Investigating the effect of coir substrate on the growth, yield and quality of sweet pepper (*Capsicum annuum*) varieties

by

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ABSTRACT

Crop yield is the industry standard for calculating the amount of horticultural produce harvested. As a result, producing sufficient quantities of quality biochemical ingredients can help to solve food security and nutritional issues. To ensure an adequate food supply, the use of organic substrate, as opposed to natural soils, is preferred by many growers for greenhouse cultivation of crops such as peppers. The aim of the study was to determine the effect of coconut coir substrate on the yield and biochemical constituents of pepper varieties grown under greenhouse conditions. Two sweet peppers varieties (Sondela and Ilanga) were grown in fertigated coconut coir (experiment) or loamy soil (control) under greenhouse conditions for two consecutive growing seasons in 2021 and 2022. The number of pepper fruits, as well as their dried weight and selected biochemical contents, were investigated. Quantification was done using the concentration of dry matter and selected biochemical constituents from freeze-dried fruit samples. Results illustrated that the treatment combination of coconut coir and variety (Ilanga) resulted in a higher fruit number when compared to other treatments. Biochemical constituents such as vitamins, total phenols, total flavonoids, copper, iron and zinc were superior in fruits grown under coir substrate when compared to loamy soil (control). Therefore, farmers are encouraged to grow sweet peppers varieties under coconut coir substrate for better yield, nutritional quality and profit maximisation.

Keywords: Sweet pepper, *Capsicum annuum*, coir, total biomass, harvest index, biochemical constituents, micro- and macronutrients

OPSOMMING

Opbrengste is die standaard waarvolgens die bedryf bepaal hoeveel tuinbouprodukte geoes is. Die vervaardiging van voldoende hoeveelhede eersteklas biochemiese bestanddele kan voedselveiligheid verseker en voedingstekorte aanvul. Die meeste kwekers verkies ’n organiese substraat bo natuurlike grond om gewasse soos soetrissies in kweekhuise te verbou omdat die gewasse sodoende genoegsame voeding ontvang. Hierdie studie wou vasstel of ’n klapperhaarsubstraat enige uitwerking het op die opbrengs en biochemiese samestelling van soetrissievariëteite wat in ’n kweekhuis verbou word. Twee soetrissievariëteite (Sondela en Ilanga) is in twee opeenvolgende seisoene (2021 en 2022) in ’n kweekhuis in bemeste klapperhaar en ook in leemgrond (die kontrole) geplant. Die aantal soetrissievrugte, hulle droë gewig asook ’n keur van hul biochemiese bestanddele is ontleed. Die kwantifisering is gedoen op grond van ’n konsentrasie droë materie en ’n keur van die biochemiese bestanddele van vriesgedroogde vrugtemonsters. Daar is bevind dat die kombinasie van klapperhaar en variëteit (Ilanga) ’n groter opbrengs as enige ander behandeling lewer. Die biochemiese bestanddele van vrugte wat in ’n klapperhaarsubstraat gekweek is, soos vitamiene, totale fenol, totale flavonoïed, koper, yster en sink, was van ’n hoër gehalte as dié van vrugte wat in leemgrond (die kontrole) gekweek is. Boere word dus aangeraai om soetrissievariëteite in ’n klapperhaarsubstraat te kweek met die oog op ’n hoër opbrengs, groter voedingswaarde en ’n maksimumwins.

Sleutelwoorde: Totale biomassa, oesindeks, biochemiese bestanddele, mikro- en makrovoedingstowwe

KAKARETŠO

Palo ya tšweletšo ya temo ya dibjalo tšeo di bunnwego ke maemo ao a šomišwago ke intasteri go lekola ditšweletšwa tša temo tšeo di bunnwego. Ka lebaka leo, go tšweletša palo ye e lekanego ya metswako ya boleng ya dikhemikhale tša phepo ya dibjalo go ka thuša go rarolla mathata a tšhireletšo ya dijo le mathata a tša phepo. Tšhomišo ya manyora a tlhago ka ntlong ya go godiša dibjalo tše bjalo ka dipherefere go netefatša gore go na le kabo ya dijo ye e lekanego, ke mokgwa wo o šomišwago ke bontši bja balemi bakeng sa mabu a tlhago. Maikemišetšo a nyakišišo ye e be e le go laetša khuetšo ya morole wa khokhonate go puno le metswako ya dikhemikhale tša phepo ya dibjalo go mehuta ya pherefere ye bjetšwego ka gare ga ntlo ya go godiša dibjalo. Mehuta e mebedi ya pherefere e bose (Sondela le Ilanga) e bjetšwe ka gare ga morole wa khokhonate wo o nontšhitšwego le go nošetšwa le mobu wa serota goba seloko (taolo) ka gare ga ntlo ya go godiša ka dihla tše pedi tša go latelana [2021 le 2022]. Palo ya dienywa tša pherefere, gammogo le boima bja tše di omilego le metswako ye e kgethilwego tša dikhemikhale tša phepo ya dibjalo, di ile tša nyakišišwa. Tekanyo e dirilwe ka go šomiša motswako wa dikarolo tša kgolo ya dibjalo tšeo di omilego le dikarolo tše di kgethilwego tša dikhemikhale tša phepo ya dibjalo go tšwa go disampole tša dienywa tše di omišitšwego le go kgahlišwa ka setšidifatši. Dipoelo tša nyakišišo di laeditše gore mokgwa wa go tswaka morole wa khokhonate le mehuta e mengwe (Ilanga) go bile le puno ye kgolo ya dienywa ge go bapetšwa le mekgwa e mengwe. Dikarolo tša dikhemikhale tša phepo ya dibjalo bjalo ka dibithamini, palomoka ya diphenole, palomoka ya difolavonoite, koporo, tšhipi le zinki di hweditšwe go dienywa tša go bjalwa ka fase ga manyora ge e bapetšwa le dienywa tša go bjalwa mmung wa serota goba seloko (taolo). Bjalo, balemi ba hlohleletšwa go bjala mehuta ya go fapana ya di pherefere tše di bose ka fase ga morole wa khokhonate go tšweletša puno e kaone, boleng bja phepo le go oketša letseno.

Mantšu a bohlokwa: Palomoka ya payomase, intekese ya puno, dikarolo tša dikhemikhale tša phepo ya dibjalo, bomedišetšo/dijo tša dibjalo

DECLARATION

I, Roger Bernadis Tuckeldoe, declare that this dissertation entitled "**Investigating the effect of coir substrate on the growth, yield and quality of sweet pepper (*Capsicum annuum*) varieties"** which I hereby submit for the degree of Master of Science in Agriculture at the University of South Africa is my own work and has not previously been submitted by me for a degree at this or any other institution.

The researcher and the Unisa library conducted a literature assessment before the research project started to ensure that no other identical studies had been registered before this one, either in South Africa or abroad.

I further declare that I have that I have not copied and pasted any information from the Internet, without specifically acknowledging the source and have made use of or quoted from original works and that all references to these works have been properly cited.

I declare that during my study I adhered to the Research Ethics Policy of the University of South Africa, received ethics approval for the duration of my study prior to the commencement of data gathering, and have not acted outside the approval conditions.

I declare that the content of my dissertation has been submitted through an electronic plagiarism detection program before the final submission for examination.

August 2022

Signature Date

Student number

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APPENDICES

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ABBREVIATIONS

ABG	Above-ground biomass
ARC	Agricultural Research Council
cm	centimetre
DW	dry weight
EDTA	ethylenediaminetetraacetate
GAE	gallic acid equivalent
HPLC	high-performance liquid chromatography
HTR	high temperature range
ITR	intermediate temperature range
kg	kilogram
LTR	low temperature range
mg	milligram
mm	millimetre
TSS	total soluble sugars
$\mu mol/m^2$	mass per area of leaf surface/milligram per square

GLOSSARY

βeta carotene	a naturally occurring orange colour that is a component of vitamin A (Manthey & Perkins-Veazie, 2009).
Chlorophyll	the compound that gives many plants their distinctive green colour and is essential for photosynthesis (Abu-Zinada, 2015).
Crude protein	the protein content of plant matter (Alomran & Luki, 2012; Wang, Shen & Zhu, 2018).
Flavonoids	a significant class of phytochemical compounds that are present in plant pigment and share flavone's basic structure (Krogholm, 2011).
Phenols	a class of phytochemical substances that are often formed from aromatic amino acids and are present in plant tissues (Hossain & Shah, 2015).
Total soluble sugars	the quantity of water-soluble carbohydrates, primarily in the form of soluble sugar content (Arrom & Munné-Bosch, 2012).
Macro-nutrients	a greater number of the elements that are needed by both plants and animals (Wang, Chen, Sciarappa & Camp, 2008).
Micro-nutrients	elements in smaller quantities needed by plants and animals (Schauer & Fernie, 2006).

Chapter 1: Introduction

The aim of this chapter is to introduce the research topic and to provide background information on the growing conditions required for optimal plant production, performance and quality. This chapter also highlights the purpose of the research and objectives of the study.

1.1 Background

Agriculture, which supplies food and provides an income to the many of the world’s inhabitants, is the backbone of the economies of many developing, emergent, and established countries (Jamnadass et al., 2011). Tomás-Callejas et al. (2011) reported that an increase in plants as output used for food and other secondary applications such as medicine, cosmetics and flavour should result from an increase in agricultural inputs such as substrate, fertilizers and water. Thus, food growers must find sustainable strategies to optimise food production to meet the demand and supply as the world's population continues to expand (Pingali, 2001). Most producers prefer to use substrate instead of natural soils for greenhouse crop cultivation in order to assure a sufficient and efficient food supply (Jawaad Ati et al., 2016).

The effects of various growth media on crop growth, development and yield have been extensively studied. As an example, Gungor and Yildirim (2013) studied how peat, sand and perlite affected the quality, growth and production of pepper (*Capsicum annuum*) in a greenhouse environment. However, literature is limited as to the impact of organic substrates on the biochemical constituents of *Capsicum annuum* (*C. annuum*), including vitamins, total phenols, flavonoids and proteins, (Moyo et al., 2018).

One such growth medium with promising potential to positively impact the growth, development and yield of *C. annuum* is coconut coir substrate, the subject of this study. Coir is an organically generated product formed from the external husk or mesocarp of coconut fruit – a fruit that provides environmental benefits due to its regenerative nature (Gama et al., 2015).Olle *et al*. (2012) suggested that the benefits of coir substrate include the following attributes:

- It is 100% organic and is renewable
- It provides good drainage
- It has a high water-holding capacity
- It promotes accelerated root growth and development
- It is cheap and easily available

According to Konduri et al. (1999), coir fibre, also known as substrate, is a coarse substance that is derived from the husk that covers the coconut seed. The coconut fruits husks are used to make the coir substrate, which has a number of agronomic benefits (Nouguera et al., 2003). On the other hand, Van der Knaap (2021) describes coconut coir as a growth medium made of fine coconut material and crushed coconut husk that is useful for crop generative and vegetative guidance.

Noguera et al., (1998), examined the usage of coconut coir waste in Mexico as a fresh and practical environmentally acceptable alternative to peat and vermiculite for growing plants in containers. Comparing coconut coir waste media to other substrates like peat and vermiculite, they found that the majority of plant species grew as well as or better.

Abad et al. (2002) assessed the use of coconut coir dust from Sri Lanka and the Ivory Coast as a peat replacement for container-grown decorative plants. The scientists discovered that when comparing coconut coir to peat substrate, overall biomass, plant height, and flowers were superior on coconut coir. The use of coconut coir for horticulture crop cultivation in South Africa appears to be underutilised and documented.

As a result, in the South African context , to the best of our knowledge, the effect coconut coir on the growth, development, yield and quality parameters of sweet peppers (*C. annuum)* varieties is not known (Gungor & Yildrim, 2013).

1.2 Problem statement

According to Legwaila et al. (2011), establishing food security can assist in alleviating poverty in most developing countries, including South Africa, and a first step in addressing this challenge may involve a systematic investigation into the use of organic substrates to promote environmental and agricultural sustainability. This, particularly when organic substrate promotion and use may result in increased environmental sustainability and improved crop yields to aid in sustainable agriculture practices, minimize soil contamination and boost crop productivity (Vink, 2013).

Capsicum annuum is thought to be one of the most nutritious fruit crops but its productivity and quality are determined by the substrate in which it is grown. Various factors have been linked to this issue, including substrate water holding capacity, drainage, aeration and nutritional content (Length, 2009). Olle et al. (2012) indicated that the use of coir might benefit pepper cultivation by providing an answer to substrate issues associated with its cultivation.

Thus, the current study set out to determine the growth performance and analyse the biochemistry of two *C. annuum* varieties grown in coconut coir under greenhouse conditions and to compare these to pepper plants grown in soil without coir.

1.3 Research questions

The research study addressed the following research questions below:

- What are the major effects of coir substrate on the growth parameters of *C. annuum* varieties?
- Does coir substrate affect the yield of sweet pepper (*C. annuum*) varieties?
- What are the effect of coir substrate on the concentration of biochemical constituents of *C. annuum* fruit varieties?

1.4 Aims and objectives

1.4.1 Aim

The main aim of the study was to determine the effect of coconut coir substrate on the crop characteristics (growth, yield and quality) and biochemical features of sweet pepper (*C. annuum*) varieties grown under greenhouse and to compare these features to those of control pepper plants grown without coconut coir but rather with loamy soil as substrate.

1.4.2 Objective

In achieving this study aim, the following study objectives were addressed:

- To evaluate the effect of coconut coir substrate on the growth and development of sweet pepper (*C. annuum*) varieties grown under greenhouse conditions.
- To evaluate the effect of coir substrate on the yield performance of sweet peppers (*C. annuum*) varieties grown under greenhouse conditions.
- To assess the effect of coir substrate on biochemical constituents of sweet pepper (*C. annuum*) varieties grown under greenhouse conditions.

1.5 Reliability and validity

According to Creswell (2014), the consistency and dependability of tools and techniques used to assess plant growth, development and production in this study, is referred to as reliability. Credibility, or internal validity, refers to the accuracy and integrity of the research and its findings (Pandey & Patnaik, 2014) which aims to answer the question of how the findings correspond with reality (Shenton, 2004). The degree of credibility in scientific research is determined by the procedures and equipment utilized to gather information and evaluate data in order to answer the research questions of interest. Employing dependable, genuine and fair techniques, supervising tests and, most importantly, accurately recording data were all vital in this case (Creswell, 2014).

The growth and development of the *C. annuum* varieties crop was assessed using a randomised design under greenhouse controlled climatic factors for crop growth, yield performance, and biochemical content. The resulting data were analysed using appropriate statistical processes in order to draw findings.

1.6 Bias

It is vital to use practical strategies to avoid prejudice when experimenting. Bias, according to Creswell (2014), is a flaw in the design or execution of an experiment that is skewed in one direction due to non-random factors. The number of replications, randomization, and seasonal recurrence of the investigations were considered in this study to reduce the experimental error in each trial (Mouton. 2013).

