Investigating the effect of different coir substrates on the growth, yield and biochemical constituents of tomato (*Solanum lycopersicum var. Esculentum)*

by

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ABSTRACT

Fruit crops depend on the quality of the substrate for improved development, yield and nutrient content. To assure higher crop quality and to answer year-round market demand, most producers employ organic substrate for greenhouse crop cultivation. Due to its regenerative nature, coconut coir, an organic substate made from the mesocarp or exterior husk of coconut fruit, provides advantages not only for crop cultivation but also, by being renewable, for the environment as well. The goal of the study was to ascertain the impact of two coconut coir substrate types (Profit and Power) on the development, production and biochemical components of tomato fruit produced in a greenhouse setting. Evaluated elements included plant physiology and yield such as plant height, stem diameter, fruit length and count and harvest index as well as plant biochemical components such as fruit protein, carbohydrate, vitamin, lycopene, phenolic, flavonoid and nutrient content. Results indicated that tomato plant cultivation in coconut coir (Power) resulted in increased fruit number production and an increase in biochemical content such as vitamin C and lycopene compared to the other cultivation treatments. Cultivation in coconut coir (Profit) showed a relative increase in harvest index compared to the other treatments. Overall, growing tomatoes in coconut coir (Power) substrate increased yield, nutrient-dense fruit and farmers are urged to grow tomato fruit on this coconut coir to realise an increase in superior tomato crop output and increase in profit from tomato cultivation in a greenhouse environment. However, costs and availability in terms of quantity should be considered.

Keywords: Tomato, coconut coir, yield, vitamins, lycopene

SETSOPOLWA

Dibjalo tša dikenywa di laolwa ke boleng bja lefelo la go bjalela gore di gole bokaone, di enywe le go ba le phepo ya boleng. Bontši bja batšweletši ba kgetha go šomiša lefelo la tlhago go bjala dibjalo tša ka gare ga moago go netefatša gore go ba le boleng bjo bokaone go fihlelela nyakego ya mebaraka ngwaga ka moka. Faepa ya khokhonate ke lefelo la go bjalela leo le tšweletšwago ka tlhago leo le nago le magapi a ka ntle goba mesokhapo ya kenywa ya khokhonate ebile e bonwa e na le dikholego go tikologo ka lebaka la go šomišwa leswa ga yona. Maikemišetšo a dinyakišišo tše e bile go tseba seabe sa mehuta ye e fapafapanego ya lefelo la go bjalela la faepa ya khokhonate le a (e lego ya poelo le ya maatla) kgolo, tšweletšo le diteng tša dipayokhemikhale tša tamati ka seemong sa ntlo ya go bjalela. Dilo tše di fapafapanego tša go swana le palo ya dikenywa, dipalopalo mabapi le puno, dibithamene, le laesophine di ile tša sekasekwa. Dinyakišišo di utollotše gore faepa ya khokhonate (maatla) e bile le dipalo tše ntši tša dikenywa ge e bapetšwa le ditswaki tše dingwe tša mobu wa dibjalo. Dipalopalo mabapi le puno di bile tše kgolo go faepa ya khokhonate (poelo) ge go bapetšwa le ditswaki tše dingwe tša mobu wa dibjalo. Dikenywa tše di bjetšwego go faepa ya khokhonate (maatla) di bile le maemo a godingwana a dibithamene C le laesophine ge di bapetšwa le ditswaki tše dingwe. Ka fao, dipoelo tša dinyakišišo di laetša gore faepa ya khokhonate (maatla) e okeditše palo ya dikenywa ge go bapetšwa le ditswaki tše dingwe. Diteng tša dipayokhemikhale tša go swana le dibithamene le laesophine di bile godimo ka dikenyweng tša ditamati tšeo di bjetšwego go faepa ya khokhonate (maatla) go feta ditswaki tše dingwe. Bjale re ka tšea gore go bjala ditamati go lefelo la go bjalela la faepa ya khokhonate (maatla) go tla feletša ka tšweletšo ya godingwana le dikenywa tše di tletšego ka phepo. Balemi ba hlohleletšwa go bjala kenywa ya tamati ba šomišwa lefelo la go bjalela la faepa ya khokhonate (maatla) go hwetša puno ya godingwana, tšweletšo ya boleng le koketšo ya poelo ka fase ga maemo a ntlo ya go bjalela.

Mantšu a bohlokwa: *Solanum lycopersicum*, faepa ya khokhonate, tšweletšo, dibithamene, laesophine

ISIFINQO

Izitshalo zezithelo zincike kuwungqimba lokhethelo ukuze zikhule kangcono, isivuno kanye nezinga lokudla okunempilo. Abakhiqizi abaningi bakhetha ukusetshenziswa kokudla noma izindlela zokulima ezikhiqizwe noma ezibandakanya ukukhiqizwa ngaphandle kokusebenzisa umanyolo wamakhemikhali, ukuze kutshalwe izitshalo ezibamba ukushisa kubuye kuqinisekiswe ikhwalithi engcono ukuhlangabezana nesidingo semakethe unyaka wonke. Ifayiba yemvelo ekhishwe ekhobeni langaphandle likakhukhunathi iwumkhiqizo oyingqimba okhiqizwa ngokwemzelo ekhiqizwa ngokuphilayo equkethe ikhoba lwangaphandle noma ungqimba olune-fayiba phakathi nendawo yesithelo sikakhukhunathi futhi ibhekwa njengenzuzo yemvelo ngenxa yemvelo yayo evuselelekayo. Inhloso yocwaningo kwakuwukuthola umthelela wezinhlobo ezahlukene zongqimba lwekhukhunathi (inzuzo namandla) ekukhuleni, ekuvuneni kanye nezakhi zamakhemikhali ezinto eziphilayo zesithelo sikatamatisi esitshalwe endaweni ebamba ukushisa. Izinguquko ezifana nenombolo yezithelo, inkomba yokuvuna, amavithamini, nelayikhophini ziye zahlolwa. Ucwaningo luveze ukuthi ifayiba yemvelo ekhishwe ekhobeni langaphandle likakhukhunathi (amandla) yayinezinombolo zezithelo eziningi uma kuqhathaniswa nezinye izindlela zokwelapha. Inkomba yokuvuna ibiphezulu kuyifayiba yemvelo ekhishwe ekhobeni langaphandle likakhukhunathi (inzuzo) uma kuqhathaniswa nezinye izindlela zokwelapha. Isithelo esikhuliswe ngaphansi kukakhukhunathi (amandla) sasinamazinga aphezulu kavithamini C kanye nelikhophini uma siqhathaniswa nezinye izindlela zokwelapha. Amakhemikhali ezinto eziphilayo ezifana namavithamini kanye ne-likhophini zaziphezulu esithelweni sikatamatisi esitshalwe ngaphansi kwekhoyili kakhukhunathi (amandla) kunezinye izindlela zokwelapha. Ngakho-ke kungatholakala ukuthi ukukhulisa utamatisi ngaphansi kongqimba lwefayiba yemvelo ekhishwe ekhobeni langaphandle likakhukhunathi (amandla) kuzoholela ekuvuneni okuphezulu kanye nezithelo eziminyene ezinomsoco. Abalimi bayakhuthazwa ukuthi balime isithelo sikatamatisi besebenzisa iungqimba lwefayiba yemvelo ekhishwe ekhobeni langaphandle likakhukhunathi (amandla) ukuze bathole isivuno esiphezulu, umkhiqizo osezingeni eliphezulu kanye nokwandisa inzuzo ngaphansi kwezimo zendawo ezibamba ukushisa.

Amagama abalulekile: Solaniyamu layikhophesiyamu Ifayiba yemvelo ekhishwe ekhobeni langaphandle likakhukhunathi, ukuveza , amavithamini, ilikhophini

DECLARATION

I, Jeffry Thema Mogale, declare that this dissertation entitled: ”**Investigating the effect of different coir substrates on the growth, yield and biochemical constituents of tomato (*Solanum lycopersicum*)**” 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.

I declare that the dissertation does not contain any written work presented by other persons whether written, pictures, graphs or data or any other information without acknowledging the source. Prior to the registration of this project, both the researcher and the Unisa library undertook a literature assessment to ensure that no other similar research had been conducted in South Africa or abroad.

I declare that where words from a written source have been used the words have been paraphrased and referenced and where exact words from a source have been used the words have been placed inside quotation marks and referenced.

I declare that I have not copied and pasted any information from the Internet, without specifically acknowledging the source and have inserted appropriate references to these sources in the reference section of the dissertation.

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/thesis has been submitted through an electronic plagiarism detection program before the final submission for examination.

______________________ 03 September 2022

Signature Date

Student number : 60107839

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ABBREVIATIONS

AGB	Above-ground biomass
ARC	Agricultural Research Council
CE	Catechin equivalents
cm	Centimeter
EC	Electrical conductivity
g	Gram
DW	Dry weight
GAE	Garlic acid equivelant
HPLC	High-performance liquid chromatography
$\mu mol/m^2$	Mass per area of leaf surface/micromoles per square meter
$mmol\ m^{-2}\ s^{-1}$	Millimoles per square meter per second

GLOSSARY

βeta carotene	An essential dietary component and precursor to vitamin A, a plant pigment that is an isomer of carotene (Gul et al.,2015).
Chlorophyll	Chlorophyll is a pigment that gives plants their distinctive green color and aids in photosynthesis, which enables plants to produce their own food (Davis & Brema,2017).
Crude protein	A measure of the protein content in a plant material which is culclated through multiplying the nitrogen content by 6.25. The term "crude" alludes to the fact that most plant do not include all of the nitrogen in the form of protein (Mariotti,2020).
Flavonoids	A group of secondary polyphenolic compounds which which contribute towards human health. Structurally, flavonoids have a 15-carbon skeleton that is made up of two phenyl rings and a heterocyclic ring (Ignat et al, 2011).
Phenols	A class of phytochemical compounds that are often formed from aromatic amino acids and are present in plant tissues (Ignat et al., 2011).
Stomatal conductance	The measurement of water vapor from leaf stomatal and the rate at which carbon dioxide enters the leaf (Farquhar & Sharkey,1982).
Total soluble sugars	The soluble water carbohydrate content, primarily as dissolved sugar content in plant material (Irigoyen et al., 1992).

Lycopene	A potent antioxidant that provides health advantages, including improved heart health, reduced risk of certain cancers, and protection from the effects of UV rays from the sun (Bhowmik et al.,2012).
Macro-nutrients	The nutrients that both plants and animals require in greater amounts and are major sources of energy (Tripathi et al.,2014).
Micro-nutrients	A chemical element or substance that is necessary in very small amounts for the regular growth and development of living organisation (Kumar et al., 2021).

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The main duties of substrates/growing media include (i) supporting/anchor the plant, (ii) supplying water to the plant roots, (iii) supplying air to the plant roots, and (iv) supplying nutrients to the plant roots. Substrates/growing media are made up of particles that are grouped together as larger, medium, and fine particles (Tzortzakis & Economakis, 2008). Researchers have assessed several growth media with respect to their physical and chemical composition and with regard to their contribution to plant growth, yield and biochemical contents involving strawberries and cucumbers (Ameri et al., 2012; Guuml et al., 2010). They concluded that high-quality growth media are essential to the entire development and quality of crops.

Because functional aspects of cultivation such as drainage, aeration and water holding capacity are involved, the physical characteristics of growth media are essential in optimising plant growth and outputs (Urrestarazu et al., 2008). The growth media's nutritional qualities serve a supporting role and can be improved by having a lower content (Martini et al., 2004). According to Celikel (1997), a good growing medium is one that is free of compaction, has a high nutritional content, and has a good capacity to hold water.

Inden and Torres (2001) endorsed coir substrate because of its many benefits including (i) effective drainage, (ii) high water holding capacity, (iii) promotion of root growth, and (iv) reusability because it is made from organic materials. Thus, coir, a substrate formed from the mesocarp of coconut fruit, was suggested as a growing medium for agronomic crops (Abrahimi et al., 2012). One of the best-known greenhouse crops in South Africa, is tomato (*Solanum lycopersicum*), which has a variety of nutritional advantages due to its high vitamin A, B, and C content (Cunha et al., 2014). However, the effect of varying coconut coir substrate types (Power and Profit) has not been extensively investigated, particularly on tomato crop. Therefore, the current study sought to investigate how tomato crops respond to coconut coir substrate types (Power and Profit).

1.2 Research questions

The research study addressed the following research questions below:

- What is the major effect of different coir substrates on the growth parameters of *S. lycopersicum* plants?
- Do different coir substrate affect the yield of *S. lycopersicum* plants under greenhouse environment?
- What is the effect of different coir substrates on the biochemical concentration or quality parameters of *S. lycopersicum* fruit?

1.3 Research problem

In spite of the fact that intensive farming methods can increase food production, Othman et al., (2019) suggested that more work needs to be done to prevent environmental deterioration. The promotion and use of organic substrate may result in an improvement in the sustainability of the environment and the crop yield, which will then support sustainable agricultural practices, lessen soil pollution, and boost output (Jerca et al., 2015). It is critical to evaluate the advantages and disadvantages of organic substrates regarding agricultural yield in light of the need to encourage their use as alternatives to traditional soils. More specifically, utilizing growth media that is efficient, inexpensive, reusable and less harmful to the environment is crucial since the production and supply of food is under extreme strain. Thus, the results of such experimental studies should be made available to aid farmers in embracing the use of effective growing substrates. The productivity of the aforementioned treatment on tomato crops produced in greenhouses was assessed by comparing the use of various coir substrates to control, loamy soil as a control regarding improvement in growth, yield and biochemistry of such tomatoes.

1.4 Research gap

In Southern Africa, the use of organic substrate such coir has not yet been fully realized as a dependable method with the potential for industrial application and increased crop production (Agboola et al., 2018). An important reason for this is the scarcity of literature describing the use of coir substrate for agricultural cultivation on a commercial scale (Mojeremane et al., 2016).

Research should determine the effects of coir as substrate on tomatoes, as well as agronomical analysis of plant growth metrics, yield and fruit quality profile. Data acquired from this study will be treated as a benchmark on the use of coir substrate in commercial farming operations for tomato and agronomical crops, locally and internationally. Thus, the main emphasis of this study is to assess the impact of various coir substrates on the growth, development and biochemical constituents of tomato (*S. lycopersicum*) by comparison of factors associated with control tomato plants, cultivated in loamy soil, and to then publish the results of this study to increase and spread knowledge of the advantages of the use of coir as a plant substrate, with a view to expanding future commercialization of this cultivation method.

1.5 Aims and objectives of the study

1.5.1 Study aim

The main aim of the study is to determine the effect of different coir substrates on the growth, yield, and quality of tomato grown under greenhouse environment.

1.5.2 Study objectives

The objectives of the study are:

- Objective 1: To determine the most effective coir substrate for growing *S. lycopersicum* plants grown under greenhouse environment by comparing plant growth, development across three different substrates, each with a specific nutrient composition, and measuring outcomes through plant height, chlorophyll content, stomatal conductance, total biomass, fruit number, fruit length and harvest index.
- Objective 2: To assess the most effective coir substrate for growing nutrient dense *S. lycopersicum* fruit across three different substrates with a specific nutrient composition under greenhouse environment by comparing biochemical constituents such as crude proteins, *β*-carotene, vitamin C, vitamin E, total flavonoids, total phenols, lycopene, macro and micro-nutrients.

1.6 Reliability and validity

The methods and tools used to gather information and analyze data in order to address the relevant research questions are what determine the extent to which a study is credible. Thus, it is crucial that the study utilizes trustworthy, legitimate and appropriate methodologies, control tests, and, most importantly, record data with the utmost accuracy. According to Creswell (2014), reliability refers to the accuracy and dependability of the tools and techniques used to measure plant growth, development, yield and the biochemical profile of the study on tomato plants. In this study, a randomized block design was used to assess the tomato crop growth and development under various environmental conditions, yield performance and biochemical profile. To make inferences, the generated data were properly statistically analyzed.

1.7 Bias

It is crucial to employ realistic methods that will reduce biases when performing experimental research. According to Creswell (2014), bias is a mistake made during the planning or execution of an experimental study that causes a distortion in one direction due to non-random factors. By increasing the blocks, replications, randomization, and seasonal recurrence of the trials in this study, experimental error was minimized and bias was eliminated (Mouton, 2013).

1.8 Significance of the study

When investigating the effect of different coir substrates on the growth, development, yield, and biochemical profile of tomato (*S. lycopersicum*) under greenhouse conditions, it is important to expect variability in the growth performance, yield and biochemical constituents of the crop. The impact of coir substrate on the growth and yield characteristics may be favorable or unfavorable as crop growth, yield and biochemical components can be affected positively or negatively by factors such as pH, EC, temperature, irrigation and fertilizers (Pawlowski et al., 2017). It could be possible that most farmers don't utilise coconut coir as a substrate because they lack sufficient knowledge as to how different coir substrates affect tomato *(S. lycopersicum*) growth, yield, quality and biochemical profile, making it risky for the farmers to invest in this substrate. Farmers will be more inclined to adopt coir as a substrate for agronomic reasons and potential rewards if they are given scientifically validated information as to how it affects the crop's performance (growth, development, and yield) and biochemical profile (vitamin A, vitamin B, vitamin C, total phenols, total flavonoids, total soluble sugars, crude proteins, macro and micronutrients).

1.9 Dissertation overview

The study process and activities are outlined in the dissertation framework, and the research findings are presented in a systematic and thorough way. The following are descriptions of the chapters' headings and brief explanations of each of their contents:

Chapter 1: Introduction

This chapter provides a brief background to the cultivation of tomato plants in the presence of coir and then describes a study problem statement, aim and study objectives, and the significance of the study.

Chapter 2: Literature review

The literature review provides in-depth background information on the impact of various substrates on the growth, yield, and biochemical content of various horticultural crops, factors that have a direct and indirect impact on the growth, development, yield, and biochemical content of the crop, as well as the necessity of further research into the impact of coconut coir on the quality of agricultural crops. The conclusion of this chapter identifies gaps in the literature and justifies the investigation.

Chapter 3: Effect of coir substrates on the growth and yield of tomato (*Solanum lycopersicum*)

This experimental chapter investigated the effect of varying coconut coir substrate on the growth and yield of tomatoes under greenhouse environment. Gathered data were statistically analysed in order to reach factual conclusion.

Chapter 4: Biochemical profile of tomato (*Solanum lycopersicum*) fruit from plant grown on coconut coir substrate under greenhouse environment.

This chapter examined the effect of different coconut coir substrates types (Profit and Power) on the biochemical constituents such as β-*carotene*, crude protein, total soluble sugars, lycopene, vitamins, flavonoids, phenols, macro and micro-nutrients of tomato fruit (*Solanum lycopersicum*) grown under greenhouse environment. Data gathered was statistically analysed in order to reach factual conclusion.

Chapter 5: General conclusions, recommendations and future work

The main research findings are outlined in this dissertation's concluding chapter, along with the key conclusions drawn from the study. It also suggest the potential utilisation of coconut coir as a substrate for horticultural and agricultural crops. Moreover, further investigations are suggested.

1.10 References

Agboola, O. O., Oseni, O. M., Adewale, O. M., & Shonubi, O. (2018). Effect of the use of sawdust as a growth medium on the growth and yield of tomato. Annales of West University of Timisoara. Series of Biology, 21(1): 67-74.

Alan, R., Zulkadir, A., & Padem, H. (1993). The influence of growing media on growth, yield and quality of tomato grown under greenhouse conditions. In II Symposium on Protected Cultivation of Solanacea in Mild Winter Climates. *Acta Horticulturae*, 366: 429-436.

Ameri, A., Tehranifar, A., Shoor, M., & Davarynejad, G. H. (2012). Effect of substrate and cultivar on growth characteristic of strawberry in soilless culture system. *African Journal of Biotechnology*, *11*(56), 11960-11966.

Bhowmik, D., Kumar, K. S., Paswan, S., & Srivastava, S. (2012). Tomato-a natural medicine and its health benefits. *Journal of Pharmacognosy and Phytochemistry*, 1(1), 33-43.

Celikel, G. (1997). Effect of different substrates on yield and quality of tomato. In International Symposium Greenhouse Management for Better Yield & Quality in Mild Winter Climates, *Acta Horticulturae,* 49: 353-356.

Creswell, J. W. (2014). Research design: qualitative, quantitative, and mixed methods approaches (4th ed.). Thousand Oaks, California: Sage Publications.

