An investigation of alternative growth media to replace peat for the cultivation of potted *Dendranthema* x *grandiflorum*

By

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DECLARATION

Student Number: 55745091

I declare that "**An investigation of alternative growth media to replace peat for the cultivation of potted *Dendranthema* x *grandiflorum***" is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

28 February 2019

…….. ……..

SIGNATURE DATE

(Mr Katlego Gustaff Koopa)

DEDICATION

I dedicate this study to a very special person who nurtured, mentored and loved me throughout my personal and academic life.

Ellen Mampaotjie Koopa (*nee'* Leoto), you are the best Mom ever!

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ABSTRACT

Peat extraction for horticultural production poses a threat to wetland ecosystems. The rapid growth rate of the horticulture industry has prompted an ongoing search for sustainable alternative growth media components to replace peat. The alternative components need to provide properties (physical and chemical) similar to or better than peat and provide conditions that will enhance ideal growth and yield of potted plants. Potted *Dendranthema* x *grandiflorum* is one of the most important pot plants cultivated worldwide in the floriculture industry. There is a global research effort to replace peat with a sustainable alternative growth media for potted plants; however, so far, no study has been conducted in South Africa that used similar treatments on potted *Dendranthema* x *grandiflorum*. The aim of this study was to determine a suitable alternative growth media to replace peat as a growth media for cultivation of potted *D*. x *grandiflorum*. A greenhouse experiment was conducted at the University of South Africa's Horticulture centre in Florida, Johannesburg for 89 days. Eight growth media (100 % peat (T1) (control), 100 % bagasse (T2), 50:50 % v/v bagasse:peat (T3), 75:25 % v/v bagasse:peat (T4), 25:75 % v/v bagasse:peat (T5), composted bagasse (T6), Coir (T7), and pine bark (T8)) as treatments and one hybrid (Mount® Runca) of *D*. *x grandiflorum* were arranged in a randomized complete block design with four replicates. In this study, nutrient uptake, chlorophyll content, growth, and yield parameters were measured for potted *D*. x *grandiflorum* grown in all eight growth media. The results show that treatments had different chemical and physical properties compared to peat. The pH of 100 % bagasse and coir were within the ideal range recommended for growth media. The EC results indicated that after the experiment, other treatments were within the defined range except for composted bagasse due to high concentration of soluble salts. The BD of control and composted bagasse were similar and may have resulted in the low root response. The concentration of total N was high in the shoots of plants cultivated in 100 % peat with a subsequent increased fresh and dry shoots weight. The highest significant chlorophyll content was present in plants cultivated in composted bagasse, which contained high total N and, Fe and Zn concentrations in shoots. Taken together, the results showed that composted bagasse was the best alternative to replace peat for cultivation of potted *D*. x *grandiflorum*.

Keywords: *Dendranthema* x *grandiflorum*, growth media, peat, peat alternatives

OPSOMMING

Turfonttrekking vir tuinboukundige produksie hou ’n bedreiging vir moerasland-ekostelsels in. Die vinnige groeitempo van die tuinboubedryf het gelei tot ’n voortdurende soektog na volhoubare groeimediakomponente om turf te vervang. Die alternatiewe komponente moet (fisiese en chemiese) eienskappe kan bied wat soortgelyk aan, of beter as dié van turf is, en moet toestande gee wat die ideale groei en opbrengs van potplante verbeter. Potplant- *Dendranthema* x *grandiflorum* is een van die belangrikste potplante wêreldwyd wat in die blomboerderybedryf aangeplant word. Daar word wêreldwyd navorsing gedoen om turf met ’n volhoubare groeimedium vir potplante te vervang; sover is daar egter nog nie in Suid-Afrika ’n studie gedoen wat soortgelyke behandelings vir potplante-*Dendranthema* x *grandiflorum* gebruik nie. Die doel van hierdie studie was om ’n gepaste alternatiewe groeimedium te bepaal om turf as ’n groeimedium te vervang vir die aanplanting van *D*. x *grandiflorum*-potplante. ’n Kweekhuis-eksperiment is by die Universiteit van Suid-Afrika se Tuinbousentrum in Florida, Johannesburg uitgevoer vir 89 dae. Agt groeimedia (100% turf (T1) (beheer), 100% bagasse (T2), 50:50% v/v bagasse:turf (T3), 75:25% v/v bagasse:turf (T4), 25:75 % v/v bagasse:turf (T5), bagasse wat tot kompos verwerk is (T6), klapperhaar (T7), en dennebas (T8)) as behandelings en een hibried (Mount® Runca) van *D*. *x grandiflorum* is in ’n verewekansigde, volledige blokontwerp met vier repliserings gerangskik. In hierdie studie is voedingstofopname-, chlorofilinhoud-, groei- en opbrengs-parameters gemeet vir potgroei van *D*. x *grandiflorum* in al agt groeimedia. Die resultate toon dat die behandelings verskillende chemiese en fisiese eienskappe in vergelyking met turf het. Die pH van 100% bagasse en klapperhaar val binne die ideale reikwydte wat vir groeimedia aanbeveel word. Volgens die EG (elektriese geleiding)-resultate was ander behandelings binne die gedefinieerde reikwydte – behalwe vir bagasse wat tot kompos verwerk is – vanweë die hoë konsentrasie oplosbare soute. Die BD van beheer en bagasse wat tot kompos verwerk is, was soortgelyk en kon die lae wortelrespons veroorsaak het. Die konsentrasie totale N was hoog in die lote van plante wat in 100% turf aangeplant is, met ’n gevolglike verhoging in die gewig van vars en droë lote. Die hoogste beduidende chlorofilinhoud was teenwoordig in plante wat gekweek is in bagasse wat tot kompos verwerk is, en wat hoë totale konsentrasies van N, Fe en Zn in die lote bevat het. Alles in ag genome het die resultate getoon dat bagasse wat tot kompos verwerk is, die beste alternatief is om turf te vervang in die kweking van *D*. x *grandiflorum* in potte.

Sleutelwoorde: *Dendranthema* x *grandiflorum*, groeimedia, turf, turfalternatiewe

TSHOBOKANYO

Go ntsha borubu mo kumong ya mokgwa wa temo go na le matshosetsi mo matshelong a dipholologolo le ditlhare tsa lefatshe le le kolobileng. Kelo ya kgodiso e e bonako ya intaseteri ya matshelo a dipholologolo le ditlhare e susumetsa patlo e e tswelelang ya dikarolo tsa mekgwa ya kgodiso ya thefosano e e tswelelang ya go emela go ntsha borubu. Dikarolo tse dingwe di tlhoka go neela dipharologantsho (sebopego le khemikale) tse di tshwanang le kgotsa botoka mo go ntsheng borubu le go neela mabaka a a ka tsholetsang kgodiso e e ikaeletsweng, mme ya ntsha dijalo tse di ka fa dipitseng. *Dendranthema* x *grandiflorum* e e ka fa dipitseng ke thefosano nngwe ya dijalo tsa ka fa dipitseng tse di botlhokwa thata tse di jadilweng mo lefatsheng ka bophara mo intasetering ya mokgwa wa temo ya dithunya. Go na le boiteko jwa patlisiso ya bogotlhe ya go emela go ntsha borubu ka mokgwa wa kgodiso wa thefosano o mongwe o o tswelelang wa dijalo tsa ka fa dipitseng; le gale, go le kalo, ga go na thuto e e setseng e dirilwe mo Aforikaborwa e e dirisang ditshwaro tse di tshwanang mo go *Dendranthema* x *grandiflorum* e e mo dipitseng. Maikaelelo a thuto eno e ne e le go tlhomamisa mekgwa ya kgodiso ya thefosano e mengwe e e tshwanelang go emela go ntsha borubu jaaka mekgwa ya kgodiso ya go jala *D*. x *grandiflorum* ka mo dipitseng. Tekelelo ya ntlo e tala e ne ya dirwa kwa lefelong la Mokgwa wa matshelo a dipholologolo le ditlhare ya Yunibesiti ya Aforikaborwa kwa Florida, Johannesburg mo matsatsing a le 89. Mekgwa ya kgodiso e merobedi (100 % ya go ntsha borubu (T1) (taolo), 100 % *bagasse* (T2), 50:50 % v/v *bagasse*: go ntsha borubu (T3), 75:25 % v/v *bagasse*: go ntsha borubu (T4), 25:75 % v/v bagasse: go ntsha borubu (T5), *bagasse* e e bodisitsweng (T6), *Coir* (T7), le kutu ya phaene (T8)) jaaka ditshwaro le lotswakwa lo lo longwe (Mount® Runca) ya *D*. *x grandiflorum* di ne di beilwe ka moakanyetso wa boloko e e feletseng ka kakaretso ka ditshwano di le nne. Mo thutong eno, go tsaya kotlo, diteng tsa setalafatsi, kgodiso le diparametara tse di ntshitsweng di ne tsa lekanyediwa mo go *D*. x *grandiflorum* e e mo dipitseng e e jadilweng mo mekgweng ya dikgodiso tse di robedi tse tsotlhe. Dipheto di bontsha gore ditshwaro di na le dikarolo tsa dikhemikale le dibopego tse di farologaneng fa di tshwantshanngwa le go ntsha borubu. *Bagasse* ya pH ya 100 % le *coir* di ne di le magareng ga paka ya botlhokwa ya kgodiso e e atlenegisitsweng mo mekgweng ya kgodiso. Dipheto tsa EC di bontsha gore morago ga tekelelo, ditshwaro tse dingwe di ne di le magareng ga paka e e tlhalositsweng kwa ntle ga *bagasse* e e bodisitsweng kwa kokoanong e e kwa godimo ya matswai a a tlhaolositsweng. BD ya taolo le *bagasse* e e bodisitsweng, mme go ka bo go dirile gore go nne le tsibogelo ya medi e e kwa tlase.

Kokoano ya N yotlhe e ne e le kwa godimo mo matlhogeding a dijalo tse di jadilweng ka go ntsha borubu jwa 100 % ka koketso e e latelang ya bokete jwa matlhogedi a mantshwa le a a omileng. Diteng tsa setalafatsi se se botlhokwa se se kwa godimodimo di ne di le teng mo dijalong tse di jadilweng ka *bagasse* e e bodisitsweng, e e nang le kokoano ya bogotlhe jo bo kwa godimo jwa N, Fe le Zn mo matlhogeding. Di tserwe mmogo, dipheto di bontsha gore *bagasse* e e bodileng jaaka sengwe se se gaisang go emela go ntsha borubu mo jalong ya *D*. x *grandiflorum* ka mo dipitseng.

Mafoko a motheo: *Dendranthema* x *grandiflorum*, mekgwa ya kgodiso, go ntsha borubu, dithefosano tsa go ntsha borubu

ABBREVIATIONS

°C:	Degrees Celsius
CEC:	Cation Exchange Capacity
C/N:	Carbon/Nitrogen
cm:	Centimetre
DEFRA:	Department for the Environment, Food and Rural Affairs
EC:	Electrical Conductivity
g:	Grams
g/cm^{-3}:	Grams per cubic centimetre
g/kg:	Grams per kilogram
kg/L:	Kilograms per litre
L:	Litre
mg/kg:	Milligram per kilogram
mg/L:	Milligram per litre
mg/m^2:	Milligram per square metre
mL:	Millilitre
mm:	Millimitres
mS/cm^{-1}:	Milli-siemens per centimetre
ppm:	Parts per million
SMRI:	South African Sugarcane Research Institute
UK:	United Kingdom
USA:	United States of America
µg/mL:	Micro grams per millilitre

GLOSARY

Air filled porosity (AFP):	The difference in water content between total porosity and container capacity is air filled porosity (Caron & Rivière, 2002).
Alkaloids:	A class of naturally occurring organic nitrogen-containing bases found primarily in plants. They are suggested to be of no value to plants but simply waste products of plants' metabolic processes ("Alkaloids," n.d.).
Available water:	The difference between field capacity and wilting point. Field capacity is the maximum amount of water the growth media can hold and wilting point is where the plant roots can no longer extract water from the growth media (Sheppard & Hoyle, 2016).
Bagasse:	The residual cane fibre that remains after the sugar juice has been extracted (Vetayasuporn**,** Chutichudet, & Cho-Ruk, 2006). It is of homogenous nature with regards to chemical and physical characteristics (Rossi, Monteiro, Machado, Andrioli, & Barbosa, 2003).
Black peat:	An extraction from the bottom layer of the peatland. It is dark in colour and has a heavy weight due to its dense, compact structure. This type of peat is originates exclusively from Germany (Van Egmond, 2016).
Botanical characteristics:	The growth period and form, root profile, leaf shape and size, inflorescence arrangement, flower structure, fruit formation, and seed structure of plants (Anonymous, n.d.).

Bog:	A wet, spongy ground with soil derived mainly of decayed vegetable matter (“Bog.” n.d).
Buffering capacity:	A measure of resistance to pH change (Brumfield, Heston, Travis, Heyse, Lopez, Raterman & Oh, n.d.).
Bulk density (BD):	A measure of the oven dry weight of the sample per unit volume (Reed, 1996).
Carbon sequestration:	The removal and a long term storage of carbon from the atmosphere in plants through biological processes such as photosynthesis ("Carbon sequestration," n.d.; Selin, 2016).
Cation Exchange Capacity:	A measure of the nutrient holding capacity of the growth media (Fonteno, 1996).
Cellulose:	The substance that makes up most of the plant's cell walls ("Cellulose," 2002).
Coconut fibre (coir):	Course, short natural fibre extracted from the outer shell of coconut fruits (Food and Agriculture Organisation [FAO], 2015; Nichols, 2013).
Degradation:	A process of damaging an environment (“Degradation,” n.d.).
Ecosystem:	The interaction of plants and animal in a particular environment (Pirot, Meynell, & Elder, 2000).
Electrical Conductivity:	The sum of dissolved salts in the growth media that provides the grower with information regarding the nutrient status of the media (Adriaanse, 2013).
Fatty acid:	An acid that is naturally found in fats and various oils (“Fatty acid,” n.d.).
Fertigation:	The addition of fertilizer to plants dissolved in irrigation water (Jones, 2012).

Floriculture:	A discipline in horticulture related to cultivation of flowering and ornamental plants (Macaskill, 2018).
Green compost:	Compost made from grass clippings, food scraps and other material from a typical garden maintenance (Schwarz & Bonhotal, 2011).
Growth media:	It is a soilless, artificial mixture of pure materials (Whitcomb, 2003) used for growing plants in containers (Olle, Ngouajio, & Siomos, 2012).
Hemi-cellulose:	Resembling cellulose but are more soluble and easily extracted and decomposed ("Hemicellulose," n.d.).
Humidification:	A process that occurs in soils and peats in which organic material is decomposed and breaks down to form humus (Davies, Farmer, Royles, Amesbury, Payne, Swindles, van Bellen, & Royland, n.d.).
Humus:	Organic matter ranging from brown to black in colour. It is formed by microbial decomposition of plant and animal materials ("Humus," n.d.).
Lignin:	Is found in vascular plants (consisting of phloem and xylem), mostly between the cells, but also within the cells, and in the cell walls (McCrady, 1991; "Vascular plant," n.d.).
Microflora:	Refers to microscopic plants ("Microflora," n.d.).
Organic components:	Materials derived from living organisms i.e. plants and animals ("Organic components," 2015).
Peat:	Organic growth media component consisting of incompletely decomposed plant remains that have developed under water over time in a peat bog (Boodley & Newman, 2009; Couwenberg, 2011; Whitcomb, 2003).

pH:	Measure of acidity and alkalinity ranging from 0 to 14, where a value of 0 is most acidic, 14 most alkaline and 7 being neutral (Whitcomb, 2003).
Photoperiod:	Refers to the amount of light and darkness in a cycle of 24 h (Jackson, 2009).
Phototropism:	A term used to describe the responses of plants to the relative length of the light and dark periods (Boyle, 1992).
Plant growth regulators:	Chemicals formulated to affect plant growth and/or development. They are applied for specific purposes to regulate specific plant responses (Whipker, McCall, & Latimer, 2011b).
Protein:	A molecule that is made up of polymers of amino acids that are joined together by peptide bonds. It differs from fats and carbohydrates because it contains nitrogen (Proteins, n.d.).
Residual:	The material which is left over at the end of a process (“Residual,” 2015).
Shoot apex:	It is the growing tip of the plant shoot where new leaves or flowers emerge (Robinson, Burian, Couturier, Landrein, Louveaux, Neumann, Peaucelle, Weber & Nakamaya, 2013).
Soilless:	Composed of no soil in the material (“Soilless,” 2015).
Sterilization:	Process where all living organisms, including microorganisms, are killed in the growth media by steaming or use of chemicals (Boodley & Newman, 2009; Whitcomb, 2003).
Sphagnum moss:	Dried moss plant of the genus *Sphagnum* that is used as a growth media to cover seeds in the germination tray (Ingram, Henley, & Yeager, 1993).

Sustainable:	Relates to a method of harvesting or using a resource so that the resource is not depleted or permanently damaged (“Sustainable,” 2015).
Tannin:	A reddish acid that comes from plants. It occurs mainly in the roots, wood, bark, leaves, and fruit of many plants ("Tannin(a)," n.d.; "Tannin(b)," n.d.).
Total porosity:	Refers to all of the pore space within the growth media (Dole & Wilkins, 2005).
Water holding capacity (WHC):	The amount of water remaining in the container after water stops draining from a growth media that was saturated (Gruda, Qaryouti & Leonardi, 2013).
Wetland:	The Ramsar Convention defines wetlands as “*areas of marsh, fern, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh , brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres*” (Turpie, Lannas, Scovronick, & Louw, 2010).
Vermicompost:	Compost made out of organic matter processed by using earthworms and microorganisms (Sherman, 2015).

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CHAPTER 1: INTRODUCTION

1.1 BACKROUND

Growth media is a soilless, artificial mixture (Whitcomb, 2003), which is used for growing plants in containers (Olle et al., 2012). It allows the production of uniform high quality plants at an optimal rate (Gaudig, Fengler, Krebs, Prager, Schulz, Wichmann & Joosten, 2014). Challenges that led to the development of soilless mixtures are that suitable top soil is difficult to find, heavy when plants have to be transported, does not have sufficient air and water circulation and usually contains pathogens (Adams, Bamford & Early, 2008; Greer, 1998; Raviv & Lieth, 2008).

Peat is a primary organic component of growth media (Gaudig et al., 2014). The main uses of peat as a component of growth media in commercial horticulture are container and bedding plant production in greenhouses (Abad, Noguera & Burés, 2001; Adams et al., 2008; Caron & Rivière, 2002; Fitzgerald, Atkinson, Harrison & Hall., 2012; Maher, Prasad & Raviv, 2008). Good quality peat has good physical properties (bulk density, water holding capacity and air filled porosity), along with adequate chemical properties [Cation Exchange Capacity (CEC), Electrical Conductivity (EC) and manageable pH] (Caron & Rivière, 2002; Reed, 1996).

Peat is harvested from wetland ecosystems at a non-sustainable rate as indicated by wetland ecologists (Di Benedetto, Klasman, & Boschi, 2004; Gorham & Rochefort, 2003). There is a worldwide interest for peat replacement, recycling and re-use of biodegradable waste. Several alternatives have been used in experiments to find a suitable alternative, but not all materials are suitable for use as growing media components (Schmilewski, 2008).

The substitution of peat with renewable materials will potentially extend the life of the peat resources and aid in preservation of wetlands (Adams et al., 2008; Maher et al., 2008). The rising cost of high quality peat for horticultural use and its uncertain availability in the future due to environmental constraints has also encouraged a search for alternative materials (Chavez, Di Benedetto, Civeira & Lavado, 2008; Di Benedetto, Petracchi, Marcella, Montaron & Chavez, 2006). Laiche & Nash (1986) suggested that the availability of material for growth media in large quantities is considered fundamental to the horticulture industry. The potential alternatives to peat that can be used in horticulture are organic in origin (Fitzgerald, et al., 2012).

The Natural Environment White Paper published in 2011 in the UK aims to reduce peat use in horticulture in UK to zero by 2030 (Fitzgerald et al., 2012). According to Charman (2002), the peat industry should recognize the increased potential of peat alternatives. The Sustainable Growth Media Task Force (SGMTF) was established in the UK to investigate how to succeed in peat reduction and to come up with strategies that will enable the transition to using alternative sustainable growing media. Organic alternatives to peat will also provide methods that can be used to disregard peat as a suitable growth media (Fitzgerald et al., 2012).

A number of organic materials have been experimented with as peat alternatives in the UK. The materials most likely to be used as alternative to peat in commercially growing media are bark products, coir and composted green waste (Adams et al., 2008; Fitzgerald et al., 2012; Maher et al., 2008). These alternatives must be free from toxins and pathogens and they must be environmentally friendly (Adams et al, 2008). In South Africa however, there is limited research concerning the replacement of peat as a component of growth media for cultivation of potted plants.

Globally, *D. x grandiflorum* (Chrysanthemum) is one of the most important pot plants and cut flowers (Teixeira Da Silva, 2003). It is the most commonly cultivated year-round floricultural greenhouse crop in the world (Crater, 1992; MacDonald, Blom, Tsujita, & Shelp, 2013). Therefore, the aim of the study was to determine a suitable alternative growth media to replace peat as a growth media for cultivation of potted *D.* x *grandiflorum.*

1.2 PROBLEM STATEMENT AND RESEARCH QUESTION

Environmental issues and increased costs that are related to peat have stimulated the use of new materials as alternatives to peat-based growing media. In South Africa, there is a dire need to search for cheaper and environmentally-friendly non-peat-based growth media for the cultivation of potted *D.* x *grandiflorum.*

Can potted *D.* x *grandiflorum* plants cultivated in alternative growth media perform better than those cultivated in peat?

1.3 SIGNIFICANCE OF THE STUDY

There is significant evidence that peat extraction for use in horticultural growth media results in degradation of wetlands. Wetlands are important ecosystems that clean the water, store carbon and are a habitat to different types of plant and animal species. If not addressed, the consequences will lead to ecological imbalance (Siyoum, Surridge, & Korsten, 2010; van Vuuren, 2010). Peat mining for horticultural use is a global concern (van Vuuren, 2010).

There was no evidence of research concerning replacing peat with the same alternatives used in the current study for cultivation of potted *D.* x *grandiflorum* available in South Africa. This research filled the gap by providing the potted chrysanthemum growers in South Africa with an environmentally friendly peat alternative.

1.4 RESEARCH AIM

The aim of the study was to determine a suitable alternative growth media to replace peat as a growth media for cultivation of potted *D.* x *grandiflorum.*

1.5 OBJECTIVES

The objectives of the study were:

- To evaluate the chemical properties of alternative growth media in comparison to peat.
    - Chemical qualities analysed in the current study are: pH, EC, C/N ratio and mineral composition
- To evaluate the physical properties of alternative growth media in comparison to peat.
    - Physical qualities are: water holding capacity, air filled porosity, and bulk density
- To determine shoot mineral content and chlorophyll content of potted *D.* x *grandiflorum* cultivated in different growth media in comparison to peat.
- To assess the growth and yield of potted *D.* x *grandiflorum* cultivated in alternative growth media in comparison to peat.

1.6 HYPOTHESIS

- The chemical properties of alternative growth media are not different compared to peat.
- The physical properties of alternative growth media are not different compared to peat.
- The shoot nutrient content and chlorophyll content of potted *D.* x *grandiflorum* are not influenced by alternative growth media.
- The growth and yield of potted *D.* x *grandiflorum* are not influenced by alternative growth media.

1.7 RELIABILITY, VALIDITY AND OBJECTIVITY

The credibility of any scientific research is dependent on procedures (and/or methods) and instruments applied to generate information and data analysis in order to respond to the research question. It is therefore crucial to make use of reliable, valid and fair methods when establishing and managing experiments. Reliable instruments applied while conducting quantitative research are necessary to yield consistent results. It is also very important to record data with a highest level of precision as possible (Maluleke, 2016; Mathiba, 2015). For this study, the instruments used were of the desirable standard while the methods followed were adopted from similar studies. The plant growth and yield parameters were measured and the laboratory analyses carried out by qualified personnel at a registered laboratory.

Validity of the research techniques was applied to ensure that data generated is relevant to explain the responses observed during the course of the experiment . During this study, bias was minimized by ensuring that experimental error is redused by increased replications and randomization (Davis, Harris, Roberts & MacDonald, 2017; Mathiba, 2015). A randomized complete block design (RCBD) with four replications was used as discussed in section 3.3.

The research methods were carried out objectively in order to avoid biasness, preconception and subjective evaluation. The findings were discussed with reference to

the verified statistical analyses techniques and trends were associated with observations and conclusions from similar studies (Mathiba, 2015).

1.8 ASSUMPTIONS AND LIMITATIONS

1.8.1 Assumptions

- Rooted cuttings of *D.* x *grandiflorum* were viable. They were purchased from a reliable supplier.
    - The cuttings were taken from the plants with same genetic makeup. The name of the plant breeding company is *Royal van Zanten* and the hybrid "Mount® Runca" was used
- The experiment was carried out in an environmentally controlled greenhouse that simulates the environmental conditions in a production greenhouse. Optimum growth conditions were at all times simulated.
    - Prophylactic pest control programmes were instituted as per specifications by the greenhouse Manager of the UNISA Horticulture Centre
    - All infected materials were removed from the greenhouse and destroyed
- Bagasse that was used in this research was sterilized to eliminate disease causing microorganisms and also to avoid the sucrose content interference in the study.

1.8.2 Limitations

The sample plants used for the research were of the same cultivar and therefore used to make a statistical conclusion for the broader population of the plant species. The biological properties of growth media were not taken into consideration because of the scope of the research. It is important to note that that there are more growth media components available which were not used during the experiment. Cation exchange capacity was not measured due to limited instruments to measure this parameter. The physical properties for used growth media collected at the end of the experiment were not measured due to insufficient samples to get reliable results. This was due to the destructive sampling adopted in the current study as indicated in 3.8.2.

1.9 CHAPTER LAYOUT

Chapter 1 introduces the research topic with a detailed outline of the uses of peat as a growth media component in the horticulture industry and the challenges that warrants its replacement. It briefly explains the keywords used in the title, includes the problem statement, significance of the study, research aim, objectives, hypothesis, limitations, and the general outline of this dissertation.

Chapter 2 provides detailed background of growth media used in the horticulture industry. The history and the characteristics of a suitable growth media as well as examples of growth media components used in the horticulture industry are highlighted. The research plant and its cultural requirements are discussed in detail.

Chapter 3 outlines a brief overview of the area in which the study took place. It outlines the research methodology, sampling methods and data collection methods employed in this research to achieve the set objectives.

Chapter 4 presents the data, interpretation and discussion of the results, and findings of the study.

Chapter 5 concludes and makes recommendations based on the findings of the experiment and gives an overall summary of the study.

1.10 SUMMARY

This chapter has examined the importance of finding an alternative for peat as a growth media. In this chapter, the problem statement; significance of the study; research aim; objectives; hypothesis; reliability, validity and objectivity of the study; assumptions and limitations, and chapter layout of this dissertation were clearly defined. The next chapter covers the literature review.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter investigates the background of growth media and its components used in the horticulture industry worldwide. It includes alternative growth media components that can be used to replace peat for cultivation of potted plants. The information on the research plant, *Dendranthema* x g*randiflorum* is also contained in this chapter including its cultural practices.

2.2 GROWTH MEDIA

Growth media are used in horticulture for growing seedlings, plant propagation and ornamental plant production in containers (Chavez et al., 2008). Plant growers should pay attention into developing or selecting a suitable growth media (Dole & Wilkins, 2005). McMahon, Kofranek, & Rubatsky (2002) suggest that the choice of growth media for container production should receive primary attention. This is because using the right growth media allows a commercial grower to supply quality plants to the market quickly, thus gaining a competitive edge for sales. Growth media plays an essential role, as it makes the plant grow faster, reach maximum height and volume earlier in the growing season and start flowering sooner. The maximum number of flowers is an indication of good quality for the market (Adriaanse, 2013).

According to Raviv & Lieth (2008), the Egyptians grew plants in containers almost 4000 years ago. The type of growing media for the containers is not known but as the containers were shown (illustration is found in the source) as being carried by potters for longer distances, it is perceived that lighter materials than pure soils, were used.

Significant developments resulted from the work done in the 1930s at the John Innes Institute (Norwich, UK), where the importance of sterile (pest and disease free), stable and uniform ingredients were demonstrated. The range of composts that resulted from this work established the methods of achieving uniform production and reliable results with a single potting mixture, suitable for a wide range of plant species (Adams et al., 2008).