1.7 Significance of the study

The human population is currently increasing at an exponential rate and so the need for food is increasing while at the same time the available space for agricultural production is diminishing as urban settlements expand (Crist and Engelman, 2017). South Africa is no different, as the worldwide agricultural industry's challenges revolve around creating new technologies that enhance crop yields per unit of area while also improving the quality of the products. The South African farming community is exploring and slowly opening up to organic substrates for the development of cash crops such as sweet peppers and other vegetables due to rising challenges regarding climate, as well as soil and water supplies for irrigation in South Africa. The biggest downside of such substrates, however, is the high initial setup cost (Cooper, 1975; Winsor and Schwarz, 1990).

A meta-analysis indicated that there are little data on the effects of coir substrate on sweet pepper (*C. annum*) growth, yield and quality, and so most farmers are not incentivised to use it as a plant growth substrate. However, if scientific evidence is provided, as in this dissertation, that shows how its use may improve crop performance (growth, development, and yield). Farmers may be more interested in adopting its use for agronomic reasons and increased potential returns.

When analysing the effect of coir substrate on the growth, development, yield and quality of sweet pepper (*C. annuum*) varieties within a greenhouse setting, it was necessary to anticipate variation in the crop's growth performance and yield. Temperature, irrigation, pH, electric conductivity and fertilizers all variably impact the performance of the pepper varieties (Eifediyi et al., 2010). Likewise, the use of coir substrate may have a variable effect on crop growth and yield characteristics. Crop varieties are also variably affected by irrigation and fertilizers (Eifediyi et al., 2010).

Coconut coir as an alternative to Rockwool is increasingly being used as a substrate for soilless hydroponic production of sweet peppers under greenhouse (Olle et al. (2012). *Capsicum annuum* yield and fruit quality may be influenced by substrate composition which may affect nutrient availability under timed fertigation. Rubio et al. (2010) noted that the influence of mineral nutrition on crop quality characteristics, such as soluble solids, flavonoids, and on physical characteristics, such as fruit shape index, firmness and pulp thickness, has not been studied extensively in pepper plants grown with coconut coir under greenhouse conditions. The use of coir may contribute to a substantial reduction in operational costs in addition to other benefits such as composting.

Additionally, using coconut coir substrate as a growth medium may have an impact on the biochemical characteristics of pepper varieties, particularly those grown in greenhouse environments, subsequently contributing towards improving consumer health (Achaglinkame et al., 2019).

1.8 Dissertation overview

The structure of the dissertation outlines the research study process and activities. Chapters 1 and 2 introduces the reader to the use of coir, particularly for optimizing sweet pepper plant cultivation while Chapters 3 and 4 are formulated as publishable articles that report research outcomes in a systemic and comprehensive manner. Chapter 5 provides a summary of the research and results and suggests future, relevant research.

The different chapters and the summaries of their contents are as follows:

Chapter 1 Introduction

This chapter provides a brief background to improving the cultivation of pepper plants (*C. annuum*) in the presence of coir and goes on to describe a study problem statement, aim and study objectives, and the significance of the study.

Chapter 2: Literature review

The literature review provides detailed background information on the importance of agronomic factors which have a direct and indirect effect on the growth, development and yield of *C. annuum* as a crop, and the need to research the quality of this crop. This chapter concludes by identifying gaps in the literature and justifying the research.

Chapter 3: The effect of coir substrate on the growth, development and yield of *Capsicum annuum* varieties

This chapter briefly introduces aspects of sweet pepper plant growth using coir as a substrate before focusing on current study results regarding parameters of growth, development and yield *C. Annuum* varieties grown with coconut coir as substrate under greenhouse conditions. These results are then discussed in detail and compared to control pepper plants grown under similar conditions but in loamy soil.

Chapter 4: investigating the effect of coconut coir substrate on the biochemical constituents of different *Capsicum annuum* fruit varieties

This chapter introduces and then focuses on the effects of coconut coir substrate on biochemical quality, such as vitamins, flavonoids, etc, of different *C. annuum* varieties grown in coir substrate and compares these study results to results obtained from pepper plants grown in loamy soil.

Chapter 5: Summary and future work

This final chapter of the thesis collates the main research findings and articulates major conclusions arising from the research study. Further research is suggested.

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Chapter 2: Literature Review

The purpose of this literature review is to critically evaluate published studies on *C. annuum* particularly focussing on relevant research describing *C. annuum* performance, yield and quality. In this literature review, the numerous approaches and criteria used to measure agricultural performance and yield are key dynamics. This literature review also provides background information on the importance of the use of coconut coir in agronomic crops, factors which have a direct and indirect effect on the growth, development and yield of the crop, and the need to research coconut coir and its impact on the growth, yield and quality of crop.

2.1 *Capsicum annuum* as a research crop

Capsicum annuum, also known as sweet pepper, is an annual crop belonging to the family *Solanaceae*. These plants have dark green leaves, milky white flowers, hollow with many seeded berries (Unal., 2013). The fruits vary in size, shape and colour but characteristically droop in different forms.

The crop is native to Central and Southern America, with Mexico and the Caribbean being well-known recorded origins of the plant (Callejón-ferre et al., 2011). Researchers such as Vigyan et al. (2011) and Zhang et al. (2014) reported that *C. annuum* was developed into an agronomic crop at least 5 000 years ago and can grow across a range of dry, sub-arid, sub-humid and humid forests from sea level to an altitude of 2 500 metres. Although normally considered a self-pollinating crop, outcrossing of up to 91% may occur, depending on bee activity and heterostyly (Vigyan et al., 2011). The preferred soil type for *C. annuum* is light to well-manured, limey soil and, during rainy seasons, well drained and heavy soils (Basu & De, 2003).

2.2 Environmental factors affecting growth, development, yield and quality of Capsicum annuum

Pramanik et al. (2020) reviewed factors that influence the growth of *C. annuum* under protective structures such as greenhouses. Although some species of *C. annuum* display a photoperiodic reaction, they are considered warm-season, day-neutral plants (, 2015). Imposing particular photoperiods may speed up the vegetative cycle but reports in the literature regarding this are mixed (Basu & De, 2003). *Capsicum annuum* can tolerate shade up to 45% of prevailing sun energy but this can cause a delay in flowering that subsequently may extend the growing season. *Capsicum annuum* thrives in well-drained loamy soils with a pH range of 5.5 to 6.8 (Luna-Ruiz et al., 2018) necessary for growth in regions with a rainfall ranging between 600 mm to 1 250 mm. Most cultivars are harmed by severe flooding or drought.

The current study used coconut coir with the experimental plants and loamy soil with the control plants to investigate their impact on growth, yield and quality on two different pepper varieties (Sondela and Ilanga).

2.2.1 Temperature

The direct effect of temperature on plant growth, development and yield has been investigated by various researchers (Benzioni et al., 1991; Adachi et al., 2000). Their findings reported that extreme temperatures ranging between 10˚C and 40˚C could lead to plant death but some plants have adapted to extreme temperatures associated with their natural habitat (Shvarts et al., 1997: Weiss & Borochov, 1997). If the temperature range of a certain region prohibits the normal growth of certain crops, the use of plant growth structures such as greenhouses and shade netting should be used as alternatives to overcome the challenges caused by unfavorable conditions (Hochmuth, 2001).

According to Polowick and Sawhney (1985), temperature conditions strongly influence the development of flowers and fruits of sweet pepper plants. A low temperature ranges (LTR) of 18°C day/15°C night exerts much more of a vegetative effect on flowers and fruits than an intermediate temperature range (ITR) of 23°C day/18°C night or a high temperature range (HTR) of 28°C day/23°C night).

2.2.2 Irrigation management

The most critical factor that must be met in order to maintain high agricultural yield quality is the plant-water relation (Alomran & Luki, 2012). Water availability has a direct impact on plant organs including roots, stems, leaves and fruits, as well as physiological parameters such as chlorophyll, stomatal conductance and plant height (Li et al., 2018). Plants spend very little energy in maintaining and repairing their metabolomics pools, and so they are able to compensate for stress associated with, for example, water deficit (Maria et al., 2013). When such stress factors surpass a plant's ability to regenerate, its physiological and ecological function suffers (Parajuli et al., 2019). For the current study, coconut coir growing bags and loam soil were fertigated using drip irrigation immediately after transplanting.

2.2.3 Growth media

Rhodes (1995) defined soil as a shallow, degraded mantle of material covering the bedrock sheath of the earth, that has been modified and advocated by biological, chemical and physical agents, with its primary roles being to anchor plant roots, hold nutrients and moisture and make them available for plants roots. Sigüenza et al. (2005) indicated that sweet peppers perform well in organic-rich, well-drained soil with moderate water-holding capacity. Therefore, the present study evaluated the effect of coir substrate on the growth, development and yield of sweet pepper varieties under greenhouse conditions because of the ability of coir to drain water freely, its capacity to retain water and to provide aeration.

2.2.4 Light

According to Brazaityte et al. (2009), light is the most important environmental component that influences plant growth, biomass production and metabolic activity. In addition, Pettersen et al. (2010) studied how plants convert sunlight into chemical energy through photosynthesis. Fruit quality and yield are determined by the amount of light that the plant receive but Kaiser et al. (2019) did find differences in terms of height and leaf index for seedlings grown under different light intensities. Under low-light intensity, most seedling leaves become etiolated and more prone to disease, whereas seedlings grown under high light intensity demonstrated longer stem height and an intensive leaf area index. The current study monitored light intensity during different growth stages (pre-flowering, flowering and fruiting) to determine its effect in sweet pepper plant growth, development and fruit yield.

2.3 Physiological factors affecting plants grown under different substrates

According to Savvas et al. (2008), plant physiological activities such as growth and development are regulated by the growing environment and the availability of nutrients. Consequently, the high production and quality of fruits are governed by the environmental conditions to which the plant is exposed. The physiology of two sweet pepper varieties were monitored in this study with the goal of evaluating the effect of coir substrate on the development, yield and quality of these sweet pepper varieties.

2.3.1 Chlorophyll content

Chlorophyll is essential for plant growth and development since it turns sunlight into energy through photosynthesis (Waters et al., 2010). The chlorophyll content is the amount of chlorophyll accumulated during the photosynthesis process when plants convert solar energy into chemical energy (Adachi et al., 2000). Chlorophyll molecules are most effective at absorbing light wavelengths in the blue and red range and contribute to the plant leaves' green colour (Alomran & Luki, 2012). Chlorophyll is also important for converting light energy into chemical energy, which allows the plant to perform metabolic tasks (Abu-Zinada, 2015). Because chlorophyll has a direct impact on plant growth, development, and yield, the current study examined this factor at various growth phases (pre-flowering, blooming, and fruiting) of the sweet pepper plants.

2.4 The effect of growth media on yield components of Capsicum varieties

2.4.1 Plant biomass

The weight of living plant material that is present above and below a certain unit of ground surface area at a particular time is known as plant biomass (W). Production is the weight or biomass of organic matter consumed by a group or species per unit of time and land area. There are various variables that affect plant biomass, including genotype, photoperiod, solar radiation, and soil temperature, and soil and air humidity. Soil nutrient availability is one of the most crucial elements affecting biomass (Arancon et al, 2005).

Peat, perlite, and vermicompost were three different growth media that were examined by (Alboho et al 2009) to see how they affected pepper variety growth and yield. The scientists found that the two examined varieties responded differently in terms of plant height, leaf size, chlorophyll content, and overall yield when they were cultivated on various substrates.

To fill a gap in the body of research, the current study examined specifically how coconut coir substrate affected the growth, development, and yield of various Capsicum cultivars cultivated in greenhouse environments.

2.4.2 Fruit number and yield

The average quantity of fruit and its size, which are carefully assessed in order to compute the yield, are referred to as fruit yield and number. Numerous variables, including light, temperature, growth conditions, and nutrition, affect fruit output, number, and size (Roy et al, 2011).

Under greenhouse settings, Gungor and Yildirim (2013) assessed the impact of various growth media (individually-peat and perlite) as well as combined or mixed growth substrate on the growth, and yield of pepper. When compared to individual substrates like peat and perlite, researchers found that mixed substrates had a better fruit production and number of fruits. To fill this gap in the literature, the current study assessed the impact of coconut coir on the quantity and yield of various Capsicum types cultivated in greenhouse environments.

2.4.3 Harvest index

The harvest index, which gauges productivity effectiveness, is calculated as the ratio of dried fruit to total dry biomass. The harvest index of 0.50 is typically regarded as the ideal value in the majority of horticultural crops. While this is a helpful generalization that can be used to assess crop yield, it is important to remember that this number might change based on the environmental factors. The entire harvest index of the crop is significantly influenced by additional variables like soil type, temperature, and irrigation.

Hedge (1987) assessed the relationship between soil moisture and nitrogen fertilization and bell pepper growth analyses. The author discovered that irrigation at 40 percent soil moisture resulted in the maximum harvest index of Capsicum types as opposed to 60 percent available soil moisture. In this study, the impact of coconut coir on th harvest index of *C. annuum* varieties cultivated in greenhouse environment was assessed in order to fill the gap in the existing literature.

2.5 Bio-chemical constituents in plants

Although people consume certain groups of fruit for a variety of reasons, the main traditional goal for consuming fruit is the possible absorption of energy and nutrients (Kader, 2005). Sugars are obtained by humans following the consumption of plant products such as fruit and vegetables and so it is critical to assess the sugar content of certain fruits grown in a particular substrate (Ali & Abdelatif, 2001). Nagre (2013) studied the effect of substrates on the quality of sweet pepper fruit and recorded the maximum number of fruits per plant, average fruit weight and the fruit yield per plant was observed to be the best package for high yield and better quality.

2.5.1 Total soluble sugars

According to Osuji et al. (2015), soluble sugars are very prevalent molecules, accounting for around 80% of sugar in plant fruits. Arrom and Munné-Bosch (2012) described them as one of the first products of photosynthesis that are mobilized in plant cells to produce energy during respiration and glycolysis. Total soluble sugar is mostly present in fruit, and it is the principal source of energy for body cells (Bernaert et al., 2013). Sugars are a primary source of carbon and energy in plants but they also play a vital signaling role in numerous physiological processes (Otalora et al., 2020).

Recent research reported that when plants were exposed to abiotic stress, sucrose import was restricted to significantly impact generative plant growth and result in fruit abortion (Otalora et al., 2020).. Heat stress increases the sugar content of leaves in general but salicylic acid had the opposite effect in plants treated to a combination of these stresses leading to a reduction in glucose and fructose concentrations, but not the sucrose concentration (Osuji et al.,2015). Elwan et al. (2009) reported that spraying sweet pepper plants with a low concentration of salicylic acid (1 M) reduced the sugar content of the leaves but increased it in the fruit and linked this to the role of salicylic acid in energy status balancing, assimilation, translocation and storage.

