EFFECT OF TYPE OF INITIATION AND GROWING MEDIA ON GROWTH AND NUTRIENT UPTAKE OF PLANTAIN (*Musa* AAB) AT THE NURSERY STAGE

BY

HOPE KORBLAH KUMAH

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DECLARATION

I hereby declare that except for references to other people's works which have been duly cited, this work is the result of my original research and that this thesis has neither in whole nor in part been presented for a degree elsewhere.

HOPE KORBLAH KUMAH SIGNATURE……...……………………

(STUDENT) DATE..

DR. KG OFOSU-BUDU SIGNATURE...

(PRINCIPAL SUPERVISOR) DATE...

PROF. JOHN OFOSU-ANIM SIGNATURE..

(CO-SUPERVISOR) DATE...

DEDICATION

To the Almighty God. Also to my loving wife and children, for their sacrifice towards my education and this work.

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ABSTRACT

Plantain (*Musa* spp) is one of the most important food crops. A limiting factor to large-scale production and or expansion of existing plantation is the difficulty in obtaining adequate planting materials. Although the tissue culture technique provides a higher multiplication rate, facilities are non-existent, and if available, the cost will be expensive and unavailable to most farmers in developing countries such as Ghana. The split-corm technique is a cheaper method for raising planting material from the parent sucker. However, the type of sucker (sword or maiden), initiation and growing media and nutrient requirements has not been adequately studied. In experiment 1, the study evaluated the split-corm materials derived from sword and maiden sucker on different initiation media; sawdust (SD) (100%), carbonated rice husk (CRH) (100%) and mixture of SD and CRH (50%:50% v/v). Data was collected on number of sprout, percentage sprout, number of shoot, shoot height, shoot diameter, number of root and root diameter at 3, 6 and 9 weeks after planting (WAP). Initiation media did not have any significant effect on the number of sprouted corm and percentage of sprouted corm. The CRH induced the greatest pseudostem height, pseudostem girth, number of roots/corm, and root diameter and was significantly different from that of the SD and SD:CRH. The percentage sprouted corms decreased with time after planting. No significant difference was observed between sword or maiden sucker in most of the parameters considered, although the sword sucker derived material induced thicker shoot, greater number of roots and bigger root diameter than maiden sucker derived material. Significant ($p < 0.05$) difference was observed between type of propagule and type of initiation media interaction for shoot height, shoot diameter and number roots/split-corm. In experiment 2, the performance of split-corm derived material was evaluated in three types of growing media; soil only (100%), mixture of soil and carbonated rice husk (CRH) (50%:50% v/v) and mixture of soil, carbonated rice husk and compost (25%:25%:50% v/v, SOIL/CRH/COMP) and four nitrogen fertilizer rates (0, 5, 10 and 20 gN) /plant on sucker growth, dry matter production and nutrient uptake were studied under pot conditions. Sprouted split-corm plantlets were transferred to the growing media at 3, 6 and 9 weeks after planting in the initiation media, and monitored for 17 weeks. Data was collected on total plant dry weight and partitioned to plant parts. Other vegetative parameters considered included root length, leaf area, plant height, pseudostem girth, corm circumference, corm height. Results showed that the SOIL/CRH/COMPOST growing media significantly induced the greatest total dry matter and was 73% higher than that of soil only and over 100% higher for 3 and 6 week transplants respectively. SOIL/CRH/COMPOST significantly induced the greatest leaf area, pseudostem girth and plant height. The partitioning of the total dry matter to plant parts ranged between 12.5 – 17.5% to the leaf, 22.6 – 30.4% to the pseudostem, 20.6 -28.4% to corm and 32.5 – 36.6% to roots for 3 week transplant, and 16.3 – 20.9% to the leaf, 27.2 – 35.5% to the pseudostem, 19.5% - 23.5% to corm and 24.1 – 34.1% to root for 6 weeks transplant. Nitrogen accumulation was highest in SOIL/CRH/COMPOST medium, and was four- fold higher for 3 weeks transplant, and 3-fold higher for 6 week transplant than SOIL ONLY. The total N accumulated by the plant and partitioned to the various plant parts was influenced by the type of growing media and the plant part. The highest N was partitioned to the leaf, followed by the pseudostem for 3 week transplant, while for 6 week transplant between 36.33% -51.43% of N accumulated was partitioned to the leaf, followed by 17.65%-25.01% to the corm, 14.48% - 17% to the pseudostem, and 13.83%-24.21% to the roots for 6 weeks transplants. The SOIL/CRH/COMPOST medium produced the highest dry matter of 289.6g at 5gN fertilization for 3 week old transplants, while the same medium SOIL/CRH/COMPOST produced the highest dry matter at 10gN for 6 week old transplants. A predictive equation of $Y= 20.41x + 4022$, was established between total plant dry weight and leaf area with $R^2 = 0.89$ for 6 week old plantlets, while $Y= 0.19x + 19.19$ was established between pseudostem dry weight and total dry weight with $R^2 = 0.99$ for 6 week old plantlets. The SOIL/CRH/COMPOST medium produced the highest dry matter for both 3 and 6 week old transplants but this was observed at different N rates for the different transplants. This result is due to the low bulk density, better aeration porosity, water holding capacity and better growing medium provided by the SOIL/CRH/COMPOST. The addition of the compost greatly promoted growth and reduced the use of external N source.

TABLE OF CONTENTS

LIST OF PLATES

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1.0 GENERAL INTRODUCTION

Plantains and Bananas (*Musa* species L.) are perennial monocotyledonous tropical herbs that belong to the *Eumusa* species of the genus *Musa*. . They are staple foods for consumers in the humid tropics and an important source of rural income particularly in some locations where small holders produce them in some compound or home gardens (Chandler, 1995). In West and Central Africa, it is estimated that about 70 million people derive 25% of their food energy requirement from plantain (IITA, 1992), and production in this region account for about 26% of the world's total production (IITA, 1995).

Plantain (*Musa spp.* AAB) is an important staple crop which contributes about 13.1 % of the GDP (MOFA- SRID, 2006) in Ghana. About 90 % of production is consumed locally because plantain is ranked high in food preference (Schill *et al*., 1996). The largest share of Ghana's output comprises plantain (cooking banana). It has a per capita annual consumption of 101.8kg per head (Dankyi *et al*., 2007). Plantain has an export potential because apart from its huge consumption in Ghana, it is also consumed in most parts of Africa and Africans in the diaspora.

In spite of its importance in the diet of most Ghanaians and its export potential, the cultivation of the crop has however not caught up with even the domestic demands. The present low production level has arisen due to several constraints including lack of adequate certified planting material, disease and pest problems as well as poor agronomic practices. Various innovations have been put in place to solve the problem of the shortage of adequate certified planting material; some of these include the split-corm, tissue manipulation and the decapitation techniques. Several micro and macro propagation multiplication methods have also been used in recent times to commercially provide materials such as horticultural propagation of corm explants on saw-dust (Kwa 2003; Faturoti *et al*., 2002; Baiyeri and Aba, 2005; Tenkouano *et al*., 2006) and split corm propagation in saw dust. Tissue culture techniques (*in vitro)* propagation technique provides excellent advantages over traditional propagation, including a high multiplication rate, physiological uniformity, the availability of disease-free material all year round, rapid dissemination of new plant materials throughout the world, uniformity of shoots, short harvest interval in comparison with conventional plants and faster growth in the early growing stages compared to conventional materials (Daniells and Smith, 1991; Arias, 1992). However, the in vitro propagation materials are not easily available to Ghanaian farmers. In addition, if available they are expensive and the farmers cannot afford to buy in commercial quantities.

The sword and maiden suckers are used by farmers to establish banana and plantain fields. Preparation of conventional suckers consists of detaching the sucker from the mother plant, removing the upper part of the pseudostem and paring the corm (Blomme *et al.*, 2008). This conventional planting material however is usually contaminated with soil-borne pests and is bulky with a low multiplication rate. The GATSBY plantain project worked on the development of split corm technique as an appropriate method of rapid multiplication of suckers between 1991 and 1998 and subsequent dissemination of the technology to farmers (Acheampong, 1999). The lack of popular adoption of this technique could be due to several factors including the lack of its development in the polybag to facilitate easy transport and establishment in the field.

1.1 Justification

The split corm technique utilizes soil as sprouting and growing medium which result in delayed sprouting of split corms and sometimes rot due to disease and poor physical and chemical properties of the soil (Persley and de Langhe, 1987, Rasheed, 2003). The use of organic substrate (compost) offers a greater advantage over the conventional topsoil (Adams *et al.*, 2003; Akanbi *et al.*, 2002). Organic substrates provide adequate nutrients to the seedlings, better root substrate relation than conventional soil mix and less pre-dispose the seedlings to soil borne pests and diseases. Although some work have been done on the use of organic media to commercially sprout and produce suckers (Baiyeri and Aba, 2005, Baiyeri, 2005), there is the need to investigate further on other local organic materials that could be used as initiation and growing media. Container production has several advantages over traditional in ground (field) production (Gilman and Beeson, 1996; Harris and Gilman, 1991). Plants grown in containers are easier to handle and transport and are less prone to injury. Information on N fertilizer rates on growth, and dry matter production of plantain suckers is scarce. The sword and maiden suckers are physiologically different and it is important to evaluate which of the two types of the propagule sword or maiden, when used as split corm materials can be easily used as propagating material. It is important to evaluate organic materials that are easily available as initiation media for the sprouting of the materials since soil is not a suitable medium. This study investigated the use of various media (Sawdust (SD) 100%; CRH 100%, mixture of CRH 50% and SD 50% v/v and addition of compost) for raising planting materials at the nursery. Inorganic N fertilizer is known to promote vegetative growth and dry matter production in plants. The application of N fertilizer will boost the growth rate of the plantain suckers. However, little information exists on the rate of N fertilizer application on growth of plantain suckers in different media, when grown in polybags. It is therefore important to evaluate the response of different levels of N fertilizer application to the plantain suckers (split-corm derived) and their response evaluated over a period of time. The provision of information on the use of recycled organic waste and inorganic N fertilizer rates will boost the industry, and will also solve environmental problems. Currently being encountered in several parts of the country around rice mills and saw mills where the disposal of rice husk and saw dust have become a major problem. The commercial utilization of these alternative media as soil amendment materials will partly solve the environmental issue. The optimization of multiplication and rooting of these new types will aid plantain cultivation not only in Ghana but also in other tropical and subtropical regions.

HYPOTHESES

i. The different initiation media do not have any effect on rooting and sprouting of split-corm derived materials
ii. There are no differences between split-corm derived materials from sword and maiden suckers in rooting, sprouting parameters in the different initiation media
iii. There is no difference in growth, dry matter production and partitioning to plant parts between the different growing media
iv. There is no difference between 3 and 6 weeks after planting (WAP) transplants in initiation media in growth, dry matter production and partitioning to various plant parts after growing for 17 and 14 weeks respectively in different growing media
v. The growth and dry matter production of split-corm derived plantlets does not respond to N fertilizer application in the different growing media

vi. There is no difference in N accumulation of split-corm derived plantain plantlets in the different growing media.

1.2 **Objectives**

Main objective

The general objective of the experiment was to study the effect of different initiation and growing media and nutrient application on growth of Musa (AAB) spp APANTU, at the nursery stage.

Specific objectives

The objectives of the study were also to:

i. Determine the effect of initiation media (carbonated rice husk CRH 100%), saw dust SD 100%, and mixture of sawdust (SD) 50 % and carbonated rice husk CRH (50 % v/v) and type of plantain propagule (sword or maiden sucker) on rooting and sprouting of split-corm materials.

ii. Study the effect of time of transfer (3 and 6 weeks in initiation media) of sprouted corm on growth, dry matter production and nutrient uptake of the sucker in growing media.

iii. Study whether differences in the physical and chemical properties of the growing media affect the growth of the sucker.

iv. Study the effect of N fertilizer application rates on the growth of the sucker.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and distribution of plantain

Simmonds (1962) indicated that Bananas originated from South East Asia, a region considered as the primary centre of diversification of the crop and where the earliest domestication has occurred. *Musa acuminata* is said to have originated from Malaysia, while the hardy *Musa balbisiana* originated from Indochina. The low land areas of West Africa contain the world's largest range of genetic diversity in plantains (*Musa* AAB) (Ortiz and Vuylsteke, 1994).

2.2 Botany of plantain

Plantains are large, perennial, herbaceous plants consisting of underground stems known as corms or bulbs. The corm is the basal part and has a central bud from which leaves and flowers initiate. A large number of roots form from the corm and often remain grouped together in the upper 30 cm layer of the soil. The corm also has lateral buds of which 3-4 become suckers. The leaves of the plantain consist of three parts: the sheath, the petiole, and the midrib which bears the leaf blades. The sheaths extend from the base of the plant forming the 'trunk' or pseudo stem which, as it grows thinner, forms the petiole and then the midrib. When plantain has formed a number of leaves the terminal bud of the corm develops, rises in the pseudo stem and produces an inflorescence, which emerges from the center of the leaf cluster and turns downwards forming the bunch.

2.3 Economic importance of plantain

Plantains and Bananas (*Musa* species L.) are the most important tropical fruit crops (Ortiz *et al*., 1998). They rank the fourth most important global food commodity after rice, wheat and milk in terms of gross value of production (INIBAP, 1992). World production is estimated to be 28 million tons—65% from Latin America, 27 % from Southeast Asia, and 7 % from Africa (Morton, 1987). One-fifth of the crop is exported to Europe, Canada, the United States and Japan as fresh fruit. Tropical Africa (principally the Ivory Coast and Somalia) grows nearly 9 million tons of bananas each year and exports large quantities to Europe (Morton, J. 1987).

In Ghana, the plantain is a staple food but up to the late 1960's the crop was grown only in home gardens or as a shade for cocoa plantations. Plantain (*Musa spp.* AAB) contributes about 13.1 % of the GDP (MOFA- SRID, 2006). About 90 % of production is consumed locally because plantain is ranked high in food preference (Schill *et al*., 1996). Being an important source of family income, plantain is highly priced compared with other starchy staples (Dadzie and Wainwright, 1995). According to FAO statistics, Ghanaian *Musa* production in 2005 (most recent figures) covered nearly 300,000 hectares, with production of 2.8 million tons, valued at $710 million. The largest share of Ghana’s output comprises plantain (cooking banana). It has a per capita annual consumption of 101.8 kg per head (Dankyi *et al*., 2007). Plantain has an export potential because apart from its huge consumption in Ghana, it is also consumed in most parts of Africa.

2.4 Types of planting materials

Different types of planting materials including the maiden sucker, water sucker, sword suckers, butt, peeper, and bits are used for the establishment of plantations, but they vary in their degree of suitability (Ndubizu and Obiefuna, 1982; Baiyeri and Ndubizu, 1994, Baiyeri *et al*., 1994). Micro and macro propagation multiplication methods have been used in various organic media (rice hulls and sawdust to provide materials of corm explants (Kwa 2003; Faturoti *et al*. 2002; Baiyeri and Aba, 2005; Tenkouano *et al*., 2006).

In vitro propagation of bananas (tissue culture materials) provides excellent advantages over conventional propagation, including a high multiplication rate, physiological uniformity, the availability of disease-free material all year round, rapid dissemination of new plant materials throughout the world, uniformity of shoots, short harvest interval in comparison with conventional plants and faster growth in the early growing stages compared to conventional materials (Daniells and Smith, 1991; Arias, 1992). However, the tissue culture propagation materials are not easily available to farmers in developing countries, including Ghana. If available, the prices are expensive and the farmers cannot afford to buy in commercial quantities. However, Ndubizu and Obiefuna (1982) showed that peeper (a young sucker just merging from the ground), which is an inferior propagating material, was improved to good quality sucker for field planting using poly bag nursery technique.

2.5 Methods of propagation

Bananas/plantains are propagated vegetatively because almost all cultivated banana/plantain cultivars are triploid, seedless, or seed sterile. The materials used for conventional propagation include corms, maiden and sword suckers (Arias, 1992).

However, conventional planting materials are not ideal propagule, because they carry weevils, fungal pathogens, nematodes, and viruses (Arias 1992; Sagi *et al*., 1998) and also suffer from slow multiplication, bulkiness, and poor phytosanitary quality (Vuylsteke, 1989). Tissue culture plays a vital role in the distribution of germplasm, conservation, safe exchange of internal planting material and rapid propagation of newly selected hybrid cultivars.

Micro-propagation (i.e. meristem/tissue culture) assures more rapid production of planting materials. These planting materials are healthy, vigorous, and free from pests and diseases (Swennen, 1990) but require a more sophisticated technique, facilities and skills and care to handle (Vuylsteke and Talengera, 1998). Tissue culture as a method of generating plantain planting materials is still developed in Ghana and so, grossly unavailable to farmers who are the major stakeholders in the production of bananas and plantain in Ghana.

The Plantain and Banana Improvement Program of the International Institute of Tropical Agriculture (IITA), Nigeria, advanced the use of a macro propagation method for increasing sucker multiplication. The method generates plantlets from sword-sucker corm utilizing sawdust as plantlet initiation medium (Baiyeri and Aba, 2005).

2.5 Constraints to current production system

Farmers traditionally grow plantains using sword and maiden suckers of various sizes as planting material. These materials are normally unselected, untreated corms weighing 3 to 6kg. These materials are of little physiological homogeneity and are often contaminated by banana borer weevils, nematodes,. Farmers tend to use lateral suckers that are differentiated from the mother-plant and possess an independent root system and food reserves (1-2kg). These are known as sword or maiden suckers and are reputed to be vigorous, healthy and easy to handle (Belalcázar and Valencia 1990).

Plant-parasitic nematodes constitute one of the major biological constraints in plantain production resulting in estimated annual yield loss of 19.7 – 36.8% (Kashaija *et al.*, 1998). The nematodes feed on roots, causing root necrosis which gradually leads to root rotting and reduced number of functional roots (Kashaija *et al.*, 1998). Damage to roots impairs nutrient-flow, translates into suppressed shoot growth and subsequently reduced yield of infected plants. Vegetative propagation using infested corms or suckers has disseminated this pest throughout the world. Some important plant parasitic nematodes that have been found associated with banana and plantain include: *Radopholus similis*, *Pratylenchus goodeyi*, *Helicotylinchus multicinctus*, *Hoplolaismus spp.*, and *Meloidogyne spp (*Kashaija *et al.*, 1998).

2.6 Recent development in planting material

Several micro and macro propagation/multiplication methods have been used in recent times to commercially provide materials such as horticultural propagation of corm explants on saw-dust (Kwa 2003; Baiyeri and Aba, 2005; Tenkouano *et al.*, 2006) and split corm propagation in saw dust. Tissue culture or *In vitro* propagation of bananas provides excellent advantages over traditional propagation, including a high multiplication rate, physiological uniformity, the availability of disease-free material all year round, rapid dissemination of new plant materials throughout the world, uniformity of shoots, (Arias, 1992).

2.6.1 Macropropagation techniques

These are methods that use whole suckers, large pieces of the parent corms, or sword-sucker-corms to produce planting materials (Faturoti *et al*., 2002). Macropropagation provides cheap, simple, and relatively rapid techniques for vegetative multiplication of *Musa* species that could be suitable to the low-income, unskilled, small- and medium-scale farmers These *ex vitro* multiplication techniques involve the stimulation of lateral shoot development on the sucker corms.

2.6.2 Field decapitation techniques

Field decapitation technique generally involves two methods *vis-à-vis* false decapitation and total decapitation. The two decapitation methods involve stimulating lateral bud production by destroying the active growing point (apical meristem) in the pseudostem (Faturoti *et al*., 2002; Tenkouano *et al*., 2006). The rate of suckering per plant ranges from 9-14 suckers per annum.

2.6.3 Detached corm multiplication techniques

A well-developed banana or plantain corm contains several axillary buds, which essentially host meristems of different ages and stages of development (Kwa 2003). Sword sucker-corms, as well as corms from preflowering and harvested plants could be used in detached corm multiplication techniques (Faturoti *et al*., 2002; Tenkouano *et al*., 2006). Detached corm multiplication techniques can either be in form of whole-corm or split-corm. In split-corm technique, the dug-out corm is cleaned of roots and outer leaf sheaths to expose the lateral buds, then washed and split into two or several fragments (bits). These are planted face down and raised in a well composted organic nursery substrate. In whole-corm technique, the apical meristems of the pared corms are scarified, either by making two cross-wise incisions on the buds (Kwa 2003; Tenkouano *et al*., 2006) or by mechanical removal by screwing with sharp knife (Baiyeri and Aba 2005). Scarification of side buds on the corm has the potential to further increase plantlet production by a factor of 2-10 (Tenkouano *et al*., 2006). Lateral bud growth is activated by planting the corms in rich composted organic substrate (Faturoti *et al*. 2002) in nursery bags or more recently, in humidity chamber conditions resulting in the high production of planting material (Kwa 2003; Tenkouano *et al*., 2006). A well-composted rice husk could also be used as an alternative plantlet initiation medium (Baiyeri and Aba, 2005) to the recommended sawdust. This detached corm technique is relatively simple and requires minimum investment to set up. Moreover, plantlets obtained thereof, have the uniformity of tissue-cultured ones.

2.7 Nursery management of macro propagated *Musa* plantlets

The nursery phase is an important part of the planting operation in the cultivation of many horticultural crops. Raisinging the seedlings at the nursery until they are larger, tougher and more vigorous, makes it possible to give maximum care to weak seedlings, saves seeds, space and water (Baiyeri 2003), and reduces the risk of damage to, or loss of the plant. It also allows the grower to select the most vigorous seedlings for transplanting into the permanent field (Aiyelaagbe, 1989), as the quality of nursery seedlings influences re-establishment and the future productivity of the orchard (Baiyeri and Ndubizu 1994).

The quality of nursery potting or growing medium is important to the successful growing of plants in containers (Bunt, 1988). The physical characteristics has a significant effect on the supply of water and air to the growing plants (Beardsell and Nichols 1982), as well as providing anchorage, and nutrient and water-holding capacity.

