**Comparative Evaluation of Soilless Growing Media for Enhancing Tomato (*Solanum lycopersicum* *L*.) Yield and Nutritional Quality**

**ABSTRACT**

**Aims**  
The study was conducted to evaluate the effects of different growing media on the growth, yield, and nutritional quality of tomato (Solanum lycopersicum L.) under soilless farming conditions, as a sustainable alternative to traditional soil-based cultivation.

**Study Design**  
A Completely Randomized Design (CRD) was employed to assess plant performance using five different growing media treatments.

**Place and Duration of Study**  
The experiment was conducted at the teaching and research farm of Faculty of Agricultural sciences ,Ekiti State University and was carried out between July and December.

**Methodology**  
Five growing media were evaluated: cocopeat, rice husk, rice husk biochar, topsoil, and water. Tomato seedlings were transplanted into containers filled with the respective media. Growth parameters including plant height, stem girth, and number of leaves were recorded weekly for a period of six weeks. At harvest, yield parameters such as total fruit weight, fruit girth, fruit length, and number of fruits were measured. Additionally, the nutritional qualities of the harvested fruits were analyzed to assess treatment effects.

**Results**  
The highest values for plant height, number of leaves, and stem girth were observed in tomato plants that were grown using cocopeat, in terms of yield, tomato grown in rice husk was most productive with 1884g of fruits per plant compared to 831 g of fruits per plant for the tomato grown in top soil medium, also the number of fruits observed in tomato grown in rice husk was 91% more than that grown in soil. Overall, the media (rice husk biochar, rice husk, and cocopeat) significantly outperformed the soil medium in terms of fruit yield and growth characteristics, variations were also observed in the nutritional qualities with respect to the different media used.

**Conclusion**  
Soilless farming using alternative media especially those derived from agricultural waste enhances plant growth and fruit yield, thus, promoting sustainability.

Keywords; **Growing Media, Tomato, Soilless culture, soil based culture**

**1.INTRODUCTION**

The rapidly growing global population, projected to reach 9.7 billion by 2050 (UN 2019), has led to rising living standards and a greater demand for high-quality crops, including off-season and premium vegetables. Vegetables play a key role and have become a substantial part of diets worldwide in human nutrition. They are rich sources of phytonutrients such as vitamins (C, A, B1, B6, B9, E), minerals, dietary fiber, and phytochemicals (Dias and Ryder, 2011). Some of these phytochemicals, known for their strong antioxidant properties, are believed to help reduce the risk of chronic diseases by protecting the tissues against free-radical damage and influencing the activation and detoxification of carcinogens (Southon, 2000). Regular consumption of vegetables has been linked to better overall health, improved gastrointestinal function, and a lower risk of diseases such as cancer, heart disease, stroke, and diabetes (Golberg, 2003). In Nigeria, tomatoes (*Solanum lycopersicum*), a member of the Solanaceae family, stand out as one of the most important and widely consumed vegetables (Jaafar *et al*., 2023; Meseret *et al.,* 2012). Tomatoes are cultivated annually due to their significant economic value. Over the past century, tomato cultivation has gained immense popularity and now ranks second in global vegetable production, after potatoes (FAOSTAT 2019), with annual production exceeding 108 million metric tonnes. Tomatoes are grown on approximately 3.9 million hectares worldwide, both for fresh markets and processing (Bhatia *et al*., 2004). Nutritionally, tomatoes are valued for their rich content of carbohydrates, minerals, amino acids, vitamins (especially B and C), and lycopene; a powerful antioxidant that helps neutralize free radicals linked to cancer development (Marti *et al*., 2016). Despite Nigeria’s position as the 14th largest tomato producer globally, with a production of 1.51 million metric tonnes (Adegbola *et al*., 2012), tomato production faces challenges such as shrinking arable land, urbanization, water scarcity, and climate change (Gruda, 2019). Even in areas where soil is used for cultivation, issues such as soil-borne diseases, nematodes, soil compaction, and poor drainage further complicate agricultural production. To overcome these challenges, soilless cultivation method, offers a promising solution for optimizing tomato production. Soilless farming /hydroponics involves growing plants in nutrient solutions with or without an artificial medium for mechanical support, such as sand, gravel, vermiculite, or peat moss (Bihari *et al*., 2013). This system has gained considerable attention due to its ability to address food security and urban agricultural challenges by enhancing resource efficiency and enabling plant growth in non-arable or space-limited areas (Li *et al*., 2018; Lakhiar *et al*., 2020). This system not only improves water-use efficiency but also accelerates plant growth compared to traditional farming methods, making it an attractive option for urban agriculture and areas with unfavorable soil conditions (Sundari *et al.*, 2023). Research has demonstrated that soilless systems are versatile and adaptable to different environments, including open and closed systems, vertical farming, and stress-affected regions (Sharma *et al*., 2022). These systems can control root diseases and offer more precise life cycle assessments in urban agriculture (Fujiwara *et al*., 2012; Llorach-Massana *et al*., 2017). Economically, soilless farming/hydroponics has been shown to be viable for vegetable production, with the potential for high market attractiveness (Balqiah *et al*., 2020; Ramsari and Hidayat, 2022). While soil serves as a traditional medium for plant growth by providing nutrients, water, and anchorage, it can also present challenges, such as soil-borne diseases, unsuitable soil conditions, and erosion (Sepehri *et al*., 2018; Ellis *et al*., 1974). Soil-based agriculture is also labor-intensive and requires larger areas and water resources, especially in urban environments where soil quality and availability are limited (Butler and Oebker, 2006). Plants grown in soilless systems generally produce higher yields, faster harvests, and better-quality produce, helping to mitigate climate change impacts and resource constraints while addressing malnutrition (Butler and Oebker, 2006). Soilless systems have gained significant interest in the intensive cultivation of vegetables, ornamental plants, and urban green infrastructure (Gruda, 2022). By utilizing organic or inorganic substrates and balanced nutrient solutions, soilless farming maximizes crop yields with efficient resource use. This research was therefore aimed at evaluating the effects of different growing media, both soil-based and soilless, on tomato performance and nutritional quality.