2.5.2 Crude proteins

According to López et al. (2013), crude protein is the amount of protein contained in plant organs. It is usually calculated by determining the total nitrogen content of plant tissue, primarily in dried fruit (Osuji et al., 2015). The overall proportion of crude protein in dry fruit matter varies depending on the genotype of the plant and the growing conditions to which the plant was subjected during cultivation (Mabhaudhi et al., 2013). However, the crude protein content of the crop may be influenced by the many cultural treatments to which it is subjected during production (Legwaila et al., 2011). Therefore, the current study quantified the crude protein percentage of two *C. annuum* varieties grown on coconut coir under greenhouse conditions.

2.5.3 Beta carotene

Beta carotene includes lipids that improve human vision, cell division and differentiation, bone growth and reproduction (Moyo et al., 2018). In plants, it also has a range of other functions, such as fruit yellowing (Ismail, 2014) as well as intercepting blue light and transmitting it to photosynthetic centres (Manthey & Perkins-Veazie, 2009).

Multiple environmental factors influence the beta carotene content of fruits and vegetables and so significant differences may be noted in the beta carotene content in vegetables such as carrots cultivated in different climatic zones (Fenech et al., 2019). There is scanty literature regarding beta carotene in *C. annuum* varieties grown under coconut coir substrate and so the current study set out to quantify the beta carotene content of the fruit of two *C. annuum* varieties grown on coconut coir substrate under greenhouse conditions.

2.5.4 Vitamins

Vitamins are essential organic substances that must be consumed in sufficient quantities for optimal growth and development (Esch et al., 2010). Fruit vitamins play an important role in human health because they are involved in many of the body's natural functions such as development, digestion, immunity and metabolism (Locato et al., 2013). Moreover, due to environmental conditions that surround the plants, the vitamin content of fruit varies. For example, in a study conducted by Sinha (2015) to assess the vitamin C content of citrus fruit gathered from various locations, it was discovered that fruit harvested from soil sites that had never been fertilized had a lower vitamin content than those harvested from fertilized soil. In addition, differences in vitamin E levels were found in similar cultivar varieties that were grown under the same conditions and location. The current study set out to quantify the vitamin C and vitamin E content of the fruit of two different *C. annuum* varieties grown under coconut coir substrate and compared to control varieties grown in loamy soil under greenhouse conditions.

2.5.5 Total flavonoids

Flavonoids are phenolic chemicals naturally found in various fruits such as berries, grains, tree bark, tea and grapes (Hu et al., 2019). These organic compounds are well-known for their beneficial effects on human health, including the prevention of disorders such as autism, asthma and obesity (Saeed et al., 2012). According to Fenech et al. (2019), flavonoids are one of the reasons why humans should consume fruit and vegetables daily. People whose survival depends on the careful selection of certain meals are more likely to follow a diet plan that takes into account not just the food's nutritional content, but also its acceptability and supply of helpful elements such as flavonoids (Krogholm, 2011). In the current study, the effect of coconut coir on the expression of flavonoids in *C. annuum* fruit varieties was evaluated to contribute to knowledge on this subject.

2.5.6 Total phenols

Phenols are a group of compounds made up of aromatic amino acids (Hossain & Shah, 2015). Plants use these chemicals to protect themselves from predators and UV rays. Most fruit and flowers can become pigmented as a result of a deficit in phenolic (Bernaert et al., 2013). In food science and nutrition, phenolic chemicals such as those found in berries and other fruits are known to play a pivotal role in human health (Oliveira et al., 2008). Research has focused on extracting and analysing phenolics from a variety of fruits. For example, Zhang et al. (2019) extracted phenolics from *C. annuum* plants treated with ammonium ions (NH^{4+}) and nitrate (NO_3^{2-}). They found considerably higher levels of phenolics in fruits grown from treated plants as compared to untreated fruits. The current study set out to contribute to the literature by quantifying the total phenolic in the fruit of two varieties of *C. annuum* grown under greenhouse conditions using coconut coir substrate or loamy soil as growth media.

2.5.7 Macro and micro-nutrients

Micronutrients are required in small amounts, whereas macronutrients are required in relatively large amounts by both plants and humans (Barrett et al., 2010). Several studies have indicated that macronutrient availability in fruit is consistent (Wang et al., 2008) but their concentrations vary depending on environmental factors such as soil type, irrigation water regime, location and temperature (Olle et al., 2012; Schauer & Fernie, 2006). These factors have shown a significant impact on the levels of macronutrients such as phosphate, magnesium and sulphur in tomatoes grown under varying greenhouse conditions.

Water stress causes a decrease in some macronutrient elements, whereas micronutrients such as iron, zinc and molybdenum may remain unaffected and even increase in some fruits (Sezen et al., 2010). In the study conducted by Baloch et al. (2008) on the effect of foliar application of macro- and micronutrients on production of green chillies, they found that plant height, biomass, fruit length, fresh fruit weight and yield varied according to treatments. Furthermore, a decrease in the levels of macronutrients was noted in fruit of plants that were not treated.

There appears to be scanty knowledge on the macro- and micronutrient content of *C. annuum* variety fruit grown under coconut substrate and so the current study set out also to quantify these elements in *C. annuum* varieties grown under coconut coir.

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Chapter 3: The effect of coir substrate on the growth characteristics and fruit yield of *Capsicum annuum* varieties

3.1 Abstract

A factorial experiment with sweet pepper varieties- (Ilanga and Sondela) was conducted under greenhouse conditions (20-30˚C). The growing bags experiment was a completely randomized design with 18 replicates. Growing bags were spaced 40 cm apart, and up-rope vertical trellising was used to support plants. Well-established uniform and healthy seedling that were 40 days old were germinated from peat substrate were transplanted into 20 cm deep × 40 cm wide bags, either under coir as substrate (experiment) or in loamy soil (control). Data on plant growth parameters were collected during different stages of plant growth (pre-flowering, flowering and fruiting). The plant growth parameters measured included chlorophyll content, stem diameter, plant height and fruit number. Yield components were also measured, which included above ground biomass, total biomass, the harvest index and water content. The study results showed that there was no substantial variation on the total biomass, harvest index and fruit number of the two *Capsicum annuum* varieties (Ilanga and Sondela) grown under varying conditions - substrate coir and loamy soil-control. However, the highest total biomass (0.26 kg) was observed from the combination of variety (Sondela) and coir substrate and compares to that of (0.13 kg) recorded from a combination of variety (Ilanga) and coir substrate. The treatment combination of variety (Sondela) and loamy soil substrate resulted in the highest harvest index of (0.47), while a maximum harvest index of 0.43 was shown for the Ilanga variety combined with coir substrate. The treatment combination of variety (Ilanga) and coir substrate resulted in a higher fruit number (n=5), whereas the treatment combination of variety (Sondela) and substrate coir obtained a maximum fruit number of (n=4). It can thus, be deduced that treatment combination of variety (Ilanga) and coir substrate are desirable for yield maximisation. Therefore, growers are encouraged to select variety (Ilanga) when using coir substrate under greenhouse condition for profit maximisation.

Keywords: *Capsicum annuum*, fruit number, harvest index, total biomass, yield

3.2 Introduction

An ever-increasing global population necessitates that food growers must look for sustainable way of producing food in order to meet food demand and supply (Pingali, 2001). Fundamental to optimal plant growth is that plant roots should acquire sufficient oxygen and have optimal water and nutrient absorption to promote plant growth, development and yield (Maluleke et al, 2021). Consequently, most growers will choose growth media as opposed to natural soils that will require a lower irrigation frequency and fertilizer regime within greenhouse environments (Jawaad Ati et al., 2016; Li et al., 2018). However, while there is substantial literature on the effect of various growth media on the growth, development and yield of various crops, there is little information on the use of organic substrates. Coconut coir substrate is one such growth medium that has promising potential benefits to plant growth, development and yield. Gama et al. (2015) defined coir as an organic, natural product derived from the external husk or mesocarp of coconut fruit. As indicated in Chapter 2, the advantages of coconut coir substrate were explained by Olle et al. (2012) as: (i) coir is almost 100% organic and is renewable, (ii) its use as a substrate provides good drainage, (ii) coir provides high water holding capacity, (iv) coir promotes accelerated root growth and development and (v) coir is relatively affordable. A wise grower will invest much thought and resources into selecting a suitable growth medium as well as crop variety that shows the potential to yield better economic returns (Tomás-Callejas et al., 2011). Growing a plant in a container is different from growing it in the field (Dole, 2005) and while there are publications reporting various effect on cultivation of peppers (*Capsicum annuum*) using substrates such as compost, potting soil and sandy loam, relatively little attention has been paid to research on the impact of coconut coir on the cultivation of pepper varieties (Unal, 2013). An objective of the current study was, therefore, to investigate the effect of coconut coir on the growth and yield of greenhouse grown pepper varieties.

3.3 Materials and methods

3.3.1 Study site and experimental overview

The study was conducted during the spring and summer seasons of 2021 and 2022 under greenhouse conditions at the Science Campus, University of South Africa, Florida, Johannesburg, South Africa. The site coordinates are 26^{o} 10’ 30’’S, 27^{o} 55’ 22.8’’ E. The study involved two consecutive experiments where pepper (*C. annuum*) plants were cultivated from seedlings before the plants were harvested and analysed followed by a postharvest nutritional analysis of the fruit. The greenhouse temperature was maintained between 16˚C and 30˚C and the relative humidity was maintained between 50% and 60% using automated aerial sprinklers controlled by a humidistat (Anden Wall Mount Digital Humidistat, South Africa). The randomized experimental design involved two sweet pepper varieties, Ilanga and Sondela, grown in 18-replicate bags. The growing bags were spaced 40 cm apart, and up-rope vertical trellising was used to support the pepper plants. Well-established uniform and healthy germinated seedlings from peat substrate were transplanted into 20 cm deep × 40 cm wide bags before data on plant growth parameters were collected during different plant growth stages.

3.3.2 Fertiliser and irrigation treatments

Growing bags were fertigated using drip irrigation immediately following transplantation. This involved automatic mixing of multi-feed soluble fertilizers with water to ensure that plant nutrients were constantly supplied. Measurement of fertilizer EC and pH was monitored using a Priva-system, Netherlands.

The fertiliser concentration was applied as shown on the table 3.1 below:

Table 3.1. Nutrient composition of fertigation system/water

	Product	Application Rate 1000 L Tank	Injection rates L per 1000 L Pre 3rd truss flower	 Post 3rd truss
Tank A	Calcium Nitrate	80 kg	5	5
	Iron 6% EDDHA-chelate	1 kg	5	5
		8.10%		
Tank B	MAP	36 kg	5	5
Tank C	Magnesium Nitrate	80 kg	5	5
	Micromix with Iron 11% DTPA-chelate	4kg		
		8.40%		
Tank D	Potassium Sulphate	90kg	5	5
		9.00%		
Tank E	Nitric Acid	8L		
		11.90%		
	Calculated EC (mS.cm-1) at specified injections =		1.55	1.8

3.3.3 Analysis of coir and soil properties

As indicated in Table 3.2, prior to cultivation or transplanting, coir substrate and soil samples were analysed for cationic mineral content as well as physical properties such as moisture content and water absorption capacity of dry material and air filled porosity at saturation, using methods described by Rahil and Qanadillo. (2015). This analysis was conducted at the Agricultural Research Council, Institute for Soil, Climate and Water (ARC-ISWC) in Pretoria at coordinates 25° 44′ 19.4″ S, 28° 12′ 26.4″ E.

Table 3.2. Mineral analysis for substrates used for experiment.

Mineral analysis substrates					
	Fe mg kg^{-1}	Mn mg kg^{-1}	Cu mg kg^{-1}		Zn mg kg^{-1}
Coir power	40	10	5		10
Loamy soil	33.2	59.3	12.4		8.5
	P mg kg^{-1}	Ca mg kg^{-1}	Mg mg kg^{-1}	K mg kg^{-1}	Na mg kg^{-1}
Coir power	6	22	7	117	46
Loamy soil	27.8	1390	148	223	56.4

3.4 Data collection

3.4.1 Chlorophyll content

Plant chlorophyll content was measured at different growth stages during the experimental period. The leaf chlorophyll content (µmol/m^2) was measured in the morning using a leaf chlorophyll meter (Opti-Sciences-CCM 200 PLUS, USA). The instrument recorded four (4) replicate readings of the adaxial or upper leaf surface, since chlorophyll activities are more dominant on the upper leaf surface when compared to the lower surface (Shu et al., 2013), and provided an average value.

3.4.2 Total and above ground biomass

Above-ground fresh biomass (stem, leaves and fruits) was determined by weighing at the end of the experiment using an electronic scale (Uni-Bioc, China). Briefly, the plant material that had already been counted was weighed, placed in paper bags in an oven for 72 hours at 80˚C followed by re-weighing to determine the dry weight. Total biomass was determined using the formula below:

Total biomass = above-ground biomass (dry) + fruit biomass (dry) (Equation 1)

3.4.3 Fruit length and number

The number of fruits was visually counted, and length of each fruit was measured using a 30 cm ruler at the end of the experiment.

3.4.4 Harvest index

The *C. annuum* harvest index was determined by adopting the formula used by El-mageed & Semida, (2015) below:

$$\mathbf{HI} = \frac{\text{fruit dry biomass (dry)}}{\text{total biomass (dry)}} \qquad \text{(Equation 2)}$$

3.5 Data analysis

Generalised linear mixed model procedures for GenStat (version 14, VSN, UK) was used for data analysis. The model was used to assess the fixed effects of different varieties-(Ilanga and Sondela) and substrates (loamy soil-control and coir) during different seasons/years on the studied variables. Significant differences for one factor was considered and reported under results section to determine the effects of all studied variables (stem diameter, plant height, chlorophyll content, stomatal conductance, fruit number and length, total biomass, above-ground biomass, harvest index. Shapiro Wilk's and Bartlett's test was used to check the normality and homogeneity of variance. Least significant difference (LSD) of means was considered. All statistical analysis was done using GenStat (version 14, VSN, UK).

3.6 Results

3.6.1 Physiological parameters of *C. annuum* grown on coir substrate

Table 3.3. Plant growth parameters of *C. annuum* varieties grown under substrates coir and loamy soil (control)

Treatment	**Chlorophyll content (μmol.m-2)**		**stem diameter (mm)**		**plant height (cm)**	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**
Coir & variety						
Ilanga	41.3(6.3)	40.7(12.1)	10.12(2.1)	8.96(3.2)	64.9(6.5)	44.3(6.2)
Sondela	49.6(7.1)	48.3(8.4)	8.25(0.5)	10.19(3.4)	62.8(4.1)	44.09(7.8)
Loamy soil (control) & variety						
Ilanga	46.9(10.1)	42.3(7.1)	11.41(4.8)	10.2(0.8)	72.4(4.9)	55.1(11.1)
Sondela	53.5(11.4)	42.6(8.2)	11.81(6.3)	9.9(2.1)	70.9(10.5)	54.9(9.6)
Grand Mean	45.63	45.63	10.10	10.10	58.69	58.69
LSD0.05	6.04	6.04	1.04	1.04	2.21	2.21
Pvalue	0.745	0.745	**0.001**	**0.001**	**0.001**	**0.001**

Numbers in brackets represent the standard deviations of the mean. $LSD_{0.05}$ is the least significant difference of means. Years [seasons one – 2021 and season two – 2022]. P values in bold are lower than 0.05. $LSD_{0.05}$ is the least significant difference of means.