2.8 Initiation and growing media

2.8.1 Initiation media

Rooting media has been found to be one of the most important factors which affect rooting success of cuttings (Baiyeri, 2005). The physical properties of the rooting media have a significant effect on the supply of water and air to the growing plant (Baiyeri, 2005). Physical properties of rooting media include total porosity, bulk density, air space, water holding capacity and available water content. Among these, aeration and moisture content appear to be the two properties of major concern in a rooting media. This affects the emergence and vigor of roots with consequent effect on quality of rooted cuttings (Leakey *et al.*, 1990). Hartmann *et al.* (1997) reported that an ideal rooting media should provide sufficient porosity to allow good aeration and ensure adequate oxygen availability for the developing rooting system. Baiyeri and Aba (2004) used rice husk and sawdust as initiation media for propagating different plantain genotypes. These scientists reported that the number, quality and pattern of plantlets produced and their survival were affected by the initiation media.

2.8.2 Growing media

Organic wastes and other industrial by-products could be used as nursery potting medium. The preference and selection of any organic waste or use as potting media should largely be determined by considerations of availability, economics, physical and chemical characteristics (Akanbi *et al*., 2002).

The physical composition of the growing media have a profound effect on the supply of water and air to the growing plant (Beardsell and Nichols 1982), as well as affect anchorage, and nutrient and water holding capacity of the medium. These physical characteristics of the growth medium affect the emergence and vigour of seedling with consequent effect on quality of seedlings produced. Several growing media/organic nursery mixtures have been developed (Baiyeri and Aba 2005; Baiyeri 2005) for raising *Musa* plantlets to vigorous suckers for field planting. It is often common to think of soil as a good medium, but most soils when used alone are very poor growing medium. Soil has been the traditional growing media for raising planting materials. However, there are several disadvantages, including being the easiest way through which seedlings become infected by diseases such as root knot nematode and seedling root rots (Egunjobi and Ekundare 1981). Besides, soils have the attribute of heavy weight when large volumes are used to raise containerized plants, and nursery men may have the problem of bulkiness in transporting them (Bunt 1988).

The minimal use of soil or use of organic substrate (compost) offers a great advantage over the conventional topsoil (Akanbi *et al*., 2002; Adams *et al*., 2003). Organic substrates provide better root-substrate relation than conventional soil mix, adequate nutrients for the seedlings, less pre-dispose the seedlings to soil borne pests and diseases, ensures better moisture and nutrient management (by minimizing leaching losses) and as well maintain optimum pH. The nutrient value of nursery mixtures could be further improved by incorporating inorganic salts such as rock phosphates, lime and nitrogenous fertilizers during composting (Matthew and Karikari 1990).

2.8.3 Compost

Compost is used extensively in the nursery industry to replace peat moss. Effects of compost on root growth in containers are a function of their interactive effects on substrate physical, chemical and biological properties. The physical (porosity, aeration) and chemical (pH) properties of composted materials can change over time (Kraus *et al*., 2000). Bunt (1961) discusses other effects of compost on plant growth and found that compaction of compost over time can influence root growth and function. Composted materials often lack the coarse, large particles necessary for adequate aeration and as they decompose their effects on aeration porosity become more pronounced leading to possible water logging and anoxia of roots (Bilderback and Jones, 2001). It is recommended that composted materials should not be used in amounts greater than 50% by volume for most container substrates (Bilderback *et al*., 2005). Animal waste composts usually have high EC and nutrient levels and are generally limited to 10 to 30 % by volume of potting substrates. Composts usually have a “liming effect” (raise pH) so no dolomitic lime should be added and minor packages are often not required (Bilderback *et al*., 2005).

2.8.4 Physical and chemical properties of growing media

2.8.4.1 Physical properties

The physical quality of growing media is dependent on the substrate’s ability to store and supply air and water. The physical components that are important to quality media include: pore size, water-holding capacity, hydraulic conductivity, aeration porosity, and bulk density. These properties interact to influence the growth, function, and morphology of root systems growing in containers.

2.8.4.1.1 Bulk density

Bulk density is defined as the weight per volume a substrate occupies including solid particles and pore spaces. Bulk density of soilless media are low, therefore additions of sand are usually done to increase weight (Brown and Pokorny, 1975; Fonteno *et al*., 1981; Hanan, 1981). Increasing bulk density provides support to the plant in lightweight containers. Fonteno *et al*. (1981) also found that shrinkage and settling in a pot will increase bulk density.

2.8.4.1.2 Total porosity

Total porosity is defined as the total volume of pore space in a substrate. Total porosity can be estimated from bulk density because they are inversely related (Beardsell *et al*., 1979; Hanan, 1981). The total porosity of a media controls the movement of water through the soil profile. Water-holding capacity and aeration porosity are two very important physical properties. They directly influence the amount of available air and water to plant roots. The drier the media, the less available water exists and a plant uses more energy to get water (De Boot and De Waele, 1968). Verdonck *et al*. (1983) suggested that any growing media should consist of 20% air and 20 to 30% available water by volume.

2.8.4.1.3 Water holding capacity

The water holding capacity is the percent of the total volume of the medium that is filled with water after irrigation and drainage.

2.8.4.2 Chemical properties

The chemical properties of the media have a major influence on plant growth and quality. Chemical properties directly affect nutrient solubility and retention, thus availability for plant uptake. Suspensions, saturated media extracts, and displaced soil solutions are three methods used to analyze the chemical properties of soils (Bunt, 1988). Three of the main components that contribute to a media's chemical make-up are pH, cation exchange capacity (CEC), and electrical conductivity (EC).

2.8.4.2.1 Media pH

The pH is a measure of hydrogen (H+) ions in solution. It is recorded on a logarithmic scale of 0 to 14, with 7 being neutral. Substrate values above 7 are considered basic or alkaline and below 7 acid. The ability of roots to acquire and utilize nutrients is strongly influenced by pH. The pH of substrate affects availability and solubility of some nutrients. The optimum pH of container substrate varies with plant species and some species grow best within a narrow range of pH values. Plants grown outside their optimum pH range can exhibit symptoms of nutrient toxicity or deficiency, as well as stunted growth and poor performance.

In general, substrate pH should range from 5.4 to 6.0 and 6.2 to 6.8 in substrate that contain >20% of mineral soils. In high pH substrates, ions of aluminum (Al), iron (Fe) and manganese (Mn) precipitate and the availability of these elements decrease. Plants in a high pH substrate may express deficiencies of Fe, boron (B), zinc (Zn), Mn, copper (Cu) and molybdenum (Mo) (Mathers, 2003a). Phosphorus (P) may also become deficient in alkaline substrates as it complexes with calcium (Ca) to form insoluble Ca-phosphates. Plants in low pH substrates may express toxicities in Fe, Mn, Zn, and Cu, deficiencies in Ca or magnesium Mg, sensitivity to ammonium (NH_4^+) and leaching of phosphates (PO_4^{-2}). Deficiencies of most of the micronutrients can be corrected by adjusting substrate pH.

2.8.4.2.2 Cation exchange capacity (CEC)

The CEC is defined as the total of exchangeable cations that a substrate can absorb per weight (Bunt, 1988). Clay or organic particles have negative charges which attract positive charges of fertilizers. CEC provides a reservoir of nutrients for plant uptake. The pH is known to affect the CEC of various soils (Helling *et al*., 1964). The exchange capacity of an organic soil increased by 140 meq/100g from pH 3.5 to 8 compared to mineral soils that only increased by 18 meq $100g^{-1}$.

CEC represents a substrate's nutrient holding capacity or the total exchangeable cations a substrate can retain per unit weight. The recommended CEC range for container substrate is from 6 to 15 meq/100 g. Cation binding strength to particles in order of strongest to weakest are: $H^+ > Ca^{+2} > Mg^{+2} > K^+ = NH^{4+} > Na^+$. Low substrate CEC in container production can increase the frequency of fertilizer applications compared to plants grown in soils. Anions are nitrate (NO_3^-), phosphates (PO_4^{-2}) and sulfates (SO_4^{-2}). Most NO_3, like other anions, is easily leached from container substrate by heavy rains or excessive irrigation. Periodic monitoring of substrate NO_3 levels are essential in container production because NO_3-availability is so important to plant growth and yet so easily leached (Mathers, 2004).

2.8.4.2.3 Electrical conductivity (EC)

The EC is the measure of salt content of water or a substance based on the flow of electrical current. Soluble salts (SS) come from fertilizers, organic matter used in the substrate, and salts in irrigation water. Plant sensitivity to SS can be cultivar-specific and vary with plant age and length of exposure. Periodic monitoring of SS will provide an estimate of the total dissolved salts in a container production system. One way to measure SS dissolved in water is by electrical conductivity (EC). Decisiemens per meter (dS/m) is a commonly used unit for measuring EC. The relationship between the EC of water (EC_w) and total dissolved salts is EC_w X 640 = total dissolved salts (in ppm or mg l^{-1}). The initial total dissolved salts of a substrate should be low especially for salt sensitive plants, liners, seedlings and other young plant material. Generally, EC values for plants fertilized with Controlled Release Fertilizerss should range from 0.20-1.00 $dS.m^{-1}$. Acceptable media EC levels are 1.0 to 2.0 dS/m for seedlings and plugs and 2.0 to 3.0 dS/m for established plants (Lang, 1996).

2.9 Container nursery production

Container production has many advantages over traditional in-ground (field) production (Gilman and Beeson, 1996;) including less damage occurring to the root system when transplanted, better establishment after transplanting, decreased labour and land acquisition costs for production, and increased product availability. Plants grown in containers are easier to handle and transport, and less prone to injury compared to balled and burlapped root balls. Growing plants in containers, however, alters root growth and function and can change root morphology. There are numerous factors that influence root growth in containers. Roots of container-grown plants are subjected to temperature and moisture extremes not normally found under field conditions. The effects of substrate aeration as well as water holding capacity interact with different pot characteristics resulting in changes to root morphology. Successful plant establishment after transplanting is often linked to root health.

The greatest advantage of container production over field production may be seen in establishment success after transplanting, or in transplant quality (Gilman, 2001; Nillson and Örlander, 1995). Water stress after transplanting is probably the most limiting factor for plant growth and the major factor responsible for transplanting failure (Ferrini *et al*., 2000). This is especially true of container grown plants. Mathers *et al*. (2005) found container grown materials had higher survival rates, caliper and height growth and shortened production time compared to the bare root stock. The root system of container-grown plants is packaged and transplant stress is minimized compared to field grown stock. During digging and handling of bare root , many fine roots, accounting for up to 30% of a plants' root area, are left in the soil, lost, or damaged (Thomas, 2000). These fine roots are generally feeder roots responsible for water and nutrient uptake. When these roots are damaged or lost, this causes the plant considerable stress and in some cases decline after transplanting (Harris and Gilman, 1991; Harris and Gilman, 1993). In container production, however, plants are produced, handled, and transplanted with intact root systems, thus increasing the potential for transplanting success.

2.10 Fertilizer management

The supply of nutrients to plants grown in containers is a key component to proper management practices. The ultimate aim of fertilizer application program is to maintain an optimum level of nutrients in the growing media throughout the growing season. Fertilizer selection and method of application profoundly influences the chemical properties of substrates used in container production. Fertilizer selection considers crop, cost, labour, substrate, growth stage, production time, and irrigation practices. For container production, methods of fertilizer placement include dibbling, top dressing, incorporation, and fertigation. Slow-release fertilizers (SRFs) and CRFs are the predominant types of fertilizer used in container production due to their simplicity of use and potential for decreasing nutrient runoff.

2.11 Organic matter content

The steady decline in food production is partly due to reduced length of fallow on land, that makes it imperative that farmers amend the soil with different materials (organic and inorganic) in order to enhance plant growth and increase crop yield (Reijnties *et al*., 1992; Adepetu, 1997). Sobulo and Babalola (1992), Ismail *et al*. (1996), Olayinka (1996) and Olayinka *et al.* (1998) have reported the use of several organic materials especially cow dung, poultry droppings, refuse compost and farmyard manure as soil amendments suitable for increasing crop production particularly among subsistence farmers in West Africa. Among the different sources of organic manure, which have been used in crop production, poultry manure was found to be the most concentrated in terms of nutrient content (Yayock and Awoniyi, 1974; Lombin *et al.*, 1992) in the farm. Mokwunye (1980) and Kotschi *et al*. (1989) observed that manure application improved the availability of some minerals in the soil and especially the transfer of nutrients to the crop plant. The positive effect of the application of inorganic fertilizers on crop yields and yield improvements had been reported (Carsky and Iwuafor, 1999). There are few reports available on the effects of fertilizers on some traits in the plant that influence yield. Follet *et al*. (1981) reported that chlorophyll coloration is related to the amount of nutrients absorbed by the plant from the soil. Organic and inorganic fertilizers applied to the soil supply plant nutrients for crop growth and affect the plant's physiological processes. Animal manure is often readily available and may constitute a valuable source of nutrients and organic matter, which can improve soil physical conditions (Munoz *et al*., 2004). Increasing organic matter content improves the biophysical characteristics of the soil, and makes it more sustainably productive. Thus, manure or compost application may increase soil nutrients and organic matter, with long lasting residual effects on crop yield and soil properties (Eghball *et al*., 2004). The long term effects of the combined application of organic and inorganic fertilizers in improving soil fertility and crop yield have been demonstrated (Lin and Lin1985, Xie *et al. (*1987)., Chen *et al*., (1988), and Liu *et al.* (1996) Recently Wang *et al.* (2001), reported that organic and inorganic fertilizer showed great benefits not only for increase in N uptake by plant and in soil available N, but also for the improvement of maize yield.

2.12 Macro nutrients

2.12.1 Nitrogen

Nitrogen (N) is an essential macronutrient that is deficient in most soils (Herandez *et al*., 1997). It is an important component of many structural, genetic and metabolic compounds in plants (Hassan *et al*., 2005; Tisdale and Nelson, 1975). It is taken up by plants both in organic (urea as foliar spray) and inorganic ammonium (NH_4^+) and nitrate (NO_3^-) forms. In plants, NO3 is reduced to NH_4^+ for assimilation into plant organic N (Jalloh *et al*., 2009). Nitrogen affects carbon partitioning and it improves accumulation of soluble sugars and especially starch which in turn improve leaf growth

(Rufty *et al.*, 1988). Nitrogen applied as fertilizers or in other forms is closely related to the ability of plant roots to absorb water from soil. Vos and Biemond (1992) reported reduction in leaf production, individual leaf area and total leaf area under N deficient conditions. Trapni *et al*. (1999) observed increased cell production and cell expansion leading to an increase in final leaf area in sunflower with high N availability. Increased leaf area index, leaf area duration, crop photosynthetic rate, radiation interception and radiation use efficiency have also been reported by enhanced nitrogen supply (Muchow, 1988). Goudriaan and van Keulen (1979) and Just *et al.* (1989) observed changes in leaf photosynthesis in response to variations in plant nitrogen supply. Leaf photosynthesis is influenced by lamina nitrogen content over a wide range of irradiance and varies widely between different crop species (Sinclair and Horie, 1989). Consequently, lower rates of photosynthesis under conditions of nitrogen limitation are often attributed to reduction in chlorophyll contents and rubisco activity (Verhoeven *et al*., 1997; Toth *et al.*, 2002). In C3 plants, three quarters of nitrogen content in leaf is associated with photosynthesis and in sunflower 50% leaf soluble protein accounts for the single photosynthetic enzyme rubisco (Gimenez *et al.*, 1992). Lawlor (2002) reported that plant metabolic processes, based on proteins, leading to increase in vegetative and reproductive growth and yield are totally dependent upon the adequate supply of nitrogen.

2.12.2 Phosphorus

Phosphate is the principal element involved in plant energy processes. The need for P by plants is critical because of its role in ATP (Adenosine triphosphate) and recovery (Palta, 2000). Phosphorus is a constituent of nucleic acids, phospholipids, phosphorproteins, dinucleotides, and adenosine triphosphate. Hence, P is required for processes including the storage and transfer of energy, photosynthesis, the regulation of some enzymes, and the transport of carbohydrates (Hu and Schmidhalter, 2001). Phosphate levels may be low due to dry soil conditions or impaired root uptake and should be reinforced for both types of stresses. The relative leaf-growth rate is one of the most sensitive parameters to phosphorus deficiency (Kirschbaum and Tompkins, 1990), as it affects the photosynthetic rate per unit area. Phosphorous deficiency induced decline in leaf growth and photosynthetic rate may be ascribed to reduction in stomatal conductance and ribulose 1,5 bisphosphate (RuBP) carboxylase regeneration capacity (Brooks, 1986). Phosphorus deficiency is known to reduce the uptake rate of nitrates and its assimilation by the nitrate reductase (Pilbeam *et al*., 1993). Radin (1984) reported that P nutrition alters the relation between leaf turgor and stomatal conductance in cotton.

The application of P fertilizer can improve plant growth considerably under drought conditions (Ackerson, 1985; Studer, 1993; Garg *et al.*, 2004). The positive effects of P on plant growth under drought have been attributed to an increase in stomatal conductance (Brück *et al*., 2000), photosynthesis (Ackerson, 1985), higher cell-membrane stability, water relations (Sawwan *et al*., 2000) and drought tolerance. Ajouri *et al*. (2004) reported that priming seeds with solutions containing the limiting nutrients under drought conditions (such as P and Zn) can improve barley establishment. Phosphorus improves the root growth and maintains high leaf water potential. The improved root growth results in improved water and nutrient uptake and increases the activity of nitrate reductase which improves the assimilation of nitrate under drought condition. Phosphorus maintains the cell turgidity by maintaining the high leaf water potential which in turn increases the stomatal conductance and increases the photosynthetic rate under drought.

2.12.3 Potassium

Potassium is a key element in banana nutrition. The most universal symptom of potassium deficiency is the appearance of orange-yellow colour in the oldest leaves and their subsequent rapid desiccation. This results in reduced total leaf area of the plant and the longevity of the leaf (Lahav, 1972). Other effects of potassium deficiency are choking, delay in flower initiation and reduced fruit size. Studies of the ontogenic course of potassium uptake under field conditions have shown an overall decrease in whole plant concentration of potassium in the dry matter from sucker to fruit harvest. The potassium uptake is proportionally greater than dry matter accumulation early in the life of the plant. Under restricted potassium supply, the highest potassium uptake rate occurs during the first half of the vegetative phase. It is redistributed within the plant (Vorm and Diest, 1982) to allow further accumulation of dry matter.

Potassium is found to regulate the transfer of nutrients to the xylem. Where potassium supply is low, the transfer of nitrogen, phosphorus, calcium, magnesium, sodium, manganese, copper and zinc across the xylem is restricted (Turner, 1987). Insufficient potassium supply reduces the total dry matter production of banana plants and the distribution of dry matter within the plant. The bunch is the most drastically affected organ. Turner and Barkus (1980) found that while low potassium supply halved the total dry matter produced, the bunch dry matter was reduced by 80% and the roots were unaffected. Among the various organs competing for potassium, those nearest the source of supply is the most successful in obtaining their requirements. Low potassium supply reduced respiration but produced a large variation in the photosynthesis of leaf discs (Martin-Prevel, 1973). Martin-Prevel (1973) suggested that a major effect of potassium is through stomatal control, with potassium deficiency slowing down stomatal movements.

Potassium deficiency impairs protein synthesis, since free amino acids (Freiberg and Stewart, 1960) and soluble forms of nitrogen (Martin-Prevel, 1973) increase in low-potassium plants. The main amino acid to accumulate is Cysteine-methionine (Lahav, 1975). Fruit growth is conspicuously restricted by low potassium supply in two ways. The reduction in translocation of carbohydrates from leaves to fruits and their conversion to starch (Martin-Prevel, 1973). Thus, low potassium supply produces ‘thin’ fruit and fragile bunches, a phenomenon frequently observed in the field (Sathiamoorthy and Jeyabaskaran 1998).

CHAPTER THREE

3.0 EXPERIMENT 1

Effect of initiation media and type of propagule on sprouting of split corm derived material

3.1 Introduction

A common limiting factor to large-scale production of plantains and/or expansion of existing plantation is the difficulty in obtaining good planting material (Baiyeri and Ajayi, 2000). There are several types of planting materials (which include the maiden sucker, water sucker, sword suckers, butt, peeper, and bits) used for the establishment of plantations, but they vary in their degree of suitability (Ndubizu and Obiefuna, 1982; Baiyeri and Ndubizu, 1994, Baiyeri *et al*., 1994). These conventional propagating materials are usually in short supply due to poor suckering ability of parent plant (Robinson, 1996) and inadequate to meet the demand of medium to large-scale farmers (Rasheed, 2003). The IITA, advanced the use of macropropagation method for increasing sucker multiplication at farm level. The method generates plantlets from sword-sucker corm utilizing sawdust as initiation medium. Initiation/rooting media has been found to be one of the most important factors which affect rooting success of cuttings (Baiyeri, 2005). The physical properties of the rooting media can have a profound effect on the supply of water and air to the growing plant (Baiyeri, 2005). Some of the commonly used media for rooting cuttings include peat moss, coir, rockwool, vermiculite, perlite, sand shredded bark, garden soil, compost etc. However the choice of medium component used depends on availability of materials, size and type of container used method of watering etc. Notwithstanding the above, the, medium should be free of pathogens, weeds, pests, nematodes, and have good water holding capacity and good drainage. Soil-less media have become very popular with propagators because of their consistency, excellent aeration, reproducibility and low bulk density, carbonated rice husk and sawdust are easily available organic materials that can be used as initiation media. Sawdust is preferred in any nursery mix. Rice husk which is a by-product of rice processing, it is light in weight, has uniform quality, resistant to decay and depletion of available nitrogen by microorganisms. Rice husk has the advantage of being easily incorporated into media to improve drainage and aeration. The physical composition of the initiation medium has a profound effect on moisture relations and air flow to the propagule (Beardsell and Nichols, 1982) as well as affect anchorage, supply of nutrient. These physical properties s of the initiation medium directly affect the emergence and vigor of seedling with consequent effect on quality of seedling produced (Baiyeri, 2003). Sand proved to be a better propagation media than a mixture of sand and topsoil or sole forest topsoil for stem cuttings as it rooted better and showed higher values for all rooting parameters considered. The different responses of cuttings to different rooting media suggest the existence of significant variation in their physical characteristics particularly differences in total porosity, water holding capacity and aeration porosity of the media used.