Growth media is suitable because of the consistency, excellent aeration, reproducibility and low bulk density, which reduces transportation and handling costs of the medium itself and of the finished product. It can be disinfected between uses to eliminate unwanted

microorganisms. Different growth media components can be prepared and mixed to achieve a rooting environment that is free from pests and disease organisms, easily available water and nutrients for the plant to be grown (Adams et al., 2008; Dole & Wilkins, 2005; Lang, 1996; Raviv & Lieth, 2008).

Soilless cultivation is practiced in large scale in arid regions such as most parts of Australia, parts of South Africa, Saudi Arabia and the Southern part of Israel (Raviv & Lieth, 2008). In South Africa, there are some commercial growth media mixtures that are imported by local suppliers for the green industry, i.e. peat and coir (Adriaanse, 2013). The growers also have a choice to purchase a ready mix growth media or mix their own depending on the type of the crops they produce (Schroeder, Seagle, Felton, Ruter, Kelly, & Krewer, 2009).

The use of growth media for the cultivation of potted plants requires knowledge of their physical and chemical characteristics to optimize conditions for the plant growth (Chavez et al., 2008). Most growth media comprise blends of two or more components (peat, vermiculite, perlite etc.). The physical and chemical properties of the resulting growth media are not always equal to the sum of its individual parts. When growth media components are blended, the chemical and physical properties of the components are combined to form new properties that are different from the individual components (Fonteno, 1996).

Growth media plays a role in the growth of the plants and has various functions. Suitable growth media serves the following functions:

- Stores and provides water to the plant roots (Adams et al., 2008; Boodley & Newman, 2009; Dole & Wilkins, 2005; Fonteno, 1996)
- Stores and makes the nutrients available (Adams et al., 2008; Boodley & Newman, 2009; Dole & Wilkins, 2005; Fonteno, 1996)
- Allows gas exchange to and from the roots (Adams et al., 2008; Dole & Wilkins, 2005; Fonteno, 1996)
- Provides mechanical support for the plants (Boodley & Newman, 2009; Dole & Wilkins, 2005; Fonteno, 1996)

The components of growth media must have stable physical and chemical properties during plant cultivation (Chavez et al., 2008) and should be readily available (Lang, 1996).

Properties of the growth media are as follows:

- Chemical: are properties that involve chemical reactions and supply of nutrients (pH, CEC, EC, and C/N ratio) (Dole & Wilkins, 2005; Fonteno, 1996; Handreck & Black, 2002; Maher et al., 2008)
- Physical: are those properties we can see and feel (Bulk density, Total porosity, container capacity, aeration, stability (does not collapse when kept wet for longer periods) (Adams et al., 2008; Dole & Wilkins, 2005; Fonteno, 1996; Handreck & Black, 2002; Maher et al., 2008)
- Biological properties: have to do with living organisms, both visible and invisible to the naked eye (Handreck & Black, 2002). This is not covered in the current study because of the scope of the experiment

2.3 PHYSICAL AND CHEMICAL PROPERTIES OF GROWTH MEDIA

Chemical properties often have a major effect on physical properties. The correct physical and nutritional conditions are important for successful cultivation of ornamental plants containers (Adams et al., 2008). In order to produce high quality plants, much attention must be given to physical and chemical properties of the growth media (Caron & Rivière, 2002).

2.3.1 Physical properties

According to Handreck and Black (2002), physical properties of the growth media are properties that we can see and feel. The most important physical properties affecting plant growth are water holding capacity and aeration. They determine the availability of water and air, and also affect growth media temperature, biological activities and availability of minerals (Chavez et al., 2008). To produce an ideal growth media, all the necessary physical properties must be present in one material. It is however challenging to find a single substrate that possesses all the desired characteristics. To achieve the desired properties, materials are often combined, which may result in increased cost of the final product (Gutiérrez, Altamirano, & Urrestarazu, 2012).

2.3.1.1 Water holding capacity/Container capacity

Water holding capacity (also referred to as container capacity) is the amount of water remaining in the container after water stops draining from a growth media that was saturated (Dole & Wilkins, 2005; Gruda et al., 2013). It is the percentage of moisture on a volume basis available after saturation and drainage (Reed, 1996). Water holding capacity of growth media components varies significantly. Peat has a better container capacity compared to other growth media components, as an example, peat requires almost 48 hours to dry (Adams et al., 2008; Reed, 1996). The proportions of water and air in the pore space of the growth media in containers of the same height depend on the sizes of those pores. Growth media with large pores holds less water and has higher air filled porosity than media comprising mainly small pores (Handreck & Black, 2002).

Cultivation of ornamental plants in the field is different from cultivation in containers. Plants growing in containers have less available water and drainage is restricted. Growers must provide plants with water for the container grown plants at frequent intervals using various irrigation systems. The most common irrigation systems used for irrigation of container plants is over-head sprinkler irrigation and micro-irrigation (Dole & Wilkins, 2005; Geneve, Nambuthiri, & Kester, 2015). There is a science to understanding the relationship between growth media and application of water to the cultivated plants (Adriaanse, 2013).

According to Handreck and Black (2002), growing media may be suitable, but unless it contains enough water for the plant growth, it is not useful. Adams et al. (2008) reported that if there is a constant supply of water through irrigation systems, water holding property of the growth media is less significant. Infiltration rate, which is the rate at which water soil soaks into the growth media, is an important property. It is measured as the height (in mm) of water soaking in the growth media per hour (Handreck & Black, 2002).

Plant yield decreases if water in growth media is lowered below -10 kilo pascal (kPa). This varies with the type of plant cultivated, root distribution, salt accumulation and experimental conditions. Higher matrix potentials promote increased growth rates of the plants. Growers are able to reduce water potentials to manipulate the induction of flowers, hardiness and restrict stem elongation (Caron & Rivière, 2002).

2.3.1.2 Air filled porosity (AFP)

The difference in water content between total porosity and container capacity is air filled porosity (Caron & Rivière, 2002). Total porosity refers to all of the pore space within the growth media (Dole & Wilkins, 2005). Reed (1996) defines total porosity as percent total pore space on volume basis.

According to Handreck and Black (2002), the holes in the growth media are called pores. These pores are found between particles and crumbs, and some are found inside them.

All pores in the growth media are called pore space or total pore space. This is the volume that is filled with air.

Plant roots need oxygen to maintain healthy growth and activity. There must be a gaseous exchange movement through the potted growth media. Creating a growth media with adequate aeration depends on the use of components that provide a high proportion of macro pores (Adams et al., 2008; Handreck & Black, 2002).

The grower should also ensure that containers in the greenhouse are placed on similar sized pore spaces like sand or capillary matting. This is because water does not readily leave the container when placed on less porous surfaces (Adams et al., 2008). It is generally considered that 10 – 15 % AFP is needed for a wide range of plants (Adams et al., 2008).

2.3.1.3 Bulk Density (BD)

Bulk density is the ratio of mass of dry solids to the bulk volume of the growth media. The bulk volume also includes the volume of solids and pore space within the growth media (Fonteno, 1996). According to Caron and Rivière (2002), a reliable approach to measure bulk density is vital. This is because standard methods are based on the relationship between bulk density and plant growth. The method must be repeatable, accurate and inexpensive (Caron & Rivière, 2002).

Bulk density affects the weight of the growth media. Low bulk density reduces transportation and handling costs of the growth media and of the finished product to the suppliers (Dole & Wilkins, 2005). Decreased bulk density is consequent to increased

particle size of the growth media (Noguera, Abad, Puchades, Maquieira, & Noguera, 2003).

2.3.2 Chemical properties

According to Handreck and Black (2002), chemical properties are properties of the growth media that involve chemical reactions and supply of nutrients. They play a role because they govern the efficiency of nutrient supply and influence the environmental balance during and after cultivation (Chavez et al., 2008).

Analyzing growth media for pH, EC and specific nutrients is important to monitor plant nutrient status and control fertilizer use (Lang, 1996). Availability of nutrients in the growth media is primarily related to pH, EC and CEC (Caron & Rivière, 2002).

2.3.2.1 pH

pH can be defined as a measure of concentration of hydrogen ions (H^+) that is found in the growth media solution. The pH scale ranges from 0 to 14, where a value of 0 is most acidic, 14 most alkaline and 7 being neutral (Fonteno, 1996; Whitcomb, 2003). Growth media pH defines the fertility status of the growth media and affects the availability of nutrients to the plants (Jones, 2012; Lang, 1996). This occurs when the growth media pH is within the plants' optimum range (Fonteno, 1996). Most ornamental plants grown in growth media perform better when the pH range is between 5.6 and 6.4. At this range, micronutrients are available to the roots. This will also depend on the cultivated plant species (Bailey, 1996; Fisher, 2011). Analysis of pH depends on selecting a suitable extraction method, properly measuring media solution and correctly interpreting the results. These are usually conducted by a registered laboratory (Lang, 1996).

2.3.2.2 Salinity/ Electrical Conductivity (EC)

Electrical Conductivity (EC) (also referred to as the salinity of growth media) is the sum of dissolved salts in the growth media that provides the grower with information regarding the nutrient status of the media (Adriaanse, 2013). All the nutrients in the growth media solution are regarded as soluble salts (Dole & Wilkins, 1999; Westervelt, 2003). When the EC of the growth media is too low, poor plant growth and nutrients deficiencies may be observed (Whipker, Cavins, Gibson, Dole, Nelson & Fonteno, 2011a). Measuring EC of

the growth media solution quantifies soluble salts that are present and not the levels of individual nutrient elements. In greenhouse production using growth media, salts are derived from addition of fertilizers. EC is therefore used to monitor the fertilizer levels in growth media. For this reason, information about the growth media EC is important for growers (Dole & Wilkins, 1999; Lang, 1996; Westervelt, 2003). This parameter, like pH, is analyzed by selecting a suitable extraction method, properly measuring media solution and correctly interpreting the results, preferably in a registered laboratory (Lang, 1996).

2.3.2.3 Cation Exchange Capacity (CEC)

This is a measure of the nutrient holding capacity of the growth media. More nutrients are held in the growth media if the CEC is higher. Growth media components with a higher CEC are most desired for use in growth media mixes. The following components have a high CEC; peat, bark and vermiculite, and components with a low CEC are perlite and sand (Fonteno, 1996; Westervelt, 2003).

This parameter was not measured in the current study due to lack of capacity to measure CEC in the growth media.

2.3.2.4 Nutrition

Nutrition can be defined as the supply and absorption of chemical elements required for plant growth and metabolism (Katalin, 2011). Many growth media components have low nutrient levels. This enables growers to manipulate plant growth more precisely through nutrition. The control of nutrients is important as many growth media components have low buffering capacity (Adams et al., 2008). Cultivation of plants in the field is different from growing a plant in a container for greenhouse production. Plants growing in containers have fewer nutrients because the growth media are typically well drained. Growers must provide nutrients for the container grown plants at frequent intervals (Dole & Wilkins, 2005; Lang, 1996).

To supplement the nutrient released from the materials in the growth media, inorganic fertilizers can be added to provide necessary nutrition for the cultivated plant. The addition of nutrients must take into account nutrient characteristics of the growth media components used (Adams et al., 2008).

Growth media need to be supplemented with micro nutrient elements and macro nutrient elements (Adams et al., 2008). According to Brown (2002), growth media must contain all the essential plant nutrient elements in sufficient quantity and in balanced proportions. These nutrients must be present in an available form before plants can use them. A shortage of these elements will hinder plants from growing to their full potential (Brown, 2002).

The common macro nutrient elements required by plants are: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S), carbon (C), hydrogen (H) and oxygen (O). They are called macro nutrients because they are needed in large quantities in the plant tissue (Jones, 2012; Nelson, 1996). In the past, Ca, Mg and S were regarded as secondary elements, but the term is no longer accepted. C, H and O are primarily required for production of carbohydrates which occur through a plant process called photosynthesis. Carbon dioxide (CO_2) is absorbed through the stomata during gaseous exchange and H is available in water (Jones, 2012).

The common micro plant nutrient elements required for healthy plant growth are iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B) and molybdenum (Mo). They are called micro nutrients because they are required in small quantities for healthy plant growth (Nelson, 1996).

The availability of soluble nutrients for the plants' root uptake is dependent on pH (Reed, 1996). When the growth media pH is high, Ca and Mg levels will generally be higher (Nelson, 1996). The high pH also decreases the solubility of the following nutrient elements: P, Fe, Mn, Cu, Zn, and B (Reed, 1996).

2.4 COMPONENTS OF GROWTH MEDIA

A range of different materials are being used in the horticulture growth media industry, worldwide and in South Africa to grow plants in containers. The growth media components can be of organic (i.e. compost) or inorganic nature (i.e. sand, vermiculite and perlite) (Beyl & Trigiano, 2015; Maher et al., 2008). The following growth media components are used for cultivation of plants in containers.

2.4.1 Organic components

2.4.1.1 Peat

Peat is defined as organic residues of plants, partially decomposed due to lack of oxygen under wet conditions. It comprises at least 30 percent (%) (dry mass) and dead organic matter, it is formed under permanent saturated conditions (Barkovskii, Fukui, Leisen, Kim, Marsh, & Khijniak, 2009; Fitzgerald et al., 2012; Joosten & Clarke, 2002; Ollis, Snaddon, Job, & Mbona, 2013; Reed, 1996).

Peat is a highly variable material, with different types of peat dependent on species of plants from which the peat is formed, the level of decomposition of the organic material, and the environment under which it is formed (Adams et al., 2008; Charman, 2002; Fitzgerald et al., 2012). The main constituents of peat are lignin, cellulose, hemi-celluloses, humic substances, waxes and proteins. There are traces of other organic substances in sphagnum peat such as sugars, fatty acids, tannins, pigments and alkaloids (Fitzgerald et al., 2012).

Peat is formed by partial decomposition of mosses, reeds, and sedges found mainly in Canada, Northern Europe and Russia. The quality and usefulness is determined by species of plant debris, level of decomposition, local climate, harvesting method and moisture levels during harvest (Bonin, 2015; Reed, 1996). Traditionally, peat was harvested by cutting blocks from the peatland. In recent years, peat companies rake in or till the layer of peat 2.5 - 7.5 cm thick and then vacuum up the loose peat. This method is economical but the particle size is reduced (Reed, 1996).

Air filled porosity, total porosity, and storage capacity for available water, and container capacity are directly associated with the degree of composition and botanical characteristics (Caron & Rivière, 2002). The chemical composition and microflora of peat depends on the type of peat, the locality and the depth in the wetland from which it is obtained. The best horticultural peat comes from the upper, less humified peat, while the more humified deeper peat provides the most suitable source of fuel material (Charman, 2002; Fitzgerald et al., 2012). These characteristics can change during storage (Fitzgerald et al., 2012).

By far the most preferred and used types of peat for horticultural growing media are those formed from mosses, particularly *Sphagnum* species because they create an almost ideal

environment for plant roots. They have a high physical and chemical stability and low degradation rate (Adams et al., 2008; Caron & Rivière, 2002; Chavez et al,, 2008; Fitzgerald et al., 2012). Sedge peats contain more plant nutrients than sphagnum moss. They are darker in colour, highly decomposed and have a higher pH level but they have lower water holding capacity. They are mainly used for making peat blocks than as a potting growth media (Adams et al., 2008).

Peat has been the most important component of growth media for many years because of its characteristics that match the functions of growth media. The following are the characteristics of peat as a growth media:

- It provides good water holding ability and good aeration (Adams et al., 2008; Charman, 2002; Dole & Wilkins, 2005; Schmilewski, 2008)
- High level of readily available water. It can absorb up to 60 % of its total volume in water (Dole & Wilkins, 2005; Handreck & Black, 2002)
- It has low bulk density which results in easy and low cost handling, use and transportation (Charman, 2002; Dole & Wilkins, 2005; Handreck & Black, 2002)
- Low pH (3.0 - 4.0) which makes it easy to adjust the acidity level to any desirable value (Charman, 2002; Dole & Wilkins, 2005; Handreck & Black, 2002; Schmilewski, 2008)
- Low nutrient values apart to nitrogen which allows adjustment to any value by addition of nutrients (Charman, 2002; Fitzgerald et al., 2012)
- Free from pest, pathogens and weed seeds depending on handling during production (Charman, 2002; Schmilewski, 2008)
- Ease of processing, grading and blending (Charman, 2002)
- Medium to high CEC, which gives them some buffering capacity (Adams et al., 2008; Dole & Wilkins, 2005; Handreck & Black, 2002)
- It is a very stable growth media component (Adams et al., 2008; Dole & Wilkins, 2005). It is also easy to mix with minimal health risks (Schmilewski, 2008)

Peat production is estimated at about 25,000,000 cubic metres per year (m^3/yr) worldwide, mostly in Canada and Europe (95 %). The main buyers are the US (5.800000 m^3/yr) and

Nederland (2.500000 m³/yr) (Caron & Rivière, 2002; Chavez et al., 2008; Reed, 1996). By 2009, a total of 6.975100 m³ of horticultural growing products was used in the UK, of which 2.963200 cubic metres (m³) (42 %) was derived from peat (Department for the Environment, Food and Rural Affairs [DEFRA], 2010; Fitzgerald, et al., 2012).

About half of the peat used in horticulture industry in UK originates from the Republic of Ireland, and about 7 % from Baltic States including Finland. The remainder originates from the UK (Alexander, Bragg, Meade, Padelopoulos & Watts, 2008; DEFRA, 2010). A small proportion of black peat for propagation blocking media originates from Germany. Most peats used in European horticulture are formed in temperate regions of North America, Northern Europe and Russia (Fitzgerald et al., 2012). The vast majority of peat used in the US comes from Canada, with lesser amounts from Michigan and Florida (Reed, 1996).

In southern European countries, authorization to mine peatlands is restricted to protect these valuable ecosystems. There is a greater restriction on peat extraction with some embarking on restoration of peatlands. The use of peat in horticulture is questioned from an environmental viewpoint. This is because peat is a non-renewable resource. It is proven to play a major role in atmospheric CO_2 sequestration, improves the quality of water in many parts of the world and serves as habitat for plants and animals (Maher et al., 2008).

Since the late 1970's there has been a worldwide search for new peat substitutes. That is due to the high price of high-quality horticultural peat, especially in countries without peat moss resources. Another reason is the uncertain availability of peat in the near future due to environmental constraints (Abad et al., 2001; Chavez et al., 2008; Handreck & Black, 2002). In countries were peat is readily available, this material tends to be less expensive than in countries where it is to be imported (Raviv & Lieth, 2008; Wallace, Holmes, Alexander, England, & Gaze, 2010). Peat in South Africa is scarce and it is imported for use in the horticulture industry (Lazemby, 2010; Rand Water, n.d.).

2.4.1.2 Coir

Coir is the fibre that constitutes the husks of the coconut fruit (*Cocos nucifera* L.) (Abad, Noguera, Puchades, Maquieira, & Noguera, 2002). The structure of coir mainly consists of lignin (Bonin, 2015). Coir has been tried and it was proven as a suitable replacement for peat. It can also be used in combination with peat to extend peat supplies (Adams et al., 2008; Bonin, 2015; Fonteno, 1996; Maher et al., 2008). Coir waste is composted and

screened to remove part of most of the fibre and the remaining product is dried and compressed into bricks or bales. This is then wrapped and transported to the suppliers and growers for use in horticultural growth media. The coir bricks are rehydrated to make them useable in filling the containers for cultivation of ornamental plants (Abad et al., 2002; Fonteno, 1996).

This material is popularly used as an environmentally friendly alternative to using peat as a growth media component for container grown ornamental plants. Sri Lanka is the leading manufacturer of horticultural coir. Other countries in Asia, tropical America and Africa are major coconut producers and processors (Abad et al., 2002; Bonin, 2015).

As with various organic growth media components, properties of coir can vary with the source (Fonteno, 1996). The following are the properties of coir as a component of growth media:

- Has shorter fibre length than peat (Fonteno, 1996)
- Has physical properties similar to peat (Fonteno, 1996)
- Slightly less aeration than peat (Fonteno, 1996)
- Has good water holding capacity (Adams et al., 2008; Boodley & Newman, 2009)
- Good rewetting characteristics (Adams et al., 2008; Bonin, 2015; Boodley & Newman, 2009)
- Good air filled porosity (Adams et al., 2008; Bonin, 2015)
- It has a pH between 5 and 6, which makes it suitable for a wide range of plants (Adams et al., 2008)
- It has a high C/N ratio of 80 %. Allowance has to be made for its tendencies to “lock up” nitrogen (Adams et al., 2008)

2.4.1.3 Bark and wood fibre

Chief among replacement of peat for growth media is bark and wood fibre from forestry and wood industry (Maher et al., 2008). Bark is a variable by-product of saw mills. It is a generic term that includes several species of hardwood or softwood trees. Its variability is due to the type of wood, species of tree, age of tree, method of bark removal and the degree of bark decomposition. Bark is removed from logs by drum or ring debarkers. Until the 1950’s, this material was regarded as a waste product. It is now mainly used in the

horticulture industry as a growth media component. Bark has a potential to provide good plant growth if it is prepared properly (Fonteno, 1996).

There are many different types of bark and they have different properties (Adams et al., 2008). The following are the properties of bark as a component of growth media:

- Improves aeration (Adams et al., 2008; Fonteno, 1996)
- Reduce the cost of media (Fonteno, 1996)
- Presence of toxins, which can be overcome by composting (Adams et al., 2008)
- A tendency to lock up N (Adams et al., 2008; Handreck & Black, 2002; Westervelt, 2003)
- The main role of bark is in mulching (Adams et al., 2008)
- Wood fibres based on stabilized shredded wood are being used to increase the air filled porosity of mixes (Adams et al., 2008)

2.4.1.4 Compost and municipal waste

Compost is a decomposed organic material (Paulin & O'Malley, 2008). Different organic residues generated by municipalities are being successfully used as container growth media for ornamental plant production (Abad et al., 2001). Since the 1990's, municipalities have reduced the amount of green waste that goes to the landfill by processing the material for use in the horticultural growth media. Amongst the products offered to the growth media industry is composted sewage sludge and composted garbage. These materials are constantly being improved to offer the performance found in traditional components of growth media (Fonteno, 1996).

Compost can be used to increase the water holding capacity of the growth media. Salt content tends to be high before leaching and N lockup is common especially with woody composts (Handreck & Black, 2002). Composted sludge has a high CEC, it is heavy and has reduced aeration properties. Composted yard wastes are variable and are recommended for landscape use and not for cultivation ornamental plants in containers. Composted garbage is too variable and a lot of research is still required before it can be recommended (Fonteno, 1996).

2.4.2 Inorganic components

2.4.2.1 Sand

Sand is finely ground stones and is available in different grades. For growth media purposes, growers prefer medium to very coarse particle sizes (0.25 - 2 mm). Sand assists in the growth media with water drainage and aeration and the pH depends on the parent material (Boodley & Newman, 2009; Handreck & Black, 2002).

2.4.2.2 Vermiculite

Vermiculite is mined silica that is heated at high temperature. The temperature expands the silica 15 to 20 times its original size. It is available in different ranges of particle sizes of which the smallest sizes are commonly preferred for seed germination growth media. Vermiculite is very light in weight and has a great water holding capacity. It also has a high CEC (Boodley & Newman, 2009; Dole & Wilkins, 1999; Westervelt, 2003).

2.4.2.3 Perlite

Perlite is a volcanic rock that is heated at high temperature (1200 °C). As a result, it expands into a very porous, sterile and light weight material. It is often used as an alternative to sand for aeration and drainage with an added benefit of its light weight composition. It supplies no nutrients to plants because it has little to almost no CEC with a pH range slightly above 7 (Boodley & Newman, 2009; Fonteno, 1996; Handreck & Black, 2002; Westervelt, 2003).

2.5 *Dendranthema* x *grandiflorum*

Figure 2. 1: Potted *D.* x *grandiflorum* (Chrysanthemum) plants

The focus of plant production in the horticulture industry revolves around flowering plants. Potted flowers are a very large industry (Chavez et al., 2008; Maree & van Wyk, 2010). Brown (2002) indicated that until the late 1970's limited research was conducted on flowering container plants.

Pot chrysanthemum, *D.* x *grandiflorum* was selected as the research plant used to evaluate the growth media. It was selected because it is the main selling pot plant in supermarkets and florists (Nau, 2011). The marketability of potted flowering plants is greatly dependent on the conditions of their production and the most important conditions are growth media quality, drainage, irrigation, water quality and fertilization (Chavez et al., 2008). The flowering process is considered the most important for the potted flowering plant growers. The three main environmental control mechanisms for flowering crops are photoperiod, light intensity and temperature (Dole & Wilkins, 2005).

Maree & van Wyk (2010) describe *D*. x *grandiflorum* as an aromatic perennial herb with glandular, distinctly lobed leaves and colourful flower heads which belongs to the *Asteraceae* family. It originates from China, with many breeders around the world introducing different hybrids to the market. The whole flowering plant is sold and used as potted flower, and it does not make a good garden plant because it is sensitive to frost. Many cultivars are available in different colours (Crater, 1992; Maree & van Wyk, 2010).

From transplanting into the pot to flowering, the pot chrysanthemum can take about 3 months (Crater, 1992). The hybrid used for this study is called "Mount® Runca" and name of the plant breeding company is *Royal van Zanten*.

The flowering period of potted *D*. x *grandiflorum* can be scheduled. It is initiated by lessening the day length (short days). In most cultivars, this is achieved by providing the plant with 12 hours or less of day light. During this time, the dark period must be completely dark (Maree & van Wyk, 2010). Quality growth media, irrigation and nutrition play an important role for producing high quality flowering plants which will have a good shelf life (Chavez et al., 2008; Maree & van Wyk, 2010).

2.5.1 Cultivation

Potted *D*. x *grandiflorum* is propagated from cuttings. Cuttings should be from the same mother plant which is not infested or affected by pests and diseases. The size of the cuttings is usually made approximately 5 cm long depending on the cultivar (Crater, 1992). The cuttings are then dipped in a rooting hormone and can be planted directly into the final pot, usually in 10 or 15 cm pots. When planted in this manner, no transplanting is required therefore labour costs are reduced and it is time efficient (Crater, 1992; Maree & van Wyk, 2010; Nau, 2011).

2.5.1.1 Growth media used for potted *D*. x *grandiflorum*

Growth media for potted *D*. x *grandiflorum* in a protected environment is recommended as follows:

- Should be moist and well drained (Maree & van Wyk, 2010; Nau, 2011)
- Requires a slightly acidic pH (5.6 - 6.5) (Brown, 2002; Dole & Wilkins, 2005; Fisher, 2011; Maree & van Wyk, 2010)
- Aeration should be intermediate (Caron & Rivière, 2002)
- Air filled porosity should be around 0.05 – 0.10 m^3 (5 – 10 % AFP) (Adams et al., 2008; Caron & Rivière, 2002)
- EC target range= 2.2 to 3.3 mS/ cm^{-1} (Dole & Wilkins, 2005)

2.5.1.2 Fertilization

Fertilization programmes are developed with the aim to provide nutrients in accordance to the needs of the cultivated plant. Potted plants are mostly fertilized by mixing fertilizers into irrigation systems. These crops require frequent irrigation and high fertilization rates (Chavez et al., 2008). Table 2.1 and 2.2 represent the tissue nutrient element levels of high quality potted *D*. x *grandiflorum* (Dole & Wilkins, 2005; Whipker et al., 2011a).

Table 2. 1: Macro nutrient level concentration of high-quality potted *D*. x *grandiflorum*

Macro nutrient elements	Concentration (ppm)
Nitrogen (N)	4.0 - 6.5
Phosphorus (P)	0.3 - 1.0
Potassium (K)	4.5 - 6.5
Calcium (Ca)	1.0 - 2.0
Magnesium (Mg)	0.4 - 0.7

Table 2. 2: Micro nutrient level concentration of high-quality potted *D*. x *grandiflorum*

Micro nutrient elements	Concentration (ppm)
Iron (Fe)	30 - 350
Manganese (Mn)	60 - 500
Zinc (Zn)	15 - 50
Copper (Cu)	25 - 75
Boron (B)	50 - 100

2.5.1.3 Irrigation

According to Lieth & Oki (2008), irrigation is the process of delivering water to plants in order to meet the plant needs. They further stated that providing too little or too much water will reduce crop productivity and when either of these conditions is extreme, it can lead to plant death. An adequate supply of high-quality water is of high importance in soilless ornamental plant production. The quality of irrigation water is measured by evaluating the dissolved minerals and salts in the water (Van Os, Gieling, & Lieth, 2008).