Cunha, A. H., Sandri, D., Vieira, J. A., Cortez, T. B., & Oliveira, T. H. D. (2014). Sweet grape mini tomato grown in culture substrates and effluent with nutrient complementation. *Engenharia Agrícola*, 34: 707-715.

Davis, J., & Brema, J. (2017). Increasing the Plant Metabolism in Polyhouse Farming Using Colour Filters. *International Journal of Innovative Research and Advanced Studies*,4: 2394-4404

Ebrahimi, R., Souri, M. K., Ebrahimi, F., & Ahmadizadeh, M. (2012). Growth and yield of strawberries under different potassium concentrations of hydroponic system in three substrates. *World Applied Sciences Journal*, *16*(10), 1380-1386.

Farquhar, G. D., & Sharkey, T. D. (1982). Stomatal conductance and photosynthesis. *Annual Review of Plant Physiology*, 33(1): 317-345.

Gul, K., Tak, A., Singh, A. K., Singh, P., Yousuf, B., & Wani, A. A. (2015). Chemistry, encapsulation, and health benefits of β-carotene-A review. *Cogent Food & Agriculture*, 1(1): 1-12.

Kumar, S., Kumar, S., & Mohapatra, T. (2021). Interaction between macro-and micro-nutrients in plants. *Frontiers in Plant Science*, 12: 1-9.

Ignat, I., Volf, I., & Popa, V. I. (2011). A critical review of methods for characterisation of polyphenolic compounds in fruits and vegetables. Food chemistry, 126(4): 1821-1835.

Inden, H., & Torres, A. (2001). Comparison of four substrates on the growth and quality of tomatoes. *In International Symposium on Growing Media and Hydroponics,* 644: 205-210.

Irigoyen, J. J., Einerich, D. W., & Sánchez-Díaz, M. (1992). Water stress induced changes in concentrations of proline and total soluble sugars in nodulated alfalfa (Medicago sativd) plants. *Physiologia Plantarum*, 84(1): 55-60.

Jerca, I.O., Sorin Mihai Cîmpeanu, S.M., Dudu, G., Burghilă, D.V. (2015). Study on the influence of the type of substrate and the quantity upon the tomato crop. Scientific papers. *Series B, Horticulture*. LIX: 225-228.

Mariotti, F., Tomé, D., & Mirand, P. P. (2008). Converting nitrogen into protein—beyond 6.25 and Jones' factors. *Critical Reviews in Food science and Nutrition*, 48(2): 177-184.

Martini, E. A., Buyer, J. S., Bryant, D. C., Hartz, T. K., & Denison, R. F. (2004). Yield increases during the organic transition: improving soil quality or increasing experience? *Field Crops Research*, 86(2-3): 255-266.

Mojeremane, W., Moseki, O., Mathowa, T., Legwaila, G. M., & Machacha, S. (2016). Yield and yield attributes of tomato as influenced by organic fertilizer. *American Journal of Experimental Agriculture*, 12(1): 1-10.

Mouton, J. (2001). *How to succeed in your masters' and doctoral studie*s. Pretoria: Van Schaik.

Othman, Y., Bataineh, K., Al-Ajlouni, M., Alsmairat, N., Ayad, J., Shiyab, S., ... & St Hilaire, R. (2019). Soilless culture: Management of growing substrate, water, nutrient, salinity, microorganism and product quality. *Fresenius Environmental Bulletin*, 28(4): 3249-3260.

Pawlowski, A., Sánchez-Molina, J. A., Guzmán, J. L., Rodríguez, F., & Dormido, S. J. A. W. M. (2017). Evaluation of event-based irrigation system control scheme for tomato crops in greenhouses. *Agricultural Water Management*, 183: 16-25.

Urrestarazu, M., Mazuela, P. C., & Martínez, G. A. (2008). Effect of substrate reutilization on yield and properties of melon and tomato crops. *Journal of Plant Nutrition*, 31(11): 2031-2043.

Tripathi, D. K., Singh, V. P., Chauhan, D. K., Prasad, S. M., & Dubey, N. K. (2014). Role of macronutrients in plant growth and acclimation: *Recent Advances and Future Prospective. Improvement of Crops in The Era of Climatic Changes*, 197-216.

Tzortzakis, N. G., & Economakis, C. D. (2008). Impacts of the substrate medium on tomato yield and fruit quality in soilless cultivation. *Horticultural Science*,83-89.

Zekki, H., Gauthier, L., & Gosselin, A. (1996). Growth, productivity, and mineral composition of hydroponically cultivated greenhouse tomatoes, with or without nutrient solution recycling. *Journal of the American Society for Horticultural Science*, 121(6), 1082-1088.

CHAPTER 2: LITERATURE REVIEW

This literature review's main objective is to examine earlier studies on the effects of coir substrate or comparable growth medium on crop growth, development, and yield. It was also to review pertinent research on how it affects the performance of other crops in terms of their growth, development, yield, and quality. Additionally, it evaluates numerous approaches and metrics used to quantify its impact on the development, growth, yield, and quality of the crop.

The desire to generate food to meet the world's expanding food need is increasing becoming the SDG prioty in the twenty-first century. However, in order to protect the environment, this should be carried out in a sustainable manner (Gruda & Schnitzler,2004). Both industrialized and developing nations have a strong demand for high-quality food, which puts heavy pressure on food producers to grow these crops. A continuous search for, discovery of, and use of organic growth media will play a vital role in environmental protection while helping to solve the food insecurity issues (Sihlongonyane, et al., 2018). The gap in the promotion of organic agriculture will be filled by the use of organic substrates, such as various coir substrates, which will also lessen environmental deterioration.

2.1 Impact of soil and environment on tomato production

The effects of soil water deficit on yield and quality of processing tomato under a Mediterranean climate has been investigated by Patane and Cosentino (2010). Increases in fruit firmness, total solids, and soluble solids were shown to be a result of rising soil water deficit, according to the authors, who also noted a negative trend in fruit production and size as a result of growing soil water deficit. Healy et al (2017), trialled different tomato variety for productivity and quality in organic hoop house versus open field management. Authors found that the yield, disease severity, and °Brix (soluble sugars) of tomatoes produced in a protected environment compared to those grown in an open field were all significantly higher.

Vermicompost on tomato yield and quality and soil fertility in greenhouse under different soil water regimes has investigated by authors such as Yang et al (2015). Authors determined that when compared to other treatments, vermicompost boosted both the yield and the amount of vitamin C. Moreover, under three different soil water regimes, vermicompost did, however, reduce the overall acidity and soluble solids.

There appears to be scanty knowledge on the yield responses and quality profile of tomato plant to various grown from varying coconut coir substrate under greenhouse environment. Therefore, the current study sought to fill the gap in literature by investigating the effect on varying coir substrates on the growth, yield and biochemical profile of *S. lycopersicum* under greenhouse environment.

2.2 Tomato (*S. lycopersicum*) as a research crop

In most of Central and Southern America, tomato (*S. Lycopersicum*), is a annual crop and a member of the solanaceae family, thrives as a weed by nature (Costa & Heuvelink, 2018). Usually, it takes between 20 and 30 days for *S. lycopersicum* to reach flowering stage, and it has yellow petals. As of 40 to 50 days following transplant, according to Menda et al. (2013), fruit set begin take place. Fruit development is primarily caused by the meiotic process, in which haploid pollen grains are produced by the anther (Huang et al., 2015). The berries of the tomato plant *(S. lycopersicum)* can be small, egg-shaped, or large (Kimura & Sinha, 2008).

When processed into sauce and juice, tomatoes serve as a source of valuable minerals (Burton-Freeman and Reimers, 2011). One of the typical crops, that is also a good source of carbohydrates, minerals, and vitamins (Erba et al., 2013). As a crucial component of salads, it can also be used in its raw form. In order to fully understand how this valuable crop responds to organic substrate, particularly coir, which is the major subject of this study, it is therefore, of paramount importance to examine.

Figure 2.1: Ripe tomato fruit grown under coconut coir (Power) substrate.

2.3 Cultivation of tomato *(S. lycopersicum*)

Tomato is easily grown from the seeds undergrowth media with good drainage, good aeration and medium water holding capacity (Burmistrov et al., 2021). The optimum germination temperatures ranged between 20 to 27 degrees Celcius and must be maintained until the development of the second leaf stage (Barceloux, 2009). Healthy matured seedlings should be transplanted two to three weeks under full to the moderate sun and rich well-drained soil (Kowalczyk et al., 2012).

2.3.1 Irrigation of tomato (*S lycopersicum*)

Wang and Xing (2016) reported that plants cannot transport the essential nutrients they requires if there is a lack of water. Therefore, both the lack of and abundance of water on soil can have a direct impact on the general growth and development of crops, as well as their yield and quality of tomato plant (Pan et al., 2019). Overwatering causes the active root zone of the crops to become more moist than the soil can hold (Klaring et al., 2015). Any moisture above this field water capacity point begins to leak out of the root zone of the plants, depriving them of water and removing vital nitrogen (Xiukang and Yingying, 2016).

Mahajan and Singh (2006) investigated the response of greenhouse grown tomato to to irrigation and fertigation. Authors determined that in comparison to surface-irrigated crops, drip-irrigated crops have longer total roots. In terms of fruit size, total soluble sugars concentration, ascorbic acid content, and pH, greenhouse-grown tomato fruits were shown to be superior to those from open-field crops. Additionally, drip irrigation considerably improved all of the quality characteristics of greenhouse crops compared to other treatments. There seems to be scanty literature on the effect of varying coconut coir substrates on the growth, yield and biochemical profile of S. *lycopersicum* crop grown under greenhouse environment. Therefore, the current study filled the void.

2.3.2 Fertilisers

The tomato yield could be increased more successfully by using chemical fertilizer (Yang et al., 2015). However, using organic manure, particularly fermenting manure, might considerably lower nitrate content in tomato fruit and increase the content of soluble sugar and vitamin C while also improving fruit quality. Mzibra et al. (2021) evaluated growth, yield and quality of tomato plants treated with seaweed-based biostimulants. Authors found that plant growth, yield and other biochemical constituents such as glucose, galactose and maltose improved under seaweed-based biostimulas as compared to other treatments.

The current study examined how different coconut coir substrates affected growth, yield, and biochemical profile *L. lycopersicum* in a greenhouse setting to fill the gap in the body of literature. Therefore, an automatic fertigation system was used to distribute fertilizer to ensure that plants had access to well-balanced nutrients.

2.3.3 Light

The production of in tomato plant fruit, the size and color of leaves, and flowering are all impacted by light intensity (Ilic et al., 2021). Tomato plants that are grown in low light typically have spindly growth and leaves that are light green. When cultivated in intense light, a similar plant would typically develop shorter, better branches and larger, dark green leaves (Paucek et al., 2020).

Authors such Ilic et al. (2021), investigated the effects of the modification of light intensity by color shade nets on yield and quality of tomato fruits. Athours reported that in comparison to non-shading conditions, the production of marketable tomatoes increased by roughly 35% in red and pearl nets with 40% shade. Shading also greatly reduced tomato cracking's visual appearance and removed sunscalds on tomato fruits. Lycopene and beta-carotene production in tomatoes was impacted by modifying the light intensity with color-shade nets. The currently study focused the in the effect of different coir substrates on the growth, yield and biochemical profile of *S. lycopersicum* grown under greenhouse environment in order to fill the void in exisiting literature.

2.3.4 Temperature

Photosynthesis, transpiration, respiration, germination, and flowering are just a few of the processes that are impacted by temperature (Maluleke et al., 2022). High temperatures have an adverse effect on crop growth, particularly crops like tomatoes (Ibrahim et al., 2014). High air temperatures inhibit shoot growth, which inhibits root growth. As severe root injury results in a significant reduction in shoot growth, high soil temperature is even more important (Kläring et al., 2015).Combined effect of ventilation, irrigation, temperature and humidity on the yield and quality of greenhouse grown tomatoes has been evaluated by Ge et al. (2021). Authors found that total soluble solids, vitamin C content, organic acid content, and soluble sugars content were fruit quality indicators that were inversely connected with irrigation water quantity, but tomato yeild was positively correlated with it. Ventilation mostly affected the harvest season; yield was not much impacted. In comparison to other treatments, the combination of temperature and drip irrigation is strongly advised as the best treatment for greenhouse tomatoes in order to generate the best crop output and fruit quality.

2.4 Soil/substrate requirement of tomato (*S. lycopersicum*)

It is established that substrate plays a pivotal basic role in the growth, development, yield, and biochemical constituents of most agricultural crops (Akhter et al,. 2015). Almost all aspects of plant bio-physiological processes are directly affected by the substrate since the plant depends on it for water, nutrients, and air (Carballo-Méndez et al., 2016). Researchers such as Tran et al. (2021) stated that the choice to use a specific growth medium is mainly determined by its biological, physical, and chemical properties since they directly affect plant growth.

Tomato (*S. lycopersicum)* prefers fertile soil that has a good drainage capacity and is free from compaction (Kouřimská et al., 2009). Other important qualities for the substrate used for tomato (*S. lycopersicum*) cultivation are moderate particles size and shape which will enable air movement for better aeration (Kimura & Sinha, 2008). Unfortunately, there is a paucity of literature concerning the use of different coir substrates on the growth, development, yield and biochemical constituents of tomato (*S. lycopersicum*) crop. Therefore, the present study holds a view that the use of different coir substrates may fill the void on its effect on growth, development, yield and biochemical constituents of tomato (*S. lycopersicum*) crop.

2.5 Coir substrate

Konduru et al. (1999) indicated that coir fiber or substrate comes from the husk that surrounds the coconut seed and is classified as a coarse substance. The coir substrate is made from the husks (Noguera et al., 2003). Mariotti et al. (2020) reported the advantages of coir being: (i) good water holding, (ii) good drainage, (iii) good aeration, (iv) re-usability and (v) free from soil borne related disease.

Van der Knaap (2021) describes coconut coir (Power) as a grow medium comprised of fine coconut material and crushed coconut husk that is effective for crop generative and vegetative guiding. On the other hand, coconut coir (Profit), which is also made from coconut husk, is excellent for promoting the crop's vegetative organs. The media exhibits a modest rate of air-filled porosity and water absorption (Van der Knaap, 2021).

There appears to be scanty knowledge and scientific information on the use of different coir substrate on the growth, yield and quality on the tomato (*S. lycopersicum*) crop. Therefore, this current study seeks to close the gap on the effect of different coir substrate on growth, development, yield and quality of tomato *S. lycopersicum.*

2.6 Physiological factors in plants grown under different substrates

According to Weinberger and Lumpkin (2007), plant growth is the gradual increase in the plant's weight and size brought on by the emergence of new leaves, cells, flowers, fruits, and seeds. In order to produce as much as possible throughout the photosynthesis process, the plant cell employs water, carbon dioxide, light, and enzymes (Adachi et al., 2000). By analysing the chlorophyll content, stomatal conductance, and biomass of the roots, stems, leaves, and fruits of a plant, one may determine its physiological growth (Ebrahim (2004).

2.6.1 Effect of different substrates on the plant chlorophyll content

The amount of chlorophyll accumulated during the photosynthetic process, through which plants transform solar energy into chemical energy, was described by Adachi et al. (2000) as the chlorophyll content. The plant's chlorophylls are the most efficient component for absorbing blue and red wavelengths, which helps explain why plant leaves are greener (Alomran & Luki, 2012). Additionally, the chlorophyll plays a significant role in the transformation of light energy into chemical energy, which enables the plant to carry out its metabolic processes (Abu-Zinada, 2015). Chlorophyll content is impacted when plants are grown under varying environmental conditions such as temperature, water availability and soil types (Tewari & Tripathy, 1998; Shu et al., 2013).

According to various sources, the amount of chlorophyll in plant leaves may vary depending on the kind of soil and the amount of water available (Shu et al, 2013; Penfield & MacGregor, 2017). Analysis of chlorophyll content can be used to measure plant's physiological growth and development (Ibrahim, 2014). In order to address a gap on the physiological impact of *S. lycopersicum'* s chlorophyll concentration under greenhouse environment, the current study utilised different coir substrates.

2.6.2 Effect of different substrate on the plant stomatal conductance

The physiological processes of the plant are directly influenced by the kind of soil and the availability of water; hence, transpiration and photosynthesis rates can be increased or decreased (Zhang et al., 2003). Numerous studies have looked into the direct impact of stomatal opening or closure brought on by water scarcity on plants' capacity for photosynthetic activity. Researchers like Savvides et al. (2012) and Hirano et al. (1995) have made the case that temperature is not the single significant factor affecting stomatal opening and closing. They noted that in some heat-loving plants, low water content and soil temperature have the power to impair stomatal conductance.

There seems to be limited information available on how different coir substrates affect the stomatal conductance of *S. lycopersicum* crops grown under greenhouse environments. By measuring the stomatal conductance of *S. lycopersicum* grown on various coir substrates under greenhouse environment, the current study thereby filled the gap.

2.6.3 Effect of different substrate on the crop yield

Crop yields are the amount of crop products that are harvested for each unit of harvested area. Most of the time, crop yield data they are calculated by dividing production data by harvested area data Demura & Ye, 2010). The most important factors to measure for estimating crop output are total biomass, harvest index, fruit number, and length, according to authors like Rahil and Qanadillo (2015) and (Wang et al., 2020).

2.6.3.1 Total biomass

According to Hao and Papadopoulos (1999), biomass is the combined weight of all plant components, including both above-ground (leaves, stem and fruits) and below-ground (roots). Solar energy, carbon dioxide, soil type, and water all have an impact on the photosynthetic process, which converts solar energy into vegetative tissues and increases plant biomass production (Demura & Ye, 2010). On the other hand, Ge et al. (2021), identified variations in tomato crop biomass productivity grown under various temperature, soil type, and irrigation regimes.

There seem to be paucity of literature on the effect of varying coir substrates on the total biomass of S. lycopersicum crop grown under greenhouse environment. Therefore, the current study filled the void in literature by determining the total biomass of the crop grown on different coir substrates under greenhouse.

2.6.3.2 Fruit number and length

Rahil & Qanadillo (2015) claim that one of the most important factors influencing total fruit production, including fruit biomass, fruit number and number of crops is the availability of water, light intensity, soil types and the growing environment. Nerson (2015), on the other hand, noted that pollination greatly enhanced the amount and size of fruit on crops cultivated in open fields as opposed to those that were grown in covered structures. The current study investigated the effect of different coir substrates on the fruit number and length of *S. lycopersicum* crop grown under greenhouse environment to fill the void in literature.

2.6.3.4 Harvest index

The kilograms of dry fruit biomass are divided by the total kilograms of above-ground biomass to determine the harvest index (Maluleke et al., 2021). Crop growth rate, photosynthetic performance, and radiation usage efficiency within the plant all affect the plant biomass and harvest index. Consequently, increasing plant biomass and harvest index are essential for yield (Wang et al., 2017). The most crucial factor in determining how the harvest index evolves, according to Sinclair (1998), is photosynthesis among all plant growth parameters.

According to Tardieu (2013), harvest index is sensitive to environmental factors like weather, soil quality, and water availability throughout crop reproductive development. These factors should therefore be considered since they could have an impact on the plant's development, growth, and production (Fageria, 2014). Research on the impact of various coir substrates on the harvest index of *S. lycopersicum* crop grown in greenhouse environments appears to be limited. In order to fill this gap in the literature, the current study evaluated the harvest index of a *S. lycopersicum* crop cultivated in a greenhouse environment on various coir substrates.

2.7 Nutritional uses and propertis of tomato (*S. lycopersicum*) fruit

Authors such as Dorais et al. (2011) and van Wyk (2005) indicated that raw, cooked and processed tomato remains one of the most used products in the world. When cooked, it becomes one of the most delicious sauces for meat, pasta, salads and soup (Hobson & Grierson,1993). Tomato fruits are also processed for various products such as juice, jam, sauces, preservatives and powder (Zhang et al., 2011). The nutritional qualities of tomato have been reported by authors such as Frusciante et al. (2007) as being:

- High sources of vitamin A, B and C
- High source of both macro-micro nutrients such as potassium and folate

Which has been reported by Dorais et al. (2008) vital nutrients responsible for the prevention of cancer and potential heart diseases. This study, therefore, evaluated the effect of varying coir substrate on the biochemical constituents content of tomato (*S. lycopersicum*) under greenhouse environment.

