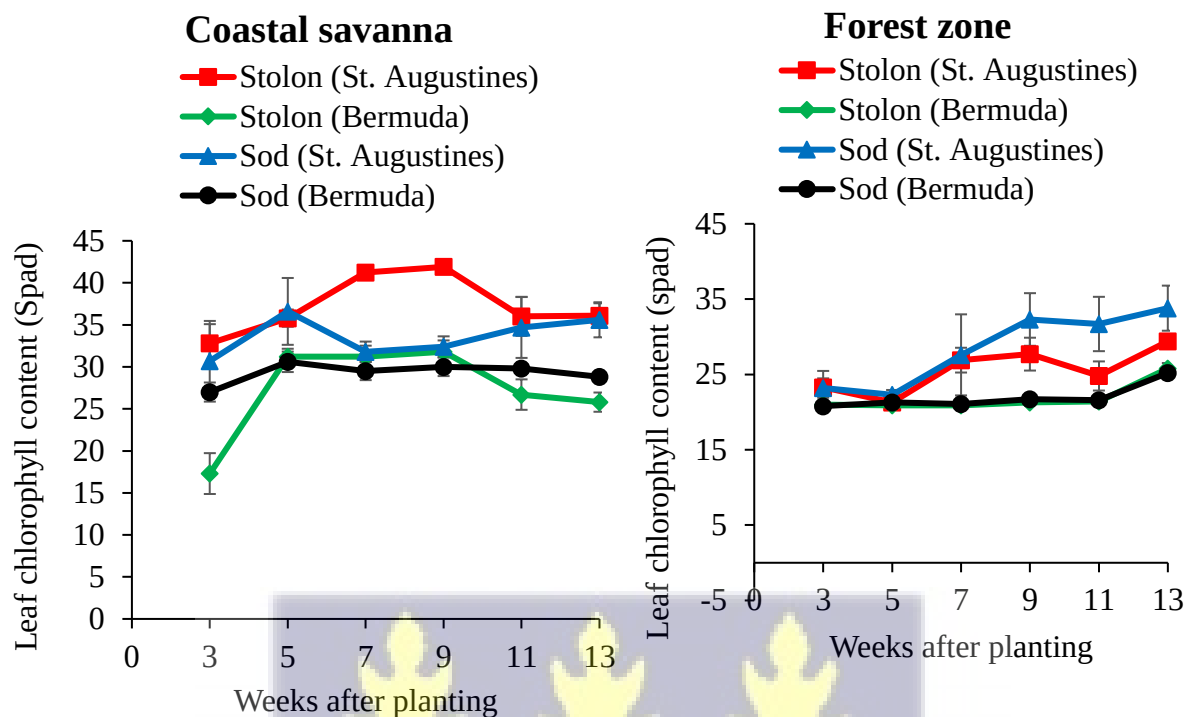


Figure 6.2: Changes in leaf chlorophyll content of sod and stolons of Bermuda and St. Augustine's grasses during the experimental period

6.3.3 Effect of method of establishment on the internode length of sod and stolon of Bermuda and St. Augustine's grasses

Grasses, planting methods and location interaction had significant impact ($P \leq 0.05$) the internode length of grasses across the sampling periods at both locations (Fig. 6.3). Internode length of Sod (Bermuda) and Sod (St Augustine's grass) presented an advanced increase throughout the selection periods from 3 WAP to 13 WAP at both sites. Highest length was detected for sod (Bermuda) and sod (St. Augustine's grass) in grass establishment than those planted by stolons. Sod (Bermuda) at the coastal savanna produced the longest grass internode of 9.4 cm at 13 WAP, whereas stolon (Bermuda) recored the shortest internode with 6.2 cm. Internode length for the sod (St. Augustine's grass) produced the longest grass internode of 8.1cm whereas stolon (St. Augustine's grass)

recorded the shortest internode length of 6.8cm at 13 WAP at the forest zone. The internode length spread was greater in the coastal savanna than the forest; for example Bermuda sod ranged between 1 cm at 3 weeks, to 6 cm at 13th week, while that of Bermuda sod ranged between 4 cm and 10 cm for the 3 and 13th weeks respectively for stolon St Augustine's, this was from 2 cm at 3 weeks and 8 cm at 13th week for coastal savanna. The internode length of Bermuda sod was significantly different from that of the stolon for St. Augustine's. This was different for the internode length for the forest zone. There was no significant difference in the internode lengths among the various treatments in the forest region. The range of the internodes was between 6 cm and 9 cm in the forest zone.

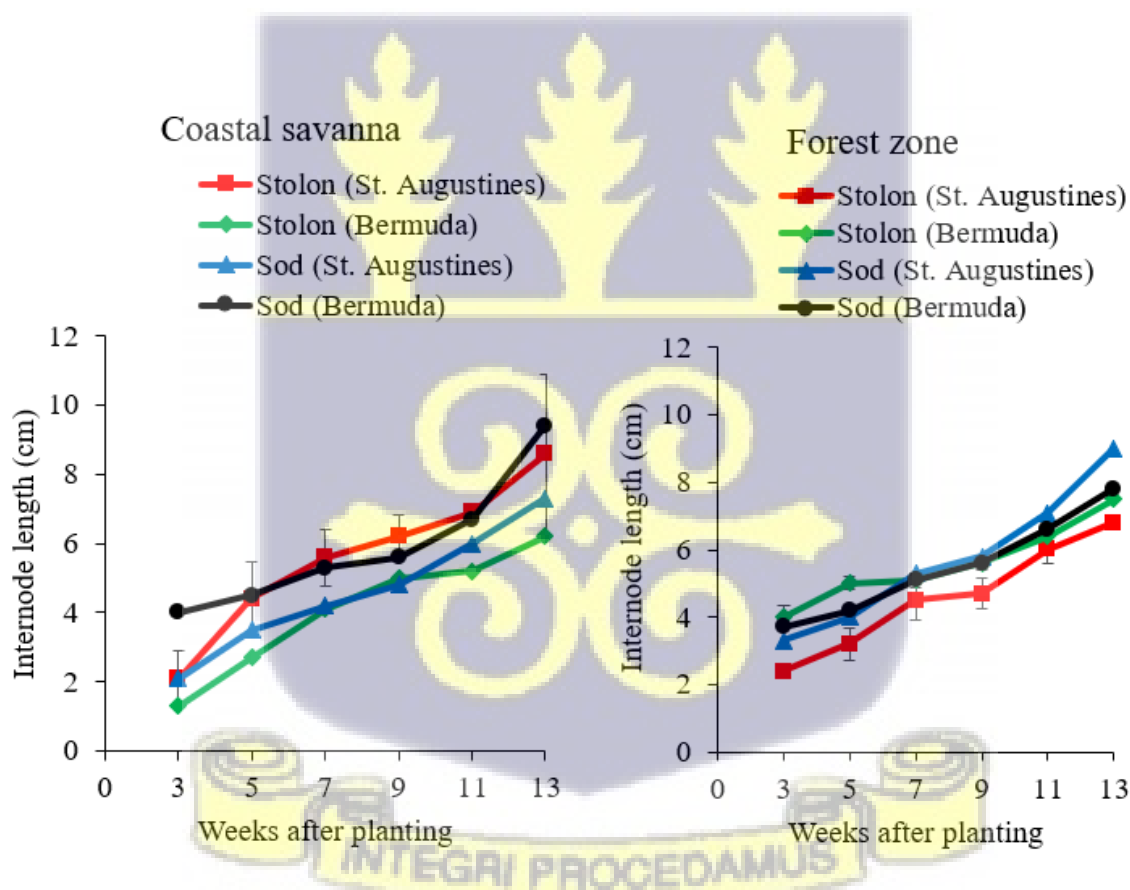
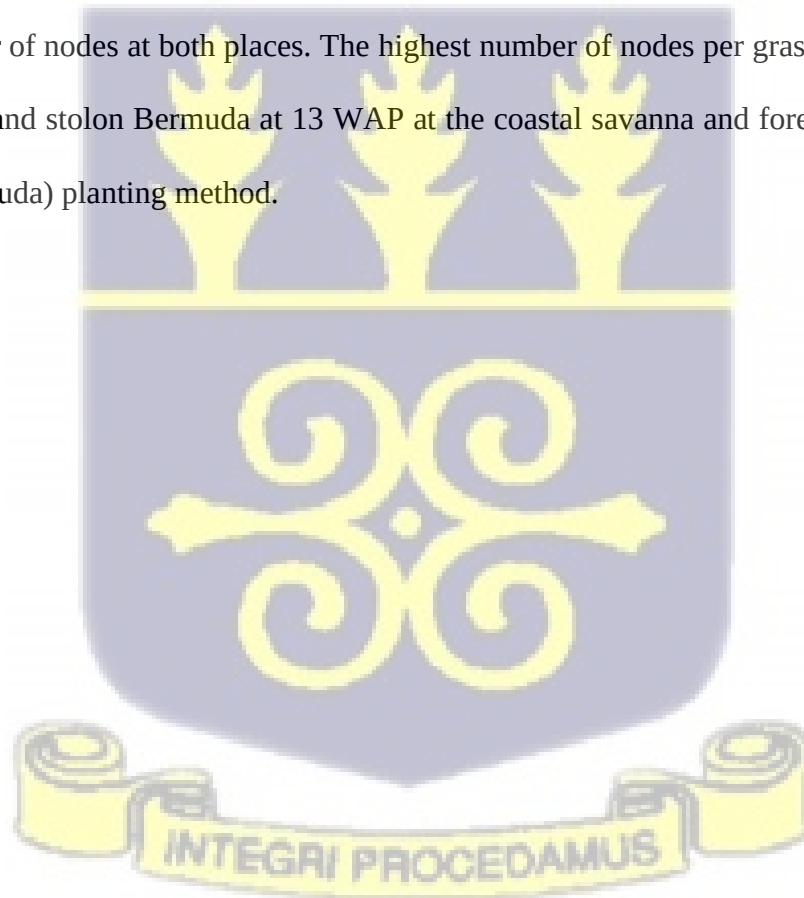