There are four types of suckers: peeper (small sucker appearing just above the ground and bearing scale leaves only), sword sucker (large sucker with lanceolate leaves and a broad corm base), maiden sucker (large non-fruiting sucker with foliage leaves) and water sucker (small sucker with foliage leaves, which has a non-existent or weak connection with the mother plant corm due to biotic or abiotic factors.), that vary in morphology and physiological parameters. However, these can be used as propagating materials for plantain. The purpose of this study was to evaluate the effectiveness of different initiation media in the propagation of plantain suckers. Furthermore, it is also aimed at determining if differences exist in sprouting between split-corm derived from split-corm derived from sword and maiden suckers.

3.2 Materials and methods

3.2.1 Experimental site

The study was carried out at the University of Ghana Agricultural Research Centre (ARC), Okumaning- Kade, in the Kwaebribirim district, (6º 05’ N; 0º 05’W), and 175 km from Accra. It is located in the moist semi - deciduous vegetation zone in the Eastern Region of Ghana.

3.2.2 Experimental design

A split plot design was used with the growing media (sawdust, carbonated rice husk and sawdust + carbonated rice husk) as the main plots and the type of propagule (maiden and sword suckers) as the subplots.

3.2.3 Preparation of initiation media

The initiation media used were carbonated rice husk, sawdust and a mixture of carbonated rice husk and sawdust (one part of carbonated rice husk + one part sawdust).

3.2.3.1 Carbonated rice husk

Rice husk was obtained from the University of Ghana Agricultural Research Centre's, Kade, rice mill. The carbonated rice husk was prepared by charring the rice husk. The rice husk was carbonated in a drum (burnt under limited oxygen). As the rice husk turned black it was frequently turned over to prevent it from burning to ashes until it was finally charred. The hot carbonated rice husk was cooled by applying water to it and bagged.

3.2.3.2 Saw dust

Saw dust was obtained from a saw mill in Kade.

3.2.3.3 Carbonated rice husk and saw dust mixture

A mixture of carbonated rice husk and saw dust was prepared by adding one part of the carbonated rice husk to one part of the sawdust (v/v basis) and then mixed thoroughly with a shovel.

3.2.4 Determination of physical and chemical characteristics of the initiation media

3.2.4.1 pH

A suspension was prepared by weighing 6 g of each medium. 30 ml of distilled water was then added, stirred and allowed to stand for twenty minutes before filtering. Three replicates of each medium were prepared and the average taken. A digital pH meter, (pH tester 30), was used to determine the pH of the prepared suspensions after it had been calibrated with standard solutions. The pH values recorded are the average of three replications for each media.

3.2.4.2 Electrical conductivity (EC)

EC was determined from the same suspension prepared for the pH, using a digital EC meter. The electrode end of the EC meter was lowered into the suspension in the beaker and EC values recorded after five minutes.

3.2.4.3 Bulk density

Bulk density was determined by first determining the volume of the metal core sampler after which it was filled with100g of the medium. The core sampler was tapped on its bottom vigorously until the medium was compressed. This was replicated three times. The media was subsequently placed into a convection oven at 100 ºC for 48 hours. The media was removed from the oven and weighed. Bulk density was calculated by dividing the weight of dried media by its volume. The bulk density was determined for both the initiation and growing media.

3.2.4.4 Percent air space and water holding capacity

A pop bottle (500ml) was used for the determination of the water holding capacity and the aeration porosity of the various media. First the bigger end of the bottle was cut open and the narrower end was sealed with the cover. The container volume was measured, by first pouring in water to a line that had been drawn at the open end within 3 cm from the brim. The quantity of water in the container to that level was recorded (*volume of container*). The medium (initiation or growing medium) was used to fill the bottle to the same "fill line" mark as was used to determine the container volume. Small quantities of water at a time were used to saturate the media. The quantity of water used to saturate the media was recorded (*total pore space of the medium*). The tape covering the bottle seal that had been perforated was loosen to allow the water to drain completely from the medium. The drainage holes on the seal were covered once again and the medium was re-saturated with water (The volume of water used to re-saturate the medium was recorded. Thereafter, the water was drained out of the medium over a 2-hr period. The volume of the water that was drained was recorded (*volume of drained water*). The percentatge air space and water holding capacity was calculated according to equation below;

$$\%\, air\ space = \frac{volume\ of\ drained\ water}{container\ volume} \times 100$$

$$water\ holding\ capacity = \frac{total\ pore\ space - volume\ of\ drained\ water}{container\ volume} \times 100$$

3.2.5 Split corm preparation

Sword and maiden suckers (plates 3.1 and 3.1b) of plantain Musa spp cv. APANTU (AAB) genotype were acquired from fields of ARC, Kade. The corms were pared to remove all roots and pseudostem and the corms were split into smaller parts with weights ranging between 230 – 250 grams (plates 3.2a and 3.2b). Thereafter the growing point (i.e. apical meristem) was excised using a sharp knife, **(**Baiyeri and Aba, 2004) and treated with fungicide (carbendazim) at a dilution rate of 50 g per 15 liters of water to cure for two hours prior to planting in the various initiation media. Each subplot received 25 pieces of split corm and this was replicated three times. A total of four hundred and fifty split corms were prepared and later planted in the various initiation media.

Plate 3.1a Sword suckers

Plate 3.1b. Maiden sucker

Plates 3.1a & 3.1b: Maiden and sword suckers of plantain

Plate 3.2a. Preparation of split corms

Plate 3.2b. Split corms of plantain

Plates 3.2a & 3.2b. Preparation of split corm

3.2.6 Site preparation and planting of split corms into initiation media

The initiation media was performed in the ground after the soil has been dug and scooped. Different compartments were prepared and filledback with with the different initiation media (plate 3.3a). Each compartment measured 1m × 1m x 20cm (length x breadth x depth). The cured split corms were buried in the different initiation media at 3 – 4 cm deep (plate 3.3b) and were immediately watered copiously for a start and thereafter when necessary. The corms were monitored for sprouting and other vegetative parameters 3, 6 and 9 weeks after planting into the initiation media.

Plate 3.3a. Initiation chamber filled with sawdust initiation media

Plate 3.3b. Planting split corms into

Plates 3.3a & 3.3b. Preparation of initiation media and planting of split corms

Plate 3.4. Sprouted split-corm of plantain

3.2.8 Harvesting of sprouted corms

A split corm was considered sprouted, when at least a root develops, or more it differentiates to shoot and root. The sprouted split-corms were harvested by pulling them gently from the initiation media ensuring that shoots were not detached from the corm and the roots also intact. The sprouted corms were conveyed to the laboratory after washing off the media from the roots under running water.

3.2.8 Data collection

3.2.8.1 Number of shoots

The number of shoots per corm were counted and recorded.

3.2.8.2 Shoot height (cm)

The shoot height was determined by measuring the distance between the point of attachment and the pseudostem to the point of first leaf emergence, using a measuring tape.

3.2.8.3 Pseudostem girth (cm)

The pseudostem girth was measured with a veneer caliper at 1cm above point of emergence of attachment to the split-corm.

3.2.8.4 Number of roots

The number of roots per split-corm was counted and recorded.

3.2.8.5 Root diameter (cm)

The root diameter was determined with a veneer caliper at the point of emergence from the split-corm. The diameters of five roots were measured and the average recorded.

3.2.8.6 Percentage sprouted corms

The percentage sprouted corms was determined using the formula;

$$Percentage\ sprouted\ corm = \frac{number\ of\ sprouted\ corms}{number\ of\ corms\ planted} \times 100$$

3.2.9 Data analysis

Data were subjected to ANOVA and Least Significant Differences (LSDs) at P = 0.05 was used to separate means when significant differences were recorded. Analysis of variance was performed using the software GenStat (Released 9.2, Ninth Edition).

3.3 Results

3.3.1 Physical and chemical characteristics of initiation media

The results of the pH of the initiation media is presented in Table 1. The pH of the sawdust was lowest, while CRH recorded the highest among the different media. Carbonated rice husk was denser and had more pore spaces for root aeration than sawdust. Sawdust however, had higher water holding capacity thus retained more moisture than rice husk (Table 1). The bulk density ranged between 0.51 and 0.60 g/cm^3 and CRH recorded the highest, while sawdust recorded the lowest. Sawdust recorded the highest EC, whilst CRH recorded the lowest among the media. The mixture of CRH:SD recorded the lowest, while sawdust recorded the highest water-holding capacity.

Table 1: Physical and chemical characteristics of the initiation media

Initiation media	pH	E.C (dS/m)	Bulk density (g/cm^3)	Aeration porosity (%)	Water holding capacity (%)
CRH	7.16	0.40	0.60	17.10	50.00
CRH:SD	7.04	0.50	0.55	32.90	43.10
SD	6.99	0.70	0.51	28.10	52.10

SD- sawdust; CRH:SD-carbonated rice husk: sawdust; CRH-carbonated rice husk

3.3.2 Effect of initiation media on corm and vegetative parameters

The initiation media did not significantly affect the mean number of sprouted corm, percentage of corm sprouted and number of shoot/split corm, 3 WAP. However, the shoot height was influenced by the media as CRH (100%) significantly increased the shoot height, compared to the sawdust (100%) and the 50:50 sawdust:CRH. Similarly, results was observed for the mean shoot girth and mean number of roots/split corm. As CRH induced the highest shoot girth and was significantly different from the other media. Similar observations were made for number of roots/split corm and root diameter. Sawdust consistently recorded the lowest values among the various media for these parameters (Table 2). However, initiation had no significant effect on mean number of sprouted corm and mean percentage sprouted corm for 3 weeks initiation (Table 2).

The mean number of shoots/plant was insignificant with respect to media effects on initiation.

Table 2: Effect of initiation media on number of split-corm sprouted on some vegetative parameters after 3 weeks in initiation media

MEDIA	No. of corm sprouted	Sprouted corm (%)	No. of shoots/split-corm	Mean shoot height (cm)	Mean shoot girth (cm).	Mean No. of roots	Mean root diam. (cm)
Sawdust	23.33	93.30	1.50	12.55	1.33	3.67	0.27
CRH:SD:	23.67	94.70	1.67	13.90	1.44	5.00	0.29
CRH	24.00	96.00	1.33	16.64	1.50	5.00	0.32
Lsd	Ns	ns	ns	0.376	0.026	0.886	0.009

Initiation media had significant effect on number of sprouted corm and percentage of sprouted corm at 6 weeks in the initiation media and was highest in the CRH treatment. However, no significant difference was observed between CRH (100%) and SD/CRH 50:50 media for this parameter. At 6 weeks, SD/CRH (50:50 mixture) induced the highest shoot height while the CRH medium induced the lowest, and was significantly different from each other. There was no significant difference in mean number of shoots/split corm but mean shoot height and mean shoot diameter was significant.

The initiation media had significant effect on mean number of shoot/plant and mean shoot height, nine WAP. However, no significant difference was observed other vegetative parameters (Table 3 and 4).

Table 3: Effect of initiation media on corm number of split-corm sprouted and some vegetative parameters 6 weeks in initiation media

MEDIA	No. of sprouted corm	No. of sprouted corm (%)	No. of shoots/split-corm	Shoot height (cm)	Shoot girth (cm)	No. of roots/plt	Root diam.(cm)
Saw dust	23.00	92.00	1.83	9.51	1.41	2.83	0.24
CRH:SD:	24.00	96.00	1.33	11.06	1.40	3.33	0.34
CRH	25.00	98.00	1.50	7.37	1.12	3.50	0.22
Lsd	1.035	4.14	ns	0.364	0.083	ns	0.21

Table 4: Effect of initiation media on number of split-corm sprouted and some vegetative parameters 9 weeks in initiation media

MEDIA	No. of sprouted corm	% of sprouted corm	No. of shoots/plt	Shoot height/plt (cm)	Shoot diam.(cm)	No. of roots/plt	Root diam(cm)
Saw dust	21.17	84.67	0.67	19.95	1.69	2.52	0.29
CRH	21.00	84.00	0.50	20.21	1.84	2.33	0.29
CRH:SD:	21.50	86.00	1.33	18.91	1.88	2.48	0.28
Lsd	Ns	ns	0.077	0.952	ns	ns	ns

At 3 WAP, no significant difference was observed between the type of propagules on mean number of sprouted corm, mean percentage of sprouted corm and mean number of shoots. However, the type of propagule affected the mean shoot height, mean shoot diameter, mean number of roots and mean root diameter (Table 5). Except for the shoot height, where the maiden sucker derived split corm induced the greatest height, the sword sucker derived split corm induced greater shoot diameter, number of roots

and root diameter/plant and was significantly different from that of maiden sucker derived ones.

Table 5: Effect of type of propagule on vegetative parameters, 3 weeks after planting in initiation media

Propagule	No. of sprouted corm	Sprouted corm (%)	No. of shoots	Shoot height (cm)	Shoot diam.(cm)	No. of roots	Root diam
Maiden	23.67	94.70	1.22	16.26	1.24	4.11	0.26
Sword	23.67	94.70	1.78	12.47	1.60	5.00	0.32
Lsd	Ns	Ns	Ns	0.18	0.02	0.54	0.03

The response of the split-corm to the different initiation media at six weeks was different from that of 3 weeks (Table 6). There was no significant difference in the shoot height, compared to maiden sucker derived material that recorded higher shoot height at 3 weeks. Split-corm derived materials from sword sucker induced higher number of shoots/plant, mean shoot diameter per plant, mean number of roots per plant and mean root diameter per plant and was significantly different from that of the split corm materials derived from maiden sucker, at 6 WAP. Although there were no significant differences in mean number of sprouted corm, mean percentage of sprouted corm and mean shoot height between propagule types, however there were significant differences in mean number of shoots, mean shoot diameter, mean number of roots and mean root diameter with sword sucker derived materials showing higher values.

Table 6: Effect of type of propagule on some vegetative parameters at 6 weeks after planting in initiation media

Type of Propagule	No. of sprouted corm	% of sprouted corm	No. of shoots/plt	Shoot height (cm)	Mean shoot diam. (cm)	Mean No. of roots	Mean root diam (cm)
Maiden	23.89	95.60	1.22	9.38	1.24	2.11	0.23
Sword	23.78	95.10	1.89	9.24	1.38	4.33	0.30
Lsd	Ns	Ns	0.646	ns	0.11	0.54	0.03

The type of propagule affected some vegetative parameters during sprouting in the initiation media, 9 WAP. The split corm derived materials from sword sucker significantly induced higher mean number of sprouted corm, percentage of sprouted corm, shoot height, and shoot diameter than materials derived from maiden sucker (Table 7). There were however no significant difference in mean number of shoots, mean number of roots and mean root diameter.

Table 7: Effect of type of propagule on vegetative parameters, 9 weeks in initiation media

Propagule	Mean No. of sprouted corm	Mean % of sprouted corm	Mean No. of shoots	Mean shoot height	Mean shoot diam	Mean No. of roots	Mean root diam
Maiden	19.33	77.33	0.891	17.67	1.679	2.33	0.274
Sword	23.11	92.44	0.776	21.71	1.922	2.56	0.30
Lsd	1.185	4.604	Ns	1.575	0.231	Ns	Ns

There was a significant interaction effect between the type of propagule and initiation media on percentage sprout at 3, 6 and 9 WAP sprouts. All the initiation media and propagule induced higher percentage of sprouts irrespective of type of propagule with time. Thus, the percentage sprouts of materials at 9 weeks was highest and significant different from that of 6 and 3 WAP in the initiation media. Irrespective of the initiation media, split corm materials derived from sword suckers recorded higher percentage sprouting than maiden suckers. The CRH media induced higher percentage of sprouts in sword sucker than in maiden sucker, except at 9 WAP. Similar interactive effects were observed for SD:CRH and sword sucker materials in inducing higher percentage of sprouts with time. Although SD also induced higher percentage of sprouts in the sword sucker materials and was significantly higher than that of maiden sucker, it was the lowest among the initiation media (Table 8).

Table 8: Interactive effect of type of propagule and initiation media on percentage sprouted corms

Media	**3 weeks**		**6 weeks**		**9 weeks**	
	Maiden	**Sword**	**Maiden**	**Sword**	**Maiden**	**Sword**
CRH	15.30	37.63	66.23	91.77	94.70	87.37
CRH:SD	12.33	26.00	60.00	87.50	85.22	100.00
SD	8.53	24.90	52.37	82.73	51,82	100.00
LSD	6.54					

Media and propagule interaction had significant influence on shoot girth of sprouted corm. The CRH and sword sucker split corm induced a higher shoot girth and was significantly higher than that of CRH and maiden sucker at 3 weeks and was also significantly different at 9 weeks. For each transfer period, sword suckers had higher shoot girth than maiden suckers in all media. At 6 weeks both maiden and sword had lower shoot girth in CRH:SD than CRH and SD (Table 9).

Table 9: Interactive effect of type of propagule and initiation media on shoot girth of sprouted corms

Media	**3 weeks**		**6 weeks**		**9 weeks**	
	Maiden	**Sword**	**maiden**	**sword**	**Maiden**	**Sword**
CRH	1.42	1.58	1.34	1.47	1.77	1.20
CRH:SD	1.18	1.68	1.02	1.22	1.79	1.88
SD	1.12	1.53	1.37	1.45	1.48	1.89
LSD	0.1777					

The CRH and sword sucker interaction induced highest shoot heights at 3 and 9 week transfers for both maiden and sword suckers and was followed by SD. CRH:SD was the least. Sword sucker in CRH:SD at 3 weeks had the least shoot height indicating an interactive effect (Table 10).

Table 10: Effect of type of propagule and initiation media on shoot height (cm) of sprouted corms

Media	**3 weeks**		**6 weeks**		**9 weeks**	
	Maiden	**Sword**	**Maiden**	**sword**	**Maiden**	**Sword**
CRH	28.90	29.07	19.72	18.70	26.84	29.40
CRH:SD	16.73	5.50	7.21	15.69	22.29	23.45
SD	17.70	18.47	16.20	15.97	18.64	24.29
LSD	1.405					

The CRH initiation medium and sword sucker split corm interaction was significant for number of roots on sprouted corms than similar material derived from maiden sucker at 3 WAP. On the otherhand, the CRH and sword sucker interaction was not significant at 9 WAP. The CRH:SD mixture and sword sucker interaction was significant at 6 weeks only, while SD and sword sucker interaction was significant at only 3WAP (Table 11).

Table 11: Effect of type of propagule and initiation media on number of roots on sprouted corms

Media	**3 weeks**		**6 weeks**		**9 weeks**	
	Maiden	**Sword**	**Maiden**	**Sword**	**Maiden**	**Sword**
CRH	4.00	6.00	2.00	4.67	2.30	2.67
CRH:SD	5.00	5.00	2.00	5.00	2.00	2.70
SD	3.30	4.00	2.30	3.30	2.70	2.30
LSD	0.8944					

The CRH and sword sucker interaction was significant for root diameter at 3 and 6 weeks sprouts, but not at 9 weeks. Similarly, SD:CRH and sword sucker split corm sprout interaction was significant at all the sampling periods for root diameter; 3, 6 and 9 WAP, however for the SD and sword sucker sprout interaction was significant at 3 and 9 WAP but not at 6WAP (Table 12).

Table 12: Effect of type of propagule and initiation media on root diameter (cm) of sprouted corms

Media	**3 weeks**		**6 weeks**		**9 weeks**	
	Maiden	**Sword**	**Maiden**	**Sword**	**Maiden**	**Sword**
CRH	0.30	0.34	0.26	0.41	0.31	0.24
CRH:SD	0.26	0.32	0.16	0.28	0.25	0.33
SD	0.23	0.30	0.26	0.22	0.27	0.31
LSD	0.0407					

3.2.11 Discussion

The initiation media essentially served as anchorage, moisture supply and proper root aeration for the split-corms. Similarity of the effects of the initiation media on sucker plantlets sprouting/rooting might be associated with the similarity in the physical properties such as bulk density, aeration porosity and water holding capacity as suggested earlier (Butler, 1960). Some of the conditions that favor sprouting of cuttings include soil moisture, aeration porosity and bulk density of the medium. The physical properties were quite similar, except for the aeration porosity that was different. The CRH media recorded the lowest aeration porosity and tended to increase the number of sprouts, improve on the vegetative parameters and the initiation media and type of sucker interaction was quite significant for most of the parameters that were monitored. This suggests that the CRH looks more promising as an initiation medium than the other media. The results indicated that the different media did not have any significant effect on sprouting at 3 and 9 weeks but had significant effect on sprouting at 6 weeks. It is likely that the physical and chemical properties of the 3 different media did not differ much from one another, hence the non significant effect of the media. This result agrees with that of Baiyeri, (1996), Baiyeri, and Aba, (2005) who indicated that the initiation media essentially served for anchorage, moisture supply and proper root aeration.

Similarity of their effects on sucker plantlets initiation might be associated with their relative similarity in amounts of pore spaces and moisture retention capacity. Butler (1960) showed that sucker corm is a nutrient reserve, which could support growth for sometimes prior to foliage development. Baiyeri (1996) reported that sucker plantlets initiation from corm is dependent on factors other than media for initiation (at least within the limit of the two media compared in his experiment which were saw dust and rice hull).

The materials derived from sword tended to sprout or root better than that of maiden sucker. These two propagules are different in morphology and physiological functions. It can therefore be suggested that differences could exist in some growth or root promoting factors such as auxins and sugar contents. These could account for the differences observed in the responses of the propagule and the initiation media Agbo and Obi (2007) reported significant variability in rooting and shoot development and growth of shoots (seedlings) of three physiological ages in *Gongronema latifolia* Benth over the two seasons Similarly, Enyi (1996) observed differences in the sprouting in cocoyam corm cuttings from different parts (young to old). Many internal factors have been shown to influence root initiation and shoot development in stem cuttings. Such factors are auxins, rooting co-factors, carbohydrate and nitrogen levels in the rooting stock (Hartmann, and Kester, 1975). They explained further that the easily rooted cuttings have high correlation with carbohydrate level in the stems. Stem cuttings taken from young seedling plant (in the juvenile growth phase) have been shown to root much more readily than those taken from older plants (Sax, 1962). Reduced rooting potential as plants age in some species was reported to be caused as a result of lowering phenolic level that act as auxin co-factors in the root or shoot initiation (Hartmann, and Kester, 1975). The significant ($p < 0.05$) combined effect of sword sucker and initiation media interaction on number of roots, root diameter, shoot number and shoot height at various times of sampling, gave an insight of the right type of propagule selection and initiation media for propagation. Similar observations between the physiological age of the planting material and the propagation environment have been reported (Agbo and Obi, 2007) and between plantain genotypes and environment (Baiyeri, 2005).