**2. Materials and Methods**

**2.1. Study Site Description:**  
The experiment was conducted at the Teaching and Research farm, in the screen house of the Department of Crop, Horticulture, and Landscape Design, Faculty of Agricultural Sciences, Ekiti State University. The geographical coordinates are between 7°31' and 7°49' North latitude and 5°71' and 5°27' East longitude.

**2.2. Experimental** **Design:**  
A Completely Randomized Design (CRD) was used for the study.

**2.3. Data Collection:**  
The following parameters were recorded:

* **Growth characteristics:** Plant height (cm), number of leaves per plant and stem girth (cm).
* **Yield characteristics:** Number of fruits per plant, fruit weight (g), and fruit girth.
* **Fruit quality characteristics:** Proximate characters**,** Titratable acidity, ascorbic acid, lycopene content, and total soluble solids (TSS) were measured.

**2.4. Statistical Analysis**

All data were subjected to analysis of variance (ANOVA) using SAS® 9.1.3 (2010), and Duncan's Multiple Range Test was used to separate differences among the means at a significance level of p<0.05.

## 3. Results

## 3.1 Properties of the growing media used for the research

The Properties of the different growing media used in the research are shown in Table 1, the results of the media used for planting were slightly acidic pH with a value between 6.11 and 6.62. While soil has a pH of 6.62, coco peat has a pH of 6.45, rice husk has a pH of 6.36 and rice husk biochar has a pH of 6.11, Coco peat has the highest nitrogen content (2.54%), followed by rice husk biochar with 0.82% nitrogen, rice husk with 0.72% nitrogen while soil has the least N (0.09%.). Soil has the highest value of total phosphorus (10.92%). All the soilless media have high organic carbon, ranging from 23.2% in rice husk to 32.25% in cocopeat; the highest value of Calcium, Magnesium and Potassium was found in cocopeat which were 16.78, 8.28 and 32.24 cmolkg‑1 respectively.

### 3.2 Effect of growing media on growth parameters of tomato

The effects of the different growing media used on plant height, number of leaves and stem girth of tomato are shown in Table 2, Significant differences were observed at 4, 5, and 6 WAT (weeks after transplanting) between cocopeat (CP) and other media; tomato grown in cocopeat had the highest plant height while the lowest plant height (73.57 cm) was observed in tomato grown in hydroponic water culture.