3.6.1.1 Chlorophyll content

The impact of coconut coir on different pepper cultivars' chlorophyll content, stem diameter, and plant height is shown in Table 3.3. The results demonstrated that there was no significant (P>0.05) change in the chlorophyll content of *C. annuum* cultivars cultivated in both coconut coir and loamy soil (control) during various seasons [2021 and 2022] that was statistically significant (P>0.05). However, the range of chlorophyll content for the 2021 season was 41.3 to 53.5 µmol.m^{-2}, whereas the range for the 2022 season was 40.7 to 48.3 µmol.m^{-2}. In contrast, the treatment combination of loamy soil (control) and variety (Sondela) increased chlorophyll content from 41.3 to 53.5 µmol.m^{-2}, as shown by the reduction of chlorophyll content caused by the combination of coconut coir substrate and variety (Ilanga) from 53.5 to 41.3 µmol.m^{-2}

3.6.1.2 Stem diameter

The study's findings showed that the effect of substrate on different C. annuum cultivars varied significantly (P≤0.05) in terms of stem diameter and plant height. Steam diameter varied from 8.2 to 11.8 mm in the [2021] season and from 8.9 to 10.2 mm in the [2022] season. The study's findings showed that using coconut coir and the Sondela cultivar together lowered stem diameter from 11.8 to 8.2 mm. The combination of loamy soil (control) and variety had the largest stem diameter, measuring 11.8 mm (Sondela).

3.6.1.3 Plant height

According to the study's findings, the influence of substrate on different C. annuum types varied significantly (P≤0.05) for stem diameter and plant height. The steam diameter ranged from 8.2 to 11.8 mm in the season [2021], and from 8.9 to 10.2 mm in the season [2022). According to the study's findings, the Sondela variety's stem diameter decreased from 11.8 to 8.2 mm when coconut coir was used as the therapy. In a combination of loamy soil (control) and variety, the largest stem diameter of 11.8 mm was found (Sondela).

3.6.1.4 Fruit number

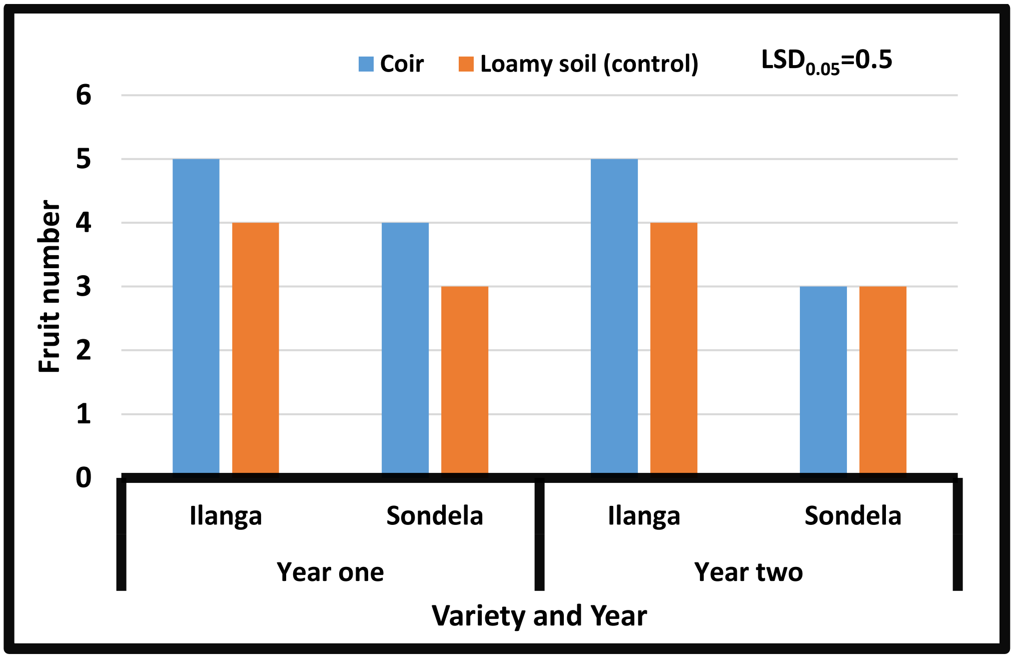

Figure 3.1. Effect of coconut coir on the fruit number of peppers varieties. Years [one – 2021 and two – 2022] represent seasons. $LSD_{0.05}$ is the least significant difference of means.

The quantity of fruits produced by Ilanga and Sondela cultivars of C. annuum cultivated in coir substrate and loamy soil (control) under greenhouse conditions over the course of many seasons is shown in Figure 3.1 [2021/2022]. The study's findings showed that the quantity of fruits produced by several pepper cultivars grown on coir substrate varied significantly ($P \leq 0.05$). Data from season one [2021] indicated that fruit numbers ranged from 3 to 5. Season two [2022] results also indicated that fruit numbers ranged from 3 to 5. The number of fruits decreased from 5 to 3 when the substrate and variety were combined with loamy soil-control and coconut coir, however it grew from 3 to 5 when the substrate and variety were combined with the coir variety (Ilanga). The cultivar (Ilanga) shows greater fruit production in both seasons (2021 and 2022), which is noteworthy.

3.6.2 Yield components

Table 3.4. Yield components of *C. annuum* varieties and combination of coir substrate and loamy soil (control)

Treatment	Total biomass (kg)		Above Ground Biomass (AGB)		Harvest index	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**
Coir & variety						
Ilanga	0.15(0.01)	0.16(0.02)	0.08(0.01)	0.09(0.01)	0.43(0.01)	0.42(0.1)
Sondela	0.13(0.02)	0.26(0.01)	0.07(0.01)	0.06(0.02)	0.42(0.1)	0.44(0.3)
Loamy soil (control) & variety						
Ilanga	0.14(0.02)	0.13(0.02)	0.08(0.02)	0.08(0.01)	0.42(0.02)	0.39(0.01)
Sondela	0.10(0.03)	0.08(0.01)	0.06(0.01)	0.04(0.01)	0.43(0.03)	0.47(0.02)
Grand Mean	0.14	0.14	0.07	0.07	0.44	0.44
LSD0.05	0.10	0.10	0.02	0.02	0.04	0.04
Pvalue	0.418	0.418	0.410	0.410	0.138	0.138

Numbers in brackets represent the standard deviations of the mean. $LSD_{0.05}$ is the least significant difference of means. Years [seasons one – 2021 and season two – 2022]. P values in bold are lower than 0.05. $LSD_{0.05}$ is the least significant difference of means.

3.6.2.1 Total biomass

According to Table 3.4's, there was no discernible difference (P>0.05) in the total biomass of *C. annuum* types planted in both the 2021 and 2022 growing seasons between those grown on coconut coir and loamy soil (control). While biomass for season [2021] ranged from 0.10 to 0.15 kg, it varied from 0.08 to 0.26 kg during season [2022. Instead of increasing total biomass from 0.08 to 0.26 kg, coir substrate and variety (Ilanga) raised it from 0.08 to 0.26 kg in the treatment combination of loamy soil (control) and variety (Sondela).

3.6.2.2 Aboveground biomass

The study findings on Table 3.4 showed that there was no significant (P>0.05) difference in aboveground biomass of C. annuum cultivars cultivated on various substrates (coconut coir and loamy soil-control) for both seasons [2021 and 2022]. However, during season one [2021], above-ground biomass varied between 0.06 and 0.08 kg, while during season two [2022], it varied between 0.09 and 0.04 kg. While coir substrate combined with variety (Ilanga) increased aboveground biomass from 0.04 to 0.09 kg, the treatment combination of loamy soil-control and variety (Sondela) decreased it from 0.09 to 0.04 kg.

3.6.2.3 Harvest index

Table 3.4's findings regarding the harvest index indicate that there was no significant (P>0.05) difference in C. annuum growth on substrates (coir and loamy soil-control) during the two seasons [2021 and 2022]. But during season one [2021], the harvest index ranged from 0.42 to 0.45, whereas in season two [2022,] it varied from 0.39 to 0.47. The study's findings also demonstrated that the harvest index was reduced from 0.47 to 0.39 by the treatment combination of loamy soil and control (Ilanga), but it was increased from 0.39 to 0.47 by the treatment combination of loamy soil and variety (Sondela).

3.6.2.4 Water content

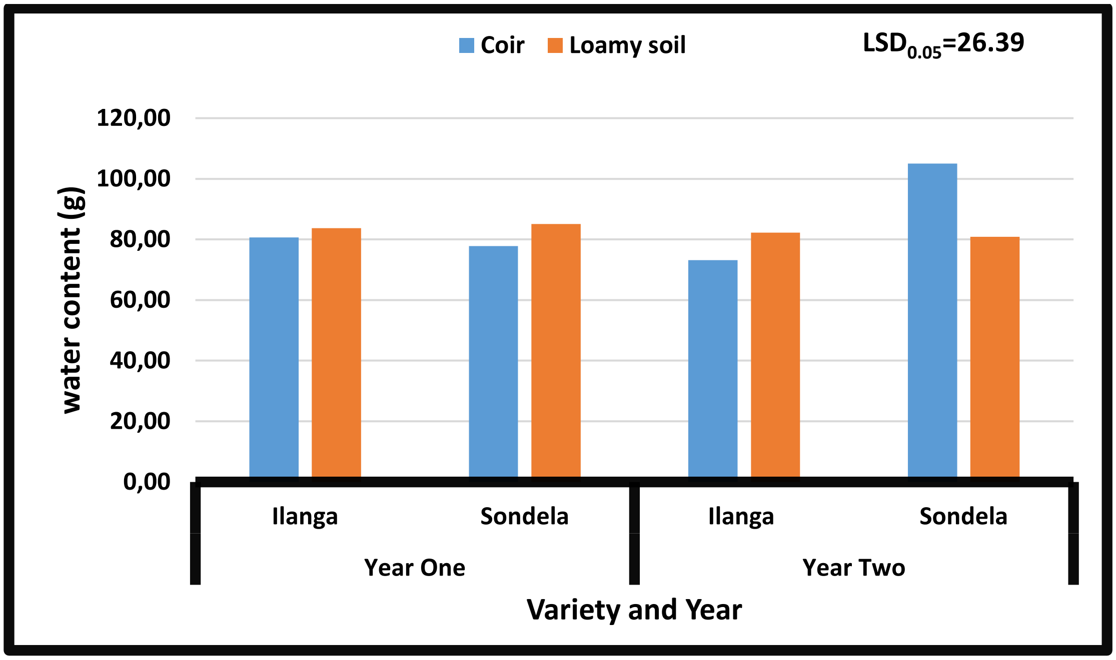

Figure 3.2. Effect of coconut coir on the water content of *C. annuum* varieties. Years [one – 2021 and two – 2022] represent seasons. $LSD_{0.05}$ is the least significant difference of means.

The influence of substrate (coconut coir and loamy soil-control) on the water content of different C. annuum cultivars throughout various seasons [2021 and 2022] is shown in Figure 3.2. The study's findings show that there was no change in the water content of pepper cultivars grown on substrates that was statistically significant ($P>0.05$) (coconut coir and loamy soil-control). While season two's water content ranged from 73.2 to 105 g, season one's water content ranged from 77.8 to 83.7 g. The treatment of coconut coir combined with variety (Sondela) increased water content from 73.2 to 105 kg, whereas the treatment of coconut coir combined with variety (Ilanga) decreased water content from 105 to 73.2 g.

3.7 Discussion

This study assessed the effect of coconut coir substrate on the of growth of pepper varieties under greenhouse conditions over two growing seasons as compared to the effect on the growth of these pepper varieties grown in control, loamy soil. Previous research investigated the effect of nutrient management, postharvest quality, and on the yield, quality and physiological response of peppers grown on various substrate such as vermicompost and other soilless culture. According to the best of our knowledge, this is the first study to evaluate the effect of coconut coir on the growth, development and yield of different pepper varieties (Ilanga and Sondela). Therefore, the findings of this work are novel.

Stem diameter

The soil's nutritional makeup affects the growth and development of stems. In addition to provide physical support, soil must constantly feed plants with enough nutrients, water, and a gaseous environment for their root systems. The results of the study showed that plants grown in loamy soil accumulated greater stem diameters than those cultivated in coconut coir. In comparison to coconut coir, the study's findings showed that the stem diameter from loamy soil-control was greater (10.8 mm) (9.3 mm). The difference between the mean values for the two substrates was 1.5 mm. It has been demonstrated that macronutrients, such as phosphorus, play a crucial structural function in plant growth and development, including cell division and the emergence of new tissue (Khanal, 2018). A significant factor in the difference in stem diameter may have been the loamy soil's high phosphorus concentration. These results are consistent with those of Khanal, (2018) who found variance in plant height grown on various substrates with various macronutrient contents.

Total biomass

The findings show that total biomass was higher under the coir substrate (0.17), compared to the control, loamy soil (0.11). Between substrates, there was a 0.06 kg difference. Total biomass variation between these two substrates indicates that coconut coir and variety (Ilanga) were superior than loamy soil (control) and variety, despite the statistically insignificant difference (Sondela). Turgor pressure within guard cells and plant total biomass are related. When solutes are actively building up in the guard cells, stomata open. As solutes pile up, water moves into the guard cells and turgor pressure rises above that of the epidermal cells in the area around them. When compared to coconut coir, which has higher drainage and aeration capacity, loamy soil may have had low biomass because it has medium to poor drainage and aeration capacity. As a result, coconut coir has a better ability to collect more total biomass than loamy soil (control). These results are in line with those of Amor (2009), who found that plants cultivated on coconut coir dust produced greater biomass than plants grown on alternative substrates.

Harvest index

Results from the study showed that coconut coir harvest index varied marginally (0.428) from the loamy soil-control group (0.432). It is common knowledge that a plant's capacity to increase its harvest index is correlated with how effectively it can absorb micronutrients. Although coconut coir substrates' superior micro-mineral composition in loamy soil (the control) was greater, this difference had no effect on either variety's harvest index (Ilanga and Sondela). Although the study's findings showed that there was no difference between these substrates, we had anticipated that the loamy soil (control) harvest index would be higher than that of coconut coir. Between the substrates (coconut coir and control loamy soil), the harvest index values were essentially equal.

Despite this, there were large differences in the mineral makeup. The results of this study so suggested that, if the nutritional composition is well controlled, coir substrate could be a sturdy substrate that can be used for commercially cultivating pepper crops in greenhouse environments. These results support those of Castellanos et al. (2017), who discovered a higher yield on vermicomposting compared to other substrates. Harvest index values obtained between substrates (coconut coir and loamy soil-control) were almost identical.