2.8 Biochemical constituents in plants

People consume different kinds of fruit for a variety of reasons, according to Kader (2005), but the main traditional goal of eating is the potential provision of energy and nutrients. It is crucial to assess the biochemical content of specific fruits before storage since humans receive nutrients such as *β-carotene*, sugars, protein, flavonoids, phenols, vitamins,macro and micro-nutirnets through consuming plant products like fruits and vegetables (Ali & Abdelatif, 2001).

Researchers have looked into how the quality of tomato fruits is influenced by the type of soil or growing medium (Chen et al., 2013; Xiukangand Yingying, 2016; Liu et al., 2019). As opposed to fruits produced on vermi-compost, fruits cultivated in loam soil included less total soluble sugars, flavonoids, total phenols, and vitamins, according to their research. To the best of our knowledge, there seems to be limited literature regarding the effect of varying coir substrates on the growth, yield and quality of tomatoes. Therefore, the current study filled the void.

2.8.1 Beta carotene

Carotene is an abundant organic red-orange pigment that is found in a variety of fungi, plants, and fruits (Ismail, 2014). It belongs to the family of terpenoids known as carotenes and is produced biochemically from isoprene units. A large part of -carotene's contribution to human health includes the enhancement of vision, cell division and differentiation, bone growth, and reproduction (Moyo et al., 2018). Additionally, it serves a variety of other functions in plants, including blocking blue radiation from reaching the photosynthetic organs (Manthey & Perkins-Veazie, 2009).

For instance, according to research by Chen et al. (2013), tomato fruit quality such as vitamins, lycopene, and total flavanoids was significatly affected by varrying irrigation water deficits. There seem to be paucity of information regarding the effect of varrying coir substrates on the growth, yield and quality of tomatoes.

This would imply that measurements of the *β-carotene* content of tomato fruit grown under greenhousee should be undertaken, and results should be applicable to the business world.

2.8.2 Total soluble sugars

According to Abuajah et al. (2015), soluble sugars are one of the most prevalent substances and account for around 80% of the sugar in plant fruits. It is one of the earliest byproducts of photosynthesis and is used by plant cells for respiration and glycolysis, which both require energy production (Arrom & Munné-Bosch, 2012). The majority of total soluble sugar is found in fruit, and the cells of the body use it as their main source of energy (Ali & Abdelatif, 2001; Bernaert et al., 2013).

Olle et al. (2012) examined the vegetable quality and productivity as influenced growing medium. Authors concluded that total soluble sugars of crops depend on the substrate being utilized, some inorganic substrates might affect the growing media to cause vegetables to grow more quickly. They farthur indicated that it is challenging to draw broad conclusions about how inorganic and organic media affect the chemical makeup of a crop.

Furthermore, results vary depending on the crop, the organic and inorganic substrate's chemical make-up, and the elements' availability affect crop quality. The current study evaluuated the effect of different coir substrates on the total soluble sugars on *S. lycopersicum* fruit grown under greenhouse environment.

2.8.3 Crude proteins

Crude protein, as defined by Lopez et al. (2013), is the quantity of protein present in plant organs. Typically, it is calculated by measuring the total nitrogen content of plant tissue, primarily in fruit dry matter (Osuji et al., 2015). The genotype of the plant and the environmental environments to which it was exposed during cultivation affect the overall percentage of crude protein in fruit dry matter (Mabhaudhi et al., 2013).

Shiyab et al. (2013) evaluated growth, nutrient concentration and physiological responses of hydroponic grown tomato fruits. Authors discovered that biochemical constitunts of tomato plant material reduced significantly in respond to increased salimity levels when compared to other treatments. There seem to be scanty literature on the effect of different coir substrates on crude protein of tomato fruit. Therefore, by quantifying the amount of crude protein in tomato fruits that were harvested from various coir substrates in a greenhouse environment, the current study filled the gap in the literature.

2.8.4 Vitamins

Vitamins, according to Esch et al. (2010), are essential organic substances that must be consumed in significant amounts for healthy growth and development. Fruit's vitamin content is very beneficial to human health because vitamins are necessary for the body's regular daily functions (Locato et al., 2013). Because of the surrounding environment of the plants, the ratio of vitamins in fruit fluctuates. Citrus fruit harvested from unfertilised soil, for instance, had a lower vitamin content when compared to those harvested from fertilized soil, according to a study by Sinha (2015) that looked at the vitamin C content of citrus.

The impact of various coir substrates on the vitamin content of *S. lycopersicum* fruit produced in greenhouse environments appears to be a topic on which there is little information. To fill this gap in the literature, the current work assessed the vitamin content of S. lycopersocum cultivated on various coconut coir substrates in a greenhouse environment.

2.8.5 Total flavanoids

Generally found in berries, fruits, cereals, tree bark, tea, grapes, tomatoes and other fruits, total flavonoids are known as naturally occurring compounds with phenolic structures (Hu et al., 2019). Such organic compounds are well known for their various benefits on human health, including prevention of conditions like obesity, asthma, and autism (Saeed et al.,2012). Total flavonoids are one of the factors, according to Fenech et al. (2019), that support fruit and vegetables as essential components of a regular diet for people. People whose survival depends on the careful selection of certain foods are more likely to adhere to a diet plan that considers the nutritional value of food as well as its acceptability and the source of beneficial substances (Krogholm, 2011).

Vermicomposts' effects on greenhouse tomato productivity, quality, and soil fertility under various soil water regimes has been evaluated by Ibrahim et al. (2014). Researchers found that vermicomposted soil had higher levels of biochemical compounds component such flavanoids than non-vermicomposted soil. To fill a gap in the literature, the current study assessed the impact of various coir substrates on the total flavanoids of *S. lycopersicum* fruit cultivated in a greenhouse.

2.8.6 Total phenols

Hossain and Shah (2015) describe total phenols as groups of compounds that develop from aromatic amino acids. These compounds primarily serve as a defense mechanism against potential predators and as a form of UV radiation protection. They can also cause coloration in the fruit and flowers of most crops (Bernaert et al., 2013). Fruit like berries, tomatoes and pumkins are known in food science and nutrition to be high in phenolic compounds (Oliveira et al., 2008; Saeed et al., 2012).

Previous research work has been undertaken to extract and analyse phenols in different fruits. For instance, Sezen et al. (2010), examined the impact of irrigation management on the quality of tomatoes fruit in various soilless media under greenhouse environment. When compared to when there was only moderate water availability in the tomato crop, researchers discovered that having more water available during irrigation considerably lowered the total phenols.

There seem to be scanty information available on how different coir substrates affect the total phenolic content of *S. lycopersicum fruit* grown under greenhouse environment. Because of this, the current study assessed the total phenolic content of *S. lycopersicum* fruit grown under greenhouse enviroment in order to close the literature gap.

2.8.7 Macro and micro nutrients

Micronutrients are needed in much smaller amounts than macronutrients, which are a set of elements needed in substantial amounts (Barrett et al., 2010). According to several studies, the availability of macronutrients in fruit is stable (Wang et al., 2008); however, factors such soil type, irrigation water regime, and location may affect nutritional content (Maluleke et al., 2021).

Schauer and Fernie (2006), environmental variables including soil quality, temperature, and water availability have a substantial impact on macronutrients like phosphate, magnesium, and sulfur. Sezen et al. (2010), water stress causes some macronutrient elements to decrease, however micronutrients (iron, zinc, and molybdenum) were not impacted and even increased in other fruits. Due to their direct impact on human health, macro- and micronutrients of *S. lycopersicum* fruit under varied irrigation and fertilizer types have been extensively studied by numerous authors such as Chen et al (2013) and Liu et al. (2019). The research on the impact of various coir substrates on the macro and microelement concentration of tomato fruit cultivated in a greenhouse setting, however, appears to be sparse.

Data gathered from the current study might help farmers produce fruit that is rich in nutrients and necessary for human health. Therefore, the current study filled the gap by quantifying the nutrients found in *S. lycopersicum* fruit cultivated on several types of coir substrates.This information might help farmers produce fruit that is rich in nutrients and necessary for human health. The current study fills this gap by quantifying the nutrients found in *S. lycopersicum* fruit cultivated on several types of coir substrates.

2.9 References

Abuajah, C. I., Ogbonna, A. C., & Osuji, C. M. (2015). Functional components and medicinal properties of food: a review. *Journal of food science and technology*: *52*(5), 2522-2529.

Adachi, M., Kawabata, S., & Sakiyama, R. (2000). Effects of temperature and stem length on changes in carbohydrate content in summer-grown cut chrysanthemums during development and senescence. *Postharvest Biology and Technology*, *1*(20), 63-70.

Akhter, A., Hage-Ahmed, K., Soja, G., & Steinkellner, S. (2015). Compost and biochar alter mycorrhization, tomato root exudation, and development of *Fusarium oxysporum f. sp. lycopersici*. *Frontiers in Plant Science*, 6, (529): 1-13.

Ali, N. A., & Abdelatif, A. H. (2001). *Chemical measurement of total soluble sugars as a parameter for cotton lint stickiness grading: Seminar of the project 'Improvement of the marketability of cotton produced in zones affected by stickiness'*, held in Lille, France on 4-7 July 2001.

Alomran, A. M., & Luki, I. I. (2012). Effects of deficit irrigation on yield and water use of grown cucumbers in Saudi Arabia. *WIT Transactions on Ecology and the Environment*, *168*, 353-358.

Barceloux, D. G. (2009). Potatoes, tomatoes, and solanine toxicity (Solanum tuberosum L., *Solanum lycopersicum* L.). Disease-a-month, 55(6), 391-402.

Barrett, D. M., Beaulieu, J. C., & Shewfelt, R. (2010). Color, flavor, texture, and nutritional quality of fresh-cut fruits and vegetables: Desirable levels, instrumental and sensory measurement, and the effects of processing. *Food Science and Nutrition*, *50*(5), 369-389.

Bernaert, N., De Clercq, H., Van Bockstaele, E., De Loose, M., & Van Droogenbroeck, B. (2013). Antioxidant changes during postharvest processing and storage of leek (*Allium ampeloprasum* var. porrum). *Postharvest Biology and Technology*, *86*, 8-16.

Burmistrov, D. E., Yanykin, D. V., Simakin, A. V., Paskhin, M. O., Ivanyuk, V. V., Kuznetsov, S. V. & Gudkov, S. V. (2021). Cultivation of *Solanum lycopersicum* under Glass Coated with Nanosized Upconversion Luminophore. Applied Sciences, 11, (10726): 1-9.

Burton-Freeman, B., & Reimers, K. (2011). Tomato consumption and health: emerging benefits. *American Journal of Lifestyle Medicine*, *5*(2), 182-191.

Chen, J., Kang, S., Du, T., Qiu, R., Guo, P., & Chen, R. (2013). Quantitative response of greenhouse tomato yield and quality to water deficit at different growth stages. *Agricultural water management*, *129*: 152-162.

Dam, B. V., Goffau, M. D., Lidth de Jeude, J. V., & Naika, S. (2005). Cultivation of tomato: Production, processing and marketing. *Agrodok*, 1-93.

De Jesús Carballo-Méndez, F., Rodríguez-Ortiz, J. C., Alcalá-Jáuregui, J. A., Rodríguez-Fuentes, H., Preciado-Rangel, P., & García-Hernández, J. L. (2018). Comparison of two organic determinate tomato (*Solanum lycopersicum* L) production systems in a control environment. *Interciencia*, 43(1): 62-65.

Demura, T., & Ye, Z. H. (2010). Regulation of plant biomass production. *Current opinion in plant biology*, *13*(3): 298-303.

Dorais, M., Ehret, D. L., & Papadopoulos, A. P. (2008). Tomato (Solanum lycopersicum) health components: from the seed to the consumer. *Phytochemistry Reviews*, 7(2): 231-250.

Ebrahim, M. K. (2004). Comparison, determination and optimizing the conditions required for rhizome and shoot formation, and flowering of in vitro cultured calla explants. *Scientia Horticulturae*, *101*(3), 305-313.

Erba, D., Casiraghi, M. C., Ribas-Agustí, A., Cáceres, R., Marfà, O., & Castellari, M. (2013). Nutritional value of tomatoes (Solanum lycopersicum L.) grown in greenhouse by different agronomic techniques. *Journal of Food Composition and Analysis*, *31*(2), 245-251.

Esch, J. R., Friend, J. R., & Kariuki, J. K. (2010). Determination of the vitamin C content of conventionally and organically grown fruits by cyclic voltammetry. *International Journal of Electochemical Science*, *5,* 1464-1474.

Fageria, N. K. (2014). Nitrogen harvest index and its association with crop yields. *Journal of plant nutrition*, *37*(6): 795-810.

Fenech, M., Amaya, I., Valpuesta, V., & Botella, M. A. (2019). Vitamin C content in fruits: Biosynthesis and regulation. *Frontiers in Plant Science*, *9,* 1-21.

Frusciante, L., Carli, P., Ercolano, M. R., Pernice, R., Di Matteo, A., Fogliano, V., & Pellegrini, N. (2007). Antioxidant nutritional quality of tomato. *Molecular nutrition & food research*, 51(5): 609-617.

Ge, J., Zhao, L., Gong, X., Lai, Z., Traore, S., Li, Y., & Zhang, L. (2021). Combined effects of ventilation and irrigation on temperature, humidity, tomato yield, and quality in the greenhouse. *HortScience*, *56*(9): 1080-1088.

Gul, S., Whalen, J. K., Thomas, B. W., Sachdeva, V., & Deng, H. (2015). Physico-chemical properties and microbial responses in biochar-amended soils: mechanisms and future directions. *Agriculture, Ecosystems & Environment*, *206*: 46-59.

Gruda, N., & Schnitzler, W. H. (2004). Suitability of wood fiber substrates for production of vegetable transplants II.: The effect of wood fiber substrates and their volume weights on the growth of tomato transplants. *Scientia Horticulturae*, 100(1-4): 333-340.

Hao, X., & Papadopoulos, A. P. (1999). Effects of supplemental lighting and cover materials on growth, photosynthesis, biomass partitioning, early yield and quality of greenhouse cucumber. *Scientia Horticulturae*, *80*(1-2): 1-18.

Healy, G. K., Emerson, B.J & Dawson, J. C. (2017). Tomato variety trials for productivity and quality in organic hoop versus open field management. *Renewable Agriculture and Food Systems*, 32(6): 562-572.

Hobson, G., Grierson, D., Seymour, G. B., Taylor, J. E., & Tucker, G. A. (1993). Tomato (Biochemistry of Fruit Ripening). *Dordrecht: Springer*, 405-442.

Hossain, M. A., & Shah, M. D. (2015). A study on the total phenols content and antioxidant activity of essential oil and different solvent extracts of endemic plant *Merremia borneensis*. *Arabian Journal of Chemistry*, *8*(1), 66-71.

Hu, C., Zhao, H., Shi, J., Li, J., Nie, X., & Yang, G. (2019). Effects of 2, 4-dichlorophenoxyacetic acid on cucumber fruit development and metabolism. *International Journal of Molecular Sciences*, *20*(1126), 1-16.

Huang, W., Liao, S., Lv, H., Khaldun, A. B. M., & Wang, Y. (2015). Characterization of the growth and fruit quality of tomato grafted on a woody medicinal plant, *Lycium chinense*. *Scientia horticulturae*, 197, 447-453.

https://www.vanderknaap.info/en/products/sustainable-growing-systems/148. Accessed [October 2021].

Ibrahim, A., Wahb-Allah, M., Abdel-Razzak, H., & Alsadon, A. (2014). Growth, yield, quality and water use efficiency of grafted tomato plants grown in greenhouse under different irrigation levels. *Life Science. Journal*, *11*(2): 118-126.

Julián-loaeza, A. P., Santos-sánchez, N. F., Valadez-blanco, R., Sánchez-guzmán, B. S., & Salas-coronado, R. (2011). Chemical composition, colour, and antioxidant activity of three varieties of *Annona diversifolia* Safford fruits. *Industrial Crops and Products*, 34, 1262–1268.

Kilic, P., Erdal, I & Aktas, H. (2018). Effect of different substrates on yield and fruit quality of tomato grown in soilless culture. Suleyman Demirel University. Turkey.

Kimura, S., & Sinha, N. (2008). Tomato (Solanum lycopersicum): a model fruit-bearing crop. Department of Plant Biology, University of California, Davis, CA 95616: USA.

Kläring, H. P., Klopotek, Y., Krumbein, A., & Schwarz, D. (2015). The effect of reducing the heating set point on the photosynthesis, growth, yield and fruit quality in greenhouse tomato production. *Agricultural and Forest Meteorology*, *214*: 178-188.

Konduru, S., Evans, M. R., & Stamps, R. H. (1999). Coconut husk and processing effects on chemical and physical properties of coconut coir dust. *HortScience*, 34(1): 88-90.

Kouřimská, L., BaBičKa, L., Václavíková, K., Miholová, D., Pacáková, Z., & Koudela, M. (2009). The effect of fertilisation with fermented pig slurry on the quantitative and qualitative parameters of tomatoes (*Solanum lycopersicum*). *Soil and Water Research*, 4(3): 116-121.

Kowalczyk, K., Gajc-Wolska, J., Metera, A., Mazur, K., Radzanowska, J., & Szatkowski, M. (2012, October). Effect of supplementary lighting on the quality of tomato fruit (*Solanum lycopersicum L.*) in autumn-winter cultivation. Acta Horticulturae, 956, 395-401.

Krogholm, K. S. (2011). Flavonoids as fruit and vegetable intake biomarkers – Flavonoids as fruit and vegetable intake biomarkers – Development, validation and application of flavonoid biomarkers in nutritional research. PhD, University of Copenhagen.

Liu, H., Li, H., Ning, H., Zhang, X., Li, S., Pang, J., ... & Sun, J. (2019). Optimizing irrigation frequency and amount to balance yield, fruit quality and water use efficiency of greenhouse tomato. *Agricultural Water Management*, *226*(105787),1-11.

Ilić, Z. S., Milenković, L., Stanojević, L., Cvetković, D., & Fallik, E. (2012). Effects of the modification of light intensity by color shade nets on yield and quality of tomato fruits. *Scientia Horticulturae*, *139*, 90-95.

Locato, V., Cimini, S., & De Gara, L. (2013). Strategies to increase vitamin C in plants: From plant defense perspective to food biofortification. *Frontiers in Plant Science*, *4*, 1-12.

López, A., Arazuri, S., Jarén, C., Mangado, J., Arnal, P., Ruiz, I., & López, R. (2013). Crude protein content determination of potatoes by NIRS technology. *Procedia Technology*, *8*, 488-492.

Mabhaudhi, T., Modi, A. T., Africa, S., Beletse, Y. G., & Africa, S. (2013). Growth response of selected taro [*Colocasia esculenta* (L.) Schott] landraces to water stress. *Acta Hort*, *979*, 327-334.

Mahajan, G., & Singh, K. G. (2006). Response of greenhouse tomato to irrigation and fertigation. *Agricultural water management*, *84*(1-2): 202-206.

Maluleke, M. K. (2022). Metabolite profile of African horned cucumber (Cucumis metuliferus E. May. Ex Naudin) fruit grown under differing environmental conditions. *Scientific Reports*, *12*(1), 1-18.

Mariotti, B., Martini, S., Raddi, S., Tani, A., Jacobs, D. F., Oliet, J. A., & Maltoni, A. (2020). Coconut coir as a sustainable nursery growing media for seedling production of the ecologically diverse Quercus species. Forests, 11(5): 1-19.

Menda, N., Strickler, S. R., & Mueller, L. A. (2013). Advances in tomato research in the post-genome era. *Plant Biotechnology*, 30(3): 243-256.

Mzibra, A., Aasfar, A., Khouloud, M., Farrie, Y., Boulif, R., Kadmiri, I. M., & Douira, A. (2021). Improving Growth, Yield, and Quality of Tomato Plants (*Solanum Lycopersicum* L) by the Application of Moroccan Seaweed-Based Biostimulants under Greenhouse Conditions. *Agronomy*, *11*(7): 1373.

Noguera, P., Abad, M., Puchades, R., Maquieira, A., & Noguera, V. (2003). Influence of particle size on physical and chemical properties of coconut coir dust as container medium. *Communications in soil science and plant analysis*, *34*(3-4): 593-605.