Drip tubes or ebb-and-flow flood systems are mostly used in cultivation of potted chrysanthemums (Maree & van Wyk, 2010; Nau, 2011). Drip irrigation is an effective method for both water and fertilizer application in greenhouse ornamental plant production because it delivers water directly to the container (Geneve et al., 2015; Reed, 1996). Advantages of drip irrigation include efficient supply of water and fertilizer, and the application time can be controlled and is flexible (Reed, 1996).

2.5.1.4 Temperature

Temperature influences plant processes which include rooting, flowering, production time, plant structure, and quality. Temperature controls the rate of plant development which includes the period it takes for the plant to develop leaves and flowers. There is a direct link between temperature and light for optimum plant production. Therefore, these two factors should be considered and controlled properly in the greenhouse (Blanchard & Runkle, 2011). Most plants are grown in greenhouses under optimal production conditions required by the cultivated plants (Raviv & Lieth, 2008).

Greenhouse temperature recommendations for ornamental plant production are usually based on air temperature. Thermometers are inexpensive instruments commonly used to measure air temperature in the greenhouse. Potted *D*. x *grandiflorum* is regarded as an intermediate crop with regards to base temperature (BT). Base temperature is the temperature at or below which plant development stops. For these plants, BT is between 4 - 7 °C, which means that it is relatively cold tolerant. Plants grown for their flowers, like this research plant, are grown 11 - 17 °C higher than their base temperature. An exception can be made when there are no markets to receive the plants. These plants can be grown closer to their base temperatures to delay the plant development (Blanchard & Runkle, 2011).

Potted *D*. *x grandiflorum* requires moderate night temperature (Dole & Wilkins, 2005). Flower initiation is delayed when the night temperature is above 25 – 26 °C. This is commonly known as “heat delay”. Stem elongation of *D*. x *grandiflorum* is affected by the mathematical difference between night and day temperature (DIF) (Blanchard & Runkle, 2011). The temperature in the greenhouse should be regulated between 18 – 24 °C (Blanchard & Runkle, 2011; Faust, 2011).

2.5.1.5 Pinching

Pinching is the removal of the shoot apex so that the maximum number of lateral shoots can be produced. Potted *D*. x *grandiflorum* is pinched to produce plants with multiple stems and to even up the height of the plants (Crater, 1992; Whipker et al., 2011b).

2.5.1.6 Disbudding

Disbudding is the removal of immature flower buds. Most potted chrysanthemums are disbudded so that the plants will be more attractive and uniform, and to produce numerous flowers (Crater, 1992).

2.5.1.7 Plant growth regulators

Height control is of utmost importance for potted *D*. x *grandiflorum*. Therefore, additional control of plant height is required for potted chrysanthemums. This is achieved by addition of plant growth regulators. Chemical plant growth regulators do not only retard stem elongation but can also result in dark green foliage and strong stems (Crater, 1992).

2.5.1.8 Phototropism and Flowering

The flowering process of potted *D*. x *grandiflorum* is influenced by photoperiod (Dole & Wilkins, 2005; Faust, 2011). Rooted cuttings must be given 2 to 3 week’s long days (non-inductive photoperiod) before being introduced to short days (inductive photoperiod) to initiate flowering. The plants will be too short and the flowers too small if this is not followed (Dole & Wilkins, 2005; Nau, 2011).

Flowering initiation of potted *D*. x *grandiflorum* does not end vegetative growth and has minimum effect on the number of nodes or plant height. Different cultivars are arranged in response groups, which are defined as the amount of time from placement of the plant in the proper environmental conditions (Dole & Wilkins, 2005).

Photoperiodic response of potted *D*. x *grandiflorum* is obligate to facultative SD (short day) (Dole & Wilkins, 2005). According to Faust (2011), obligate short-day plants need short days to flower and the plants will not flower under long days. Facultative SD plants can flower under long days or short days with the highest rate of flowering occurring under short days (Dole & Wilkins, 2005; Faust, 2011).

To manipulate the flowering, dark period must be introduced at 6 to 15 weeks (matured phase) after cultivation. The phase before maturity is called juvenile period and the plant will not flower even if the proper environment to induce flowers is in place. Knowledge of the response group allows plant growers to anticipate the flowering date and schedule the crops accordingly. While flowering is important, total plant mass must also be considered. Plants must be matured and have enough foliage to support the size and quantity of flowers required for commercial production (Dole & Wilkins, 2005). To manipulate flowering, a black cloth is pulled over the plants to block out the light for at least 12 h (Nau, 2011).

2.5.1.9 Light intensity

Light intensity is the amount of light which is delivered to the plant at any given second. Light is an important factor to manage in the greenhouse because of its contribution to photosynthesis (Faust, 2011). The photosynthetic active range of the light spectrum is 400 to 700 nanometers (nm) (Fisher, 2015). Photosynthesis occurs between low to moderate light intensities. There is no significant difference in the rate of photosynthesis when increasing the light intensity, argues Faust (2011). Light has a primary influence on the root growth, shoot growth (branching, stem thickness, and leaf size) and flowering (flower initiation, number of flowers, and flowering time) (Blanchard & Runkle, 2011; Faust, 2011). Plant growth is affected by the amount of light that the plant has absorbed (Faust, 2011).

The commercially acceptable plant growth in the greenhouse occurs under moderate light conditions which are 10 - 20 moles per day. In this range, the plant will initiate a good number of flowers and have good branching. Day light integral requirements for producing high quality potted *D*. x *grandiflorum* in a greenhouse is 15 - 20 moles/day (Faust, 2011).

Light intensity was not measured for this study since it was not in the scope of this experiment.

2.5.1.10 Pests and Diseases

The most common pests that attack *D*. x *grandiflorum* are; Chrysanthemum aphid (*Macrosiphoniella sanborni*) (Cloyd, 2011), leaf miners, thrips caterpillars, fungus gnats, spider mites and whiteflies. The common diseases include bacterial leaf spot, crown gall, TSWV, *Fusarium*, *Phythium*, *Rhizoctonia*, and leaf and flower blights (Nau, 2011).

2.5.1.11 Vase life

Potted Chrysanthemums are ready for sale after one-third to three-fourths of the flowers are open. They should be transported in temperature storage of 2 - 4 °C for less than seven days. This species is not affected by ethylene. To maintain the flower colour, retailers must display them under temperature range of 18 - 24 °C and minimum light of 538 lux (Nau, 2011).

2.6 SUMMARY

This review has examined the importance of growth media and its different components that are used worldwide for horticultural purposes. It provided attributes of a suitable growth media and how its chemical and physical properties can affect suitability for growing plants. These properties are highlighted as the main indicators of a suitable growth media and have to be used for comparison of peat with potential alternatives. The literature reviewed also helped the researcher to define the cultivation needs of potted *D*. x *grandiflorum* with which growth and yield parameters should be measured when comparing the response among peat grown plants and the proposed alternatives. The cultural practices of this plant as indicated in the literature reviewed were taken into consideration in executing the experiments. The next chapter covers the research design and methodology of the study.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

The experimental design, materials used, and methods followed during the experiment are discussed in this chapter.

3.2 LOCATION OF THE EXPERIMENT

The experiment was conducted in an automated, temperature-controlled greenhouse at the University of South Africa's Horticulture Centre in the Florida campus, Johannesburg, South Africa (26° 10' 30" S, 27° 55' 22.8" E). Destructive sampling measurements were taken in a botany laboratory at the Eureka Building, UNISA Florida campus. The analyses of growth media for chemical and physical properties was done at the Agricultural Research Council (ARC) – Institute for Soil, Climate and Water laboratory (ISCW) in Pretoria, South Africa (25° 44'19.4" S 28° 12'26.6" E).

3.3 EXPERIMENTAL DESIGN

The experimental design used in the study was a randomized complete block design (RCBD) with eight treatments and four replications. Replication of treatments in plant science experimentation is a critical issue. In this study, replication was crucial to ensure that variation in the measured effect was minimized. The purpose for replication was to allow for more accurate estimation of how the treatments affected the growth and yield of the test plant (Davis et al., 2017). According to Whitcomb (2003), the most satisfactory method to use for experimentation in plant sciences is the RCBD. In this design, experimental plots are arranged into blocks and the treatments are allocated to plots within a block in a random manner (Davis et al., 2017). According to Greenfield (2002), a randomized experimental trial is planned and designed to compare more than two treatments. Randomization in an experiment means that the treatments are allocated to plots without a followed pattern (Davis et al., 2017). Adriaanse (2013) applied randomized replicates for more than two treatments in blocks as an experimental design. The same experimental design (RCBD) was adopted for this study with eight treatments and 10 plants per treatment in a block replicated four times (10 (plants) x 8 (treatments) x 4 (replications) = 320 plants). There were 400 plants in total for the experiment. Data was

collected from 256 plants and the remaining 144 plants served as guard rows (refer to annexure 2). Plants at the edges of experimental plots are prone to external factors and according to Vanclay (2006), it is important to have guard rows to reduce edge-effects in experiments.

3.4 RESEARCH METHODOLOGY

This section discusses the different materials and methods used for conducting the experiment.

3.4.1 Planting material and plant population

In this study, four different planting materials were used namely peat, coir, pine bark and bagasse. Peat, coir, composted bagasse, and pine bark were purchased from commercial manufacturers and suppliers. However, the names of the manufacturers or suppliers are not published because of ethical reasons (refer to 3.10).

Rooted cuttings of pot chrysanthemum cultivar 'Mount® Runca', were used in this experiment. Five-week-old rooted cuttings were bought from a specialist nursery (Tuberflora (Pty) Ltd).

3.4.2 Plant growing conditions

The greenhouse used in this study was covered with a polyethylene cladding and the floor shielded with sand and a capillary mat. The greenhouse used was equipped with temperature control units (wet wall, extraction fan and a heater). The greenhouse temperature was set between 18 °C and 26 °C. A blackout screen was installed and utilized to control and manipulate flowering of the research plant. This was a requirement for the successful cultivation of the crop (refer to 2.5.1.8). The screen was set to automatically close at 16:00 and open at 07:00 after 21 days after transplanting (three weeks) to allow rooted cuttings to establish before they could be induced to flower.

3.4.3 Growth media selection, preparation and formulation

3.4.3.1 Growth media selection

Growth media were prepared using the four planting materials mentioned above (section 3.4.1). In this study, eight different growth media were used as treatments namely 100 % peat (control) (T1), 100 % bagasse (T2), 50:50 % bagasse:peat (v/v) (T3), 75:25 % bagasse:peat (v/v) (T4), 25:75 % bagasse:peat (v/v) (T5), commercially available composted bagasse (T6), coir (T7), and pine bark (T8). Selection of coir and pine bark as treatments, T7 & T8, can be attributed to the fact that they have been recommended as the most likely replacement for peat as a growth media component (Adams et al., 2008; Fitzgerald et al., 2012; Maher et al., 2008). Bagasse was included due to the limited research as a peat alternative for growth media and the outdated reported results (Higaki & Imamura, 1985; Trochoulias, Burton, & White, 1990; Yogi, Hensley, & Hollyer, 1997).

3.4.3.2 Growth media preparation

Bagasse obtained from Sugar Milling Research Institute (SMRI) in Durban (29.8716° S, 30.9789 E) was dried in open air and sterilized in an oven (Nüve EN500). A 20 L bucket filled with bagasse was placed in an oven at 60 °C for 48 h. Treatments (T3, T4, and T5) were mixed to the required ratios as mentioned in (3.4.3.1). The experiment consisted of 3 mixes of bagasse and peat which were (50:50 % bagasse:peat (v/v) (T3), 75:25 % bagasse:peat (v/v) (T4), 25:75 % bagasse:peat (v/v) (T5)). The separate dry growth media components were filled into similar sized containers of a known volume (5 L) at the same level. To formulate T3, the contents of the containers were mixed together with the same proportions while they were still dry to make sure that they are properly mixed. The method for T4 and T5 formulation was similar to the one above but the volume was increased for bagasse and reduced for peat in T4 and vice versa for T5. Mixing of the growth media took place on a clean plastic surface in the greenhouse to prevent contamination with other substances. For planting, 10 cm planting pots were filled with each of the eight treatments on the 15th of June 2017. Each growth media was first moistened with tap water before filling the planting pots in order to improve moisture distribution and to minimize transplant shock.

3.4.4 Transplanting phase

Five-week-old rooted cuttings of *D*. x *grandiflorum* were bought from the nursery and were transplanted into 10 cm pots filled with the different growth media. Only one cutting was transplanted per pot and was planted in the center as recommended for potted plants. The rooted cuttings were transplanted on 15th of June 2017. Transplanting was conducted in the greenhouse where the growth-media filled pots were already prepared in designated blocks according to the experimental design.

3.4.5 Fertigation and plant growth regulation

3.4.5.1 Fertigation

The plants were irrigated by hand once per day using a beaker at 200 mL per pot. Water soluble fertilizers used were Multisol® 'P' 2.1.2 (43) + trace elements, Multisol® 'K' 3.1.6 (46) + trace elements and Multi-Cal (GC), which contains N (155 g/kg (15.5 %)) and Ca (190 g/kg (15.5 %)). The composition and chemical concentration of fertilizers used were: Multisol® 'P' 2.1.2 (43) + trace elements comprising (N (190 g/kg), P (86 g/kg), K (172 g/kg), Mg (0.9 g/kg), Zn (0.350 g/kg), Fe (0.763 g/kg), Cu (0.077 g/kg), Mn (0.310 mg/kg), B (1.005 g/kg)) and Multisol® 'K' 3.1.6 (46) + trace elements comprising (N (138 g/kg), P (45 g/kg), K (276 g/kg), Mg (0.900 g/kg), Zn (0.350 g/kg), Fe (0.763 g/kg), Cu (0.077 g/kg), Mn (0.310 mg/kg), and B (1.00 g/kg)).

Multisol® 'P' 2.1.2 (43) was applied from transplanting stage until the plants had buds (for the first 3 weeks after transplanting) with one-day intervals watering without the fertilizer, Multi-Cal (GC) was used once off at week four (for the whole week) thereafter Multisol® 'K' 3.1.6 (46) was used until the end of the experiment with one-day intervals watering without the fertilizer.

The soluble fertilizers were mixed with water in 10 L buckets prior irrigation at a recommended EC of 2.0 mS/cm^{-1}. The EC of the irrigation water was measured using a hand-held pH/EC meter (Eutech™ PCTestr 35- Multi-Parameter) available at the UNISA Horticulture Centre. When this threshold was exceeded, tap water was added to the fresh nutrient solution in order to restore it to the predetermined EC value. The water pH fluctuated between 6.0 and 6.5, which is favourable for the research plant (Dispenza, De

Pasquale, Fascella, Mammano, & Alonzo, 2016). This fertilizer program adopted was recommended by Mr. Andrew Winkworth (personal communication, March 3, 2017), who is an experienced specialized potted Chrysanthemum grower at Tuberflora (Pty) Ltd.

3.4.5.2 Plant growth regulation

Quality standards of potted plants grown in greenhouses requires them to be compact, and have short internodes, a consistent height, and strong stems (Whipker et al., 2011b). In this case, a plant growth regulator to retard the growth was applied. The plant growth regulator that was used is Cultar with an active ingredient of paclobutrazol (triazole) 250 g/L. Paclobutrazol is a widely used growth retardant for greenhouse grown floriculture crops (Whipker et al., 2011b). The plant growth regulator was applied once off at week 4. When plants developed the first buds, the shoot apex was pinched off (I cm from apex tip) and thereafter, the measurement for height on data plants was no longer considered. The first buds were also removed as suggested for potted chrysanthemum cultivation (refer to 2.5.1.6).

3.4.6 Pest and diseases control

Pests and diseases were scouted daily. The common pests identified were thrips and leaf borer. Seizer® (Active ingredient: bifenthrin (pyrethroid)) at 40 mL/100 L and Servus (Active ingredient: Deltamethrin (pyrethroid)) at 20 mL/100L of water were used interchangeably every week to control these insects. The spray program for pests and diseases adopted was recommended by Andrew Winkworth (personal communication, March 3, 2017), who is an experienced specialized potted chrysanthemum grower at Tuberflora (Pty) Ltd. In addition, some fungal growths were identified and the chemical fungicide, Bravo® 750, at 20 mL per 100 L of water was used to control fungal diseases.

3.5 DATA COLLECTION FOR OBJECTIVE 1

Objective 1 was aimed at evaluating the chemical properties of alternative growth media in comparison to peat. The chemical properties analysed were pH, Electrical Conductivity (EC), growth media mineral composition, and C:N ratios.

Before the experiment started, samples of the eight growth media treatments were packaged in paper bags and sent to the ARC – ISCW laboratory for determination of their chemical properties. Similarly, after the experiment (89 days after transplanting (DAT)), 24 samples (eight treatments by three replicates) were also analysed for their chemical properties.

3.5.1 Chemical tests and extraction for analysis

In this study, three chemical tests were done and includes pH, electrical conductivity, bicarbonate and other anions. For each of these parameters, a 100 mL of sample as received (no drying or milling), was extracted with 150 mL deionized water and the water extract was filtered using a Whatman No. 1 filter paper. For each of these parameters, only one sample was analysed (not replicated) due to the high cost of analyzing replicates at the ARC in Pretoria.

3.5.1.1 pH

The pH of an aliquot of the extract solution assessed at ARC laboratories was measured using a pH electrode and pH meter (Eutech™ Instruments pH 700) calibrated against buffers at pH 4 and 7 and checked against a pH 10 buffer.

3.5.1.2 Electrical conductivity (EC)

The conductivity of another aliquot assessed at ARC laboratories was measured with a conductivity electrode and meter (Radiometer).

3.5.1.3. Determination of bicarbonate (HCO_3^-)

Bicarbonate was determined at the ARC laboratories using a pH titration of an aliquot of the extract.

3.5.1.4 Determination of anions by Ion Chromatography (IC)

An aliquot of the extract solution was analysed (as soon as possible after extraction) by Ion Chromatography using a Dionex Model 1600 Ion Chromatograph with a conductivity detector and eluted through an ion exchange column using a carbonate/ bicarbonate buffer solution. The anions determined included fluoride (F^-), chloride (Cl^-), nitrite (NO_2^-), nitrate (NO_3^-), phosphate (PO_4^{-3}) and sulphate (SO_4^{-2}), and they were eluted sequentially in this order (fluoride first and sulphate last). The instrument was calibrated against a standard solution containing all these anions.

3.5.1.5 Determination of mineral elements using Inductively Coupled Plasma Optical Emission Spectrometric (ICP-OES)

An aliquot of the extract solution was used for the ICP-OES determination of Ca, Mg, K, Na, Fe, Zn, Mn, B and Cu. P was also included in order to confirm the phosphate values. The ICP-OES instrument used was an Agilent 725 (700 Series) simultaneous instrument (Australia), where all the elements (and all wavelengths) are determined simultaneously. Thus, several elements were determined at more than one wavelength, allowing confirmation of the values, with no increase in analysis time or consumption of digest solution. Each element was measured at one or two appropriate emission wavelengths, chosen for high sensitivity and lack of spectral interferences. The wavelengths for each element used were: Mg: 383.829 and 279.553 nm; Ca: 422.673 and 317.933 nm; K: 769.897 and 766.491 nm; P: 213.618 nm; Na: 589.592 nm; Fe: 259.94 and 238.204 nm; Mn: 257.61 nm; Zn: 213.857 nm; Cu: 324.754 and 327.395 nm and B 249.678 and 249.772 nm. Background correction on one side or both sides of the peak was used. Where two wavelengths were used for an element, the average of the values from both elements was usually taken. If the sample concentration for an element was very low (close to the detection limit, e.g. B and Cu for some samples), then the value from the wavelength giving the stronger signal was instead used, or alternatively a weighted mean was used with the higher weight given to the wavelength with a stronger signal.

The instrument was set up and operated according to the recommended procedures in the manufacturer's manual for optimised conditions. Since all elements were determined simultaneously, it was not possible to optimise for each individual element, but only for the group of elements. The instrument was calibrated against a series of standard solutions, containing all the elements of interest in the proportions found in typical growth media or leaf samples [Unpublished method developed and optimised at ARC - ISCW, based on the recommended procedures in the instrument manual (Agilent 700 Series ICP Optical Emission Spectrometers: Users Guide, Third Edition, Aug. 2010. Agilent Technologies Inc)].

3.5.1.5.1 Adjustment of concentrations of anions, cations & elements for moisture

The extract concentrations for all anions, cations and other elements were adjusted for the moisture content of the samples. Thus, all analytes in the extract (chemical tests) except for the pH and EC were adjusted. For the extraction, 100 mL of water was added to 150 mL sample, but since the fresh samples were not oven dried, the total amount of water present was more than 150 mL. The total water present equals the 150 mL added plus the moisture already present in the samples (m), (m% is the % moisture on a volume basis). The conversion factor used was thus (150+m) /150.

3.5.1.6 C and N determination

The sample were used directly (in finely milled or powder form) for C and N determinations on a Thermo Scientific Flash 2000 Elemental Analyzer, using approximately 7 to 13 mg sample weighed into a tin foil container for each determination (Jimenez & Ladha, 1993). This method is a dry oxidation (total combustion) method generally known as the Dumas method.

The sample and tin container were ignited at high temperature (950 ˚C) in oxygen (on a chrome oxide catalyst) to produce CO_2, N gas and oxides of N (plus other oxides etc.). The gases produced passed through silvered cobalt oxide (to remove oxides of S and halogens) and a column of Cu (650 to 680 ˚C), which reduces the oxides of N to N_2 gas and removes excess free O_2. After removal of water vapour by a trap of anhydrous magnesium perchlorate (anhydrone), the N_2 gas and CO_2 are finally separated by gas

chromatography (GC), using a helium carrier gas and detected by a thermal conductivity detector (TCD).

The instrument was calibrated against a certified standard of a pure organic compound of known composition. The compound chosen for our calibration standard was phenylalanine, an amino acid, which contains 8.48 % N and 65.4 % C.

“Eager Xperience” software was used to control the instrument, integrate, calibrate (linear or quadratic) and compute the N and C concentrations (from the peak areas).

3.6 DATA COLLECTION FOR OBJECTIVE 2

Objective 2 aimed at evaluating the physical properties of alternative growth media in comparison to peat. The physical properties measured included water holding capacity, air filled porosity and bulk density.

Before transplanting, samples of each of the eight growth media treatments were packaged in paper bags and sent to the Agricultural Research Council, Institute for Soil, Climate and Water (ARC - ISCW) for the physical properties measurements. However, the collected growth media samples at the end of the experiment were not sufficient for the instruments to give reliable results, hence the measurements for physical properties were not done. This was a limitation to the current study.

3.6.1 Air filled porosity (AFP)

A cylinder of known capacity (VS = 461.8 mL) was filled with the sample and then filled with water to saturate the sample. Additional sample was added to the top of the cylinder if the water added caused any settling of the sample. The excess water was drained off, and measured as Vw. The AFP is determined as the ratio between these two volumes, i.e. AFP = Vw/ VS (multiplied by 100 to convert to a percentage).

3.6.2 Water Holding capacity (WHC)

The wet, drained sample from the method above was transferred into a beaker, which was weighed before (mb) and after transfer of sample (mw). The sample in the beaker was dried in an oven and then reweighed (md). The WHC was determined as the difference

between the masses before and after drying divided by the original water saturated sample volume or WHC = (mw - md) / VS (multiplied by 100 to convert to a percentage).

3.6.3 Bulk density

Bulk density was measured by weighing the 100 mL of original sample that was used for the extraction (before the addition of the water). The bulk density was calculated as the ratio of the sample mass to sample volume i.e. sample mass in grams (g) divided by 100.

3.7 DATA COLLECTION FOR OBJECTIVE 3

Objective 3 was aimed at determining shoot mineral (plant nutritional content) and leaf chlorophyll content of potted *D.* x *grandiflorum* cultivated in different growth media. For this experiment, the shoot (stem and leaf) was used to determine the plant nutritional content and was regarded as the plant part without the roots, flower buds, and flowers.

3.7.1 Shoot mineral content

After the collection of the dry weight data at the end of the experiment (89 DAT) as described in section 3.8.2.6, 24 (eight treatments by three replicates) dried shoot samples were randomly selected and packaged in plastic bags (Nasco Whirl-Pak® write-on bags (118 mL)) and sent to the ARC - ISCW laboratory for shoot nutrient analyses. The sample preparation was conducted at the referred laboratory. The procedure to extract and analyze the nutrients was similar as described in section 3.5.1.5 and 3.1.5.6 for growth media chemical analyses.

3.7.2 Chlorophyll content

The chlorophyll content was measured using a non-destructive method with a hand-held chlorophyll meter also called SPAD meter (Opti-Sciences model CCM-200 plus, Hudson, USA) (Figure 3.1). Determination of relative chlorophyll content using the SPAD meter is quick, efficient and relatively reliable. Measuring chlorophyll content without destroying the plant enables monitoring of several parameters in the same plant and obtaining data that is reliable (Pavlovic, Nikolic, Durovic, Waisi, Andelkovic, & Marisavljevic, 2014).

Chlorophyll levels are a key indicator of a plant's health, which is a vital aspect of this study (Liang, Urano, Liao, Hedrick, Gao, & Jones, 2017). However, the chlorophyll level data was collected later during the experimental period due to the unavailability of the chlorophyll meter. The chlorophyll meter was purchased before the experiment but was only received from the suppliers at 80 DAT. The data was collected from three plants per treatment in the four blocks (96 plants in total) with the remaining plants at 80 DAT. Data was collected at 2-days interval on the following days (80, 82 and 84 DAT). To ensure consistency, the leaf used for chlorophyll content determination was marked with a marking pen (see Figure 3.1). A matured and fully expanded leaf, fourth from the base of the plant, was randomly selected for the measurement. For each plant, chlorophyll content on the adaxial (upper) and abaxial (lower) sides of the leaf were measured.

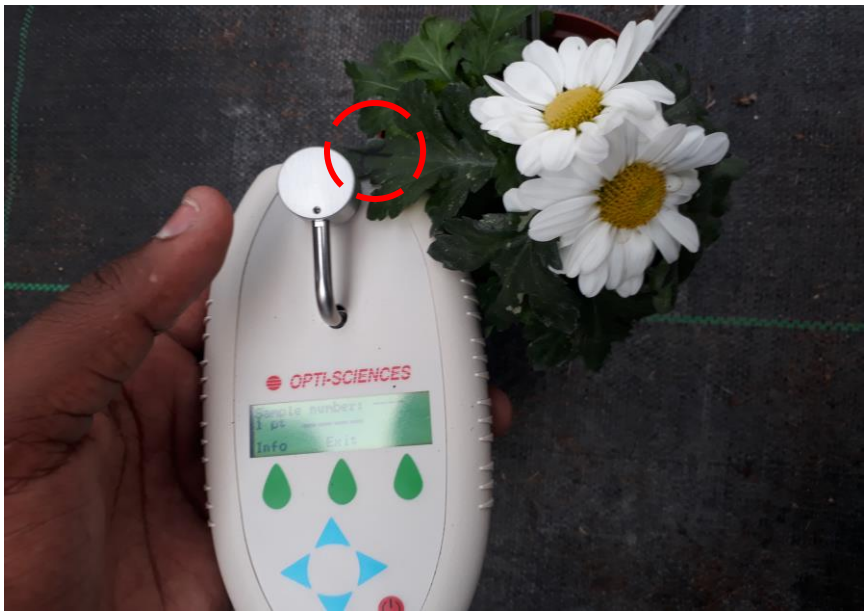

Figure 3. 1: Measuring chlorophyll content with a chlorophyll meter (Koopa, KG. 2017)

3.8 DATA COLLECTION FOR OBJECTIVE 4

Objective 4 was aimed at assessing the growth and yield of potted *D*. x *grandiflorum* cultivated in alternative growth media in comparison to peat.

Two sampling methods (non-destructive and destructive) were adapted for plant growth and yield measurements. During data collection, all results were recorded in a data sheet (annexure 3) compiled by the researcher using a pen. The results were later transferred to a Microsoft Excel sheet.

3.8.1 Non-Destructive sampling method

This method was carried out in the greenhouse were the plants were grown. Two plants per treatment in each of the four blocks were randomly selected in the beginning of the experiment. These data plants were spared from being selected for destruction sampling. The total number of data plants for the experiment was 64 (16 x 4 = 64). Data for plant height (in mm) and number of leaves were collected at three growth stages (7 DAT, 14 DAT and 21 DAT). Data collection for the number of leaves ended at 21 DAT due to the plant's growth habit (too many leaves that are clustered), which made counting challenging. Data for plant height was also terminated after the first flower buds were removed, this is because the shoot apex was removed and increase in plant height was restricted.