Figure 6.3: Internode length of Bermuda and St. Augustine's grasses as influenced by establishment method in coastal/forest zones

6.3.4 Effect of method of establishment on the number of nodes of sod and stolon of Bermuda and St. Augustine's grasses

Significant variations ($P \leq 0.05$) were noticed for quantity of nodes of grasses with the planting regimes throughout the sampling periods at both locations (Fig. 6.4). Inversely, the impact of grass and planting methods interaction was statistically significant for this treatment at the coastal savanna. At the forest zone, the influence of grass and planting method interaction significantly influenced the number of nodes across the sampling periods except at 9, 11 and 13 WAP (Fig. 6.4). Number of nodes under the different planting methods generally increased from 3 WAP to a peak at 13 WAP. Stolon (St. Augustine's grass) and sod (St. Augustine's grass) planted provided the least number of nodes at both places. The highest number of nodes per grass was detected for sod (Bermuda) and stolon Bermuda at 13 WAP at the coastal savanna and forest zones followed by stolon (Bermuda) planting method.



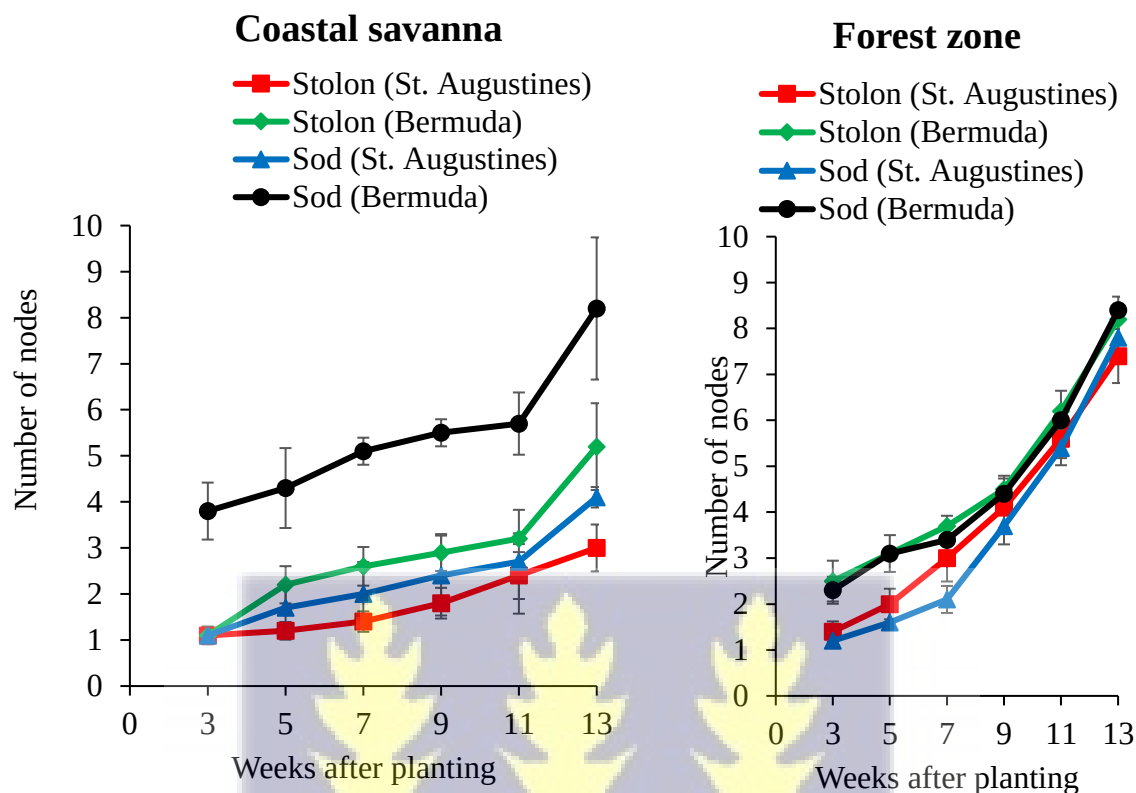


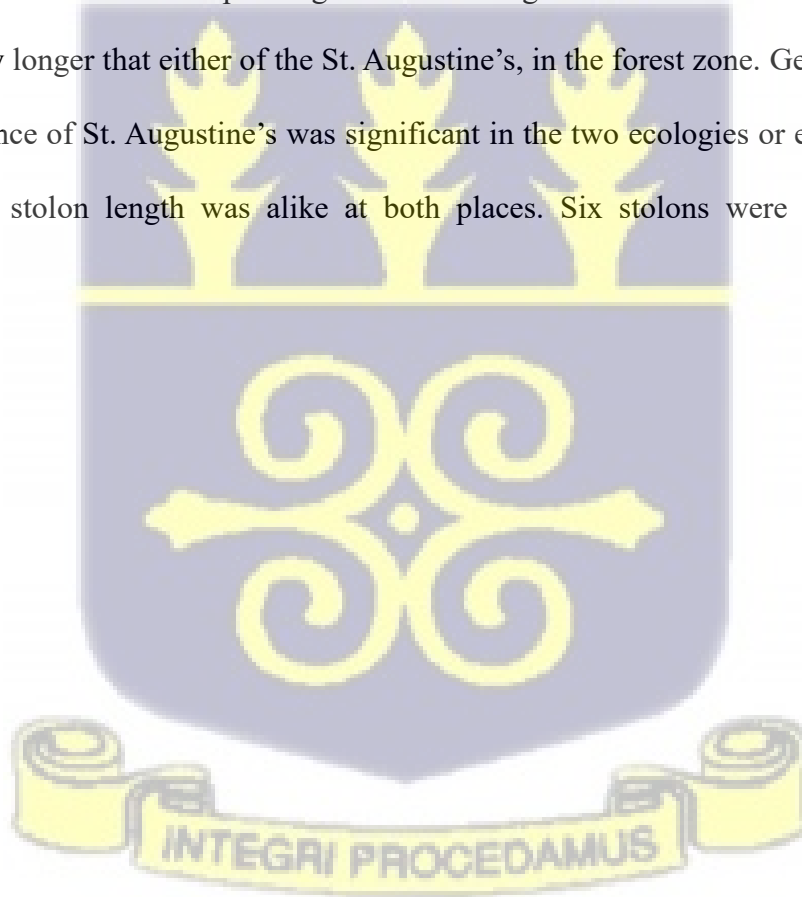
Figure 6.4: Effect of method of establishment on the number of nodes of sod and stolon of Bermuda and St. Augustine's grasses.

