BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

DEPARTMENT OF CROP SCIENCE

Comparative analysis of growth rate, yield, and quality (color size) of *Tejaswini* Chili grown in peat-based organic media and inorganic fertilizers



MWARAMBA SHALOOM

B223399B

A dissertation submitted in partial fulfilment of the requirements of the Bachelor of Agricultural Science Honours Degree in Crop Science

2026

Supervisor: Dr T Goche

Submission date: June 2026

APPROVAL FORM

I Shalom Mwaramba, do hereby declare this thesis is a result of my original research work except where l clearly specifically acknowledged. This research project "**Comparative analysis of growth rate, yield, and quality (color size) of *Tejaswini* Chili grown in peat-based organic media and inorganic fertilizers**" is being submitted for the first time, it has not been submitted at any institution either in a form of degree or examination

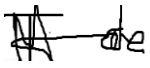
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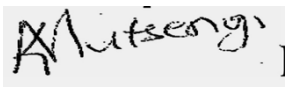
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Dr Goche (supervisor)

Signature 

Date 30/06/2026

Mr Mutsengi (Crop Science Chairperson)

Signature 

Date. 02/09/2026

DECLARATION

This project is dedicated to all commercial and smallholder farmers in Zimbabwe who is growing Tejaswini Chili as a cash crop for export

DEDICATION

I dedicate this thesis to chili smallholder and commercial farmers in Zimbabwe.

ACKNOWLEDGEMENTS

Special thanks go to the Almighty God for the divine guidance and good healthy during the study period. I would like to express my sincere gratitude to my supervisor Dr Goche for the support and guidance during my compilation of this work. I also give thanks to Stagri Brands company for the support they gave me through the provision of resources and facilities to carry my project under the supervision of T Saruchera

ABSTRACT

Chili production in Zimbabwe is expanding as part of horticulture diversification and income generation strategies. However, productivity and market quality remain inconsistent among growers. The study evaluated the effects of peat-based organic media and inorganic fertilizer nutrient management systems on the growth, yield, and fruit quality of Tejaswini chili (*Capsicum annuum L.*) under greenhouse conditions in Banket, Zimbabwe. The experiment was conducted using a Completely Randomized Design (CRD) consisting of two treatments, namely peat-based organic media and inorganic fertilizer, with ten replicates per treatment. Data were collected on vegetative growth parameters (plant height and number of leaves), yield parameters, and fruit quality attributes (fruit size and fruit color). Analysis of Variance (ANOVA) was performed using GenStat 18th Edition software, and treatment means were separated using the Least Significant Difference (LSD) test at the 5% significance level. Results showed highly significant differences ($P \leq 0.001$) between the two nutrient management systems for all measured parameters. Plants grown under inorganic fertilizer exhibited significantly greater vegetative growth, 6 weeks after transplanting respectively, compared to plants under peat-based organic media. Fruit color development was significantly enhanced under inorganic fertilization, which recorded a mean color score of 3.7 compared to 2.4 under peat-based organic media. The study concludes that inorganic fertilizer is more effective than peat-based organic media in enhancing growth, yield, and fruit quality of Tejaswini chili under greenhouse conditions. **Keywords**: Tejaswini chili, inorganic fertilizer, peat-based organic media, fruit quality, yield, nutrient management, Zimbabwe.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CRD	Complete Randomized Design
^{0}C	Degrees Celsius
CV	Coefficient of Variation
H_0	Null Hypotheses
LSD	Least Significance Difference
pH	Potential Hydrogen

CHAPTER 1

INTRODUCTION

1.1 Background of study

Chili pepper (*Capsicum annum L.)* is an important horticultural crop grown for both domestic consumption and commercial markets. Globally, its production continues to increase due to rising demand for fresh and processed products (Food Agriculture Organization [FAO] 2023). In Zimbabwe, chili production contributes to household income, nutrition and agricultural diversification, particularly within smallholder and peri urban farming systems. Growth performance, yield and fruit quality in chili are strongly influenced by nutrient management and the type of growing medium used. Inorganic fertilizers provide nutrients in readily available forms and often promote rapid vegetative growth (Marschner 2012). However, concerns about long term soil sustainability have encouraged interest in inorganic growing media such as peat, which is valued in horticulture for its favorable physical properties including high water and aeration. Research has shown that nutrient supply and media composition can significantly affect fruit size and color, which are key quality attributes I chili marketing. Despite the increasing use of both inorganic fertilizers and organic media in vegetable production, there is limited comparative evidence under Zimbabwean conditions, particularly for improved varieties such as *Tejaswini* chili. This study therefore compares growth rate, yield and selected quality parameters (color and size) of *Tejaswini* chili grown in peat based organic media and under inorganic fertilization system.

1.2 Problem statement

Chili production in Zimbabwe is expanding as part of horticulture diversification and income generation strategies. However, productivity and market quality remain inconsistent among growers. Growth rate, fruit yield and quality characteristics such as size and color are strongly influenced by nutrient management and the type of growing medium used (Marschner 2012). Many farmers rely primarily on inorganic fertilizers because they provide

nutrients in readily available forms and are known to promote rapid plant growth *(Rai et al. 2014).* Despite these advantages, concerns about long term soil fertility decline and sustainability associated with continuous use of synthetic fertilizers have been widely reported (*Tilman et al. 2002*).

At the same time, peat based organic media are increasingly used in horticulture production due to their favorable physical properties, including high water retention and aeration, which support root development (*Abad et al. 2001).* Research has shown that media composition can influence nutrient uptake, fruit development and quality attributes such as color intensity and fruit size (Gruda 2012; *Howard et al. 2000).* However, most of these studies have been conducted outside Zimbabwe, and there is limited localized experimental evidence comparing peat-based organic media with conventional inorganic fertilization systems under Zimbabwean agro-ecological conditions. Furthermore, improved chili varieties such as *Tejaswin*i are cultivated for their uniform fruit size and attractive color, which are critical for market acceptance. Yet, there is insufficient empirical data to guide farmers on whether peat-based organic media or inorganic fertilizer provide better outcomes in terms of growth rate, yield and fruit quality for this specific variety. The absence of comparative, locally generated data creates uncertainty in decision-making and may limit optimal production practices. Therefore, there is a need for a synthetic comparative analysis of the growth rate, yield and quality (color and size) of *Tejaswini* chili grown in peat-based organic media and under inorganic fertilization systems in order to provide evidence-based recommendations for sustainable and efficient chili production in Zimbabwe.

1.3 Justification

Horticulture remains an important component of agricultural diversification and income generation in Zimbabwe (Government of Zimbabwe 2020). Chili production in particular, offers opportunities for both fresh markets and ago-processing industries. However, achieving consistent growth performance, high yield and desirable fruit quality depends largely on appropriate nutrient management and growing media selection (Marschner 2012). While inorganic fertilizers are widely used due to their immediate nutrient availability, concerns regarding long-term soil sustainability have encouraged interest in alternative organic based media (*Tilman et al. 2002; Abad et al. 2001*). Despite this shift, there is limited comparative evidence under Zimbabwean conditions, especially for improved varieties such

as *Tejaswini* chili. This study is therefore justified as it will generate locally relevant experimental data to guide farmers, extension officers, and policymakers on the most effective and sustainable production approach. The findings will contribute to improved productivity, better fruit quality and informed decision-making in chili production systems.

1.4 Objectives of the study

1.4.1 Main objectives

- To compare growth rate, yield and quality (color size) of *Tejaswini* Chili grown in peat-based organic media and inorganic fertilizers

1.4.2 Specific objectives

- To determine the effect of peat-based organic media and inorganic fertilizers on the vegetative growth rate of T*ejaswini* chili
- To compare the total fruit yield of *Tejaswin*i chili produced under peat-based organic media and inorganic fertilization systems.
- To evaluate the effect of the two nutrient management systems on fruit size of *Tejaswini* chili
- To assess the influence of peat-based organic media and inorganic fertilizers on fruit color development of *Tejaswini* chili

1.5 Hypotheses

H_0**:** There is no significant effect of peat-based organic media and inorganic fertilizers on the vegetative growth rate of T*ejaswini* chili

H_0: There is no significant effect on the total fruit yield of *Tejaswin*i chili produced under peat-based organic media and inorganic fertilization systems.

