Physiochemical Properties and Enzyme Activity of Different Growing Media in Blueberry Production

Soil health is a reliable indicator of the potential for optimum production of agricultural produce. However, due to limited natural resources, such as the availability of high-quality soil, production can be hindered. The use of growing media has gained attention in most production systems over the years due to the beneficial components they provide, which support sustainable production. Fruit crops such as blueberries are mainly cultivated using soilless systems. The study aims to assess the physiochemical and microbial enzyme activity of four growing media compositions. The research study was conducted at the Cape Peninsula University of Technology Agri-Hub from 2022 to 2025. A pot experiment was laid out in a randomised complete block design with five replications. Initial and final growing media samples were collected for physicochemical and enzyme activity analysis. Macronutrient properties were determined using the Kjeldahl and Bray II methods and the β-glucosidase assay using the colourimetric determination of the release of p-nitrophenyl glucopyranoside. The growing media combination, which included coir, peat moss, and mushroom compost, improved the media's macronutrient content. Enzyme activity β-glucosidase was improved by the media combination with 60% coir and 40% peat moss. The hydrolases of β-glucosidase activity demonstrate a strong positive correlation with nitrogen and carbon, which are critical to the carbon cycle and to the production of glucose used by the microorganisms present in the growing media. These findings suggest that the growing media combination containing coir and peat moss can potentially improve macro- and micronutrient availability and enzyme activity for blueberries cultivated under soilless conditions.

Keywords: *Growing media, macronutrients, enzyme activity, β-glucosidase, organic matter*

Aim of the research

This research study investigated the influence of various growing media, including coir, peat moss, zeolite and mushroom compost, on physiochemical properties and enzyme activity to evaluate the benefits of using these media compositions in blueberry production. Specific objectives are as follows:

- To assess the nutrient content of the different types of growth media.
- To assess the microbial enzyme activities (β-glucosidase, phosphatase & urease) of the different types of growth media.

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Introduction

Blueberry species are commonly cultivated under protected environments such as tunnels to better manage/manipulate microclimate, pests, and other cultivation practices to improve fruit quality and yield (Fang *et al*., 2020). The benefits of such a controlled environment are well-documented (Ogden & van Iersel, 2009; Santos & Salame-Donoso, 2012). Conventionally, blueberries are planted on raised beds that are well-prepared to ensure root growth and water drainage (Zietsman, 2020). However, this system limits plant growth due to the unavailability of natural resources that ensure blueberry optimum growth (Fang *et al.,* 2020). Mulching materials are commonly used for blueberries to retain soil moisture and reduce weed growth (Webb, 1981; Taparauskiene & Miseckaite, 2014). The plant root system is shallow and restricts water uptake (Gough, 1980; Bryla, 2011). Environmental factors and cultivation practices influence the plants' water requirement, which subsequently influences vegetative and reproductive growth (Holzapfel et al., 2004). According to Palvis. (2006), soil and leaf analysis are essential when determining the plant's nutrient requirements. Blueberry plants mainly require an ammonium form of nitrogen, and the most common forms applied is ammonium sulphate and urea (Claussen & Lenz, 1999; Banados et al., 2012; Bryla & Strik, 2015). According to Vargas & Bryla (2015), fertigation is more effective and increases yield by up to 40% compared to granular fertiliser application.

Irrigation scheduling (IS) is the practice of monitoring the frequency and quantity of water applied to plants to optimise efficiency, minimise energy wastage, and maximise crop yield, thereby preventing water stress and overwatering. In recent years, these have been automated, linking the sensors to the irrigation system and accounting for field capacity and the quantity to be applied. (García *et al*., 2020), which relies on strategies for a specific crop's water requirements. Different factors influence irrigation scheduling, which relies on strategies tailored to a specific crop's water requirements (Annandale *et al*. 2011). As the world is challenged with fluctuations in weather patterns, water scarcity can lead to drought conditions during the growing season (El-Geziry, 2022). It is evident that over the years, the increase in temperatures have greatly affected natural resources, affecting agricultural systems and their productivity (Gercek, 2024). Blueberry plants are characterised as having shallow, fine, and fibrous root systems of approximately 30 cm; therefore, the effective absorption potential is restricted (Holzapfel, 2008).