The plant height of tomato grown in soil was not significantly different from the height of tomato grown in Rice husk biochar and rice husk, although the two soilless media supported tomato height that were taller than that of the soil, no significant difference was observed at 6 weeks after planting (WAT) among all the media utilized, indicating their superior performance relative to soil medium. Media of growth significantly influenced the number of leaves of tomato throughout the period of observation except at 6WAT, cocopeat appeared to have consistently enhanced the number of leaves and plants grown in hydroponics water solution generally had the least number of leaves. Tomato plants grown in cocopeat exhibited significant differences compared to other media from 3 to 6 WAT. At 6 WAT, plants grown in Cocopeat had a stem girth of 1.02 cm significantly higher than other media. The premium variety had significantly thicker girth than the maxim variety from 4-6 WAT.

Table1. Characteristics of the growing media used for the research

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Properties | Soil | Cocopeat | Rice Husk Biochar | Rice Husk |
| Organic Carbon ( %) | 1.25 | 32.25 | 31.61 | 23.20 |
| pH 1:2(water) | 6.62 | 6.45 | 6.36 | 6.11 |
| Nitrogen ( %) | 0.09 | 2.54 | 0.82 | 0.72 |
| Available Phosphorus mgkg-1 | 10.92 | 0.89 | 0.21 | 0.71 |
| Calcium cmolkg‑1 | 4.12 | 16.78 | 5.24 | 2.70 |
| Magnesium cmolkg‑1 | 2.20 | 8.28 | 4.34 | 7.32 |
| Potassium cmolkg‑1 | 0.26 | 32.24 | 8.45 | 18.24 |
| Sodium cmolkg‑1 | 0.02 |  |  |  |
| Exchanged Acidity | 0.80 |  |  |  |
| Particle size analysis |  |  |  |  |
| Sand % | 88.4 |  |  |  |
| Silt % | 7.0 |  |  |  |
| Clay % | 4.6 |  |  |  |
| Textural class | Sandy loam |  |  |  |

Table 2. Effects of the different media on growth parameters of tomato

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Weeks After Transplanting | | | | | |
| MEDIA | 2 | 3 | 4 | 5 | 6 |
| Plant Height (cm) | | | | | |
| CP | 21.65a | 37.31a | 56.16a | 71.59a | 87.68a |
| RHB | 21.2a | 39.56a | 33.17b | 68.65ab | 83.33b |
| RH | 20.18b | 35.83a | 53.72b | 68.78ab | 82.60b |
| SO | 19.40b | 33.04a | 52.10b | 67.46b | 82.21b |
| HP | 14.29c | 24.00b | 38.13c | 52.67c | 73.57c |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Number Of Leaves | | | | | |
| CP | 5.67a | 7.00a | 8.60a | 10.10b | 11.93a |
| RHB | 5.58ab | 6.65bc | 7.85b | 9.85b | 11.43a |
| RH | 5.58ab | 6.72ab | 7.53b | 9.73b | 11.37a |
| SO | 5.33b | 6.38c | 8.50a | 10.67a | 11.88a |
| HP | 4.61c | 5.71d | 7.52b | 9.95b | 11.46a |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Stem Girth ( cm) | | | | | |
| CP | 0.55 a | 0.72 a | 0.89 a | 0.93 a | 1.02 a |
| RHB | 0.53 a | 0.66 b | 0.82 b | 0.89 b | 0.96 ab |
| RH | 0.50 b | 0.65 b | 0.81 b | 0.87 b | 0.94 b |
| SO | 0.45 c | 0.58 c | 0.78 b | 0.89 ab | 0.95 b |
| HP | 0.35 d | 0.48 d | 0.61 c | 0.78 c | 0.89 c |

Means with the same letter(s) on the same column are not significantly different at 5% probability using Duncan’s Multiple Range Test. Note: CP= cocopeat; RHB= rice husk biochar; RH= rice husk; SO= soil; HP= hydroponics.