H_0: There is no significant effect of the two nutrient management systems on fruit size of *Tejaswini* chili

H_0: The is no influence of peat-based organic media and inorganic fertilizers on fruit color development of *Tejaswini* chili

H_0: There is no significant overall production efficiency of the two systems in relation to growth performance and market acceptance.

CHAPTER 2

LITERATURE REVIEW

2.1 Theoretical Frameworks

2.1.1 Plant Nutrition Theory

Plant Nutrition Theory provides the foundational basis for understanding how plants acquire, utilize, and respond to mineral elements essential for growth and reproduction. The theory is anchored in the law of the minimum, originally articulated by Justus von Liebig in the nineteenth century, which holds that plant growth is governed not by the total availability of all nutrients but by the scarcest essential nutrient in the environment (Marschner, 2012). Liebig's principle established that deficiencies in even a single nutrient, regardless of the abundance of others, will constrain plant development and productivity. This has enduring relevance to experimental nutrient management studies, as it explains why both the source and balance of nutrients are critical in determining crop performance outcomes. Modern plant nutrition science categorizes essential elements into macronutrients, which include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S), and micronutrients such as iron (Fe), zinc (Zn), manganese (Mn), boron (B), copper (Cu), molybdenum (Mo), and chlorine (Cl). Each nutrient performs specific biochemical and physiological functions within the plant system. Nitrogen is indispensable for chlorophyll synthesis, amino acid production, and protein formation, all of which underpin vegetative biomass accumulation (Marschner, 2012). Phosphorus supports energy transfer through adenosine triphosphate (ATP) and is critical during flowering and fruit set. Potassium regulates osmotic balance, stomatal function, enzyme activation, and carbohydrate transport within the plant. In the context of chili production, Plant Nutrition Theory is directly applicable to explaining differences in growth performance, yield, and fruit quality under

peat-based organic media versus inorganic fertilization. The form, solubility, and timing of nutrient delivery are central variables that determine the rate and extent of nutrient uptake. Inorganic fertilizers provide nutrients in readily soluble ionic forms that are immediately accessible for root absorption, while organic media release nutrients gradually through microbial decomposition processes. Understanding this theoretical distinction provides the conceptual lens through which the comparative effects of the two nutrient management systems on Tejaswini chili can be interpreted and discussed.

2.1.2 Soilless Culture and Growing Media Theory

Soilless Culture Theory emerged as a branch of horticultural science recognizing that plants can be successfully cultivated outside conventional soil systems when provided with appropriate substrates that fulfil the physical and chemical functions of natural soil. The theory holds that the growing medium must perform three primary roles: providing physical anchorage for the root system, facilitating water and oxygen availability in the root zone, and supporting nutrient delivery either by holding nutrients in accessible chemical forms or by enabling the efficient use of applied fertilizers (Resh, 2013). Substrates used in soilless or container culture vary widely in their physical and chemical properties. Organic substrates such as peat, coconut coir, and composted bark are valued for their high water-holding capacity, adequate porosity, and relatively low bulk density, which collectively create a favorable root environment (Abad *et al*., 2001). Peat-based media, in particular, exhibit high cation exchange capacity (CEC), meaning they can retain positively charged nutrient ions such as potassium, calcium, and magnesium and release them to roots over time. These properties are important for maintaining nutrient availability between irrigation events and for buffering against rapid fluctuations in root-zone chemistry. The theory also recognizes the importance of balancing water retention with air-filled porosity. Substrates that retain excessive moisture risk root suffocation by displacing oxygen from pore spaces, while overly porous media may dry out rapidly and result in nutrient and water stress (Gruda, 2012). The balance between these competing demands is central to substrate selection and management in horticultural production systems. For the present study, Soilless Culture Theory provides the theoretical basis for evaluating how peat-based organic media differ from conventional soil amended with inorganic fertilizers in supporting root function and overall plant performance in Tejaswini chili.

2.1.3 Quality Attributes Theory

Quality Attributes Theory in horticultural science provides the theoretical basis for understanding the physiological and biochemical determinants of marketable fruit characteristics. The theory posits that fruit quality is not simply a consequence of biomass accumulation but reflects complex interactions among genetic potential, environmental conditions, nutritional status, and developmental physiology (Bosland and Votava, 2012). The theory is particularly relevant to chili production, where fruit color, size, pungency, and uniformity are the primary determinants of commercial value and consumer preference. Fruit color in Capsicum annuum is primarily determined by the biosynthesis and accumulation of carotenoid pigments, including capsanthin, capsorubin, lutein, and beta-carotene, during fruit maturation. The transition from green to red coloration during ripening results from the simultaneous degradation of chlorophyll and the active synthesis of carotenoids through the isoprenoid biosynthetic pathway (Howard *et al*., 2000). These pigments not only contribute to visual appeal but also serve as antioxidants and precursors to vitamin A, contributing to the nutritional quality of the fruit. Nutrient availability, particularly adequate nitrogen and micronutrients such as magnesium and iron, influences the biochemical processes underlying pigment biosynthesis. Fruit size is governed primarily by cell division and expansion during early fruit development following pollination and fertilization. Adequate nutrient supply supports cell cycle progression, protein synthesis, and turgor maintenance, all of which are necessary for optimal fruit enlargement (Marschner, 2012). Potassium plays a particularly important role in fruit development by regulating carbohydrate transport from leaves to developing fruits and by maintaining cellular water relations that support tissue expansion. Understanding these quality-determining processes through the lens of Quality Attributes Theory provides a framework for interpreting differences in fruit size and color between plants grown under peat-based organic media and inorganic fertilization.

2.2 Global Production and Economic Importance of Chili

Chili pepper (Capsicum annuum L.) occupies a prominent position in global agriculture as one of the most widely cultivated and economically significant horticultural crops. The genus Capsicum traces its domestication origins to Mesoamerica approximately six to eight thousand years ago, from where it was disseminated across the globe following European

exploration in the fifteenth and sixteenth centuries. Today, chili is cultivated across tropical, subtropical, and temperate regions and constitutes a fundamental ingredient in the culinary traditions of numerous cultures worldwide (Bosland and Votava, 2012).

Data from the Food and Agriculture Organization of the United Nations (FAO, 2023) indicate that global production of fresh and dried chilies and peppers has increased substantially over recent decades, driven by rising demand in both domestic food consumption and international trade. Annual global production has grown from approximately seventeen million metric tons to over thirty-five million metric tons within two decades, with harvested area expanding by approximately thirty-five percent during the same period. Asia dominates world chili production, contributing approximately sixty-five percent of global output, with China and India accounting for the largest shares. India alone is the world's largest producer of dried chilies, with production spread across states such as Andhra Pradesh, Karnataka, and Maharashtra, while China leads in fresh pepper production. The economic importance of chili extends across multiple dimensions of the agricultural and food systems value chain. As a high-value horticultural commodity, chili generates income for smallholder and commercial producers, contributes to agro-processing industries through the manufacture of spice powders, oleoresins, hot sauces, and condiments, and supports export earnings for producing nations (FAO, 2023). The crop commands favorable prices relative to staple grains, making it an attractive diversification enterprise for smallholder farmers in many developing countries. Beyond its economic role, chili is nutritionally significant, providing vitamins C and A, antioxidant carotenoids, and the alkaloid capsaicin, which has demonstrated pharmacological properties including anti-inflammatory and analgesic effects in biomedical research. The growing international market for ethnic and spiced foods has further expanded demand for chili products, particularly in North American, European, and East Asian markets where consumer interest in diverse culinary experiences has grown. This global demand trajectory has incentivized the development and commercial release of improved chili cultivars, including hybrid varieties with superior yield, uniformity, and quality characteristics. Tejaswini chili, a high-performance hybrid variety originating from India and commercialized by companies such as Stagri Brands in Zimbabwe, exemplifies this trend toward improved genetic material tailored for both domestic and export markets.