Olle, M., Ngouajio, M., & Siomos, A. (2012). Vegetable quality and productivity as influenced by growing medium: *Žemdirbystė=Agriculture*, *99*(4), 399-408.

Osuji, G. O., Duffus, E., Johnson, P., Woldesenbet, S., Weerasooriya, A., Ampim, P. A. Y., & Johnson, A. (2015). Enhancement of the essential amino acid composition of food crop proteins through biotechnology. *American Journal of Plant Sciences*, *6*(12), 3091-3108.

Pan, T., Ding, J., Qin, G., Wang, Y., Xi, L., Yang, J., & Zou, Z. (2019). Interaction of supplementary light and CO2 enrichment improves growth, photosynthesis, yield, and quality of tomato in autumn through spring greenhouse production. *HortScience*, *54*(2): 246-252.

Patanè, C., & Cosentino, S. L. (2010). Effects of soil water deficit on yield and quality of processing tomato under a Mediterranean climate. *Agricultural water management*, *97*(1), 131-138.

Paucek, I., Pennisi, G., Pistillo, A., Appolloni, E., Crepaldi, A., Calegari, B., ... & Gianquinto, G. (2020). Supplementary LED interlighting improves yield and precocity of greenhouse tomatoes in the Mediterranean. *Agronomy*, *10*(7):2-14.

Quinet, M., Angosto, T., Yuste-Lisbona, F. J., Blanchard-Gros, R., Bigot, S., Martinez, J. P., & Lutts, S. (2019). Tomato fruit development and metabolism. *Frontiers in plant science*, 10 (1554): 1-23.

Saeed, N., Khan, M. R., & Shabbir, M. (2012). Antioxidant activity, total phenols and total flavonoid content of whole plant extracts Torilis leptophylla L. *BMC Complementary and Alternative Medicine*, *12* (221), 2-12.

Shiyab, S. M., Shatnawi, M. A., Shibli, R. A., Al Smeirat, N. G., Ayad, J., & Akash, M. W. (2013). Growth, nutrient acquisition, and physiological responses of hydroponic grown tomato to sodium chloride salt induced stress. *Journal of plant nutrition*, *36*(4): 665-676.

Sihlongonyane, S. A., Oseni, T. O., Wahome, P. K., Masarirambi, M. T., & Kunene, E. N. (2018). Effects of different media and cultivars on the yield and quality of tomato (*Solanum lycopersicum*) grown in hydroponics. *American Eurasian Journal of Agriculture and Environmental Science*, 18(6), 338-346.

Tardieu, F. (2013). Plant response to environmental conditions: assessing potential production, water demand, and negative effects of water deficit. *Frontiers in physiology*, *4*(17):1-11.

Tran, C. T., Watts-Williams, S. J., Smernik, R. J., & Cavagnaro, T. R. (2021). Root and arbuscular mycorrhizal effects on soil nutrient loss are modulated by soil texture. *Applied Soil Ecology*, 167, 104097.

Urrestarazu, M., Mazuela, P. C., & Martínez, G. A. (2008). Effect of substrate reutilization on yield and properties of melon and tomato crops. *Journal of Plant Nutrition*, 31(11): 2031-2043.

Wang, X. X., Zhao, F., Zhang, G., Zhang, Y., & Yang, L. (2017). Vermicompost improves tomato yield and quality and the biochemical properties of soils with different tomato planting history in a greenhouse study. *Frontiers in plant science*, *8*, (1978): 1-11.

Weinberger, K., & Lumpkin, T. A. (2007). Diversification into horticulture and poverty reduction. *World Development*, *35*(8), 1464-1480.

Zhang, J., Wang, X., Yu, O., Tang, J., Gu, X., Wan, X., & Fang, C. (2011). Metabolic profiling of strawberry (Fragaria 3 ananassa Dutch.) during fruit development and maturation. *Journal of Experimental Botany*, 62(3): 1103–1118.

Yang, L., Zhao, F., Chang, Q., Li, T., & Li, F. (2015). Effects of vermicompost on tomato yield and quality and soil fertility in greenhouse under different soil water regimes. *Agricultural Water Management*, *160*: 98-105.

CHAPTER 3: Effect of varying coir substrates on the growth and yield of tomato (*Solanum lycopersicum*)

3.1 Abstract

Fruit crops depend on the substrate quality for improved growth, development and yield. Most producers choose the use of organic substrate for greenhouse crop cultivation to ensure better quality to meet market demand all year round. Coconut coir is organically produced substate from the external husk or mesocarp of coconut fruit that has environmental benefits due to its renewable nature. The objective of the study was to determine the effect of different coconut coir substrate types (Profit and Power) on the growth and yield of tomato fruit grown under greenhouse environment. Variables such as fruit number, harvest index, total biomass and water content were assessed. The study revealed that tomato plant grown in coconut coir (Power) resulted in an increased fruit number compare to other treatments. The harvest index was superior following the plant grown in coconut coir (Profit) compared to other treatments. Regarding total biomass, results showed that cultivation in coconut coir resulted in a relative increase in the total biomass while the coconut coir substrate (Profit) had the highest water content. Therefore, it can be concluded that growing tomatoes in coconut coir (Power) substrate will produce more fruit, whereas coconut coir (Profit) has the necessary capacity to boost yield. Farmers are encouraged to grow tomato plants in coconut coir (Power and Profit) substrate for higher fruit number and yield for profit maximisation under greenhouse environment.

Keywords: Tomato, coconut coir, yield, total biomass, water content.

3.2 Introduction

In the agricultural and horticultural industries, growers refer to specialised soil and soilless mixes as growth media (Kerkhofs et al., 2003). Thus, growing quality plants begins with choosing the correct media for your crops that should continuously supply plants roots with water, air, nutrients and effectively anchor the plants (Uddain et al., 2009). Such media are assessed in terms of their physical and chemical qualities (Vivek and Duraisamy, 2017). The physical properties of growth media are crucial because they involve functional qualities such as drainage, aeration, water holding capacity and compaction (Hadid, 2016; Kilic et al., 2018; Mariotti et al., 2020). The nutritional characteristics of the growth media play a secondary role and can be improved if it has lower content of valuable elements needed by plants for growth, development and yield (Maluleke et al., 2021).

As most horticultural crops are grown in plastic bags or pots, growth media are carefully developed to provide the best possible environment for the crop to grow efficiently, consequently improving yield and quality (Paucek et al., 2020). Many growth media do not contain soil but are mostly processed from organic and inorganic materials (Johann, 2007). One of such substrates is coconut coir, which is defined as an organic product that is made from the outer husk (mesocarp) of a coconut fruit (Konduru et al., 1999). The advantages of using coconut coir substrate as growth media has been explained by Olle et al. (2012) as being: (i) renewable and organic, (ii) odourless and uniform chemical composition, (iii) good aeration and drainage, (iv) high capacity for retaining water and excellent absorption, (v) encourage robust root growth and relatively affordable.

Pretty (2018) indicated that while it is possible to improve food production through intensive agricultural systems, effort should be improved to reduce environmental degradation. Promotion and utilisation of organic substrate could lead to an increase in environmental sustainability and improving the yield of crops which will then aid in sustainable agricultural practice, reduce soil pollution and increase production (Weng, 2010). Several authors investigated the effect of various soilless media on the growth and yield of different horticultural crops (Sun et al., 2021; Kilic et al., 2018).

However, there seems to be scanty knowledge on the impact of different coconut coir substrate on the growth and yield of tomato (*S. lycopersicum*) under greenhouse environment. Therefore, an objective of the study was to determine the effect of different coconut coir substrates on the growth and yield of tomato (*S. lycopersicum*) grown under greenhouse environment.

3.3 Methodology

This study was conducted during the year (2021) and repeated in (2022 growing in a greenhouse at Florida Science Campus of the University of South Africa (26˚ 10’ 30’’S, 27o 55’ 22.8’’ E). The greenhouse temperature was kept between 15 and 25˚C, the optimal range for tomato crop growth in general, and the relative humidity was maintained between 60 and 75% using automated drip irrigation system (Erba et al., 2013). A factorial experiment with one factor – different coconut coir substrate types (Power and Profit) was conducted in a greenhouse environment. Coconut coir (Power and Profit) growing/planting bags were sourced from commercial manufacturer (Van der Knaap, South Africa). The planting/growing bags experiment was a completely randomised design with ten (10) replicates. The pots were spaced 1 m apart, and an up-rope vertical trellising was used to support the plants. Plants pots were either filled with power or profit coconut coir. Each block comprised 10 plants, resulting in 30 plants per site including control plants. A total of 60 plants were used for the experiment. Each site had plants used as guard plants. Well established, uniform and healthy 30 days old tomato seedlings, germinated from peat substrate, were transplanted into planting/growing bags. The calculation below shows the size of the planting bag:

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

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

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

Figure 3.1: Experimental layout of *Solanum lycopersicum* grown under greenhouse environment.

Data on plant growth parameters were collected during different experimental periods [2021, planting year one] and [2022, planting year two]. It is worth noting that the experiment was conducted by strictly adhering to the standards and requirement of the Research and Higher Degree Committee of the College of Agriculture and Environmental Sciences at UNISA. In addition, the study received ethical approval from the UNISA-CAES Health Research Ethics Committee, reference number 2021/CAES_HREC/136.

3.3.1 Data collection

3.3.1.1 Soil/substrate properties analysis

Table 3.1: Mineral/chemical composition of varying substrates.

Chemical Analysis (Micro and Macro minerals)					
	Fe mg kg^{-1}	Mn mg kg^{-1}	Cu mg kg^{-1}		Zn mg kg^{-1}
Coir Profit	34	12	8		14
Coir Power	40	10	5		10
Loamy soil	33	59	124		8.52
	P Mg kg^{-1}	Ca Mg kg^{-1}	Mg Mg kg^{-1}	K mg kg^{-1}	Na Mg kg^{-1}
Coir Profit	11	15	13	151	64
Coir Power	6	12	7	117	46
Loamy soil	27,8	1390	148	223	56.4

Before planting, soil samples (coir Profit, coir Power and loamy soil) were tested for mineral and/or chemical content (Table 3.1), using methods described Rahil and Qanadillo (2015). The analysis described above was conducted at the Agricultural Research Council's Institute for Soil, Climate, and Water (ARC-ISWC) in Pretoria (25° 44′ 19.4″ S28° 12′ 26.4″ E).

3.3.1.2 Determination of plant height

Plant height was measured once every week (day five) at different growth stages (pre-flowering, flowering and fruiting) during the experimental period. The measuring tape (Webco Tool, South Africa) was used to measure of plant height (cm).

3.3.1.3 Determination of stem diameter

Stem diameter was measured once every week (day five) at different growth stages (pre-flowering, flowering and fruiting) during the experimental period. A vernier calliper (Mitutoyo, Japan) was used for the measurement of stem diameter.

3.3.1.4 ***Determination of above and total biomass***

Above-ground fresh biomass (stem, leaves and fruits) was weighed at the end of the experiment using an electronic scale (Uni-Bioc, China). To determine dry weight, plant material that had already been counted was weighed, placed in paper bags and then into an oven for 72 hours at 80˚C before re-weighing, using methods described Rahil and Qanadillo (2015). Total biomass was determined using the formula below:

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

3.3.1.5 *Determination of fruit number and length*

Number of fruits was visually counted, and fruit lengths were measured (using a 30cm ruler) at the end of the experiment.

3.3.1.6 Determination of harvest index

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

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

3.4 Statistical analysis

Generalised linear mixed model procedures for GenStat (version 14, VSN, UK) was used for data analysis. Response variables can have any type of exponential distribution with the general linear model. It can handle categorical predictors in addition to the aforementioned factors. The general linear gives a clear knowledge of how predictors such as different coconut coir types influence the result and is relatability simple to interpret. The model was used to assess the fixed variables of different coir (Power and Profit) substrates on *Solanum lycopersicum* - during different seasons/years [2021, season one] and [2022, season two] on the studied variables (plant height, chlorophyll content, stomatal conductance, total biomass, fruit number, fruit length, harvest index) . Significant differences were considered and reported in the results section to determine the effects of all studied variables (stem diameter, plant height, chlorophyll content, stomatal conductance, fruit number and length, total biomass and harvest index). Least significant difference (LSD) of means reported per variable. All statistical analysis was done using GenStat (version 14, VSN, UK).

3.5 Results

3.5.1 Plant height

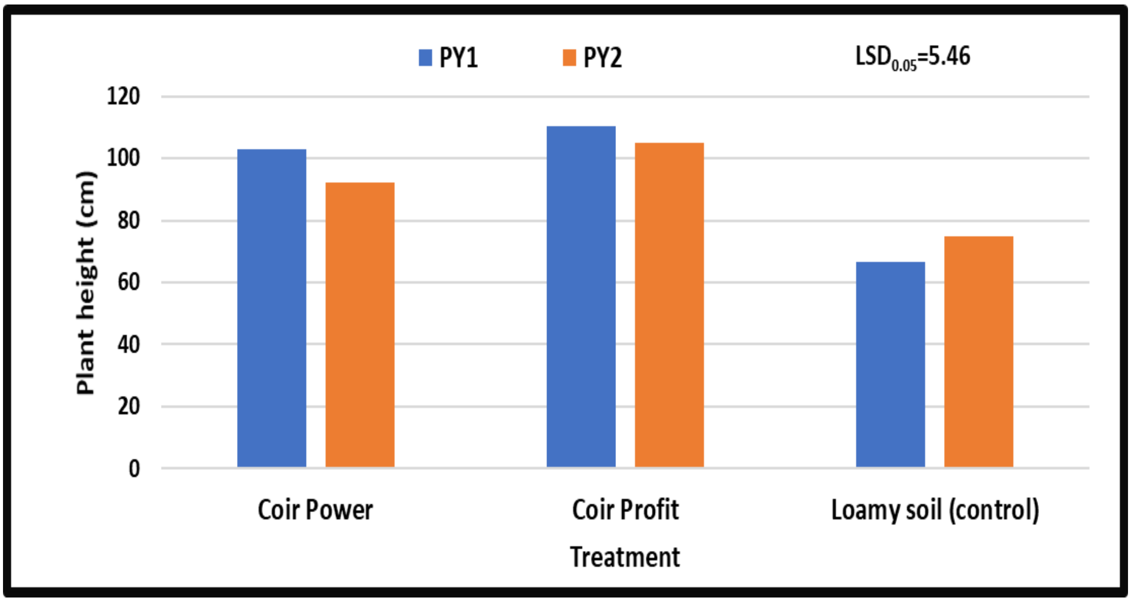

Figure 3.2 Effect of different coir substrates on the plant height of tomato grown under greenhouse environment. Values are average over treatment; substrates (coir Profit, coir Power and loamy soil-control). **PY1** means planting year one **(2021)**; **PY2** means planting year two **(2022)**. LSD0.05 is the least significant difference of means.

The study results showed that there was no significant ($P>0.05$) difference on the plant height of tomato crop grown under the two different coir substrates. However, plant height during planting year one (2021) ranged from 66.6 to 110.2 cm. During planting year two (2022), plant height ranged 75.0 to 105.0 cm. The study results showed that loamy soil substrate reduced aboveground biomass from 103.0 to 75.05 cm, whereas coir Power substrate increased it from 75.05 to 103.0 cm.

3.5.2 Chlorophyll content, stomatal conductance and stem diameter

Table 3.2: Effect of substrates on chlorophyll content, stomatal conductance and stem diameter of tomato crop grown under greenhouse environment.

	Chlorophyll content (µmol.m-2)		Stomatal conductance (mmol m-2 s-1)		Stem diameter (mm)	
Treatment	**PY1 (2021)**	**PY2 (2022)**	**PY1 (2021)**	**PY2 (2022)**	**PY1 (2021)**	**PY2 (2022)**
Coir Power	35.2(1.3)	30.6(1.2)	49.1(1.1)	44.6(1.4)	8.8(0.1)	8.94(0.2)
Coir Profit	38.4(1.2)	38.1(1.1)	51.9(1.2)	51.3(1.1)	8.1(0.2)	8.4(0.1)
Loamy soil (control)	36.2(1.1)	42.3(1.2)	52.4(1.2)	53.6(1.3)	8.5(0.1)	7.9(0.2)
Grand Mean	36.8	36.8	50.55	50.55	8.46	8.46
LSD0.05	1.30	1.30	1.45	1.45	0.66	0.66
Pvalue	**0.001**	**0.001**	**0.001**	**0.001**	0.165	0.165

PY1 meant planting year one **(2021)**; PY2 means planting year two **(2022).** 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. Note: The unit of chlorophyll content is provided as µmol/m^2, that of stomatal conductance as mmol/m^2/s and stem diameter in mm.

Table 3.2 shows the effect of a varied substrate on the amount of chlorophyll, stomatal conductance, and stem diameter of tomato crops cultivated in greenhouses during different planting years [2021 and 2022]. The study's findings revealed a noticeable (P≥0.05) difference in chlorophyll content. Planting year one [2021], chlorophyll content ranged from 35.2 to 38.4 mol m^{-2}, but planting year two [2022], ranged from 30.6 to 42.3 mol m-2 in 2022. Additionally, the study's findings demonstrated that planting year two [2022], coconut coir substrate (Power) decreased chlorophyll content from 42.3 to 30.6 mol m^{-2}, whereas loamy soil-control increased it from 30.6 to 42.3 mol m^{-2} during similar planting year.

Concerning stomatal conductance, the study results delineated that there was significant difference among treatments. During planting year one [2021], stomatal conductance ranged from 49.1 to 52.4 mmol $m^{-2} s^{-1}$, whereas planting year two [2022] ranged from 44.6 to 52.6 mmol $m^{-2} s^{-1}$. In addition, the results demonstrated that coconut coir substrate (Power) treatment reduced stomatal conductance from 53.6 to 44.6 mmol $m^{-2} s^{-1}$ during planting year two [2022], whereas loamy soil-control increased it from 44.6 to 53.6 mmol $m^{-2} s^{-1}$ during similar season.

For stem diameter, the findings demonstrated that there was no discernible difference between treatments for stem diameter. However, in planting year one [2021], stem diameter varied from 8.1 to 8.8 mm, whereas in planting year two [2022], it varied from 7.9 to 8.9 mm. Additionally, the results showed that during season two [2022], loamy soil-control decreased stem diameter from 8.9 to 7.9 mm, but coconut coir (Power) treatment increased it from 7.9 to 8.9 mm during the same planting period.

3.5.3 Total biomass

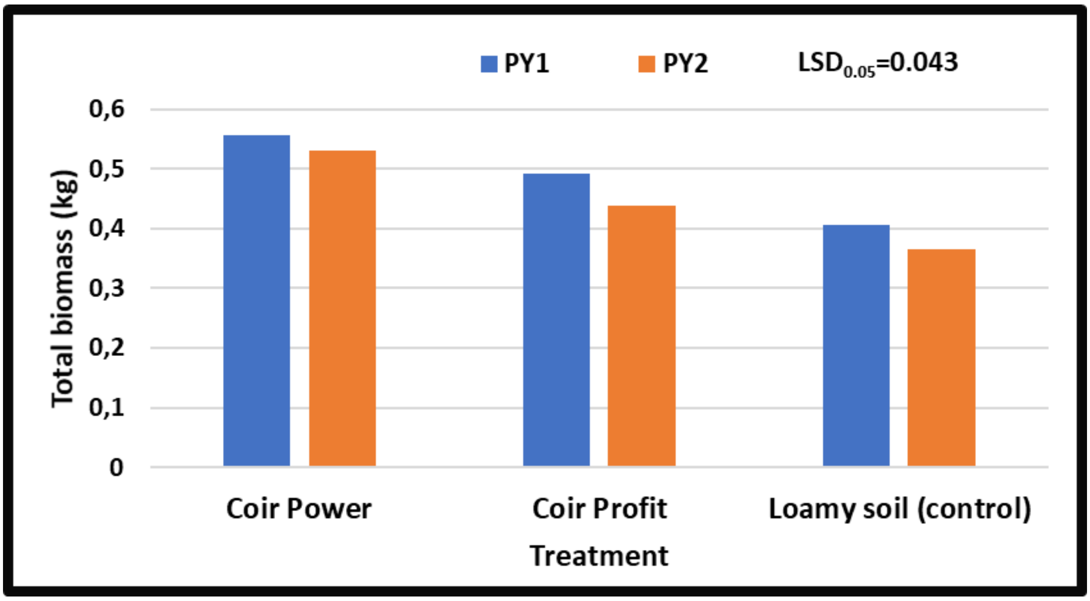

Figure 3.3: Effect of different coir substrates on the total biomass of tomato crop grown under greenhouse environment. Values are average over treatment; substrates (coir profit, coir power and loamy soil-control). PY1 means plaint year one (**2021)**; PY2 means planting year two (**2022)**. $LSD_{0.05}$ is the least significant difference of means.