Environmental conditions in the rhizosphere were considered to be one of the important factors on root formation and further root growth. The better quality of cuttings observed carbonized rice husk indicated that this media gave more conducive environment in rhizosphere to facilitate root initiation and formation during the rooting process. Even though not properly observed, carbonized rice husk was predictably to have better water holding capacity and drainage. These supplied the root environment more constant moisture and sufficient air. The macro spores are filled up with air and supply sufficient oxygen for cells respiration (Frenck and Kim, 1995) during the rooting process. The moisture in smaller pores then, serves not only for metabolic activities but also provides sufficient humidity to avoid excessive transpiration (Karlsen, 1997) and destructive temperature fluctuation that may be happened in the rhizosphere (Klapwijk, 1987).

Another possible roles is that the endogenous hormones that is influenced by the environment. Light apparently gave significant impact on the translocation/accumulation of root promoter eg (auxin). Low light interception due to the dark rhizosphere environment in CRH promoted the accumulation of auxin at the basal part of cuttings where root initials appear and these induce the cell division and differentiation for root formation (Moe, 1988).

The non-significant differences in the number of sprouts, percentage sprout at 3 and 6 WAP due to type of propagule may be due to higher levels of some factors responsible for sprouting which could have been above the threshold for sprouting within the period. Therefore the significant difference at 9 weeks could be the result of differences in the same growth promoting factors. Therefore, it is suggested that split-corms can be sprouted in initiation media for 3 weeks rather than 6 and 9 weeks, since no significant differences were observed. This will give more time for the plant to be grown in the growing media and transplanted to the field much early.

There was not much difference between the sword and maiden sucker for number of sprouts and percentage sprouts for 3 and 6 weeks sampling. However significant differences was observed in the number of shoots, shoot height, number of roots and root diameter at 3 and 6 weeks sampling. However differences between sword and maiden sucker were significant for most of the parameters examined at 9 weeks of sampling. Similar observations have been made in the cutting Agbo and Obi (2007) reported significant variability in rooting and shoot development and growth of shoots (seedlings) of the three physiological ages in *Gongronema latifolia* Benth over the two seasons. Many internal factors have been shown to influence root initiation and shoot development in stem cuttings. Such factors are auxins, rooting co-factors, carbohydrate and nitrogen levels in the rooting stock (Hartmann, and Kester, 1975). They explained further that the easily rooted cuttings have high correlation with carbohydrate level in the stems. Stem cuttings taken from young seedling plant (in the juvenile growth phase) have been shown to root much more readily than those taken from older plants (Sax, 1962). Reduced rooting potential as plants age in some species was reported to be caused as a result of lowering phenolic level that act as auxin co-factors in the root or shoot initiation (Hartmann, and Kester, 1975).

The significant type of propagule and initiation media interaction on number of sprouts, percentage sprout, and other important vegetative parameters give an insight of the importance of initiation media, type of propagule and better timing of propagation of the optimum conditions for propagation. Rooting in cuttings is associated with auxins of the vegetative parameters for the main effects.

The initiation media and type of propagule interaction was highly significant for 3, 6 WAP for CRH, 3, 6, and 9 WAP for CRH:SD and 3 and 9 WAP for root diameter of sprouted split corms. This result suggests that propagule type differ in their response to initiation media, possibly due to the physical and chemical properties of the different media.

CHAPTER FOUR

4.0 **Effect of Growing Media and Nitrogen application rate on growth, dry matter production and nutrient uptake of plantain sucker at the nursery.**

4.1 Introduction

The early maturity and high yields of plantain are very much dependent on the production of uniformly good and healthy planting materials from a nursery and this can be achieved with good nursery management. The quality of seedling obtained from a nursery influences re-establishment in the field (Baiyeri, 2006) and the eventual productivity of an orchard (Baiyeri and Ndubizu, 1994). Ndubizu and Obiefuna (1982) showed that the quality of peeper was improved for field planting using polybag nursery technique. The quality of seedling obtained from a nursery influences its establishment in the field (Baiyeri, 2006) and eventual productivity of an orchard (Baiyeri and Ndubizu, 1994). The quality of growing media is one of the main factors that influence the success of horticultural nursery activity. Specific physical (high water holding capacity, low bulk density, high total pore space), chemical (high cation exchange capacity, low electrical conductivity, high buffer capacity, slightly acidic pH) and biological characteristics (absence of pathogens and stable organic matter) are required for materials to be useful as components of growing media for seedling production (Zapata *et al.*, 2005). The traditional nursery potting medium in Ghana is topsoil, often dug up from farmland and amended with or without sand. Soil has been indicated as the easiest way through which seedlings are infected by diseases such as root knot nematode and seedling root rots (Egunjobi and Ekundare 1981). Besides, soils have the attribute of heavy weight when large volumes are used to raise containerized plants, and nursery operators have the problem of bulkiness in transporting them (Bunt

1988). Baiyeri (2003) reported on variable crop species responses to ratios of topsoil, poultry manure and river sand.

The physical and chemical properties of the growing medium are very important to the early establishment and growth of the seedling. The bulk density of the growing media is very important for the growth, nutrient uptake of the plant. The compaction of the growing media can alter aeration porosity, root system morphology and whole plant growth. Yeager *et al*. (1997) suggested a bulk density range of 0.19 to 0.7 g/cm^{-3} dry weight for substrates used in container production.

The supply of nutrients to plants grown in containers is a key component to proper management practices. The ultimate aim of any fertilizer program is to maintain an optimum level of nutrients in the growing media throughout the growing season.

Plantain requires high amounts of nutrients which are often supplied only in part by the soil (Lahav, 1995). Studies (Tezenus du Montchel, 1987) has shown the importance of nitrogen fertilization to the growth and yield of Musa spp. Nitrogen (N) influences plantain growth and quality more than any other nutrient. Nitrogen is an integral component of amino acids that make up the protein and enzymes in all living organisms. The need for nitrogen is highest at times of vigorous growth when leaf and seed proteins develop. Notwithstanding its importance to plant growth, Baiyeri (1997) did not observe effects of N fertilizer application on the growth of the plantain peeper propagule. Obiefuna (1984a) reported that plantain suckers did not suffer growth retardation when fertilizer application was delayed for three to four months**.**

Butler (1960) reported that the corm is a nutrient reserve that could support growth for some time prior to foliage. The use of plantain peeper for propagation could be different from that of split corm, with respect to the physiology and size of the corm used in the propagation. The sword or maiden sucker from which the split-corm is derived is physiologically older than the peeper. Furthermore, in the split corm developed from sword or maiden sucker, the corm normally decomposes or, growth ceases for sometime before a new corm develops. However, in the case of peepers or non-split corm, there is continuity in growth of the corm and development of foliage if environmental conditions are conducive. Therefore the development of a split-corm derived planting material could be different from a normal full corm.

The objectives of this study were to study 1) the effects of N fertilizer application rates on the growth, dry matter production and partitioning to plant parts of split-corm derived plantain suckers in different growing media; 2) the N uptake and partitioning of split-corm derived plantain sucker to various plant parts as affected by the growing media 3) the growth and N uptake of split-corm derived planting materials planted at different times into polybags.

4.2 Materials and methods

4.2.1 Experimental site

The experiment was conducted at the University of Ghana Agricultural Research Centre (ARC), Okumaning- Kade, in the Kwaebibirim district of the Eastern region of Ghana.

4.2.2 Experimental design

A split plot design was used with the growing media (soil, soil + carbonated rice husk in a 1:1 v/v ratio and soil + carbonated rice husk + compost in a 1:1:2 v/v ratio) as the main plots and nitrogen rates (0g, 5g, 10g and 20g) as the subplots. The treatments were replicated three times.

4.2.3 Compost preparation

Materials used for the compost preparation were cocoa pod husk, empty fruit bunch, and poultry manure and palm kernel cake. The empty fruit bunch (EFB) used was chopped into smaller pieces to hasten decay. The composition of these materials in the compost heap was 1.5:1:1:1 (EFB: cocoa husk: poultry manure: palm kernel cake) volume by volume (v/v). The compost materials were stock piled on a patio and thoroughly mixed up for uniformity, moistened and four hollow bamboo stems inserted to provide ventilation. A thermometer was inserted to measure temperature inside the pile as a guide to compost maturity. It was finally covered with a polythene sheet to protect the pile from rains and direct sunshine. Compost was moistened when necessary and turned weekly to facilitate decay. Matured compost was obtained after seven weeks and was dried and milled to further reduce the size of the larger particles.

4.2.4 Preparation of growing media and transfer of sprouted split corms into media

The preparation of the carbonated rice husk has been described elsewhere in chapter 3. Three different growing media were used for the 3 and 6 week transplants. Soil weighing 16.2 kg at moisture content of 13.2 % was filled into each polyethylene bag measuring 45 cm × 35 cm (length x breadth). A 1:1 mixture of soil + carbonated rice husk (v/v) weighing 11.0 kg with moisture content of 13.4 % was also filled into polybags and finally 1:1:2 ratio of soil + carbonated rice husk + compost (v/v) weighing 9.1 kg and moisture content of 18.4 % was filled into the polybags leaving 4 cm to the brim. Three or six week old sprouted plantain (Apantu, Musa AAB) split-corm were transferred to polybags filled with the respective growing media as described elsewhere. The transplants were kept under shade for two weeks for acclimatization before carrying them into the open field.

4.2.5 Determination of physical and chemical characteristics of the growing media

The procedure used in the determination of the pH, EC, bulk density, aeration porosity and water holding capacity of the growing media was similar to that of the initiation media described elsewhere in chapter 3. The N, P and K content of the growing media were also determined as follows:

4.2.5.1 Nitrogen

The modified Kjeldahl method as described by Black (1965) was used to determine total N in plant, compost or soil samples. The samples were air dried, ground and passed through 2mm seive, after which 0.1g of each of the samples were weighed into 500ml Kjeldahl flask and heated with 5ml of concentrated H_2SO_4 in the presence of selenium catalyst and salts ($Na_2\ SO_4$) .The resulting digest was distilled with excess strong alkali (NaOH) and condensed as ammonium hydroxide (NH_4OH) to liberate ammonia. The liberated ammonium was trapped in 5ml of 2% boric acid and was titrated against 0.01M HCl using mixed indicator (bromocresol green and methyl red) until the solution changed from green to reddish end point. The percentage nitrogen was calculated as shown below.

$$\%N\ in\ media\ sample = \frac{(titre\ value) \times 0.01 \times 14 \times v}{w \times al \times 1000} \times 100$$

4.2.5.2 Phosphorus

The procedure described by Okalebo *et al.* (2002) was used in determination of total phosphorus in soil, plants, compost and its related treatments. The samples were oven-dried at 80°C and ground, and 0.2g of the sample was weighed into a 125ml Erlenmeyer flask which was previously washed with acid and distilled water. Four mills (4ml) of perchloric acid, 25ml conc. HNO_3 and 2ml conc. H_2SO_4 were added to the sample under a fume hood. The contents were mixed and heated gently at low to medium heat on a hot plate under a perchloric acid fume hood. The heating was continued until dense white fumes appeared. This again was finally heated strongly (medium to high heat) for half a minute and allowed to cool. Fifty mills (50ml) of distilled water was added and boiled for half a minute on the same plate at medium heat. After the solution had cooled it was filtered completely with Whatman No.42 filter paper, into a 100ml Pyrex volumetric flask and made up to the mark with distilled water. P was determined colorimetry using spectrophotometer (Philip PU8620 UV/VIS/NIR model) at a wave length of 712 nm. Calcium and magnesium were determined with Perklen Herman Atomic Absorption Spectrophotometer, Analyst 400**.**

Calculation

$$\text{P in sample (\%)} = \frac{\text{meter reading} \times \text{volume of digest}}{\text{weight of sample} \times \text{volume of aliquot} \times 10^6} \times 100$$

Titre value = volume of the titre HCl for the sample

v = final volume of the digestion = 50ml

w = weight of the sample taken in grams = 0.1g

al = aliquot of the solution taken for analysis =5ml

0.01 = Molarity or Normality of HCl

14 = Molar weight of nitrogen

4.2.5.3 Potassium

Total K for soil, plant samples, compost and its related treatments were determined according to the procedure outlined by Chapman and Pratt (1961). Samples were air-dried and sieved through 2.0mm mesh and 0.2g of the sample was weighed into a conical flask and digested with 5 ml Ternary mixture (20ml of 60% conc. perchloric acid, 500ml conc. nitric acid mixture and 50ml H_2SO_4). The compost- acid mixture was digested in a fume chamber till digest turned white. The digest was allowed to cool and filtered into 100ml volumetric flask which was top up to the mark. Because of the high concentration of K 10 ml aliquot of the digest was taken into 100ml volumetric flask and top up with distilled water to the mark. .The concentration was read by aspirating into Jenway flame photometer (PFP7) that was calibrated at 25ppm.

Calculation

$$K\ (\%) = \frac{flame\ reading \times digest}{weight\ of\ sample \times 10} \times 100$$

4.2.6 Layout and planting in the nursery

For each week of transplant (3 and 6 weeks), three growing media were used and four fertilizer application rates were applied three weeks after transplanting. A total of 216 polybags comprising 6 plants/treatment x 3 growing media x 4 nitrogen rates x 3 replications each for 3 week and 6 week split-corm transplants was adopted. The plants in the polybags were put on raised wooden slabs about 30 cm from the ground in order to avoid the roots from feeding from the soil. The poly bag (plates 4.1 and 4.2) were spaced at 1m x 1m interval.

Plate 4.1. Poly bags raised on slabs

Plate 4.2. Mature suckers on raised slabs

Plates 4.1 and 4.2: Young and mature suckers (ready for transplanting) in polybags on raised wooden slabs

4.2.7 Routine management and cultural practice

4.2.7.1 Weed control and irrigation

At the nursery, periodic weed control and watering were carried out. Manual and Chemical weeding were employed in the nursery. Glyphosate was sprayed between the rows at the rate of 10 ml/lt with knapsack sprayer. Watering was also done during dry periods especially during the hamattan using a watering can

4.2.7.2 Pest and disease control

The nursery was sprayed against caterpillars observed feeding on the foliar part using Lambda cyhalothrin at a rate of 40 ml/15litre water with CP 15 knapsack sprayer at low pressure. During high humidity period the plants developed Sigatoka, *Mycosphaerela fijiensis*, and were controlled with Propiconazole at a dilution rate of 25ml per 15 litre of water. Affected branches which were photosynthetically inactive were pruned to reduce microbial load and further spread and also enhance aeration.

4.2.7.3 Chemical fertilizer application

Urea, triple superphosphate and muriate of potash were applied to supply N, P and K, respectively. These straight fertilizers were selected to provide single nutrients required for the experiment and which will make evaluations meaningful. Four (4) levels of nitrogen, 0g, 5g, 10g, and 20gN/ plant were applied to the respective treatments. The urea fertilizer (N source) was split-applied at 5 weeks interval with each application supplying 5gN/plant. The first dose of urea fertilizer together with 10g K/plant and 3g P/plant was applied ten days after transplants. The same quantities of muriate of potash and triple superphosphate were applied to all treatments.

4.2.8 Field data collection

Data collection started at ten weeks after transfer of sprouted corms into growing media for both the 3 weeks and 6 weeks transplants. The following parameters were taken at two weeks interval;

4.2.8.1 Plant height (cm)

Plant height was measured from the base of the plant at the medium level to the ‘ V’ junction of the last two upper leaves with a measuring tape.

4.2.8.2 Pseudostem girth (cm)

The pseudostem girth was measured with a veneer caliper at 5 cm above the media level.

4.2.8.3 Number of Leaves

The number of leaves per plant were counted and recorded.

4.2.8.4 Leaf area (cm^2)

The leaf area was determined according to Obiefuna and Ndubizu (1975). Briefly, leaf area was determined by first measuring the length and the widest breadth of each leaf. The leaf area of each leaf was determined by multiplying its length by its breadth and then by a factor of 0.8. The total leaf area per plant was determined by summing up the leaf areas obtained from each leaf.

4.2.9 Data collection at sampling

The plantain seedlings were raised in the polybags for 17 and 14weeks for the 3 and 6 weeks transplant respectively. Some seedlings were sampled for destructive analysis. Plants were removed from the poly bags and medium washed off from the roots. The following parameters were taken on the seedlings.

4.2.9.1 Plant height (cm)

The plant heights of the sampled seedlings were taken from the point of emergence of the pseudostem to the ‘V’ junction of the last two upper leaves with a measuring tape.

4.2.9.2 Pseudostem girth (cm)

The pseudostem girth was measured with a veneer caliper at 5 cm above the point of pseudostem emergence.

4.2.9.3 Number of leaves

The number of leaves per plant was counted and recorded.

4.2.9.4 Corm height

The corm was placed on a flat surface and the height taken with a rule from the base to the point of emergence of the pseudostem.

4.2.9.5 Corm weight (g)

The corm weight was taken with a weighing scale.

4.2.9.6 Corm circumference (cm)

The corm circumference was taken with a measuring tape.

4.2.9.7 Root volume (cm^3)

The root volume was determined by displacement method. A container was filled to the brim with water and the roots immersed in the water. The volume of water displaced was measured with graduated cylinder and taken as the root volume.

4.2.9.8 Root diameter (cm)

The root diameter was determined with a veneer caliper at the point of emergence from the pseudostem. The diameters of five roots were measured and the average value recorded.

4.2.9.9 Root length (cm)

The root length was measured using the line intersect method (Newman, 1966, Tennant, 1975). The line intersect method consists of scattering the roots on a grid and counting the number of root grid line interaction points. The number of points was then multiplied by the conversion factor 2.3571 appropriate for the 3cm x 3cm grid used.

4.2.9.10 Dry weights (g)

The dry weights of the leaves, pseudostem, corm and root were determined by first taking samples and determining their fresh weights with a weighing scale. The samples were then placed in the oven at 70^{o}C for 72 hours and their dry weights recorded.

4.2.11 Data analysis

Data were subjected to ANOVA and Least Significant Differences (LSDs) determined at P = 0.05 was used to separate means when significant differences were recorded. Analysis of variance was performed using the software GenStat (Released 9.2, Ninth Edition). Correlation analysis was performed with Microsoft excel software (2007).

4.3 Results

4.3.1 Physical and chemical characteristics of growing media

The physical and chemical characteristics of the growing media used for the experiment are presented in Table 13 below.

Table 13: Some physical and chemical characteristics of the growing media

Media	pH	E.C (dS/m)	Bulk density g/cm³	Aeration porosity (%)	Water holding capacity (g/g)	N (%)	P (%)	K (%)
Soil only	5.79	0.20	1.33	40.70	0.21	0.24	0.03	0.24
Soil:CRH	6.42	0.30	1.02	50.75	0.47	0.91	0.09	-
Soil:CRH:COMP	7.92	3.1	0.80	49.96	0.74	1.53	0.42	0.80
Compost only	8.2	5.5	0.42	29.24	1.50	1.75	1.51	4.40

4.3.2 Growth parameters

4.3.2.1 Effect of growing media on growth parameters for 3 and 6 week transplants

Plant height and pseudostem girth were not significantly affected by the type of growing media before 10 weeks after transplanting (Figures 1 and 2). Significant differences were observed at 12, 14 and 16 weeks after transplanting, with SOIL:CRH:COMPOST showing higher and significant difference in plant height and pseudostem girth than the other media. No significant difference was observed in plant height between the SOIL: CRH and Soil only media.

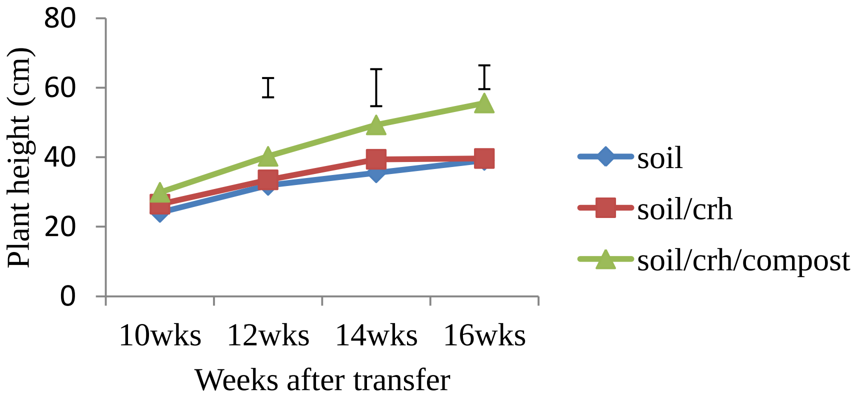

Figure 1: Effect of growing media on plant height of 3 week–old plantlet, after transplanting

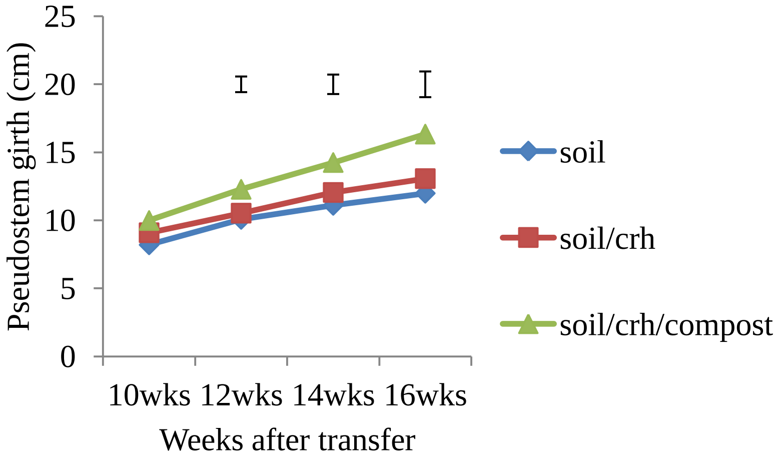

Figure 2: Effect of growing media on pseudostem girth of 3 week –old plantlet after transplanting

The number of leaves was significantly affected by the type of the growing media only at 16 weeks after transplanting, when SOIL:CRH:COMPOST induced significantly higher number of leaves than the SOIL only treatment (figure 4.3). No significant difference in number of leaves per plant was observed between SOIL:CRH and SOIL only medium during the experimental period. The leaf area was significantly affected by the growing media with SOIL:CRH:COMPOST and SOIL ONLY media recording the highest and lowest leaf areas respectively (Figure 3).