2.3 Chili Production in Zimbabwe: Status and Challenges

In Zimbabwe, chili production forms part of a broader horticultural diversification strategy that has gained momentum in the context of agricultural policy reforms and growing recognition of the crop's potential for income generation. According to FAOSTAT (2023), Zimbabwe's production of green chilies and peppers reached approximately 3.52 thousand metric tons in 2022, reflecting year-on-year growth of approximately 4.31 percent and indicating incremental expansion in the national chili sector. While this outputs places Zimbabwe relatively modestly in global rankings, the production growth trajectory suggests increasing adoption of chili cultivation among both smallholder and commercial farmers. The production system in Zimbabwe encompasses diverse scales of operation, from subsistence-level smallholder plots to organized peri-urban horticulture schemes and, increasingly, commercial contract farming arrangements supported by private sector off-takers such as Stagri Brands. Stagri Brands has established a contract farming model in Mashonaland West Province, supplying quality seedlings of Tejaswini chili to contracted farmers and facilitating market linkages for the harvested produce. This model represents an important innovation in the Zimbabwean chili value chain and has helped to introduce improved varieties and practices that can enhance productivity and marketable quality at the farm level (Chikuvire *et al*., 2020). Despite encouraging growth trends, several structural constraints continue to limit the full development of Zimbabwe's chili sector. Access to quality seed and improved planting material remains inconsistent, particularly among smallholder farmers who may not be enrolled in formal contract farming schemes. Inadequate irrigation infrastructure constrains production in many areas, as chili requires consistent moisture availability throughout the growing season, especially during flowering and fruit development. Post-harvest losses due to poor handling, limited cold storage, and inadequate transportation infrastructure further reduce the marketable yield available for domestic and export sale (Government of Zimbabwe, 2020). Soil fertility constraints represent a particularly significant challenge in the Zimbabwean context. Many smallholder farming areas are characterized by sandy, low-organic-matter soils derived from granite parent material, which have inherently limited nutrient-holding capacity and are susceptible to leaching and degradation under continuous cultivation (Zingore *et al*., 2007). Without consistent application of nutrient inputs, soil fertility declines progressively, reducing the capacity of chili plants to achieve their yield and quality potential. Limited research and extension support for chili production, compared to the historically more emphasized staple cereal

sector, has further slowed the adoption of evidence-based nutrient management and agronomic practices that could improve outcomes for growers at all scales.

2.4 Nutrient Management Systems in Horticultural Crops

2.4.1 Organic Nutrient Sources: Definitions, Composition, and Mechanisms

Organic nutrient sources encompass a diverse range of materials derived from plant, animal, or microbial biomass that supply nutrients to crops through biological decomposition and mineralization processes. These include animal manures, composts, green manures, crop residues, and organic substrates such as peat, all of which contain pools of organic nitrogen, phosphorus, potassium, and micronutrients held within complex organic molecules (Magnusson, 2018). Unlike mineral fertilizers, organic materials do not deliver nutrients in immediately soluble ionic forms. Instead, the nutrients contained within organic matter must first be released through microbial decomposition, a process known as mineralization, before they become available for plant uptake (Brady and Weil, 2016). Nitrogen mineralization, for example, proceeds through the sequential decomposition of organic nitrogen compounds to ammonium (NH_4^+) through the process of ammonification, followed by nitrification in which ammonium is oxidized to nitrate (NO_3^-) by autotrophic bacteria. The rate of mineralization is influenced by temperature, moisture, oxygen availability, carbon-to-nitrogen ratio of the organic material, and the microbial community composition of the growing medium (Gaskell and Smith, 2008). Peat specifically exhibits a slow rate of mineralization due to its high degree of humification and recalcitrant chemical structure, meaning that nutrients are released gradually over time rather than in concentrated pulses following application. The value of organic nutrient sources extends beyond their nutrient content. Organic materials contribute to improving the physical, chemical, and biological properties of growing media. They enhance structural stability, increase water retention, improve aeration through modification of pore size distribution, and stimulate microbial activity that drives nutrient cycling (Edmeades, 2003). Peat, in particular, is prized in horticulture for its high water-holding capacity, favorable bulk density, and substantial cation exchange capacity, which collectively create conditions conducive to root development and efficient nutrient acquisition (Abad *et al*., 2001). However, organic sources vary considerably in their nutrient composition and availability depending on feedstock, decomposition state,

and management history, making precise and standardized nutrient delivery more challenging than with inorganic formulations.

2.4.2 Inorganic Fertilizers: Definitions, Mechanisms, and Implications

Inorganic fertilizers, also referred to as mineral or synthetic fertilizers, are manufactured chemical compounds formulated to deliver specific plant nutrients in concentrated, water-soluble forms. They include a wide range of products providing primary macronutrients such as nitrogen (in urea, ammonium nitrate, or calcium ammonium nitrate), phosphorus (in single or triple superphosphate), and potassium (in potassium chloride or potassium sulfate), as well as compound NPK blends that supply multiple nutrients in defined ratios (Havlin *et al*., 2014). The primary characteristic that distinguishes inorganic from organic sources is the immediate solubility and availability of nutrients upon application, which enables rapid plant uptake without requiring prior microbial transformation. The mechanism of nutrient delivery from inorganic fertilizers involves dissolution in soil or substrate water, followed by movement of ions toward the root surface through mass flow and diffusion. At the root surface, specific membrane transport proteins facilitate the absorption of nutrient ions into root cells, from where they are translocated within the plant to sites of utilization (Taiz *et al*., 2015). Because this process does not depend on microbial activity, inorganic fertilizers provide predictable and rapid nutrient availability, making them effective for managing nutrient supply at critical crop growth stages such as early establishment, flowering, and fruit development. Despite their agronomic benefits, inorganic fertilizers carry well-documented environmental and sustainability risks. The high solubility of mineral nutrients increases susceptibility to leaching losses, particularly for nitrate nitrogen which is negatively charged and therefore poorly retained by soil cation exchange sites (Tilman *et al*., 2002). Under conditions of excessive rainfall or irrigation, nitrate can be leached below the root zone, reducing fertilizer use efficiency and contributing to groundwater contamination. Continuous reliance on inorganic fertilizers without organic matter replenishment can also lead to progressive decline in soil organic carbon, reduced microbial biomass and diversity, and deterioration of soil physical structure over time, undermining the long-term productive capacity of the growing system (Lal, 2004). These considerations justify the comparative evaluation of inorganic fertilizers against organic alternatives such as peat-based media in supporting sustainable chili production.

2.5 Growing Media and Substrate Selection in Horticulture

2.5.1 Properties and Functions of Peat-Based Organic Media

Peat-based substrates have historically dominated the commercial horticultural growing media market due to their consistent physical and chemical properties, which create a favorable environment for root development and crop production in container and protected cultivation systems. Peat is formed through the partial decomposition of sphagnum mosses and other wetland plant material under waterlogged, anaerobic conditions over thousands to tens of thousands of years, resulting in an organic material with distinctive physical characteristics including high porosity, low bulk density, and substantial water-holding capacity (Abad *et al.*, 2001). The physical structure of peat enables a favorable distribution of macro- and micropores within the substrate matrix. Macropores facilitate the movement of air through the medium following irrigation events, ensuring adequate oxygen availability for root respiration, while micropores retain water against gravitational drainage, providing a reservoir of moisture accessible to roots between watering intervals. This dual function is particularly important in container production where the restricted root volume means that plants are heavily dependent on the substrate's ability to buffer water availability (Gruda, 2012). The low bulk density of peat facilitates root penetration and exploration of the growing medium, supporting the development of extensive root systems that can more effectively absorb water and nutrients. The chemical properties of peat are also agriculturally significant. Peat typically exhibits a high cation exchange capacity, which allows it to adsorb positively charged nutrient ions including potassium, calcium, and magnesium and release them gradually to plant roots (Leichter, 2021). This buffering function helps to maintain a more stable nutrient supply to plants and reduces the risk of nutrient leaching during irrigation events. However, untreated peat is characteristically acidic, often with pH values ranging from 3.5 to 4.5, and is naturally low in plant-available nutrients. Adjustment of pH through liming and supplementation with fertilizers or slow-release nutrient sources is therefore required to produce a growing medium suitable for horticultural crops including chili (Abad *et al*., 2001).