Plant height

The research found that there was a considerable difference in plant height across treatments for both kinds (Ilanga and Sondela). The greatest loamy soil-control (63 cm) and the lowest coconut coir (54 cm) had mean values that differed by 9 cm, with variety (Ilanga) showing greater height than variety (Sondela). It is commonly recognized that calcium is essential for the development of plant tissues, which allows for greater growth. Perhaps a key factor in the variance in plant height was the greater calcium content of loamy soil (the control) compared to coconut coir. The medium's mineral content has a big impact on how well plants grow. In a study by Jasso-Chaverria, (2005) for instance, it was discovered that an NPK-rich substrate increased fruit output by two times compared to a substrate with a low composition. It takes a lot of energy for plants to absorb minerals. As a result, when roots are deficient in calcium, the plant's capacity to absorb other nutrients is hampered, which has an adverse effect on the ratio of carbohydrates. Calcium is recognized to play a crucial role in root development. According to the study, coconut coir's low calcium content can cause it to degrade more quickly than substrates with greater calcium concentrations.

Fruit number

Grand mean data showed that Ilanga variety produced more fruits than other varieties, with fruit number being higher on coconut substrate compared to loamy soil (control) (Sondela). Among the substrates, the average fruit variation was 2. Due to their capacity to supply water, nutrients, and air movement for gaseous exchange inside the roots, substrates play a crucial role in the life of plants. In order to show that the substrate can increase fruit production to assist satisfy market demand, values obtained from coconut coir may be a powerful indicator. For farmers that raise fruits primarily for the fresh market, where quantity is crucial to fulfil daily customer demand, these findings are significant. These findings are comparable to those of Khanal (2018), who discovered that well-drained substrates produced more fruit than substrates with poor drainage.

3.8 Conclusion

The results of this study have demonstrated that the variety (Ilanga) mixed with coconut coir has the potential to be used as a dependable combination for commercial production in a greenhouse setting. Additionally, as the worldwide focus has shifted to eradicating hunger, this research has given farmers vital information. Additionally, this is helpful information for farmers that specifically supply the fresh market, where a certain quantity of fruits are needed to satisfy customer demand and generate a profit. The majority of markets also place a strong emphasis on organoleptic quality in pricey market places, for instance, it may be beneficial to grow the variety (Ilanga) under coconut coir because it is an organic product. The substrate's ability to be reused several times without endangering the environment is another benefit.

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Chapter 4: investigating the effect of coconut coir substrate on the biochemical constituents of different Capsicum annuum fruit varieties

4.1 Abstract

Biochemical constituents of crops depend on various factors such as growing environment and substrates. The use of organic substrates like coconut coir for greenhouse crop cultivation to ensure adequate food production of high quality has been preferred for various reasons such as; (i) its almost 100% organic and renewability, (ii) good water holding capacity, (iii) good aeration, and its relatively affordable, compared to natural soil. Therefore, the objective of the study was to determine the effect of coconut coir substrate on the yield and biochemical constituents of peppers varieties grown under greenhouse environment. Two *C. annuum* varieties (Sondela and Ilanga) were grown in fertigated coconut coir and loamy soil (control) under greenhouse environment for two consecutive seasons [2021 and 2022]. The number of *C. annuum* fruits, as well as their dried weight and selected biochemical contents, were investigated. Quantification was done using the concentration of dry matter and selected biochemical constituents from freeze-dried fruits samples. Results illustrated that treatment combination of coconut coir and variety (Ilanga) had more fruit number when compared to other treatments. Biochemical constituents such as vitamins, total phenols, total flavonoids, copper, iron, zinc, calcium, phosphorus, potassium and sodium were higher in fruits grown under coir substrate when compared to loamy soil (control). Growers are advised to utilise coconut coir substrates and varieties (Ilanga and Sondela) for higher crop yield and nutritional dance fruits, for good economical returns.

Keywords: Total phenols, macro and micro-nutrients, flavonoids, vitamins, iron, sodium

4.2 Introduction

Horticultural crops are an important part of a balanced diet required by human in both larger and small quantities (Ariel et al, 2009). Water, carbohydrates, lipids, proteins, fibre, minerals, organic acids, pigments, vitamins, and antioxidants are among the elements received by the human body from fruits (Salunkhe et al., 1991). Fruits are high in fibre, vitamins, and antioxidants (Anderson et al., 2007). Most fruits are accessible in a wide range practically during a specific period, and they not only taste delicious, but they also have appealing texture, colour, flavour, and ease of preparation (Benbrook, 2005). Fresh, cooked, hot or cold, canned, pickled, frozen, or dried are all options that can be utilised from fruits (Hiza and Bente, 2007). Fruits are consumed at all times, and they form components of great meals such as snack due to their size (Bernhardt and Schlich, 2006). They are low in calories and fat, cholesterol-free, high in carbohydrates and fibre, high in vitamin C and beta carotene (Barrett et al, 2007). Due to their low salt and a high potassium content, they play a pivotal role in human health and nutrition (Barrett et al, 2007) In addition, it has been established that the bioavailability of iron in the human diet is improved by ascorbic acid, which is normally found in fruit (Brummell, 2006). Although fruits contain a large number of metabolites, it is likely that no single item will have all of them. Fruits are high in potassium and comparatively low in salt. The bioavailability of iron in the diet is improved by ascorbic acid found in fruits. Consuming fruits is linked to a lower chance of developing serious diseases and may even delay the beginning of age-related ailments, according to a growing body of research, which promotes good health (Guillon and Champ, 2000). Authors such as Bvenura and Sivakumar (2017), reported that many individuals in sub-Saharan Africa do not consume enough fruits, which undermines the provision of a balanced and healthy diet. To counteract diet-related non-communicable diseases, the World Health Organization (WHO) recommended that each person should consume more than 400 g of fruit per day (WHO, 2003). The main causes of the low consumption have been attributed to a number of variables, some of which include unavailability, affordability, ignorance, and neglect (Miller et al, 2016).

The objective of the study was therefore, to determine the effect of coconut coir substrate on the yield and biochemical constituents of peppers varieties (Ilanga and Sondela) grown under greenhouse environment.

4.3 Materials and methods

The study was conducted during [2021 and 2022] growing season under greenhouse conditions at the University of South Africa at Florida campus in Johannesburg (26^{o} 10' 30''S, 27^{o} 55' 22.8'' E). Two consecutive experiments from seedlings, harvesting and postharvest nutritional analysis of the crop was undertaken. The greenhouse temperature was kept between (21 to 26 ˚C) and relative humidity was maintained between 50 and 60% using automated aerial sprinklers and (Anden Wall Mount Digital Humidistat). A factorial experiment with one factor *C. annuum* varieties (Ilanga and Sondela) was conducted under greenhouse conditions. The growing bags were spaced 1 m apart, and an up-rope vertical trellising was used to support the plants. On each site, growing bags were either filled coconut coir media or loamy soil (control). Each block comprised 18 plants, resulting in 36 plants on the site. Each site had plants used as guard plants. Well established, uniform and healthy sweet peppers varieties seedlings (Sondela and Ilanga) that were 30 days old, were transplanted into planting/growing bags:

$$V = Length(L) \times Width\ (W) \times Height\ (H)$$

$$L = 100\ cm \times W = 15\ cm\ \times H = 25$$

$$V = 11\ 250\ cm3.$$

4.3.1 Determination of Crude Proteins

Samples of freeze-dried fruit weighing 0.2 g was weighed, duplicated, and then analysed using a crude protein analyser (Trumac CN-Leco, Germany). The Dumas technique is used to calculate the carbon and nitrogen percentages per 100 g. To convert nitrogen to protein, the universal protein factor 6.25 was utilized, as previously described by (Lopez et al., 2013). Ethylenediaminetetra-acetic acid was used to calibrate the Trumac CN analyser (EDTA). Glycine was utilized as a certified reference material for quality monitoring.

4.3.2 Determination of Total Soluble Sugars

Peppers varieties fruit harvested from greenhouse were analysed for total soluble sugars concentration (˚Brix) following the method by (Tavarini et al., 2008). The fruit was cut into two portions, then juice was squeezed from a fruit portion by hand to release about 0.03 mL juice onto the aperture of the hand refractometer (HI 96801 Refractometer, USA) and readings were taken immediately. About 18 fruits were measured per treatment/variety. The aperture was washed between different juice samples with distilled water and dried with a soft paper towel.

4.3.3 Determination of Vitamin C and E

Fruit samples were freeze-dried for 72 hours using a freeze drier (HARVEST-RIGHT, Barcelona). The freeze-dried fruit slices were rigorously homogenized using a sterilised food blender and mixed with dried powder before nutritional analysis. The method described by Moyo et al., (2018), was followed with slight modifications (triplicate). Individual samples were weighed (1g) into tube, followed by the addition of 5% metaphosphoric acid (10 ml). It was sonicated 15 minutes before centrifuging and filtration in the ice-cold water bath. The analysis was carried out on the model system described above, Prominence-i HLCP-PDA.

A C18 Luna ® column (150/4.6 mm, 5 µl) held at 25 µC was used to achieve chromatographic separation. A water-based isocratic mobile phase: acetonitrile: formic acid (99:0.9:0.1) was used at a flow rate of 1 mL/min. The volume of injection was 20 µ1 and 245 nm of detection was set. Depending on the calibration curve plotted using L-ascorbic acid, sample quantification was achieved.

4.3.4 Determination of total flavonoids

The aluminium chloride colorimetric method reported by Baba and Malik, (2018) was modified to quantify *C. annuum* variety fruit samples. The total flavonoid content was determined using the aluminium chloride colorimetric technique. In a casing, 50 mg of fruit powder (1 mg/mL ethanol) were dissolved in 1 mL methanol, mixed with 4 mL distilled water, and then 0.3 mL of 5% NaNO2 solution; after 5 minutes of incubation, 0.3 mL of 10% AlCl3 solution was added, and the mixture was allowed to stand for 6 minutes. After adding 2 mL of 1 mol/L NaOH solution, the total volume of the mixture was brought to 10 mL using double-distilled water. The absorbance was measured at 510 nm after the mixture had been allowed to sit for 15 minutes. The total flavonoids content was reported in mg catechin equivalents (CE) per dry weight, with catechin as the calibration standard.

4.3.5 Determination of total phenols

Method used by Brahmi, (2013), was adopted for the determination of total phenolic content of fruit samples, with minor modifications (triplicate). For an extraction of total phenolic content, the total phenol concentration of freeze-dried *C. annuum* fruit was employed, with gallic acid as a reference (Sigma, St. Louis, MO). Folin Ciocalteu reagent (2 N, Sigma, and St. Louis, MO) was used to oxidize an aliquot of the extract in a 10:1 volume/volume ratio. Samples were incubated in 96-well microplates for 20 minutes at room temperature, and absorbance was measured in a microplate reader at 750 nm (Synergy HT, Bio-Tek, and Winooski, VT). The amount of total phenolic content was measured in mg garlic acid equivalents (GAE) per gram of dry weight (DW).

4.3.6 Determination of macro and micro-nutrients

Freeze dried fruit samples were digested in a diffused microwave system (MLS 1200 Mega; Milestone S.r. L, Sorisole, Italy) and samples further congelated-dried following the procedure described by Maluleke et al (2021) with minor modifications. The modifications were that samples were measured in three (3) replicates per treatment (around 15-25 mg) weighed into polytetrafluoroethylene vessels and 2 ml HNO_3 (67 %, analphur) and 1 ml H_20_2 (30 %, analytical grade) added in the vessels. Every solution was diluted to 15 ml in a deionised water test tube after digestion and analysed by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). An ICP-MS (Agilent 7,700; Agilent Technologies, Tokyo, Japan) based on quadrupole mass analyser and octapole reaction system (ORS 3), was used to conduct the analysis. Nutrient elements such (β-carotene), iron (Fe), copper (Cu), zinc (Zn), calcium (Ca), phosphorus (P), potassium (K), and sodium (Na) were analysed. The calibration solution was prepared by appropriate dilution of the single element certified reference material with 1.000 ± 0.002 g/L for each element (Analytika Ltd, Czech Republic) with deionised water (18.2 MΏ.cm, Direct-Q; Millipore, France). Measurement of accuracy was verified by using certified reference material of water TM-15.2 (National Water Research Institution, Ontario, Canada).

4.3.7 Data analysis for biochemical constituents

Data on the effect of coir and loamy soil (control) substrates on nutritional composition of *C. annuum* varieties (Ilanga and Sondela) fruit on the study variables (β-carotene, crude protein, total soluble sugars, total flavonoids, total phenols, calcium, phosphorus, potassium, sodium, copper, iron, Zinc) were analysed using a one-way ANOVA analysis. All study variables were tested at ($P \leq 0.05$) significance level and Duncan multiple range test was used for separation between treatment means at $P \leq 0.05$ (95% confidence level) significant test. For all statistical analysis, Statistica v. 10, StatSoft (USA) was used.

4.4 Results

4.4.1 Total soluble sugars and vitamins

Table 4.1: Effect of coconut coir on the on the biochemical constituents of *C. annuum* varieties grown under greenhouse environment.

Treatment	**Crude protein %**		**Total soluble sugars** (˚Brix)		**Vitamin C** (mg 100 g^{-1} DW)		**Vitamin E** (mg 100 g^{-1} DW)	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Coir & variety								
Ilanga	6.3(2)	6.4(1)	7.6(1)	8.7(1)	205.2(16)	208.1(27)	48.81(12)	49.7(8)
Sondela	6.2(1)	6.3(1)	6.4(1)	5.2(1)	501.2(64)	524.4(34)	76(8.7)	81.1(8)
Loamy soil (control) & variety								
Ilanga	6.2 (1)	6.3(1)	5.8(1)	6.6(1.1)	343.1 (53)	189.6(87)	31.7(6)	36.9(6)
Sondela	6.2 (1)	6.1(2)	4.8(1)	5.1(1)	403.1(59)	363.6(57)	57.3(4)	57.6(14)
Grand Mean	6.23	6.23	6.26	6.26	342.3	342.3	54.88	54.88
LSD0.05	1.86	1.86	2.19	2.19	38.70	38.70	3.81	3.81
Pvalue	0.32	0.32	0.41	0.41	**0.01**	**0.01**	**0.01**	**0.01**

2021 means year one; **2022** means year two. Numbers in brackets represent the standard deviations of the mean. P values in bold are lower than 0.05. $LSD_{0.05}$ is the least significant difference of means.