6.3.5 Performance of stolon length of Bermuda and St. Augustine's grasses established from sod and stolons, 13 weeks after planting

The length of stolons varied significantly with the planting methods and the time of planting but for sod (St. Augustine's grass) and Stolon (Augustine's grass) planting materials at the forest zone (Fig. 6.5). The varietal effect on the stolon length of both grasses was significant across the six sample periods at the coastal savanna, whereas the impact of planting methods was significant at 9 WAP, 11 WAP and 13 WAP at the forest zone. Sod (Bermuda) reached the highest stolon length .at 13 WAP at both locations. In the coastal savanna, the longest stolon of 55.6 cm was obtained by sod (Bermuda) and 53.8 cm by sod (St. Augustine's) in the forest zone.

The longest stolon length was observed in Bermuda sod that recorded 55.6 cm, and this was longer and significantly different from the other treatment. No significant differences in stolon length were observed between St Augustine's, Bermuda solon and St. Augustine's stolon for the treatments at the coastal savanna.

In the forest zone the performance of the stolon length was different. similar to the stolon length recorded at the coastal savanna, Bermuda stolon recorded the longest stolon length at 13th week. Furthermore, the difference in stolon length of Bermuda sod was significant compared to Bermuda stolon. However, no difference in stolon length was observed between St. Augustine's sod or stolon in the forest zone 13 weeks after planting. the stolon length of both Bermuda planting materials was significantly longer than either of the St. Augustine's, in the forest zone. Generally, the stolon length performance of St. Augustine's was significant in the two ecologies or environments. The development of stolon length was alike at both places. Six stolons were used in this data presentation.



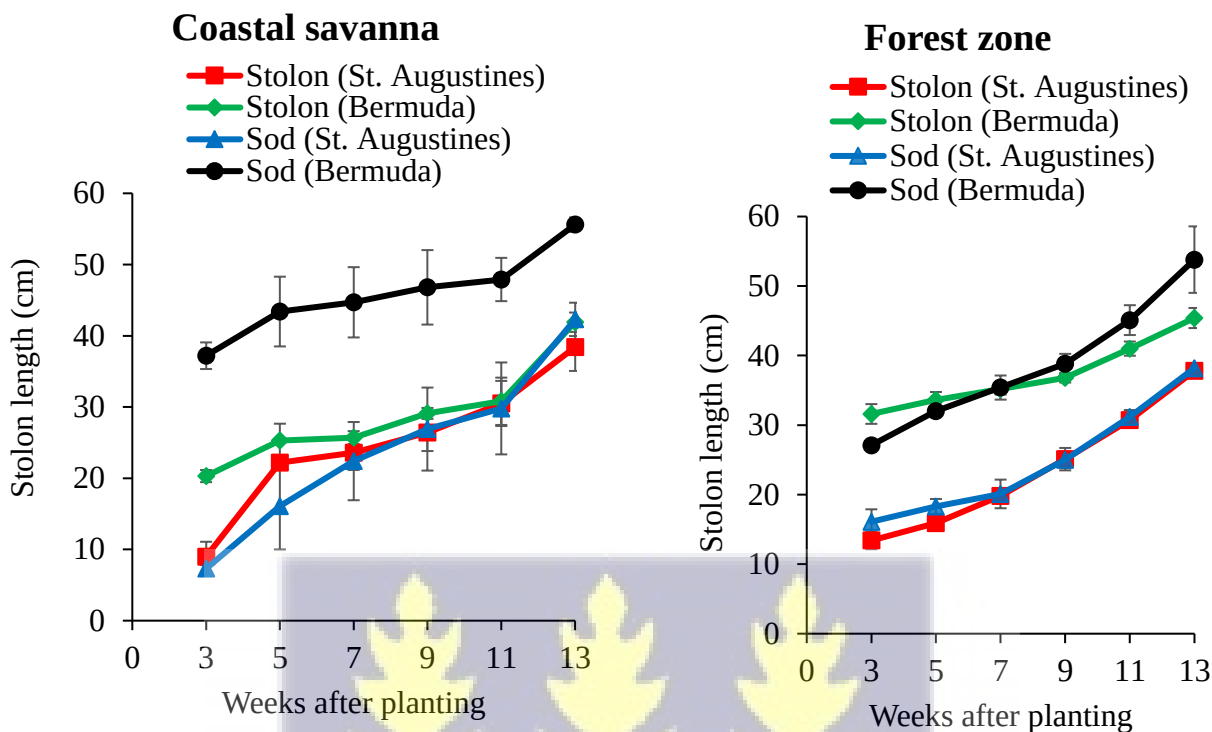


Figure 6.5: Performance of stolon length of Bermuda and St. Augustine's grasses established from sod and stolons, 13 weeks after planting in the coastal savanna (left) and Forest zone (right).

6.3.6 Performance of stolon length of Bermuda and St. Augustine's grasses established through sod and stolons in two ecologies.

The variation observed among the grasses and planting methods for stolon length was significant ($P \leq 0.05$) at both sites (Table 6.7). Bermuda grass increased in stolon length than St. Augustine's grass at both agro-ecological zones. Stolon (Bermuda) recorded the longest stolon (130 cm) at coastal savanna, followed by sod (Bermuda) of 105 cm. Sod (Bermuda) had the longest stolon length of 222.7 cm at the forest zone, followed by stolon (Bermuda) of 139.9 cm. Sod (St. Augustine's) grass consistently produced the shortest stolon length at both locations.

Table 6.7: Performance of stolon length of Bermuda and St. Augustine's grasses established through sod and stolons in two ecologies.

Treatment	Coastal savanna	Forest zone
	Stolon length (cm)	Stolon length (cm)
Stolon (St. Augustine's)	84.0 a	113.3 b
Stolon (Bermuda)	130.0 b	139.9 b
Sod (St. Augustine's)	76.2 a	147.8 a
Sod (Bermuda)	105.0 ab	222.7 c
LSD ($P \leq 0.05$)	45.52	27.84
% CV	28.70	52.2

* Means with the same letters are significantly not different.

6.3.7 Performance of stolon dry weight of Bermuda and St. Augustine's grasses established through sod and stolons in two ecologies.