In the past, food production was based on production per unit area; however, due to worldwide water scarcity, the focus is currently on production per unit of water used as a management practice (Fanadzo & Ncube, 2018; Fereres & Soriano, 2007). South Africa (SA) is also affected by reduced per capita water resources and is classified as a water-scarce country (Fanadzo & Ncube, 2018). According to Bonetti *et al*. (2022), irrigation demand in SA is estimated to increase by 6.5% to 32% by 2090 due to unsustainable cultivation practices on staple crops grown in arid areas of the country.

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There is a need to cultivate blueberries in growing media due to the plant's requirement for acidic soils, and this is usually limited in soils (Clark & Zheng, 2020; Smrke *et al*., 2022). Blueberries are now largely grown in media due to the plant's requirement for acidic soils, which is often not easily attainable in the soil. Growth mediums such as peat moss, coconut coir, and perlite are mostly utilised for blueberries grown in pots (Fang et al., 2020; Zietsman, 2020). According to Kingston *et al*. (2017), peat moss and coir increase water-holding capacity as plants grown in soilless substrate experience drought stress. These findings are in agreement with research conducted for the variety 'Legacy' (Ortiz-Delvasto *et al*. 2022). Improved use of growth media can be a crucial strategy to reduce water use and improve blueberry production. These include bulk density, total porosity, porosity ratios, pH, and electrical conductivity (EC), which have a direct influence on plant growth (Xie & Wu, 2009). The use of different substrate composition ratios on potted blueberry plants is effective, as each substrate used contributes useful attributes for plant growth (Kingston *et al*., 2020).

The decomposition of these organic materials (growth media) or the mulching material can produce allelochemicals to improve the growth and productivity of crops. Use of these soil amendments has potential and is used as one of the cropping techniques that is commonly used for different crops in conserving water and increasing soil temperature (Zegada-Lizarazu & Berliner, 2011), and improving crop growth and plant pest (Radicetti et al., 2013). Insufficient water supply at critical stages of crop development is a very critical factor that affects the total yield (Kruger *et al*., 2002). A study done by Taparauskiene (2006), showed that soil moisture reduction had a negative impact on strawberry production by affecting both vegetative and reproductive parameters. Organic growth media significantly reduce the loss of moisture from the soil when incorporated with media, and consequently, an increased and homogeneous soil moisture regime that is sustainable (Ramakrishna et al., 2006). Li *et al*. (2004) stated that the application of organic plant material is effective in reducing soil evaporation and saving water. Several of these organic materials improve blueberry biomass as well as improve water use efficiency and can lower irrigation requirements by up to fifty percent (Li et al., 2021). The application of compost enhances water permeability and water storage, resulting in reduced evaporation (Zhang & Sun, 2014). Some authors (Costello & Sullivan, 2013) evaluated compost suitability for strawberries in a pot trial (soil amended with 30% compost). They recorded reduced weed growth, lower soil pH, maintenance of uniform soil moisture, and increase growth rate and yield.

However, other growth media such as peat also create physical conditions that are more favourable to root growth (e.g. increased aeration and water-holding capacity), with the ability to lower pH in the root environment (Strik et al., 2011). The development of an organic market for blueberry production recently has generated attention in using organic growth media for the provision of organic matter, nutrients and stimulate favourable soil microbial enzyme activities (Gale *et al*., 2006).

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The activities of soil enzymes are known to play crucial roles in C, P, and N cycling, respectively, and serve as indicators of the soil quality index (Rao et al., 2014). Factors such as cultivation practices, substrate organic matter and environmental conditions directly influence the availability and quantity of these microorganisms (Sobucki et al., 2021). Soils high in organic matter have higher activity compared to those that have low quantities (Biggs & Spedding, 1963).