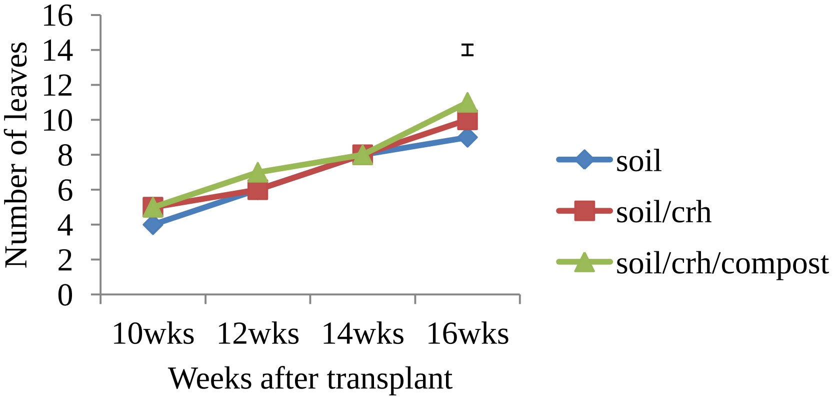

Figure 3: Effect of growing media on number of leaves of 3 week old plantlet after transplanting

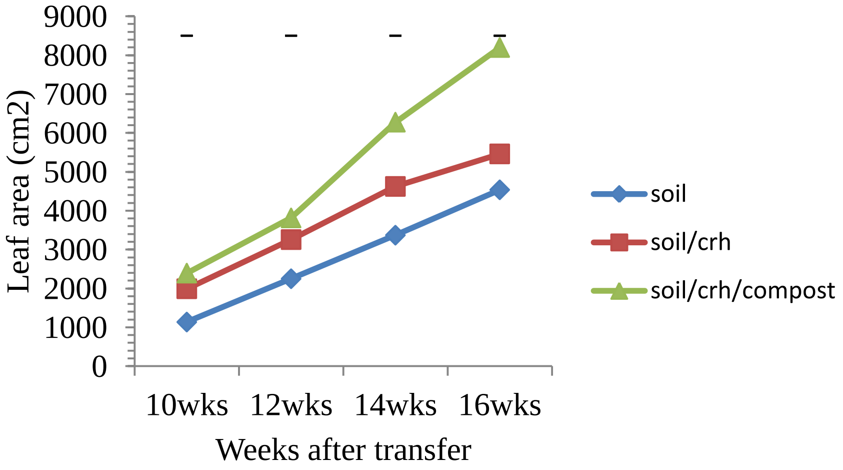

Figure 4: Effect of growing media on leaf area development of 3 week old plantlet after transplanting

The response of the 6 weeks transplants plantain sucker morphological characters, plant height, pseudostem girth, number of leaves and leaf area, to the type of growing media is shown in figures 5, 6, 7 and 8. The growing media had significant effects on the morphological characters for the 6 weeks transplant. The SOIL:CRH:COMPOST growing medium consistently recorded significantly higher morphological characters compared to that of the other growing media. Plants grown in the SOIL only growing medium recorded the least plant height, pseudostem girth, number of leaves and leaf area.

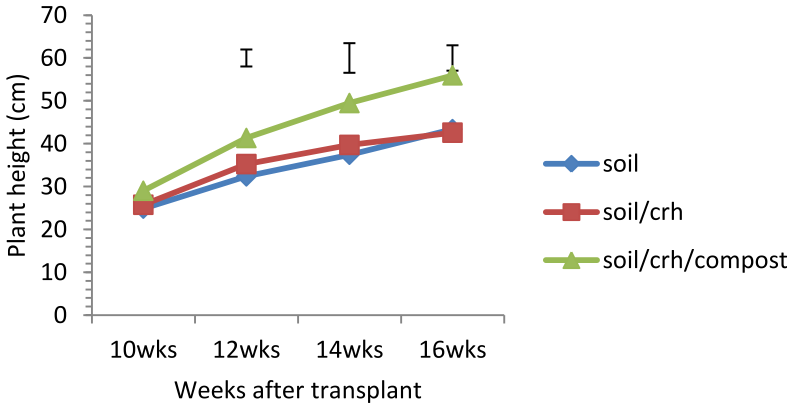

Figure 5: Effect of growing media on plant height of 6-week old plantlet after transplanting

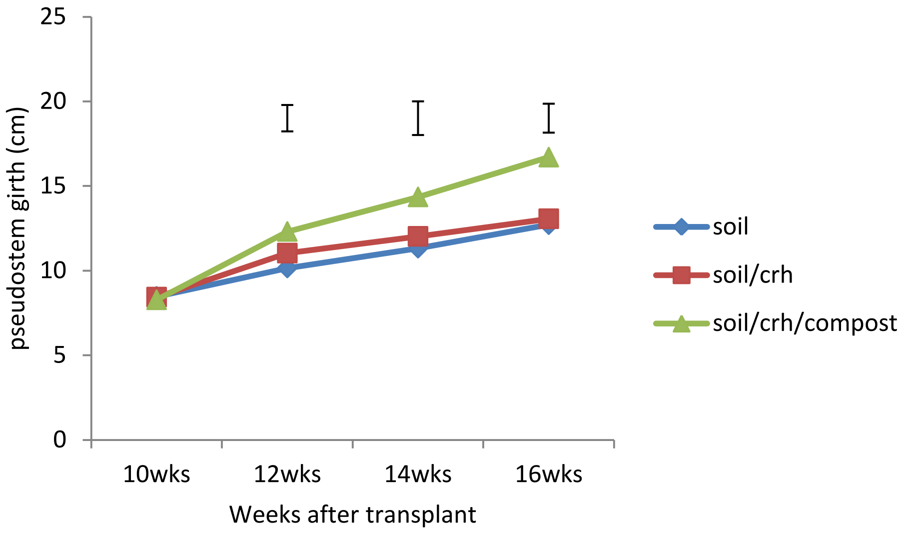

Figure 6: Effect of growing media on pseudostem girth of 6- week old plantlet after transplanting

The SOIL:CRH:COMPOST medium impacted positively on the pseudostem and was significantly different from the other growing media from 12 weeks onwards, while the no significant diiference was observed between the soil ONLY and SOIL:CRH .

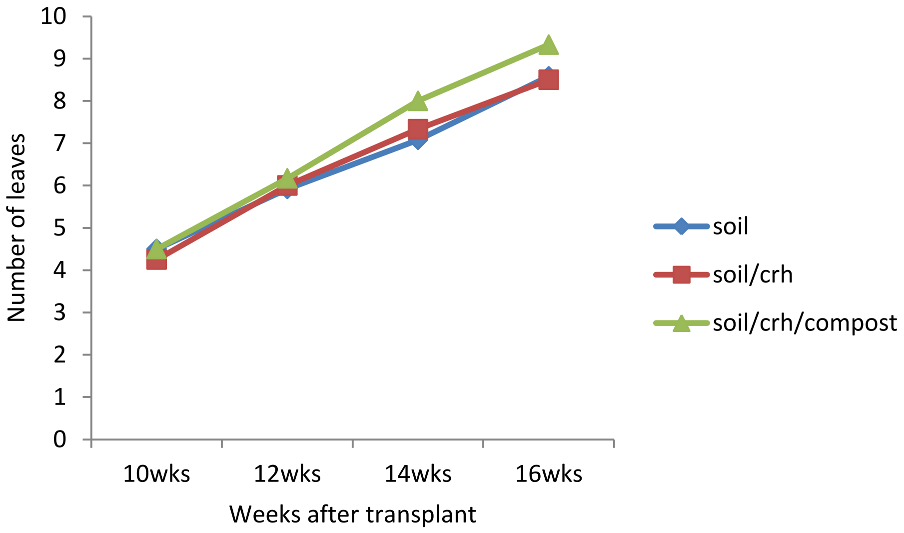

Figure 7: Effect of growing media on number of leaves of 6- week old plantlet after transplanting

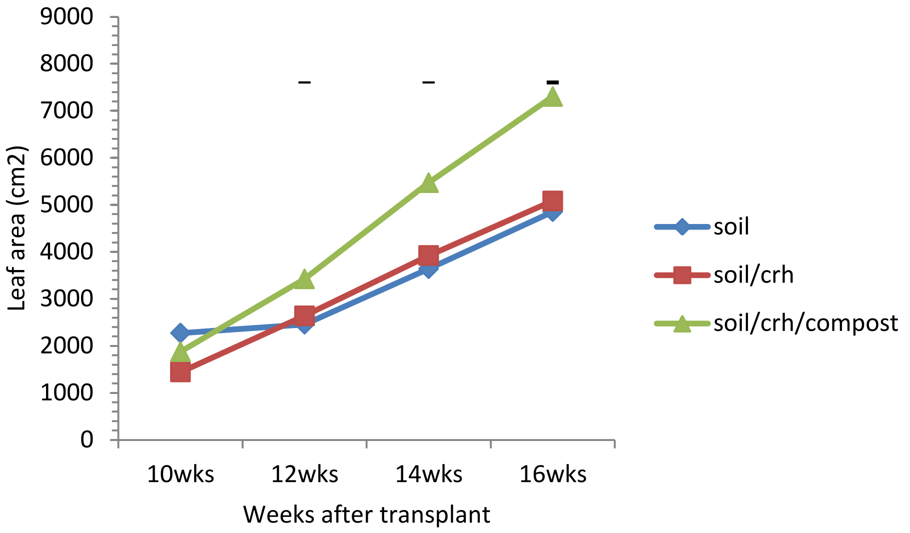

Figure 8: Effect of growing media on leaf area development of 6- week old plantlet after transplanting

4.3.2.2 Effect of nitrogen rates on growth parameters for 3 and 6 weeks transplants

Nitrogen application rates affected the morphological characteristics such as the plant height, pseudostem girth, number of leaves and leaf area (Figures 9, 10, 11 and 12). The effect of the N rate however differed depending on the morphological characteristic. For example application of N fertilizer induced significant higher plant height compared to the no fertilizer application at 14 and 16 weeks. No significant difference between the different rates of N fertilizer on plant height was observed. Similar observations were made on the effects of N fertilizer rates on the pseudostem girth. The response of number of leaves and leaf area to N fertilizer application rates almost followed the same trend as its effects on the plant height and pseudostem girth. The highest number of leaves was induced by the 10gN application rate, and it was significantly different from that of the control (no N fertilizer application) at 14 and 16 weeks only. The response of the leaf area to N fertilizer application rates was observed earlier compared to its effects on the other morphological parameters. Variations in the leaf area were observed from 10 weeks after transplanting onwards. Whereas, the 5gN induced the largest leaf area and was significantly different from that of 10gN from 10 to 12 weeks, the leaf area was not significantly different from 14 weeks onwards. In fact at 16 weeks, the 10gN treatment induced the largest leaf area among the treatments and was significantly different from the other treatments that received the fertilizer treatments (Figure 9). The smallest leaf area was induced by the 0gN treatment, and was significantly different from the other treatments after 10 weeks.

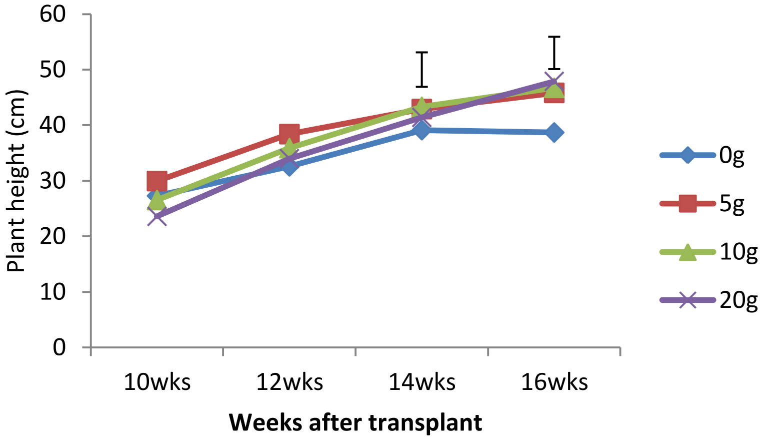

Figure 9: Effect of nitrogen application rate on plant height of 3-week old plantlet after transplanting

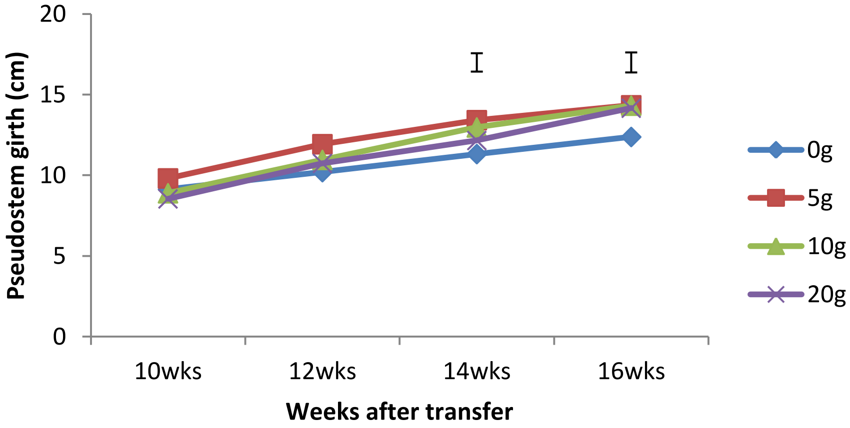

Figure 10: Effect of nitrogen application rate on pseudostem girth of 3-week old plantlet after transplanting

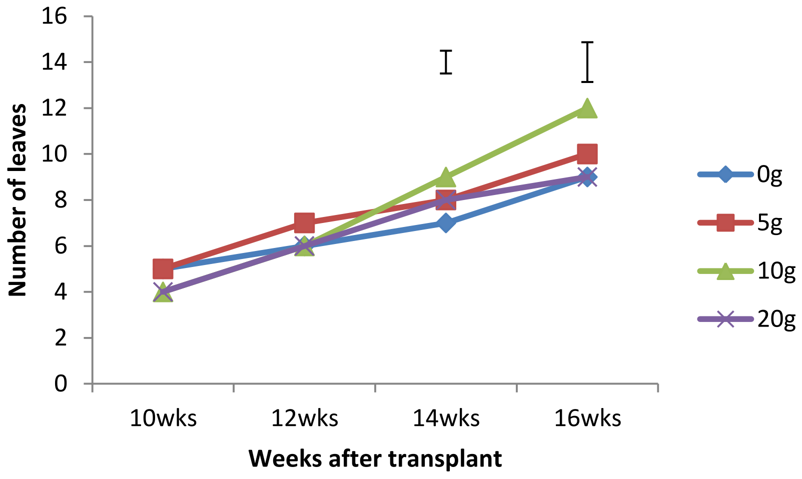

Figure 11: Effect of nitrogen application rate on number of leaves of 3- week old plantlet after transplanting

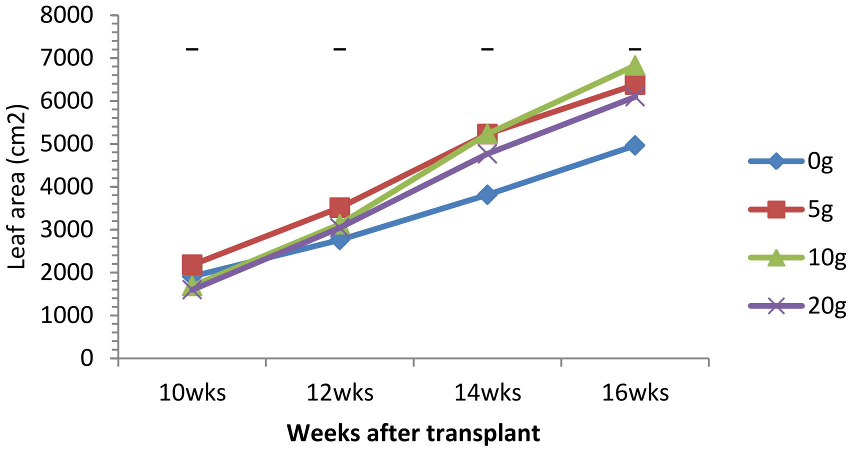

Figure 12: Effect of N fertilizer application rates on total leaf area development of 3-week old plantlet after transplanting

Nitrogen levels had significant increases on plant height. Fortnightly increases in plant height were observed and 10g nitrogen recorded the highest plant height of 56 cm, followed by 20g nitrogen and then 5g nitrogen as shown in Figure 13.

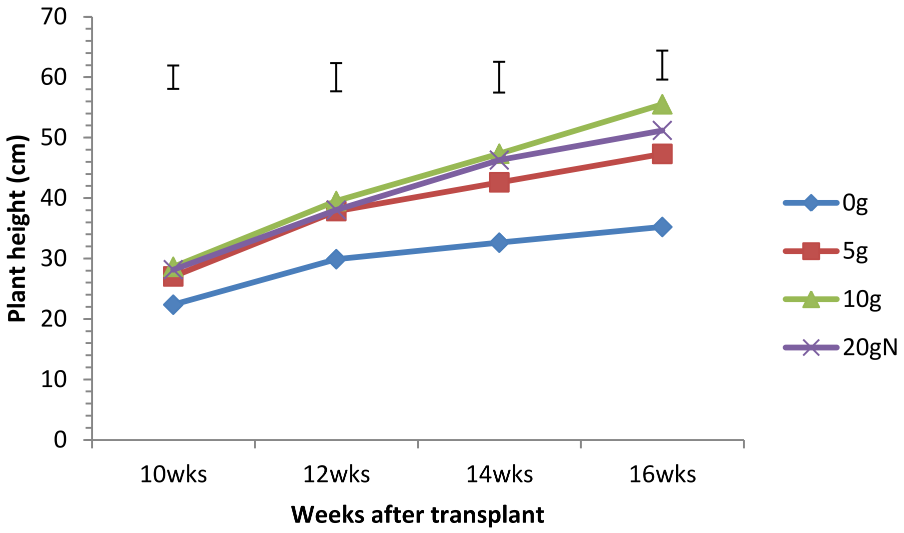

Figure 13: Effect of Nitrogen rate on plant height of 6-week old plantlet after transplanting

The same pattern was observed in pseudostem girth and leaf area for 6 weeks old transplant as was recorded in plant height and weeks of transplant for 6 weeks transplant as shown in Figures 14 and 15. Significant difference in number of leaves was recorded for 5g, 10g and 20g nitrogen after 16 weeks of transplant. Even though 5g nitrogen lagged behind initially, it also had 9 leaves by the 16th week. No significant difference was recorded in leaf area for plants that received 5g and 20g nitrogen. The lowest leaf area was recorded in plants that received 0g nitrogen (Figure 14).

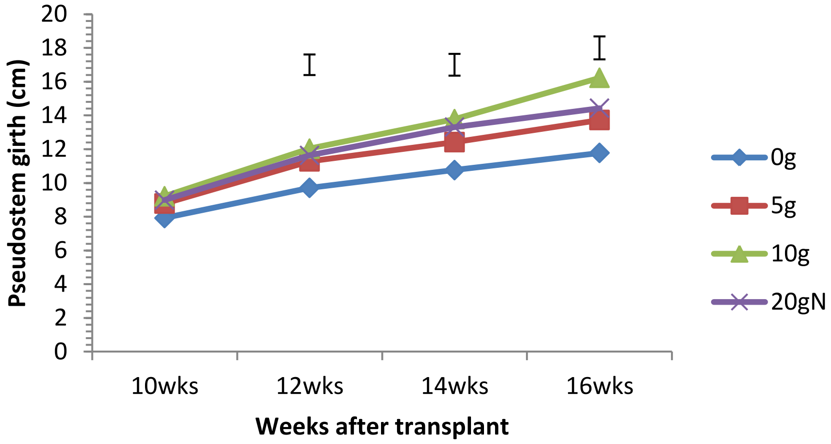

Figure 14: Effect of Nitrogen rate on pseudostem girth of 6 week old plantlet after transplanting

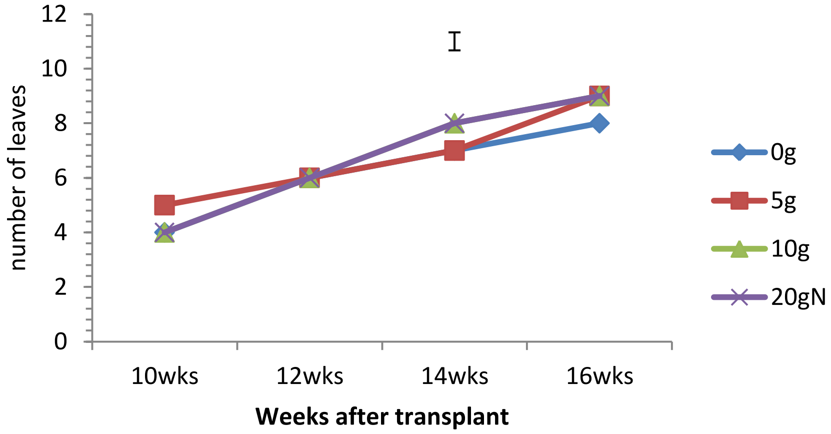

Figure 15: Effect of Nitrogen rate on number of leaves of 6- week old plantlet after transplanting

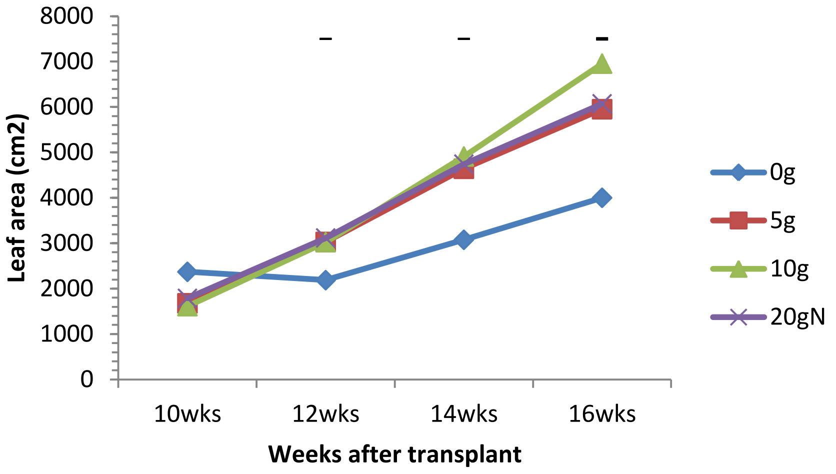

Figure 16: Effect of Nitrogen rate on leaf area development of 6 week old plants

4.3.3 Dry matter and vegetative parameters at harvest for 17 weeks old suckers, 3 weeks transplant

4.3.3.1 Effect of growing media on dry matter production and vegetative parameters

The type of growing media affected the total dry matter production and partitioning. Suckers raised in medium SOIL:CRH:COMP accumulated the highest dry matter, followed by the SOIL:CRH medium and the lowest in the SOIL only medium (Table 4.1). The dry matter accumulated by the suckers grown in the SOIL:CRH:COMP medium was 73% higher and significantly different from that of the SOIL only medium, and 27% greater than the SOIL:CRH medium. The dry matter partitioning to the various plant parts was also affected by the growing media (Table 14).