But for the interaction impact of grass and sod (Bermuda) that significantly controlled stolon dry matter ($P \leq 0.05$) at 7 WAP, the variance detected amongst the grasses and planting methods was not substantial at coastal savanna (Table 6.8). The sod (Bermuda) consequence on stolon dry matter at forest zone was substantial at 7 WAP, while the sod (St. Augustine's) interaction effects were not significant. Stolon dry matter of both grasses usually increased from 7 WAP to 13 WAP (Table 6.8). Bermuda grass planted by the sod (Bermuda) recorded the highest stolon dry weight 7 WAP and 13 WAP (122 g/m^2 and 2429 g/m^2) respectively at coastal savanna followed by sod (Bermuda) with 121 g/m^2 at 7WAP and Sod (St. Augustine's) with 1504 g/m^2 at 13 WAP. In the case of St. Augustine's grass, at 13 WAP, the stolon (St. Augustine's) treatment recorded the highest stolon dry weight of 91 g/m^2 , whereas stolon (St. Augustine's) recorded 41 g/m^2 at the

coastal savanna. At the forest zone, St. Augustine's grass planted by sod (St. Augustine's) had the highest stolon dry weight (1462 g/m²), followed by sod (Bermuda) of 1422 g/m², then stolon (Bermuda) of 1374 g/m² and stolon (St. Augustine's) producing the least of 1126 g/m². The stolon dry matter of treatments at 7 WAP followed the same trend observed at the forest zone.

Table 6.8: Performance of stolon dry weight of Bermuda and St. Augustine's grasses established through sod and stolons in two ecologies.

Treatments	Coastal savanna			Forest zone		
	7 WAP	13WAP	RGR	7 WAP	13 WAP	RGR
	DW (g/m ²)	DW (g/m ²)	(g/day)	DW(g/m ²)	DW(g/m ²)	(g/day)
Stolon (St. Augustine's)	91.0 a	1146.0 a	0.060	60.9 a	1126.0 a	0.069
Stolon (Bermuda)	121.0 a	1387.0 a	0.058	78.2 a	1374.0 a	0.068
Sod (St. Augustine's)	41.0 a	1504.0 a	0.086	78.9 a	1462.0 a	0.070
Sod (Bermuda)	122.0 a	2429.0 a	0.071	421.2 b	1422.0 a	0.069
LSD ($P \leq 0.05$)	107.7	1208.1		26.22	470.4	
% CV	62.1	45.0		101.2	18.2	

DW=Dry weight WAP=Week after planting RDW=Relative dry weight

* Means with the same letters are significantly not different from each other.

6.3.8 Number of weeds and weed dry weight observed in plots established with sod and stolons of Bermuda and St. Augustine's grasses in two ecologies

But for the interaction consequence of grass and planting methods that significantly controlled the number of broad leaves ($P \leq 0.05$) during the sampling period, the variance detected amongst the

grass and planting methods was not substantial at coastal savanna (Table 6.9). The planting methods impact on weed DW was not significant at both locations. Stolon (Bermuda) recorded the maximum weed dry matter of 92 g/ m² at coastal savanna followed by stolon (St Augustine's) with 83 g/ m². Moreover, the stolon (Bermuda) material registered the highest weed dry matter of 142 g/ m², after that the stolon (St. Augustine's) recording 94 g/ m² at the forest zone. Generally, sod (Bermuda) and sod (St. Augustine's) treatments recorded few numbers of weeds at both locations. At coastal savanna, stolon (Bermuda) had the highest number of broadleaf weeds with sod (St. Augustine's) recording the highest number of grass weeds. The number of broadleaf and grass weeds at the forest zone followed the same trend observed at coastal savanna. Broadleaf weeds identified were: *Aeschynomene rudis*, *Phyllanthus urinaria*, *Arctium minus* and *Amaranthus spinossis*. Grass weeds identified were: *Dyctyloctenium aegyptium*, *Chloris virgata*, *Eleusine indica* and *Echinochloa colona*.



Table 6.9 Number of weeds and weed dry weight observed in plots established with sod and stolons of Bermuda and St. Augustine's grasses in two ecologies

Treatment	Coastal savanna			Forest zone		
	No.	of	No. of DW (g/m ²)@	No.	of	No. of DW
	broad	grass		broad leaf	grass	(g/m ²)
	leaf	weeds		weeds	weeds	@
	weeds					
Stolon (St. Augustine's)	9 a	41 a	83 a	11 ab	50 a	97 a
Stolon (Bermuda)	12 a	38 a	92 a	18 b	55 a	142 b
Sod (St. Augustine's)	8 a	46 a	61 a	5 a	55 a	77 a
Sod (Bermuda)	10 a	36a	64 a	11 ab	42 a	57 a
LSD ($P \leq 0.05$)	6 NS	19 NS	104NS	13	24	19
% CV	31	21	58	83	21	57

@= dry weights of both broad and grass weeds

* Means with the same letters are not significantly different.

6.3.9 Sod/stolon dry weight of Bermuda and St. Augustine grasses established with sod and stolons in two ecologies

The interaction effect of type of grass and planting methods significantly stimulated sod DW ($P \leq 0.05$) at 13 WAP at both locations (Table 6.10). The stolon effect on sod DW at coastal savanna was significant at 13 WAP, while the sod effect was significant at 13 WAP. Sod (Bermuda) reported the highest sod DW of 330.6 g/ m² at the coastal savanna followed by the sod (St. Augustine's) with 305.7 g/ m². In the case of the forest zone, the sod (Bermuda) reported the maximum sod DW of 294 g/ m², trailed by the sod (St. Augustine's). The sod dry weight at forest zone trailed similar tendency detected at the coastal savanna. Generally, the stolon treatments

produced the least dry matter at both locations.

The environmental sustainability of turfgrasses is an increasingly urgent issue and it involves both a restriction of management inputs and a careful evaluation of species and cultivars that are best adapted to low maintenance requirements. Therefore, regenerative structures such as stolons and rhizomes are increasingly important in cultivar discrimination and development, especially in transition zone environments where they play an important role in survival from stress.

Table 6.10 Sod/stolon dry weight of Bermuda and St. Augustine grasses established with sod and stolons in two ecologies

Treatment	Coastal savanna	Forest zone
	Sod /stolon DW (g/m ²)	Sod/stolon DW (g/m ²)
Stolon (St. Augustine's)	171.5 a	173.2 b
Stolon (Bermuda)	287.8 b	152.3 a
Sod (St. Augustine's)	305.7 bc	244.4 c
Sod (Bermuda)	330.6 c	294.4 d
LSD ($P \leq 0.05$)	35.24	54.77
% CV	25.7	45.4

* Means with the same letters are significantly not different.

6.3.10 Root dry weight of sod/stolon of Bermuda and St. Augustine grasses established with sod and stolons in two ecologies

The interaction consequence of grass and planting methods significantly impacted root dry matter ($P \leq 0.05$) at 13 WAP at both locations (Table 6.11). The sod effect on root DW at coastal savanna was substantial at 13 WAP, while the stolon effect was significant at 13 WAP. Sod (Bermuda) recorded the highest root dry matter of 42.80 g at the coastal savanna followed by the sod (St.

Augustine's) with 39.58 g. In the case of the forest zone, the sod (Bermuda) recorded the highest root dry matter of 51.06 g, followed by the sod (St. Augustine's) recording 31.65 g. The root dry matter at forest zone followed the same trend observed at the coastal savanna. Generally, the stolon treatments produced the least dry matter at both locations.

Table 6.11 Root dry weight of sod/stolon of Bermuda and St. Augustine's grasses established with sod and stolons in two ecologies

Treatment	Coastal savanna	Forest zone
	Root dry weight (g)	Root dry weight
Sod (St. Augustine's)	39.58 bc	31.65b
Sod (Bermuda)	42.80 c	51.06c
Stolon (St. Augustine's)	22.20 a	22.42a
Stolon (Bermuda)	37.26 b	19.72a
LSD ($P \leq 0.05$)	4.56	7.09
%CV	25.7	45.43

* Means with the same letters are significantly not different.