The demand for fresh blueberries has steadily increased, and therefore increasing demand. However, sustainable cultivation practices are of great importance as the natural resources are limited. The study investigated the influence of the different growth media on physicochemical properties and enzymes

Materials and methods

Study site and experimental design

The research experiment was conducted at the Department of Agriculture, Agricultural Hub, Cape Peninsula University of Technology, Wellington (S 33°37'55.08" E 19°00'37.4") under a tunnel during the 2022/2023, 2023/2024, and 2024/2025 seasons. The Wellington region is characterised by a Mediterranean climate; the winter season is cold and wet, while the summer season is hot and dry. The blueberry plants were transplanted into 45 L growing bags that were elevated with bag stands.

The study employed a randomised complete block design (RCBD) with five replications. Three plants per treatment, for a total plant population of 105 plants. Four different growing media were used, and different compositions were used to formulate seven treatments. The treatment composition used in this experiment is illustrated in Table I below:

Table 1. *Growing media composition*

Treatments	Media composition
1	100% coir (control)
2	80% coir + 20% zeolite
3	60% coir + 40% mushroom compost
4	60% coir + 40% peat moss
5	40% coir + 20% zeolite + 40% mushroom compost
6	40% coir + 20% zeolite + 40% peat moss
7	40% coir + 30% mushroom compost + 30% peat moss

Data Collection

Throughout the three-year growing seasons, moisture probes were used to monitor the media water content in the effective root zone (30 cm depth) for each treatment replicate using the DFM moisture probes. The maximum soil water content was 100% pot capacity (PC). From this, an allowable depletion level (ADL) of 25% was permitted before irrigating the soil back to 100% PC. Water

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demand/input for each treatment/potted-media was recorded from 13:00-15:00 pm daily throughout the data collection period. Moisture readings were taken between 13:00 and15:00 pm. The replenishment quantities for the treatments are as follows: 4.25, 4, 4.5, 3.7, 4.5, 4.25, and 4.5, respectively. Before transplanting, the water field capacity (FC) of each medium was determined, as discussed in detail by Mfeka *et al*. (2023), and the replenishment level was set at 75%.

Cultivation practices

Agronomic practices, such as weeding, were performed manually using hand forks and hand-pulling. Diseases and insect pests were controlled as necessary. The fertilisation programme for blueberry was as follows: 9 g N per pot (ammonium sulfate) will be applied in the first year (2022/2023), while 12 g N per pot (ammonium sulfate) will be applied in the second and third years (2024, 2025, 2026), respectively (Wilber & Williamson, 2008).

Growing media analysis

A pot experiment was established during the 2022 growing season on the deciduous blueberry cultivar "Legacy". Prior to transplanting, growing media samples were sent to a commercial laboratory (https://www.bemlab.co.za/) for a full baseline physical and physiochemical analysis, including the media pH, soil organic matter (SOM), resistance, N, Na, K, Mg, C, P Bray II, titratable acid, stone %, Fe, Mn, Cu, Zn and B (Table II). The samples were taken at a depth of 0-30 cm, and each sample contained 500g. Growing media samples were taken in two phases before transplanting and after the second harvest season.

Enzyme Activity Procedure and Assays

The growing media samples were air-dried and stored at 4°C. Prior to conducting the analysis, the media were sieved using a 2mm sieve to standardise the samples. The moisture content of the samples was determined as the difference between the wet and dry weights and expressed as a percentage. 5 g of the growing media was used and incubated for 2 hours at 37 °C. Samples were done in triplicate.

The activity of β-glucosidase was analysed using a method by Eivazi & Tabatabai (1988). Urease was estimated using the colourimetric determination of released urea as outlined by Kader & Gerber (1988). Acid phosphatase was assayed by a colourimetric method of Tabatabai & Bremner (1972), but will be optimised using a homogenised reaction of 1.0 mL 25 mM p-nitrophenol phosphate (substrate), 4.0 mL MUB and 0.25 mL toluene, and the product p-nitrophenol will be extracted with 4.0 mL of 0.5 M NaOH at pH 6.5. The samples were incubated as per the essay followed, and the samples and diluent were aliquoted into a microplate for readings. After the incubation period, the Whatman No. 2 filter paper was used to filter the suspension. BioTek ELx800 spectrophotometer for the readings. The wavelengths were set at 405nm for β-glucosidase and phosphatase and 630nm for urease.