2.5.2 Alternative Soilless Media and Commercial Substrates

Growing concern about the environmental sustainability of peat extraction, due to the destruction of ecologically significant peatland ecosystems and the release of stored carbon dioxide, has stimulated research into and commercial development of alternative substrates that can match or exceed the horticultural performance of peat while reducing ecological impact (Gruda, 2012). Among the most extensively evaluated alternatives, coconut coir has emerged as a widely adopted substitute. Coir is a by-product of coconut processing, characterized by high structural stability, good water-holding capacity, and a near-neutral pH that reduces the need for pH amendment compared to peat. Coir is renewable on short timescales compared to peat and has a lower carbon footprint when sourced sustainably. Other components commonly incorporated into commercial soilless growing media include perlite, a volcanic mineral expanded by heat treatment that contributes to substrate aeration and drainage; vermiculite, a hydrated phyllosilicate mineral that improves water retention and cation exchange capacity; composted bark, which provides both physical support and a modest organic nutrient reserve; and rice hull ash, which contributes silica and improves drainage. These components are frequently blended in proprietary ratios to achieve a target balance of water retention, aeration, and nutrient provision suited to specific crops and production systems (Savvas and Passam, 2002). The selection and optimization of substrate components is an active area of horticultural research with direct relevance to maximizing the performance of improved varieties such as Tejaswini chili under controlled growing conditions.

2.5.3 Physical and Chemical Substrate Characteristics Affecting Plant Growth

The influence of growing media on plant performance is mediated through a suite of physical and chemical characteristics that collectively determine the root environment. Among the most critical physical properties is water-holding capacity, which determines the volume of plant-available water retained within the substrate between irrigation events. Substrates with insufficient water-holding capacity may expose plants to intermittent water stress that disrupts nutrient uptake and metabolic processes, while substrates with excessive water retention may reduce air-filled porosity and create oxygen-deficient conditions that impair root function (Resh, 2013). Substrate pH is one of the most important chemical characteristics governing nutrient availability in horticultural growing media. Soil and substrate pH influence the solubility of mineral nutrients through its effects on the charge and speciation of nutrient ions and the dissolution of mineral compounds. For most vegetable

crops, including chili, a slightly acidic to near-neutral substrate pH in the range of 5.8 to 6.5 maximizes the simultaneous availability of major nutrients including nitrogen, phosphorus, and potassium as well as micronutrients such as iron, manganese, and zinc (Hochmuth and Hanlon, 2010). Outside this optimal range, specific nutrients may become chemically unavailable even when present in adequate total concentrations. Electrical conductivity of the substrate solution is another important chemical parameter, providing an integrated measure of the total concentration of soluble salts including dissolved nutrient ions. Elevated electrical conductivity can indicate excessive fertilizer salt accumulation that may exert osmotic stress on plant roots, reducing water uptake and compromising growth. Conversely, very low electrical conductivity may signal insufficient nutrient concentration in the root zone (Gruda, 2012). Managing electrical conductivity through careful fertilizer application and monitoring is therefore an important component of nutrient management in both organic and inorganic growing systems.

2.6 Vegetative Growth Responses to Organic and Inorganic Nutrient Systems

Vegetative growth constitutes the foundational phase of crop development during which the photosynthetic apparatus, structural biomass, and root system are established. The quality and extent of vegetative growth in chili and other fruiting vegetables has important implications for subsequent yield and quality formation, as a more vigorous canopy supports greater light interception and photosynthate production, while a well-developed root system facilitates more effective uptake of water and nutrients during reproductive growth (Jones, 2018). Studies in solanaceous crops including tomato and pepper have consistently demonstrated that nitrogen supply from inorganic fertilizers stimulates rapid vegetative development. Nitrogen is a primary constituent of amino acids, proteins, and chlorophyll, and its adequate availability promotes leaf expansion, stem elongation, and overall biomass accumulation. Research by Rai *et al*. (2014) reported significant increases in plant height, leaf area index, and stem diameter in chili plants receiving balanced NPK inorganic fertilizer compared to unfertilized controls. These responses reflect the role of nitrogen in driving cell division and expansion in meristematic tissues and in supporting the production of photosynthetic pigments that fuel vegetative growth. Organic nutrient systems, by contrast, typically result in a more gradual trajectory of vegetative growth, reflecting the slower release of nutrients through mineralization compared to the immediate availability provided by inorganic fertilizers. However, organic materials including peat substrates can positively influence root

morphology and architecture by improving the physical conditions of the root environment. Brady and Weil (2016) emphasized that organic substrates stimulate the development of finer root branches and root hairs, expanding the absorptive surface area available for nutrient uptake. Research by Lori *et al.* (2017) reported that organic amendments in vegetable crop systems enhanced root biomass and root length density, improvements that may not immediately translate into rapid above-ground biomass gains but contribute to more sustained nutrient and water acquisition as the crop matures.

Comparative studies in lettuce and other salad crops have illustrated the contrasting growth dynamics between organic and inorganic nutrient systems. Benitez *et al*. (2015) observed that lettuce grown under organic fertilization achieved slower initial shoot growth than plants receiving inorganic fertilizers but developed a more extensive root system with improved nutrient balance at later growth stages. While direct comparative evidence in Tejaswini chili is limited, analogous physiological dynamics are expected in this variety based on the established understanding of nutrient effects on Capsicum species growth.

2.7 Yield Responses under Organic and Inorganic Nutrient Management

Crop yield in fruiting vegetables such as chili is determined by a complex chain of developmental events including floral initiation, pollination, fruit set, fruit enlargement, and biomass accumulation in harvested organs. Each of these stages requires adequate and balanced nutrient supply, and the type, availability, and timing of nutrient delivery from organic or inorganic sources can significantly influence the magnitude and distribution of yield across these developmental phases (Rai *et al*., 2014).Inorganic fertilizers, due to their immediate nutrient availability, are frequently associated with higher yield outcomes in short-duration controlled experiments. Studies in Capsicum annuum have shown that balanced NPK inorganic fertilization increases fruit number per plant, individual fruit weight, and total fresh yield compared to either unfertilized controls or organically managed treatments, particularly when applied at rates calibrated to match crop nutrient demand (Rai *et al.*, 2014). The mechanisms underlying these responses involve improved nitrogen availability during vegetative growth that supports the development of a productive canopy, followed by adequate phosphorus and potassium supply during reproductive growth that promotes efficient fruit set and biomass partitioning.

Meta-analyses of yield comparisons between organic and inorganic nutrient management systems in horticultural crops have generally indicated that organic systems produce lower yields on average, though the magnitude of the difference varies considerably across crops, management contexts, and experimental conditions. Seufert *et al*. (2012) conducted a comprehensive meta-analysis and found that organic farming yields were on average approximately nineteen to twenty-five percent lower than conventional inorganic systems, but that the gap was smaller for some crop types and under well-managed organic management. Importantly, organic systems that include careful matching of organic nutrient supply to crop demand and supplementation with approved mineral amendments can narrow the yield gap considerably. In the context of peat-based organic substrate systems, yield outcomes reflect the indirect benefits of an improved root environment as well as the direct effects of nutrient supply from the substrate and any added organic amendments. The high water-holding capacity and stable physical structure of peat can support consistent root function and nutrient uptake throughout the growing season, potentially sustaining productivity even when instantaneous nutrient concentrations in the root zone are lower than under inorganic fertilization. Gruda (2012) observed that horticultural crops grown in well-managed peat-based systems achieved commercially acceptable yields, though performance may be inferior to optimally fertilized inorganic systems under some conditions.

2.8 Fruit Quality Attributes under Organic and Inorganic Nutrient Systems

2.8.1 Fruit Color Development

Fruit color is among the most important quality attributes in chili from both consumer preference and market value perspectives. The development of the characteristic red coloration in mature Tejaswini chili fruits is governed by the biosynthesis and accumulation of carotenoid pigments, primarily capsanthin and capsorubin, which are synthesized through the isoprenoid biosynthetic pathway during fruit ripening (Bosland and Votava, 2012). The onset and intensity of color development are influenced by genetic factors specific to the variety, environmental conditions including temperature and light during ripening, and the nutritional status of the plant throughout the growing season.

Howard *et al*. (2000) demonstrated that nutrient management significantly influences carotenoid accumulation in Capsicum fruits. Adequate nitrogen nutrition supports the

production of photosynthetic precursors necessary for carotenoid biosynthesis, while deficiencies in magnesium and iron can impair the enzymatic reactions involved in pigment synthesis pathways. Research in other Capsicum cultivars has indicated that organic amendments, particularly those that improve overall plant health and root function, can enhance the concentration of certain phytochemicals in fruits, potentially through stress-induced metabolic responses that upregulate secondary metabolite biosynthesis (Wang and Zheng, 2001). However, the relationship between nutrient source and carotenoid accumulation in Tejaswini chili specifically requires experimental investigation under local conditions.