Dry matter partitioning was influenced by the growing media. The SOIL:CRH:COMP medium significantly induced the greatest amount of dry matter and was 73% and 27% greater than that of SOIL ONLY and SOIL:CRH respectively (Table 4.1). The greatest amount of dry matter was partitioned to the root, and the least to the leaf, irrespective of the growing medium. The percentage of dry matter partitioned to the corm and pseudostem was influenced by the type of the growing medium. The percentage of dry matter distribution to plant parts did not follow the same pattern. The SOIL ONLY medium induced the highest dry matter that was partitioned to the root (32.5%), followed by the pseudostem (30.4%) and 22% to the corm. A similar order of partitioning to the plant parts was observed in the SOIL:CRH :COMP However, in the case of SOIL:CRH, the order was different and the dry matter partitioned to the corm was second after that partitioned to the root. The SOIL:CRH:COMP medium induced the highest dry matter partitioned to the leaf and the percentage of total dry matter partitioned to the leaf among the growing media, The SOIL:CRH:COMP medium again induced the highest shoot:root, and the least was observed in SOIL:CRH medium.

Table 14: Effect of growing media on total plant dry weight and partitioning to various plant parts of 3 week plantlet, 17 weeks after transplanting

MEDIA	**Total plant dry wt (g)**	**Leaf dry weight (g)**	**Pseudostem dry weight (g)**	**Corm dry weight (g)**	**Root dry weight (g)**	**Shoot:root ratio**
Soil	152.5	24.12 (15.8%)	46.29 (30.4%)	33.1 (21.7%)	49.05 (32.5%)	0.85
Soil:CRH	207.2	25.80 (12.5%)	46.75 (22.6%)	58.8 (28.4%)	75.86 (36.6%)	0.50
Soil:CRH: Comp	263.5	47.12 (17.9%)	73.89 (28.0%)	54.2 (20.6%)	88.30 (33.7%)	0.89
Lsd	**15.80**	**1.171**	**1.607**	**ns**	**2.184**	

Root = corm and root dry weights. Percentage of plant part to total dry weight in brackets

The growing media affected several vegetative parameters examined at final harvest, 17 weeks after transplanting to the growing medium. Suckers raised in the SOIL:CRH:COMP medium induced greatest plant height, thicker pseudostem girth, and biggest leaf area at final harvest, compared to the other media (Table 4.2). However, the SOIL:CRH medium induced the longest root length and highest specific root length which was significantly different from that of SOIL:CRH medium and soil only medium.

Table 15: Effect of growing media on some vegetative parameters of 3 week plantlet, 17 weeks after transplanting

Growing media	Plant height (cm)	Pseudostem girth (cm)	Leaf area (cm^2)	Specific leaf area (cm^2/g)	Total Root length (cm)	Specific root length (cm/g)
Soil	44.27	12.62	6446.60	244.10	1846.70	39.99
Soil:CRH	45.12	14.29	5332.50	204.10	3567.80	46.57
Soil:CRHh: Comp	67.00	17.84	9609.00	204.20	3279.10	37.53
Lsd	0.85	0.59	5.84	8.66	136.15	2.014

The growing media affected some of the vegetative parameters of the underground plant parts of the sucker. The corm circumference and height, number of roots were highest in the SOIL:CRH:COMP medium and was significantly different from that of the other media (Table 16). However, no significant difference was observed between SOIL:CRH:COMP and SOIL:CRH for the root volume, although these were higher and significantly different from that of the soil only medium.

Table 16: Effect of growing media on some vegetative parameters of 3 week sucker, 17 weeks after transplanting

Growing media	Corm circum (cm)	Corm height (cm)	Number of roots	Root volume (cm3)	Root diameter (cm)
Soil	20.17	6.27	29.33	240.25	5.80
Soil:crh	21.14	6.01	38.42	382.75	0.50
Soil:crh: Comp	26.61	7.40	48.25	383.92	0.50
Lsd	2.15	0.30	2.91	11.32	Ns

4.3.3.2 Effect of nitrogen rates on dry matter and vegetative parameters

Nitrogen application rates influenced dry matter production and partitioning to the various plant parts. Increasing N application rates did not necessarily increase in corresponding amount of dry matter production. Generally, there was an increase in the total plant dry weight, leaf dry weight, pseudostem dry weight, corm and root dry weights, with application of 5gN, compared to the 0gN. Subsequent application of additional quantity of N did not elicit similar increases in dry matter production. Apart from leaf and corm dry weights, increase application of N fertilizer to the sucker caused reductions in total plant dry weight, pseudostem girth and root dry weights (Table 17). The highest total dry matter production was observed in the 5gN application rate, while the 0gN also recorded the least. Dry matter distribution to the leaf was highest at 20gN and least in the 0gN, whereas the highest root dry weight was recorded at 5gN rate. No significant difference in the corm dry weight was observed, although 10gN recorded the highest value. The shoot to root ratio was also affected by N application rate, and 20gN induced the highest percentage of dry matter allocation to the shoot, while 10gN induced the lowest, but the highest dry matter to the underground plant parts.

Table 17: Effect of nitrogen fertilizer application rates on total plant dry weights and partitioning to plant parts of 3 week plantlet, 17 weeks after transplanting

Nitrogen levels	Total plant dry weight (g)	leaf dry weight (g)	Pseudostem dry weight (g)	Corm dry weight (g)	Root dry weight (g)	Shoot:root
0g N	179.0	25.40	50.49	38.7	64.37	0.74
5gN	238.6	32.41	66.83	51.2	88.08	0.71
10gN	211.0	34.09	50.51	68.9	57.48	0.67
20gN	202.5	37.49	54.75	35.9	74.34	0.84
Lsd	30.39	1.490	2.202	ns	1.414	

Increasing N application rates tended to increase the leaf area of the sucker. The 20gN application rate induced the largest leaf area, and was two-fold greater than that of 0gN which recorded the least among the treatments (Table 18). Similar result was observed for the specific leaf area, with 20gN again inducing the highest and 0gN recording the least among the treatments. Furthermore, the application of 20gN induced thicker pseudostem and taller height than the treatments that received fertilizer N application. The smallest pseudostem girth was recorded in the 0gN treatment. The N application rates affected the distribution of dry matter to the plant parts as the 20gN recorded the highest leaf mass ratio (percentage of leaf dry weight to total plant dry weight) and the least in 0gN. No difference was observed between leaf mass ratio between 5gN and 0gN. The leaf mass ratio (percentage of leaf dry weight to total plant dry weight) signifies the percentage of dry matter allocated to the photosynthetic apparatus.

Table 18: Effect of nitrogen application rates on some aboveground vegetative parameters of 3 week plantlet, 17 weeks after transplanting

Nitrogen level	Leaf area (cm^2)	Specific leaf area(cm2)	Pseudostem girth(cm)	Plant height (cm)	Leaf mass ratio
0gN	4722.6	163.5	13.72	46.61	0.14
5gN	7052.1	219.9	14.89	49.22	0.14
10gN	7034.5	213.8	14.84	51.30	0.16
20gN	9708.2	272.6	16.22	61.38	**0.19**
Lsd	9.52	10.40	1.209	3.282	nd

nd-not determined

The vegetative parameter of the underground plant parts was affected by the N application rates. The application of 5gN induced the widest and tallest corm, while the 0gN induced the greatest number of roots. Increasing N application tended to reduce the number of roots developed by the corm (Table 19). The biggest root volume was induced by application of 5gN and the smallest by 10gN. Similarly, the highest specific root length was induced by application of 10gN while the least was induced by 5gN application.

Table 19: Effect of nitrogen application rates on some vegetative parameters of underground plant parts of 3 week old plantlet at final harvest

Nitrogen level	Corm circum (cm)	Corm height (cm)	Number of roots	Total root length (cm)	Root volume (cm^3)	Specific root length (cm/g)
0gN	20.33	6.14	46.56	2627.5	271.56	40.61
5gN	24.63	7.44	41.78	3344.3	463.67	37.66
10gN	22.72	7.14	30.11	2531.2	273.44	44.50
20gN	22.88	5.50	36.22	3088.4	333.89	42.69
Lsd	2.189	0.902	3.151	52.57	4.787	1.439

4.3.4 Dry matter and vegetative parameters at harvest for 14 weeks old suckers, 6 weeks transplants

4.3.4.1 Effect of growing media on dry matter and vegetative parameters for 6 weeks transfer

The growing media affected the total plant dry matter production of the 6- week old plantlet. The highest dry matter was produced by the SOIL:CRH:COMP medium, and the least by the SOIL medium. The total dry matter produced by SOIL:CRH:COMP was more than two-fold increase over that of the SOIL only. The dry matter increase in SOIL:CRH:COMP was 21% higher than that of SOIL:CRH. The partitioning of dry matter to the plant parts was similarly affected by the growing media. Whereas 30.3 g was recorded for the root dry weight for the SOIL only medium, and constituted 24.1% of the total plant dry weight, that for the SOIL:CRH:COMP recorded 82.49 g to the root, and this represented 31.5% of the total plant dry weight. Similarly, the dry matter allocation to the pseudostem was affected by the growing medium. For example, 44.6g was recorded for the SOIL medium and represented about 35.5% of the total plant dry weight, while 71.36g was recorded in the SOIL:CRH:COMP, which represented 27.2% of the total plant dry matte. Similarly, the growing media affected the corm dry weight and percentage of the total dry matter allocated to the corm The SOIL only medium recorded 24.61g for the corm dry weight, representing 19.5%, while SOIL:CRH:COMPOST allocated 61.43g to the corm, representing 23.5% of the total plant dry weight. Generally, higher proportion of the total dry matter was contributed by the leaf and corm irrespective of genotype and age at sampling. The contribution of root to the total dry matter decreased with plant age in most genotypes while the contribution of leaf remained fairly stable over time in most genotypes. There was inconsistent proportion of contribution of the corm to the total dry matter yield. Details are outlined in Table 20.

Table 20: Effect of growing media on total plant dry weight and partitioning to various plant parts of 6 week plantlet, 14 weeks after transplanting, at final harvest

Media	Total plant dry weight (g)	leaf dry weight (g)	Pseudostem dry weight (g)	Corm dry weight (g)	Root dry weight (g)
Soil	125.93	26.37	44.65	24.61	30.30
		(20.9%)	(35.5%)	(19.5%)	(24.1%)
Soil:CRH	216.35	35.41	61.44	45.72	73.78
		(16.3%)	(28.4%)	(21.1%)	(34.1%)
Soil:CRH:comp	261.92	46.65	71.36	61.43	82.49
		(17.8%)	(27.2%)	(23.5%)	(31.5%)
Lsd	1.599	0.945	1.365	2.150	1.250

% partitioned in brackets

The growing media affected the leaf area of the suckers significantly. Decreasing the soil bulk density through the addition of CRH (SOIL:CRH) and compost (SOIL:CRH:COMPOST) consistently increased the leaf area. Similar effects of the growing media on the pseudostem girth and plant height were observed (Table 21). On the other hand, decreasing the bulk density of the growing media, decreased the specific leaf area. The specific leaf area was therefore highest in the SOIl only medium and lowest in the SOIL:CRH:COMPOST.

Table 21: Effect of growing media on some vegetative parameters of 6 week old plantlet, 14 weeks after transplanting at final harvest

Media	Leaf area (cm^2)	Specific leaf area(cm^2/g)	Pseudostem girth(cm)	Plant height (cm)
Soil	6780.8	247.3	14.22	50.02
Soil:CRH	7878.2	220.4	15.98	51.29
Soil: CRH: COMP	9741.8	211.8	18.00	63.52
Lsd	9.48	7.88	1.016	1.262

4.3.4.2 Effect of N application rates and growing media on dry matter and vegetative parameters

Nitrogen application rate had positive impact on total dry matter production. The increase in N fertilizer application did not result in similar increase in dry matter production. The application of N increased the corm circumference but not the corm height. Similarly, increased application of N increased the leaf area, but the rate of increase was significant only after 5gN application, after which the increase was marginal (5gN to 20gN) an increase of only 1000 cm, compared to a massive increase from 0gN to 5gN (an increase of almost 100%). Similar response of plant height to N application was observed as observed in the response of the leaf area to N application. These marginal increases in the leaf area, plant height, root numbers and root volume (actually decreased marginally with increase in N application) (Table 22).

Nitrogen application rate had positive impact on total dry matter production. The increase in N fertilizer application did not result in similar increase in dry matter production. Leaf area, number of roots, plant height, and root volume had significant differences as shown in (Table 22). Leaf area showed a clear increase as nitrogen level increases except where 20g nitrogen was applied which had a decrease comparatively.

Table 22: Effect of nitrogen rates on some vegetative parameters at final harvest of 6 weeks transplants

Nitrogen levels	Corm circumference (cm)	Corm height (cm)	Leaf area (cm^2)	Number of roots	Plant height (cm)	Root volume (cm^3)
0 gN	17.30	6.82	4273.8	24.44	37.12	140.44
5 gN	25.80	6.07	8409.7	33.11	60.56	287.11
10 gN	24.93	5.99	10226.1	38.22	63.76	250.22
20 gN	25.00	6.76	9624.8	42.22	58.36	243.56
Lsd	1.172	Ns	10.21	3.054	3.159	5.553

The changes in allocation when nutrients are limiting are the strongest of all allocation responses, with a large increase in roots at the expense of stem and, especially, of leaf biomass. This clearly supports the idea of functional biomass allocation. The response of specific leaf area and specific root length to increase N application is shown in Table 23. Increasing N application did not show any specific trend in specific leaf area and specific root length. However it can be suggested that N application tended to increase specific leaf area. Total corm dry weight responded positively and consistently to N application. Specific leaf area, specific root length and stem girth did not follow an increasing pattern, rather inconsistent. Total corm dry weight and total leaf dry weight responded positively and consistent up to 10gN after which there was a decrease to additional N application.

Table 23: Effect of Nitrogen rates on some vegetative parameters final harvest for 6 weeks transplants

Nitrogen level	Specific leaf area (cm^2)	Specific root length (cm)	Stem girth (cm)	Total corm dry weight (g)	Total leaf dry weight (g)
0gN	209.2	42.78	11.64	29.89	20.09
5gN	243.1	40.32	17.53	46.76	34.84
10gN	227.2	44.15	18.00	46.99	46.12
20gN	226.7	35.62	17.08	52.03	43.53
Lsd	16.10	1.504	1.013	1.855	2.077

4.3.5 N accumulation and partitioning for 3 weeks transplant

4.3.5.1 Effect of growing media on N accumulation

The total N accumulated by the plant and partitioning to the various plant parts was influenced by the type of growing medium and was highest in the SOIL:CRH:COMPOST and lowest in the SOIl only medium. The N accumulated by the plant in the SOIL:CRH:COMPOST medium was more than three-fold and 35.8% increase over that accumulated by the plant in the SOIL only and SOIL:CRH medium respectively (Table 24). The N partitioned to the leaf was highest irrespective of the growing media and again was influenced by the growing media. Whereas 0.541 gN was partitioned to the leaf under the SOIL ONLY growing medium, 2.1425 gN was partitioned under theL:CRH :COMPOST. The percentage increase in the N accumulation in the leaf for the SOIL:CRH:COMPOST over that of the SOIL only was almost three fold increase, close to that of the total N accumulation for the whole plant (Table 4.11). Averagely, the SOIL"\: CRH:COMP treatment induced greater and significant N to plant parts compared to the other growing media. For example the N accumulated to the roots was about 4 fold higher than that of SOIl ONLY. On the other hand, although significant, the N accumulation to the pseudostem in the

SOIL:CRH:COMPOST treatment was only 117% higher than that of SOIL ONLY and far lower than the N partitioned to the leaf and root. The percentage of N accumulated or partitioned to the pseudostem recorded the least variation among the various plant parts examined (Table 4.11). Similar significant effect of growing media in partitioning N to the corm by the SOIL:CRH:COMP as against SOIL ONLY was observed, and in fact was almost two-fold compared to the SOIL ONLY treatment.

Table 24; Effect of growing media on N accumulation and partitioning to the various plant parts for 3 weeks transplant

Growing media	Total N accumulation (gN/plant)	N accumulation leaf (gN)	N accumulation pseudostem (gN)	N accumulation corm (gN)	N accumulation roots (gN)
Soil	1.211	0.5408	0.1908	0.2400	0.2400
Soil:CRH	3.586	1.6950	0.5683	0.1950	1.1292
Soil:CRH:COMP	4.870	2.1425	0.9208	0.5225	1.2850
Lsd	0.075	0.03	0.027	0.05	0.052

The N partitioned to the aboveground parts was influenced by the growing media. The N accumulated in the aboveground partsranged between 60% in SOIl ONLY and 63% in both SOIL/CRH and SOIL:CRH:COMP of the total N accumulated by the plant. Similar effects of growing media affecting the N partitioning was observed on the allocation of N to the roots as the N accumulated in roots was 19.8% under SOIL ONLY and 31.5% under SOIL:CRH (Table 25).

Table 25: Effect of growing media on N accumulation and percentage partitioning to the various plant parts for 3 weeks transplant

Growing media	Total N accumulation (gN/plant)	N accumulation in leaf (%)	N accumulation in pseudostem (%)	N accumulation in Corm (%)	N accumulation in roots (%)
Soil	1.211	44.65	15.75	19.80	19.80
Soil:Crh	3.586	47.20	15.80	5.41	31.50
Soil:Crh:comp	4.870	44.00	18.90	10.72	26.38
Lsd	0.08	Ns	0.69	2.03	0.76

4.3.5.2 Effect of nitrogen rate on N accumulation and partitioning

Nitrogen application rate affected the N accumulation and partitioning to the various plant parts. There was a consistent increase in the N partitioned to the root, and the highest N was accumulated at 20gN treatment. This was significantly different from that of the 10gN that was the nearest. Although the 20gN induced the highest total N accumulation, and was almost four-fold increase over the control (0gN) treatment, the N partitioning to the plant parts differed considerably and was part specific. For example, while there was a 70% increase over the 0gN treatment in N accumulation by adding 5gN, addition of 10gN did not result in 70% increase in N accumulation over the 5gN treatment, but 60% increase in N accumulation. The partitioning of N to the leaf was the greatest, followed by that of the root. Except for the N partitioned to the corm, increasing application of N resulted in corresponding increase in N accumulation of plant part. The N partitioned to the root through the 20gN treatment, was almost two- and a half fold increase over the corresponding 0gN treatment, however there was over four-fold increase in the N accumulation, over that of 0gN treatment (Tables 26, 27).

Table 26: Effect of N application rate on N accumulation and partitioning to the various plant parts for 3-weeks plantlets

N-level	Total N (gN/plant)	N accumulation leaf (gN)	N accumulation pseudostem (gN)	N accumulation Corm (gN)	N accumulation roots (gN)
0g N	1.426	0.6611	0.2733	0.0967	0.3956
5g N	2.840	1.1233	0.5600	0.3300	0.8289
10g N	3.717	1.8033	0.6622	0.3200	0.9333
20gN	4.907	2.2500	0.7444	0.5300	1.3811
Lsd	0.10	0.06	0.030	0.02	0.035

The N allocation to aboveground plant part was influenced by the N application rate. The highest N allocated to the aboveground parts was observed at 10gN, representing about 66.3% of the total N accumulated, while the control (0gN) also allocated 65.5% to the aboveground parts. The lowest N allocated to the aboveground part was observed in 20gN representing 61% of the total N accumulated.

Table 27: 13Effect of N application rate on N accumulation and percentage partitioning to the various plant parts for 3- weeks plantlets

N-level	Total N (gN/plant)	N accumulation leaf (%)	N accumulation pseudostem (%)	N accumulation corm (%)	N accumulation roots (%)
0g N	1.426	46.36	19.17	6.78	27.74
5g N	2.840	39.55	19.72	11.62	29.19
10g N	3.717	48.51	17.82	8.61	25.11
20gN	4.907	45.85	15.17	10.8	28.14
Lsd	0.10	1.42	0.72	1.25	1.01

4.3.6 N accumulation and partitioning for 6 weeks plantlets

4.3.6.1 Effect of growing media on N accumulation and partitioning

The total N accumulated by the plant and partitioning to the various plant parts was influenced by the type of growing medium and was highest in the SOIL:CRH:COMPOST and lowest in the SOIl only medium (Tables 28 and 29) as experienced under the three week transplant. The total N accumulated by the plant in the SOIL:CRH:COMPOST medium was highest and significantly different from the other growing media, and was about four-fold and 42% increase over that accumulated in the SOIL only , and SOIL:CRH media respectively. Similar to what was observed under the 3 week transplant, the N partitioned to the leaf was highest irrespective of the growing media and ranged between 1.13gN (51.43% of the total N accumulated by the plant under SOIL ONLY -3.16 gN representing36.33% of the total N accumulated by the plant under SOIL:CRH :COMPOST. The percentage increase in the N accumulation in the leaf for the SOIL:CRH:COMPOST was over four fold increase over that of the SOIL ONLY. Similar increases in N accumulation of plant parts due to the growing media was observed in the root, however in the case of the root, SOIL:CRH:COMPOST induced a six-fold increase over that of SOIL ONLY. On the other hand, the SOIL:CRH:COMPOST induced only 70% increase in N accumulation in the pseudostem over that of SOIL ONLY The percentage of N accumulated or partitioned to the pseudostem recorded the least variation among the various plant parts examined.