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Table 2. *Physical and chemical composition of growing media properties*

Trt	Physical and chemical properties																
	Initial														Final		
	Type	Stone (%)	pH (KCl)	Resistance (Ω)	N (mg/kg)	P (mg/kg)	K (mg/kg)	S (mg/kg)	C (%)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	B (mg/kg)	Fe (mg/kg)	Stone (%)	pH (KCl)	Resistance (Ω)
1	Sand	0.93	3.8	460	53.7	5.4	156	21	19.74	0.33	3	4.4	0.32	43.1	4.92	3.5	170
2	Sand	1.52	4.2	290	73	2.6	553	15.1	11.81	0.33	1	4.9	0.37	24.8	2.47	3.6	155
3	Sand	0.93	6.4	140	6.4	154	225	110	20.78	1.6	23.4	22.7	0.69	83.8	2.24	3.7	150
4	Sand	0.93	3.3	210	132	6	148	24.6	21.88	0.33	2.8	2.9	0.32	50.1	2.6	3.4	130
5	Sand	0.93	6.6	150	11.7	118	4840	783	11.59	1.2	19.4	19	0.38	62.6	2.78	3.8	140
6	Sand	0.93	4.7	290	87.4	6.2	1960	64.2	18.84	0.33	2.5	5.1	0.62	32.6	3.35	3.4	175
7	Sand	0.93	6.1	180	30.1	109	765	570	22.38	1	5.8	60.7	0.89	19.3	2.06	4	120

Trt= treatment; %= percentage; mg/kg= milligram per kilogram

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Statistical Analysis

Univariate Analyses (ANOVA) were performed using the GLM Procedure in SAS statistical software (version 9.4; SAS Institute Inc., Cary, NC, USA). Multivariate analyses (Correlations, PCA, MFA) were done using XLStat (Lumivero (2025) XLSTAT statistical and data analysis solution. https://www.xlstat.com/en)