6.4 Discussion

6.4. Effect of method of establishment on the canopy spread of sod and stolon of Bermuda and St. Augustine's grasses

The outcomes usually presented that Bermuda grass was superior for entirely the morphological characters including canopy spread, stolon length, number of nodes and internode length compared to the St. Augustine's grass (Dhanasekaran 2018). These variances might be credited to the differences in soil type as forest zone had higher bulk density than the coastal savanna, and intrinsic

hereditary features such as, sluggish growth habit, meagre dispersal and canopy making feature of St. Augustine's grass (Dhanalakshmi 2015). Bulk density directly affects the above ground biomass and underground biomass (Wu *et al.*, 2017). Soil of high bulk density restrict roots growth and development which ultimately affect above ground biomass production in grasses at the forest zone compared with that of the coastal savanna. This confirms earlier work done by Lardy *et al.*, (2022) on "effects of soil bulk density and water content on penetration resistance". Also in the present study, Bermuda grass spread faster than the St. Augustine's grass in both agro- ecologies that is because of differences in the genetic make-up of both grasses. Mathew *et al.*, (2020) reported earlier, that Bermuda grass obtained the maximum ground cover in their study. Sod treatments recording the highest rooting might have stimulated initial spread, fast growth and development of the grasses thus reducing the establishment period at both locations. This confirms earlier work done by Chaudhary, (2022). With the quick development of the basis, the late canopy spread detected in all the stolonization planting methods was because stolons develop roots at the site after planting unlike sod that comes in with intact roots. In this case, sod treatment comprising of grass with growing media attached bound to its roots allows it to continue growing seamlessly when transplanted, compared with stolon treatment (Owusu *et al.*, 2023). Yi (2012) significantly produced almost instant results in football and soccer pitches as well as lawns early. This is in agreement with Chaudhary, (2022) who recorded that sod turfgrass establishes faster when sod is used than planting stolons.

6.4.2 Changes in leaf chlorophyll content of sod and stolons of Bermuda and St. Augustine's grasses during the experimental period

Chlorophyll substance signifies the concentration of the green colour and is measurable quality parameter for turf "(Dhanalakshmi *et al.*, 2018)". Chlorophyll content in lawn grasses is not only

for photosynthetic props but for aesthetic value. For instance, grasses such as St. Augustine and Bermuda grass exhibit medium green colour whereas Taiwan grass is noted for dark green colour. Therefore, these different species having different colours could be used for creating shades of green colour in a lawn or turf. Chlorophyll content in the leaves is directly influenced by climatic conditions such as temperature and rainfall. From the present study, chlorophyll content was high in the St. Augustine's treatments in coastal savanna and this may be due to higher temperatures at the period of study. However, the chlorophyll content was relatively low in both grass species in the forest region where temperatures are low with high amount of rainfall. This is in agreement with the results by Li *et al.*, (2018), who studied on the factors influencing leaf chlorophyll content in natural forests and recorded environmental factor such as temperature and precipitation had influence on chlorophyll content and thus, determined photosynthetic capability and henceforth plant growth. They continued to argue that the synthesis of chlorophyll requires to go through a series of enzymatic reactions, and when the temperatures are too high or low, inhibiting the enzyme reaction, to even destroy the original chlorophyll. The optimum temperature required for chlorophyll synthesis is 30°C with precipitation affect the photochemical activity of chloroplasts of plants (Li *et al.*, 2018).

St. Augustine's grass generally produced more chlorophyll than Bermuda grass at both locations. This may be due to varietal differences in the sense that St. Augustine's grass has broad leaves, whereas Bermuda grass has narrow leaves. Therefore, with broader leaves, St. Augustine's grass is able to trap more sunlight for photosynthesis. In the present study, concentration of total chlorophyll among Bermuda and St. Augustine's grass increased in May/June and early August, 2023. As all sun tolerant turfs grow best in high temperatures, it augmented the chlorophyll to extreme in hot months. This agrees with Solanki *et al.*, (2021). Chlorophyll amount is inclined by

hereditary features of the species, growing conditions “(biotic and abiotic stress)” along with survivability to specific location (Solanki *et al.*, 2021).

6.4.3 Effect of method of establishment on the internode length of sod and stolon of Bermuda and St. Augustine’s grasses

The results obtained in this study have shown some variation in internode length of the Bermuda and St. Augustine’s grasses to the coastal and forest environments. The high bulk density observed in the forest zone restricted the growth of development resulting in slow growth of stolons internodes. The results are in line with earlier work done by Fotis *et al.*, (2018) on “Above-ground biomass driven by mass-ratio effects and stand structural attributes in a temperate deciduous forest”. Also, low forest temperatures and inappropriate trimming regime may have had some influence on the results. The highest internode growth parameters in sod treatments could be attributed to vigorous growth of grass. This result was in conformity with Mathew *et al.*, (2020) in Bermuda, and Agnihotri, *et al.*, (2017) in St. Augustine. The internode length tallness upsurges increasingly with rise in grass age in Bermuda and St. Augustine’s grass species. This may contribute to enormous root, stolon, and foliage growth and effectual nutrient absorption, letting the plant to linger to develop longer internode. All these growth features are influenced by climatic conditions such as temperature and rainfall. The current result also indicated that the longest internode was recorded for Bermuda and St. Augustine’s sod. This may be ascribed to earlier establishment of sod, media and climatical circumstances at the coastal and forest regions.

6.4.4 Effect of method of establishment on the number of nodes of sod and stolon of Bermuda and St. Augustine’s grasses

Number of nodes per stolon varied among treatments in the coastal and forest environments. It is interesting to know that Bermuda grass produced more nodes in both coastal and forest regions

than St. Augustine's grass. The highest nodes developed could be attributed to vigorous growth of Bermuda grass. This result was in conformity with Mathew *et al.*, (2020) who recorded the highest number of nodes in Bermuda grass. However, comparing these two locations, Bermuda grass produced more stolon nodes in the coastal region than in the forest region. This may be due to the low bulk density and high temperature in the coastal region with relatively low rainfall distribution compared with that of the forest region. Like other agronomical characters, node production is also stimulated by difference in soil kind, temperature, amount and supply of precipitation, genetic constitution and trimming phase. Trimming influences node production because tillers or stem maintains vegetative and the apical meristem is unknown and hypothetically can produce an immeasurable quantity of fresh nodes and leaves.

6.4.5 Performance of stolon length of Bermuda and St. Augustine's grasses established from sod and stolons, 13 weeks after planting

The observed result of stolon length increment in Sod (Bermuda) at coastal and forest environments may come from hereditary disparity of turf variety, soil kinds, supervision, and climatical circumstances. Stolon length augmentation was steady with grass age. Sod appeared greater owing to healthier root diffusion and additional obtainability of nutrients which enhanced stolon development in Bermuda turf at both locations. Differences in stolon length might be ascribed to types of turf, earth, and climatical circumstances. St. Augustine's grass however had shorter stolon length in the forest region. This agrees with Ma *et al.*, (2021) who researched on "the global distribution and environmental drivers of aboveground versus belowground plant biomass". Low forest temperatures and an unsuitable trimming regime may have had some impact on the results. Stolon longevity is also related to plant habit. St. Augustine's grass with a running

habit (bunch or clump-forming grasses) show a lower cold tolerance than rhizomatous upright grasses (Solanki *et al.*, 2021) and thus, influenced by agroecological variations.

6.4.6 Performance of stolon dry weight of Bermuda and St. Augustine's grasses established through sod and stolons in two agroecologies.

The increased dry weight of grass in this study for the sod (Bermuda) and sod (St. Augustine's) planting materials was not astonishing because those materials had intact roots before planting on the field, for fast growth of turf. Coastal savanna recording the highest DM was as a result of low bulk density of soil which promoted more biomass production in both grasses. This confirms earlier work by van der Sande *et al.*, (2018) on "Soil fertility and species traits, but not diversity, drive productivity and biomass stocks in a Guyanese tropical rainforest". The fast growth of the basis also provided additional period for the multiplicative stage as revealed in the lengthy spread phase of the turf treated plots. This permitted additional period for photosynthesis and segmentation of DM to the stolon and yield. This could have brought about the universal advanced harvest obtained from the sod planting materials, whereas the combined effect of Bermuda grass and sod (Bermuda) described predominantly for the increased dry matter as also with the St. Augustine's grass. The superiority of the sod treatments was likewise observable in the morphological data such as stolon length; number of nodes and stolon dry mass of the grass assumed them the proportional benefit to adapt additional photosynthates for division to the stolons and trimmings. This extended vegetative growth resulted in enhanced stolon length and number of nodes and eventually the enhanced produce of the sod (Bermuda) and sod (St. Augustine's) treatments.