3.8.1.1 Plant height

The plant height for non-destructive sampling was determined as the distance from the top of the pot to the top of the plant's apex due to contraction nature of some treatments. A Vernier electronic caliper was used to measure the plant height (in mm).

3.8.1.2 Number of leaves

The number of leaves per plant was physically counted in the greenhouse.

3.8.2 Destructive sampling method

Thirty-two plants (one plant per treatment in each block) were randomly selected at the following dates; 14, 28, 42, 56 and 70 DAT for destruction sampling. The plants were removed from the pots with the growth media still attached to the roots (Figure 3.2) and placed in a brown paper bag. The paper bags were clearly marked to avoid mixing of plants with different treatments. The plants were transferred to the laboratory (UNISA Eureka Building) where the separation and measurements were conducted. In the laboratory, the plants were removed from the growth media by gently squeezing it to limit breakage and root loss. The remaining growth media was washed off with tap water. When there was no growth media attached to the roots, the plants were dried with hand towels carefully not to break or remove the leaves.

The following growth measurements were taken; plant height (mm), stem diameter (mm), fresh and dry root weight (g), fresh and dry shoot weight (g), number of buds when available, fresh and dry flower bud weight (g), number of flowers when available, and fresh and dry flower weight (g). At the end of the experiment (89 DAT), 96 plants (three plants per treatment in each block) were used to measure the growth parameters mentioned above. A total of 256 plants were destroyed by the end of the experiment.

Figure 3. 2: Removing of the plant from the pot during destructive sampling (Koopa, KG. 2017)

Measurements taken during the destruction sampling method were carried out as follows:

3.8.2.1 Plant height

The plant height was determined as the distance from the root crown to the top of the plant. A Vernier electronic caliper was used to measure the plant height (in mm).

3.8.2.2 Number of leaves

The number of leaves per plant was counted in the same manner as described in section 3.8.1.2 for non-destructive sampling.

3.8.2.3 Stem diameter

The stem diameter measurement was taken 15 mm above the root crown. A mark was made using a permanent marker to make sure that the measurement is taken at the right place. A Vernier electronic caliper was used to measure the stem diameter (in mm).

3.8.2.4 Number of flower buds and flowers

The flower buds and flowers for each sampled plant were separated from the shoots by hand and counted separately. Buds were available for counting from 56 DAT and flowers were counted from 70 DAT.

3.8.2.5 Fresh and dry roots weight

The roots were separated from the plant by cutting them off at the root crown level using a pair of scissors and weighed on an Adama- PW254 sensitive scale (Figure 3.3). The roots were then stored in a freezer prior to freeze drying. The freezer was set at -50 °C. The frozen roots were removed from the freezer and dried separately in a freeze dryer (Labonco® Freezone 2.5 freeze drier) available in the laboratory. The samples were left to dry 48 h before the dry root weight was determined.

Figure 3. 3: Measuring the plant biomass (Koopa, KG. 2017)

3.8.2.6 Fresh and dry shoots weight

The fresh shoots weight was measured using the same scale mentioned in 3.8.2.5. The same storage procedure as mentioned above was followed. The same procedures for drying and weighing the dry roots were also followed.

3.8.2.7 Fresh and dry weight of flower buds and flowers

The counted flower buds and flowers were weighed (fresh and dry) using a sensitive scale. The storage procedure, drying and weighing of flower buds and flowers was as described for roots and shoots in 3.8.2.5 and 3.8.2.6.

3.8.2.8 Root to shoot ratio (R/S)

Root to shoot ratio (R/S) was calculated by dividing the root dry weight by the shoot dry weight. The dry root and shoot weights were measured for plants harvested at 14, 28, 42, 56, 70, and 89 DAT.

3.9 STATISTICAL ANALYSIS

One-way analysis of variance (ANOVA) was used to analyse differences among the eight growth media for chemical and physical characteristics. The differences among all parameters (growth and yield) and chlorophyll content measurements were analysed in a similar way. All parameters and measurements were tested at $p<0.05$ significance level and the Duncan multiple range test (DMRT) was used for separation between treatment means. Statistica v. 10, StatSoft (USA) was used for all statistical analysis.

3.10 ETHICAL CONSIDERATIONS

Ethical consideration impacted this study whereby names of the manufacturers and suppliers of growth media are excluded for the purpose of protecting their brands. The general principle of ethical consideration is that no damage or harm should occur from any research project. The brands should be respected, and their rights, privacy and integrity should be taken into consideration. To ensure an ethically acceptable research and adherence to UNISA's policy on ethics, the research proposal was approved by CAES committee (ethical number: 2015/CAES/125) in November 2015 and the approval was reviewed annually until completion of the experiment. This document is available in annexure 1.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 INTRODUCTION

Results for the research study are presented and discussed in this chapter. The results and discussion are presented according to the individual objectives of the study.

4.2 DIFFERENCES IN CHEMICAL PROPERTIES OF GROWTH MEDIA

Growth media analyses results revealed differences in the chemical properties of the different treatments before and after the experiment (Tables 4.1 - 4.5). It is important to highlight that single samples were analyzed for each treatment because of the high cost of analysis and unavailability of sample materials. There were no replicate samples so values reported in this section are absolutes and not means/averages.

4.2.1 pH and EC in the treatments before and after the experiment

4.2.1.1 pH

Growth media pH affects nutrients availability to plants (Lang, 1996; Stanton & Milkelbart, 2014). The availability of soluble nutrients for the plants' root uptake is dependent on soil pH. When the growth media pH is high, Ca and Mg levels will generally be higher. High pH also decreases the solubility of P, Fe, Mn, Cu, Zn, and B (Reed, 1996). Table 4.1 shows the results for the pH tested in the eight different treatments before (bf) and after (af) the experiment.

At the beginning of the experiment, the pH was highest in T7 (5.9) followed by T2 and T4 (5.4) and lowest in T8 (3.9). The pH in T7 was 11.8 % higher compared to the control medium (5.2) (Table 4.1). After the experiment, the pH in T7 was again the highest (5.8) followed by T2 (5.5) and T8 (5.2) and the lowest was in T1 (4.6). The pH of both T3 and T4 were similar (5.1). The pH in T7 was 20.6 % higher than in the control medium. However, the pH in T7 reduced by 0.1 % after the experiment when compared to the initial pH (5.9) recorded before the experiment. The same was observed in T1, which reduced by 0.6 % from the pH recorded before the experiment. In general, at the end of the experiment slight pH changes in some media are noted. Notably, the pH of T1, T4, and T7 reduced slightly

whilst the pH of T2, T5, T6, and T8 increased after the experiment (Table 4.1). These changes in media pH after the experiment in this study are in agreement with reports by Chavez et al. (2008) from a similar study. These authors reported that the pH's of substrates with the highest proportion of Sphagnum (Sp1(Sphagnum peat (80%) + Perlite (10%) + Vermiculite (10%)), Sp2 (Sphagnum peat (70%) + Perlite (20%) + Vermiculite (10%)), and Carex (Ca1(Carex peat (80%) + Perlite (10%) + Vermiculite (10%)), Ca2(Carex peat (70%) + Perlite (20%) + Vermiculite (10%)), were reduced whilst others remained the same at the end of the experiment. These findings are consistent with the fact that the pH of growth media can be affected by many factors (fertilizer, plant age, medium type etc.) (Chavez et al., 2008).

In general, the pH of all the treatments was in the acidic range both before (3.9 - 5.9) and after (4.6 - 5.8) the experiment (Table 4.1). According to Benito, Masaguer, De Antonio, and Moliner (2005), the established optimal pH range of growth media for growing ornamental plants in containers is 5.2 - 6.3. The pH levels in T1 (5.2), T2 (5.4), T4 (5.4), T5 (5.2), T6 (5.3), and T7 (5.9) were within these limits before the experiment. At the end of the experiment, the pH of the other treatments was reduced, only T2 (5.5) and T7 (5.8) were within the stated established range. The pH in T8 was increased but still not within the established ideal range. The low pH can be rectified by adding lime to the growth media (Jones, 2012). In the study by Hernández-Apaolaza and Guerrero, (2008), coir-based substrates showed pH's around 5.8, which the author concluded as being typical for these substrates. This result was consistent with findings in the current study (Table 4.1). Furthermore, Abad et al. (2002) is of an opinion that coir, in comparison with peat, requires little or no liming when used for ornamental potted plant production.

According to Brown (2002); Dole and Wilkins (2005); Fisher (2011) and Maree and van Wyk (2010), potted chrysanthemums require a slightly acidic pH (5.6 - 6.5) growth condition. Slightly acidic conditions facilitate maximum uptake of nutrient elements (Wang, Gabriel, Legard, & Sjulin, 2016). According to results obtained in this study (Table 4.1), the pH of Coir (T7) was almost stable and within the recommended range (5.6 - 6.5) for potted chrysanthemums when compared to control and the other treatments. This finding seems to suggest that Coir has potential to replace peat for better growth performance (Brown, 2002; Dole, & Wilkins, 2005; Fisher, 2011; Maree, & van Wyk, 2010).

Table 4. 1: pH and EC composition in the treatments before and after the experiment (n=1)

Parameters	Period	Treatments								
		T1	T2	T3	T4	T5	T6	T7	T8	Units
pH	(bf)	5.2	5.4	5.1	5.4	5.2	5.3	5.9	3.9	
	(af)	4.6	5.5	5.1	5.1	4.9	4.7	5.8	5.2	
EC	(bf)	0.22	0.23	0.2	0.14	0.18	3.42	1.32	0.16	mS/cm^{-1}
	(af)	1.49	1.81	2.03	2.26	2.25	3.99	1.11	0.8	mS/cm^{-1}

af=after the experiment, bf=before the experiment

4.2.1.2 Electrical Conductivity

The concentration of soluble salts is an important parameter for the use of materials as growing media, because salinity is one of the main factors limiting plant growth (Bustamante, Pareded, Moral, Agulló, Pérez-Murcis, & Abad, 2008; Méndez, Paz-Ferreiro, Gil, & Gascó, 2015). Table 4.1 shows results of the EC tested in the eight different treatments before and after the experiment.

Before the experiment, the EC was highest in T6 (3.4 mS/cm^{-1}) followed by T7 (1.3 mS/cm^{-1}) and lowest in T4 (0.1 mS/cm^{-1}). The concentration of soluble salts in T6 was 93.5 % higher compared to control medium (0.2 mS/cm^{-1}) (Table 4.1). After the end of the experiment, the EC was again highest in T6 (3.9 mS/cm^{-1}) followed by T4 and T5 (2.2 mS/cm^{-1}) and the lowest was recorded in T8 (0.8 mS/cm^{-1}). The concentration in T6 was 62.6 % higher compared to control medium (1.4 mS/cm^{-1}) (Table 4.1). The EC in growth media can be influenced by high concentrations of soluble salts (chloride (Cl^-), sodium (Na^+), and sulphate (SO_4^{-2})) and nutrients i.e. potassium (K), nitrate (NO_3^-), magnesium (Mg), and calcium (Ca) (Chong, Cline, & Rinker, 1994; Garcia-Gomez, Bernal, & Roig, 2002; Whipker et al., 2011a). Bark composts and coir usually contribute few soluble salts to growth media hence the low concentration of EC in T7 and T8 after the experiment (Hernández-Apaolaza & Guerrero, 2008).

After the experiment, an increased EC was recorded in all treatments except for T7 (1.1 mS/cm^{-1}) which reduced by 15.9 % compared to its initial EC (1.32 mS/cm^{-1}). The EC in T4 (with lowest EC before the experiment) increased by 2.1 mS/cm^{-1} to record the second highest EC (2.2 mS/cm^{-1}) after the experiment (Table 4.1). The addition of fertilizers during cultivation might have resulted in the observed increases in EC values after the experiment as suggested by Iglesias-Díaz, Lamosa, Rodil, and Díaz-Rodríguez (2009).

Before the experiment, only T7 (1.32 mS/cm^{-1}) was within the recommended ideal EC range (0.6 - 2.0 mS/cm^{-1}) for plants grown in containers (Hernández-Apaolaza & Guererro, 2008). Despite increases in EC in the treatments after the experiment, the recorded values were within the recommended range except for T6, which had a concentration higher than 3.5 mS/cm^{-1}, which is considered too high to support healthy growth for plants grown in containers (Hernández-Apaolaza, Gascó, Gascó, & Guerrero, 2005). However, the targeted EC range for the successful cultivation of potted chrysanthemums is 2.2 - 3.3 mS/cm^{-1} (Dole & Wilkins, 2005). Only T4 and T5 were within this range but T6 was just 0.3 above the range required for cultivating potted chrysanthemums.

Chong, Cline, and Rinker (1994) however, observed satisfactory growth of several plant species in growth media containing spent mushroom compost with initial high EC levels. The same observation was reported by Guerrero, Gascó, and Hernández-Apaolaza (2002) using pine bark and sewage sludge as container growth media. Also, excess soluble salts can easily and effectively be leached out during irrigation for ornamental plants in containers (Abad et al., 2002; Yogi et al., 1997).

4.2.2 Macronutrients in the treatments before and after the experiment

In this study, the treatments were analyzed for five elements (N, C, K, Ca & Mg) to determine their macronutrient compositions. Table 4.2 shows the macronutrient composition in the eight different treatments before (bf) and after (af) the experiment. Single samples were analyzed for each treatment because of high cost of analysis. There were no replicate samples so the values reported are absolutes and not means.

4.2.2.1 Total Nitrogen

The Nitrogen content has a close link with chlorophyll content. Nitrogen deficiency can lead to loss of green colour in leaves, decrease leaf area and intensity of photosynthesis. The relationship between N and biomass accumulation is dependent on the reciprocal regulation of multiple crop physiological process. Therefore, N uptake and distribution in plants involves many aspects of growth and development (Bojović & Marković, 2009).

At the beginning of the experiment, the highest percentage of total N was recorded in T6 (4778.0 mg/L) followed by T1 (1972.2 mg/L) and T5 (1352.0 mg/L) and the lowest in T8 (429.0 mg/L). The N concentration in T6 was 58.7 % higher than in the control medium (1972.2 mg/L) (Table 4.2). After the experiment, the total N concentration was still higher in T6 (4997.0 mg/L) followed by T5 (1609.4 mg/L) and T3 (1507.9 mg/L) and lowest in T8 (734.5 mg/L). The concentration in T6 was 72.2 % higher than in the control medium (1388.7 mg/L). It was noted that the total N in T1 and T7 was reduced by 583.5 and 99.0 mg/L, respectively, at the end of the experiment (Table 4.2) and this may have affected the growth media fertility and plant yield as previously reported by Cameron, Di, and Moir, (2013). The mineral-N reductions could have resulted from ammonia volatilisation, leaching, denitrification and transformation into gaseous forms (Cameron, Di, & Moir, 2013).

Relative to the initial nutrient concentrations in treatments, the total N content was increased by 60.8, 14.4, 34.7, 15.9, 4.3, and 41.5 % in T2, T3, T4, T5, T6, and T8 respectively after the experiment. This may be attributed to the fact that each time that organic compounds are composted, two thirds of the carbon is lost to the atmosphere as CO_2 gas and most of the nitrogen is recycled (Grunert, Reheul, Van Labeke, Perneel, Hernandez-Sanabria, Vlaeminck, & Boon, 2016). High level of N in the growth media is an indication of incomplete composting, which means that enough organic material will be available for plant growth (Yogi et al., 1997).

4.2.2.2 Total Carbon

The highest percentage of total C was recorded in T8 (104.7 g/L) followed by T1 and T6 (>87 g/L) and the lowest in T2 (38.5 g/L) before the experiment (Table 4.2). The total C concentration in T8 was 16.5 % higher compared to control medium (87.4 g/L). After the experiment, the total C concentration was still the highest in T8 (92.7 g/L), followed closely by T6 (84.7 g/L) and lowest in T7 (24.5 g/L). Similarly, total C concentration in T8 was higher by 42.9 % compared to control medium (52.9 g/L) (Table 4.2) after the experiment.

In a study conducted by Jayasinghe, Tokashiki, and Arachchi (2011), the authors reported that peat had the highest C content compared to other treatments. However, the current study recorded the highest C content in pine bark. This finding seems to suggest that pine bark has a higher carbon sequestration and nutrient retention abilities because of its relative higher organic matter (humus) content (total C content). Generally, after the experiment, the C content decreased from the values recorded before the experiment. This may be due to loss of C through carbon dioxide (CO_2) released into the atmosphere (Grunert et al., 2016).

4.2.2.3 Potassium (K)

Potassium is an important macronutrient for plants and constitutes between 2 % and 10 % of plant dry weight (Ashley, Grant, & Grabov, 2006; Nieves-Cordones, Alemán, Martínez, & Rubio, 2014). At the beginning of the current study, the highest content of K was recorded in T7 (409.9 mg/L) followed by T6 (58.5 mg/L) and the lowest in T1 (4.2 mg/L) (Table 4.2). The concentration in T7 (coir) was 98.9 % higher compared to control medium. This finding agrees with the results by Abad et al. (2002), who reported that the K content in coir exceeded the optimal concentration ranges of growth media for potted ornamental plant production in comparison to peat. The authors concluded that K ions mostly contributed to the salinity of coir dust.

After the experiment, the K concentration was highest in T4 (477.3 mg/L) and lowest in T8 (163.9 mg/L). The concentration in T4 was higher by 32.8 % compared to control medium (320.5 mg/L). Relative to the initial nutrient concentrations in treatments, the K content was increased by 316.3, 342.6, 415.8, 454.7, 456.3, 386.6 and 141.1 mg/L in T1, T2, T3, T4, T5, T6, and T8, respectively, after the experiment. A decrease of 33.1 % was recorded in

T7, which had the highest K content before the experiment (Table 4.2). This decrease might be due to leaching of K because it is a mobile ion (Alfaro, Jarvis, & Gregory, 2004).

For the cultivation of potted crops, the ideal concentration of K in growth media is suggested between 150 - 249 µg mL^{-1} (Abad et al., 2001; Di Benedetto et al., 2006). All treatments in the current study were below this range before the experiment except for T7 (409.9 mg/L). At the end of the experiment, the concentration in T8 was within the range and all the other treatments contained K levels above the recommended range.

4.2.2.4 Calcium (Ca)

Before the experiment, the highest Ca concentration in the treatments was recorded in T6 (753.2 mg/L) followed by the second highest in T1 (22.1 mg/L) and the lowest in T8 (3.7 mg/L) (Table 4.2). The concentration in T6 was 97.0 % higher compared to control medium (22.1 mg/L). After the experiment, the Ca concentration was again highest in T6 (844.0 mg/L) followed by second highest in T5 (137.0 mg/L) and lowest in T8 (5.0 mg/L). The concentration in T6 was 89.1 % higher compared to control medium (91.7 mg/L) (Table 4.2). The low levels of Ca in T8 may be due to the low pH in the growth media as mentioned by Nelson (1996). The high EC in T6 (Table 4.1) may be as a result of high Ca as suggested by Whipker et al. (2011a).

Relative to the initial treatments' nutrient concentrations, Ca content was increased by 69.6, 62.0, 80.0, 94.4, 119.9, 90.8, 16.3, and 1.3 mg/L in T1, T2, T3, T4, T5, T6, T7, and T8 respectively at the end of the experiment. The least increase was observed in T8, which increased only by 1.3 % (Table 4.2) and this may be partly associated with lower water uptake by plants (see 4.3.1) as previously reported by Massa, Malorgio, Lazzereschi, Carmassi, Prisa, and Burchi (2018).

The highest concentration in T6 might have been due to the addition of lime during production of the growth media (Jayasinghe, Tokashiki, & Kitou, 2010b) and not because of the pH as alluded by Fonteno (2011) who reported that high pH increases Ca in growth media. Calcium levels in ideal growth media are recommended between 35 -100 mg/L (Silber & Bar-Tal, 2008; Wang et al., 2016). None of the treatments were within this range before the experiment. However, after the experiment, T1 (91.7 mg/L), T2 (74.7 mg/L), and

T3 (94.0 mg/L) were within the recommended range. This finding seems to suggest that 100 % bagasse (T2) and 50:50 % bagasse: peat (T3) are potential replacements for 100 % peat with respect to the concentration of Ca in the media.

4.2.2.5 Magnesium (Mg)

The highest Mg concentration was recorded in T6 (41.3 mg/L) followed by second highest T2 (9.7 mg/L) and the lowest in T8 (2.2 mg/L) before the experiment. The Mg concentration in T6 was 92.0 % higher compared to control medium (3.3 mg/L) (Table 4.2). After the experiment, the Mg concentration was highest in T4 (30.1 mg/L) followed by T2 (26.2 mg/L) and lowest in T8 (2.8 mg/L). The concentration in T4 was 49.8 % higher compared to control medium (15.1 mg/L). Relative to initial treatments' nutrient concentrations, the Mg content was increased by 11.8, 16.5, 19.2, 24.9, 22.4, 11.2, and 0.6 mg/L in T1, T2, T3, T4, T5, T7, and T8 respectively at the end of the experiment. A decrease of 44.3 % was recorded in T6 (23.0 mg/L) which had the highest Mg content before the experiment (Table 4.2).

The recommended range for ideal growth media is 35 - 100 mg/L (Silber & Bar-Tal, 2008; Wang et al., 2016). The concentration in T6 was within the recommended range before the experiment compared to the other treatments. However, it reduced to concentrations below the recommended range after the experiment. All the tested treatments were below the established range after the experiment. The lowest Mg concentration in T8 may be as a consequence of the decreased pH, reported in 4.2.1.1. The results of the current study support previous findings by Jones (2012) who also reported that lower pH can affect Mg retention in soils. Nevertheless, Mg deficiency can be resolved by adding Mg nitrate, Gypsum or dolomite limestone (Abad et al., 2002).

Table 4. 2: Macronutrient composition in the treatments before and after the experiment (n=1)

		Treatments								
Parameters	**Period**	T1	T2	T3	T4	T5	T6	T7	T8	**Units**
Total N	(bf)	1972.2	504.5	1290.0	924.0	1352.0	4778.0	571.0	429.0	mg/L
	(af)	1388.7	1288.2	1507.9	1416.5	1609.4	4997.0	472.0	734.5	mg/L
Total C	(bf)	87.4	38.5	67.1	57.5	66.4	87.5	69.5	104.7	g/L
	(af)	52.9	31.7	45.3	39.2	55.0	84.7	24.5	92.7	g/L
K	(bf)	4.2	35.2	12.9	22.6	9.3	58.5	409.9	22.8	mg/L
	(af)	320.5	376.8	428.7	477.3	465.6	445.1	273.9	163.9	mg/L
Ca	(bf)	22.1	12.7	13.7	16.2	17.1	753.2	4.3	3.7	mg/L
	(af)	91.7	74.7	94.0	108.9	137.0	844.0	20.6	5.0	mg/L
Mg	(bf)	3.3	9.7	3.2	5.2	3.5	41.3	4.3	2.2	mg/L
	(af)	15.1	26.2	22.4	30.1	25.9	23.0	15.5	2.8	mg/L

af=after the experiment, bf=before the experiment

4.2.3 Micronutrients in the treatments before and after the experiment

In this study, the treatments were analyzed for six elements (Na, B, Fe, Mn, Zn, & Cu) to determine their micronutrient compositions. Table 4.3 below shows the micronutrient composition in the eight different treatments before (bf) and after (af) the experiment. Single samples were analyzed for each treatment because of high cost of analysis. There were no replicate samples so the values reported are absolutes and not means.

4.2.3.1 Sodium (Na)

At the beginning of the experiment, the highest Na concentration was recorded in T6 (219.0 mg/L), followed by T7 (39.0 mg/L) and the lowest in T8 (2.9 mg/L) (Table 4.3). The Na concentration in T6 was higher (94.7 %) compared to the control medium (11.6 mg/L). After the experiment, Na concentration was still highest in T6 (27.1 mg/L) followed closely by T4 and T5 (24.5 mg/L) and lowest in T8 (9.9 mg/L). The concentration in T6 was 45.3 % higher compared to control medium (14.8 mg/L). Relative to initial treatments' nutrient content, Na concentrations increased by 3.2, 15.4, 15.8, 18.2, 15.5, and 7.0 mg/L in T1, T2, T3, T4, T5, and T8 respectively, at the end of the experiment (Table 4.3). A decrease of 87.6 % was observed in T6, which had the highest Na content before the experiment. A decrease of 62.5 % was also observed in T7. The decrease in Na after the experiment might be as a result of leaching as Na has been previously reported to leak from the growth media by Abad et al. (2002).

The ideal concentration in growth media is suggested to be <115 µg mL^{-1} (Abad et al., 2001; Di Benedetto et al., 2006) and all the treatments were consistent within this range before and after the experiment. The high concentration of Na^{+} could be harmful for salt sensitive plants in containers (Abad et al., 2002; Konduru, Evans, & Stamps, 1999). Chrysanthemums were reported to be salt tolerant in a study by Sonneveld and Voogt (1983).

4.2.3.2 Boron (B)

At the beginning of the experiment, the B concentrations in T1, T2, T3, T4 and T5 were below detection and therefore not determined. However, T7 slightly contained the highest B content (0.2 mg/L) while T6 and T8 contained similar lower contents (0.1 mg/L) (Table 4.3). After the experiment, the B concentration was increased in all treatments. Relative to

the initial B concentrations in treatments, there was an increase of 100 % each in the B content in T1, T2, T3, T4, and T5, and 66.6, 60.0 and 50 % in T6, T7, and T8 respectively. A slightly higher B content was observed in T7 (0.5 mg/L) and lower in T8 (0.2 mg/L). The B concentration in T7 (coir) was 25.9 % higher compared to control medium (100 % peat) (0.4 mg/L) (Table 4.3). This finding seems to suggest that coir (T7), compared to peat, has more potential to influence the physiology of the tested species since B is reported to play a structural role in plant cell walls, membrane function and metabolic activities (Blevins & Krystyna, 1998).

4.2.3.3 Iron (Fe)

Inductively Coupled Plasma Optical Emission Spectrometric (ICP-OES) analysis revealed that the highest Fe concentration was in T2 (17.5 mg/L), followed by T4 (8.2 mg/L) and then the lowest in T6 (1.3 mg/L) (Table 4.3). Generally, the Fe concentrations in other treatments were very low (<1.0 mg/L). The lowest concentration was recorded in T1 (0.1 mg/L) before the experiment and the concentration in T2 was 99.4 % higher compared to control medium (Table 4.3). After the experiment, the Fe concentration was highest in T2 (2.8 mg/L) and lowest in T7 (0.1 mg/L). The concentration in T4 was 82.1 % higher than the control medium (0.5 mg/L). Relative to the initial nutrient concentrations in treatments, Fe content increased by 0.4, 0.4, 0.1, and 0.1 mg/L in T1, T3, T5, and T6, but however decreased by 14.7, 7.2, 0.1, and 0.1 mg/L in T2, T4, T7, and T8 respectively, at the end of the experiment (Table 4.3). The low Fe concentration in T7 may be as a consequence of the increased pH as previously suggested by Jones (2012), who highlighted that soil pH can affect the concentrations of salts and micronutrients including Fe.

4.2.3.4 Manganese (Mn)

The Mn concentration was slightly higher in T6 (1.3 mg/L) before the experiment but was below detection in control medium (0.0 mg/L) (Table 4.3). After the experiment, Mn concentration was slightly higher in T2 (1.8 mg/L) and lowest in T7 and T8 (0.2 mg/L). The concentration in T4 was 72.2 % higher than the control medium (0.5 mg/L). Relative to the initial nutrient concentrations in treatments, the Mn content was increased by 0.3, 1.0, 0.4, 0.7, 0.4, and 0.1 mg/L in T1, T2, T3, T5, and T7 and was reduced by 0.3 and 0.5 mg/L in

T6 and T8 respectively, at the end of the experiment. The low Mn concentration in T7 after the experiment may be as a result of the increased pH (Jones, 2012).