The impact of coir substrate on the biochemical components of various C. annuum cultivars cultivated in a greenhouse is shown in Table 4.1. The findings revealed that the crude protein and total soluble sugar contents of the C. annuum types cultivated under coconut coir and loamy soil (control) across various seasons [2021 and 2022] did not differ significantly ($P>0.05$). While season two's crude protein composition ranged from 6.1 to 6.4 %, season one's ranged from 6.2 to 6.3 %. Additionally, the study's findings showed that, during season two [2022], the combination of loamy soil (control) and variety (Sondela) lowered crude protein from 6.4 to 6.1%, whereas the combination of coconut coir substrate and variety (Ilanga) boosted it from 6.1 to 6.4 %. The study's findings revealed a significant ($P\leq0.05$) difference between Ilanga and Sondela cultivars of C. annuum in the coconut coir and loamy soil-control substrates for vitamin C and E content. Season one's vitamin C content [2021] ranged from 205 to 501.2 mg 100 g^{-1} DW, whereas season two's vitamin C content [2022] ranged from 208 to 524 mg 100 g^{-1} DW. Additionally, season one [2021] data showed that the treatment combination of coconut coir substrate and variety (Ilanga) lowered vitamin C content from 524 to 205 mg 100 g^{-1} DW, but season two [2022] results showed an increase from 205 to 524 mg 100 g^{-1} DW. According to the study's findings, the amount of vitamin E in season one [2021] ranged from 31.1 to 76 mg 100 g^{-1} DW, whereas season two [2022] ranged from 36 to 81 mg 100 g^{-1} DW. Further analysis of the study's findings revealed that during season one [2021], the loamy soil substrate (control) and variety (Ilanga) reduced the vitamin E content from 81.1 to 31.7 mg 100 g^{-1} DW, whereas during season two [2022], the coconut coir substrate and variety (Sondela) increased it from 31.7 to 81.1 mg 100 g^{-1} DW.

4.4.2 Micro-nutrients

Table 4.2: Effect of coconut coir on the on the micro-nutrients (mg 100 g^{-1} DW) of *C. annuum* varieties grown under greenhouse environment.

Treatment	**Beta-carotene** (mg 100 g^{-1} DW)		**Copper** (mg 100 g^{-1} DW)		**Iron** (mg 100 g^{-1} DW)		**Zinc** (mg 100 g^{-1} DW)	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Coir & variety								
Ilanga	4.1(1)	2.6(1))	12.2(2)	10.1(1.3)	6.9(2.4)	4.691.4)	5.7(1.1)	5.2(1.2)
Sondela	2.9(2)	2.6(0.4)	11.6(1.3)	9.16(1.4)	6.8(1.2)	4.8(1.3)	6.9(1.3)	5(1.1)
Loamy soil (control) & variety								
Ilanga	1.9(1)	3.0(0.3)	11.5(1.4)	9.2(1.1)	6.3(1.1)	6.8(2.1)	6(2.3)	5.6(1.3)
Sondela	1.9(2)	2.53(1)	11.6(2.1)	9.2(1.3)	5.2(1.2)	4.8(1.1)	5.4(1.4)	4.9(1.2)
Grand Mean	2.56	2.56	9.5	9.5	5.8	5.8	5.63	5.63
LSD0.05	0.66	0.66	2.11	2.11	2.05	2.05	0.61	0.61
Pvalue	**0.01**	**0.01**	**0.02**	**0.02**	0.55	0.55	**0.03**	**0.03**

2021 means year one; **2022** means year two. Numbers in brackets represent the standard deviations of the mean. P values in bold are lower than 0.05. LSD$_{0.05}$ is the least significant difference of means.

The micronutrients (beta carotene, copper, iron, and zinc) of the C. annuum cultivars (Ilanga and Sondela) produced under greenhouse conditions are shown in Table 4.2 as a result of the substrates (coconut coir and loamy soil-control). Results revealed that the iron content of C. annuum cultivars (Ilanga and Sondela) grown on substrates (coconut coir and loamy soil-control) under greenhouse conditions did not differ significantly ($P>0.05$). However, there were significant differences in the amounts of beta-carotene, copper, and zinc ($P\leq 0.05$). During season [2021], beta-carotene levels varied from 1.9 to 4.1 645.5 mg 100 g^{-1} DW, whereas levels in season two [2022] ranged from 2.5 to 3.0 mg 100 g^{-1} DW.

Results also showed that the combination of loamy soil (control) and both varieties (Ilanga and Sondela) during the first season of 2021 reduced beta carotene from 4.1 to 1.9 mg 100 g^{-1} DW, whereas the combination of coconut coir and variety (Ilanga) during the same season increased it from 1.9 to 4.1 mg 100 g^{-1} DW. According to the findings, copper content varied between 11.5 and 12.2 100 g^{-1} DW in season one [2021] and 9.2 to 10.1 100 g^{-1} DW in season two [2022]. Additionally, the results demonstrated that the loamy soil (control) treatment and variety (Sondela) lowered copper concentration from 12.2 to 9.1 mg 100 g^{-1} DW, whereas the coconut coir substrate and variety (Ilanga) during season one [2021] raised it from 9.1 to 12.2 mg 100 g^{-1} DW. Results for iron content indicated that it varied between 5.2 and 6.9 mg 100 g^{-1} DW in season one [2021] and between 4.8 and 6.8 mg 100 g^{-1} DW in season two [2022]. Results also showed that the treatment combination of loamy soil (control) and variety (Sondela) decreased iron content during the first sea [2021] from 6.9 to 4.8 mg 100 g^{-1} DW, but the treatment combination of coconut coir and variety (Ilanga) raised it from 4.8 to 6.9 mg 100 g^{-1} DW. According to the findings, the zinc level varied between 5.4 and 6.9 mg 100 g^{-1} DW in season one [2021], and between 4.9 and 5.6 mg 100 g^{-1} DW in season two [2022]. Additionally, the findings demonstrated that during season two [2022], loamy soil (control) and variety (Sondela) lowered zinc concentration from 6.9 to 4.9 mg 100 g^{-1} DW, but during season one [2021], coconut coir and variety (Sondela) raised it from 4.9 to 6.9 mg 100 g^{-1} DW.

4.4.3 Macro-nutrients

Table 4.3: Effect of coir on the on the Macro-nutrients (mg 100 g^{-1} DW) of *C. annuum* varieties grown under greenhouse environment.

Treatment	**Calcium** (mg 100g^{-1} DW)		**Phosphorus** (mg 100g^{-1})		**Potassium** (mg 100g^{-1} DW)		**Sodium** (mg 100g^{-1} DW)	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Coir & variety								
Ilanga	488.5(25)	467.7(32)	565.6(95)	429.3(53)	297.9(39)	364.2(60)	565.3(57)	429.3(52)
Sondela	508.3(41)	477.6(29)	634.9(49)	645.5(81)	583(63)	650(66)	634.9(93)	645.5(62)
Loamy soil (control) & variety								
Ilanga	492.3(62)	439.6(49)	373.8(53)	370.8(58)	261.8(44)	255.8(74)	373.8(69)	370.8(63)
Sondela	455.2(20)	460.1(32)	469(92)	484(57)	398.6(92)	487(81)	469(41)	484(98)
Grand Mean	473.2	473.2	496.6	496.6	412.3	412.3	496.6	496.6
LSD0.05	40.07	40.07	31.7	31.7	38.4	38.4	31.7	317.0
Pvalue	0.07	0.07	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**

2021 means year one; **2022** means year two. Numbers in brackets represent the standard deviations of the mean. P values in bold are lower than 0.05. LSD$_{0.05}$ is the least significant difference of means.

The impact of the substrates (coconut coir and loamy soil-control) on the macronutrients (calcium, phosphorus, potassium, and sodium) of the C. annum cultivars (Ilanga and Sondela) cultivated in a greenhouse is shown in Table 4.3. The calcium content of C. annuum cultivars Ilanga and Sondela cultivated on substrates (coconut coir and loamy soil-control) in a greenhouse setting did not differ significantly (P>0.05), according to the results.

Phosphorus, potassium, and sodium content, however, differed significantly ($P \leq 0.05$). The calcium concentration in season one [2021] ranged from 455 to 508 mg 100 g^{-1} DW, whereas the calcium content in season two [2022] ranged from 439.8 to 477.6 mg 100 g^{-1} DW. The results also showed that the calcium concentration decreased when loamy soil (control) and variety Ilanga were combined, going from 508.3 to 439.6 mg 100 g^{-1} DW, however it increased when coconut coir and variety Sondela were combined. Phosphorus levels in season [2021] varied from 373.8 to 634.9 mg 100 g^{-1} DW, while season two [2022] levels ranged from 370.8 to 645.5 mg 100 g^{-1} DW. Additionally, the findings demonstrated that the treatment combination of loamy soil (control) and varieties (Ilanga) during season one [2021] decreased phosphorus from 645.5 to 373.8 mg 100 g^{-1} DW, whereas the treatment combination of coconut coir and variety (Sondela) during season one [2021] increased it from 373.8 to 645.5 mg 100 g^{-1} DW. According to the findings, the potassium concentration varied between 261.8 and 583 mg 100 g^{-1} DW during season one [2021], and between 255.8 and 650 mg 100 g^{-1} DW during season two [2022]. Results also revealed that the potassium content of coconut coir substrate combined with the variety Sondela during season two [2022] increased from 26.1.8 to 650 mg 100 g^{-1} DW, in contrast to loamy soil (control) and variety Ilanga, which lowered it from 650.9 to 261.8 mg 100 g^{-1} DW. In terms of sodium content, the results showed that season one [2021] ranged from 373.8 to 634 mg 100 g^{-1} DW, whereas season two [2022] ranged from 370.8 to 645.5 mg 100 g^{-1} DW. Furthermore, the results showed that during the first season of [2021], the loamy soil (control) and variety (Ilanga) lowered the potassium level from 645.5 to 373.8 mg 100 g^{-1} DW, whereas the coconut coir and variety (Sondela) boosted it from 373.8 to 64.5 mg 100 g^{-1} DW.

4.4.4 Total flavonoids

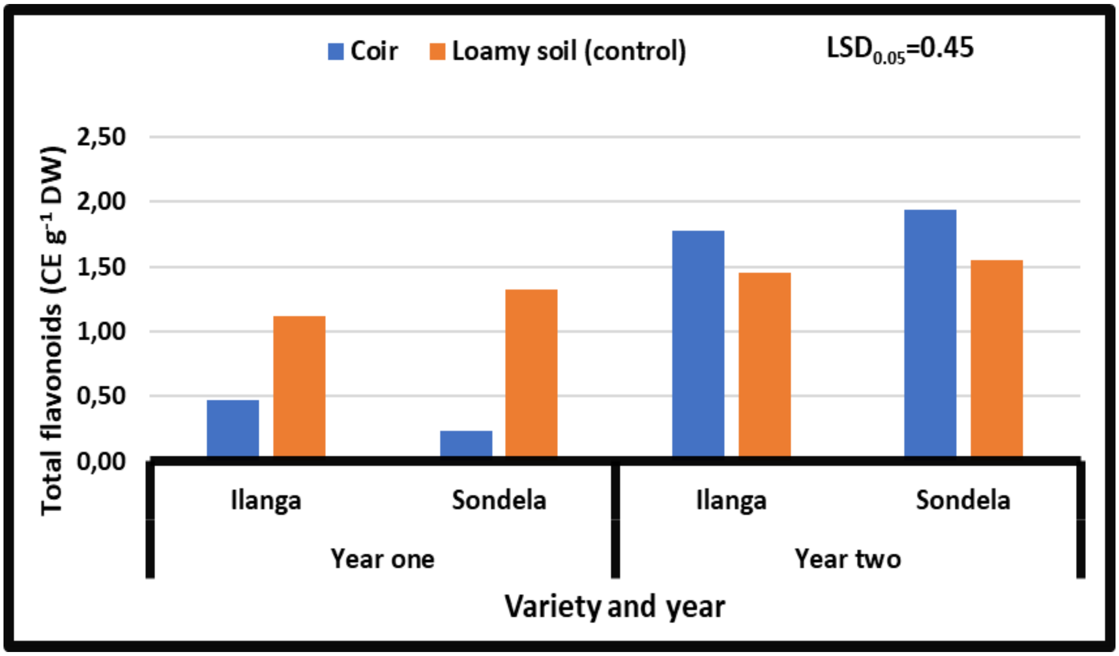

Figure 4.1 Effect of coir on the total phenolic content of sweet peppers varieties grown under greenhouse environment. Values are average over treatment; varieties (Ilanga and Sondela). $LSD_{0.05}$ is the least significant difference of means.

The impact of the substrates (coconut coir and loamy soil-control) on the total flavonoid content of the C. annuum cultivars (Ilanga and Sondela) grown in a greenhouse is shown in Figure 4.1. The Ilanga and Sondela cultivars of C. annuum grown in substrates (coconut coir and loamy soil-control) during various seasons [2021 and 2022] did not differ significantly (P>0.05) in their total flavonoid content. Total flavonoids content in season one [2021] ranged from 0.23 to 1.33 CE g^{-1} DW, while season two [2022] ranged from 1.45 to 1.93 CE g^{-1} DW. As a consequence, total flavonoids content decreased from 1.93 to 0.23 CE g^{-1} DW during season one [2021] when coconut coir and variety (Sondela) were combined as a treatment, whereas it grew from 0.23 to 1.93 CE g^{-1} DW when coconut coir and variety (Sondela) were combined as a therapy.

4.4.5 Total phenols

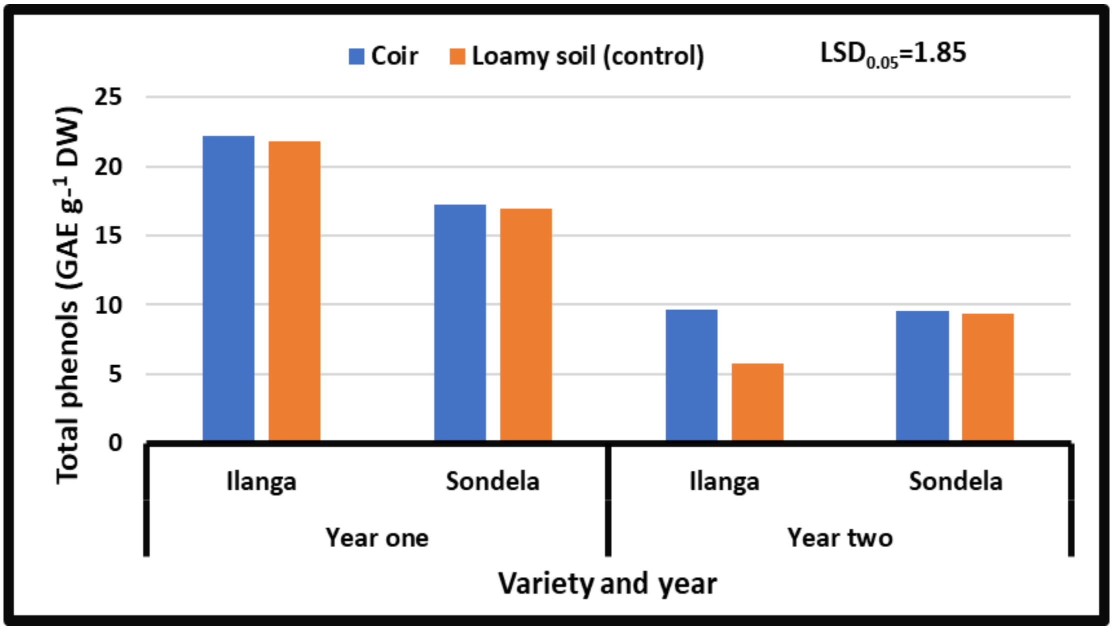

Figure 4.2 Effect of coir on the total phenolic content of Sweet peppers varieties grown under greenhouse environment. Values are average over treatment; varieties (Ilanga and Sondela). $LSD_{0.05}$ is the least significant difference of means.