6.4.7 **Response of root dry weight of sod/stolon of Bermuda and St. Augustines grasses established with sod and stolons in two ecologies**

Roots imbibe H₂O and nutrients from the earth and sustain above ground stolon. The growth and dry matter of stolons depend on the development of underneath root dry matter (Merrill *et al.*, 2002; Fageria & Moreira, (2011). Roots biomass affects the establishment and performance of turf grasses on the field for optimum nutrients and up-take (Paustian *et al.*, 1997).

Disparities in root growth and circulation in the soil profile amongst planting methods can bring variances in H₂O and nutrient imbibement by roots. High bulk density in the forest zone decreased roots dry weight due to a decrease in root biomass production. This agrees with the work by Farooq *et al.*, (2019) on “growth, biomass production and root development of Chinese fir in relation to initial planting density”. Roots that raise nearby H₂O and nutrient accessibility are typically solid, have big width, and are vigorous in growth and substance uptake (Pierret *et al.*, 2007). The greater root dry matter in sod (Bermuda) than other planting methods (Table 11) displays the spread of roots at the shallow soil probably related to increased accessibility of soil water and nutrients as revealed in other research (Hodge, 2004; Skinner and Comas, 2010). Extra likely explanations for superior root dry matter might be for improved nutrient accessibility, decreased soil bulk density, and/or dissimilar soil texture that endorsed root growth at both locations, but these features were not scrutinized in the study. The lower root dry matter was a consequence of meagre growth that also decreased stolon yield as revealed above, even though the turf growing period and yearly rainfall were superior than the means (Table 8 &10). Bollinder *et al.*, (2002) instituted that fine brome grass produced inferior root yield at zero to fifteen centimeters than some grasses in early years in easterly Canada. Variations in earth and climatical circumstances at both locations, management activities, depth of soil sample, and age of turf might have caused disparities in root dry matter of planting methods among locations and periods of study. Lesser values for root

biomass for sod and climatic settings “(annual precipitation 350–400 mm)” in coastal savanna because of less yearly rainfall, as forest zone has more annual precipitation than the coastal savanna.

6.4.8 Number of weeds and weed dry weight observed in plots established with sod and stolons of Bermuda and St. Augustine’s grasses in two ecologies

Method of establishment has effect on weed growth. On the ground cover of grasses is controlled by means of planting and main climatic variations (Braun *et al.*, 2020). More grass weeds as well as broadleaf weeds were recorded in the forest zone which may be due to the high level of seed bank contained in the soil compared with that of the coastal savanna recording the least weeds. This agrees with the work done by Siva (2014) on “Alternative strategies for broadleaf weed management in residential lawns”. Turf grass established by stolon recorded significantly highest total weed count with highest dry matter and lowest canopy spread. Whereas, lowest total weed count and highest canopy spread score was recorded for sod treatments. This agrees with the work done by Ervin *et al.*, (2022) on “Contemporary challenges and opportunities for improved lawn weed management”. Bermuda grass which was on par with St. Augustine’s grass established through sod. It might be ascribed to healthier establishment and aggressive nature of sod (Bermuda) and sod (St. Augustine’s) treatments which decreased the weed populace and variation in growing pattern of turf at different phases of growth. Broadleaf weeds identified were: *Aeschynomene rudis*, *Phyllanthus urinaria*, *Arctium minus* and *Amaranthus spinosa*. Grass weeds identified were: *Dyctyloctenium aegyptium*, *Chloris virgata*, *Eluesine indica* and *Echinochloa colona*.

6.5 Conclusion

Root dry weight of sod was greater than stolon for both Bermuda and St Augustine's in both agroecological zones. Sod was observed to be a better propagating material than stolon recording higher root dry weights in both agroecological zones, control more weeds, during experimental period. The different environments (coastal savanna and forest zone) affected the performance (trimmed dry weight, root dry weight, tillering, leaf chlorophyll content and canopy spread) of Bermuda and St. Augustine's grasses in growth and dry matter production. The observed differences could be due to environmental factors (such as rain fall amount, soil type, nutrient release and absorption patterns) and genetic factors between Bermuda and St. Augustine's grasses.

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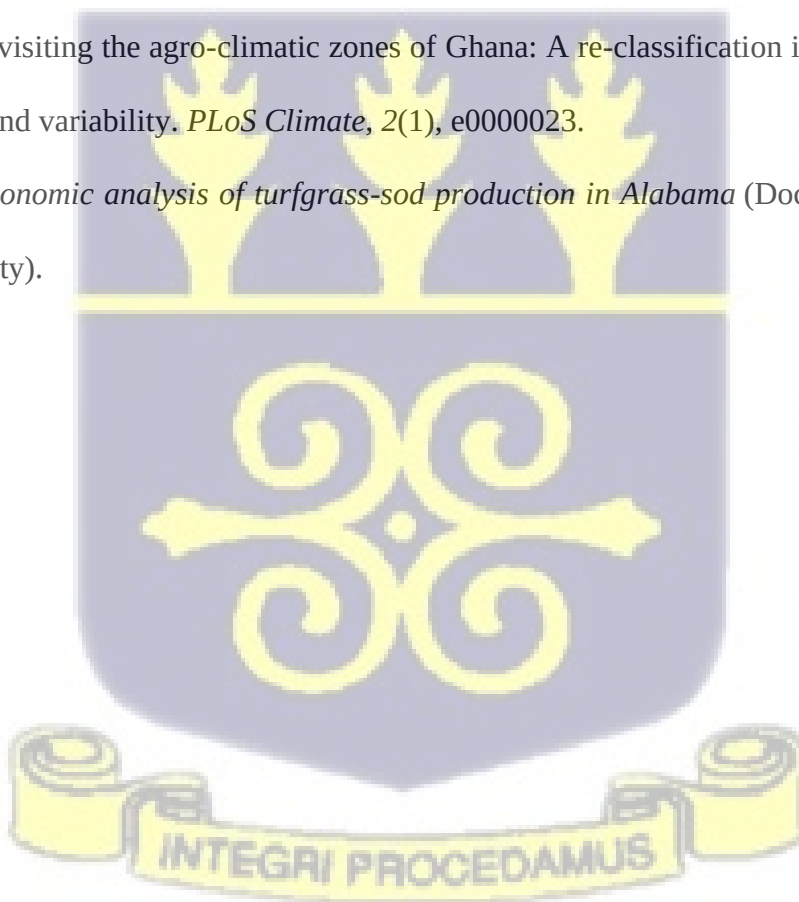
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CHAPTER SEVEN

7.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

7.1 General conclusions

It is preferable to use locally available materials such as poultry manure, rice husk biochar and sawdust because they are cheap, and easily accessible which will reduce the cost of production of sod. These organic materials also contain enough nutrients for plants growth and development. Different species however need to be assessed accordingly. The results of this study demonstrated clearly the ability of biochar to reduce EC depending on rate of application and biochar surface area.