The study results showed that there was Significant ($P \leq 0.05$) difference on the total biomass of tomato crop grown under different coir substrates. However total biomass during planting year one [2021] ranged from 0.404 to 0.556 kg. During planting year two [2022] total biomass ranged from 0.634 to 0.530 kg. The study results showed that loamy soil substrate reduced total biomass from 0.556 to 0.364 kg, whereas coir power substrate increased it from 0.364 to 0.556 kg.

3.5.4 Fruit number and length

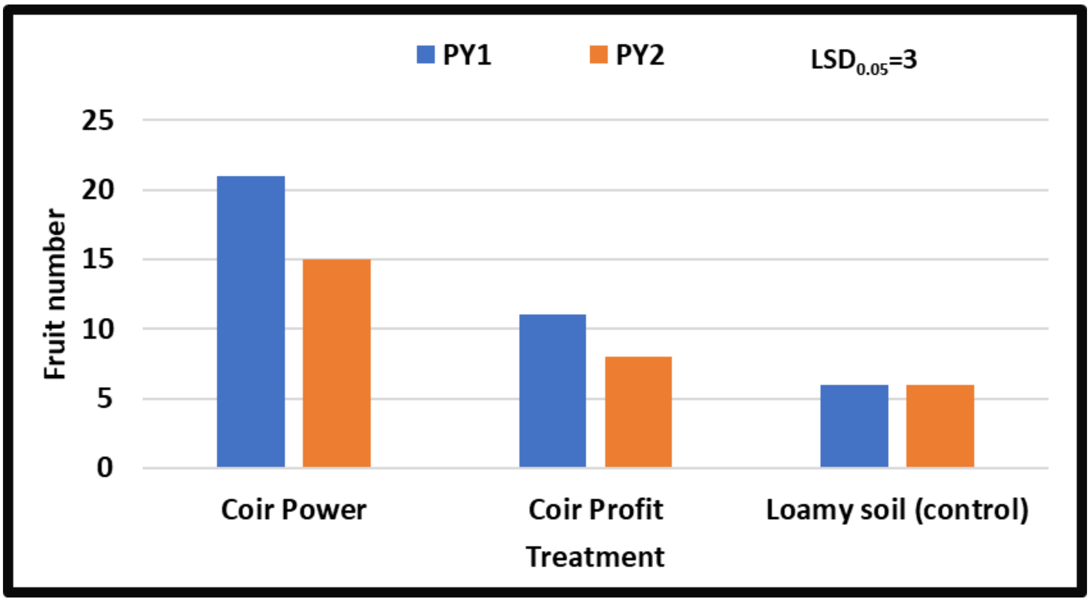

Figure 3.4: Effect of different coir substrates on the fruit number of tomato crop grown under greenhouse environment. Values are average over treatment; substrates (coir profit, coir power and loamy soil-control). PY1 means planting year one (**2022)**; PY2 means planting year two (**2022)**. $LSD_{0.05}$ is the least significant difference of means.

Figure 3.4 demonstrates that there was no significant (P>0.05) difference on the fruit number of tomato crop grown under different coir substrates. However, fruit number during planting year one [2021] ranged from 6 to 21, whereas planting year two [2022] fruit number ranged from 6 to 15. The study results showed that loamy soil substrate reduced fruit number from 21 to 6, whereas coir power substrate increased it from 6 to 21.

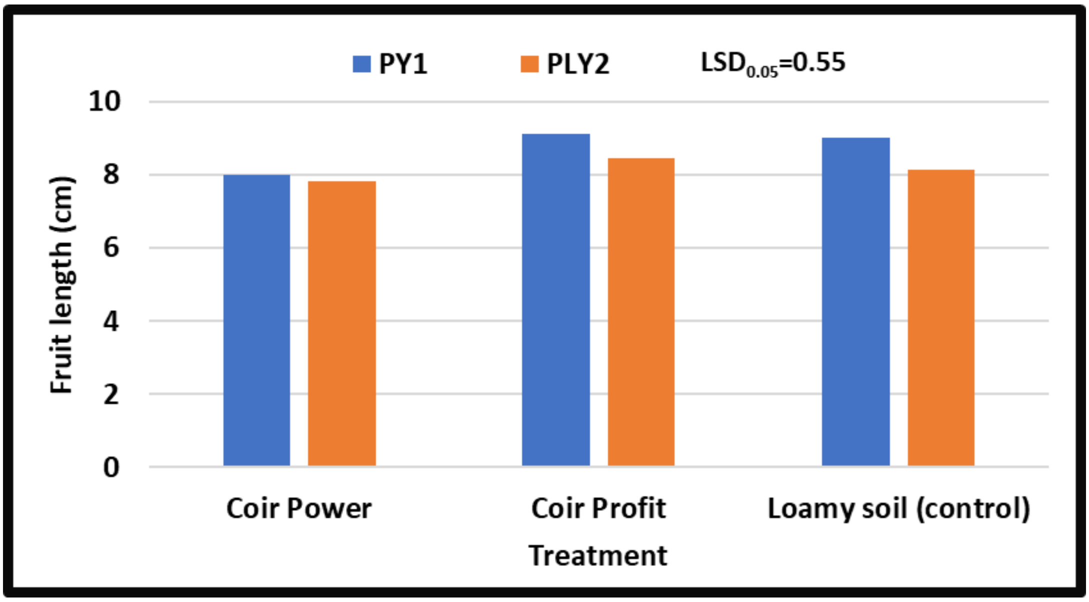

Figure 3.5: Effect of different coir substrates on the fruit length of tomato grown under greenhouse environment. Values are average over treatment; substrates (coir profit, coir power and loamy soil-control). Planting year one means (**2021)**; Planting year two means (**2022)**. $LSD_{0.05}$ is the least significant difference of means.

The study results show that there was no significant (P>0.05) difference on the fruit length of tomato crop grown under different coir substrates. However, fruit length during planting year one (2021) ranged from 8.0 to 9.1 cm. During planting year two (2022) fruit length ranged from 7.8 to 8.13 cm. The study results showed that loamy soil substrate reduced fruit number from 9.1 to 7.8 cm, whereas coir power substrate increased it from 7.8 to 9.1 cm.

3.5.5 Harvest index

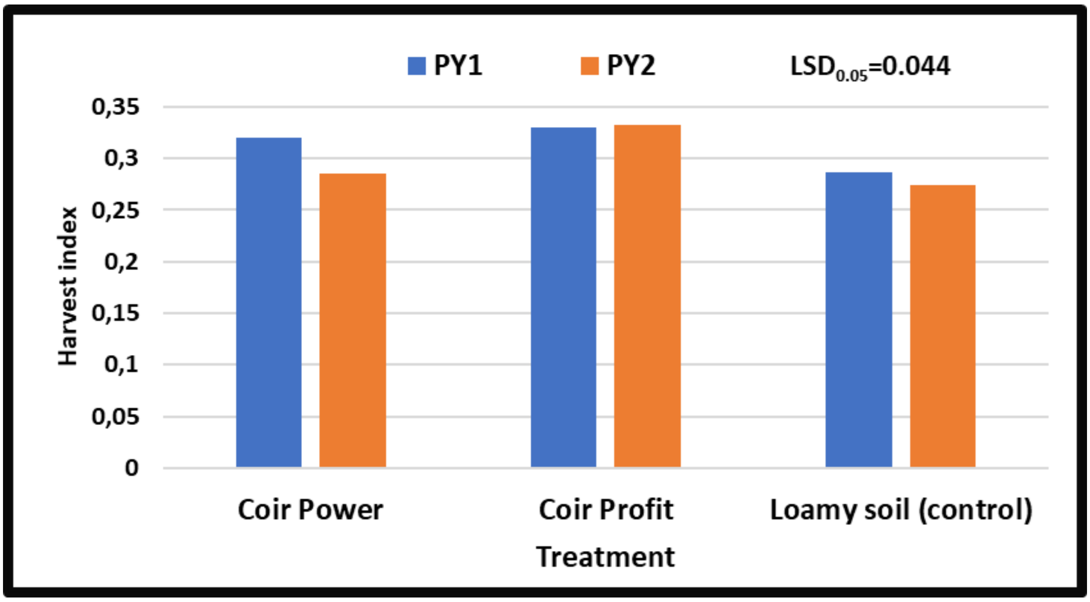

Figure 3.6: Effect of different coir substrates on the harvest index of tomato grown under greenhouse environment. Values are average over treatment; substrates (coir profit, coir power and loamy soil-control). PY1 means planting year one (**2021)**; planting year two means (**2022)**. $LSD_{0.05}$ is the least significant difference of means.

Figure 3.6 outlines the effect of different coir substrate on harvest index of tomato. It shows that there was significant (P≥0.05) difference on the harvest index of (Tomato) grown under different coir substrate. The harvest index during planting year one (2021) ranged from 0.28 to 0.33 kg. During planting year two (2022) it ranged 0.27 to 0.33 kg. The study results showed that loamy soil substrate reduced harvest index from 0.28 to 0.33 kg, whereas coir power substrate increased it from 0.28 to 0.33 kg.

3.6 Discussion

The use of organic substrates as growth media has recently attracted a lot of interest, particularly because of their advantages for the environment (Mojeremane et al., 2016). However, relatively few crops have been scientifically investigated to determine their performance and yield on organic substrates such as coconut coir (Power and Profit). The results of such research offer innovative and dependable cultivation techniques to encourage farmers to use substrates for a variety of horticultural crops, particularly as coir because it is reusable, and the development of dependable agronomic practices using coir may even lead to reduction in its costs to the farmers.

This study investigated the effect of different coir substrates (Power and Profit) on the growth and yield of tomato crop under greenhouse environment. Previous studies evaluated the effect of different substrates such as vermiculite, compost, rock wool and peat on various horticultural crops such as tomatoes, peppers and cucumber (Gruda,2019). There seems to be scanty literature on the use of different coconut coir substrates (Power and Profit) on the growth and yield of tomato. Therefore, findings from this study serves as a benchmark in relation to the use and advantages of cultivation of tomato plants using coir as substrate.

Physiological components

Chlorophyll content and stomatal conductance

Chlorophyll, which is the green pigment found in plants, is used for photosynthesis of plants. Each molecule of chlorophyll contains 6.7% magnesium, which is positioned in the middle of the molecule. The activation of the enzymes responsible for respiration, photosynthesis, and the synthesis of nucleic acids is greatly aided by magnesium (Abbas et al., 2021). Moreover, the fact that there was a significant difference between the magnesium content between control loamy soil (148 mg/kg) and coconut coir Profit (13 mg/kg) could be the cause of variation in chlorophyll content among plants grown under the above-mentioned treatments.

In the study, the slight variation between the highest chlorophyll content (42 µmol/m^2) on loamy soil-control and the highest chlorophyll content under coconut coir (Profit) (38 µmol/m^2) serves as a proof that coconut coir substrate (Profit) has great potential to provide required elements needed for healthy growth of tomato crop. The findings of this study concur with those of Olle et al. (2012), who found variation in chlorophyll content of various horticultural crops grown under different substrates such as vermicompost, rockwool and peat.

Variation between the highest stomatal conductance (53.5 mmol m^2/s) of control tomato plants cultivated in loamy soil and plants cultivated in coconut coir Profit (51.8 mmol/m^2 s^{-1}) was slight. The movement of plant stomata is controlled by potassium. On plant leaves, stomata permit the exchange of gases and water vapor. When plants receive sufficient potassium, guard cells develop to enable the opening and closing of stomata. In addition, potassium is also responsible for fruit formation and growth, depending on the environmental conditions (Ahammed et al., 2022). Perhaps, the fact that potassium content of loamy soil-control and coconut coir was superior to other treatment was the factual cause for variation of stomatal conductance of tomato crop.

These findings illustrate that coconut coir has a potential to be utilized as a reliable substrate for tomato cultivation under a protected environment. The study findings agree with those of Bhattarai & Swarnima (2016), who reported higher growth of crops treated with moderate potassium-rich fertilizers as compared to crop growth with plants that received potassium at a lower concentration.

Plant height, stem diameter and fruit number

The difference between the tallest plant (110.2 cm), measured on a plant cultivated on coconut coir Profit, and the shortest plant (66.6 cm), cultivated on loamy soil, may be ascribed to a variation in calcium content among substrates. This could also have been the reason for variation in stem diameter and fruit number. Biddulph et al. (1958), reported calcium in the bean plant as one of the few minerals that can migrate up the plant through the xylem. However, once it has reached its destination, it cannot be remobilized and transferred to newly forming tissues (Maathuis & Diatloff, 2013).

The most vulnerable tissues are those that are still developing, like growth points and fruiting bodies. In addition to helping plants develop more effectively, calcium is crucial for the synthesis of plant tissues (Upadhyaya et al.,2017). Additionally, calcium it is essential for signaling the coordination of specific cellular functions, stem diameter, fruit number and for the activation of specific enzymes (Upadhyaya et al.,2017). The results of the study contradict those of various authors because loamy soil-control had a higher calcium content. but lower plant height, a smaller stem diameter, and fewer fruits than coconut coir (Profit), which had a lower calcium content, but a longer plant height, a wider stem diameter, and more fruits.

Yield components

Total biomass and water content

Concerning the total biomass, the variation between the highest coconut coir-power (0.56 kg) and the lowest loamy soil-control (0.41 kg) was (0.15 kg). These observation serves a strong evidence that coconut coir substrate can be reliable used as a substrate for greenhouse tomato crop production. The energy unit of plants known as ATP contains phosphorus (Lovelock et al., 2006). Phosphorus is a component of ATP, which is typically created during photosynthesis and its role that starts from seedling and continues through the production vegetative organs until maturity (Olle et al., 2012). As a result, phosphorus is necessary for all plants' overall well-being and vigour (Huskisson et al., 2007). The variation of phosphorus content between loamy soil-control (27.8 mg kg^{1}) and coconut coir-Profit (11 mg kg^{1}) was (16 ma kg^{1}). These observations suggest that coconut coir (Profit) has a good potential to be utilised as a substrate for greenhouse tomato production since it can increase the total biomass of the plant. Furthermore, these findings are in harmony with those of Johann (2007), who reported variation in total biomass of tomato varieties grown under vermicompost substrate.

The water content variation between the highest (323 g) from coconut coir (Profit) and the lowest (189 g) from loamy soil-control was (134). The transport of water, minerals, and carbohydrates in plant tissue are all influenced by potassium. It is responsible for the plant's ability to activate enzymes, which has an impact on how much protein and starch. These observations demonstrate the beneficial impact coconut coir substrate has on enhancing tomato yield and farmer income. Additionally, these findings which showed a statistical variation, are consistent with those of Bhattarai & Swarnima (2016), who discovered a difference in the water content of cucumber fruits growing in potassium-rich substrates compared to those that have little potassium.

3.7 Conclusion

The study found that coconut coir (Profit) substrate provided optimal conditions for tomato plant growth in terms of chlorophyll content, plant height, stem diameter and water content—all of which are essential for overall yield—while coconut coir (Power) substrate produced more fruit overall. Therefore, the study's findings show that farmers utilizing coconut coir (Power or Profit) for greenhouse tomato production are likely to increase financial returns due to their capacity to enhance plant growth and yield. However, farmers are encouraged to consider accessibility and affordability of these substrates before adopting them for commercial large-scale production. To draw a conclusion that is supported by evidence, these coir substrates must first be examined in association with growth from other horticultural crops such as strawberries and cucumbers.

3.8 References

Abbas, S., Javed, M. T., Ali, Q., Azeem, M., & Ali, S. (2021). Nutrient Deficiency Stress and Relation with Plant Growth and Development. In Engineering Tolerance in Crop Plants Against Abiotic Stress (pp. 239-262). CRC Press.

Ahammed, G. J., Chen, Y., Liu, C., & Yang, Y. (2022). Light regulation of potassium in plants. Plant Physiology and Biochemistry, 170, 316-324.

Biddulph, O., Biddulph, S., Cory, R., & Koontz, H. (1958). Circulation patterns for phosphorus, sulfur and calcium in the bean plant. Plant Physiology, 33(4), 293.

Bhattarai, B., & Swarnima, K. C. (2016). Effect of potassium on quality and yield of potato tubers-A review. International Journal of Agriculture & Environmental Science, 3(6), 7-12.

El-Mageed, T. A., & Semida, W. M. (2015). Effect of deficit irrigation and growing seasons on plant water status, fruit yield and water use effeciency of squash under saline soil. *Scientia Horticulture*, *186*: 89-100.

Erba, D., Casiraghi, M. C., Ribas-Agustí, A., Cáceres, R., Marfà, O., & Castellari, M. (2013). Nutritional value of tomatoes (Solanum lycopersicum L.) grown in greenhouse by different agronomic techniques. *Journal of Food Composition and Analysis*, *31*(2), 245-251.

Frusciante, L., Carli, P., Ercolano, M. R., Pernice, R., Di Matteo, A., Fogliano, V., & Pellegrini, N. (2007). Antioxidant nutritional quality of tomato. Molecular nutrition & food research, 51(5), 609-617.

Gruda, N. S. (2019). Increasing sustainability of growing media constituents and stand-alone substrates in soilless culture systems. Agronomy, 9(6), 298.

Hadid, A. F. A. (2016). The effect of different growing media on cucumber seedling production, fruit yield and quality under greenhouse conditions. *Acta Horticulturae*, *486*, 369-376.

Huskisson, E., Maggini, S., & Ruf, M. (2007). The role of vitamins and minerals in energy metabolism and well-being. Journal of international medical research, 35(3), 277-289.

Johann G. Zaller, J. G. (2007). Vermicompost as a substitute for peat in potting media: Effects on germination, biomass allocation, yields and fruit quality of three tomato varieties. Scientia Horticulturae, 112 (2007) 191–199.

Kerkhofs, N. S., Lister, C. E. & Savage. G. P. (2003). Antioxidant compounds in fresh tomatoes. Nutrition and health team, New Zealand institute & Food research.

Kilic, P., Erdal, I. & Aktas, H. (2018). Effect of different substrates on yield and fruit quality of tomato grown in soilless culture. Suleyman Demirel University, Isparta, Turkey.

Konduru, S., Evans, M. R., & Stamps, R. H. (1999). Coconut husk and processing effects on chemical and physical properties of coconut coir dust. HortScience, 34(1), 88-90.

Lovelock, C. E., Feller, I. C., Ball, M. C., Engelbrecht, B. M., & Ewe, M. L. (2006). Differences in plant function in phosphorus-and nitrogen-limited mangrove ecosystems. New Phytologist, 172(3), 514-522.

Maathuis, F. J., & Diatloff, E. (2013). Roles and functions of plant mineral nutrients. Plant mineral nutrients, 1-21.

Maluleke, M. K., Moja, S. J., Nyathi, M., & Modise, D. M. (2021). Nutrient Concentration of African Horned Cucumber (Cucumis metuliferus L) Fruit under Different Soil Types, Environments, and Varying Irrigation Water Levels. *Horticulturae*, *7*(4): 1-16.

Mariotti, B., Martini, S., Raddi, S., Tani, A., Jacobs, D. F., Oliet, J. A., & Maltoni, A. (2020). Coconut coir as a sustainable nursery growing media for seedling production of the ecologically diverse Quercus species. Forests, 11(5): 1-19.

Mojeremane, W., Moseki, O., Mathowa, T., Legwaila, G. M., & Machacha, S. (2016). Yield and yield attributes of tomato as influenced by organic fertilizer, 1-10.

Olle, M., Ngouajio, M., & Siomos, A. (2012). Vegetable quality and productivity as influenced by growing medium: a review. Agriculture, 99(4), 399-408.

Paucek, I., Pennisi, G., Pistillo, A., Appolloni, E., Crepaldi, A., Calegari, B., & Gianquinto, G. (2020). Supplementary LED interlighting improves yield and precocity of greenhouse tomatoes in the Mediterranean. *Agronomy*, *10*(7), 1-14.