In Figure 4.2, the influence of the substrates (coconut coir and loamy soil-control) is shown in relation to the total phenol content of the C. annuum cultivars (Ilanga and Sondela) grown in a greenhouse environment. The Ilanga and Sondela varieties of *C. annuum* that were cultivated in coconut coir and loamy soil as a control over various seasons [2021 and 2022] did not differ significantly ($P>0.05$) in terms of their total phenol content. Season one (2021) saw a total phenol content range of 16.93 to 22.2 GAE g-1 DW, while Season two (2022) saw a range of 5.74 to 9.68 GAE g-1 DW Results also showed that the treatment combination of loamy soil (control) combined with variety (Ilanga) during season two [2022] decreased total phenols content from 22.2 to 5.74 GAE g-1 DW, whereas the treatment combination of coconut coir and variety (Ilanga) during season two increased it from 5.74 to 22.2 GAE g-1 DW during season one [2021].

4.5 Discussion

This study evaluated the biochemical characteristics of C. annuum types cultivated in loamy soil or under coconut coir throughout two growth seasons. It also investigated biochemical characteristics of C. annuum variants grown under greenhouse conditions. Previous studies looked into the physiological responses, yield, quality, and post-harvest quality of C. annuum grown on different substrates, like other soilless cultures. To the best of our knowledge, this study is the first to assess how coconut coir affects the development, growth, and production of various pepper cultivars (Ilanga and Sondela).

Vitamin C

Vitamin C, commonly known as ascorbic acid, is essential for the growth, development, and repair of all physiological tissues. It plays a part in a number of body processes, including the formation of collagen, iron absorption, immune system operation, wound healing, and preservation of cartilage, bone, and teeth (Achaglinkame et al., 2019). The difference in vitamin C content between the lowest variety (Ilanga) and the greatest variety (Sondela) was found to be (335 mg 100 g^{-1} DW), indicating a reasonable greater content (45 g/day) across different age groups (Uusiku et al., 2010). The fruit variety (Sondela) cultivated in coir substrate has a high potential to provide the human body with a sufficient amount of vitamin C, which is essential for human health, as a result. Citrus fruits reported by Paradikovic et al. (2011) have higher vitamin C values than the C. annuum variety (Sondela) grown with coir substrate (Tavarini et al., 2008).

Vitamin E

Vitamin E is a fat-soluble vitamin important for the human skin, blood and brain and whose primary function is to act as an antioxidant by scavenging free radicals that can cause cell damage (Legwaila et al., 2011). The recommended daily allowance of vitamin E for adults is 15 mg per day (Mayo Clinic, 2020) but vitamin E-only supplements may supply 67 mg of vitamin E (NHI, 2021). In the current study, the highest concentration of vitamin E (81 mg/100 g DW) was noted in the Sondela pepper variety grown under coir substrate on the 2022 growing season. These results compare with those of vitamin E in sunflower oil of 48.7 mg/100 g (Slover, 1971 cited by Rizvi et al. (2014) and correspond with those reported by Tavarini et al. (2008) who found variation in nutritional content of fruit harvested from varying regions.

Micro-nutrients

Beta carotene

β-carotene is transformed into vitamin A in the body (retinol). Humans require vitamin A for healthy skin and mucous membranes, as well as for good vision and eye health. Vitamin A in large levels can be hazardous, but your body only transforms as much as it needs from beta-carotene (Van Rensburg et al., 2007). β-carotene content variation among *C. annuum* lowest (1.9 mg 100 g^{-1} DW) for variety (Sondela) grown under loamy soil substrate (control) and highest (4.1 mg 100 g^{-1} DW) for variety (Ilanga) grown under coir substrate was (2.2 mg 100 g^{-1} DW), suggesting the mineral strength of fruit grown under coir substrate. This means that fruit grown under coir substrate could play a vital role in curbing some micro-nutrients deficiencies troubling human in underdeveloped countries since its values were 38% higher than the recommended daily intake for human across all age groups as reported by Sharma and Rao (2013).

Copper

Copper helps the body make red blood cells by combining with iron. It also helps to maintain the health of blood vessels, nerves, the immune system, and the bones. Copper aids in the absorption of iron, as well. Deficiencies in this nutrient during pregnancy can cause major morphological defects in the fetus as well as long-term neurological and immunological problems in the progeny (Maluleke et al., 2021).The difference between the lowest value (9.6 mg 100 g^{-1} DW) from variety (Sondela) and the highest value (12.2 mg 100 g^{-1} DW) from variety (Ilanga) under coir substrate was (2.6 mg 100 g^{-1} DW). This could mean that the substrate and variety had a direct impact on copper content. These findings agree with the fact that fruit nutritional content is reliant on the substrate. Therefore, growers should consider the substrate strength prior to cultivation, as this has a direct impact on the quality of produce (Brahmi et al., 2013).

Iron

Iron is an essential component for the body's growth and development. Haemoglobin, a protein found in red blood cells that transports oxygen from the lungs to all areas of the body, and myoglobin, a protein that transports oxygen to muscles, are both made from iron. Iron is also required by the body for the production of certain hormones (Sibiya, Kayitesi and Moteetee., 2021). The variation between the lowest iron content (9.1 mg 100 g^{-1} DW) from variety (Sondela) grown on coir substrate and the highest (12.2 mg 100 g^{-1} DW) from variety (Ilanga) grown from similar substrate was (3.1 mg 100 g^{-1} DW). Values obtained from this study could mean that the substrate coir, may play an important role in improving blood health related challenges such as anemia, which normally makes people get easily tired and struggle with respiration due to short of breath (Mashile et al., 2019).

Total flavonoids

Total flavonoids aid in cellular activity regulation and the battle against free radicals that cause oxidative stress in the body. In layman's words, they aid in the effective functioning of your body while also shielding it from everyday pollutants and stressors. Flavonoids are also effective antioxidants. The study findings revealed that the differences between the lowest total flavonoids content (0.23 CE g^{-1} DW) from the variety (Sondela) grown under coir substrate and the highest (1.9 g^{-1} DW) grown from the similar substrate was (1.67 g^{-1} DW). These values could be of immense importance in human body for diseases prevention, subsequently improving overall human health. Therefore, growing fruit on organic substrate, particularly coir, could have a positive impact in environmental sustainability and improving human health. These findings concur with those (Jokinen, 2021), who reported that high water use efficiency and yield on greenhouse crops grown in organic substrates.

Total phenols

Phenolic compounds are important to human health because they are potential antioxidants that prevent cell damage caused by free-radical oxidation processes. They are easily absorbed through intestinal tract walls. Humans' anti-inflammation capacity is also enhanced by phenolic acids when consumed on a regular basis (Nwofia, Ojimelukwe and Eji, 2012). The study findings revealed that the variation between the lowest (5.74 GAE g^{-1} DW) from variety (Ilanga) grown on loamy soil substrate (control) and the highest (22.2) from the same variety grown in coir substrate was (16.5 GAE g^{-1} DW). The phenolic content of fruit grown under coir substrate was reasonable high, when compared to those of loamy soil (control), indicating the coconut coir strength as a substrate that has a potential in growing healthy high nutritional crops and also could help reduce malnutrition challenges. These amounts of total phenols could be of vital significant in digestive process of humans in reducing constipation challenges. Similar findings were reported by Lopez et al., (2013).

4.6 Conclusion

This research has provided usefull evidence to farmers, as food supply and hunger elimination is a main focus of global sustainable development goals. Before a crop is commercialised, regulators must consider a number of issues, including the quantification of quality metrics like total soluble sugars and macro- and micronutrients. The findings of this study have demonstrated that *C. annuum* fruit contain essential biochemical components that people need in varying amounts. Additionally, this research has shown that treatments such as substrates have a substantial impact on the *C. annuum* fruit quality content. Since quality has grown more important to the majority of consumers worldwide, farmers might benefit from knowing that this study has shown that coconut coir combined with variety (Ilanga) and (Sondela) has a potential to be utilized as a reliable combination for commericial production under greenhouse conditions.

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Chapter 5: Summary and Future work

5.1 General

The main aim of the study was to determine the effect of coconut coir substrate on the crop characteristics (growth, yield and quality) and biochemical features of sweet pepper (*C. annuum*) varieties grown under greenhouse conditions and compare these features to those of control pepper plants grown without coconut coir but rather with loamy soil as substrate.

This chapter presents a research summary as well as a description of future work on the utilization of coconut coir substrate for cultivation of *C. annuum* and other horticultural crops under protective structures. The study results have demonstrated that the use of coconut coir as a cultivation substrate has a direct impact on plant growth, development, yield and nutritional composition of varying *C. annuum* varieties grown under greenhouse conditions.

Below is an overview of each study theme and the related future work.

5.2 The effect of coir substrate on the growth, development and yield of Capsicum annuum varieties

Study objective 1 was to evaluate the effect of coconut coir substrate on the growth and development of sweet pepper (*C. annuum*) varieties grown under greenhouse conditions. The parameters that were analysed were plant chlorophyll content, stem diameter and plant height. In general, the study showed that cultivation of plants in loamy soil, as opposed to their cultivation under coir as substrate, promoted plant growth and development. The exceptions to this observation involved peppers of the Sondela variety that were grown in 2022 whose chlorophyll content and stem diameter showed an increase when these plants were grown under coir rather than in loamy soil. Note that in 2021 this pepper variety grew and developed better in loamy soil compared to its growth under coir.

In general, the chlorophyll content of the Ilanga variety was lower than that measured in the Sondela variety. In addition, the increase in the chlorophyll content of the Sondela variety in 2022 when cultivated in coir as opposed to loamy soil mentioned above may be an artifact resulting from a relatively low chlorophyll level in plants of this variety grown in loamy soil.

Regarding stem diameter, results of the study showed that plants grown in loamy soil had a greater stem diameter than those cultivated in coconut coir. Thus, in comparison to growth under coconut coir, the study's findings showed that the stem diameter in plants grown in loamy soil was 1, 5 mm greater. As mentioned above, the stem diameter of Sondela variety plants in 2022, but not in 2021, showed an increase when these plants were cultivated under coir as compared to their growth in loamy soil. In general, the plant height of both pepper varieties was reduced when these plants were cultivated under coir as opted to in loamy soil. The research also found that there was a difference in plant height when comparing treatments for both the Ilanga and Sondela varieties. Thus, the largest difference in plant height (9 cm) showed that the Ilanga variety was taller than the Sondela variety.

The study results demonstrated that growth parameters of chlorophyll content, stem diameter and plant height of the pepper varieties cultivated in coconut coir as substrate showed little advantage over their growth in loamy soil and this analysis supports the assertion that study objective 1 was suitably addressed. The study results demonstrated that coconut coir substrate had a marginal advantage over loamy soil (control) when it comes to plant growth, development and yield parameters, namely (stem diameter, plant height, fruit number, and aboveground biomass).

5.3 The effect of coconut coir substrate on the biochemical constituents of different Capsicum annuum fruit varieties

Study objective 2 was to evaluate the effect of coir substrate on the yield performance of sweet peppers (*C. annuum*) varieties grown under greenhouse conditions. In determining the yield of pepper varieties cultivated either under coir or in loamy soil, the following parameters were assessed: total biomass, above ground biomass, fruit yield and harvest index. In general, there was relatively little difference in the total biomass, above ground biomass and harvest yield when comparing the cultivation of the two pepper varieties in either loamy soil or under coir.

Regarding total biomass, a slight increase was noted in both pepper varieties when cultivated under coir compared to cultivation in loamy soil. The variation in total biomass between the plant varieties grown in these two substrates suggests that, with the exception of the Sondela variety cultivated under coir in 2022, the growth of the Ilanga pepper variety in coconut coir was perhaps superior to the growth shown by the Sondela variety, even if the difference was not statistically significant. Regarding the above ground biomass analysis, again there was little difference between this parameter in either pepper variety cultivated in either loamy soil or under coir. The increase shown by the Sondela variety in 2022 when comparing its cultivation under coir as opposed to in loamy soil, may simply reflect the total biomass increase in this variety reported above.

Regarding fruit number, a comparison showed that there more fruit was harvested from plants of the Ilanga variety when grown under coconut coir as substrate. This assertion is supported by study results that indicate that there was a significant ($P \leq 0.05$) increase in fruit number for the two pepper varieties grown on coir substrate during both growing seasons. A treatment combination of coir substrate and the Ilanga variety consistently resulted in a relatively high fruit yield and showed at least a 25% increase in fruit yield when the Ilanga variety was cultivated under coir compared to when it was cultivated in loamy soil.

In general, with the exception in 2022 when an increase was noted in the harvest index for the Ilanga variety when cultivated under coir compared to in loamy soil, the harvest index for both varieties showed a slight reduction when cultivated under coir compared to in loamy soil. The study results demonstrated that the fruit yield of particularly the Ilanga pepper variety when cultivated in coconut coir as substrate showed a significant increase compared to the Sondela variety and when either variety was cultivated in loamy soil.

5.4 Contribution to agricultural field and body of knowledge

The current study's findings are the first to show the extent to which the use of coconut coir as substrate affects the growth, development, yield, and nutritional composition of various *C. annuum* cultivars (Ilanga and Sondela).

The relative increase in soluble sugars in the Ilanga variety when grown under coir might increase the attractiveness of consumption of fruit from this variety. In addition, the increase in concentration of vitamin C in the fruit of the Sondela variety cultivated under coir as substrate showed potential to contribute to the health of sweet pepper consumers. Likewise, the analysis of the variation in vitamin E content suggested that growth of the Sondela variety under coir as substrate might contribute roughly 30% of the daily required vitamin E intake. These results might suggest that providing a mix of these varieties to consumers may be optimal. Additionally, study results demonstrate how coconut coir, an organic substrate, may be used successfully to assist farmers in maximizing productivity and profit. Furthermore, because the substrate is reusable, this can be categorized as an element of innovation and environmental sustainability, speeding up the achievement of the sustainable development goals (SDGs).