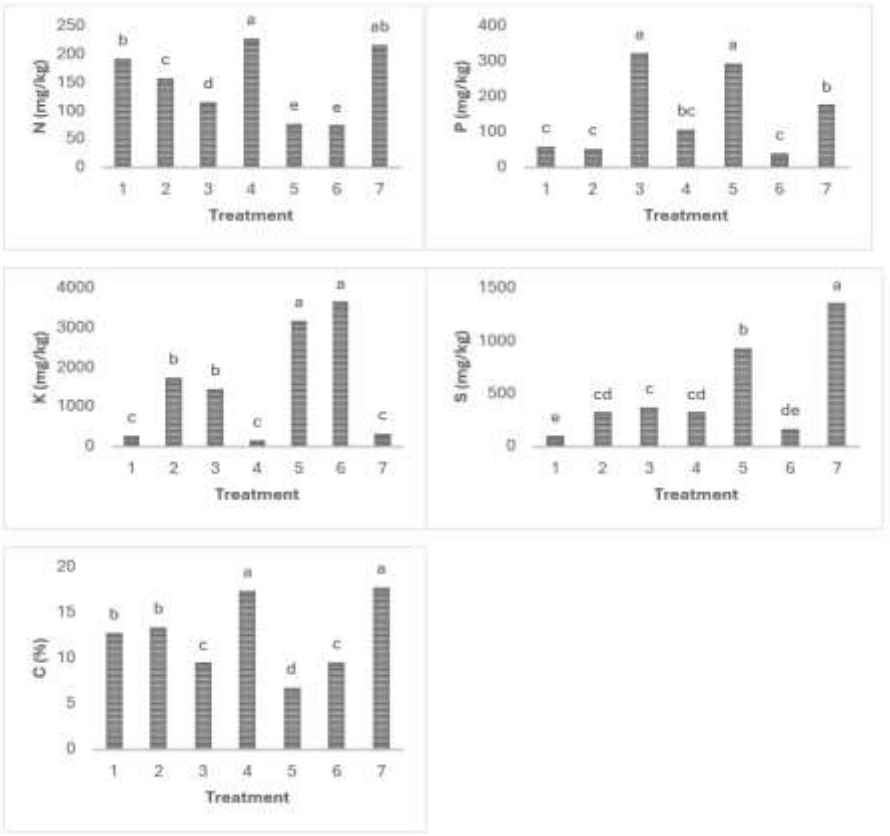
Results and discussions

Influence of different growing media on the macronutrients

The different growing media significantly influenced the macronutrients evaluated. The result of this study shows the highest nitrogen (N) content in the media combination containing 60% coir and 40% peat moss (Figure I). The high N content was also observed in the initial results prior to transplanting (Table II). Treatments 5 and 6 had the lowest N content and varied from the other treatments. A trend of higher phosphorus (P) content was observed in the initial and final analysis results for treatments 3 and 5 (Table II). This may be due to P immobility in soils/substrates (Khan *et al*., 2023). Additionally, potassium (K) shows a similar trend to that of P for treatments 5 and 6, as these treatments contained the highest K content across other treatments, with an average of 3187 and 3649.8 mg/kg, respectively. The combination of 40% coir, 30% mushroom compost, and 30% peat moss had a significantly higher sulfur (S) content, indicating that S accumulated over the four years of the project. The carbon (C) percentage showed a significant increase in treatments 4 and 7. These treatments contain coir and peat moss. It must be noted that the baseline analysis indicated a high C percentage on the initial results, as shown in Table 2.

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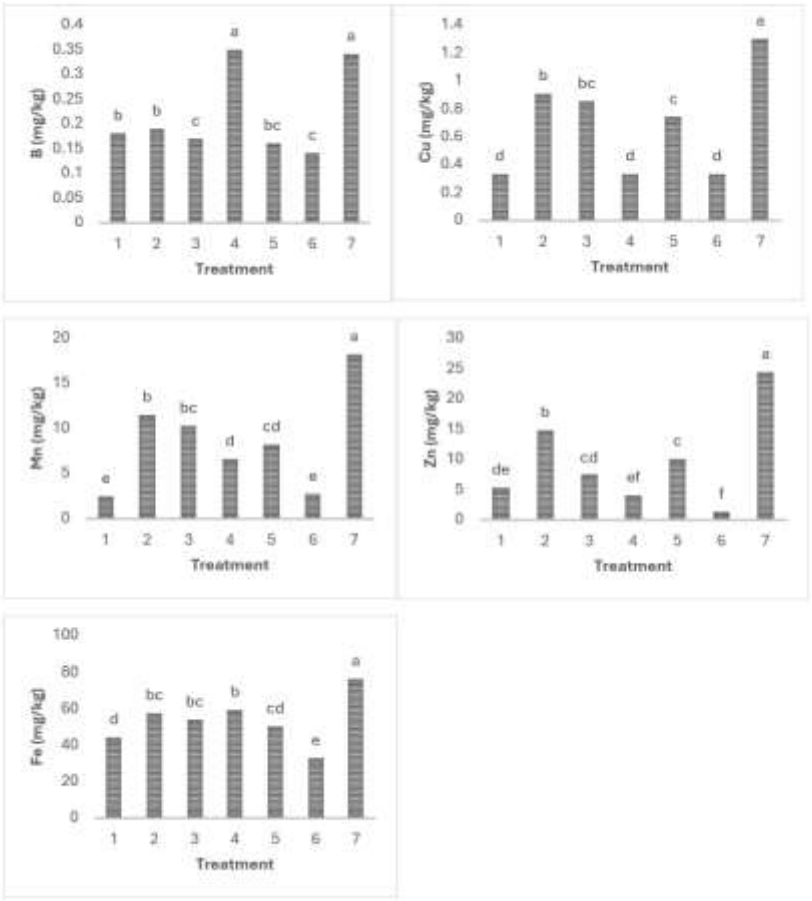
Figure 2. *The effect of different growing media on the substrate macronutrient levels after the final harvest.*



Influence of different growing media on the micronutrients

The availability and quality of all the micronutrients analysed varied for all treatments. Notably, treatment 7 had the highest content of all the micronutrients assessed (Figure 2).