2.9.2 Fruit Size

Fruit size in chili is determined primarily by the number and final volume of cells in the pericarp tissue, which in turn depend on the intensity and duration of cell division and expansion during the period of fruit development following pollination (Marschner, 2012). Potassium is the most important macronutrient for fruit enlargement, as it regulates turgor pressure in cells through control of osmotic potential and facilitates the loading and unloading of photosynthate in the phloem, enabling the efficient transport of carbohydrates to growing fruits. Deficiency of potassium during fruit development is commonly associated with small, poorly filled fruits with reduced fresh weight. Studies comparing fruit size across organic and inorganic nutrient management systems in solanaceous crops have produced variable findings. Some research has shown that well-managed organic systems can produce fruit of similar or even superior size compared to inorganic fertilizer treatments, particularly when the organic medium improves root zone conditions in ways that enhance overall plant health and nutrient uptake efficiency. Watson *et al*. (2017) reported that tomatoes grown in organic systems with high-quality compost amendments achieved fruit sizes comparable to conventionally fertilized plants, and in some cases exhibited enhanced flavor and phytochemical quality due to improved root-zone biological activity. In contrast, other studies have found that the slower nutrient release from organic materials can limit nutrient availability during the critical fruit enlargement period, resulting in smaller fruits compared to plants receiving readily available inorganic nutrient sources.

2.9 Soil Fertility and Nutrient Management in the Zimbabwean Context

The dynamics of soil fertility and nutrient management in Zimbabwe are shaped by biophysical characteristics, historical land use patterns, and socioeconomic constraints that together create a challenging environment for sustainable horticultural production. Many smallholder farming areas are situated on sandy, low-organic-matter soils derived from Precambrian granites and gneisses that form the parent material of much of Zimbabwe's highveld. These soils have inherently low cation exchange capacity, limited water retention, and low natural fertility, making them highly responsive to nutrient depletion under continuous cultivation without adequate organic matter or fertilizer inputs (Zingore *et al*., 2007). Research conducted in smallholder farming districts of Zimbabwe has documented systematic spatial gradients in soil fertility, with fields close to homesteads receiving the majority of available organic amendments such as manure and compost while more distant fields receive little or no nutrient input (Zingore *et al*., 2007). This pattern of spatially differentiated nutrient management results in heterogeneous soil fertility within farms and between farms across landscapes, complicating the prediction of crop response to nutrient inputs and making it difficult to establish general recommendations applicable across diverse growing conditions. The availability and affordability of commercial fertilizers for smallholder farmers in Zimbabwe has historically been constrained by high input prices, limited market access, and the macroeconomic challenges facing the agricultural sector. Many smallholders therefore apply fertilizers at rates substantially below those recommended for optimal crop production, contributing to suboptimal yields and progressive soil nutrient depletion (FAO, 2016).

In the context of horticultural crops, including chili, these soil fertility constraints underscore the importance of comparative research on nutrient management systems that can improve the availability and efficient use of nutrients under Zimbabwean conditions. Whether through the application of inorganic fertilizers at appropriate rates or through the adoption of organic growing media that can improve the root environment and support more efficient nutrient utilization, evidence-based nutrient management strategies are essential for improving the competitiveness and sustainability of Zimbabwe's emerging chili production sector.

2.10 Knowledge Gaps and Justification for the Study

The review of existing literature reveals several important gaps in knowledge that provide the scientific justification for the present study. First, while a substantial body of international research has evaluated the comparative effects of organic and inorganic nutrient systems on chili and other vegetable crops, very few experimental studies have specifically examined these effects under Zimbabwean agro-ecological conditions. The transferability of findings from temperate or tropical contexts with different soil types, climatic conditions, and cropping systems to the specific environment of Zimbabwe is limited, highlighting the need for locally relevant experimental evidence (Chikuvire *et al.*, 2020). Second, the specific performance of Tejaswini chili under contrasting nutrient management systems has not been empirically documented in the scientific literature. As an improved hybrid cultivar increasingly adopted through contract farming schemes in Zimbabwe, understanding the nutrient management conditions that optimize its growth, yield, and fruit quality is of direct practical importance for both contracted smallholder producers and commercial growers. Third, the comparative evaluation of peat-based organic media as an alternative to conventional soil amended with inorganic fertilizers in the Zimbabwean horticultural context is largely absent from the literature. Most comparative studies focus on compost or animal manure as the organic input, rather than on the specialized peat-based soilless media increasingly used in protected cultivation systems. Finally, fruit quality parameters including color development and fruit size, which are critical determinants of marketability and premium pricing in chili export markets, are frequently neglected as outcome variables in comparative nutrient management studies that prioritize total yield. The present study addresses these gaps by conducting a controlled experimental comparison of peat-based organic media and inorganic fertilization on the growth rate, yield, and quality of Tejaswini chili under conditions representative of Zimbabwe's horticultural production environment.

2.11 Conceptual Framework

The conceptual framework guiding this study integrates three interrelated domains derived from the theoretical and empirical literature reviewed above. The first domain encompasses the nutrient management system, constituting either peat-based organic media or inorganic fertilizers, which determines the form, availability, and timing of nutrient supply to the crop. The second domain consists of the plant physiological processes through which nutrient

inputs are translated into observable agronomic outcomes, including nutrient uptake and utilization, vegetative growth, photosynthesis, flowering, and fruit development. The third domain comprises the measurable agronomic outcomes that constitute the dependent variables of the study, namely vegetative growth rate, fruit yield, and fruit quality attributes including size and color.

The framework also recognizes that contextual moderating factors, including soil conditions in the study area, climatic variables, management practices, and the intrinsic genetic characteristics of the Tejaswini variety, influence the relationships between nutrient management inputs and crop performance outputs. The interaction among these domains forms the analytical basis for interpreting differences in crop performance between the two nutrient management systems and for generating recommendations relevant to the production conditions of Zimbabwean horticulture growers.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Description of the Study Area

The research was conducted at a greenhouse facility in Banket, Raffingora, Zimbabwe, situated within agro-ecological region 2b. Banket is a small agricultural town located in Mashonaland West Province. The area lies at an elevation of approximately 1,680 meters above sea level and experiences a subtropical highland climate with mean annual rainfall ranging from 750 mm to 1 000 mm, with the majority of precipitation occurring during the rainy season between November and March (Mupangwa *et al*., 2016). The temperature conditions of the study site are within the optimal range for Capsicum annuum production, which requires mean growing temperatures between 18 and 30 degrees Celsius for normal vegetative development, flowering, and fruit set. The greenhouse facility used for the experiment provided a controlled growing environment with management of temperature, humidity, and irrigation that minimized the influence of uncontrolled external factors on the experimental outcomes. This controlled setting was essential for isolating the effects of the

two nutrient management treatments on plant performance and ensuring that observed differences could be attributed to the contrasting growing systems rather than to variability in ambient environmental conditions. Access to quality water supply and the availability of experimental equipment for plant measurement supported the precise data collection required by the study design.

3.2 Experimental Layout

The experiment was arranged as a Completely Randomized Design (CRD) with two treatments and ten replicates per treatment. Each treatment consisted of ten replicates. Each grown in a separate pot of uniform capacity. Pots were arranged in a grid pattern within the greenhouse with sufficient spacing between pots to prevent physical contact between plants and to minimize mutual shading among canopies of adjacent experimental units. Pots within each treatment were randomly positioned within the allocated greenhouse space to ensure that any microclimatic variation within the facility was distributed randomly across experimental units, preventing systematic confounding of treatment effects with positional effects.

3.3 Experimental Treatments and Layout

3.3.1 Description of Treatments

The study compared two nutrient management systems, designated as Treatment 1 (peat-based organic media) and Treatment 2 (inorganic fertilizer), to evaluate their comparative effects on the growth, yield, and quality of Tejaswini chili.