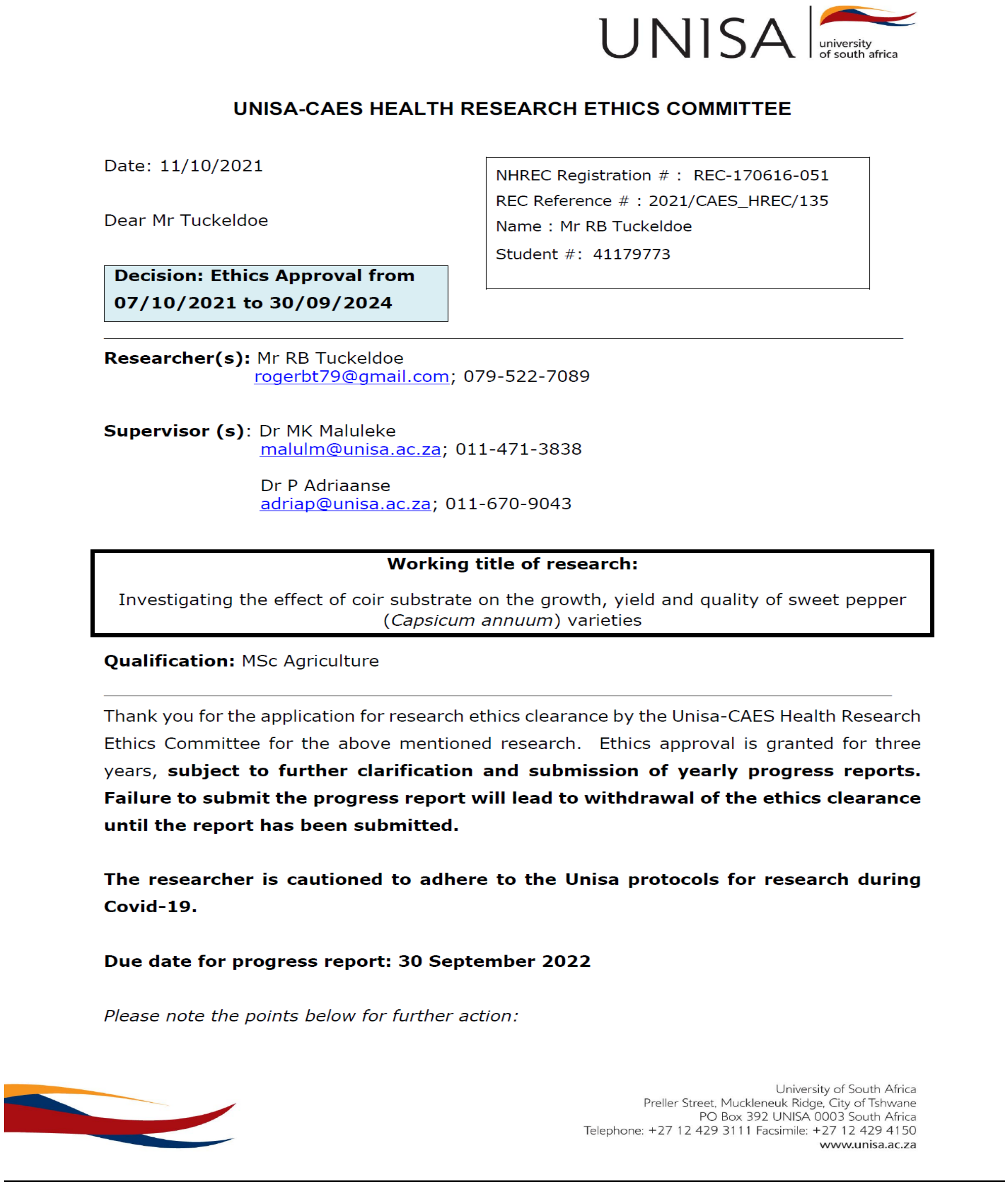
Overall, growing fruit on organic substrate, particularly coir, could have a positive impact in environmental sustainability and improving human health. These findings support similar research results reporting efficient water use and yield on greenhouse crops cultivated in organic substrates (Jokinen, 2021).

Future research is advised to take the following factors into account:

- The effect of varying organic substrates and fertilizers on the growth, development, and yield constituents of different horticultural crops such as tomatoes, peppers, strawberry and leafy vegetables crops.
- Determining the efficiency of water use when cultivating various horticultural crops grown under organic substrates
- Analysing the biochemical constituents of different horticultural crops grown under varying organic substrates and fertilizers.

APPENDICES

Appendix I: Ethical clearance approval



UNISA | university of south africa

UNISA-CAES HEALTH RESEARCH ETHICS COMMITTEE

Date: 11/10/2021

Dear Mr Tuckeldoe

Decision: Ethics Approval from 07/10/2021 to 30/09/2024

NHREC Registration # : REC-170616-051
REC Reference # : 2021/CAES_HREC/135
Name : Mr RB Tuckeldoe
Student #: 41179773

Researcher(s): Mr RB Tuckeldoe
rogerbt79@gmail.com; 079-522-7089

Supervisor (s): Dr MK Maluleke
malulm@unisa.ac.za; 011-471-3838

Dr P Adriaanse
adriap@unisa.ac.za; 011-670-9043

Working title of research:

Investigating the effect of coir substrate on the growth, yield and quality of sweet pepper (*Capsicum annuum*) varieties

Qualification: MSc Agriculture

Thank you for the application for research ethics clearance by the Unisa-CAES Health Research Ethics Committee for the above mentioned research. Ethics approval is granted for three years, **subject to further clarification and submission of yearly progress reports. Failure to submit the progress report will lead to withdrawal of the ethics clearance until the report has been submitted.**

The researcher is cautioned to adhere to the Unisa protocols for research during Covid-19.

Due date for progress report: 30 September 2022

Please note the points below for further action:

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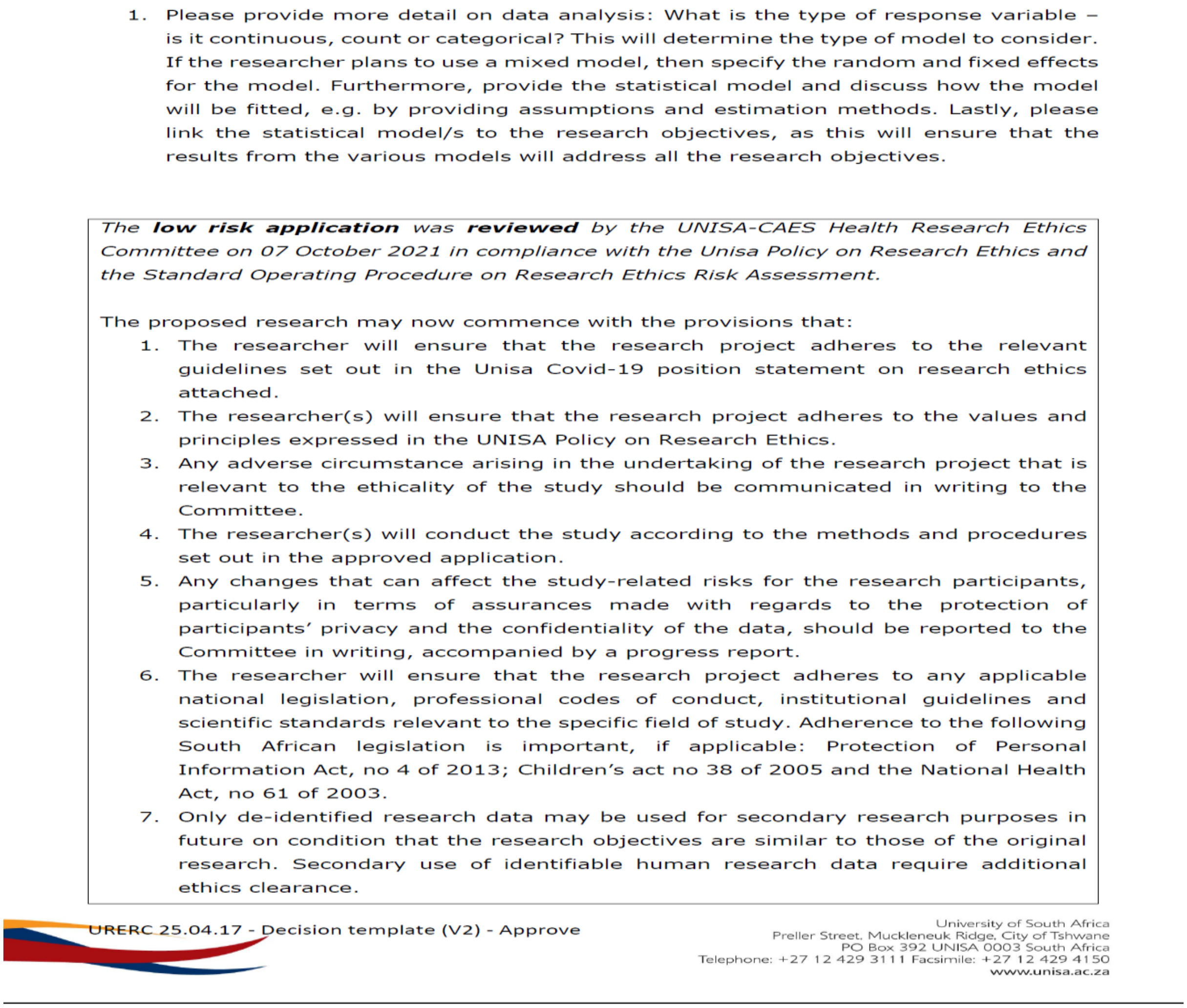

1. Please provide more detail on data analysis: What is the type of response variable – is it continuous, count or categorical? This will determine the type of model to consider. If the researcher plans to use a mixed model, then specify the random and fixed effects for the model. Furthermore, provide the statistical model and discuss how the model will be fitted, e.g. by providing assumptions and estimation methods. Lastly, please link the statistical model/s to the research objectives, as this will ensure that the results from the various models will address all the research objectives.

*The **low risk application** was **reviewed** by the UNISA-CAES Health Research Ethics Committee on 07 October 2021 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher will ensure that the research project adheres to the relevant guidelines set out in the Unisa Covid-19 position statement on research ethics attached.
2. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
3. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the Committee.
4. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
5. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
6. 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. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
7. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data require additional ethics clearance.

8. No field work activities may continue after the expiry date. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

The reference number ***2021/CAES_HREC/135*** *should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Yours sincerely,

Prof MA Antwi
Chair of UNISA-CAES Health REC
E-mail: antwima@unisa.ac.za
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Prof SR Magano
Executive Dean : CAES
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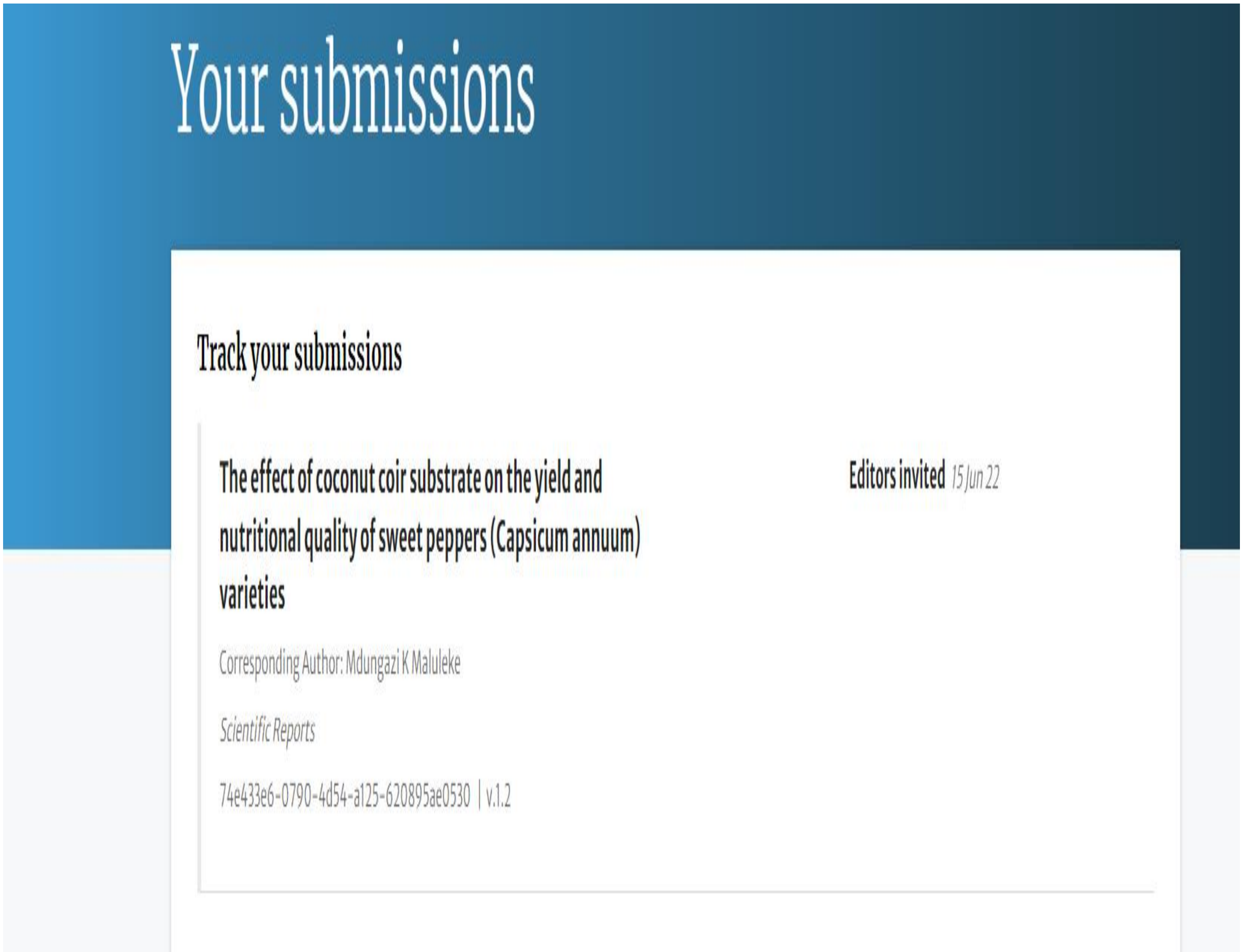
Appendix II: Proof of article submission



Your submissions

Track your submissions

The effect of coconut coir substrate on the yield and nutritional quality of sweet peppers (Capsicum annuum) varieties

Editors invited *15 Jun 22*

Corresponding Author: Mdungazi K Maluleke

Scientific Reports

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Appendix III: Language editing letter

John Dewar Tel: +27833210844
PhD, DAHM Email: johndewar65@gmail.com

Dear Dr Maluleke,

This letter is to confirm that I completed a language and content edit of a dissertation entitled: **Investigating the effect of coir substrate on the growth, yield and quality of sweet pepper (*Capsicum annuum*) varieties.** This dissertation was prepared by Mr Roger Tuckeldoe and describes a research study under your supervision. The dissertation will be presented to the Department of Environmental Sciences, College of Agricultural and Environmental Sciences, University of South Africa in fulfilment for the requirements for the degree Master of Science in Agriculture.

My edit included the following:

- Spelling and grammar
- Vocabulary and punctuation
- Sentence structure and word usage
- Correct outlay of dissertation
- Consistent formatting of references

Text formatting included:

- Adjusted legend and size of some figures and tables
- Suggested inclusion of some background and methodology theory
- Suggested alignment of conclusions with study objectives
- Suggested review of statistical analysis
- Suggested inclusion of some results

Yours sincerely,

John Dewar
5th July 2022

Appendix IV: Turnitin report

Turnitin Originality Report

MSc Agriculture dissertation by Rb Tuckeldoe

From AAH 2022 (AAH 2022)

- Processed on 18-Jul-2022 07:59 SAST
- ID: 1872012789
- Word Count: 21118

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