4.2.3.5 Zinc (Zn)

The recommended maximum permissible limit for Zn is 1500 mg/kg (Jayasinghe et al., 2011). The treatments were not analyzed for Zn before the experiment and the results discussed are for analyses after the experiment. In general, all the treatments had a very low concentration of Zn. The Zn concentration was slightly higher in T6 (0.4 mg/L) and lowest in T1 (0.1 mg/L), T3 (0.1 mg/L), T4 (0.1 mg/L), and T7 (0.1 mg/L) (Table 4.3). The concentration in T6 was 0.3 mg/L more compared to control medium. The low Zn concentration (<0.5 mg/L) in all treatments after the experiment can be attributed to Zn ions uptake by the plant as results of Zn analysis in shoots show (refer to 4.4.1.2.5) and not because of excessive HCO_3^- concentration as suggested by Fan-hua, You-zhang, Xiao-e, Jian-jun, and Jian-xiang (2004).

4.2.3.6 Copper (Cu)

Similar to Zn, the treatments were not analyzed for Cu before the experiment and the results discussed are for analyses after the experiment. In general, all treatments had very low concentrations of Cu. The Cu concentration was highest in T1 (0.02 mg/L), T2 (0.02 mg/L) and T6 (0.02 mg/L) and lowest in T5 (0.0 mg/L) (Table 4.3). The recommended maximum permissible limit for Cu is 500 mg/kg (Jayasinghe et al., 2011).

Table 4. 3: Micronutrient composition in the treatments before and after the experiment (n=1)

		Treatments								
Parameters	**Period**	T1	T2	T3	T4	T5	T6	T7	T8	**Units**
Na	(bf)	11.6	3.7	7.4	6.3	9.0	219.0	39.0	2.9	mg/L
	(af)	14.8	19.1	23.2	24.5	24.5	27.1	14.6	9.9	mg/L
B	(bf)	nd	nd	nd	nd	nd	0.1	0.2	0.1	mg/L
	(af)	0.4	0.4	0.4	0.4	0.4	0.3	0.5	0.2	mg/L
Fe	(bf)	0.1	17.5	0.9	8.2	0.5	1.3	0.2	0.6	mg/L
	(af)	0.5	2.8	1.3	1.0	0.6	1.4	0.1	0.5	mg/L
Mn	(bf)	nd	0.8	0.1	0.3	0.1	1.3	0.1	0.7	mg/L
	(af)	0.3	1.8	0.5	1.0	0.5	1.0	0.2	0.2	mg/L
Zn	(bf)	*	*	*	*	*	*	*	*	mg/L
	(af)	0.1	0.3	0.1	0.1	0.3	0.4	0.1	0.2	mg/L
Cu	(bf)	*	*	*	*	*	*	*	*	mg/L
	(af)	0.02	0.02	0.01	0.01	nd	0.02	0.01	0.01	mg/L

nd=none detected, *=data not available, af=after the experiment, bf=before the experiment

4.2.4 Soluble salts in the treatments before and after the experiment

In this study, the treatments were analyzed for the following soluble salts; Cl^-, F^-, SO_4^{-2}, PO_4^{-3}, HCO_3^-, NO_3^- & NO_2^-. Table 4.4 below shows results of analysis of the soluble salts concentration in the eight different treatments before (bf) and after (af) the experiment.

4.2.4.1 Chloride (Cl^-)

According to Table 4.4, ICP-OES analysis revealed highest Cl^- concentration in T7 (411.6 mg/L) and was hugely followed by T6 (167.0 mg/L) and the lowest was in T4 (6.5 mg/L) before the experiment. The concentration in T7 was 97.8 % higher compared to control medium (9.0 mg/L). After the experiment, the concentration was higher in T4 (23.4 mg/L) and lowest in T8 (9.0 mg/L). The concentration in T4 was 32.4 % higher than in the control medium (15.8 mg/L). Relative to the initial soluble salts concentrations in treatments, the Cl^- content increased by 6.8, 5.9, 8.0, 16.9, and 7.3 mg/L in T1, T2, T3, T4, and T5 but was reduced by 147.5, 392.7 and 2.0 mg/L in T6, T7 and T8 respectively, at the end of the experiment (Table 4.4).

The suggested ideal Cl^- limit in growth media is <180 µg mL^{-1} (Di Benedetto et al., 2006). Before the experiment, Cl^- content in T7 (411.6 mg/L) exceeded this limit but was reduced to the recommended limit at the end of the experiment. Abad et al. (2002) reported that Cl^- easily leaches out of the growth media, which is critical because high concentration of Cl^- could be harmful for salt sensitive plants cultivated in containers. However, as mentioned earlier the tested plant has been reported to be salt tolerant (Sonneveld & Voogt, 1983).

4.2.4.2 Fluoride (F^-)

At the beginning, the F^- concentration was highest in T6 (4.1 mg/L), followed by T3 (2.7 mg/L) that was closely followed by the third highest concentration in T8 (2.4 mg/L), and the lowest in T2 (0.1 mg/L). The concentration in T6 was 95.1 % higher compared to control medium (0.2 mg/L) (Table 4.4). After the experiment, the F^- concentration was higher in T6 (6.1 mg/L) followed by T7 (3.8 mg/L) and lowest in T8 (1.6 mg/L). The concentration in T4 and T5 were similar (3.0 mg/L) and was the third highest compared to other treatments. The F^- concentration in T6 was 62.2 % higher compared to control medium (2.3 mg/L).

Relative to the initial soluble salts concentrations in treatments, F^- content increased by 2.1, 2.7, 2.4, 2.6, 2.0, and 3.3 mg/L in T1, T2, T4, T5, T6, and T7 but decreased by 0.5 and 0.8 mg/L in T3 and T8 respectively, at the end of the experiment (Table 4.4).

4.2.4.3 Sulphate (SO_4^{-2})

The SO_4^{-2} concentration was highest in T1 (37.7 mg/L) followed by the second highest in T6 (25.8 mg/L) and lowest in T4 (1.1 mg/L) before the experiment (Table 4.4). The concentration in T1 was 85.6, 89.1, 97.0, 72.1, 31.5, 57.0, and 80 % higher than T2, T3, T4, T5, T6, T7, and T8 respectively. After the experiment, the concentration was higher in T1 (21.8 mg/L) and closely followed by T6 (20.7 mg/L) and T7 (20.1 mg/L) and lowest in T8 (8.2 mg/L). The SO_4^{-2} content increased by 11.3, 12.8, 13.7, 6.7, 3.9, and 1.0 mg/L in T2, T3, T4, T5, T7, and T8 but reduced by 15.9 and 5.1 mg/L in T1 and T6 respectively, at the end of the experiment (Table 4.4). The addition of bagasse at different rates (T3, T4, and T5) reduced the SO_4^{-2} content, and it was most reduced in T4 because of the high bagasse content. The suggested ideal SO_4^{-2} limit in growth media is <960 µg mL^{-1} (Di Benedetto et al., 2006) and all treatments investigated in this study were consistent with this established limit. It is critical for potted plants to be exposed to the correct amounts in the growth medium because sulphide toxicity may lead to suppressed flowering and root decay (Geurts, Saneel, Willers, Roelofs, Verhoeven, & Lamers, 2009).

4.2.4.4 Phosphate (PO_4^{-3})

The PO_4^{-3} concentration was highest in T7 (21.0 mg/L), followed by T4 (14.8 mg/L) and T2 (13.3 mg/L) and lowest in T1 (0.8 mg/L) before the experiment. The concentration in T7 was 96.1 % higher compared to control medium (Table 4.4). After the experiment, the concentration was higher in T4 (385.3 mg/L), followed by T2, T5, and T3 with concentrations of 348.8 mg/L, 336.1 mg/L, and 310.1 mg/L, respectively, and lowest in T6 (55.0 mg/L) (Table 4.4). The concentration in T4 was 28.4 % higher compared to control medium (275.7 mg/L). The high EC in T6 was therefore not affected by phosphate as suggested by Whipker et al. (2011a).

Relative to the initial soluble salts concentrations in treatments, PO_4^{-3} content increased by 270.9, 335.5, 302.8, 370.5, 332.8, 51.7, 198.3 and 76.0 mg/L in T1, T2, T3, T4, T5, T6, T7, and T8 respectively, at the end of the experiment. The addition of bagasse at different rates (T3, T4 and T5) increased the PO_4^{-3} content, and the highest increment was observed in T4 which had greater bagasse content (75 %) (Table 4.4).

4.2.4.5 Bicarbonate (HCO_3^-)

High concentration of HCO_3^- plays an important role in Zn deficiency (Fan-hua et al., 2004). In this study, the HCO_3^- concentration was highest in T2 (39.3 mg/L), followed closely by T4 (31.8 mg/L), T3 (28.0 mg/L), and T5 (26.7 mg/L), and lowest in T6 (13.1 mg/L) at the beginning of the experiment. However, no HCO_3^- was detected in T8 (0.0 mg/L). The concentration in T2 was 95.1 % higher compared to control medium (18.3 mg/L) (Table 4.4). The addition of bagasse at different rates (T3, T4, and T5) increased HCO_3^- content and the highest values corresponded with T4 (75:25), which was constituted of more bagasse in the mix. As a result, the low Zn concentration in all the treatments after the experiment can be attributed to high Zn ions accumulated in the plant shoots (refer to 4.4.1.2.5) and not because of excessive HCO_3^- concentration. The bicarbonate of the treatments after the experiment was not analyzed, hence no comparison was made.

4.2.4.6 Nitrate (NO_3^-)

Nitrate accrues through addition of fertilizers, therefore, higher N availability and lower absorption rate by plants will result in nitrate accumulation in rhizosphere soils (Olle et al., 2012). According to Table 4.4, the N concentration was higher in T6 (1489.9 mg/L), followed closely by T5 (1417.1 mg/L), T4 (1357.7 mg/L), T3 (1194.0 mg/L), and T2 (1028.5 mg/L) and lowest in T8 (2.0 mg/L). The concentration in T6 was 42.2 % higher compared to control medium (860.3 mg/L). This may be responsible for the high EC in T6 (Garcia-Gomez et al., 2002; Whipker et al., 2011a). This parameter was not analyzed before the experiment; hence no comparisons made.

The suggested concentration of NO_3^- in an ideal growth media is between 100 - 199 µg/mL (Abad et al., 2001; Di Benedetto et al., 2006) and all treatments were below this

range after the experiment. According to Ostos, López-Garrido, Murillo, and López (2008), N supply (especially under NO_3^- form) increases the Ca uptake by plant tissues.

4.2.4.7 Nitrite (NO_2^-)

The NO_2^- concentration was higher in T6 (3.4 mg/L) and lowest in T4 (0.6 mg/L). The concentration in T6 was 70.5 % higher compared to control medium (1.0 mg/L) (Table 4.4).

Table 4. 4: Soluble salts concentration in the treatments before and after the experiment (n=1)

		Treatments								
Parameters	Period	T1	T2	T3	T4	T5	T6	T7	T8	Units
Cl^-	(bf)	9.0	14.7	11.5	6.5	13.7	167.0	411.6	11.0	mg/l
	(af)	15.8	20.6	19.5	23.4	21.0	19.5	18.9	9.0	mg/l
F^-	(bf)	0.2	0.1	2.7	0.6	0.4	4.1	0.5	2.4	mg/l
	(af)	2.3	2.8	2.2	3.0	3.0	6.1	3.8	1.6	mg/l
SO_4^{-2}	(bf)	37.7	5.4	4.1	1.1	10.5	25.8	16.2	7.2	mg/l
	(af)	21.8	16.7	16.9	14.8	17.2	20.7	20.1	8.2	mg/l
PO_4^{-3}	(bf)	0.8	13.3	7.3	14.8	3.3	3.3	21.0	2.4	mg/l
	(af)	271.7	348.8	310.1	385.3	336.1	55.0	219.3	78.4	mg/l
HCO_3^-	(bf)	18.3	39.3	28.0	31.8	26.7	13.1	14.9	0.0	mg/l
	(af)	*	*	*	*	*	*	*	*	mg/l
NO_3^-	(bf)	*	*	*	*	*	*	*	*	mg/l
	(af)	860.3	1028.5	1194.0	1357.7	1417.1	1489.9	491.1	2.0	mg/l
NO_2^-	(bf)	*	*	*	*	*	*	*	*	mg/l
	(af)	1.0	1.4	1.0	0.6	1.0	3.4	1.0	1.0	mg/l

nd=none detected, *=data not available, af=after the experiment, bf=before the experiment

4.2.5 Carbon/Nitrogen ratio (C/N ratio)

Table 4.5 below shows the C/N ratios of the eight different treatments before (bf) and after (af) the experiment. The C/N of the organic material determines the availability of C in the material relative (in relation) to the available N (Grunert et al., 2016). The established ideal range of C/N ratio for a growth media is between 20 and 40 (Jayasinghe et al., 2010a). In this study, the C/N ratio was highest in T8 (244.1) followed by T6 (183.1) and lowest in T1 (44.3) before the experiment (Table 4.5). The C/N in T8 was 81.8 % higher than in the control medium. According to Hernández-Apaolaza and Guerrero (2008), C/N ratio is always higher in pine bark which corresponded to results obtained in this study.

After the experiment, the C/N ratio in T6 (169.5) was highest followed by T8 (126.2) and lowest in T2 (24.6). The C/N decreased in all treatments after the experiment by 13.9, 51.7, 42.3, 55.4, 30.3, 7.4, 57.3, and 48.3 % in T1, T2, T3, T4, T5, T6, T7, and T8 respectively (Table 4.5). As composting of organic matter proceeds, the C/N ratio gradually decreases. This may be due to loss of C through carbon dioxide (CO_2) release into the atmosphere and the increased N as it gets recycled (Grunert et al., 2016).

Table 4. 5: C/N ratio of the treatments before and after the experiment (n=1)

		Treatments							
Parameters	**Period**	T1	T2	T3	T4	T5	T6	T7	T8
C/N %	(bf)	44.3	76.3	52.0	62.2	49.1	183.1	121.7	244.1
	(af)	38.1	24.6	30.0	27.7	34.2	169.5	51.9	126.2

4.3 DIFFERENCES IN PHYSICAL PROPERTIES OF GROWTH MEDIA

In order to produce an ideal growth media, all important physical properties such as bulk density, water holding capacity and air filled porosity must be present in one material. It is however challenging to find one component of growth media that possesses all the desired characteristics (Abad, Forres, Carrion, & Noguera, 2005; Gruda et al., 2013; Gutiérrez et al., 2012). Particle size distribution of growth media is important as it determines pore space, aeration and water holding capacities (Jayasinghe et al., 2010a). An excess of larger particles may lead to excessive aeration and lower water holding capacity and an excess of fine particles in growth media may clog the pores and decrease air filled porosity. Growth media with a high percentage of particles between 0.25 and 2.00 mm are optimal for potted plants (Benito et al., 2005; Jayasinghe, 2012; Méndez et al., 2015). Particle size distribution was not measured in this study but its contribution as described by different authors was considered.

Table 4.6 below shows the results of the analysis of the physical properties tested in the eight different treatments before the experiment.

4.3.1 Water holding capacity (WHC)

Water Holding Capacity (WHC) is the amount of water remaining in the container after water stops draining from a saturated growth media (Dole & Wilkins, 2005; Gruda et al., 2013). The WHC of an ideal growth media should be in the range of 600 - 1000 mL/L (Jayasinghe et al, 2010a).

As presented in Table 4.6, the highest WHC was recorded in T1 (73.2), followed by the second highest in T5 (68.2) and the lowest in T8 (21.7) before the experiment. The highest WHC reported for T1 (peat) in the current study was consistent with results recorded in a study by Jayasinghe et al. (2011). Peat has a better WHC compared to other organic growth media components (Reed, 1996; Adams et al., 2008). This is due to the increased micro-pores in peat, which improves rewettability of growth media and therefore its water holding capacity (Hernández-Apaolaza & Guerrero, 2008). According to results obtained in this study (Table 4.6), a combination of bagasse and peat (25:75 %) in T5 with the second highest WHC seems to suggest that it could be used as a potential replacement of 100% peat for cultivation of potted *D*. x *grandiflorum.*

4.3.2 Air filled porosity (AFP)

The difference in water content between total porosity and container capacity is called air filled porosity (Caron & Rivière, 2002). Total porosity refers to all pore spaces within the growth media (Dole & Wilkins, 2005). This is the volume that is not filled with solids (Handreck & Black, 2002). The total porosity of ideal growth media should be greater than 85 % (Jayasinghe et al., 2010a).

In this study, the highest AFP was recorded in T8 (41.4) and the lowest in T1 (8.5) before the experiment. The porosity of organic material is a concern for nursery growers due to various reasons. The growth media must have adequate large pore spaces to be well-aerated for the roots, but excessive large pores decrease the amount of water the growth media can store. T8 had the highest porosity with lowest WHC and would require frequent irrigation and in small amounts to avoid leaching (Benito et al., 2005; Yogi et al., 1997).

In the study conducted by Jayasinghe et al. (2011), peat also gave the lowest air space value compared to all the other treatments. In this present study, the AFP of the mixes (T3, T4 and T5) decreased with the addition of T1. The lowest percentage was observed in the mix with 75 % of peat compared to mixes comprising 25 and 50 % addition of peat (Table 4.6).

4.3.3 Bulk density (BD)

Bulk density affects the weight of the growth media (Dole & Wilkins, 2005). Abad et al. (2001) reported that the bulk density requirements of an ideal growth media is <0.40 g/cm^{-3}.

In this study, the same bulk density (0.5 kg/L) was recorded in T1 and T6l and was found to be higher compared to the other treatments. The addition of peat at 75 % to the mix for T5, increased the bulk density by 75 % in comparison to 100 % bagasse. With the exception of T1 and T6, all other substrates were within the established ideal substrate bulk density range (Table 4.6). High bulk density values have a disadvantage of increasing the transportation cost and reducing porosity of the growth media as observed in T1 (Jayasinghe et al., 2010b). The root responses of the plants may be affected due to compaction (Hernández-Apaolaza & Guerrero, 2008).

Table 4. 6: Physical properties tested in the eight different treatments before the experiment (n=1)

	Treatments								
Parameters	T1	T2	T3	T4	T5	T6	T7	T8	**Units**
BD	0.5	0.1	0.3	0.3	0.4	0.5	0.4	0.3	kg/L
WHC	73.2	60.4	62.6	54.4	68.2	59.6	54.6	21.7	% (v/v)
AFP	8.5	19.7	13.4	18.9	10.2	13.4	35.4	41.4	% (v/v)

BD=Bulk density, WHC= Water holding capacity, AFP= Air filled porosity

4.4 SHOOT MINERAL COMPOSITION AND CHLOROPHYLL CONTENT

Shoot mineral composition and chlorophyll content analyses revealed significant ($p<0.05$) differences among the eight treatments employed in this study (Table 4.7).

4.4.1 Shoot mineral content

The dry shoot (without the roots, flower buds and flowers) samples of potted *D*. x *grandiflorum* were sent to the laboratory for macro and micronutrients analyses after the experiment. Tissue analysis is a technique used to measure nutrient content of plant tissues. It is important to assess a plant's nutrient status to help the grower determine if proper uptake of nutrients occurred (Vetanovetz, 1996).

4.4.1.1 Shoot macronutrient composition of potted *D*. x *grandiflorum*

Table 4.7 shows results of the analysis of macronutrients in shoots of potted *D*. x *grandiflorum* after the experiment.

4.4.1.1.1 Total Nitrogen (N)

The total Nitrogen content is an indicator of N accumulation in plants. A large proportion of total leaf N is represented by photosynthetic proteins and chlorophyll content is approximately proportional to leaf N content (Bojović & Marković, 2009).

In this study, treatment did not significantly affect the accumulation of N in shoots of plants after the experiment, however, the lowest total N (%) was recorded in T8 (5.6 %) (Table 4.7). The relative lower N uptake by plants grown in T8 may have been due to the low concentration of N sources (nitrates) in the growth media (Table 4.2) as indicated in sections 4.2.2.1 and 4.2.4.6.

4.4.1.1.2 Total Carbon (C)

The treatment had no significant effect on the total C in shoots of potted *D*. x *grandiflorum* grown under greenhouse conditions. However, the total C concentration in shoots of plants grown in T8 (38.5 %) was slightly higher compared to shoots of plants grown in T6 (36.1 %) and control medium (T1 (36.5 %)), The total C concentration in shoots of plants grown in T8 was higher (5.1 %) than those grown in control medium (36.5 %). The high total C concentration in plants shoots grown in T8 may be as result of enhanced photosynthesis rate compared to plants grown in the other treatments (Marino, LA Mantia, Caruso, & Marra, 2018).

4.4.1.1.3 Phosphorus (P)

Treatment significantly affected the accumulation of P in shoots of the test plant. The P concentration in shoots of plants grown in T8 (10180.7 mg/kg) was higher compared to shoots of plants grown in T4 (7983.4 mg/kg) and T6 (5916.7 mg/kg) but not significantly different in comparison to plant shoots in T1 (9415.6 mg/kg), T2 (7952.1 mg/kg), T3 (8476.6 mg/kg), T5 (8762.6 mg/kg), and T7 (8455.2 mg/kg). There were however no significant differences observed for P concentration in shoots of plants grown in T1, T2, T3, T4, T5, and T7. The lowest significant P level was observed in shoots of plants grown in T6 (5916.7 mg/kg) (Table 4.7). The concentration in T8 was higher (24.5 %) than in shoot of plants grown in the control medium (9415.6 mg/kg). The low concentration of P in shoots of plants cultivated in T6 may be due to the low concentration in the media and reduced root growth as indicated in 4.2.4.4 and 4.5.5 as previously reported by Bojović & Marković (2009), who suggested that the concentration of most nutrients in soils can affect their accumulation in organs of plants grown in those soils.

4.4.1.1.4 Potassium (K)

There were no significant differences in the concentration of K among shoots of plants grown in the different treatments. However, the highest K value was recorded in shoots of plants grown in T1 (63981.6 mg/kg) while the lowest in T8 (48180.9 mg/kg) (Table 4.7). In this study, high Na was recorded in T6 but could not be associated with the plant's K uptake (high K content in shoots) as suggested by Ashley et al. (2006). This result also contradicted the findings that higher uptake of K into the plant is generally coupled with a depletion in Na and Ca (Li, Qin, Mattson, & Ao, 2013; Massa et al., 2018).

4.4.1.1.5 Calcium (Ca)

The type of media used significantly affected the concentration of Ca in plant shoots (Table 4.7). The shoot Ca content in T6 (17939.8 mg/kg) was significantly higher compared to shoots of plants grown in T1 (13541.4 mg/kg) (control) and the other treatments. The concentration in shoots of plants grown in T6 was higher (24.5 %) than in shoots of plants grown in the control medium (13541.4 mg/kg). The Ca concentration in shoots of plants in T1, T2, T3, T4, and T5 were also significantly different to shoot Ca of plants grown in T7 and T8. The observed increased tissue Ca in plants cultivated in T6 may have been due to NO_3^- accumulated in the growth media as was previously reported by Ostos et al. (2008). These authors reported higher concentration of Ca in shoots of the native shrub, *Pistacia lentiscus* grown in municipal solid waste-based compost with high N sources compared to peat (Ostos et al., 2008). Excessive Ca content in growth media may affect the accumulation of Mg and K, depending on the concentration of these elements in the plants as indicated by Jones (2012). The results of this study suggest that composted bagasse (T6) could be a potential replacement candidate for peat with regards to provision of Ca in potted *D.* x *grandiflorum*.

4.4.1.1.6 Sulphur (S)

The type of media used significantly affected the concentration of sulphur in plant shoots (Table 4.7). The highest S concentration was observed in shoots of plants grown in T6 (4910.3 mg/kg) compared to all other treatments. There were no significant differences in S concentration among shoots of plants grown in T1 (3399.2 mg/kg), T5 (3028.0 mg/kg),

and T8 (2119.8 mg/kg). However, S concentration in shoots of plants in T1 and T8 were significantly higher compared to plants grown in T2 (1865.0 mg/kg), T3 (2287.2 mg/kg), T4 (2527.8 mg/kg) and T7 (2039.9 mg/kg). The S concentration in shoots of plants in T5 was higher compared to shoots of plants in T2 and T7 but did not differ significantly to shoots of plants in T3 and T4. The lowest S concentrations were recorded in shoots of plants grown in T2, T3, T4 and T7, which did not differ significantly from each other (Table 4.7). The S concentration in shoot of plants grown in T6 was higher (30.7 %) than those grown in the control medium.

4.4.1.1.7 Magnesium (Mg)

Magnesium is a component of the chlorophyll molecule which facilitates photosynthesis in plants (Jones, 2012). The type of media used in the current study significantly affected the Mg concentration in plant shoots. The Mg content in shoots of plants cultivated in T1 (2961.3 mg/kg), T2 (2788.5 mg/kg), and T5 (2699.8 mg/kg) was higher compared to plants cultivated in T6 (1973.4 mg/kg) and T8 (1998.4 mg/kg). However, no significant differences were noted among shoots of plants grown T1, T2 & T5. There were also no significant differences in Mg content among shoots of plants cultivated in T3, T4, T6, T7, and T8. The low Mg concentration in shoot of plants grown in T6 may be due to excess Ca, which according to Jones (2012), inhibits the presence of Mg.

Table 4. 7: Macronutrient composition in the shoots of potted *D*. x *grandiflorum* after the experiment (n=3)

	Treatments									
Parameters	T1	T2	T3	T4	T5	T6	T7	T8	**F-Statistics**	**Units**
Total N	6.6±0.0a	6.3±0.5a	6.4±0.3a	6.3±0.1a	6.2±0.2a	6.4±0.1a	6.1±0.3a	5.6±0.2a	1.47^{ns}	%
Total C	36.5±0.0a	36.7±0.9a	36.8±0.7a	36.3±0.4a	37.3±0.5a	36.1±0.6a	36.4±0.8a	38.5±0.9a	1.48^{ns}	%
P	9415.6±0.0ab	7952.1±494.2b	8476.6±213.4ab	7983.4±1244.8b	8762.6±282.0ab	5916.7±570.4c	8455.2±822.1ab	10180.7±602.5a	3.79*	mg/kg
K	63981.6±0.0a	52761.9±2791.9a	54227.0±5554.7a	60734.1±6408.3a	54090.3±4299.0a	56093.6±1923.8a	62850.6±8609.0a	48180.9±3740.6a	1.25^{ns}	mg/kg
Ca	13541.4±0.0b	10986.3±1426.5b	11168.1±231.0b	12141.6±1438.4b	11490.9±477.9b	17939.8±307.1a	5613.4±785.5c	7523.1±369.1c	21.09***	mg/kg
S	3399.2±0.0b	1865.0±203.7e	2287.2±298.5d	2527.8±489.2cd	3028.0±111.5bc	4910.3±392.5a	2039.9±190.8d	2119.8±178.6d	13.43***	mg/kg
Mg	2961.3±0.0a	2788.5±175.7a	2465.1±183.6ab	2495.3±390.4ab	2699.8±55.7a	1973.4±191.5b	2550.5±215.7ab	1998.4±145.7b	3.06*	mg/kg

Values (M±S.E. (n=3)) followed by similar letters in a row are not significantly different at *p≤0.05, **p≤0.01, ***p≤0.001 and ns = not significant.

4.4.1.2 Micronutrient composition in shoot of potted *D*. x *grandiflorum*

Table 4.8 below shows the micronutrient composition in shoots of potted *D*. x *grandiflorum* after the experiment.

4.4.1.2.1 Sodium (Na)

The media did not significantly affect the concentration of Na in shoots of the tested plant. The highest Na content was observed in shoots of plants grown in T7 (375.1 mg/kg) and lowest in those in T5 (270.2 mg/kg), however the differences were not significant among the treatments (Table 4.8). The concentration in the shoots of plants grown in T7 was 27.0 % higher than in the shoots of plants grown in control medium (273.6 mg/kg). This finding suggests that coir could supply the tested plant with more Na than peat.

4.4.1.2.2 Boron (B)

In this study, the media did not significantly affect the concentration of B in plant shoots. However, slight differences in plant shoots' B concentrations were among the treatments. For example, the highest B content was observed in shoots of plants grown in T4 (88.6 mg/kg) compared to plants grown in the control media (75.7 mg/kg) and T5 (67.0 mg/kg), which had the lowest B content. The concentration in shoots of plants grown in T4 was 14.5 % higher than in shoots of plants grown in the control medium, which suggest that T4 could supply more B to the tested plant than peat.