Pretty, J. (2018). Intensification for redesigned and sustainable agricultural systems. Science, 362(6417), eaav0294.

Rahil, M. H., & Qanadillo, A. (2015). Effects of different irrigation regimes on yield and water use efficiency of cucumber crop. *Agricultural Water Management*, *148*, 10-15.

Sun, L., Zhao, W.,Jiang, M., Yang, R. ,Sun, X.,Wang,J.& Wang, S. (2021). Rootstock screening for greenhouse tomato production under a coconut coir cultivation system. Beijing University of Agriculture. China.

Uddain, J., Akhter Hossain, K. M., Mostafa, M.G & Rahman, M. J. (2009). Effect of different plant growth regulators on growth and yield of tomato. International Journal of Sustainable Agriculture 1 (3): 58-63, 2009.

Vivek, P. & Duraisamy, V. M. (2017). Study of growth parameters and germination on tomato seedlings with different growth media. *International Journal of Agricultural Science and Research*, 7(3): 461-470.

Upadhyaya, H., Begum, L., Dey, B., Nath, P. K., & Panda, S. K. (2017). Impact of calcium phosphate nanoparticles on rice plant. Journal of Plant Science and Phytopathology, 1(1), 001-010.

Weng, Y. 2010. Genetic diversity among Cucumis metuliferus population revealed by cucumber microsatellites. *Hortscience*, 45, 214-219.

CHAPTER 4 : Biochemical constituents of tomato (Solanum lycopersicum) fruit grown on varying coconut coir substrate types under greenhouse environment

4.1 Abstract

Biochemical constituents of fruit crops depend on substrate quality for improved nutritional quality. Most crop producers choose the use of organic substrates for greenhouse crop cultivation to ensure improved quality and to meet market demand all year round. Coconut coir is an organically produced substrate from the external husk or mesocarp of coconut fruit that has environmental benefits due to its renewable nature. The objective of the study was to determine the effect of different coconut coir substrate types (Profit and Power) on the biochemical constituents of tomato fruit grown under greenhouse environment. Freeze-dried tomato fruit samples were used in the quantification of vitamins, lycopene, phosphorus, iron and zinc. The study revealed that fruit grown under coconut coir Power had a higher vitamin C, lycopene and zinc content when compared to other treatments. Iron content was greater in tomato fruit grown under coconut coir Profit when compared to other treatments. Therefore, the study results illustrate that coconut coir Power resulted in increased biochemical constituents of tomato fruit than other treatments. It can, thus, be deduced that tomato fruit is nutrient dense when grown under coconut coir Power substrate when compared to other treatments. Farmers are encouraged to grow tomato fruit on coconut coir Power in a greenhouse for high quality produce and profit maximisation.

Keywords: Biochemical constituents, coconut coir, fruit quality, total phenols

4.2 Introduction

The nutrient concentration in crops is affected by a variety of factors including water stress, location, sunlight and soil type (Sezen 2010). In contrast to natural soils, most crop producers choose to use organic soilless substrate for greenhouse crop cultivation to ensure a food supply sufficient to meet the market demand (Fletcher & Arnold, 1986). While the effects of different growth media on crop growth, development and yield is well researched, there are relatively few specifics on the benefits of organic substrates such as coir. Coconut coir, according to El-mageed and Semida (2015), is an organic organically produced substance formed from the external husk or mesocarp of coconut fruit that has environmental benefits due to its renewable nature. Olle et al. (2012) cite the following benefits of coconut substrate: (i) it is nearly 100 percent organic and renewable, (ii) it provides good drainage, (iii) it has a high water holding capacity, (iv) it accelerates root growth and development, and (v) it is reasonably inexpensive. Hashem (2011) suggested that a healthy growth medium should provide water, air and nutrients to plant roots. While mineral nutrients and water are placed on the substrate, the plant still needs to absorb them through its roots (Isah et al., 2014). Another factor to consider is the ability of the media to keep applied water and minerals from leaching, giving the plant the best chance of fully absorbing all such components (Halsema and Vincent, 2012). Leaching can occur if the medium has excessive porosity so that, consequently, applied water and nutrients may seep away and become unavailable to the plant root, resulting in a variety of deficits that might stymie plant growth and nutritional content of the plant (Barrett et al., 2010). The possibility of leaching dissuades many farmers from investing in a specific growing medium in case this is a poor investment (Sezen et al., 2010). Coconut coir is a relatively new addition to the list of low-cost, high-quality growth materials with the potential to boost horticulture crop productivity and quality (Magan et al., 2008). Therefore, the objective of the study was to investigate the effect of varying coconut coir substrate types on the nutrient composition of tomato plants cultivated in a greenhouse.

4.3 Material and Methods

This study was conducted during 2021 and 2022 in a greenhouse at the Florida Science Campus of the University of South Africa (26º 10’ 30’’S, 27º 55’ 22.8’’ E). The greenhouse temperature was maintained between 15 and 25˚C, the optimal range for tomato crop growth in general, and the relative humidity was maintained between 60 and 75% using an automated drip irrigation system. A factorial experiment with one factor – different coconut coir substrate types (Power and Profit) was conducted in a greenhouse environment. Coconut coir (Power and Profit) growing/planting bags were sourced from Van der Knaap, South Africa. The planting/growing bags experiment was a completely randomised design with ten (10) replicates. The pots were spaced 1 m apart, and an up-rope vertical trellising was used to support the plants. On each site, plant pots were either filled with Power or Profit coconut coir. Each block comprised 10 plants, resulting in 30 plants per site including control plants. A total of 60 plants were used for the experiment. Each site had plants used as guard plants. Well established, uniform and healthy 30 days-old tomato seedlings, germinated from peat substrate were transplanted into planting/growing bags. The calculation below shows the size of the planting bag:

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

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

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

Data on plant biochemical constituents were collected during different the experimental periods [2021, planting year one/ 2022, planting year two]. It is worth noting that the experiment was conducted by strictly adhering to the standards and requirement of the Research and Higher Degree Committee of the College of Agriculture and Environmental Sciences at UNISA. **In addition, the study received ethical approval from the UNISA-CAES Health Research Ethics Committee, reference number 2021/CAES_HREC/136.**

4.3.1 Soil/substrate properties

Table 4.1: Mineral/chemical composition of varying substrates.

Chemical Analysis (**Micro and Macro minerals**)					
	Fe mg kg^{-1}	Mn mg kg^{-1}	Cu mg kg^{-1}		Zn mg kg^{-1}
Coir profit	34	12	8		14
Coir power	40	10	5		10
Loamy soil	33	59	124		8,52
	P Mg kg^{-1}	Ca Mg kg^{-1}	Mg Mg kg^{-1}	K mg kg^{-1}	Na Mg kg^{-1}
Coir profit	11	15	13	151	64
Coir power	6	12	7	117	46
Loamy soil	27,8	1390	148	223	56,4

Before planting, soil samples (coir Profit, coir Power and loamy soil) were tested for micronutrients (trace minerals) such as Fe, Mn, Cu and Zn and (major minerals) such as P, Ca, Mg, K and Na. The results of this analysis are indicated in Table 4.1. Methods used are as described by Rahil and Qanadillo (2015). The analysis described above was conducted at the Agricultural Research Council Institute for Soil, Climate, and Water (ARC-ISWC) in Pretoria (25° 44′ 19.4″ S28° 12′ 26.4″ E).

4.3.2 Irrigation treatments

Table 4.2: Nutritional content of automated fertigation system used throughout the experimental period.

Fertigation treatment		**Application Rate**	**Injection rates** L per 1000 L	
	Product	1000 L Tank	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

Throughout the experimental period, the fertigation system was employed to irrigate the plants (Table 4.2).

4.4 Data collection

4.4.1 Determination of total soluble sugars

The concentration (Brix) of total soluble sugars in tomato fruit harvested from tomato plants cultivated in a greenhouse was determined using the method described by Tavarini et al. (2008). Briefly, a fruit was sliced into halves, and juice was squeezed from one of them by hand, releasing roughly 0.05 ml of juice onto the aperture of a hand refractometer (HI 96801 Refractometer, USA). Readings were immediately recorded. A total of 21 fruits from each experimental/control treatment was used. After obtaining a reading, fruit juice was gently removed from the aperture before it was rinsed with distilled water and dried with a soft paper towel.

4.4.2 Determination of crude protein

About 0.5g of the dry fruit sample was weighed and duplicated, thereafter, analysed using a crude protein analyser (Trumac CN-Leco, Germany). This instrument uses the Dumas technique to quantify carbon and nitrogen percentage per 100g. The universal protein factor 6.25 previously described by López et al. (2013), was used to convert nitrogen to protein. Calibration of the Trumac CN analyser was done using ethylenediaminetetra-acetic acid (EDTA). For quality control, glycine was used as a certified reference material.

4.4.3 Determination of β-carotene

The analysis of β-carotene was conducted using a Prominence-in High Performance Liquid Chromatography-PDA model system equipped with sample cooler LC-2030C (Shimadzu, Japan), with slight modifications - each sample was measured in triplicate - as described by Moyo et al. (2018), since most of the compounds measured were expected to be similar to those of the current study. Approximately 0.1 g/ml of extracted sample was mixed with ice-cold hexane: acetone (1:1, v/v) was vortexed for two (2) minutes before being centrifuged at 2,000 rpm for two (2) minutes.

The organic phase was decanted into a tube containing saturated sodium chloride solution and placed on ice cold. The remaining residue was similarly re-extracted until the extract was colourless. For each extraction, the extract organic phase was filtered through a 0.45 µm syringe filter before being injected into the HPLC column. Chromatographic separation was achieved using a C_{18} Luna® column (150 × 4.6 mm, 5µ) maintained at 35˚C. An isocratic mobile phase which consisted of acetonitrile: dichloromethane: methanol (7:2:1) was used with a flow rate of 1 ml/min an injection volume of 20 µl and the detection was at 450 nm. Peak identification and quantification of the compound (β-*carotene*) were achieved based on an authentic β-carotene standard which was used to plot the calibration curves (López et al., 2013).

4.4.4 Determination of vitamin C and E

The fruit samples were freeze-dried for 72 hours using a freeze drier (HARVEST-RIGHT, Barcelona). The freeze-dried fruit slices were rigorously homogenised 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 modification (triplicate). Individual samples were weighed (1 g) into tube, followed by the addition of 5% metaphosphoric acid (10 ml). Each tube was sonicated for 15 minutes before centrifuging and filtrated 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) maintained at 25 µC to achieve chromatographic separation. A water-based isocratic mobile phase consisting of acetonitrile: formic acid (99:0.9:0.1) was used at a flow rate of 1 ml/min. The volume of each sample injected was 20 µl and the detector was set at 245 nm. Sample quantification was achieved by comparison against the calibration curve plotted using L-ascorbic acid.

4.4.5 Determination of total flavonoids

The total flavonoids in tomato fruit samples was quantified using the aluminium chloride colorimetric method described by Baba and Malik (2018) with modification. Briefly, 50 mg of fruits powder (1 mg/ml ethanol) were dissolved in 1 ml methanol, combined with 4 ml distilled water, and then 0.3 ml of 5% $NaNO_2$ solution. After 5 minutes of incubation, 0.3 ml of 10% $AlCl_3$ solution was added, and the solution was left to stand for 6 minutes. The final volume of each solution was brought to 10 ml with double-distilled water after adding 2 ml of 1 mol/L NaOH solution. After allowing the mixture to incubate for 15 minutes, the absorbance was measured at 510 nm. Catechin was used as a standard to prepare a calibration curve and total flavonoids content was expressed in mg catechin equivalents (CE) per dry weight (mg CE/DW).

4.4.6 Determination of total phenolic content

Total phenolic content determination of the fruit samples was carried out as described by Santos-zea et al. (2011) and Moyo et al. (2018) with slight modification (triplicate). Briefly, the total phenol concentration of freeze dried of tomato fruit was used for extraction of total phenolic content, which used gallic acid as a reference (Sigma, St. Louis, MO). In a 10:1 volume/volume ratio, Folin-Ciocalteu reagent (2 N, Sigma, St. Louis, MO) was used to oxidize an aliquot of the extract. At room temperature, samples were incubated for 20 minutes in 96-well microplates, and absorbance was measured at 750 nm in a microplate reader (Synergy HT, Bio-Tek, Winooski, VT). Total phenolic content was expressed in mg gallic acid equivalents (GAE) per g dry weight (DW).

4.4.7 Determination of lycopene

To 100 mg of lyophilized pulp powder, 16 ml of acetone–hexane (4:6) solvent was added and thoroughly mixed. After the two phases had separated, an aliquot of the upper phase was obtained and the absorbance at 663, 645, 505 and 453 nm was measured. The content of lycopene were estimated using the Goulas and Manganaris (2012) equations.

4.4.8 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 Moyo et al. (2018) 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_2O_2 (30%, analytical grade) added in the vessels. Each solution was diluted to 15 ml in a deionized water test tube after acid 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 as Potassium (K), phosphorus (P), calcium (Ca), sodium (Na), zinc (Zn), iron (Fe), molybdenum and copper (Cu) 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).

4.4.9 Statistical analysis

The effect of coconut coir substrate types (Power and Profit) on the nutritional composition of tomato fruit data was analysed. Variables such as crude protein, total soluble sugars, β-*carotene*, vitamin C, vitamin E, total phenols, total flavonoids, lycopene, macro- and micro-nutrients were analysed using a one-way ANOVA. 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.

4.5 Results

4.5.1 Crude protein

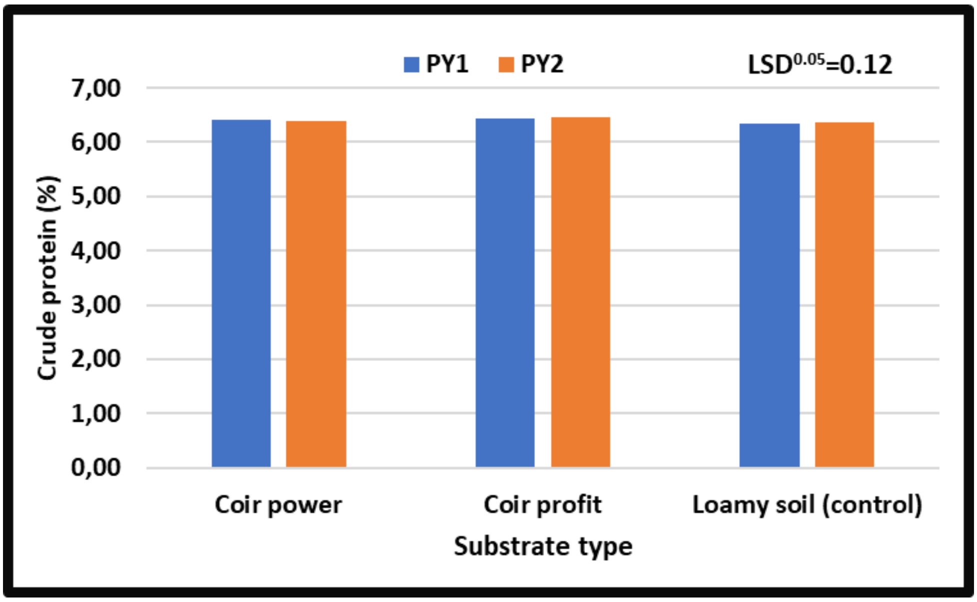

Figure 4.1: Effect of different coir substrates on the crude protein % of tomato grown under greenhouse environment. Values are average over treatment; substrates (coir profit, coir power and loamy soil-control). **PY1** means planting year one 2021; PY2 means planting year two **2022**. $LSD_{0.05}$ is the least significant difference of means.

Figure 4.1 represent the effect of varying coir substrates on the crude protein % of tomato fruit grown under greenhouse environment during different planting years [2021 and 2022]. Results showed that there was no significant ($P>0.05$) difference on the crude protein % content of tomato fruit grown under varying coconut coir substrates. However, during planting year one [2021], crude protein ranged from 6.35 to 6.43%, while planting year two [2022] ranged from 6.36 to 6.47%. In addition, results showed that tomato fruit grown under loamy soil (control) treatment reduced crude protein from 6.47 to 6.35%, whereas fruit grown under coconut coir profit increased it from 6.35 to 6.47%.

4.5.2 Total soluble sugars

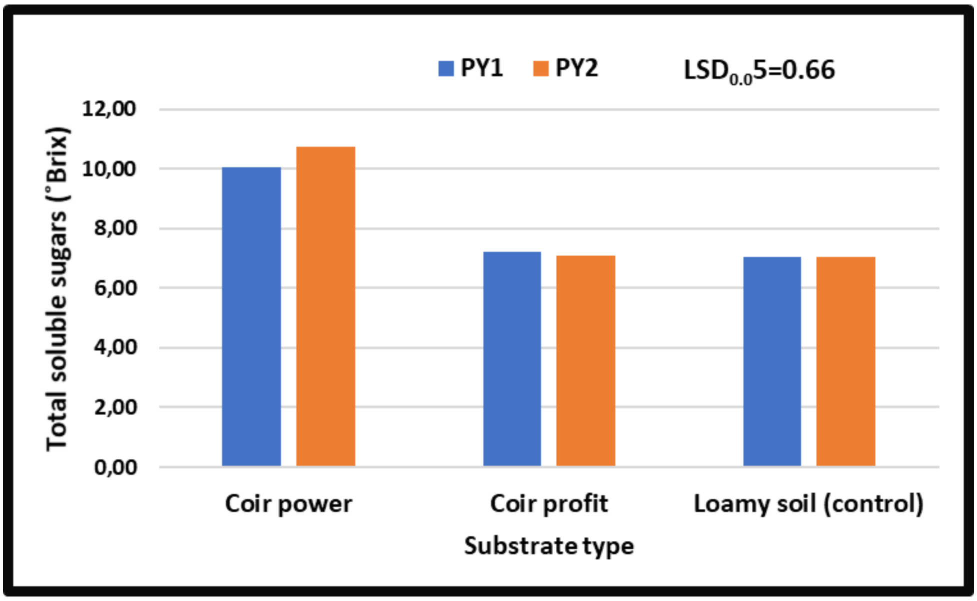

Figure 4.2: Effect of different coir substrates on the crude total soluble sugars (˚Brix) of tomato grown under greenhouse environment. Values are average over treatment; substrates (coir profit, coir power and loamy soil-control). **PY1** means planting year one 2021; **PY2** means planting year two **2022**. $LSD_{0.05}$ is the least significant difference of means.

Figure 4.2 demonstrates the effect of different coir substrates on the total soluble sugars content of tomato fruit grown under greenhouse environment during varying planting years [2021 and 2022]. Results showed there was no significant (P>0.05) different on the total soluble sugars of tomato fruit grown under varying substrates. During planting year one [2021], total soluble sugars ranged from 7.1 to 10.1 ˚Brix, while planting year two [2022], ranged from 7.1 to 10.7˚Brix. Moreover, results evinced tomato fruit grown under loamy soil (control) reduced total soluble sugars from 10.7 to 7.1 ˚Brix, whereas fruit grown under coir power during planting year two [2022], increased total soluble sugars from 7.1 to 10.7˚Brix.

4.5.3 Total flavonoids

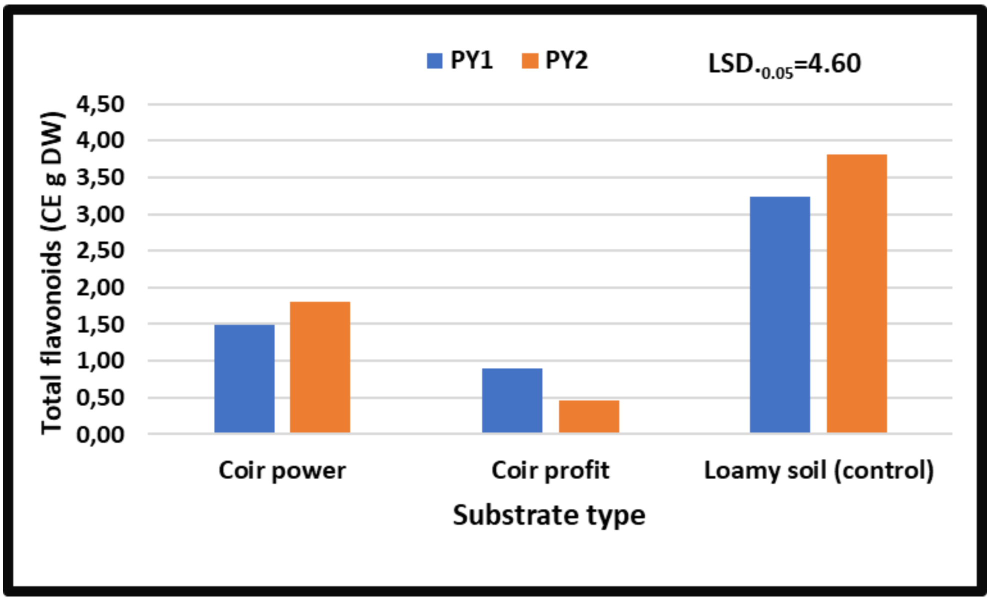

Figure 4.3: Effect of different coir substrates on the crude total flavonoids (CE g DW) of tomato grown under greenhouse environment. Values are average over treatment; substrates (coir profit, coir power and loamy soil-control). **PY1** means planting year one 2021; **PY2** means planting year two **2022**. $LSD_{0.05}$ is the least significant difference of means.