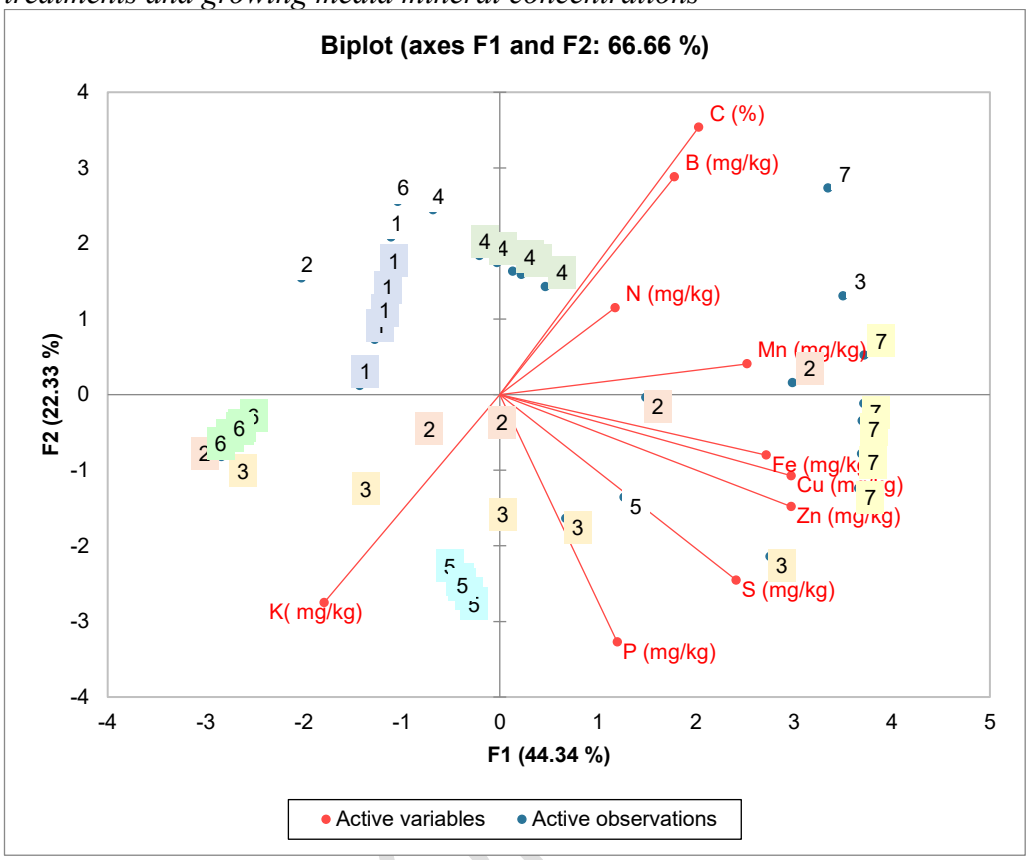
Figure 2. *The effect of different growing media on the substrate micronutrient levels after the final harvest*



Correlation between treatments and elements assessed

The results of the principal component analysis (PCA) showed that treatments 2, 3, 4, and 7 had a strong positive relationship with media minerals, including carbon, boron, nitrogen, and magnesium. Notably, no relations were observed with all the other minerals analysed when coir was solely used to cultivate blueberries (Figure III). In a study by Grunert *et al.* (2016), it was concluded that growing media selection and composition are critical, as they possess distinct properties that influence overall performance and yield compared to using a single growing medium. Even though inconstant results on the physicochemical properties (Figures I & II), a trend of reduced availability of macro and micro elements was observed when blueberries were cultivated on coir only. Additionally, coir-based growing media can be affected by salinity if not properly managed (Heller & Nunez, 2022).