4.4.1.2.3 Iron (Fe)

The highest Fe content was observed in shoots of plants grown in T6 (189.7 mg/kg) and lowest in the shoots of plants grown in T7 (111.1 mg/kg), however, the differences were not significant among the Fe concentrations in shoots of plants cultivated in the eight treatments (Table 4.8). The concentration of Fe in shoots of plants grown in T6 was 21.3 % higher than the shoots of plants grown in the control medium (149.2 mg/kg). This may have resulted in the high chlorophyll content of plants grown in the growth media as previously reported by Dispenza et al. (2016) on potted plants of *Euphorbia* x *lomi* and Netto, Campostrini, De Oliveira, and Bressan-Smith (2005) on *Coffea canephora* Pierre (coffee) leaves.

4.4.1.2.4 Manganese (Mn)

The type of media used in the current study significantly affected the Mn concentration in plant shoots. The Mn content was significantly high in shoots of plants grown in T8 (458.2 mg/kg) compared to shoots of plants grown in the other treatments. The Mn content of shoots of plants grown in T1 (215.1 mg/kg), T4 (212.2 mg/kg), T6 (278.1 mg/kg), and T8 (458.2 mg/kg) was significantly high in comparison to shoots of plants grown in T7 (114.6 mg/kg). There were however no significant differences in the Mn content of shoots of plants grown in T1 (215.1 mg/kg), T4 (212.2 mg/kg) and T6 (278.1 mg/kg). Similarly, there were no significant differences among T1 (215.1 mg/kg), T2 (175.0 mg/kg), T3 (150.4 mg/kg), T4 (212.2 mg/kg), and T5 (189.1 mg/kg). The differences among T2, T3, T5, and T7 (114.6 mg/kg) were also not significant (Table 4.8). The Mn concentration in shoots of plants grown in T8 was 53.0 % higher than in shoots of plants grown in the control medium (Table 4.8), which seems to suggest that pine bark has potential to provide the tested plant with more Mn than peat.

4.4.1.2.5 Zinc (Zn)

The type of media used in the current study significantly affected the Zn concentration in plant shoots. A significantly higher Zn content was observed in shoots of plants grown in T6 (58.6 mg/kg) and T4 (52.4 mg/kg) compared to shoots of plants grown in the other treatments. There were however, no significant differences observed among T1 (40.3 mg/kg), T2 (41.3 mg/kg), T3 (42.8 mg/kg), T5 (40.5 mg/kg), and T8 (35.5 mg/kg). The Zn content in shoots of plants grown in T2 and T3 differed significantly in comparison to T7. The Zn content in shoots of plants grown in T7 was not significantly different compared to shoots of plants grown in T1, T5 and T8. The lowest Zn was observed in shoots of plants grown in T7 (31.8 mg/kg) (Table 4.8). The concentration in shoots of plants grown in T6 was higher (31.2 %) than in shoots of plants grown in the control medium (40.3 mg/kg). This may have influenced the high chlorophyll content of plants grown in the growth media as previously reported for potted *Euphorbia x lomi* grown in biochar (Dispenza et al., 2016).

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4.4.1.2.6 Copper (Cu)

Similarly, the treatments significantly affected the concentration of Cu in plant shoots. A higher Cu content was observed in shoots of plants grown in T6 (9.9 mg/kg) compared to shoots of plants grown in the other treatments (Table. 4.8). No significant differences were found in the Cu content of shoots of plants grown in T2 (5.0 mg/kg), T3 (4.9 mg/kg), T4 (7.2 mg/kg), T5 (4.1 mg/kg), T7 (5.1 mg/kg). Also, no significant differences were observed in Cu content of shoots of plants grown in T1 (3.7 mg/kg), T2 (5.0 mg/kg), T3 (4.9 mg/kg), T5 (4.1 mg/kg), and T7 (5.1 mg/kg). However, the Cu content in the shoots of plants grown in T4 and T8 was higher compared to shoots of plants grown in T1 (control) and T5. The lowest Cu concentration was found in shoots of plants grown in T1 (3.7 mg/kg) and T5 (4.1 mg/kg) (Table 4.8). The concentration in shoots of plants grown in T6 was higher (62.6 %) than in shoots of plants grown in the control medium. This finding implies that T4, T6 and T8 could provide the tested plant with more Cu than peat.

4.4.1.2.7 Aluminium (Al)

The Al content in plant shoots was not significantly affected by the growth media (Table 4.8). There were no significant differences observed among T2 (121.3 mg/kg), T3 (111.8 mg/kg), T4 (110.9 mg/kg), T5 (99.6 mg/kg), T6 (140 mg/kg), and T8 (120.7 mg/kg). However, the Al content in shoots of plants grown in T2, T3, T4, T6 and T8, were slightly higher compared to plants grown in T1 (77.5 mg/kg) and T7 (79.1 mg/kg). The concentration in shoots of plants grown in T2 was higher (36.1 %) than in plants grown in the control medium.

Table 4. 8: Micronutrient composition in the shoots of potted *D*. x *grandiflorum* after the experiment (n=3)

	Treatments									
Parameters	T1	T2	T3	T4	T5	T6	T7	T8	**F-Statistics**	**Units**
Na	273.6a	336.0a	297.1a	328.1a	270.2a	349.0a	375.1a	343.1a	0.56^{ns}	mg/kg
B	75.7a	83.9a	70.6a	88.6a	67.0a	83.4a	75.7a	75.3a	1.76^{ns}	mg/kg
Fe	149.2a	162.8a	146.7a	172.7a	146.3a	189.7a	111.1a	132.8a	1.07^{ns}	mg/kg
Mn	215.1bc	175.0cd	150.4cd	212.2bc	189.1cd	278.1b	114.6d	458.2a	15.79***	mg/kg
Zn	40.3bc	41.3b	42.8b	52.4a	40.5bc	58.6a	31.8c	35.5bc	9.12***	mg/kg
Cu	3.7c	5.0bc	4.9bc	7.2b	4.1c	9.9a	5.1bc	7.2b	7.87***	mg/kg
Al	77.5a	121.3a	111.8a	110.9a	99.6a	140.2a	79.1a	120.7a	0.83^{ns}	mg/kg

Values (M±S.E. (n=3)) followed by similar letters in a column are not significantly different at *p≤0.05, **p≤0.01, ***p≤0.001 and ns = not significant.

4.4.2 Chlorophyll content

Chlorophyll is an important plant photosynthetic pigment that determines the photosynthetic capacity in plants and therefore influences plant growth (Li, He, Hou, Xu, Liu, Zhang, Wang, Zhang, & Wu, 2018). There is a very strong correlation between chlorophyll and N content (Bojović & Marković, 2009). Soltangheisi, Rahman, Ishak, Musa, & Zakikhani (2014) reported that Zn and Mn have an interactive influence on the growth processes and chlorophyll content of sweet corn. The increase in chlorophyll content is linked to a better availability of K, Fe, Mn and Zn, which play a fundamental role in the biosynthesis of chlorophyll and other pigments involved in the photosynthetic activity (Dispenza et al., 2016; Netto et al., 2005). In this study, the chlorophyll content in leaves of plants grown in the different treatments was measured at different days after transplanting (DAT).

4.4.2.1 Adaxial chlorophyll content

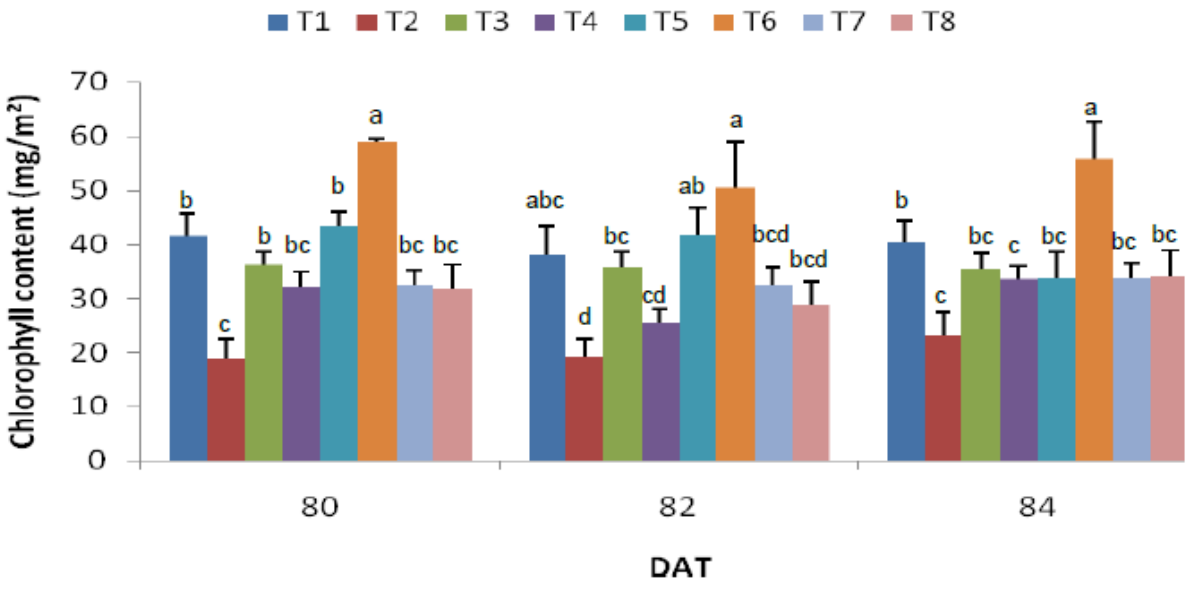
At 80 DAT, significant ($p<0.05$) differences were noted in the adaxial chlorophyll content in leaves of plants cultivated in the treatments. Leaf chlorophyll content in plants cultivated in T6 was 29.4 % higher than in those cultivated in the control medium (41.6 mg/m²) (Figure 4.1). The chlorophyll content in leaves of plants grown in T6 (59.0 mg/m²) was significantly higher compared to that of plants in all other treatments. The chlorophyll content in leaves of plants grown in T1 (41.6 mg/m²) and T3 (36.2 mg/m²) was significantly higher compared to leaves in plants grown in T2 (18.8 mg/m²). There were however, no significant differences observed in the adaxial chlorophyll content in leaves of plants in T1 (41.6 mg/m²), T3 (36.2 mg/m²), T5 (43.3 mg/m²), T7 (32.6 mg/m²), and T8 (31.7 mg/m²).

At 82 DAT, similarly, there were significant ($p<0.05$) differences in the adaxial chlorophyll content in leaves of plants cultivated in the treatments. The adaxial chlorophyll content in leaves of plants cultivated in T6 (50.4 mg/m²) was significantly higher compared to those of plants cultivated in T2 (19.0 mg/m²), T3 (35.7 mg/m²), T4 (25.3 mg/m²), T7 (32.6 mg/m²), and T8 (28.9 mg/m²) but not significantly different when compared to those plants grown in T1 (38.1 mg/m²) (control) and T5 (41.8 mg/m²). However, the chlorophyll content in leaves of plants cultivated in T6 was slightly higher (24.4 %) than in plants cultivated in the control medium (38.1 mg/m²) (Figure 4.1).

At 84 DAT, the chlorophyll content in leaves of plants grown in T6 (55.7 mg/m²) was significantly higher compared to plants grown in all other treatments. The chlorophyll content in leaves of plants cultivated in T6 was higher (27.4 %) compared to plants grown in the control medium (40.4 mg/m²) (Figure 4.1). Furthermore, the adaxial chlorophyll content in leaves of plants grown in T1 (40.1 mg/m²) was higher compared those of plants in T2 (23.2 mg/m²) and T4 (33.5 mg/m²). However, there were no significant differences observed in the adaxial chlorophyll content among leaves of plants grown in T1 (40.4 mg/m²), T3 (35.4 mg/m²), T5 (33.8 mg/m²), T7 (33.9 mg/m²), and T8 (34.1 mg/m²) (Figure 4.1).

In general, at different growth stages in the plant's development, the adaxial chlorophyll content was significantly affected by the treatments employed in the study. The highest adaxial chlorophyll content was found in leaves of plants grown in composted bagasse (T6) and the lowest was in 100% bagasse (T2). The low adaxial chlorophyll content in leaves of plants cultivated in T2 may have been due to wilting possibly caused by shrinkage of bagasse at that was observed during the experiment. According to Urry, Cain,

Wasserman, Minorsky, and Reece (2017), photosynthesis stops when leaves are wilted because the chlorophyll in the wilting leaves is degraded. The wilting of the leaves may have been caused by shrinkage of the growth media as observed by Trochoulias et al. (1990). These authors also concluded that most plants species grown in growth media, which included fresh bagasse, grew at reduced rates due to excessive medium shrinkage.



Dissimilar letters on top of the error bars show significant difference at p≤0.05.

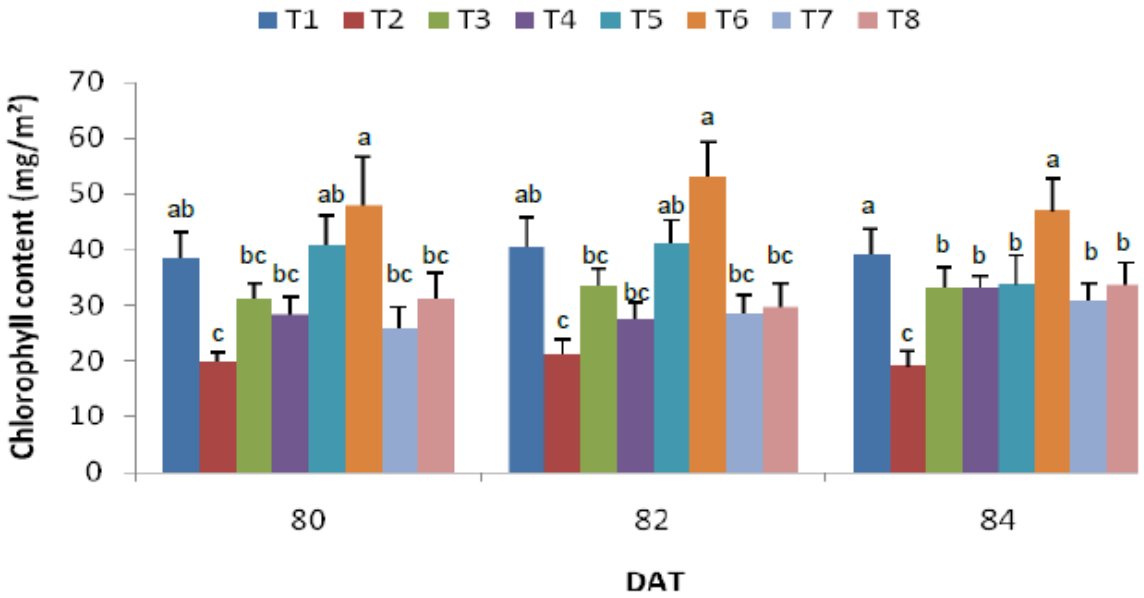
Figure 4. 1: Adaxial chlorophyll contents of potted *D*. x *grandiflorum* at 80, 82 and 84 DAT

4.4.2.2 Abaxial chlorophyll content

Similar to the chlorophyll content in the adaxial side of leaves of potted *D*. x *grandiflorum* during similar DAT (80, 82 & 84), the abaxial chlorophyll content was significantly affected by the treatments. At 80 DAT, the abaxial chlorophyll content in leaves of plants cultivated in T6 (47.9 mg/m²) was significantly higher compared to those in plants cultivated in T2 (19.8 mg/m²), T3 (31.2 mg/m²), T4 (28.3 mg/m²), T7 (25.9 mg/m²), and T8 (31.3 mg/m²)). Although no significant difference was observed in comparison to leaves of plants grown in control (38.3 mg/m²), the abaxial chlorophyll content in leaves of plants cultivated in T6 was higher (20.0 %) (Figure 4.2). There were no significant differences observed in the abaxial chlorophyll content in leaves of plants in T1, T3, T4, T5, T7, and T8. Notably, the highest abaxial chlorophyll content was recorded in plants grown in composted bagasse (T6) and the lowest was in those grown in 100% bagasse (T2).

At 82 DAT, the treatments also significantly ($p<0.05$) affected the abaxial chlorophyll contents in leaves of potted *D*. x *grandiflorum*. The abaxial chlorophyll content of plants cultivated in T6 (52.8 mg/m²) was significantly higher compared to plants cultivated in T2 (21.2 mg/m²), T3 (33.3 mg/m²), T4 (27.6 mg/m²), T7 (28.6 mg/m²), and T8 (29.7 mg/m²) but not significantly different compared to plants in control (T1). The abaxial chlorophyll content in leaves of plants cultivated in T6 was higher (23.4 %) compared to plants grown in the control medium (40.4 mg/m²) (Figure 4.2). However, there were also no significant differences observed among leaves of plants cultivated in T1, T3, T4, T7, and T8 (Figure 4.2).

Similarly, at 84 DAT, there were significant ($p<0.05$) differences in the abaxial chlorophyll contents in leaves of plants cultivated in the treatments. The abaxial chlorophyll content of plants cultivated in T1 (39.1 mg/m²) and T6 (46.9 mg/m²) were significantly higher compared to those of plants grown in the other treatments (Figure 4.2). There was no significant difference observed among abaxial chlorophyll content in leaves of plants cultivated in T3 (33.0 mg/m²), T4 (33.0 mg/m²), T5 (33.7 mg/m²), T7 (30.6 mg/m²), and T8 (33.6 mg/m²). Leaves of plants cultivated in T2 (18.9 mg/m²) (100% bagasse) had a significantly lower chlorophyll compared to all other treatments (Figure 4.2). The low abaxial chlorophyll content in leaves of plants cultivated in T2 may have been due to wilting caused by the shrinkage of the growth medium (bagasse) that was observed during the experimental period as mentioned above.



Dissimilar letters on top of the error bars show significant difference at p≤0.05.

Figure 4. 2: Abaxial chlorophyll contents potted of *D*. x *grandiflorum* at 80, 82 and 84 DAT

Treatment 2 (100 % bagasse) resulted in a significantly ($p<0.05$) reduced adaxial chlorophyll content in potted *D*. x *grandiflorum* leaves by 54.8 % at 80 DAT compared to the chlorophyll content in leaves of plants cultivated in the control medium. A similar trend was observed whereby the same treatment resulted in a significantly reduced adaxial chlorophyll by 50.1 % at 82 DAT compared to the chlorophyll content in leaves of plants cultivated in the control medium. At 84 DAT, the adaxial chlorophyll content was significantly reduced in potted *D*. x *grandiflorum* leaves cultivated in T2 (43.1 %) and T4 (17.8 %) compared to plants grown in control medium. Similar results were observed in a study by Zawadzińska and Salachna (2018) who recorded that substrates containing SSd (sewage sludge (70 %) and coniferous tree sawdust (30 %)), SPS (sewage sludge (35 %), potato pulp (35 %) and rye straw (30 %)) and SPSd (sewage sludge (35 %), potato pulp (35 %) and coniferous tree sawdust (30 %)) significantly decreased the relative chlorophyll content in *Pelargonium zonale* 'Survivor Blue' leaves by 6.5, 7.6 and 15.0 % respectively in comparison to peat control.

Treatment 2 (100 % bagasse) resulted in a significantly ($p<0.05$) reduced abaxial chlorophyll content in potted *D*. x *grandiflorum* leaves by 48.3 % at 80 DAT compared to the chlorophyll content in leaves of plants cultivated in the control medium. The same trend was observed whereby the same treatment significantly reduced the abaxial chlorophyll by 47.5 % at 82 DAT. At 84 DAT, the abaxial chlorophyll content was significantly reduced in potted *D*. x *grandiflorum* leaves cultivated in T2, T3, T4, T5, T7, and T8 by 51.6 %, 15.6 %, 15.6 %, 13.8 %, 21.7 %, and 14.0 % compared to plants grown in control medium. Similar results were also observed in a study by Zawadzińska and Salachna (2018) who recorded that substrates containing SSd, SPS and SPSd significantly decreased the relative chlorophyll content in *P*. *zonale* 'Survivor Blue' leaves by 6.5, 7.6 and 15.0 % respectively in comparison to peat control.

Overall, the total leaf chlorophyll content (abaxial and adaxial) in plants grown in composted bagasse (T6) was a higher chlorophyll content compared to plants grown in the control (T1) and other treatments. Results obtained in this study seems to suggest that composted bagasse (T6) has potential to enhance the chlorophyll content of potted *D. x grandiflorum* and hence can serve as a possible substitute to peat for growing the plant under greenhouse conditions. Findings in the current study are consistent with results obtained by Dispenza et al. (2016), who reported that leaf chlorophyll content was higher in plants grown in biochar as an alternative growth medium to peat for growing E*uphorbia* x *lomi* potted plants. Biochar has been reported to enhance the chlorophyll contents of plants because of better availability of nutrients (K, Fe, Mn, & Zn) (Netto et al., 2005),

which were also found to be relatively high in composted bagasse used in the current (Tables 4.2 & 4.3).

4.5 PLANT GROWTH PARAMETERS

According to Dispenza et al. (2016), a reduced water content of growth media generally corresponds (according to its physical properties) to a reduction of the available water stored in the growth media that can be easily absorbed by plant roots, which among other factors can affect plant growth.

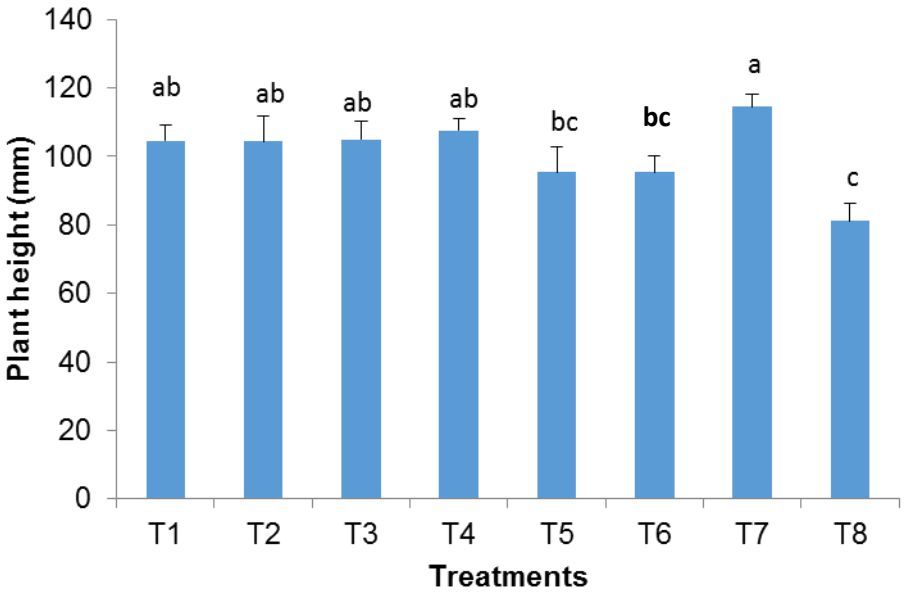
In this study, the growth of the research plant was monitored for the effect of the treatments. Measurements for plant growth parameters (plant height, stem diameter, fresh and dry root weights, fresh and dry shoot weights) were taken at 14, 28, 42, 56, 70, and 89 DAT. The number of leaves was counted at 7, 14 and 21 DAT but this parameter was discontinued due to difficulty of counting as a result of the research plant's growth habit.

One-way ANOVA analysis revealed a significant effect of treatments on each of the measured growth parameters. The results for each growth parameter measured are presented and discussed as follows:

4.5.1 Plant height

The treatments did not significantly affect plant height at 14, 28, 42, 70 and 89 DAT, however, at 56 DAT, the treatments significantly ($p<0.05$) affected plant height. The height of plants cultivated in T7 (114.3 mm) was significantly higher compared to T8 (88.8 mm), but not significantly different from the rest of the treatments. However, the height of plants grown in T7 was slightly taller (9.5 %) compared to those grown in the control treatment (Figure 4.3). Compared to control plants, the height of plants cultivated in T2, T3, T4, T5, T6, and T7 were not significantly different amongst each other.

In contrast to 56 DAT, there were no significant differences among the treatments at 70 and 89 DAT (data not shown), but it is important to note that the uniform plant height is a requirement for cultivation of pot plants (Megersa, Lemma, & Banjawu, 2018). The uniform plant height could have been due to the application of Cultar (growth regulator) at 4 weeks after transplanting. Similar results were expressed in the study by Garcia-Gomez et al. (2002) who observed no significant differences among the height of *Calendula* plants in all the growth media tested with the application of growth regulators.

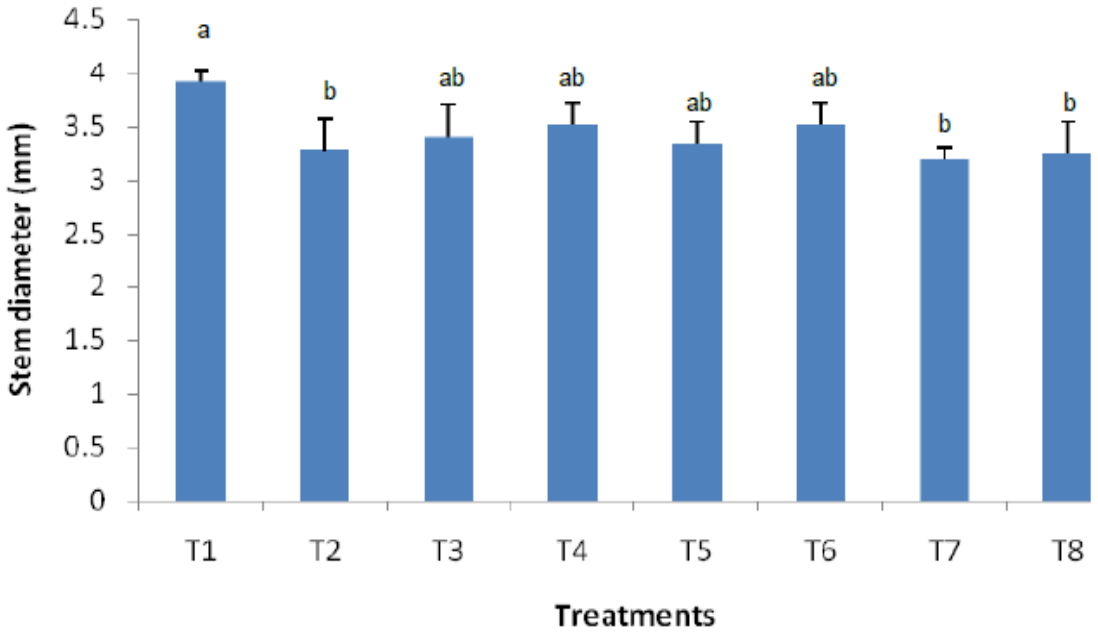


Dissimilar letters on top of the error bars show significant difference at p≤0.05.

Figure 4. 3: Plant height of potted *D*. x *grandiflorum* cultivated in different treatments at 56 DAT

4.5.2 Stem diameter

Similarly, the treatments significantly affected the stem diameter of plants. At 56 DAT, the stem diameter of plants cultivated in T1 (3.92 mm) was significantly higher compared to plants grown in T2 (3.28 mm), T7 (3.20 mm) and T8 (3.25 mm). However, there was no significant difference among stem diameters of plants cultivated in T2 (3.28 mm), T3 (3.40 mm), T4 (3.52 mm), T5 (3.35 mm), T6 (3.52 mm), T7 (3.20 mm) and T8 (3.25 mm) (Figure 4.4). Notably, there were no significant differences among stem diameters of plants in all treatments at the end of the experiment (89 DAT) (data not included).



Dissimilar letters on top of the error bars show significant difference at p≤0.05.

Figure 4. 4: Stem diameter of potted *D*. x *grandiflorum* cultivated in different treatments at 56 DAT

4.5.3 Number of leaves

There were no statistically significant differences among the treatments for number of leaves for the days' measurements were taken (7 DAT, 14 DAT and 21 DAT) (data not included).

4.5.4 Fresh and dry shoot weight

Figure 4.5 shows the effect of treatment at different time intervals (28, 42, 56, 70, & 89 days after transplanting) on the fresh shoot weight of the tested plant. Regardless of the growth period (DAT), treatments significantly ($p<0.05$) affected the fresh shoot weight of the tested plant.

At 28 DAT, the fresh shoot weight of plants cultivated in T5 (7.4 g) was significantly higher compared to plants cultivated in T8 (4.2 g) but not significantly different from plants grown in the other treatments. The fresh shoot weight of plants cultivated in the control medium did not significantly differ from the rest of the other treatments (T2 (5.1 g), T3 (7.0 g), T4 (5.7 g), T5 (7.4 g), T6 (5.9 g), T7 (7.1 g), and T8 (4.2 g)) (Figure 4.5).