Figure 3 outline the effect of different coir substrates on the total flavonoids of tomato fruit grown under greenhouse environment during varying planting years. Results delineated that there was no significant (P>0.05) difference on total flavonoids of tomato fruit grown under varying substrates during different planting years [2021 and 2022]. Furthermore, results demonstrated that tomato fruit grown under coir profit reduced total flavonoids content from 3.8 to 0.46 CE g DW during planting year one [2021], whereas loamy soil (control) treatment increased fruit total flavonoids from 0.46 to 3.8 CE g DW during planting year two [2022].

4.5.4 Total phenols

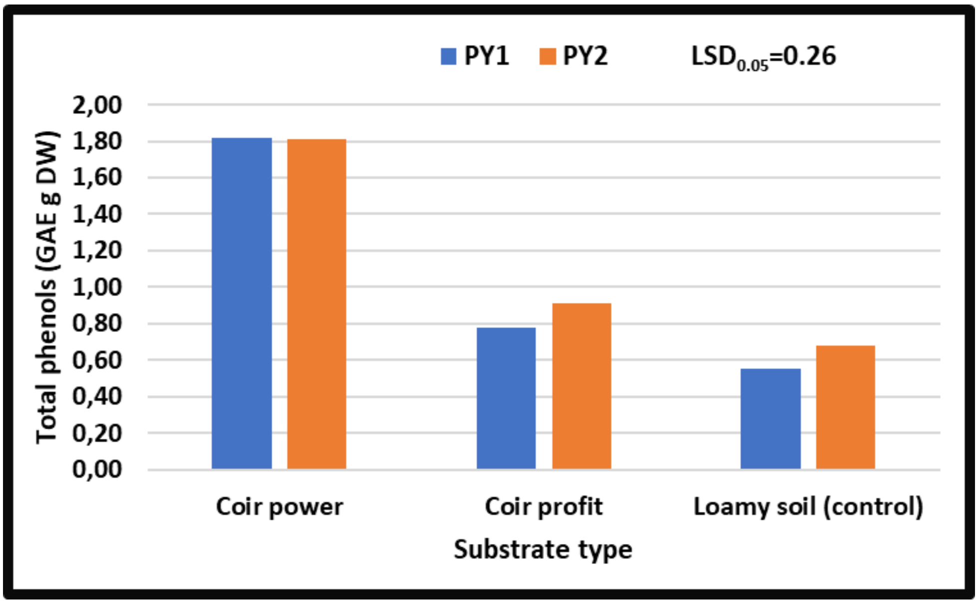

Figure 4.4: The effect of different coir substrates on the crude total phenols (GAE g DW) of tomato grown under greenhouse environment. Values are average over treatment; substrates (coir profit, coir power and loamy soil-control). **PY1** means planting year one 2021; **PY2** means planting year two **2022**. $LSD_{0.05}$ is the least significant difference of means.

Figure 4.4 present the effect of different coir substrates on the total phenols of tomato fruit grown under greenhouse environment during varying planting years. The study results showed that there was no significant (P>0.05) difference on the total flavonoids of tomato fruit grown varying substrates during different planting years [2021 and 2022]. During planting year one [2021], total phenols ranged from 0.55 to 1.82 GAE g DW, while planting year two [2022], ranged from 0.68 to 1.81 GAE g DW during planting year one [2021]. Additionally, results illustrated that fruit grown under loamy soil (control) reduced total phenols from 1.82 to 0.55 GAE g DW, whereas fruit grown under coir power increased it from 0.55 to 1.82 GAE g DW during planting year one [2021].

4.5.5 Vitamins and lycopene

Table 4.3: The effect of different substrates on the vitamins (mg 100 g DW) and Lycopene (mg 100 g DW) of tomato fruit grown under greenhouse environment.

Treatment	Vitamin C (mg 100 g DW) PY1	PY2	Vitamin E (mg 100 g DW) PY1	PY2	Lycopene (mg 100 g DW) PY1	PY2
Coir Power	10.7(1.2)	11.4(2)	70.3(13)	97.1(5)	80.7(11.2)	86.5(6.3)
Coir Profit	8.2(2.1)	7.6(1.4)	53.8(7)	85.9(16)	59.7(6.6)	52.9(5.8)
Loamy soil (control)	8.6(1.7)	7.5(1.6)	99.1(10)	59.1(9)	52.6(8)	50.5(4.2)
Grand Mean	9.28	9.28	77.5	77.5	63.8	63.8
LSD0.05	0.76	0.76	28.3	28.3	4.94	4.94
Pvalue	**0.003**	**0.003**	**0.01**	**0.01**	**0.002**	**0.002**

PY1 means planting year one 2021; **PY2** means planting year two 2022. 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.

Table 4.3 present the effect of different coir substrate on vitamin C, vitamin E and lycopene content of tomato fruit grown greenhouse environment on varying coir substrates during differing planting years [2021 and 2022]. The study results showed that there was significant ($P \leq 0.05$) difference. Regarding vitamin C content, results showed that it ranged from 8.2 to 10.7 mg 100 g DW during planting year one, whereas planting year two content ranged from 7.5 to 11.4 mg 100 g DW. Moreover, the study results illustrated that fruit grown under loamy soil (control) reduced vitamin C content from 11.4 to 7.5 mg 100 g DW during planting year two [2022], whereas fruit grown under coir power increased vitamin C content from 7.5 to 11.4 mg 100 g DW during planting year two [2022].

For vitamin E content, results delineated that it ranged from 53.8 to 99.1 mg 100 g DW during planting year one, whereas planting year two content ranged from 59.1 to 97.1 mg 100 g DW. In addition, the study results showed that fruit grown under coir profit reduced vitamin E content from 99.1 to 53.8 mg 100 g DW during year one [2021], whereas loamy soil (control) increased vitamin E content from 53.8 to 99.1 mg 100 g DW during similar planting year.

Regarding lycopene content, the study results showed that it ranged from 52.6 to 80.7 mg 100 g DW during planting year one [2021], while planting year two [2022], content ranged from 50.5 to 86.5 mg 100 g DW. Furthermore, results showed that loamy soil (control) grown fruit reduced lycopene content from 86.5 to 50.5 mg 100 g DW during planting year two [2022], meanwhile coir power increased the content from 50.5 to 86.5 mg 100 g DW during similar planting period.

4.5.6 Macro-nutrients

Table 4.4: The effect of different substrates on the macro-nutrients (mg 100 g DW) and of tomato fruit grown under greenhouse environment.

	Calcium (mg 100 g DW)		Phosphorus (mg 100 g DW)		Potassium (mg 100 g DW)	
Treatment	**PY1**	**PY2**	**PY1**	**PY2**	**PY1**	**PY2**
Coir Power	410(49)	430.2(54)	562.3(29)	542.2(45)	815.5(36)	779.8(74)
Coir Profit	283.6(29)	224.5(18)	355(68)	311.7(60)	424.9(48)	365.3(41)
Loamy soil (control)	205.1(64)	171.5(40)	197.5(49)	286.3(36)	313.1(51)	403.1(23)
Grand Mean	287.5	287.5	375.8	375.8	517	517
LSD0.05	31.08	31.08	34.45	34.5	20.32	20.32
Pvalue	**0.002**	**0.002**	**0.001**	**0.001**	**0.001**	**0.001**

PY1 means planting year one 2021; **PY2** means planting year two 2022. 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.

Table 4.4 present the effect of different coir substrates on the macro-nutrients content (calcium, phosphorus, potassium and sodium) of tomato fruit grown under greenhouse environment during differing planting years [2021 and 2022]. Results demonstrated significant (P≤0.05) difference on calcium, phosphorus and potassium content. However, there was no significant (P>0.05) difference on the sodium content of tomato fruit grown under differing substrates.

Regarding calcium content, results showed that it ranged from 205.1 to 410.2 mg 100 g DW during planting year one [2021], whereas planting year two [2022] content, ranged from 171.5 to 430.2 mg 100 g DW. In addition, results showed that fruit grown under loamy soil (control) reduced calcium content from 430.2 to 171.5 mg 100 g DW during planting two [2022], whereas fruit grown from coir power during similar planting period increased calcium content from 171.5 to 430.2 mg 100 g DW.

Concerning phosphorus content, results showed that it ranged from 197.5 to 562.3 mg 100 g DW during planting year one, whereas planting year two ranged from 286.3 to 542.2 mg 100 g DW. Moreover, results illustrated that fruit grown from loamy soil (control) reduced phosphorus content from 562.3 to 197.5 mg 100 DW during planting year one [2021], meanwhile coir profit increased it from 197.5 to 562.3 mg 100 g DW during similar planting period.

For potassium content, study results showed that it ranged from 3.13.1 to 815.5 mg 100 g DW during planting year one [2021], while planting year two [2022] content ranged from 365.3 to 779.8 mg 100 g DW. Furthermore, results demonstrated that loamy soil (control) grown fruit reduced potassium content from 815.5 to 313.1 mg 100 g DW during planting year one [2021], whereas fruit grown under coir profit increased it from 313.1 to 815.5 mg 100 g DW during similar planting period.

4.5.7 Micro-nutrients

Table 4.5: The effect of different substrates on the micro-nutrients (mg 100 g DW) and of tomato fruit grown under greenhouse environment.

	Beta carotene (mg 100 g DW)		Copper (mg 100 g DW)		Iron (mg 100 g DW)		Zinc (mg 100 g DW)	
Treatment	**PY1**	**PY2**	**PY1**	**PY2**	**PY1**	**PY2**	**PY1**	**PY2**
Coir Power	4.28(1)	4.53(1)	15.21(2)	15.57(2)	10.15(1)	9.2(1)	17.9(3)	20.5(2)
Coir Profit	1.64(2)	1.71(1)	11.54(1)	10.71(3)	12.72(2)	14.4(3)	17.2(1)	16.9(2)
Loamy soil (control)	2.1(1)	2.09(1)	9.71(2)	9.6(1)	8.67(1)	10.1(2)	10.2(2)	9.3(4)
Grand Mean	0.368	0.368	12.06	12.06	10.88	10.8	15.34	15.34
LSD0.05	0.75	0.75	1.44	1.44	1.13	1.13	1.37	1.37
Pvalue	0.362	0.362	0.516	0.517	**0.002**	**0.002**	**0.002**	**0.002**

PY1 means planting year one 2021; **PY2** means planting year two 2022. 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.

Table 4.5 present the effect of differing coir substrates on the micro-nutrients (beta carotene, copper, iron and zinc) content of tomato fruit grown under greenhouse environment during varying planting years [2021 and 2022]. The study results evinced that there was not significant (P>0.05) difference on beta carotene and copper content. However, there was significant (P≤0.05) difference on iron and zinc content. For beta carotene, results showed that it ranged from 1.64 to 4.28 mg 100 g DW during planting year one [2021], while planting year two [2022] content ranged 1.71 to 4.53 mg 100 DW. In addition, results showed that coir profit reduced beta carotene content from 4.53 to 1.64 mg 100 g DW during planting year one [2021], while coir power increased it from 1.64 to 4.53 mg 100 g DW during planting year two [2022].

Concerning copper content, results showed that it ranged from 9.71 to 15.21 mg 100 g DW during planting year one [2021], while planting year two [2022], ranged from 9.6 to 15.57 mg 100 g DW. Moreover, results showed that loamy soil grown fruit during planting two [2022] decreased copper content from 15.27 to 9.36 mg 100 g DW, whereas fruit grown from coir power increased it from 9.6 to 15.57 mg 100 g DW.

For iron content, results demonstrated that it ranged from 8.67 to 1015 mg 100 DW during planting year one [2021], while planting year two [2022] content, ranged from 9.2 to 14.4 mg 100 g DW. Furthermore, study results illustrated that fruit grown on loamy soil (control) reduced iron content from 14.4 to 8.67 mg 100 g DW during planting year one [2022], while coir profit during planting year two [2022] increased it from 8.67 to 14.4 mg 100 g DW. Reading zinc content, results showed that it ranged from 10.2 to 17.9 mg 100 g DW during planting year one [2021], while planting year two [2022] content ranged from 9.3 to 20.5 mg 100 g DW. Additionally, results showed that fruit grown under loamy soil (control) reduced zinc content from 20.5 to 9.3 mg 100 g DW during planting two [2022], while coir power increased it from 9.3 to 20.5 during similar planting period.

4.6 Discussion

The study evaluated the effect of different coir substrate on the concentration of biochemical constituent of tomato fruit from plants grown in a greenhouse. Kimura and Sinha (2008) evaluated the utilisation of waste wool as an organic substrate in pot cultivation of tomato, sweet pepper and eggplant. However, there is paucity of knowledge on the effect on varying coconut coir substrates on the biochemical constituents of tomato fruit of plants grown in a greenhouse. Therefore, findings of this study serve as a benchmark regarding the analysis of biochemical constituents of tomato fruit from plants grown under differing organic substrate types (coir Power and coir Profit) and their potential contribution to produce nutritionally dense fruits vital to human health and nutrition.

Vitamins C

When compared to other treatments, tomato fruit from plants grown under coir Power as substrate produced the highest levels of vitamin C (11.4 mg 100 g DW). Vitamin C is a potent antioxidant that helps to fight infection and speed wound healing by neutralizing damaging free radicals – as such vitamin C is one of the most important components of global sustainable development goals (Kaushik et al., 2011). Collagen is a fibrous protein that is present in connective tissue and is woven into the neural, immunological, bone, cartilage and blood systems of the body (Maluleke et al., 2021). Since vitamin C deficiency can result in skin damage and a weakened immune system, the role of coconut coir in the production of vitamin C-rich fruit cannot be undervalued as a potential organic substrate for reducing human malnutrition.

Vitamin E

Vitamin E may help to prevent coronary heart disease, strengthen the immune system, reduce inflammation, improve eye health, and reduce cancer risk (Achaglinkame et al., 2019). The study findings revealed that tomato fruit grown under loamy soil (control) and coconut coir Power, recorded high values of vitamin E (97.1 and 99.1 mg100 g DW), respectively. The vitamin E values in fruit of plants grown in coir Power demonstrate that the use of this organic plant growth substrate has potential to reduce malnutrition challenges and aid in protecting the human body against free radical damages, thereby helping the immune system and reducing cancerous cell growth (Sezen et al., 2010).

Lycopene

Fruit is a great source of health-improving lycopene (Slavin & Lloyd, 2012). Lycopene is a potent antioxidant that has several health benefits, including protection against harmful rays from the sun, improved heart health and a reduced risk of certain cancers (Maluleke et al., 2021). Though it is available as a supplement, lycopene-rich foods such as tomatoes and other red or pink fruits may be the most effective sources of lycopene (Moco et al., 2006). In the present study, tomato fruit from plants grown under coir Power demonstrated a high lycopene content when compared to the other treatments. The values in this study showed that the highest lycopene content (80.7 mg 100 g) from tomato fruit grown under coconut coir Power is three times higher than the recommended daily intake (8-21 mg 100 g DW). These results suggest that tomato fruit grown from coir substrate may play a pivotal role in skin health protection and in reducing cancer.

Total flavonoids

Flavonoids aid in the regulation of cellular activity as well as the battle against free radicals that cause oxidative stress in the body. In summary, they aid in the proper functioning of your body while also shielding it from pollutants and stressors (Flemotomou et al. 20211). Flavonoids are antioxidants with a lot of strength. Although, the total flavonoids variation between loamy soil-control (3.9 CE g DW) and coconut coir power type (1.9 CE g DW) was significantly higher (2 CE g DW). Values obtained in this could serve as a strong demonstration that coconut coir Power as a organic substrate has a potential to produce fruits that has reasonable total flavonoids required by human body for improve cellular activities and better immune system.

Total phenols

Phenols plays a vital role in human body by scavenging free radicals, chelating metals and stimulating the endogenous antioxidant system (Maluleke et al., 2021). Exogenous medicinal plants and foods high in phenolic compounds are used therapeutically to prevent numerous chronic diseases and improve health (Hossain and Shah 2015). The 200% increase in total phenolic content of fruit from tomato plants grown in coir Power compared to the total phenolics in the fruit from plants grown in loamy soil suggests that plants grown in coir substrate may provide anti-inflammatory effects and protect body cells from free radical damages.

Macro-nutrients

Calcium is mostly linked with strong bones and teeth, but it also aids in blood clotting, muscular contraction, and the regulation of normal heart rhythms and neuron activities. Additionally, an appropriate level of calcium in the body over a lifetime can help prevent osteoporosis (Aslam et al., 2020). Tomato fruit with the lowest calcium content (171.5 mg 100 g DW) were from plants grown in loamy soil (control) while fruit with the highest calcium concentration (430 mg100 g DW) were from plants grown in coir Power. The calcium levels found in this study could indicate that eating tomato fruit from plants grown on coir Power substrate may provide substantial benefits to human health, particularly in terms of robust bone synthesis, muscle contraction regulation and nerve impulse transmission (Uusiku et al., 2010).

Phosphorus

Phosphorus is essential for bone and tooth production (Uusiku et al., 2010). It affects how carbohydrates and fats are metabolized by the body. It is also needed for the body to make protein for the growth, maintenance, and repair of cells and tissues (Khattab et al., 2011). When compared to the other study treatments, tomato fruit cultivated under coir Power contained the highest concentration of phosphorus. As a result of the high phosphorus content, eating of tomato fruit from plants grown in coir Power may help prevent deficits such as hypertension, stroke and severe headaches.

Potassium

Potassium is a mineral that is abundant in most fruits (Maluleke et al., 2021). Its primary function in the body is to assist in the maintenance of proper fluid levels within our cells. Additionally, it also aids in muscle contraction and maintains a healthy blood pressure (He et al., 2018). The fruit with most potassium was from tomato plants grown under coir Power substrate. Results from this study suggest that consumption of such tomato fruit rich in potassium may help prevent fatigue, muscle cramps, constipation, abnormal heartbeat and weak muscles.

Micro-nutrients

Iron

Iron is a mineral that our bodies require in haemoglobin, a protein that transports oxygen. It aids in the storage and utilization of oxygen in our muscles. In addition, many other proteins and enzymes contain iron (Sharma and Rao, 2013). The study showed that the fruit with the highest iron content (12.7 mg100 g DW) was from plants grown under coir Power but this value is slightly below the recommended daily intake limit of 13.7 mg for males within the age range of 19-65. Therefore, consumption of tomato fruit grown under coconut coir may assist blood cells in transporting oxygen from the lungs and prevent anaemia, which is mainly responsible for fatigue and shortness of breath.

Zinc

Zinc is contained in every cell of the body where it is required for the normal functioning of the body's immune system (Maluleke et al., 2021). It is also involved in cell division, cell development, wound healing, and carbohydrate breakdown (Barrett et al., 2010). In the present study, the highest zinc content (20.5 mg 100 g DW) was observed in fruit from tomato plants grown in coir Power. This suggests that consumption of tomato fruit grown under coconut coir may prevent loss of appetite, eyes and skin related diseases and promote growth.