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### 3.3 Effects of media on yield of tomato

Tomato grown in rice husk medium yielded the highest total fruit weight of 1884g and fruit number of about 15.60 fruits, while the lowest total fruit weight of 594.4g and 7.57 fruits were observed in tomatoes cultivated in a hydroponic water culture, with these results being significantly different from those grown in other media (Table 3). In terms of average fruit girth, tomatoes grown in rice husk biochar had the largest average girth at 9.04 cm, which was not significantly different from those grown in cocopeat and rice husk, but was significantly different from those grown in soil and hydroponics water culture. For fruit length, the highest (7.04 cm) was recorded for tomatoes grown in rice husk, while the lowest length of 5.97 cm was recorded for those grown in the hydroponic system. Also, tomatoes cultivated in rice husk produced a significantly more fruits compared to those grown in other media.

**3.4 Effects of growing media on the nutritional qualities of tomatoes**

The influence of different growing media on the nutritional quality of tomatoes is shown in Table 4. The pH of tomatoes cultivated in various media did not exhibit significant differences from one another, with values ranging from 3.71 for fruit grown in soil to 3.99% for fruit grown in rice husk

Titratable acidity (TTA) values ranged from 0.24 for fruit grown in soil to 0.30% for fruit grown in rice husk biochar with soil showing the lowest acidity among the different media. Fruit grown in rice husk biochar significantly had the highest level (6.83%) of lycopene significantly different from other media. For vitamin Ccontent, fruit grown in rice husk gave the highest vitamin C content of 16.82 mg/100g, significantly different from soil with an increase of 14.9%. The brix%i.e. soluble sugar showed no significant difference between fruit grown in rice husk and Cocopeat, but significantly different from other media. The moisture content of tomato fruits grown in different media ranged from 92.5% for fruit grown in rice husk to 92.91% for fruit grown in soil. Tomato fruit grown in rice husk biochar significantly influenced the ash content of tomato fruits, with tomatoes grown in rice husk biochar having the highest ash content, significantly different from other media with a percentage increase of 7.4%, 5.88%, and 4.35% higher than rice husk, Cocopeat and soil respectively

Protein content ranged from 0.94% for fruit in cocopeat to 0.98% for fruit grown in rice husk and rice husk biochar

**Table 3**: EFFECTS OF MEDIA ON YIELD OF TOMATO

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| MEDIA | TFRTW (g) | AFGT (cm) | AFL (cm) | NOF |
| CP | 1335.3b | 9.00a | 6.99a | 11.25bc |
| RH | 1884a | 8.91a | 6.93a | 15.66a |
| RHB | 1612.5ab | 9.04a | 7.04a | 13.47b |
| SO | 831.4c | 6.80b | 6.29b | 8.20c |
| HP | 594.6c | 6.01b | 5.97b | 7.57c |

Means with the same letter(s) on the same column are not significantly different at 5% probability using Duncan’s Multiple Range Test. Note: CP= cocopeat; RHB= rice husk biochar; RH= rice husk; SO= soil; HP= hydroponics.

Tomatoes grown in rice husk had the highest crude fibre content, while those grown in soil and rice biochar had the least crude fibre content

No significant differences were observed in carbohydrate content among the four growing media used

**Effect of media on mineral content of tomato**

The effect of media on mineral content of tomatoes is presented in Table 5

Iron (Fe) content was significantly higher in tomatoes grown in rice husk biochar than other media, with a significant increase of 35.9, 1.14, and 42.97% over RH, Cocopeat, and soil respectively.

For Magnesium content, the values ranged from 41.02% for tomato fruit in rice husk to 42.29% for tomato fruit in cocopeat, with a significant difference of 3.09 %, which was relatively more present in tomatoes grown in Cocopeat and rice biochar compared to other media.

For copper content, no significant differences (*P* > 0.05) were observed among tomato fruits grown in the different media.

Manganese content was observed to be highest in cocopeat (1.01%) followed by rice biochar (0.99%), which is significantly different from other media.