Bermuda grass took shorter days to emerge than St Augustine's grass and the grasses varied in their growth performances as influenced by different growing media. All the amended growing media took shorter days to reach 50% emergence and recorded higher growth indices than the control. Increasing PM+RHB reduced grass growth parameters thereby reducing total dry matter produced. In contrast, increased SD+PM increased grass growth and dry matter buildup. Growing medium M3 comprising Topsoil : PM : RHB : Clay in the ratio of 50:30:15:5 was found to be the best in sod production under the conditions of this research, in terms of stolon length, tiller number and chlorophyll content. Whilst M2- composed of topsoil: PM: RHB: Clay in the ratio of 60:20:15:5 recorded bigger stolon girth, shoot fresh weight, shoot dry weight, root fresh weight and root dry weight and the highest total dry matter.

For Cynodon dactylon L, 98 dibble/m² planting density favored quick establishment of turfgrass.

It also possessed appropriate growth habit for lower frequency of lawn trimming and minimal weed infestation. Morphological characters of Bermuda grass and its adaptability to the tropical

environment increased its vegetative growth. Moreover, at closer planting density weed grow was minimal. the results of the study further indicated that shallow (1.5 cm) planting depth of Bermuda grass did not affect its survival. Although sowing depths (2.5 cm and 3.5 cm) had an impact on the emergence of the grass. Bermuda grass successfully recovered from delay in the emergence, and responded positively to the planting stress. Stolons of 10cm length in all planting density of 1.5 cm produced the highest stolon length.

Bermudagrass sod favored quick establishment of turfgrass and appropriate growth habit. St. Augustine's grass established slowly ensuring lower frequency of lawn mowing and minimal weed growth. Morphological characters of both grass species and their adaptability to the agroecological environments increased the vegetative growth of the grasses. Bermudagrass covered quickly and led to earliness for establishment.

7.2 Recommendations

Based on the findings of the study, the following recommendations are suggested:

More ratios of the organic materials (poultry manure, sawdust rice husk biochar, and also compost) must be investigated to assess their effect on the grasses. This is because different ratios will have different impact on the performance of the growing media.

1. Bermuda grass is highly recommended for faster establishment. Further research is needed to look at the use of grass seed instead of stolon's for sod establishment.
2. *Cynodon dactylon* grown at 98 dibble/m² planting density covers quickly and leads to earliness of establishment because of its greater capacity to adapt to the environment. A closer spacing is recommended for further study.
3. Medium planting depth (2.5 cm) is recommended for cultivation of both Bermuda and St. Augustine's grass as it produces highest grass dry biomass required by sod producers

and for pasture growers. These results can play an important role in the establishment of propagation protocols of Bermuda grass.

4. Vegetative propagation using stolons might help to meet the current and future demands on *Cynodon dactylon*. Further studies are recommended to confirm the results of this study in the same as well as in different agro-ecologies.
5. Bermudagrass sod is highly recommended for lawns establishment. Future research work can be conducted to evaluate how nutrient levels and water stress of grasses can influence sod performance in all agroecological zones in Ghana. Sod production in the coastal savanna is highly recommended over the forest zone.



APPENDICES**Appendix 1: Emergence (%) at 3 weeks after planting**

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	4	367.20	91.80	1.39	0.273
Grass	1	19354.80	19354.80	292.96	<.001
Media. Grass	4	1106.53	276.63	4.19	0.013
Residual	20	1321.33	66.07		
Total	29	22149.87			

Appendix 2: Emergence (%) at 7 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	4	2230.13	557.53	8.62	<..001
Grass	1	20803.33	20803.33	321.70	<.001
Media. Grass	4	1590.67	397.67	6.15	0.002
Residual	20	1293.33	64.67		
Total	29	25917.47			

Appendix 3: Chlorophyll content at 3 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	4	75.31	75.31	5.95	0.024
Grass	1	177.38	44.35	3.50	0.025
Media. Grass	4	256.01	64.00	5.06	0.006
Residual	20	253.14	12.66		
Total	29	761.85			

Appendix 4: Chlorophyll content at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	65.02	65.02	4.21	0.053
Grass	4	106.47	26.62	1.72	0.184
Media. Grass	4	112.87	28.22	1.83	0.163
Residual	20	308.73	15.44		
Total	29	593.10			

Appendix 5: Stolon girth at 3 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	9.09151	9.09151	333.59	<.001

Grass	4	0.51548	0.12887	4.73	0.008
Grass.Media	4	0.04854	0.01214	0.45	0.774
Residual	19	0.51782	0.02725		
Total	28	9.68723			

Appendix 6: Stolon girth at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	4102.0	4102.0	7.58	0.012
Grass	4	21155.0	5288.8	9.77	<.001
Grass.Media	4	4413.3	1103.3	2.04	0.127
Residual	20	10824.5	541.2		
Total	29	40494.8			

Appendix 7: Stolon length at 3 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	6035.01	6035.01	418.11	<.001
Grass	4	610.36	152.59	10.57	<.001
Grass.Media	4	297.61	74.40	5.15	0.005
Residual	20	288.68	14.43		
Total	29	7231.66			

Appendix 7: Stolon length at 3 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	6035.01	6035.01	418.11	<.001
Grass	4	610.36	152.59	10.57	<.001
Grass.Media	4	297.61	74.40	5.15	0.005
Residual	20	288.68	14.43		
Total	29	7231.66			

Appendix 8: Stolon length at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	4102.0	4102.0	7.58	0.012
Grass	4	21155.0	5288.8	9.77	<.001
Grass.Media	4	4413.3	1103.3	2.04	0.127
Residual	20	10824.5	541.2		
Total	29	40494.8			

Appendix 9: Root dry weight at 7 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	0.044699	0.044699	10.62	0.004
Grass	4	0.023788	0.005947	1.41	0.266
Grass.Media	4	0.019139	0.004785	1.14	0.367
Residual	20	0.084143	0.004207		
Total	29	0.171769			

Appendix 10: Root dry weight at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	0.11569	0.11569	5.64	0.028
Grass	4	0.20553	0.05138	2.51	0.075
Grass.Media	4	0.18204	0.04551	2.22	0.104
Residual	20	0.41020	0.02051		
Total	29	0.91347			

Appendix 11: Root volume at 7 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	0.00040	0.00040	0.03	0.855
Grass	4	0.09188	0.02297	1.96	0.140
Grass.Media	4	0.02061	0.00515	0.44	0.779
Residual	20	0.23453	0.01173		
Total	29	0.34743			

Appendix 12: Root volume at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	0.21675	0.21675	5.37	0.031
Grass	4	0.50467	0.12617	3.13	0.038
Grass.Media	4	0.73533	0.18383	4.56	0.009
Residual	20	0.80667	0.04033		
Total	29	2.26342			

Appendix 13: Shoot dry weight at 7 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	0.36300	0.36300	4.41	0.049

Grass	4	2.93667	0.73417	8.92	<.001
Grass.Media	4	2.41533	0.60383	7.33	<.001
Residual	20	1.64667	0.08233		
Total	29	7.36167			

Appendix 14: Shoot dry weight at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	16.1333	16.1333	16.59	<.001
Grass	4	21.2553	5.3138	5.46	0.004
Grass.Media	4	14.5167	3.6292	3.73	0.020
Residual	20	19.4533	0.9727		
Total	29	71.3587			

Appendix 15: Number of tillers at 3 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	73.6333	73.6333	109.09	<.001
Grass	4	12.1792	3.0448	4.51	0.009
Grass.Media	4	13.1375	3.2844	4.87	0.007
Residual	20	13.5000	0.6750		
Total	29	112.4500			

Appendix 16: Number of tillers at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	202.800	202.800	155.01	<.001
Grass	4	100.446	25.111	19.19	<.001
Grass.Media	4	41.013	10.253	7.84	<.001
Residual	20	26.167	1.308		
Total	29	370.425			

Appendix 17: Number of weeds

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	0.533	0.533	0.36	0.558
Grass	4	7.800	1.950	1.30	0.304
Grass.Media	4	3.133	0.783	0.52	0.720
Residual	20	30.000	1.500		
Total	29	41.467			