Treatment 1: Peat-Based Organic Media

Plants assigned to Treatment 1 were grown in a commercially prepared peat-based growing medium composed predominantly of sphagnum peat moss supplemented with perlite to improve aeration and drainage. The medium was pre-limed to adjust pH to the range of 5.8 to 6.2 suitable for *Capsicum* production and was formulated to provide an initial nutrient charge through a base fertilizer incorporated at the time of preparation. The peat substrate was selected for its well-documented physical and chemical properties, including high water-holding capacity, good porosity, moderate cation exchange capacity, and stable structural properties that support root development and efficient nutrient uptake in container growing systems (Abad et al., 2001). Plants in the peat-based treatment received water through a drip irrigation system calibrated to maintain adequate substrate moisture throughout the growing

period. No additional inorganic fertilizer applications were made to this treatment during the experiment, allowing the assessment of the growing medium's inherent capacity to support plant growth and production outcomes independently of supplementary mineral nutrient inputs. This approach enabled a direct comparison of the growth support provided by the organic substrate with the explicitly managed nutrient supply provided under the inorganic fertilizer treatment.

Treatment 2: Inorganic Fertilizer

Plants assigned to Treatment 2 were grown in a conventional growing substrate consisting of sterilized field soil collected from within the study area and amended with NPK compound fertilizer applied at a rate calibrated to supply the recommended nutrient amounts for Capsicum annuum production at each growth stage. A basal application of compound fertilizer (7:14:7 NPK formulation) was incorporated into the substrate at planting to supply phosphorus and potassium for root establishment. Subsequently, top-dressing applications of ammonium nitrate (34.5% N) were applied at two-weekly intervals during vegetative growth to maintain adequate nitrogen availability. Potassium sulfate was applied as a supplementary top-dressing at flowering initiation to support reproductive development and fruit quality formation. Fertilizer rates were based on rates reported in the literature and adapted to the crop requirements under Zimbabwean conditions (Rai *et al*., 2014; Chikuvire *et al.,* 2020).

3.4 Crop Management Practices

3.4.1 Transplanting

Tejaswini chili seedlings were transplanted into their respective treatment pots at the four to six true leaf stage, approximately four weeks after seed germination. At transplanting, each seedling was carefully removed from the propagation tray and planted into the center of the pot at a depth equivalent to the height of the original root ball to avoid disturbance of the root system. Irrigation was applied immediately after transplanting to settle the growing medium around the root system and to minimize transplanting stress

3.4.2 Irrigation

Plants were irrigated using a drip irrigation system delivering water directly to the root zone of each plant. Irrigation was applied based on visual assessment of substrate moisture status

and plant water demand, targeting consistent maintenance of adequate but not excessive moisture levels throughout the experimental period

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3.4.3 Pest and Disease management

Pest and disease monitoring were conducted on a weekly basis as part of the general growth assessment visits, and appropriate integrated pest management interventions were applied uniformly to all plants when pest or disease pressure was identified, to prevent yield losses from these confounding factors.

3.4.4 Other agricultural practices

Staking and plant support were provided to all plants as they grew to prevent stem lodging and to maintain an upright canopy architecture that facilitated measurement access and uniform light distribution.

3.5 Data Collection

3.5.1 Vegetative Growth Parameters

Vegetative growth data were collected at 2 weeks intervals throughout the experimental period, commencing two weeks after transplanting and continuing until the onset of fruit maturation at harvest. Three vegetative growth parameters were measured at each observation interval.

Plant height was measured as the vertical distance in centimeters from the soil surface level at the base of the stem to the highest point of the apical meristem. Measurements were taken using a flexible measuring tape held vertically alongside the main stem, with the zero-point positioned at the soil surface. The same measuring position was maintained across all measurement weeks for each individual plant to ensure consistency.

Leaf number was determined by manual counting of all fully expanded leaves on each plant at each observation interval. Leaves were considered fully expanded when they had reached their final dimensions and had achieved full horizontal orientation. Young leaves still in the process of unfolding from the growing tip were not included in the count.

3.5.2 Yield Parameters

Yield data collection was conducted at each harvest occasion, with fruits being harvested when they reached the stage of commercial maturity defined by the attainment of full size and uniform red coloration as specified by Stagri Brands' marketing standards for Tejaswini chili. Fruits were harvested by hand-picking with care taken to avoid damage to the plant during the harvesting operation.

The total number of fruits harvested from each plant at each picking was recorded as the fruit count per plant per harvest. Fresh weight of harvested fruits per plant per harvest was measured using a digital electronic balance with a precision of ±0.01 grams. Total yield per treatment was calculated by summing the fresh weight of all fruits harvested from all plants within each treatment across all harvest occasions.

3.5.3 Fruit Quality Parameters

Fruit quality assessment was conducted on a representative sample of fruits collected from each treatment at each harvest occasion. Fruit size was characterized through measurement of fruit length and fruit diameter. Fruit length was measured as the distance in centimeters from the stem insertion point to the apex of the fruit, using a digital caliper. Fruit diameter was measured at the widest point of the fruit perpendicular to the longitudinal axis, also using a digital caliper.

Fruit color development was evaluated using a standardized colorimetric rating scale calibrated against the Royal Horticultural Society (RHS) color chart series for Capsicum fruits. A five-point scale was used for scoring, where a rating of one indicated light green coloration (immature), two indicated yellow-green coloration (early color break), three indicated orange coloration (mid-ripening), four indicated light red coloration (near-mature), and five indicated deep bright red coloration (commercially mature). Color ratings were assigned by two trained assessors independently for each fruit sample, and the average of the two assessors' ratings was used as the final color score for each fruit, minimizing subjective assessment error.

3.6 Data Analysis

All data was subjected to the Analysis of variance (ANOVA) using Genstat 18th Edition statistical software package. Data on plant height, quality (fruit color and size) and yield were subjected for analysis. Mean separations were done using the Least Significance Difference at 5% level test.

CHAPTER 4

RESULTS

4.1 Vegetative Growth Performance of Tejaswini Chilli

4.1.1 Plant Height Development under Peat-Based Organic Media and Inorganic Fertilizers

According to table 4.1, there was a highly significant treatment effect on chilli plant height across all measured period (P=0.001). Inorganic fertilizer with NPK formulations recorded the highest plant height across all weeks.

Table 4.1: Mean Plant Height (cm) of Tejaswini Chilli under Different Nutrient Systems

Treatment	2 weeks	4 weeks	6 weeks
Peat based organic media	6.68[a]	8.23[a]	9.61[a]
Inorganic fertilizer	8.25[b]	12.8[b]	19.84[b]
Grand mean	7.47	10.52	14.72
P-value	0.001	0.001	0.001
SED	0.309	0.781	1.466
LSD	0.699	1.766	3.317
CV%	9.3	16.6	22.3

Means followed with the same letter on the same column are not different from each other at 5% test

4.1.2 Number of leaves under Peat-Based Organic Media and Inorganic Fertilizers

According to table 4.2, there was a highly significant treatment effect on the number of leaves of chilli across all sampling period. Inorganic fertilizer with NPK formulations recorded the highest number of leaves across all recorded weeks.

Table 4.2: Mean Number of Leaves per Plant

Treatment	2 weeks	4 weeks	6 weeks
Peat based organic media	4.8[a]	9.6[a]	17.3[a]
Inorganic fertilizer	6.4[b]	14[b]	27.6[b]
Grand mean	5.6	11.8	22.45
P-value	0.001	0.001	0.001
SED	0.306	0.933	1.972
LSD	0.691	2.111	4.462
CV%	12.2	17.7	19.6

Means followed with the same letter on the same column are not different from each other at 5% test

4.2 Effect of the two nutrient management systems on fruit size of *Tejaswini* chili

According to table 4.3, there was a highly significant treatment effect on fruit size of chili. Inorganic fertilizer with NPK formulations recorded the highest fruit size.

Table 4.3: Effect of the two nutrient management systems on fruit size of *Tejaswini* chili

Treatment	Fruit size (cm)
Peat based organic media	1.76[a]
Inorganic fertilizer	2.54[b]
Grand mean	2.15
P-value	0.001
SED	0.1209
LSD	0.2735
CV%	12.6

Means followed with the same letter on the same column are not different from each other at 5% test

4.3 Effects of peat-based organic media and inorganic fertilizers on fruit color development of *Tejaswini* chili

According to table 4.4, there was a highly significant treatment effect on fruit color (P=0.001). Peat based organic media had the highest score of 2.4 followed by inorganic fertilizer with NPK formulations with 3.7.