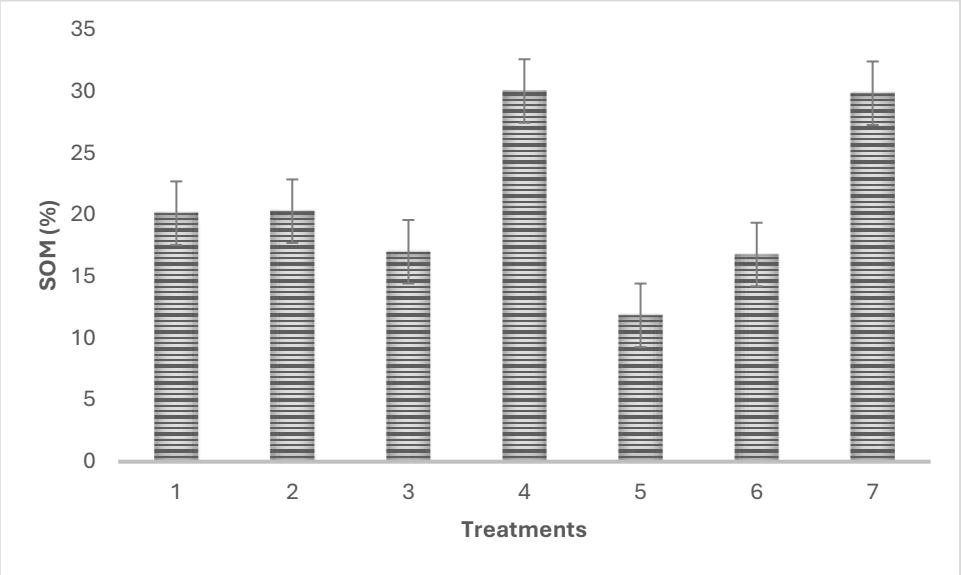
Figure 3. *The principal component analysis (PCA) of the correlation between treatments and growing media mineral concentrations*



Soil organic matter

Soil organic matter (SOM) is an important substrate property that improves nutrient availability, uptake and carbon storage (Gerke, 2022). Treatments 4 and 7 had significantly higher SOM percentages than the other treatments (Figure IV). These treatments contain coir and peat moss, and treatment 7 additionally contains 30% mushroom compost; the SOM in treatments 4 and 7 is based on the material particles, mainly due to microbial decomposition of crop residues (Khan *et al*. 2025). The growing media combination containing zeolite had a lower SOM percentage. There was no significant difference between treatment 5, with a growing combination of 40% coir, 20% zeolite and 20% mushroom compost (with the lowest SOM %) and 6, and no significant difference between treatment 6 (40% coir, 20% zeolite and 40% peat moss) and 2 (80% coir and 20% zeolite). The zeolite accounted for only 20% of the media composition; this inorganic mineral does not contribute to the *SOM, but it offers other benefits, such as water retention (Szatanik-Kloc et al. 2021; Mondal et* al. 2021).

Figure 4. *Availability of the soil organic matter as influenced by growing media combination on blueberry production*



Enzymes activity

The growing media containing 60% coir and 40% peat moss significantly improved the β-glucosidase activity (Table III). According to Su *et al*. (2021) & Cha *et al*. (2016), increased β-glucosidase activity in growing substrates indicates a biologically active, healthy soil with a high rate of carbon cycling involved in cellulose hydrolysis. This is also supported by the high C percentage for this treatment combination, as presented in Figure I. In this study, the results show that the phosphatase and urease activity varied across all treatments. However, a notable enzyme activity was observed in the treatment combination containing 40% coir, 30% mushroom compost (MC) and 30% peatmoss. Phosphatase activity is influenced by a number of factors, including variety, planting density, soil pH and plant-available phosphorus. The breakdown of organic phosphorus from both the plant material and soil microbes releases inorganic phosphorus, which is used by plants for their physiological processes (Margalef *et al.* 2017). Similarly, observations were confirmed in a study by Janes-Bassett et al. (2022), on plant response to phosphorus deficiency. The use of mushroom compost as a substrate in the media contributes to urea hydrolysis and increases urease activity, as MC is an organic fertiliser (Gil-Sotrea *et al.,* 2005; Klose & Tabatabai, 2000). This activity hydrolyses urea into ammonia, which is a preferred nitrogen source taken up by blueberry plants and carbon dioxide (Mokonnen *et al*. 2021)