Appendix 18: Weeds dry weight

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	4.0	4.0	0.03	0.868
Grass	4	437.9	109.5	0.77	0.554
Grass.Media	4	194.6	48.6	0.34	0.845
Residual	20	2825.7	141.3		
Total	29	3462.2			

Appendix 19: Trimmed grass dry weight

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Media	1	9310.4	9310.4	24.32	<.001
Grass	4	10130.8	2532.7	6.62	0.001
Grass.Media	4	873.4	218.3	0.57	0.687
Residual	20	7656.4	382.8		
Total	29	27970.9			

Appendix 20: Emergence (%) at 3 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Population	2	228.7	114.3	0.65	0.533
Depth	2	760.7	380.3	2.17	0.143
Population.Depth	4	756.0	189.0	1.08	0.397
Residual	18	3159.3	175.5		
Total	26	4904.7			

Appendix 21: Emergence (%) at 7 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Population	2	128.1	64.0	0.38	0.691
Depth	2	292.7	146.4	0.86	0.439
Population.Depth	4	265.3	66.3	0.39	0.813
Residual	18	3056.7	169.8		
Total	26	3742.7			

Appendix 22: Chlorophyll content at 7 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Population	2	17.85	8.93	0.68	0.518
Depth	2	19.56	9.78	0.75	0.488
Density.Depth	4	83.84	20.96	1.60	0.217
Residual	18	235.76	13.10		
Total	26	357.00			

Appendix 23: Chlorophyll content at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Population	2	18.117	9.058	0.94	0.410
Depth	2	22.261	11.131	1.15	0.338
Density.Depth	4	26.116	6.529	0.68	0.617
Residual	18	173.807	9.656		
Total	26	240.301			

Appendix 24: Stolon girth at 3 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Population	2	0.030646	0.015323	2.25	0.134
Depth	2	0.025862	0.012931	1.90	0.178
Density.Depth	4	0.022676	0.005669	0.83	0.522
Residual	18	0.122500	0.006806		
Total	26	0.201684			

Appendix 25: Stolon girth at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Population	2	0.05013	0.02507	1.37	0.280
Depth	2	0.00343	0.00171	0.09	0.911
Density.Depth	4	0.02903	0.00726	0.40	0.809
Residual	18	0.32955	0.01831		
Total	26	0.41214			

Appendix 26: Stolon length at 3 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Population	2	1322.3	661.2	2.27	0.132
Depth	2	84.6	42.3	0.15	0.866
Density.Depth	4	942.2	235.5	0.81	0.536
Residual	18	5242.4	291.2		
Total	26	7591.5			

Appendix 27: Stolon length at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Population	2	12778.	6389.	5.24	0.016
Depth	2	1621.	810.	0.66	0.527
Density.Depth	4	2795.	699.	0.57	0.686
Residual	18	21957.	1220.		
Total	26	39151.			

Appendix 28: Number of tillers at 3 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Population	2	1.5592	0.7796	0.98	0.394
Depth	2	0.9897	0.4949	0.62	0.548
Density.Depth	4	0.4378	0.1094	0.14	0.966
Residual	18	14.3102	0.7950		
Total	26	17.2968			

Appendix 29: Number of tillers at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Population	2	17.792	8.896	1.41	0.269
Depth	2	6.597	3.299	0.52	0.601
Density.Depth	4	6.778	1.694	0.27	0.894
Residual	18	113.208	6.289		
Total	26	144.375			

Appendix 30: Trimmed grass dry weight at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Population	2	653.1	326.6	0.66	0.530
Depth	2	92.6	46.3	0.09	0.912
Density.Depth	4	103.7	25.9	0.994	0.994
Residual	18	8949.1	497.2		
Total	26	9798.5			

Appendix 31: Number of weeds

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Population	2	0.525	0.262	0.05	0.952
Depth	2	26.702	13.351	2.50	0.115
Density.Depth	4	38.311	9.578	9.578	0.183
Residual	18 (3)	80.000	5.333	5.333	
Total	26 (3)	127.833			

Appendix 32: Weeds dry weight

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Population	2	255.29	127.65	6.42	0.010
Depth	2	106.42	53.21	2.68	0.101
Density.Depth	4	209.10	52.27	2.63	0.076
Residual	18 (3)	298.31	19.89		
Total	26 (3)	537.58			

Appendix 33: Canopy spread at 3 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	2946.9	1473.4	1.73	
Reps.*Units* stratum					
Treatment	9	54825.0	6091.7	7.17	<.001
Residual	18	15299.0	849.9		
Total	29	73070.9			

Appendix 34: Canopy spread at 9 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	5399.	2700.	0.86	
Reps.*Units* stratum					
Treatment	9	268799.	29867.	9.53	<.001
Residual	18	56398.	3133.		
Total	29	330596.			

Appendix 35: Chlorophyll content at 3 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	4.446	2.223	0.57	
Reps.*Units* stratum					
Treatment	9	30.779	3.420	0.88	0.561
Residual	18	70.032	3.891		
Total	29	105.258			

Appendix 36: Chlorophyll content at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	1.798	0.899	0.22	
Reps.*Units* stratum					
Treatment	9	434.130	48.237	11.84	<.001
Residual	18	73.325	4.074		
Total	29	509.253			

Appendix 37: Internode length at 3 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	0.7494	0.3747	0.86	
Reps.*Units* stratum					
Treatment	9	11.2622	1.2514	2.86	0.028
Residual	18	7.8802	0.4378		
Total	29	19.8919			

Appendix 38: Internode length at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	0.7627	0.3814	0.67	
Reps.*Units* stratum					
Treatment	9	35.5574	3.9508	6.91	<.001
Residual	18	10.2987	0.5722		
Total	29	46.6189			

Appendix 39: Number of nodes at 3 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	1.4081	0.7040	5.46	
Reps.*Units* stratum					
Treatment	9	5.3865	0.5985	4.64	0.003
Residual	18	2.3208	0.1289		
Total	29	9.1154			

Appendix 40: Number of nodes at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	0.1743	0.0871	0.13	
Reps.*Units* stratum					
Treatment	9	33.9719	3.7747	5.76	<.001
Residual	18	11.7887	0.6549		
Total	29	45.9349			

Appendix 41: Stolon length at 3 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	39.83	19.92	0.61	
Reps.*Units* stratum					
Treatment	9	1645.69	182.85	5.57	<.001
Residual	18	590.95	32.83		
Total	29	2276.47			

Appendix 42: Stolon length at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	12.67	6.34	0.15	
Reps.*Units* stratum					
Treatment	9	1137.48	126.39	2.91	.0026
Residual	18	782.58	43.48		
Total	29	1932.73			

Appendix 43: Biomass dry weight at 7 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	24391.	12195.	5.07	
Reps.*Units* stratum					
Treatment	9	335336.	37260.	15.50	.,<.001
Residual	18	43261.	2403.		
Total	29	402987.			

Appendix 44: Biomass dry weight at 13 weeks after planting

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	197792.	98896.	0.45	
Reps.*Units* stratum					
Treatment	9	3153776.	350420.	1.58	0.194
Residual	18	3979836.	221102.		
Total	29	7331405.			

Appendix 45: Grass weeds

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	152.9	76.4	0.46	
Reps.*Units* stratum					
Treatment	9	1018.7	113.2	0.68	0.718
Residual	18	3001.8	166.8		
Total	29	4173.4			

Appendix 45: Broad leaf weeds

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	1925.17	962.59	14.11	
Reps.*Units* stratum					
Treatment	9	674.43	74.94	1.10	0.411
Residual	18	1228.15	68.23		
Total	29	3827.75			

Appendix 46: Grass dry weight

Analysis of Variance

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	23904.	11952.	5.65	
Reps.*Units* stratum					
Treatment	9	19533.	2170.	1.03	0.456
Residual	18	38045.	2114.		
Total	29	81482.			