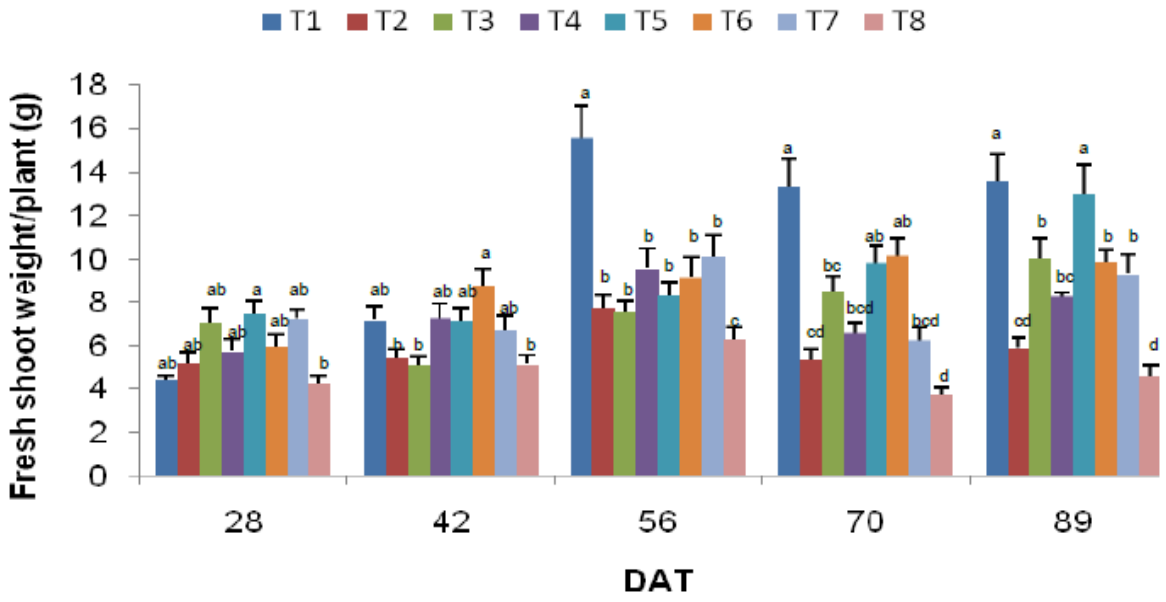
At 42 DAT, the fresh shoot weight of plants cultivated in T6 (8.7 g) was significantly higher compared to those in T2 (5.3 g), T3 (5.0 g) and T8 (5.1 g). The differences were not significant among fresh shoot weight of plants cultivated in T1 (7.1 g), T2 (5.3 g), T3 (5.8 g), T4 (7.2 g), T5 (7.1 g), T7 (6.7 g), and T8 (5.1 g) (Figure 4.5).

At 56 DAT, the fresh shoot weight of plants cultivated in T1 (15.5 g) was significantly higher compared to that of plants in all the other treatments. A significantly lower fresh shoot weight was recorded in T8 (6.3 g). It was noted that the treatments did not significantly affect fresh shoot weight among plants grown in T2, T3, T4, T5, T6, and T7, which recorded 7.7, 7.5, 9.6, 8.3, 9.2, and 10.1 g respectively (Figure 4.5).

At 70 DAT, the fresh shoot weight of plants cultivated in T1 (13.2 g) was significantly higher than T2 (5.3 g), T3 (8.4 g), T4 (6.5 g), T7 (6.2 g), and T8 (3.7 g). However, there were no significant differences among plants grown in T3 (8.4 g), T4 (6.5 g), T5 (9.8 g), T6 (10.1 g), and T7 (6.2 g) (Figure 4.5).

At the end of the experiment (89 DAT), the fresh shoot weight was significantly higher in plants cultivated in T1 (13.5 g) and T5 (13.0 g) compared to plants cultivated in other treatments. There were no significant differences among fresh shoot weight of plants cultivated in T3 (10.0 g), T4 (8.2 g), T6 (9.8 g), and T7 (9.3 g). Similarly, no significant differences were observed between fresh shoot weight of plants grown in T2 (5.8 g) and T8 (4.6 g) (Figure 4.5).

From Figure 4.5, a gradual increase up to 56 DAT and then a decrease until 89 DAT was noted in fresh shoot weight of plants cultivated in T1. The noted increase in fresh shoot weight could be as a result of might be N uptake by the plants from the growth media as the loss in growth media was reported in 4.2.2.1. This fact is also supported by the fact that highest N concentration was recorded in shoots of plants grown in T1 (Bojović & Marković, 2009). The lowest shoot growth of plants cultivated in T8 may have been due to the low water retention in the growth media as reported by Dispenza et al. (2016) in potted plants of *Euphorbia* x *lomi*. This may also have been caused by the low N concentration in the growth media, which affected fertility and, subsequently resulted in low N uptake for plant growth (Cameron, Di, & Moir, 2013). It was also observed that shoot of the plants cultivated in T2 grew at reduced rates compared to the control medium. Similar results were observed in a study by Trochoulias et al. (1990) who witnessed that plants of most species grown in a potting mix including fresh bagasse, grew at reduced rates.

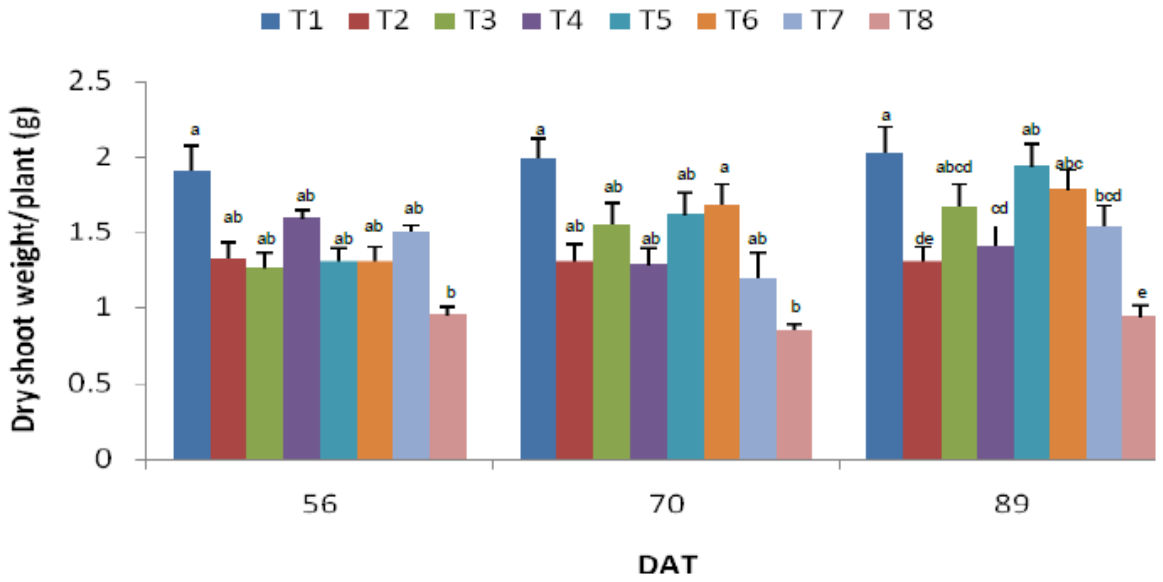


Dissimilar letters on top of the error bars show significant difference at p≤0.05.

Figure 4. 5: Fresh shoot weight of potted *D*. x *grandiflorum* cultivated in different treatments at 28, 42, 56, 70, and 89 DAT

Figure 4.6 shows the dry shoot weight of potted *D*. x *grandiflorum* cultivated in different treatments at 56, 70, and 89 DAT. There were no significant differences ($p<0.05$) in dry shoot weight at 28 and 42 DAT. However, at 56 DAT, the dry shoot weight of the plants cultivated in T1 (1.9 g) was significantly higher compared to plants cultivated in T8 (0.9 g). At 70 DAT, the dry shoot weight of the plants cultivated in T1 (1.99 g) and T6 (1.69 g) were significantly higher compared to plants cultivated in T8 (0.85 g). The treatments did not significantly affect dry shoot weight among plants grown in T1, T2, T3, T4, T5, T6, and T7 (Figure 4.6).

At the end of the experiment (89 DAT), the dry shoot weight was significantly higher in plants cultivated in T1 (2.0 g) compared to plants cultivated in T2 (1.3 g), T4 (1.4 g), T7 (1.5 g), and T8 (0.9 g) but not significantly different to those grown in T3 (1.6 g), T5 (1.9 g) and T6 (1.7 g). The dry shoot weight in plants cultivated in T8 (0.9 g) was significantly lower than plants in all the other treatments except for plants cultivated in T2 (1.3 g) (Figure 4.6).



Dissimilar letters on top of the error bars show significant difference at p≤0.05.

Figure 4. 6: Dry shoot weight of potted *D*. x *grandiflorum* cultivated in different treatments at 56 and 89 DAT

4.5.5 Fresh and dry root weight

Figure 4.7 shows the fresh root weight of potted *D*. x *grandiflorum* cultivated in different treatments at 70 and 89 DAT. Significant differences ($p<0.05$) among the fresh root weight of plants cultivated in the different treatments were observed at 70 and 89 DAT.

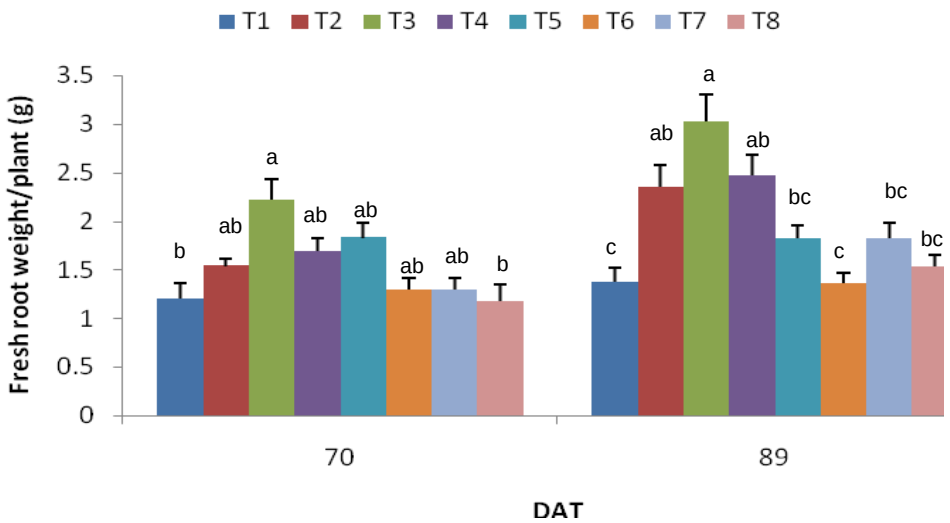
At 70 DAT, the treatments significantly ($p<0.05$) affected fresh plant root weight. The fresh root weight of plants cultivated in T3 (2.22 g) was significantly higher compared to control (1.20 g) and T8 (1.18 g). Notably, there was an 85 % increase in fresh root weight in T3 compared to plants grown in the control medium. However, the fresh root weights among plants grown in T1, T2, T4, T5, T6, T7, and T8 were not significantly different to each other. No significant difference in fresh root weight was noted between plant grown in control and T8 (Figure 4.7).

At 89 DAT, the fresh root weight of plants cultivated in T3 (3.0 g) was significantly higher than plants cultivated in T1 (1.3 g), T5 (1.8 g), T6 (1.3 g), T7 (1.8 g), and T8 (1.5 g), however, not significantly different to plants cultivated in T2 (2.3 g) and T4 (2.4 g). There were also no significant differences among the fresh root weights of plants cultivated in T2, T4, T5, T7 and T8. Also, the fresh root weight of plants cultivated in T1, T5, T6, T7, and T8 did not show significant differences amongst each other. The increased fresh roots growth may be due to the higher phosphate concentration in the treatments containing bagasse

reported in 4.2.4.4. The relative lower root growth noted in plants grown in T1 (100 % peat) and T6 (composted bagasse) may be due to high bulk density, which might have caused by the low phosphates in the growth media reported in 4.2.4.4 or compaction in these growth media as indicated by Hernández-Apaolaza & Guerrero (2008) who reported that compaction in waste materials resulted in slow root growth in ornamental plants.

When bulk density increases, the large pores are reduced, and the forces of the roots necessary for deformation and displacement of substrate particles readily become limiting and root elongation rates decreases (Hernández-Apaolaza & Guerrero, 2008; Jayasinghe et al., 2010b). This justifies the high fresh root weight of T2, T3 and T4, which had slightly less bulk density than T1 and T6. But inhibition of root elongation is not always correlated with inhibited uptake of mineral nutrients (Hernández-Apaolaza & Guerrero, 2008) as observed in this experiment. Contrary to the conclusions above, the low rooting of plants grown in T1 and T6 might be due to the available nutrients, which meant the plants did not need to invest much energy in producing roots to source for nutrients (Mašková & Herben, 2018).

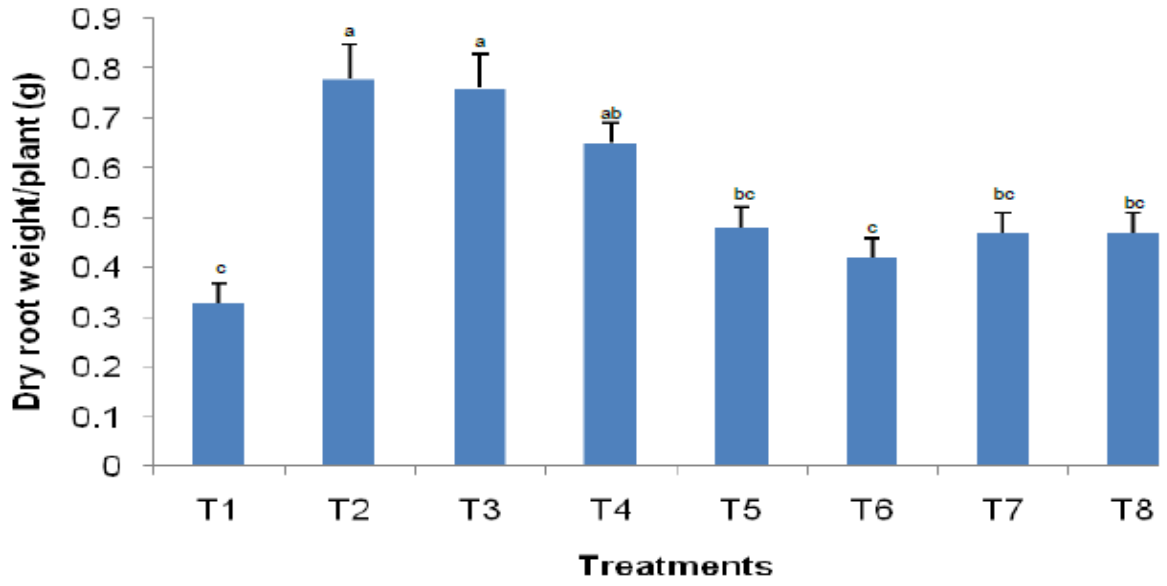
Iglesias-Díaz et al. (2009), reported that the high EC values were associated with a significant decrease in rooting success. The subsequent low rooting response of plants cultivated in T6 may also be due to this factor.



Dissimilar letters on top of the error bars show significant difference at p≤0.05.

Figure 4. 7: Fresh root weight of potted *D*. x *grandiflorum* cultivated in different treatments at 70 and 89 DAT

Figure 4.8 shows the dry root weight of potted *D*. x *grandiflorum* cultivated in different treatments at 89 DAT. Significant differences among dry root weights were observed at 89 DAT. Plants grown in T2 (0.78 g) and T3 (0.76 g) had a significantly higher dry root weight compared to plants grown in T1 (0.33 g), T5 (0.48 g), T6 (0.42 g), T7 (0.47 g), and T8 (0.47 g). There were no significant differences among T3 (0.76 g), T5 (0.48 g), T7 (0.47 g) and T8 (0.47 g). There was also no significant difference observed in T1, T5, T6, T7, and T8. These results are in contrast to findings by Trochoulias et al. (1990) who reported that African violets produced greater root dry matter in a mix containing a high proportion of composed bagasse.



Dissimilar letters on top of the error bars show significant difference at p≤0.05.

Figure 4. 8: Dry root weight of potted *D*. x *grandiflorum* cultivated in different treatments at 89 DAT

In general, potted *D*. x *grandiflorum* responded best in the control growth media (100 % peat) in terms of the measured plant growth parameters. The results are consistent with findings for similar studies reported by Arenas, Vavrina, Cornell, Hanlon, and Hochmuth (2002) who concluded that tomato transplants exhibited greater growth in peat control when grown in the summer season.

4.6 PLANT YIELD

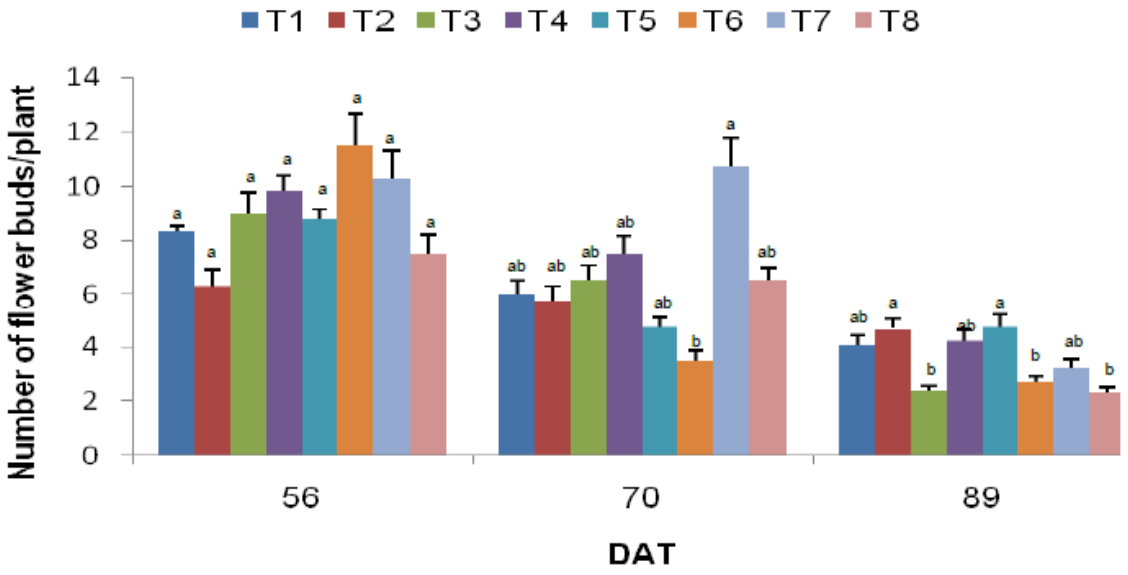
In this study, the number of flower buds and flowers, fresh and dry flower weight per plant were measured to evaluate the yield of potted *D.* x *grandiflorum* in response to the treatments. The treatment significantly affected each measured yield parameter of potted *D.* x *grandiflorum* in this experiment.

4.6.1 Number of flower buds

Figure 4.9 shows the number flower buds of *D*. x *grandiflorum* cultivated in different treatments at 56, 70, and 89 DAT. The number of flower buds was counted when they were available at 56 DAT, but the recorded values were not significantly different. It was interesting to note that plants cultivated in T6 (11.5) and T7 (10.3) had a higher number of flower buds than T1 (8.3) at first count but the difference was not statistically significant. Plants cultivated in T6 had more flower buds (42.2 %) than those cultivated in the control medium.

At 70 DAT, the number of flower buds was significantly ($p<0.05$) affected by the treatments. Plants cultivated in T8 (10.75) had higher number of flower buds compared to plants in T6 (3.50) but not significantly different to T1 (6.00), T2 (5.75), T3 (6.5), T4 (7.5), T5 (4.75), and T8 (6.5). Plants grown in T8 had more (79.2 %) flower buds than those in control medium. However, the number of flower buds on plants grown in T2 (5.75), T3 (6.5), T4 (7.5), T5 (4.75), T6 (3.5), and T8 (6.5) were not significantly different compared to plants grown in the control medium (Figure 4.9).

At the end of the experiment, the number of flower buds were significantly higher on plants cultivated in T2 (4.6) and T5 (4.7) compared to plants cultivated in T3 (2.4), T6 (2.7) and T8 (2.3), however, not significantly different to plants cultivated in T1 (4.0), T4 (4.2) and T7 (3.2). There were also no significant differences among the number of buds in T1 (4.0), T3 (2.4), T4 (4.2), T6 (2.7), T7 (3.2), and T8 (2.3)



Dissimilar letters on top of the error bars show significant difference at p≤0.05.

Figure 4. 9: The number of flower buds of potted *D*. x *grandiflorum* at 56, 70, and 89 DAT

The flower buds were abundant at 56 DAT than at 70 and 89 DAT. This is normal for a flowering plant's life cycle. The potted flowering plants are ready for the market.

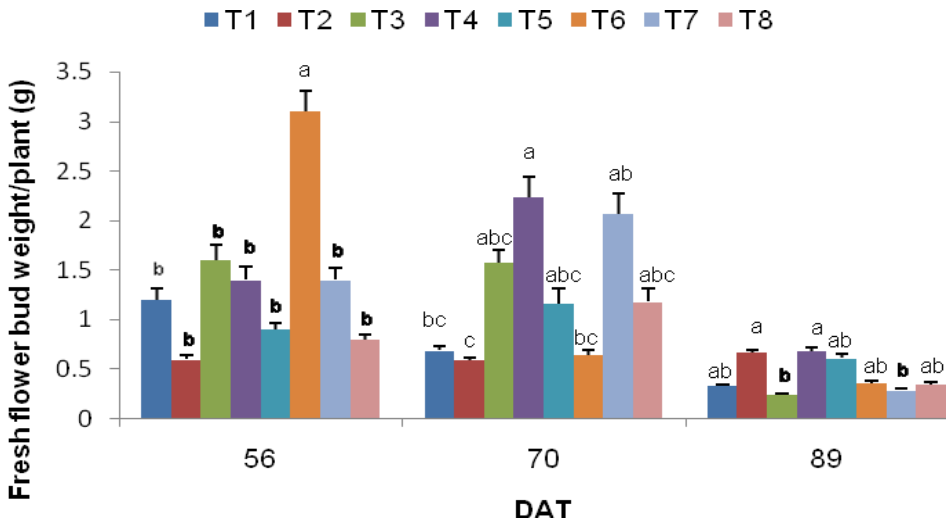
4.6.2 Fresh and dry flower bud weight

Figure 4.10 shows the fresh flower bud weight of potted *D*. x *grandiflorum* cultivated in different treatments at 56, 70, and 89 DAT. At 56 DAT, treatments significantly affected the fresh weights of plant's flower buds. The fresh flower bud weight was significantly higher in plants cultivated in T6 (3.1 g) compared to fresh flower bud weight of plants cultivated in all other treatments. The weight of fresh flower buds on plants grown in T6 was 1.9 g higher than the fresh flower buds on the plants grown in the control medium (1.2 g) (Figure 4.10)

At 70 DAT, treatments significantly affected the fresh weights of plant's flower buds. The weight of fresh flower buds was significantly higher in plants cultivated in T4 (2.23 g) compared to T1 (0.69 g), T2 (0.59 g) and T6 (0.64 g) but not significantly different to T3 (1.58 g), T4 (2.23 g), T7 (2.07 g), and T8 (1.18 g) (Figure 4.10). There were no significant differences among the fresh flower buds weight of plants grown in T1, T3, T5, T6, T7 and T8. Also, no significance differences were observed in the fresh flower buds on plants grown in T1, T2, T3, T5, T6 and T8. The weight of fresh flower buds on plants grown in T4 was 1.54 g higher than the fresh flower buds on the plants grown in the control medium

(0.69 g). The lowest fresh flower bud weight was recorded for plants grown in T2 (0.59 g). Notably, no significant difference in fresh flower bud weight was not noted when plants grown in T6 were compared to those in control medium (Figure 4.10).

At the end of the experiment (89 DAT), the weight of the fresh flower buds was significantly higher in plants cultivated in T2 (0.67 g) and T4 (0.68 g) compared to T3 (0.24 g) and T7 (0.29 g), however, no significant difference was observed when compared to plants grown in T1 (0.33 g), T5 (0.61 g), T6 (0.36 g), and T8 (0.35). The differences among the weight of fresh buds in plants cultivated in T1 (0.33 g), T3 (0.24 g), T5 (0.61 g), T6 (0.36 g), T7 (0.29 g), and T8 (0.35 g) were not significantly different to each other (Figure 4.10).



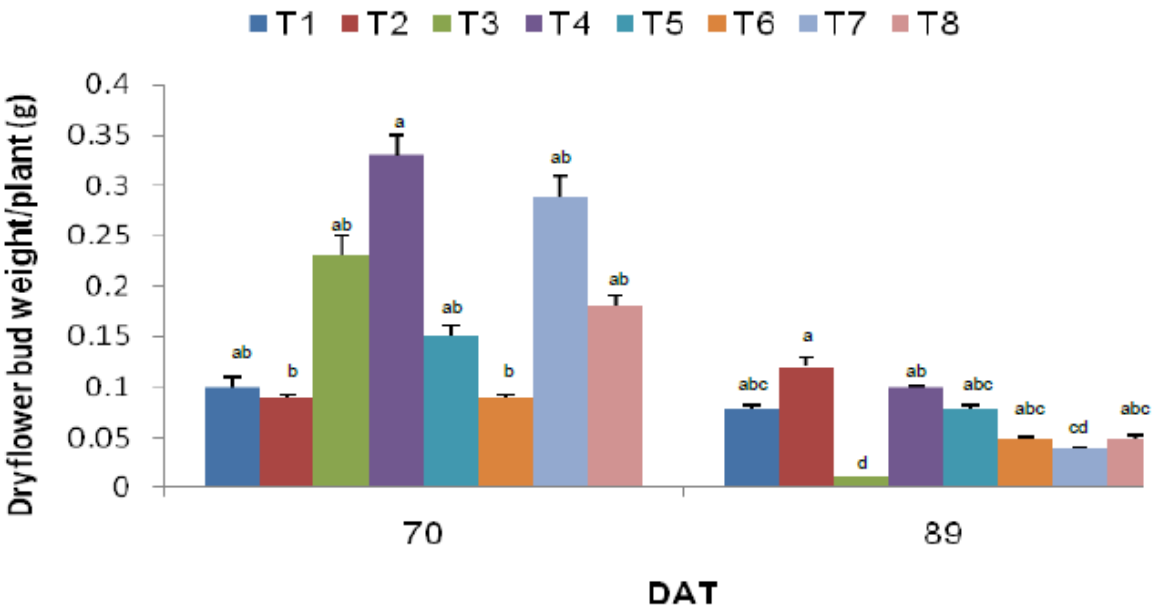
Dissimilar letters show significant difference at p≤0.05.

Figure 4. 10: Fresh flower bud weight of potted *D*. x *grandiflorum* cultivated in different treatments at 56, 70, and 89 DAT

Figure 4.11 shows the dry flower bud weight of potted *D*. x *grandiflorum* cultivated in different treatments at 70 and 89 DAT. There were no significant differences ($p<0.05$) among the dry weight of flower buds at 56 DAT (data not shown). However, the dry flower bud weight was significantly ($p<0.05$) affected by treatments at 70 and 89 DAT. At 70 DAT, the weight of the dry flower buds of plants cultivated in T4 (0.33 g) was significantly higher compared to the plants cultivated in T1 (0.10 g), T2 (0.09 g) and T6 (0.09 g) but not significantly different to T3, T5, T7, and T8 (Figure 4.11). The weight of dry flower buds on plants grown in T4 was 0.23 g higher than plants grown in the control medium (0.10 g). The weights of the dry flower buds grown in T2 (0.09 g), T3 (0.23 g), T5 (0.15 g), T6 (0.09

g), T7 (0.29 g), and T8 (0.18 g) were not significantly different compared to plants grown in the control medium.

At the end of the experiment (89 DAT), the weight of the dry flower buds of plants cultivated in T2 (0.12 g) was significantly higher compared to plants cultivated in T3 (0.01 g) and T7 (0.04 g), however, not significantly different compared to plants cultivated in T1 (0.08 g), T4 (0.10 g), T5 (0.08 g) T6 (0.05 g), and T8 (0.05 g). There was no significant difference observed in the weight of the dry flower buds of plants grown in T1 (0.08 g), T5 (0.08 g), T6 (0.05 g), T7 (0.05 g), and T8 (0.05 g) (Figure 4.11).