4.7 Conclusion

The findings of the study demonstrated that tomato fruit from plants grown on coir substrate Profit were nutritionally dense in terms of vitamins, lycopene, macro and micro-nutrients, and contribute to the recommend daily nutrient intake required for human health. However, there were no statistically variation among treatments on biochemical constituents such as crude protein, total soluble sugars, total flavonoids and total phenols. When compared to fruit from plants grown in loamy soil (control), fruit from plants grown in coir had higher nutritional concentrations of biochemical elements such as vitamin E, calcium, copper, phenols, potassium, zinc and β-carotene. As a result of the nutritional data obtained from the present study on tomato fruit from plants grown on coir substrate, it is clear that agricultural methods involving cultivation of horticultural fruit crops on coir substrate may contribute to the alleviation of malnutrition. However, access and price may be a barrier for new farmers looking to enter the market in search of higher yields and profit maximisation.

4.8 References

Aslam W, Noor R.S, Hussain F, Ameen M, Ullah S, Chen H (2020) Evaluating morphological growth, yield, and postharvest fruit quality of cucumber (Cucumis sativus L.) grafted on cucurbitaceous rootstocks. Agriculture 10: 1-19.

Baba, S. A., & Malik, S. A. (2018). Determination of total phenolic and flavonoid content, antimicrobial and antioxidant activity of a root extract of *Arisaema jacquemontii* Blume. *Journal of Taibah University for Science*, 9, 449-454.

Barrett DM, Beaulieu J, Shewfelt R (2010) Color, flavor, texture, and nutritional quality of fresh-cut fruits and vegetables: desirable levels, instrumental and sensory measurement, and the effects of processing. Critical reviews in food science and nutrition 50: 369-389.

El-Mageed, T. A., & Semida, W. M. (2015). Effect of deficit irrigation and growing seasons on plant water status, fruit yield and water use effeciency of squash under saline soil. *Scientia Horticulture*, *186*, 89-100.

Flemotomou E, Molyviatis T, Zabetakis I (2011) The effect of trace elements accumulation on the levels of secondary metabolites and antioxidant activity in carrots, onions and potatoes. Food and Nutrition Sciences 2:1071-1076.

Fletcher, R. A., & Arnold, V. (1986). Stimulation of cytokinins and chlorophyll synthesis in cucumber cotyledons by triadimefon. *Physiologia plantarum*, *66*(2), 197-201.

Górecki RS, Górecki, MT (2010) Utilization of waste wool as substrate amendment in pot cultivation of tomato, sweet pepper, and eggplant. Polish Journal of Environmental Studies 19(5): 1083-1087.

Hashem, F. A. (2011). Influence of green-house cover on potential evapotranspiration and cucumber water requirements. *Annals of Agricultural Sciences*, *56*(1), 49-55.

He L, Yu L, Li B, Du N, Guo S (2018) The effect of exogenous calcium on cucumber fruit quality, photosynthesis, chlorophyll fluorescence, and fast chlorophyll fluorescence during the fruiting period under hypoxic stress. BMC plant biology, 18(1): 1-10.

Hossain MA, Shah MD (2015) A study on the total phenols content and antioxidant activity of essential oil and different solvent extracts of endemic plant Merremia borneensis. Arabian Journal of Chemistry, *8*(1), 66-71.

Isah, A. S., Amans, E. B., Odion, E. C., & Yusuf, A. A. (2014). Growth rate and yield of two tomato varieties (Lycopersicon esculentum Mill) under green manure and NPK fertilizer rate Samaru Northern Guinea Savanna. *International Journal of Agronomy*, 1-9.

Kaushik SK, Tomar DS, Dixit AK. (2011) Genetics of fruit yield and its contributing characters in tomato (Solanum lycopersicom). Journal of Agricultural Biotechnology and Sustainable Development *3*(10), 209-213.

Khattab MM, Shaban AE, El-Shrief AH, Mohamed AED (2011) Growth and productivity of pomegranate trees under different irrigation levels. II: fruit quality. Journal of Horticultural Sciences and Ornamental Plants *3*(3): 259-264.

Magán, J. J., Gallardo, M., Thompson, R. B., & Lorenzo, P. (2008). Effects of salinity on fruit yield and quality of tomato grown in soil-less culture in greenhouses in Mediterranean climatic conditions. *Agricultural water management*, *95*(9), 1041-1055.

Moco S, Bino RJ, Vorst O., Verhoeven HA., de Groot J, van Beek TA, De Vos CR (2006) A liquid chromatography-mass spectrometry-based metabolome database for tomato. Plant physiology 141(4): 1205-1218.

Moyo, M., Amoo, S. O., Aremu, A. O., Gruz, J., Šubrtová, M., Jarošová, M., Tarkowski, P., & Doležal, K. (2018). Determination of mineral constituents, phytochemicals and antioxidant qualities of *Cleome gynandra*, compared to *Brassica oleracea* and *Beta vulgaris*. *Frontiers in Chemistry*, *5*, 1-9.

Olle, M., Ngouajio, M., & Siomos, A. (2012). Vegetable quality and productivity as influenced by growing medium: a review. Agriculture, 99(4), 399-408.

Santos-Zea, L., Gutiėrrez-Uribe, J. A., & Serna-Saldivar, S. O. (2011). Comparative analysis of total phenols, antioxidant activity, and flavonol glycoside profile if Cladode flours from different varieties of *Opuntia* spp. *Journal of Agricultural and food chemistry*, 59, 7054-7061.

Sharma S, Rao TR (2013) Nutritional quality characteristics of pumpkin fruit as revealed by its biochemical analysis. *International Food Research Journal 20*(5): 2309-2316.

Slavin, JL, Lloyd B (2012) Health benefits of fruits and vegetables. Advances in nutrition, *3*(4): 506-516.

Sezen SM, Yazar A. Tekin S, Kapur B (2010) Effect of irrigation management on yield and quality of tomatoes grown in different soilless media in a glasshouse. Scientific Research and Essays *5*(1): 041-048.

Uusiku NP, Oelofse A, Duodu KG, Bester MJ, Faber M (2010) Nutritional value of leafy vegetables of sub-Saharan Africa and their potential contribution to human health: A review. Journal of food composition and analysis 23(6): 499-509.

Wang SY, Chen CT, Sciarappa W, Wang CY, Camp MJ (2008) Fruit quality, antioxidant capacity, and flavonoid content of organically and conventionally grown blueberries. Journal of agricultural and food chemistry *56*(14): 5788-5794.

CHAPTER 5: SUMMARY AND FUTURE WORK

5.1 General summary

The study found that coconut coir (Profit) substrate provided the best conditions for plant growth in terms of chlorophyll content, plant height, stem diameter, and water content - all of which are essential for overall yield - while coconut coir (Power) substrate produced more fruit overall. Therefore, the study's findings show that farmers utilizing coconut coir (Power and Profit) for greenhouse tomato production are likely to raise their financial returns due to their capacity to enhance plant growth and yield. To draw a conclusion that is supported by evidence, the use of these coir substrates must first be examined regarding their effect on the growth and yield as well as concentration on biochemical compounds involving other horticultural crops such as strawberries and cucumbers.

5.1.1 Study conclusion 1

Objective 1: was to determine the most effective coir substrate for growing *S. lycopersicum* plants grown under greenhouse environment by comparing plant growth, development across three different substrates, each with a specific nutrient composition, and measuring outcomes through plant height, chlorophyll content, stomatal conductance, total biomass, fruit number, fruit length and harvest index.

Chlorophyll content, stomatal conductance and stem diameter

The study's findings revealed a noticeable increase of chlorophyll content and stomatal conductance in plants grown in loamy soil and coconut coir Profit, while plants grown in coir Power showed lower chlorophyll content. Regarding stem diameter, plant grown under coir Power as substrate had wider stem diameters compared to plants from other treatments, namely coir Profit or loamy soil.

Fruit number and plant height

The findings of the study demonstrated that tomato crops grown on coir Profit resulted in taller plants than those grown in other treatments. In contrast, a higher fruit yield was seen under plants cultivated in coir Power as substrate.

Total biomass, harvest index and water content

The study findings illustrated that tomato plants grown under coir Power had a higher total biomass compared to the other treatments. Concerning harvest index and water content, plant growth in coir Profit resulted in a higher harvest index when compared to the other treatments.

This brief discussion of study results describing plant growth, development and yield supports the assertion that study objective 1 was suitably addressed.

5.1.2 Study objective 2

Objective 2: was to assess the most effective coir substrate for growing nutrient dense *S. lycopersicum* fruit across three different substrates with a specific nutrient composition under greenhouse environment by comparing biochemical constituents such as crude proteins, *β*-carotene, vitamin C, vitamin E, total flavonoids, total phenols, lycopene, macro and micro-nutrients.

Crude protein and total soluble sugars

The study findings showed that there was no significant variation in crude protein content of fruit harvested from tomato plants grown in coir Profit, Power or loamy soil. Regarding total soluble sugar content, fruit grown under coir substrate Power contained more TSS content compared to other treatments.

Total flavonoids and total phenols

Regarding total flavonoids, fruit grown under loamy soil-control had higher content compared to other treatments. For total flavonoids, the study findings showed that fruit grown under coir Power contained more compared to other treatments.

The study's findings revealed that there was no statistical variation for several biochemical components, including crude proteins, total soluble sugars, total flavonoids, and total phenols. This suggests that there is no relationship between the observed set of dependent variables and the independent variables (different substrates). As a result, findings based on these dependent variables are disregarded.

Vitamin C, vitamin E, Lycopene, macro-nutrients and micro-nutrients

The study findings revealed that fruit from plants grown in coir Power had a higher vitamin C, E and lycopene content compared to the other treatments. Macro-nutrients such as calcium, phosphorus, potassium, and sodium were also at higher concentration in fruit grown in coir Power compared to other treatments. Regarding micro-nutrients such as β-carotene, copper, and zinc, the study findings showed a higher concentration of these nutrients in fruit from plants grown in coir Power compared to other treatments. Micro-nutrient content of iron was higher in fruit grown under coconut coir Profit when compared to other treatments.

The study's findings revealed that there was statistical variation for several biochemical components, including vitamin C, vitamin E, lycopene, calcium, phosphorus, potassium, iron and zinc. This suggests that there is relationship between the observed set of dependent variables and independent variables (different substrates). As a result, findings on these dependent variables are accepted.

This brief discussion of study results describing biochemical analysis of fruit from tomato plants cultivated in coir substrates or in loamy soil as control, supports the assertion that study objective 2 was suitably addressed.

5.3 Future work

The findings of the study were the first to determine the effect of varying coconut coir substrates on the growth, yield and biochemical constituents of tomato crop under greenhouse environment. It is recommended that future investigation consider the following:

- The effect of varying coconut coir substrates and fertilizer levels on the metabolomic profile of various horticultural crops such as cucumber, strawberry and tomato.
- The effect of different water regimes and varying coconut coir substrates on the growth, yield and nutritional qualities of various horticultural crops such as cucumber, strawberry and tomato.

5.4 Contribution to the body of knowledge and the science of agriculture

This investigation has provided solid evidence that organic substrates such as coconut coir can be utilised to increased crop yield, as well as higher fruit number, particularly in the case of tomato plants. In addition, findings demonstrated that tomato crop grown under coconut coir substrate produced nutrient-dense fruit when compared to loamy soil. This is useful information regarding food quality and security. Moreover, it is vital that food consumed by human beings meet the daily recommended intake as outlined by the World Health Organisation.

APPENDICES

APPENDIX I: Ethical clearance approval

UNISA university of south africa

UNISA-CAES HEALTH RESEARCH ETHICS COMMITTEE

Date: 11/10/2021

NHREC Registration # : REC-170616-051
REC Reference # : 2021/CAES_HREC/136
Name : Mr JT Mogale
Student #: 60107839

Dear Mr Mogale

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

Researcher(s): Mr JT Mogale
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Supervisor (s): Dr MK Maluleke
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Dr P Adriaanse
adriap@unisa.ac.za; 011-670-9043

Working title of research:

Investigating the effect of different coir substrates on the growth, yield and biochemical constituents of tomato (*Lycopersicon esculentum*)

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: Please note that there is no factorial experiment with only one factor. Rather, this is an experiment with one factor that has different levels – the researcher is advised to correct the wording. Furthermore, give the ANOVA structure with the statistical model, assumptions etc.
2. What type of response variable will be applied for the generalised linear mixed model? 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.

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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/136** 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
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APPENDIX II: Proof of article submission

Air, Soil and Water Research Manuscript ID - ASW-22-0084

Air, Soil and Water Research <onbehalfof@manuscriptcentral.com>
To Maluleke, Mdungazi; jtmogale@webmail.co.za

Reply | Reply All | Forward | ...

Thu 2022/09/08 12:2

08-Sep-2022

Dear Dr. Maluleke:

Your manuscript entitled "Growth, yield and biochemical constituents of tomato (Solanum lycopersicum) fruit grown on varying coconut coir substrate types under greenhouse environment" has been successfully submitted online and is presently being given full consideration for publication in Air, Soil and Water Research.

Your manuscript ID is ASW-22-0084.

You have listed the following individuals as authors of this manuscript:
Maluleke, Mdungazi; Mogale, Jeffrey

Please mention the above manuscript ID in all future correspondence or when calling the office for questions. If there are any changes in your street address or e-mail address, please log in to ScholarOne Manuscripts at https://mc.manuscriptcentral.com/asw and edit your user information as appropriate.

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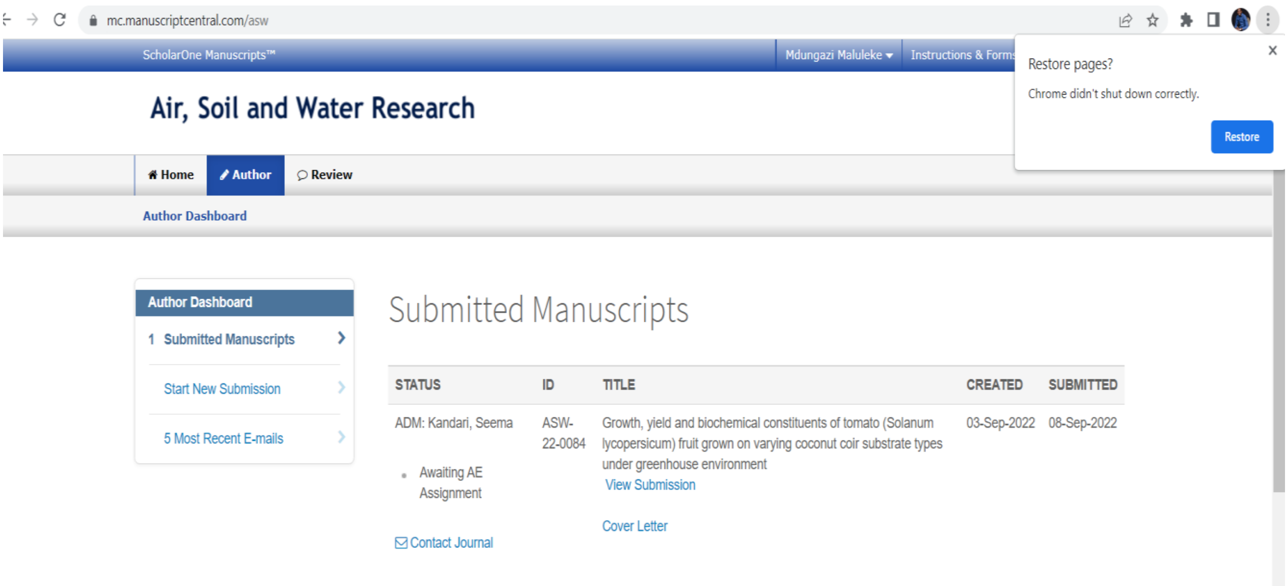
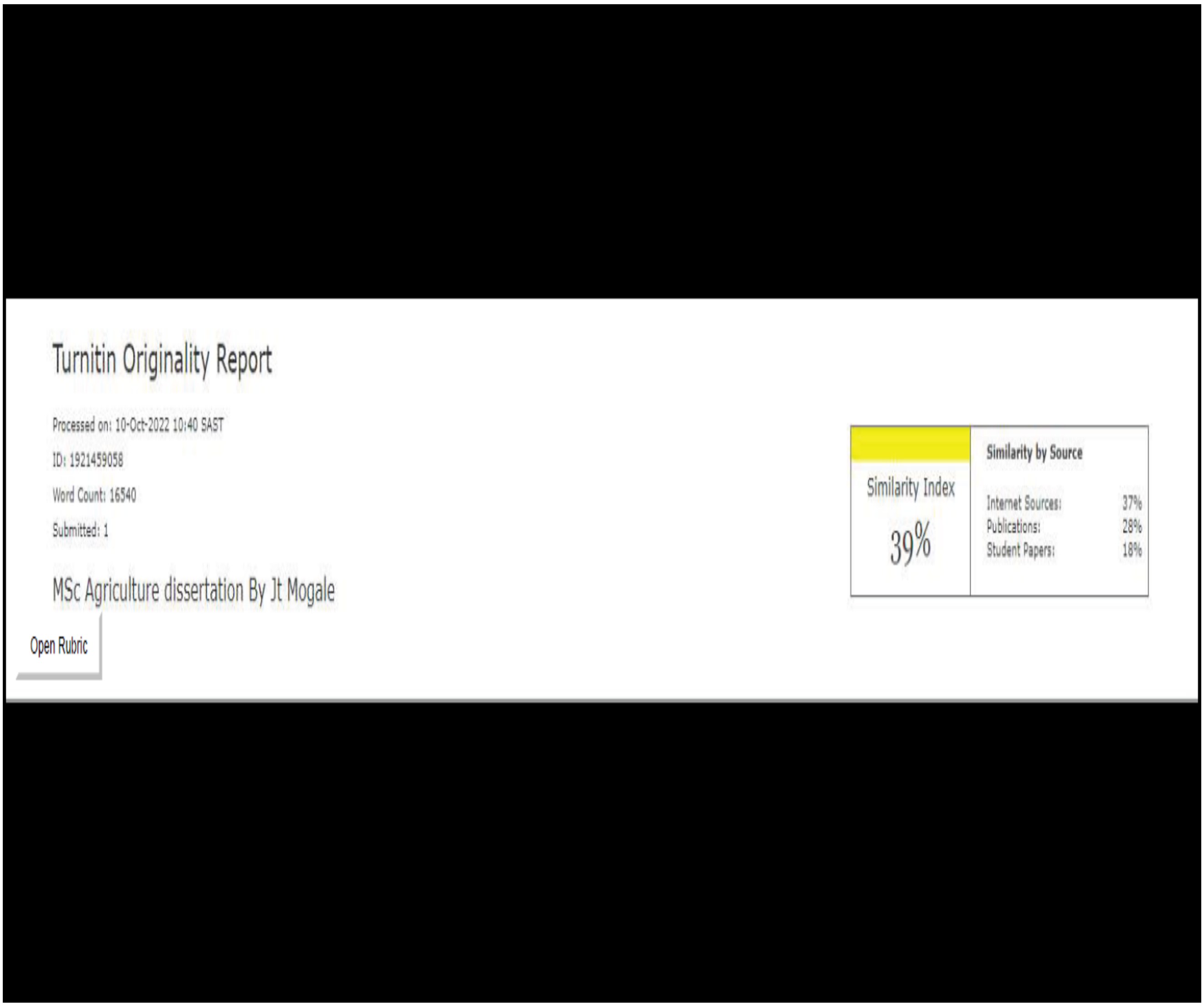
Thank you for submitting your manuscript to Air, Soil and Water Research.

Sincerely,
ASW Editorial Office
Air, Soil and Water Research
ASW@sagepub.com



APPENDIX III: Turnitin Report



Turnitin Originality Report

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ID: 1921459058

Word Count: 16540

Submitted: 1

MSc Agriculture dissertation By Jt Mogale

Open Rubric

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APPENDIX IV: Proof of language editing

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 the first version of the final draft of a dissertation entitled: **Investigating the effect of different coir substrates on the growth, yield and biochemical constituents of tomato (*Solanum lycopersicum*).** This dissertation was prepared by Mr Jeffrey Mogale and describes a research study under your and Dr Adriaanse's supervision. The dissertation will be presented to the Department of Agriculture and Animal Health, 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
- Check and format in-text references
- Adjust references according to Harvard presentation
- Introduce study conclusions according to study objectives

Text formatting included:

- Adjusted legend and size of some figures and tables
- Suggested inclusion of background information and methodology theory in Chapter 2
- Suggested review of statistical analysis
- Suggested possible inclusion of a study objective 4 describing farmer adoption of tomato cultivation in coir
- Provided examples of study conclusions aligned with study objectives

Open Rubric

Yours sincerely,

John Dewar
20th October 2022