Table 4.4: Effects of peat-based organic media and inorganic fertilizers on fruit color development of *Tejaswini* chili

Treatment	Color score
Peat based organic media	2.4[a]
Inorganic fertilizer	3.7[b]
Grand mean	3.05
P-value	0.001

SED	0.213
LSD	0.483
CV%	15.6

Means followed with the same letter on the same column are not different from each other at 5% test

4.4 Total fruit yield of *Tejaswin*i chili produced under peat-based organic media and inorganic fertilization systems

Figure 4.1 shows a highly significant treatment effect on fruit yield of Chili (P=0.001). Inorganic fertilizer with NPK formulations recorded the highest yield followed with peat based organic media.

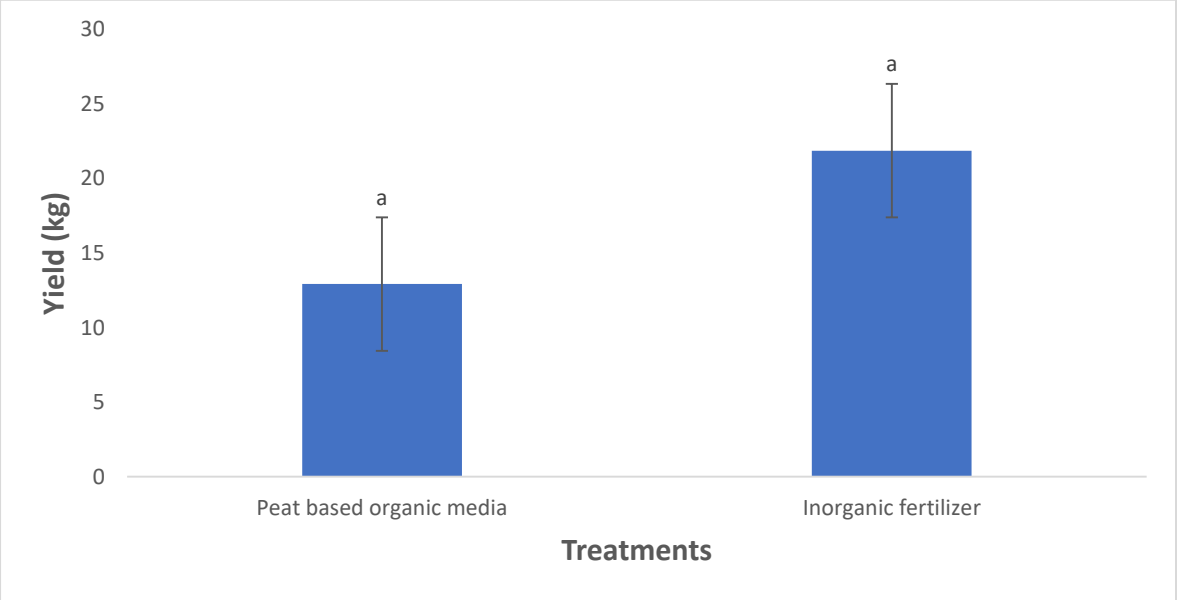


Figure 4.1: Total fruit yield of *Tejaswin*i chili produced under peat-based organic media and inorganic fertilization systems

CHAPTER 5

DISCUSSION

5.1 Effect of Nutrient Management Systems on Vegetative Growth

5.1.1 Plant Height

The study revealed highly significant differences in plant height between the two nutrient management systems throughout the experimental period. Plants grown under inorganic fertilizer consistently recorded greater plant height than those grown under peat-based organic media. At six weeks after transplanting, plants receiving inorganic fertilizer attained a mean height of 19.84 cm compared to only 9.61 cm for plants grown in peat-based organic media (Table 4.1). These findings support Plant Nutrition Theory, which emphasizes that plant growth is strongly influenced by nutrient availability and that deficiencies in essential nutrients limit growth regardless of the availability of other growth factors (Marschner, 2012). The superior plant height observed under inorganic fertilizer can be attributed to the immediate availability of nitrogen, phosphorus, and potassium supplied through the fertilizer program. Nitrogen is particularly important in stimulating cell division, cell elongation, and

chlorophyll synthesis, all of which contribute directly to stem elongation and biomass accumulation (Taiz *et al*., 2015). The results are consistent with the findings of Rai et al. (2014), who reported significantly greater plant height in chili plants supplied with balanced NPK fertilizers than in plants receiving lower nutrient inputs. Similar observations have been reported in other solanaceous crops where inorganic fertilization enhanced vegetative growth due to rapid nutrient uptake and efficient assimilation. In contrast, the relatively lower plant height observed in peat-based organic media may be attributed to the slow mineralization and gradual nutrient release characteristics of organic substrates (Brady and Weil, 2016). Although peat provides favorable physical conditions for root growth, its inherent nutrient content is relatively low and nutrient release depends on microbial decomposition processes that may not supply nutrients rapidly enough to meet crop demand during early vegetative growth.

5.1.2 Number of Leaves

The number of leaves per plant was also significantly influenced by nutrient management system (Table 4.2). Plants receiving inorganic fertilizer produced significantly more leaves than those grown under peat-based organic media throughout the study period. Leaf production is closely associated with nitrogen availability because nitrogen is a major constituent of proteins, enzymes, nucleic acids, and chlorophyll molecules involved in photosynthesis and plant metabolism (Marschner, 2012). The higher leaf numbers observed under inorganic fertilizer suggest that nutrient availability was sufficient to support continuous vegetative development and canopy expansion. These findings agree with those reported by Havlin *et al.* (2014), who noted that adequate nitrogen nutrition stimulates leaf initiation and expansion through increased metabolic activity. Similarly, Rai *et al.* (2014) observed enhanced leaf production in Capsicum annuum following application of balanced inorganic fertilizers. The lower leaf numbers recorded under peat-based organic media can be explained by slower nutrient release rates. Although organic media improve root development and nutrient retention, nutrient availability may not have matched crop demand during periods of rapid vegetative growth. Consequently, plants produced fewer leaves and accumulated less photosynthetic surface area.

5.2 Effect of Nutrient Management Systems on Fruit Size

Fruit size was significantly greater in plants grown under inorganic fertilizer than in those grown under peat-based organic media (Table 4.3). The larger fruit size observed under inorganic fertilization is likely attributable to adequate potassium availability, which plays a critical role in carbohydrate transport, osmotic regulation, and cell expansion during fruit development (Marschner, 2012). According to Quality Attributes Theory, fruit size depends on successful cell division and enlargement processes, both of which require adequate nutrient supply. Potassium enhances the movement of photosynthates from leaves to developing fruits and maintains cellular turgor pressure necessary for fruit enlargement (Bosland and Votava, 2012). The findings are consistent with Watson *et al*. (2017), who reported that nutrient availability during fruit development significantly influences final fruit size. Similarly, studies in Capsicum species have demonstrated that balanced NPK fertilization increases fruit dimensions and marketable fruit quality (Rai *et al*., 2014). Although peat-based organic media provide a favorable root environment, nutrient release may have been insufficient during the critical fruit enlargement stage. Consequently, fruit development was constrained, resulting in significantly smaller fruits.

5.3 Effect of Nutrient Management Systems on Fruit Color Development

Fruit color development was significantly influenced by nutrient management system (Table 4.4). Fruits produced under inorganic fertilizer achieved higher color scores than those grown under peat-based organic media, indicating more advanced ripening and improved color development. The development of the characteristic red color in chili fruits results from the synthesis and accumulation of carotenoid pigments such as capsanthin and capsorubin during ripening (Howard *et al*., 2000). Nutrient availability influences the biochemical pathways involved in pigment synthesis. Adequate nitrogen, magnesium, and iron availability supports chlorophyll production and subsequent carotenoid biosynthesis, resulting in improved color development. These findings support the assertions of Howard *et al*. (2000), who reported that nutrient management significantly affects pigment accumulation in *Capsicum* fruits. The higher color scores observed under inorganic fertilization indicate that nutrient supply was sufficient to support physiological processes associated with fruit maturation and pigment synthesis. The lower color scores observed under peat-based organic media suggest delayed ripening and reduced pigment accumulation. This may have resulted from slower nutrient

availability during fruit development, limiting the metabolic processes required for carotenoid production.