Table 28: Effect of growing media on total N accumulation and partitioned to plant parts in 6 week plantlet

Growing Media	Total N accumulation (gN/ plant)	N accumulation in leaf (gN)	N accumulation in pseudostem (gN)	N accumulation in corm (gN)	N accumulation in roots (gN)
Soil	2.21	1.13	0.38	0.39	0.31
Soil:CRH	5.02	2.00	0.78	0.90	1.35
Soil:CRHComp	8.69	3.16	1.26	2.17	2.10
Lsd	0.07	0.02	0.02	0.03	0.05

The growing media influenced the amount of N accumulated by the 6 week transplants, and the pattern was similar to that of the 3 week transplant. The total N accumulated in SOIL:CRH:COMP was more than three fold higher than that of SOIL ONLY. Again, the highest amount of N was allocated to the leaf, irrespective of the growing media. The highest amount of N was allocated to the leaf followed by thae root and the least to the pseudostem (Table 4.15). The percentage of the total N accumulated in the aboveground plant parts was also affected by the growing media as follows; 68.3% under SOIL ONLY, 55.6% under SOIL/CRH and 50.9% under SOIL:CRH:COMP.

Table 29: Effect of growing media on total N accumulation and percentage partitioned to plant parts in 6 week plantlet

Growing Media	Total N accumulation (gN/ plant)	N accumulation in leaf (%)	N accumulation in pseudostem (%)	N accumulation in corm (%)	N accumulation in roots (%)
Soil	2.205	51.43	17.00	17.65	13.83
Soil:CRH	5.020	39.84	15.48	17.82	26.81
Soil:CRH : Comp	8.688	36.33	14.48	25.01	24.21
Lsd	0.07	1.40	Ns	2.25	0.44

4.3.6.2 Effect of N rate on N accumulation and partitioning to plant parts

Nitrogen application rate had a marked effect on N accumulation and partitioning to the various plant parts. The highest N accumulation per plant was observed in the 20gN treatment. However, increasing N application rate did not result in corresponding increase in total N accumulation in the plant nor N partitioning to plant parts (Tables 30 and 31). For example, while there was a73% increase over the 0gN treatment in N accumulation by adding 5gN, addition of 10gN did not result in 73% increase in N accumulation over the 5gN treatment, but only 13% increase in N accumulation. The partitioning of N to the leaf was the greatest while pseudostem recorded the least. The N partitioning to the root of the 20gN treatment was 32% more than the corresponding 0gN treatment, however there was over 80% increase in the N accumulation per plant in the 20gN treatment over that of 0gN treatment. The percentage of N accumulated or partitioned to the pseudostem and leaf recorded the lower variation among the various plant parts examined.

Table 30: Effect of nitrogen application rate on total N accumulation and partitioning to plant parts in 6 week plantlet

N-level	Total N accumulated (gN/plant)	N accumulation in leaf (gN)	N accumulation in pseudostem (gN)	N accumulation in corm (gN)	N accumulation in roots (gN)
0g N	0.98	0.45	0.11	0.25	0.17
5g N	3.72	1.50	0.62	0.82	0.78
10g N	4.30	1.76	0.73	0.91	0.90
20gN	5.55	2.25	0.79	0.96	1.55
Lsd	0.09	0.04	0.02	0.04	0.03

The N allocated to aboveground plant part of the 6 week transplant was affected by the N application rate. The highest N allocated to the aboveground parts was observed at 10gN, representing about 58% of the total N accumulated, while the control (0gN) also allocated 57% to the aboveground parts. The lowest N allocated to the aboveground part was observed in 20gN representing 54.8% of the total N accumulated. The pattern of N allocation to the aboveground plant parts was similar to that observed for 3 week transplant, the difference being only the percentages that was higher in the 3 week transplant. Thus increasing the N application rate tends to decrease the percentage of total N accumulated in the aboveground parts.

Table 31: Effect of nitrogen application rate on total N accumulation and partitioning to plant parts in 6 week plantlet

N-level	Total N accumulated (gN/plant)	N accumulation in leaf (%)	N accumulation in pseudostem (%)	N accumulation in corm (%)	N accumulation in roots (%)
0g N	1.00	45.74	11.54	25.23	17.65
5g N	3.72	40.32	16.62	22.15	20.93
10g N	4.30	40.96	16.99	21.15	20.85
20gN	5.55	41.91	14.72	17.09	26.28
Lsd	0.09	0.04	0.02	0.04	0.03

The ratio of the N accumulated in root to corm was affected by the N application rate. It appears that at 0gN, a higher percentage of N is allocated to the corm (25.23%) compared to 17.65% allocated to the roots. However, at 20gN, N allocated to the corm was lower than that of the roots (17.09% compared to 26.28% to roots), although for 5gN and 10gN, the N allocated to these two parts was about the same.

4.3.7 Interactive effect of N rate and growing media on vegetative parameters

4.3.7.1 Effect of N application rate and growing media on vegetative parameters for 3 weeks transplant

Nitrogen application rate and growing media interaction was significant on dry matter of three weeks transplants, at final harvest (17 weeks after transplanting) (Table 32). The response of total plant dry and total corm dry weights to nitrogen application rate and growing media did not show any significant difference. However, differences in pseudostem, total leaf and total corm dry weights were observed. The SOIL:CRH:COMPOST growing medium and increasing N fertilizer application rates consistently increased the leaf dry weight. The highest leaf dry weight of 51.34g was recorded at SOIL:CRH:COMPOST at 20gN and the smallest leaf dry weight was recorded in SOIL only medium at 0gN. Furthermore, the leaf dry weight induced by SOIL:CRH:COMPOST was significantly different from the other growing media treatments at all N fertilizer application rates. The results suggest that the N rates and growing media interaction on total dry matter and partitioning to plant parts is strongly influenced by the growing media and N fertilizer rate and the specific plant part. Moreover, the partitioning to plant parts is also influenced by the plant part since some parts such as leaf and roots act as stronger sinks than others, such as the pseudostem. This result may be applicable under the experimental conditions for this study.

Table 32: Effect of N fertilizer rates and growing media on total dry matter production and partitioning to leaf and pseudostem of 3 week old plantlet at final harvest

N-levels	Total plant dry weight (g)			Total leaf dry weight (g)			Pseudostem dry weight (g)		
	Soil	Soil/crh	Soil/crh/comp.	Soil	Soil/crh	Soil/crh/comp.	Soil	Soil/crh	Soil/crh/comp.
0g N	116.8	169.5	250.5	13.60	18.51	44.08	38.31	52.80	60.37
5g N	220.0	206.0	289.6	28.77	26.32	42.14	63.03	42.16	95.30
10g N	150.6	238.1	244.4	27.03	24.33	50.91	45.12	38.41	67.99
20g N	122.8	215.2	269.4	27.07	34.05	51.34	38.71	53.61	71.92
Lsd	Ns			2.376			3.481		

Table 33: Effect of N fertilizer rates and growing media on total dry matter production and partitioning to leaf and pseudostem of 3 week old plantlet at final harvest

N-levels	Total corm dry weight (g)			Total root dry weight (g)		
	Soil	Soil/crh	Soil/crh/ comp.	Soil	Soil/crh	Soil/crh/comp
0g N	30.1	35.3	50.8	34.83	62.95	95.34
5g N	45.6	45.8	62.3	82.60	91.79	89.86
10g N	40.9	108.4	57.5	37.59	66.88	67.97
20g N	15.8	45.7	46.1	41.17	81.81	100.03
Lsd		Ns			2.69	

4.3.7.2 Effect of N application rate and growing media on vegetative parameters for 6 weeks transplant

Nitrogen application rate and growing media interaction was significant on total dry matter, leaf, pseudostem, corm, root dry weights, at final harvest (14 weeks after transplanting) (Table 33).The pattern of total dry matter accumulation and partitioning to various plant parts, leaf, pseudostem, corm and root was influenced by the combined effects of growing medium and N fertilizer application rate. At the different N fertilizer rates, the highest dry matter was observed at the SOIL:CRH:COMPOST medium, and was significantly different from the other treatments except for SOIL:CRH at 20 gN (Table 4.20). Except for SOIL ONLY medium at 10gN, total dry matter accumulation increased with increasing rate of N fertilizer application. Similar observations were observed at the SOIL:CRH medium at 10gN. In the case of SOIL:CRH:COMPOST, total dry matter production increased with increase N fertilizer rate, except a decrease in total dry matter accumulation that was observed between 10 and 20 g N fertilizer rate. These results suggest that total dry matter accumulation was dependent upon the type of growing medium and N fertilizer application rate. Similar to the earlier results on three weeks, the partitioning of total dry matter to plant parts is affected by the growing media and N fertilizer rate and the specific plant part but is not proportional across all the plant parts, but certain parts get more dry matter allocated, especially the leaf and the roots, while others do not get that much under the experimental conditions that prevailed under this study. It is important to note that the interaction effects on the total dry matter and its partitioning at three weeks is different from that of six week.

Table 34: Effect of growing media and N levels on total dry matter production and partitioning to plant parts of 6 week transplants at final harvest

N-levels	Total plant dry weight(g)			Total leaf dry weight(g)			Total pseudostem dry weight(g)		
	Soil	Soil/crh	Soil/crh/comp	Soil	Soil/crh	Soil/crh/comp	Soil	Soil/crh	Soil/crh/comp
0g N	67.67	99.91	223.57	11.15	14.83	34.29	18.30	21.91	63.36
5g N	136.63	247.25	262.76	26.76	39.90	37.85	57.93	67.49	80.27
10g N	121.54	243.18	285.93	30.50	46.13	61.74	38.83	76.62	75.00
20g N	177.86	275.05	275.44	37.08	40.79	52.72	63.54	79.74	66.81
Lsd	4.863			3.176			2.788		

Table 35: Effect of growing media and N levels on dry matter production/weights of underground plant parts of 6 week transplants at final harvest

N-levels	Total corm dry weight			Total root dry weight		
	soil	Soil/crh	Soil/crh comp.	Soil	Soil/crh	Soil/crh comp.
0g N	21.53	25.80	83.58	16.68	37.37	83.58
5g N	27.93	51.57	83.88	24.01	88.30	83.88
10g N	23.33	46.37	77.93	28.88	74.06	77.93
20g N	25.63	59.13	84.58	51.60	95.38	84.58
Lsd	3.189			2.002		

Nitrogen application rate and growing media interaction was significant on plant girth at both 3 and 6 weeks transplants. At the different growing media, increasing N application rate did not increase the plant girth correspondingly, but was dependent on the type of growing medium and N rate. The SOIL:CRH:COMP and growing medium interaction led to highest plant girth at 10 gN, but was not significantly different from 0gN. On the otherhand, the highest plant girth was observed at SOIL ONLY and 20gN, while for SOIL ONLY, the highest girth was observed at 5gN.

Table 36: Effect of growing media and Nitrogen levels on some vegetative parameters of 3 and 6 week-old plantain sucker split corm sprout, 14 wks after transfer to growing media

N-levels	**Plant Girth (cm) 3 wks**			**Plant Girth (cm) 6 wks**		
	Soil	**Soil/crh**	**Soil/crh/comp**	**Soil**	**Soil/ crh**	**Soil/crh/ comp**
0g N	9.40	9.77	14.80	8.77	8.87	14.63
5g N	13.60	12.93	13.73	11.87	11.00	14.40
10g N	11.77	12.20	14.93	12.73	13.47	15.13
20g N	9.63	13.30	13.53	11.93	14.77	13.23
Lsd	**2.339**			**2.452**		

Nitrogen application rate and growing media interaction was significant for SPAD readings at final harvest for 3 and 6 weeks transplants. The highest SPAD reading for the SOIL ONLY medium was observed at the 10gN which was not significantly different from that of 20gN, however, for SOIL:CRH, the highest SPAD readings was observed at 5gN and was significantly different from that of 10gN and 20gN for the 3 week transplants (Table 37).

Table 37: Effect of growing media and Nitrogen rates interaction on some vegetative parameters of 3 and 6 week-old plantain sucker split corm sprout, 14 wks after transfer to growing media

N-levels	**SPAD readings (3 wks)**			**SPAD readings (6 wks)**		
	Soil	Soil/crh	Soil/crh/comp	Soil	Soil/crh/	Soil/crh/comp
0g N	35.39	33.97	41.23	38.20	33.27	40.83
5g N	34.57	34.30	36.57	36.97	36.33	39.87
10g N	41.50	29.47	40.53	41.03	33.83	42.20
20g N	41.27	26.77	39.80	41.73	36.60	39.13
Lsd	**6.063**			**3.887**		

4.3.8 Linear relationships (Correlations)

4.3.8.2 Vegetative parameters 3 and 6 weeks plantlets

Table 38 shows the relationship between growing media effect on the R values and the correlation equations for 3 and 6 weeks plantlets. There were positive correlations for the various vegetative parameters for both the 3 and 6 weeks plantlets. These correlations, except for total plant dry weight and plant height, were higher in the 6 weeks plantlets. The strongest correlation was recorded between the total plant and root dry weights and then the total plant and pseudostem dry weights for the 3 and 6 weeks plantlets respectively.

Table 38: Effect of growing media on the relationships between some plant parameters for 3 and 6 weeks plantlets

Relationship/correlation	R^2 Value		Regression Equation	
	3 weeks	6 weeks	3 weeks	6 weeks
Total plant and leaf dry weights	0.81	0.94	Y= 0.21x + 0.87	Y= 0.14x + 7.51
Total plant and corm dry weights	0.58	0.99	Y= 0.19x + 9.45	Y= 0.26x + 9.55
Total plant and pseudostem dry weights	0.77	0.99	Y= 0.25x + 3.75	Y= 0.19x + 19.19
Total plant and root dry weights	0.95	0.97	Y= 0.35x + 2.25	Y= 0.40x + 17.86
Leaf and root dry weights	0.62	0.83	Y= 0.50x + 3.36	Y= 2.50x + 28.22
Total plant dry weight and leaf area	0.52	0.89	Y= 28.72x + 163	Y= 20.41x + 4022
Total plant dry weight and plant height	0.78	0.66	Y= 0.21x + 9.41	Y= 0.09x + 37.37
Leaf area and root dry weight	0.31	0.76	Y= 0.01x + 5.47	Y= 0.02x + 69.98

Discussion

The physical characteristics of growing media such as bulk density, aeration porosity, water holding capacity and pH affect the growth of plants. In this study, these parameters varied considerably among the different media and had varying effect on the vegetative parameters measured. The reduction in bulk density through addition of carbonated rice husk and compost confirm earlier studies by Rivenshield and Bassuk (2007) that soils, when amended with peat or food waste compost, had lower bulk density, and reduced potential root restriction. The addition of compost also affected the chemical microbiological and physical properties of the growing medium. Similarly, compost addition increased the pH of the growing media (Adamtey, 2011) as observed in this study. The decrease in bulk density, improved root growth and nutrient uptake that resulted in the improved dry matter production observed in the study. Robinson 1996; Blomme et al Swennen and Tenkuano; Salau *et al.* 1992) attributed the enhanced vegetative growth and bunch yield of a mulched crop of plantain to reduced bulk density, increased soil porosity and soil infiltration capacity.

The addition of the compost improved the organic matter content, water holding capacity increase in pH and microbial activity of the growing media. Organic matter has a profound effect on biological, chemical and physical properties of the medium. Through the decomposition of organic matter, chemical elements become available to the crop plants. Organic matter provides food and energy for soil organisms, which help in building good soil structure. Mathad and Nalwadi (1989) reported that decomposed organic material improve soil fertility by increasing soil aeration, water holding capacity and water infiltration and lower surface crusting. Similarly the poorest performance of suckers in soil only (control) may be due to nutritionally poor medium, lacking in organic material that resulted in lower growth and dry matter production, reduced leaf area and reduced root dry weight. Ahmad and Qasim (2003) found that potting media containing FYM, leaf mold, poultry manure as main source of organic matter with sand, silt and saw dust were better than sole factor of soil itself as these combinations presented more growth and vigor of the plants improving total available nitrogen and phosphorus. The lesser growth in field soil (control) may also be due to minimum number of leaves and shoots that reduced the rate of photosynthesis, thereby reducing plant growth and survival. Similar findings have been reported previously by Rahman and Ishtiaq (1996). Bashir *et al.* (2007) reported that potting media consisting of soil and organic matter improved survival rate and growth of jojoba rooted cuttings than the media consisting of soil alone or only organic matter.

Compost releases macro and micronutrients over a long period are all important factors that contribute to availability of nutrients in a balanced form for root and plant growth and development. Most nutrients are made available within the pH range observed in this study. Therefore, compost can be used to reduce acidity of growing medium and improve on the availability of nutrients to the plants. Root development and distribution are not only genotype-dependent (Kasperbauer 1990, McMichael 1990, Klepper 1992, Zobel, 1992), they are also affected by the environment (Jung 1978, Kasperbauer 1990). Soil structure, availability of nutrients and water, temperature and drainage can interact with the genetic make-up of the plant (Hamblin 1985, Box 1996, Aguilar *et al.* 2000). Root restriction as a result of high soil bulk density impaired plant growth similar to compaction concurs with the results of previous studies (Hawver 1997; Kharkina *et al*., 1999; Ne- Smith *et al*., 1992; Richards & Rowe 1977).

The SOIL:CRH:COMPOST treatment provided the optimum conditions for growth of the sucker, with or without addition of N fertilizers. There was a strong relationship between total dry weight and N accumulation in this study. This result suggest that the improved growth and dry matter production observed in SOIL:CRH:COMP was partly due to increased uptake of nutrients for growth provided by the application of fertilizer N. The addition of compost may have released other nutrients, apart from N such as P and K, Mg, Zn that may have been limiting in the other growing media over time. The combined application of inorganic fertilizer and organic (compost) have been reported to improve the growth and dry matter production of various crops as a result of the synchrony of nutrient release and root absorption.

The good environment provided by the SOIL:CRH:COMPOST medium was reflected in the high total dry matter production, and quantities partitioned to the plant parts were highest in the SOIL:CRH:COMPOST treatment than the other growing media. The greater plant height and leaf area in SOIL/CRH/COMP treatment is also attributed to more number of leaves and greater leaf area per leaf that the plants attained in this medium, which greatly increased the photosynthetic rate of the plant, which increased the plant stored material, thereby increasing plant growth and dry matter production. Similar observations have been reported in jojoba (Bashir et al., 2007). The total dry matter produced under SOIL:CRH:COMP was about 73% higher than that of the soil only treatment. This observation could be due to the higher nutrient uptake as a result of improved root dry weight, root length and provision of combined nutrient source (organic and inorganic N fertilizer application) and high leaf area. The growing medium SOIL:CRH:COMPOST supported better root and shoot development at both 3 and 6 WAT probably because nutrient release and distribution pattern within the rhizosphere was better than the other growing media. This could be attributed to lower bulk density and high aeration porosity of the media and reduced leaching of nitrates. In contrast, SOIL only treatment supported lower dry matter production and poor growth and lower N uptake/accumulation.

Eghball and Power (1999), also reported significant increases in corn yield, biomass yield and N uptake, when he evaluated the effect of placement of composted and non-composted manure on corn growth. This study showed that reducing the bulk density of the soil by addition of carbonated rice husk (SOIL:CRH) and carbonated rice husk and compost (SOIL:CRH:COMPOST) increased shoot growth, which was associated with enhanced root development. This emphasis the importance for adopting cultural practices that reduce the bulk density of the growing medium in raising plantain suckers.

A positive correlation between total dry matter and N accumulation was observed in this study. This result suggests that, growth and dry matter production is dependent on N nutrition and accumulation, and confirms earlier studies by Oscar and Tollennar (2006) who observed increased leaf area and grain yield in cereals through improved N fertilizer application and Al-Harthi and Rashid Al-Yahyai (2009) on plantain. However, the result is at variance with the observation made by Baiyeri (1997) who did not observe any growth response to N fertilizer application to plantain peeper propagule before imposition of water stress. The difference could be due to the type of propagating material used for the study. The deleterious effects of mineral deficiency, particularly nitrogen on plant growth and crop yield had been well-documented (Bowen and Nambiar 1984; Marschner 1995). Nitrogen nutrient deficiency reduces foliage mass, leaf size, numbers and longevity and adversely affects the photosynthetic process.

The linear relationship between N and SPAD values has led to the adaptation of the SPAD meter to assess crop N status and to determine the plantain’s need for additional N fertilizer (Peng *et al.*, 1995, 1996b; Balasubramanian *et al.*, 1999). SPAD readings indicate that plant N status and the amount of N to be applied are determined by the physiological N requirement of crops at different growth stages. However, increasing N application rate did not result in increases in chlorophyll content in this study. Several factors besides N availability in the soil can affect chlorophyll synthesis, interfering with the measurements of leaf greenness index by chlorophyll meters. Among them, the literature has emphasized: levels of other nutrients (Masoni *et al.*, 1996). Since differences existed in the bulk density and water holding capacities of the different growing media, this could affect the soil moisture relations, release and absorption of nutrients by the crop for various metabolic that could have impact on the chlorophyll content. Moreover, in the case of the SOIL:CRH:COMP, treatment, the mineralization of the compost would release other macro and micronutrients that would be important to the chlorophyll content such as Mg and Zn, apart from the its low bulk density.

The number of roots increased with decreasing bulk density, thus soil only recorded lower number of roots while SOIL/CRH/COMPOST recorded highest number. Similarly, the N uptake was highest in SOIL/CRH/COMPOST and lowest in SOIL only. The supply of nutrient to a plant is directly related to water movement into roots, and when such movement ceases because of lowered soil moisture roots are limited to those nutrients within the range of diffusion (Crafts, 1968). The release of nutrients from compost is known to be gradual and could meet the demands of the plants compared to that of inorganic fertilizer (Adamtey, 2011). The addition of compost to the media without application of N fertilizer compost had the best effect on parameters such leaf area, plant height, corm height, corm circumference, number of roots and root volume for 3 and 6 weeks transfer. This might probably be due to the compost supplying other nutrients to meet the growth demands of the plant. The addition of compost to the media also resulted in the release of nutrients gradually for the uptake of the suckers which accounts for better growth over the other media. Compost is effective in promoting growth and is evidenced from the results achieved in this experiment from the contributions of compost at 0 gN against 5 gN, 10 gN and 20 gN added to SOIL:CRH:COMPOST media for 3 and 6 weeks transfers.