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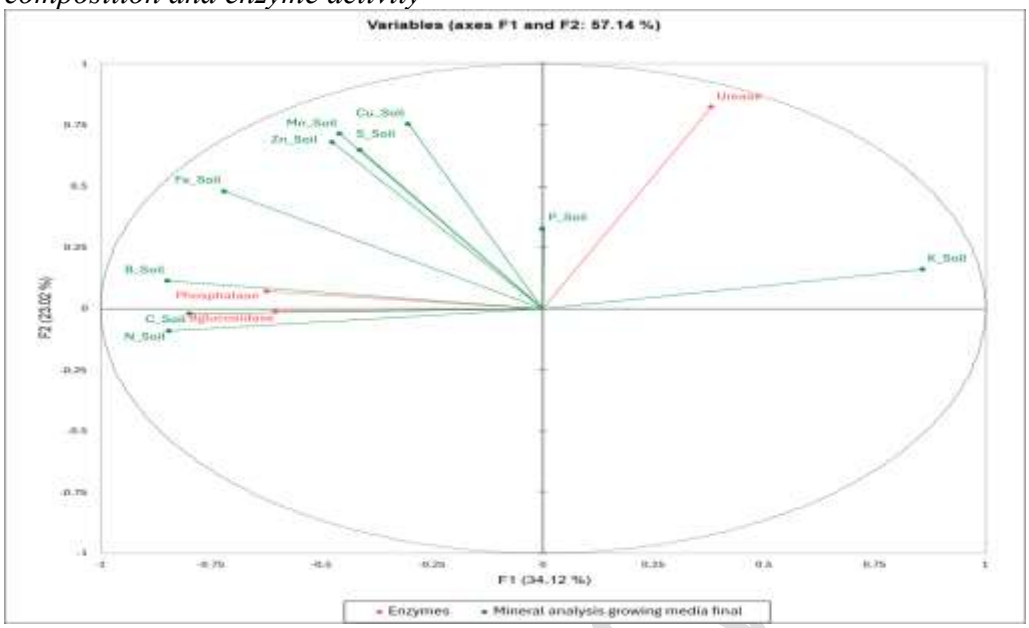
Table 3. *Enzyme activity in response to the different growing media*

Treatment	β-glucosidase (µg PNP g^{-1})	Phosphatase (µg PNP g^{-1})	Urease (µg NH_{4+} g^{-1})
1	50.84^{ab}	7.13^{a}	4.90^{c}
2	37.57^{b}	2.70^{c}	14.04^{a}
3	39.42^{b}	6.12^{a}	9.89^{abc}
4	74.86^{a}	5.49^{ab}	6.16^{bc}
5	51.45^{ab}	3.57^{bc}	11.76^{a}
6	36.98^{b}	3.43^{bc}	11.06^{ab}
7	62.08^{ab}	7.57^{a}	12.12^{a}
$LSD_{(0.05)}$	25.17	2.53	5.58

Principal Component Analysis (PCA) of the growing media chemical composition and enzyme activity. A strong positive correlation was observed between β-glucosidase, carbon, and nitrogen percentage (Figure V). β-glucosidase is the main enzyme responsible for nitrogen and carbon recycling (Adetunji *et al.* 2017).

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Figure 5. *Principal Component Analysis (PCA) of the growing media chemical composition and enzyme activity*



Conclusions and recommendations

Physiochemical and biological properties of a substrate when cultivating blueberries are critical to ensuring sustainable production. Using a growing media combination for blueberry production can improve the availability and uptake of minerals. A substrate material suitable for cultivating blueberries should be porous, provide balance with available salts and nutrients to ensure effective nutrient uptake and distribution. The findings of this study showed that incorporating coir into other growing media maintains favourable physiochemical conditions while potentially reducing overall production costs. This is critical for sustainable blueberry production amid increasing water scarcity and reduced arable land. The relationship highlighted among chemical properties, organic matter, and enzyme activity emphasises the importance of integrating biological indicators when evaluating substrates suitable for blueberry production. The effect of the media combination on substrate health required further investigation, including its impact over the long term and on physical and biochemical components.

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