5.4 Effect of Nutrient Management Systems on Fruit Yield

Fruit yield was significantly higher under inorganic fertilizer than under peat-based organic media (Figure 4.1). This finding reflects the cumulative effects of enhanced vegetative growth, increased leaf production, improved fruit size, and superior fruit development observed under inorganic fertilization. Yield formation in chili depends on adequate nutrient availability throughout the crop growth cycle. Nitrogen promotes vegetative growth and canopy development, phosphorus supports flowering and fruit set, while potassium enhances fruit filling and quality (Havlin et al., 2014). The balanced nutrient supply provided by inorganic fertilizer ensured that plants received nutrients at critical growth stages, resulting in higher productivity. These findings are consistent with those reported by Rai *et al*. (2014), who found that balanced NPK fertilization significantly increased fruit number and total fruit yield in chili production. The results also support the conclusions of Seufert *et al*. (2012), who observed that conventional nutrient management systems generally produce higher yields than organic systems due to greater nutrient availability and fertilizer use efficiency. Although peat-based organic media offer benefits such as improved water retention and root-zone buffering (Gruda, 2012), these advantages were insufficient to compensate for the slower nutrient release rates under the conditions of the present study. Consequently, plants grown under peat-based organic media produced lower yields than those receiving inorganic fertilizer.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusions

The objective of this study was to evaluate the effects of peat-based organic media and inorganic fertilizer nutrient management systems on the growth, yield, and fruit quality of Tejaswini chili under greenhouse conditions in Banket, Zimbabwe. Based on the results obtained, the study concludes that nutrient management system significantly influences the growth, productivity, and fruit quality of Tejaswini chili. Inorganic fertilizer consistently outperformed peat-based organic media across all measured parameters. Plants grown under inorganic fertilizer attained significantly greater plant height and produced more leaves throughout the experimental period, indicating superior vegetative growth. The enhanced growth performance was attributed to the rapid availability of nitrogen, phosphorus, and potassium supplied through the fertilizer program. Fruit quality characteristics were also significantly affected by nutrient management system. Inorganic fertilizer produced larger fruits and achieved superior fruit colour development compared to peat-based organic media. The improved fruit quality suggests that nutrient availability during reproductive development plays an important role in determining marketable characteristics of Tejaswini chili. Furthermore, inorganic fertilizer produced significantly higher fruit yield than peat-based organic media. The higher yield resulted from improved vegetative growth, enhanced nutrient uptake, increased fruit size, and better fruit development throughout the production cycle. Although peat-based organic media provided favourable physical properties for root growth, including improved water retention and aeration, the slower nutrient release associated with organic substrates limited plant growth and productivity under the conditions of the experiment. Therefore, inorganic fertilizer was found to be the more effective nutrient management system for maximizing growth, yield, and fruit quality of Tejaswini chili under greenhouse production conditions.

6.2 Recommendations

To farmers

- Commercial producers and contract farmers cultivating Tejaswini chili should adopt balanced inorganic fertilizer programs to maximize vegetative growth, fruit quality, and yield under greenhouse production systems.
- Growers using peat-based organic media should consider supplementing the substrate with additional nutrient sources or controlled-release fertilizers to overcome nutrient limitations associated with slow mineralization.

To Researchers

- Evaluate combinations of peat-based organic media and inorganic fertilizers to determine whether integrated nutrient management systems can achieve superior productivity and sustainability.
- Investigate the long-term effects of repeated use of peat-based organic media and inorganic fertilizers on substrate quality, nutrient dynamics, and environmental sustainability.
- Assess additional fruit quality attributes including pungency, vitamin C content, carotenoid concentration, shelf life, and consumer acceptability.
- Conduct field-based experiments under open-field production conditions to validate greenhouse findings across different agro-ecological regions of Zimbabwe.
- Examine the economic profitability and cost-benefit relationships of different nutrient management systems to support farmer decision-making and technology adoption.
- Investigate alternative organic substrates such as coconut coir, compost, and locally available organic materials as sustainable substitutes for peat-based media in Zimbabwean horticultural production systems.

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APPENDIX

Appendix 1: Analysis of variance of height at 2 weeks

Variate: Height_at_2_wks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	9	24.3205	2.7023	5.66	
Block.*Units* stratum					
Treatment	1	12.3245	12.3245	25.79	<.001
Residual	9	4.3005	0.4778		
Total	19	40.9455			

Appendix 2: Analysis of variance of height at 4 weeks

Variate: Height_at_4_wks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	9	28.121	3.125	1.02	
Block.*Units* stratum					

Treatment	1	104.425	104.425	34.25	<.001
Residual	9	27.441	3.049		
Total	19	159.986			

Appendix 3: Analysis of variance of height at 6 weeks

Variate: Height_at_6_wks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	9	153.46	17.05	1.59	
Block.*Units* stratum					
Treatment	1	523.26	523.26	48.69	<.001
Residual	9	96.73	10.75		
Total	19	773.46			

Appendix 4: Analysis of variance of number of leaves at 2 weeks

Variate: Number_of_leaves_at_2_wks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	9	23.8000	2.6444	5.67	
Block.*Units* stratum					
Treatment	1	12.8000	12.8000	27.43	<.001
Residual	9	4.2000	0.4667		
Total	19	40.8000			

Appendix 5: Analysis of variance of number of leaves at 4 weeks

Variate: Number_of_leaves_at_4_wks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	9	159.200	17.689	4.06	
Block.*Units* stratum					
Treatment	1	96.800	96.800	22.22	0.001

Residual	9	39.200	4.356		
Total	19	295.200			

Appendix 6: Analysis of variance of number of leaves at 6 weeks

Variate: Number_of_leaves_at_6_wks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	9	505.45	56.16	2.89	
Block.*Units* stratum					
Treatment	1	530.45	530.45	27.27	<.001
Residual	9	175.05	19.45		
Total	19	1210.95			

Appendix 6: Analysis of variance of fruit size

Variate: Size

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	9	4.71000	0.52333	7.16	
Block.*Units* stratum					
Treatment	1	3.04200	3.04200	41.61	<.001
Residual	9	0.65800	0.07311		
Total	19	8.41000			

Appendix 7: Analysis of variance of fruit colour

Variate: colour

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	9	16.4500	1.8278	8.02	
Block.*Units* stratum					
Treatment	1	8.4500	8.4500	37.10	<.001
Residual	9	2.0500	0.2278		

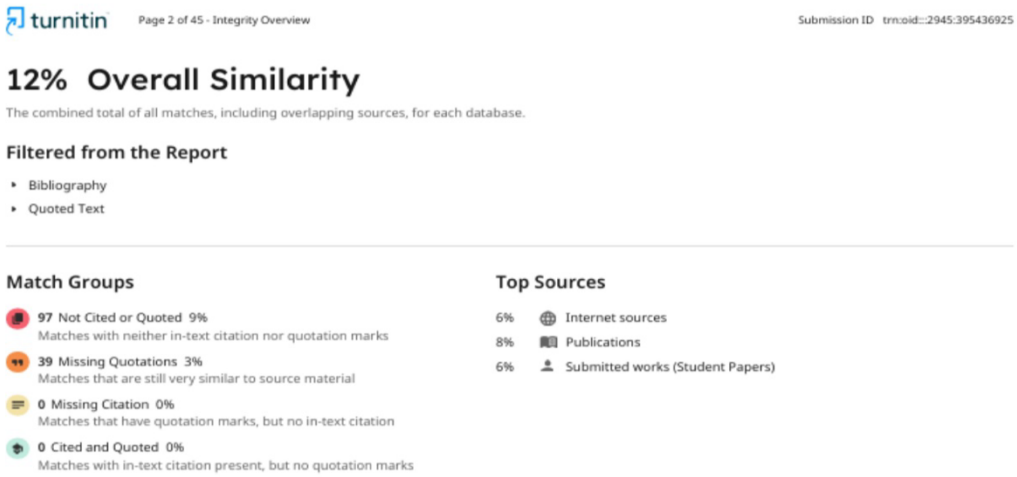
Total	19	26.9500

Appendix 8: Analysis of variance of fruit weight

Variate: weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	9	218.21	24.25	2.39	
Block.*Units* stratum					
Treatment	1	399.62	399.62	39.40	<.001
Residual	9	91.28	10.14		
Total	19	709.11			

Appendix 10: Similarity Report



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