The positive relationship between leaf dry weight and root system development suggests that the biomass production is indicative of root system development in *Musa*. Thus, agronomic treatments that enhance biomass of leaf dry weight would similarly support good root system development. Good root system will support proper ramification of the rhizosphere for moisture and nutrient uptake as well as ensuring good anchorage.

The interactive effect of the growing media and N fertilizer is of outmost agronomic importance. The study showed that, nutrient uptake especially N is dependent on several factors including the characteristics of the growing media. It is imperative to note that even at the same N application rate, the N uptake and dry matter production differed considerably and was dependent on the type of growing media. In addition, increasing N application rate within the same type of growing medium did not always result in increase in growth and dry matter production. This result could be due to several factors within the growing medium such as the physical and chemical characteristics. For example the continuous increase in growth and dry matter production as was induced by the SOIL:CRH:COMP, could be due to improved water holding capacity, that will promote the uptake of nutrients, improved soil health as a result of improved microbial activity, improved nutrient balance and synchrony of release and uptake by the plant.

The combined application of inorganic and organic fertilizers is known to reduce leaching and improve on nutrient recovery. This result is again important, in the sense that, it has proven that the use of compost is effective in providing nutrients and good environment for plant growth and also reduces the quantity of external N application considerably. Therefore, plantain nursery operators can use the compost and reduce the cost of importing N fertilizers.

Baiyeri (1997) did not observe N fertilizer response, when he used plantain peepers in the experiment. This study established that the split-corm derived plantlets responded to N fertilizer application at varying degrees. The difference between these two studies could be due to the type of planting material used. Whereas the peeper might have depended on the nutrient reserves in the corm (Butler, 1960), the split-corm material did not have that option due to the small size of the corm and thus had to depend on external sources, through fertilizer application. This might have resulted in the high root dry matter production and undoubtedly affected the partitioning of the dry matter to the various plant parts. Indeed, relatively smaller percentage of dry matter was partitioned to the corm compared to the roots, as compared to the earlier reports (Baiyeri and Ortese, 2007). Though the peepers have much nutrient reserve in the corm to support its growth, the split corm derived sucker in poly bag with a larger leaf area and well developed root system will perform better when planted in the field. This is because re-establishment will be faster in the field and growth enhanced since the root system will not be disturbed. Also the larger leaf area will have higher photosynthetic ability to produce more photosynthates for faster growth and development.

Comparing split corm material raised in SOIL/CRH/COMP to other conventional sucker planting materials will show that the conventional planting materials are usually pared prior to planting in the field and take a longer period to develop new roots and leaves therefore delaying re-establishment in the field. In some instances corms may rot thereby decreasing nutrient reserve of the sucker. Plantain suckers raised in poly bags through split corm will not suffer from paring and hot water treatment and will establish faster since they are planted with the media with leaves and roots intact that will promote rapid growth. The significant differences recorded in plant growth and biomass yield suggest that the growing media and N probably affected nutrient release pattern and the eventual quantity of nutrients available to plant roots for absorption and utilization for growth. An earlier study by Eghball and Power (1999) on the effect of placement of composted and non-composted manure on corn yield and N uptake showed significant treatment effects on biomass yield, grain yield and N uptake.

CONCLUSIONS

Initiation and growing media are important steps in raising plantain suckers through the split-corm technique. The combined use of carbonated rice husk and split corm materials derived from sword suckers appears to be good technique to raise materials at the initiation stage.

The SOIL:CRH:COMPOST growing medium was considered the best among the treatments in promoting growth, dry matter production among the planting materials. The highest dry matter production was observed in this growing medium. Nitrogen accumulation was also improved in this growing medium. The importance of reducing bulk density through addition of carbonated rice husk and compost and application of compost clearly promoted growth and dry matter production. Nitrogen application was important in promoting growth and dry matter production. The response differed depending on the growth medium. The optimum N application rate seemed to range between 5gN and 10gN.

Most of the plant parameters were positively correlated with dry matter production. These relationships can be used to predict the response of other parameters through no-destructive means. However it was realized that, the time of sampling was very important, as the relationship changed significantly as a result of changes in the time of sampling. The partitioning of dry matter to the plant parts was mainly to the shoot and roots and less amount to the corm as observed by earlier workers. It appears that the difference could be due to the type of planting material used for the experiment and the age of the plant at sampling. The use of polybag nursery should be encouraged since there is no need for paring of the materials before planting and there is continuity of plant growth.

RECOMMENDATIONS

Age of transplanting and performance of polybag raised materials in the field 10 weeks, 12 weeks, 14 weeks in soil: crh: compost to field should be reduced, since growth is restricted in the polybag after some time. Size of split-corm materials should be varied to determine optimum size for use in polybag nursery (100 g, 150g 200g).

Combined use of compost and irrigation frequency SOIL:CRH:COMPOST (50%) 25%, 35% different rates of the compost in the medium and irrigation frequency 3 times a week, 4 times a week, 5 times a week should be examined in future.

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APPENDICES

Appendix 1: Analysis of variance table for 3 weeks initiation

Variate: **mean_number_of_roots on corm**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	4.1111	2.0556	6.73	
rep.media stratum					
media	2	7.1111	3.5556	11.64	0.022
Residual	4	1.2222	0.3056	1.38	
rep.media.propagule stratum					
propagule	1	3.5556	3.5556	16.00	0.007
media.propagule	2	3.1111	1.5556	7.00	0.027
Residual	6	1.3333	0.2222		
Total	17	20.4444			

Variate: **mean_no_of_shoots**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.3333	0.1667	2.00	
rep.media stratum					
media	2	0.3333	0.1667	2.00	0.250
Residual	4	0.3333	0.0833	0.25	
rep.media.propagule stratum					
propagule	1	1.3889	1.3889	4.17	0.087
media.propagule	2	0.1111	0.0556	0.17	0.850
Residual	6	2.0000	0.3333		
Total	17	4.5000			

Variate: **mean_root_diam_On_corm_cm**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.0016444	0.0008222	26.91	
rep.media stratum					
media	2	0.0085444	0.0042722	139.82	<.001
Residual	4	0.0001222	0.0000306	0.04	
rep.media.propagule stratum					
propagule	1	0.0156056	0.0156056	22.47	0.003
media.propagule	2	0.0008778	0.0004389	0.63	0.564
Residual	6	0.0041667	0.0006944		
Total	17	0.0309611			

Variate: **mean_shoot_diam_cm**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.0271000	0.0135500	50.81	
rep.media stratum					
media	2	0.0904333	0.0452167	169.56	<.001
Residual	4	0.0010667	0.0002667	0.72	
rep.media.propagule stratum					
propagule	1	0.5653389	0.5653389	1518.82	<.001
media.propagule	2	0.0970778	0.0485389	130.40	<.001
Residual	6	0.0022333	0.0003722		
Total	17	0.7832500			

Variate: **mean_shoot_height_cm**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	2.30564	1.15282	20.96	
rep.media stratum					
media	2	52.17974	26.08987	474.39	<.001
Residual	4	0.21999	0.05500	2.29	
rep.media.propagule stratum					
propagule	1	64.41125	64.41125	2676.99	<.001
media.propagule	2	1.39603	0.69802	29.01	<.001
Residual	6	0.14437	0.02406		
Total	17	120.65703			

Variate: **total_%_of_sprouted_corms**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	112.00	56.00	2.10	
rep.media stratum					
media	2	21.33	10.67	0.40	0.694
Residual	4	106.67	26.67	0.51	
rep.media.propagule stratum					
propagule	1	0.00	0.00	0.00	1.000
media.propagule	2	85.33	42.67	0.81	0.487
Residual	6	314.67	52.44		
Total	17	640.00			

Variate: **total_no_of_sprt_Corms**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	7.000	3.500	2.10	
rep.media stratum					
media	2	1.333	0.667	0.40	0.694
Residual	4	6.667	1.667	0.51	
rep.media.propagule stratum					
propagule	1	0.000	0.000	0.00	1.000
media.propagule	2	5.333	2.667	0.81	0.487
Residual	6	19.667	3.278		
Total	17	40.000			

Appendix 2: Analysis of variance table for 6 weeks initiation

Variate: **mean_no_of_roots**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	2.1111	1.0556	7.60	
rep.media stratum					
media	2	1.4444	0.7222	5.20	0.077
Residual	4	0.5556	0.1389	0.62	
rep.media.propagule stratum					
propagule	1	22.2222	22.2222	100.00	<.001
media.propagule	2	3.4444	1.7222	7.75	0.022
Residual	6	1.3333	0.2222		
Total	17	31.1111			

Variate: **mean_no_of_shoots**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	1.8978	0.9489	5.85	
rep.media stratum					
media	2	0.7778	0.3889	2.40	0.207
Residual	4	0.6489	0.1622	0.52	
rep.media.propagule stratum					
propagule	1	2.0000	2.0000	6.38	0.045
media.propagule	2	1.0000	0.5000	1.60	0.278
Residual	6	1.8800	0.3133		
Total	17	8.2044			

Variate: **mean_root_diam_On_corm_cm**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.0007111	0.0003556	2.29	
rep.media stratum					
media	2	0.0458111	0.0229056	147.25	<.001
Residual	4	0.0006222	0.0001556	0.18	
rep.media.propagule stratum					
propagule	1	0.0272222	0.0272222	31.01	0.001
media.propagule	2	0.0340111	0.0170056	19.37	0.002
Residual	6	0.0052667	0.0008778		
Total	17	0.1136444			

Variate: **mean_shoot_diam_cm**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.000433	0.000217	0.08	
rep.media stratum					
media	2	0.330833	0.165417	61.65	<.001
Residual	4	0.010733	0.002683	0.31	
rep.media.propagule stratum					
propagule	1	0.082689	0.082689	9.53	0.021
media.propagule	2	0.010278	0.005139	0.59	0.582
Residual	6	0.052033	0.008672		
Total	17	0.487000			

Variate: **mean_shoot_height_cm**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	1.33423	0.66712	12.95	
rep.media stratum					
media	2	41.12263	20.56132	398.99	<.001
Residual	4	0.20613	0.05153	0.96	
rep.media.propagule stratum					
propagule	1	0.08542	0.08542	1.60	0.253
media.propagule	2	47.70108	23.85054	446.22	<.001
Residual	6	0.32070	0.05345		
Total	17	90.77020			

Variate: **total_%_of_sprouted_corms**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	37.33	18.67	2.80	
rep.media stratum					
media	2	112.00	56.00	8.40	0.037
Residual	4	26.67	6.67	0.22	
rep.media.propagule stratum					
propagule	1	0.89	0.89	0.03	0.869
media.propagule	2	33.78	16.89	0.56	0.599
Residual	6	181.33	30.22		
Total	17	392.00			

Variate: **total_no_of_sprt_Corms**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	2.333	1.167	2.80	
rep.media stratum					
media	2	7.000	3.500	8.40	0.037
Residual	4	1.667	0.417	0.22	
rep.media.propagule stratum					
propagule	1	0.056	0.056	0.03	0.869
media.propagule	2	2.111	1.056	0.56	0.599
Residual	6	11.333	1.889		
Total	17	24.500			

Appendix 3: Analysis of variance table for 9 weeks initiation

Variate: **mean_no_of_roots**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	1.5194	0.7597	5.86	
rep.media stratum					
media	2	0.1108	0.0554	0.43	0.679
Residual	4	0.5188	0.1297	0.17	
rep.media.propagule stratum					
propagule	1	0.2222	0.2222	0.29	0.607
media.propagule	2	0.8581	0.4291	0.57	0.595
Residual	6	4.5382	0.7564		
Total	17	7.7676			

Variate: **mean_no_of_shoots**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.01333	0.00667	2.92	
rep.media stratum					
media	2	2.32003	1.16002	508.04	<.001
Residual	4	0.00913	0.00228	0.05	
rep.media.propagule stratum					
propagule	1	0.06009	0.06009	1.24	0.308
media.propagule	2	0.11334	0.05667	1.17	0.372
Residual	6	0.29047	0.04841		
Total	17	2.80640			

Variate: **mean_root_diam_On_corm_cm**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.001419	0.000710	1.86	
rep.media stratum					
media	2	0.000719	0.000360	0.95	0.461
Residual	4	0.001522	0.000381	0.27	
rep.media.propagule stratum					
propagule	1	0.001901	0.001901	1.35	0.289
media.propagule	2	0.016219	0.008110	5.76	0.040
Residual	6	0.008442	0.001407		
Total	17	0.030224			

Variate: **mean_shoot_diam_cm**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.01172	0.00586	0.47	
rep.media stratum					
media	2	0.12671	0.06336	5.06	0.080
Residual	4	0.05004	0.01251	0.31	
rep.media.propagule stratum					
propagule	1	0.26402	0.26402	6.60	0.042
media.propagule	2	0.07734	0.03867	0.97	0.433
Residual	6	0.24001	0.04000		
Total	17	0.76984			

Variate: **mean_shoot_height_cm**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	1.786	0.893	2.53	
rep.media stratum					
media	2	5.710	2.855	8.09	0.039
Residual	4	1.411	0.353	0.19	
rep.media.propagule stratum					
propagule	1	73.568	73.568	39.48	<.001
media.propagule	2	115.917	57.959	31.10	<.001
Residual	6	11.182	1.864		
Total	17	209.575			

Variate: **total_%_of_sprouted_corms**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	513.99	257.00	1.00	
rep.media stratum					
media	2	12.44	6.22	0.02	0.976
Residual	4	1027.98	257.00	16.13	
rep.media.propagule stratum					
propagule	1	1027.56	1027.56	64.51	<.001
media.propagule	2	119.11	59.56	3.74	0.088
Residual	6	95.57	15.93		
Total	17	2796.66			

Variate: **total_no_of_sprt_Corms**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	33.444	16.722	1.03	
rep.media stratum					
media	2	0.778	0.389	0.02	0.976
Residual	4	64.889	16.222	15.37	
rep.media.propagule stratum					
propagule	1	64.222	64.222	60.84	<.001
media.propagule	2	7.444	3.722	3.53	0.097
Residual	6	6.333	1.056		
Total	17	177.111			

Appendix 4: Analysis of variance table for growth parameters for 3weeks transplant

Variate: **Leaf_Area_(cm^2) After 10 weeks of transplant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	215024.	107512.	0.56	
REP.MEDIA stratum					
MEDIA	2	9912680.	4956340.	25.82	0.005
Residual	4	767792.	191948.	0.37	
REP.MEDIA.N_LEVEL stratum					
N_LEVEL	3	1823251.	607750.	1.17	0.350
MEDIA.N_LEVEL	6	4914316.	819053.	1.57	0.212
Residual	18	9374173.	520787.		
Total	35	27007235.			

Variate: **Number_of_Leaves after 14 weeks of transplant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	2.1667	1.0833	5.20	
REP.MEDIA stratum					
MEDIA	2	9.5000	4.7500	22.80	0.007
Residual	4	0.8333	0.2083	0.54	
REP.MEDIA.N_LEVEL stratum					
N_LEVEL	3	9.8611	3.2870	8.45	0.001
MEDIA.N_LEVEL	6	1.3889	0.2315	0.60	0.730
Residual	18	7.0000	0.3889		
Total	35	30.7500			

Variate**: Plant_Girth_(cm) after 14 weeks of transplant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	2.007	1.003	0.63	
REP.MEDIA stratum					
MEDIA	2	62.660	31.330	19.66	0.009
Residual	4	6.373	1.593	0.79	
REP.MEDIA.N_LEVEL stratum					
N_LEVEL	3	23.127	7.709	3.83	0.028
MEDIA.N_LEVEL	6	39.467	6.578	3.27	0.024
Residual	18	36.207	2.011		
Total	35	169.840			

Variate: **Plant_Height_(cm) after 14 weeks of transplant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	145.92	72.96	0.83	
REP.MEDIA stratum					
MEDIA	2	1219.42	609.71	6.90	0.050
Residual	4	353.43	88.36	2.25	
REP.MEDIA.N_LEVEL stratum					
N_LEVEL	3	77.38	25.79	0.66	0.590
MEDIA.N_LEVEL	6	436.64	72.77	1.85	0.146
Residual	18	708.08	39.34		
Total	35	2940.88			

Variate: **SPAD values after 14 weeks of transplant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.21	0.11	0.01	
REP.MEDIA stratum					
MEDIA	2	495.60	247.80	21.01	0.008
Residual	4	47.18	11.80	0.90	
REP.MEDIA.N_LEVEL stratum					
N_LEVEL	3	24.88	8.29	0.63	0.604
MEDIA.N_LEVEL	6	248.84	41.47	3.16	0.027
Residual	18	236.35	13.13		
Total	35	1053.07			

Variate: **Leaf_Area_(cm^2) after 14 weeks of transplant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	230435.	115217.	0.45	
REP.MEDIA stratum					
MEDIA	2	12229178.	6114589.	23.87	0.006
Residual	4	1024854.	256214.	0.90	
REP.MEDIA.N_LEVEL stratum					
N_LEVEL	3	5163648.	1721216.	6.07	0.005
MEDIA.N_LEVEL	6	1616848.	269475.	0.95	0.484
Residual	18	5100095.	283339.		
Total	35	25365058.			

Appendix 5: Analysis of variance table for growth parameters for 6weeks transplant

Variate: **Number_of_Leaves after 10 weeks of transplant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.5000	0.2500	0.50	
REP.MEDIA stratum					
MEDIA	2	0.5000	0.2500	0.50	0.640
Residual	4	2.0000	0.5000	1.46	
REP.MEDIA.N_LEVEL stratum					
N_LEVEL	3	0.9722	0.3241	0.95	0.439
MEDIA.N_LEVEL	6	4.6111	0.7685	2.24	0.086
Residual	18	6.1667	0.3426		
Total	35	14.7500			

Variate: **Plant_Girth_(Cm) After 10 weeks of transplant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	9.617	4.809	5.66	
REP.MEDIA stratum					
MEDIA	2	5.342	2.671	3.14	0.151
Residual	4	3.398	0.849	0.51	
REP.MEDIA.N_LEVEL stratum					
N_LEVEL	3	8.527	2.842	1.72	0.199
MEDIA.N_LEVEL	6	11.387	1.898	1.15	0.376
Residual	18	29.792	1.655		
Total	35	68.062			

Variate: **Plant_Height_(cm) after 10 weeks of transplant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	261.50	130.75	8.46	
REP.MEDIA stratum					
MEDIA	2	115.37	57.68	3.73	0.122
Residual	4	61.80	15.45	1.01	
REP.MEDIA.N_LEVEL stratum					
N_LEVEL	3	222.80	74.27	4.87	0.012
MEDIA.N_LEVEL	6	132.81	22.14	1.45	0.250
Residual	18	274.57	15.25		
Total	35	1068.85			

Variate: **SPAD values after 10 weeks of transplant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	25.16	12.58	0.59	
REP.MEDIA stratum					
MEDIA	2	15.82	7.91	0.37	0.711
Residual	4	85.02	21.26	1.37	
REP.MEDIA.N_LEVEL stratum					
N_LEVEL	3	44.98	14.99	0.97	0.431
MEDIA.N_LEVEL	6	210.82	35.14	2.26	0.084
Residual	18	279.59	15.53		
Total	35	661.40			

Variate: **Leaf_Area_(cm^2) after 10 weeks of transplant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	902232.	451116.	2.16	
REP.MEDIA stratum					
MEDIA	2	1269035.	634517.	3.04	0.158
Residual	4	836160.	209040.	0.82	
REP.MEDIA.N_LEVEL stratum					
N_LEVEL	3	839838.	279946.	1.10	0.377
MEDIA.N_LEVEL	6	2508225.	418038.	1.64	0.195
Residual	18	4599988.	255555.		
Total	35	10955479.			

Variate: **Number_of_LEAVES after 14 weeks of transplant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	1.0556	0.5278	0.93	
REP.MEDIA stratum					
MEDIA	2	5.3889	2.6944	4.73	0.088
Residual	4	2.2778	0.5694	1.28	
REP.MEDIA.N_LEVEL stratum					
N_LEVEL	3	2.5278	0.8426	1.90	0.166
MEDIA.N_LEVEL	6	7.7222	1.2870	2.90	0.037
Residual	18	8.0000	0.4444		
Total	35	26.9722			

Variate: **PLANT_GIRTH_(cm) after 14 weeks of transplant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	17.982	8.991	2.92	
REP.MEDIA stratum					
MEDIA	2	60.185	30.092	9.76	0.029
Residual	4	12.333	3.083	1.83	
REP.MEDIA.N_LEVEL stratum					
N_LEVEL	3	47.898	15.966	9.49	<.001
MEDIA.N_LEVEL	6	47.371	7.895	4.69	0.005
Residual	18	30.292	1.683		
Total	35	216.060			

Variate: **PLANT_HEIGHT_(cm) after 14 weeks of transplant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	104.03	52.02	1.40	
REP.MEDIA stratum					
MEDIA	2	984.17	492.09	13.25	0.017
Residual	4	148.57	37.14	1.41	
REP.MEDIA.N_LEVEL stratum					
N_LEVEL	3	1215.77	405.26	15.34	<.001
MEDIA.N_LEVEL	6	622.98	103.83	3.93	0.011
Residual	18	475.68	26.43		
Total	35	3551.21			

Variate: **SPAD values after 14 weeks of transplant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	127.212	63.606	7.31	
REP.MEDIA stratum					
MEDIA	2	205.305	102.652	11.80	0.021
Residual	4	34.788	8.697	2.30	
REP.MEDIA.N_LEVEL stratum					
N_LEVEL	3	21.007	7.002	1.85	0.174
MEDIA.N_LEVEL	6	67.248	11.208	2.96	0.034
Residual	18	68.120	3.784		
Total	35	523.680			

Variate: **LEAF_AREA_(cm^2) after 14 weeks of transplant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	493593.	246796.	0.98	
REP.MEDIA stratum					
MEDIA	2	5370991.	2685496.	10.64	0.025
Residual	4	1009882.	252471.	1.29	
REP.MEDIA.N_LEVEL stratum					
N_LEVEL	3	4959954.	1653318.	8.42	0.001
MEDIA.N_LEVEL	6	1973962.	328994.	1.68	0.184
Residual	18	3532366.	196243.		
Total	35	17340748.			