Dissimilar letters show significant difference at p≤0.05.

Figure 4. 11: Dry flower bud weight of potted *D*. x *grandiflorum* cultivated in different treatments at 70 and 89 DAT

4.6.3 Number of flowers

Tables 4.9 and 4.10 shows the number of flowers of potted *D*. x *grandiflorum* cultivated in different treatments when the flowers were available at 70 and 89 DAT. At both dates (70 and 89 DAT), the treatments significantly ($p<0.05$) affected the number of flowers counted.

At 70 DAT, the number of flowers was higher on plants cultivated in T6 (8.25) than in the control and other treatments. Compared to control plants, the number of flowers on plants grown in T6 increased by 48.4 % (Table 4.9). The number of flowers cultivated in T1 (4.25) and T5 (4.50) were also significantly higher than those planted in T2 (0.50), T4 (0.25), T7 (0.00), and T8 (0.75). There was however, no significant difference noticed in the number

of flowers in plants cultivated in T2 (0.50), T3 (2.25), T4 (0.25), T7 (0.00), and T8 (0.75). There was also no significant difference among the number of flowers on plants grown in T1 (4.25), T3 (2.25) and T5 (4.50) (Table 4.9).

At 89 DAT, the number of flowers was significantly higher in plants cultivated in T6 (9.5) than in the other treatments except for those in T5 (7.33). The number of flowers increased by 62 % in plants cultivated in composted bagasse (T6) compared to those cultivated in the control growth media (100 % peat) (Table 4.10). However, the number of flowers was not significantly different among plants cultivated in T3 (6.58), T4 (5.33) and T5 (7.33). It was worth noting that plants cultivated in T1 (3.67) had the second lowest number of flowers. This finding seems to suggest that composted bagasse can be recommended as a substitute of peat for cultivation of potted *D*. x *grandiflorum* under greenhouse conditions. It was also worth noting that the highest number of flowers was observed in plants cultivated in treatments that possessed highest K concentrations (four) after the experiment as indicated in 4.2.2.3. These results are consistent with the findings by Garcia-Gomez et al. (2002), who reported that acceptable degree of number of flowers of *Calendula* sp. may have been due to the great contribution of K in the compost.

4.6.4 Fresh and dry flower weight

Table 4.9 and 4.10 shows the fresh flower weight of potted *D*. x *grandiflorum* cultivated in different treatments at 70 and 89 DAT.

At 70 DAT, the treatments significantly ($p<0.05$) affected fresh flower weight. The weight of fresh flowers of plants cultivated in T6 (5.92 g) was significantly higher compared to T1 (3.25 g), T2 (0.39 g), T3 (2.05 g), T4 (0.20 g), T7 (0.00 g), and T8 (0.45 g) except to those in T5 (3.62 g). The weight of fresh flowers of plants grown in T6 increased by 62.8 % compared to those in control medium. However, the weight of fresh flowers of plants cultivated in T2, T3, T4, T7, and T8 was not significantly different compared to plants cultivated in the control medium. Similarly, the weight of fresh flowers of plants cultivated in T3 and T5 were not significantly different to those cultivated in the control medium (Table 4.9).

At 89 DAT, the treatments significantly ($p<0.05$) affected weight of the fresh flowers. The weight of fresh flowers of plants cultivated in T3 (5.13 g), T5 (5.83 g) and T6 (5.67 g) were significantly higher compared to plants cultivated in T1 (2.40 g), T2 (1.29 g) and T8 (1.95 g), however, not significantly different to plants cultivated in T4 (4.21 g) and T7 (3.45 g). The weight of fresh flowers of plants grown in T6 increased by 57.8 % compared to those in control medium. The weight of the fresh flowers cultivated in T1, T2, T7 and T8 was not significantly different to each other. The weight of fresh flowers of plants cultivated in T2, T7 and T8 was also not significantly different compared to plants cultivated in the control medium (Table 4.10).

At 70 DAT, the treatments significantly ($p<0.05$) affected dry flower weight. The weight of dry flowers of plants cultivated in T6 (0.85 g) was significantly higher than plants in all the other treatments. The weight of the dry flowers cultivated in T6 was 0.43 g higher than the weight of the dry flowers cultivated in the control medium (0.38 g). The weight of dry flowers in plants cultivated in control medium was significantly higher than in plants cultivated in T2 (0.05 g), T4 (0.03 g) and T7 (0.00 g) but did not differ significantly from T3 (0.28 g), T5 (0.47 g) and T8 (0.07 g) (Table 4.9).

At 89 DAT, the treatments significantly ($p<0.05$) affected dry flower weight. The dry flowers weight of plants cultivated in T6 (0.9 g) was significantly higher compared to plants cultivated in T1 (0.27 g), T2 (0.21 g), T7 (0.42 g), and T8 (0.25 g) but not significantly different compared to plants in T3 (0.67 g), T4 (0.62 g) and T5 (0.67 g). The weight of the dry flowers cultivated in T3, T4, T5, and T6 was 0.4 g, 0.35 g, 0.4 g, and 0.63 g higher than the weight of the dry flowers cultivated in the control medium (0.27 g). The weight of dry flowers in plants cultivated in control medium did not have a significant difference when compared to plants cultivated in T2 (0.21 g), T4 (0.62 g), T7 (0.42 g), and T8 (0.25 g) (Table 4.10).

Table 4. 9: The number of flowers, fresh and dry flower weight of potted *D.* x *grandiflorum* at 70 DAT

Treatments	No. of flowers	Fresh flowers Wt. (g)	Dry flowers Wt. (g)
T1	4.25±2.66b	3.25±1.95bc	0.38±0.24bc
T2	0.50±0.50c	0.39±0.39c	0.05±0.05d
T3	2.25±0.48bc	2.05±0.58bc	0.28±0.07bcd
T4	0.25±0.02c	0.20±0.20c	0.03±0.03d
T5	4.50±0.87b	3.62±0.79ab	0.47±0.09b
T6	8.25±0.85a	5.92±0.30a	0.85±0.05a
T7	0.00±0.00c	0.00±0.00c	0.00±0.00d
T8	0.75±0.48c	0.45±0.31c	0.07±0.05cd
F-Statistics			
Treatments	7.18***	7.09***	8.73***

Means with the same letter are not significantly different at P<0.05 according to Duncan's multiple range test.

Table 4. 10: The number of flowers, fresh and dry flower weight of potted *D.* x *grandiflorum* at 89 DAT

Treatments	No. of flowers	Fresh flowers Wt. (g)	Dry flowers W.t (g)
T1	3.67±0.26cd	2.40±0.96bc	0.27±0.01cd
T2	2.50±0.66d	1.29±0.32c	0.21±0.06d
T3	6.58±1.35bc	5.13±1.27a	0.67±0.20ab
T4	5.33±0.86bcd	4.21±0.85ab	0.62±0.02abc
T5	7.33±0.96ab	5.83±0.74a	0.67±0.01ab
T6	9.50±0.70a	5.67±0.68a	0.90±0.07a
T7	4.33±1.12cd	3.45±0.18abc	0.42±0.01bcd
T8	3.50±0.63cd	1.95±0.38bc	0.25±0.05cd
F-Statistics			
Treatments	5.68***	4.28***	3.61***

Means with the same letter are not significantly different at P<0.05 according to Duncan's multiple range test.

At a marketable stage, *D*. x *grandiflorum* grown in composted bagasse (T6) had significantly ($p<0.05$) higher number of flowers and higher total fresh flower weight than 100 % peat and the other treatments. These results contradict those by van der Gaag, van Noort, Stapel-Cuijpers, de Kreij, Termorshuizen, van Rijn, Zmora-Nahum and Chen (2007) which suggested that Cyclamen grown in the 100 % peat control had significantly higher number of flowers and higher total fresh flower weight than all other treatments at the marketable stage.

4.6.5 Dry Weight of Root to shoot ratio (R/S)

There is a great interdependence of shoot and root for plant's growth and development. The shoot is reliant on the root for water and nutrients, while the roots depend on the shoots for carbohydrates. Root growth is closely related to the whole plant's growth and this relationship is called relative growth. It is therefore concluded that root dry weight is related to the total dry weight of the plant (Fageria & Moreira, 2011). Plants allocate higher amounts of biomass into leaves and stems in nutrient rich root-zone environment, whereas

in low nutrient environment, a higher proportion is located to roots (Mašková & Herben, 2018). This is because when nutrient availability is increased, plants will allocate less to their roots as increased nutrient availability means that less effort is required to acquire the available resources (Ågren & Franklin, 2003).

Figure 4.12 shows the root/shoot ratio (R/S) of potted *D*. x *grandiflorum* cultivated in different treatments. Treatments significantly ($p<0.05$) affected the root/shoot ratio (dry weights) at 89 DAT. The root/shoot ratio was lowest in the plants grown in T1 (1.17) compared to the highest in T2 (0.62). The root/shoot ratio of plants grown in T2 was significantly different to other treatments but plants grown in T3, T4 and T8 were not different from each other (Figure 4.12). The relative high root/shoot ratio of plants cultivated in T2, T3, T4, and T8 might be due to the inability of the growth media to hold water as indicated in 4.3.1 and N deficiency (indicated in 4.2.2.1) as alluded by Fageria & Moreira (2011). N deficient plants usually produce more dry matter to roots than shoots. A study by Mašková and Herben (2018) also concluded that R/S was lower in a substrate with a higher nutrient supply.

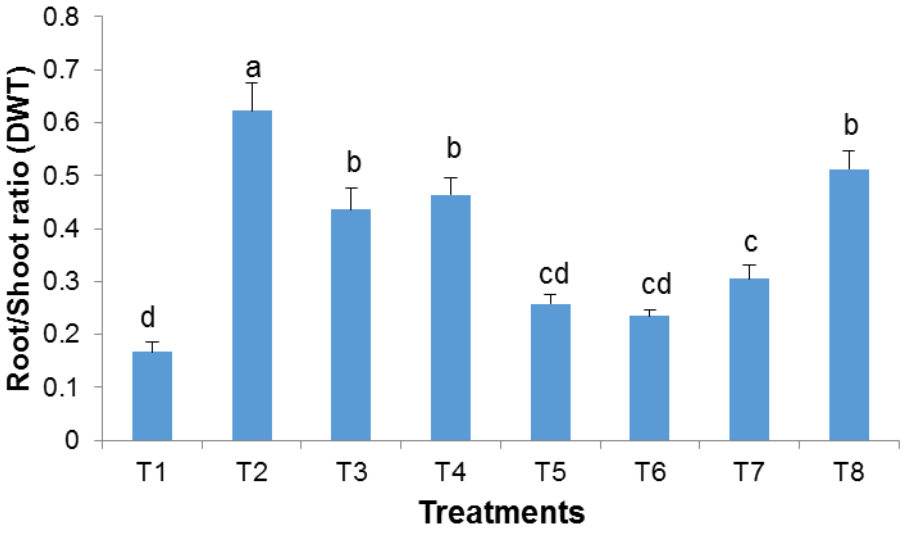


Figure 4. 12: The dry weights of root to shoot ratio of potted *D*. x *grandiflorum* cultivated in different treatments

In general, the R/S was lower with 100 % peat. Similar results were recorded by Dispenza et al. (2016), who reported that higher ratios were measured in plants grown with 80 % and 100 % biochar whereas lower ratio was recorded with 100 % peat.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter concludes on the results and discussions. Further, it provides recommendations for future research based on the experimental findings and also gives an overall summary of the study.

5.2 ACHIEVEMENT OF OBJECTIVES

The conclusions reached after the analysis of the data collected during an investigation of alternative growth media to replace peat for the cultivation of potted *D*. x *grandiflorum* are discussed in this chapter. The research objectives are discussed separately in order to determine whether they were each achieved.

5.2.1 Conclusion for objective 1

Objective 1 aimed to evaluate the chemical properties of alternative growth media in comparison to peat.

Chemical properties of growth media are important because they influence the supply of nutrients to the plants. Study findings indicated that chemical properties of different alternative growth media were different to those of peat. The pH of 100 % peat (T1), 100 % bagasse (T2), 75:25 % bagasse:peat (v/v) (T4), 25:75 % bagasse:peat (v/v) (T5), composted bagasse (T6), and coir (T7) were within the ideal range recommeded for growth media before the experiment (Table 4.1). At the end of the experiment, only 100 % bagasse (T2) and coir (T7) were within the recommended range. The EC results indicated that only coir (T7) was within the recommeded ideal limits before the experiment. A difference was observed in EC at the end of the experiment whereby the other treatments were within the defined range except for composted bagasse (T6) which had a concentration too high to support plants cultivated in containers (Table 4.1). The concentration was too high as a consequence of high soluble salts. The EC level in composted bagasse (T6) was slightly higher than the recommended limit for growth media suitable for potted *D*. x *grandiflorum*. The pH and EC may have influenced the availabilty of different macro and micro nutrients. For example, T8 recorded low levels of Ca and Mg (Table 4.2) which may be attributed to low pH (Table 4.1) as suggested by the refered

authors in the study (4.2.2.5 & 4.2.2.5). Also, a high EC recorded in T6 (Table 4.1) may have been due to the high concentration of Ca in the growth media (Table 4.2) as suggested by the refered authour (4.2.2.4). The low Fe and Mn concentration in T7 after the experiment (Table 4.3) was suggested to have been due to the increased pH in the growth media (4.2.3.3). The results for C/N ratio, macro and micro nutrients, and soluble salts present in the different treatments are discussed in detail in chapter 4. In general, the alternative growth media used in this study showed differences in chemical properties when compared to peat.

5.2.2 Conclusion for objective 2

Objective 2 aimed to evaluate the physical properties of alternative growth media in comparison to peat.

Physical properties affect the availabilty of water and air in the growth media. The physical properties were measured and the results from this study indicated that physical properties of different alternative growth media were different compared to peat. The physical characteristics that make peat a preffered growth media component were discussed in the literature review section. The control growth media registered the highest WHC as suggested by several authors cited in the results and discussion chapter. The AFP of (pine bark) T8 was the highest, which is as a consequence of the lowest WHC which may have ulitimately resulted in poor plant growth. The AFP was the lowest in 100 % peat (T1) due to the high WHC which may have been a result of its small particles size composition. The BD of 100% peat (T1) and composted bagasse (T6) were the same, which may have resulted in the low root response due to compaction of the growth media. These results are discussed in detail in the previous chapter (4.3.1, 4.3.2 & 4.3.3). In general, the alternative growth media used in this study showed differences in physical properties when compared to peat.

5.2.3 Conclusion for objective 3

Objective 3 aimed to determine the mineral content and chlorophyll content of potted *D*. x *grandiflorum* cultivated in alternative growth media in comparison to peat.

The shoot mineral content was different in the alternative growth media in comparison to peat. The conclusion was only made for the most recognized macro nutrient elements which are N, P and K. The concentration of total N and K in shoots of plants cultivated in

100 % peat was not significantly different compared to plants cultivated in all the other treatments. The concentration of P was higher in shoots of plants cultivated in T1 compared to the concentration in shoots of plants cultivated in composted bagasse (T6) (Table 4.7).

The results of the chlorophyll content show that the highest chlorophyll content (adaxial and abaxial) was present in plants cultivated in composted bagasse (T6). For example, adaxial leaf chlorophyll content was significantly higher in plants grown in T6 than in plants grown in 100 % peat at 80 DAT and 84 DAT (Figure 4.1). This may be due to the high total N in the growth media and high concentration of Fe and Zn in the shoots of the plants cultivated in composted bagasse (T6). In general, the shoot mineral content and chlorophyll content in potted *D*. x *grandiflorum* cultivated in alternative growth media were different when compared to peat.

5.2.4 Conclusion for objective 4

Objective 4 was to compare the growth and yield of potted *D*. x *grandiflorum* cultivated in alternative growth media in comparison to peat.

The results show that plant height and stem diameter were not affected by the different treatments until at 56 DAT. The highest siginificant root response was observed in treatments with highest bagasse percentage (100 % bagasse (T2) and 75:25 % bagasse:peat (v/v) (T3)) and pine bark (T8). This may have been influenced by the BD or high phosphate concentration in the growth media. The highest plant shoot weight was recorded in the control growth media, which may be due to the greater uptake of N by the plants and high WHC. In general, the growth of potted *D*. x *grandiflorum* cultivated in alternative growth media was different when compared to 100 % peat control. For example, the results obtained in this study show that plants grown in 100 % peat were observed to grow significantly higher than plants grown in pine bark (T8) at 56 DAT (Figure 4.3). Similarly, plants grown in 100 % peat had significant thicker stem diameter than plants grown in 100 % bagasse (T2), coir (T7) and pine bark (T8) at 56 DAT (Figure 4.4).

The fresh shoot weight of plants grown in 100 % peat was significantly higher than of plants in all other treatments at 56 DAT, however not significantly different compared to fresh shoot weight of plants grown in 25:75 % bagasse:peat (T5) and composted bagasse (T6) at 70 DAT. At 89 DAT, the fresh shoot weight of plants grown in 100 % peat was higher than in plants grown in other treatments except for plants grown in 25:75 % bagasse:peat (T5) (Figure 4.5). The fresh and dry root weight of plants grown in 100 %

peat control was significantly lower compared to weight of plants grown 100 % bagasse (T2), 50:50 % bagasse:peat (T3) and pine bark (T8) at 89 DAT (Figure 4.7 & 4.8).

The best yield parameters were observed in composted bagasse (T6) and it was also noted that T5, which is a mixture of 25 % bagasse and 75 % peat, gave the second highest significant number of flowers. According to the results obtained in this study, the yield of potted *D*. x *grandiflorum* cultivated in alternative growth media was different when compared to 100 % peat control. For example, the number of flower buds was significantly higher than in plants grown in composted bagasse (T6) at 70 DAT, however not significantly different compared all the other treatments at the end of the experiment (89 DAT) (Figure 4.9). At 56 DAT, the fresh flower bud weight of plants grown in composted bagasse (T6) was significantly higher than of plants grown in 100 % peat. At 70 DAT, plants grown in 100 % peat (T1), 100 % bagasse (T2) and composted bagasse (T6) produced significantly lower fresh flower bud weight compared to plants grown in 75:25 % bagasse:peat (T4). The fresh flower bud weight of plants grown in T4 was significantly higher compared to plants grown in 50:50 % bagasse:peat (T3) and coir (T7) at 89 DAT (Figure 4.10). The dry flower bud weight of plants grown in T4 was significantly higher compared to the dry flower weight of plants grown in T2 and T6 at 70 DAT. The plants grown in 100 % peat had a higher dry flower weight compared to plants grown in T3 and T7 at 89 DAT (Figure 4.11).

According to the results obtained in this study, the number of flowers was lower in plants cultivated in the control medium (T1) (4.25) compared to number of flowers cultivated in T6 (8.25) at 70 DAT (Table 4.9). Similarly, at 89 DAT, the number of flowers was lower in plants cultivated in T1 (3.67) compared to number of flowers cultivated in T5 (7.33) and T6 (9.50) (Table 4.10). The fresh flower weight of plants cultivated in T6 (5.92 g) was higher compared to fresh flower weight of plants cultivated in the control medium (3.25 g) at 70 DAT (Table 4.9). Fresh flower weight of plants grown in 100 % peat (2.40 g) was also lower compared to fresh flower weight of plants grown in T5 (4.21 g) and T6 (5.83 g) at 89 DAT (Table 4.10). Also, the root/shoot ratio of plants cultivated in T2, T3, T4, and T8 was significantly higher compared to the lowest observed in the control medium (Figure 4.12).

5.3 HYPOTHESES

5.3.1 Hypothesis A

The chemical properties of alternative growth media are not different compared to peat.

This hypothesis was rejected on the basis that differences were observed in the chemical properties tested.

5.3.2 Hypothesis B

The physical properties of alternative growth media are not different compared to peat.

This hypothesis was rejected on the basis that differences were observed in the physical properties tested.

5.3.3 Hypothesis C

The shoots nutrient content and chlorophyll content of potted *D.* x *grandiflorum* are not influenced by alternative growth media.

This hypothesis was rejected on the basis that differences were observed in the shoots nutrient and chlorophyll content tested.

5.3.4 Hypothesis D

The growth and yield of potted *D.* x *grandiflorum* are not influenced by alternative growth media.

This hypothesis was rejected on the basis that differences were observed in the growth and yield parameters that were measured.

5.4 OVERALL CONCLUSION

The aim of this study was to determine a suitable alternative growth media to replace peat as a component of growth media for cultivation of potted *D*. x *grandiflorum*. A comparative study was conducted using eight different treatments and the results have shown that composted bagasse can be used as an alternative growth media for cultivation of potted chrysanthemum due to the highest yield compared to peat and other treatments.

Potted *D*. x *grandiflorum* is a crop marketed for its flowers. Therefore, based on the findings, the study concludes and recommends that composted bagasse (T6) can be successfully used for cultivation of potted *D*. x *grandiflorum*. This recommendation is made due to the improved yield in terms of the number of flower buds, the fresh and dry weight of flower buds, the number of flowers, and the fresh and dry flowers weight results obtained from this study. This recommendation is also due to the high chlorophyll content noted in plants cultivated in composted bagasse (T6), which is indicative of enhanced photosythetic capacity and plant growth. T6 had similar BD as the control growth media and second highest WHC compared to peat. Though the results seem to confirm composted bagasse as an alternative growth media to replace peat for cultivation of potted *D*. x *grandiflorum*, soluble salts must be monitored in order to avoid negative effects for plant growth.

The researcher also concluded that a mixture of 25 % of bagasse to 75% peat produced a significant higher number of flowers compared to peat. This can also help reduce the volume of peat in the growth media for cultivating potted chrysanthemum. The results of the study have a high environmental relevance as it may involve the replacement of non-renewable resource by composted bagasse or the mixture of 25 % bagasse to 75 % peat.

The study findings could potentially assist potted chrysanthemum growers in choosing a sustainable growth media (composted bagasse), which is not detrimental to the wetlands ecosystems. These findings fulfil the need to replace peat as a growth media for cultivation of potted *D*. x *grandiflorum*.

5.5 RECOMMENDATIONS FOR FUTURE STUDIES

The challenge using composted bagasse is the high concentration of soluble salts which can be detrimental to salt sensetive plants. It is therefore recommended that future studies be conducted to see if composted bagasse can be suitable to cultivate a variety of ornamental plants in order to reduce the peat usage in the horticultural industry. Future studies may also focus on managing the chemical properties of composted bagasse that contribute to salinity. Moreover, a study can be conducted to determine the leaching rate of soluble salts in composted bagasse and the effects and potential contribution to water contamination. It would be valuable to do an economics based study or gross margin analysis to determine if composted bagasse can be cost effective growth media component to use as an alternative to peat. It would also be worthwhile to evaluate the availability of bagasse by assessing the production percentage from the sugarcane milling industry.

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ANNEXURE 1: Ethical clearance

UNISA university of south africa

CAES RESEARCH ETHICS REVIEW COMMITTEE

Date: 26/11/2015

Ref #: **2015/CAES/125**
Name of applicant: **Mr KG Koopa**
Student #: **55745091**

Dear Mr Koopa,

Decision: Ethics Approval

Proposal: An investigation of sterilised sugarcane bagasse as a replacement for peat in growth media for the cultivation of *Dendranthema x grandiflorum*

Supervisor: Prof R Hendrick

Qualification: Postgraduate degree

Thank you for the application for research ethics clearance by the CAES Research Ethics Review Committee for the above mentioned research. Final approval is granted for the duration of the project.

The application was reviewed in compliance with the Unisa Policy on Research Ethics by the CAES Research Ethics Review Committee on 26 November 2015.

The proposed research may now commence with the proviso that:

1) *The researcher/s will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.*
2) *Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study, as well as changes in the methodology, should be communicated in writing to the CAES Research Ethics Review Committee. An amended application could be requested if there are substantial changes from the existing proposal, especially if those changes affect any of the study-related risks for the research participants.*
3) *The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study.*

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Note:
The reference number [top right corner of this communiqué] should be clearly indicated on all forms of communication [e.g. Webmail, E-mail messages, letters] with the intended research participants, as well as with the CAES RERC.

Kind regards,

Signature
CAES RERC Chair: Prof EL Kempen

Signature
CAES Executive Dean: Prof MJ Linington

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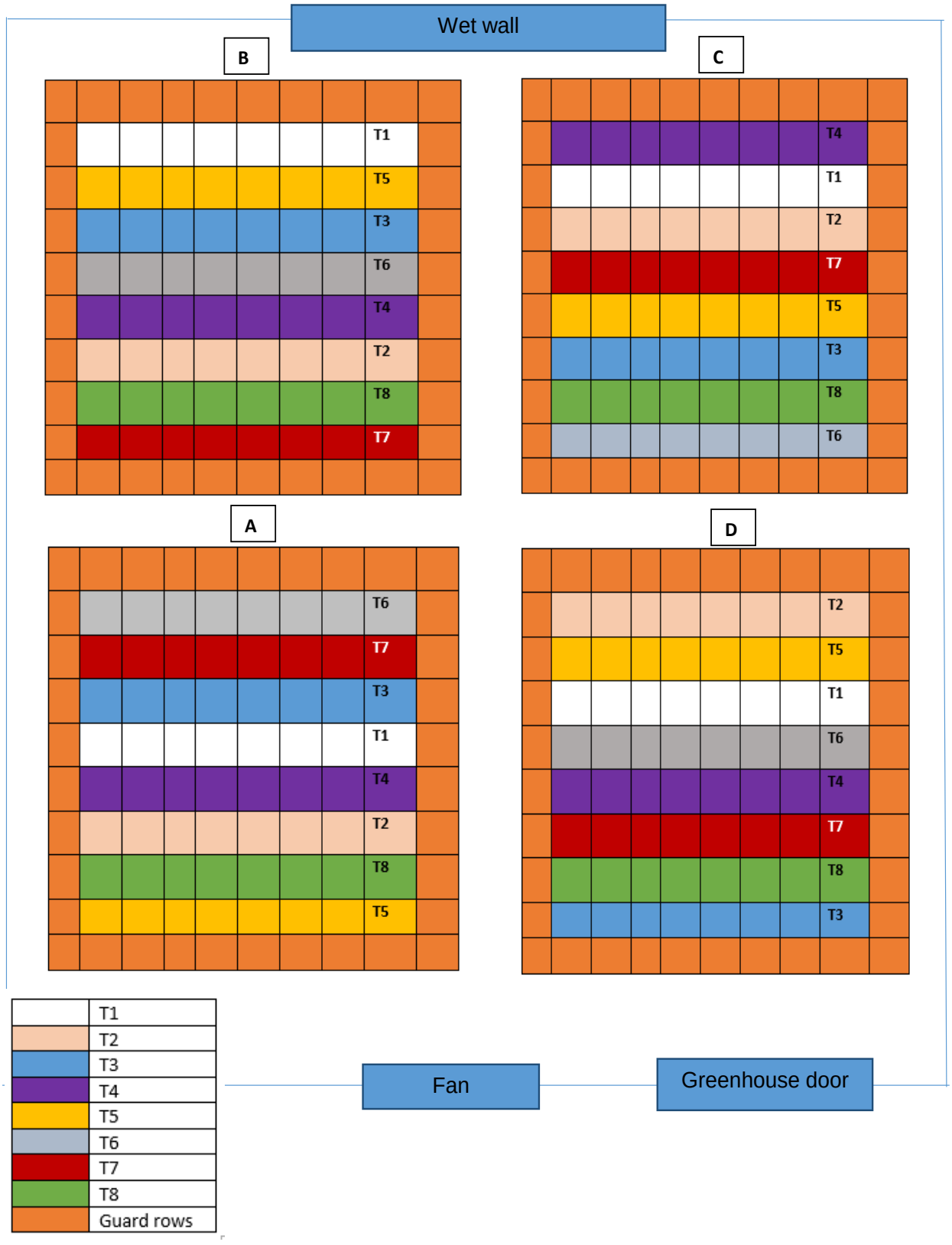
ANNEXURE 2: Experimental design (Randomized complete block design)



ANNEXURE 3: Data sheet

Data collected by: _____ Date: _____

Days after transplanting (DAT): _____ Rep no. : _____

Treat. no.	No. leaves	Plant height	Stem diam. (mm)	Fresh root (g)	Dry root (g)	Fresh shoot (g)	Dry shoot (g)	No. of flow. buds	No. of flowers	Fresh flow. bud (g)	Dry flow. bud (g)	Fresh flower (g)	Dry flower (g)
1.													
2.													
3.													
4.													
5.													
6.													
7.													
8.													