Similarly, for zinc content, Cocopeat and rice biochar exhibited higher percentages of zinc content compared to other media, with a significant *P*<0.05 difference

**Table 4**: Effect of media on nutritional quality of tomato fruit

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SUB | PH |  | TTA | LYCO | VIT C | BRIX | MOIS | FAT | ASH | PROT | CF | CHO |
| RH | 3.99a |  | 0.27a | 6.83a | 16.82a | 3.84a | 92.51a | 0.29ab | 0.67b | 0.98 a | 0.92a | 4.65a |
| CP | 3.8 a |  | 0.26c | 6.74cb | 15.25b | 3.83a | 92.79b | 0.28b | 0.68b | 0.94c | 0.91ab | 4.10a |
| SO | 3.71a |  | 0.24d | 6.78b | 14.63c | 3.72b | 92.91a | 0.29ab | 0.69b | 0.96bc | 0.90b | 4.30a |
| RHB | 3.91a |  | 0.30a | 6.70c | 13.59d | 3.52c | 92.67c | 0.30a | 0.72a | 0.98ab | 0.90b | 4.28a |

Means with the same letter(s) on the same column are not significantly different at 5% probability using Duncan’s Multiple Range Test. Note: pH= pH value; TTA= titratable acidity; LYCO= lycopene; VIT C= vitamin c; MOIS= moisture; PRO= protein; CF= crude fibre and CHO= carbohydrate. Also, CP= cocopeat; RHB= rice husk biochar; RH= rice husk; SO= soil; HP= hydroponics

**Table:5**. Effect of media on mineral (%) content of tomato

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Fe | Mg | Cu | Mn | Zn |
| RH | 2.62c | 41.02c | 0.24a | 0.93b | 1.56b |
| CP | 3.52b | 42.29a | 0.24a | 1.01a | 1.62a |
| SO | 2.49d | 41.29b | 0.24a | 0.93b | 1.56b |
| RHB | 3.56a | 42.23a | 0.26a | 0.99a | 1.61a |

Means with the same letter(s) on the same column are not significantly different at 5% probability using Duncan’s Multiple Range Test. Note: CP= cocopeat; RHB= rice husk biochar; RH= rice husk; SO= soil; HP= hydroponics and Fe= Iron; Mg= Magnesium; Cu= Copper; Mn= Manganese; and Zn= Zinc

4. DISCUSSIONS

The pH levels of the different growing media used in this study that is cocopeat, rice husk, rice husk biochar, and soil varied, with soil having a pH of 6.62, while cocopeat, rice husk, and rice husk biochar had pH values of 6.45, 6.11, and 6.36, respectively, these results indicate that all the media are within the pH range suitable for tomato cultivation, as supported by prior research (Cherrybel and Prisca, 2017, Kaplan 2024), for both soil and soilless systems. The significance of pH lies in its effect on nutrient availability and solubility, in influencing crop growth and productivity (Olubanjo and Alade, 2019). Nitrogen content was found to be highest in cocopeat, thus showing the organic nature of soilless media and their typically higher levels of organic matter when compared to soil.

This research demonstrated that different media influenced the growth, yield, and nutritional quality of tomatoes. Media serve as both structural support and a nutrient source for plant roots, with each type of media having distinct effects on root development (Harjoko, 2009). The ability of the media to retain nutrient solutions also affects nutrient uptake, which may explain the superior plant height observed in tomatoes grown in cocopeat, which had the highest levels of nitrogen, organic matter, magnesium, and potassium, these findings align with Truong *et al.* (2018), who also found that cocopeat-based media promote maximum plant height in tomatoes. The organic matter content of the medium further enhances its biological, chemical, and physical properties, affecting plant growth (Yasmeen *et al*., 2012).

The superior performance of cocopeat in supporting stem girth and leaf number can be attributed to its high cation exchange capacity and organic matter content, as noted in studies on other crops like ginger (Suhaimi *et al*., 2012), cucumber (Gul *et al.,* 2007), and roses (Fascella and Zizzo, 2003),a research by Ghimire *et al* ., 2024 also showed cocopeat enhancing a better seedling growth in the nursery production of tomato than other media used The results also showed that plants grown in soilless media such as rice husk, cocopeat, and biochar produced higher yields than those grown in soil, this is in line with findings from Rodriguez-Ortega *et al*. (2017), who reported that hydroponically grown plants had great vegetative development as measured by their growth parameters

Rice husk medium produced more fruits per plant than cocopeat, contrary to findings by Reshma and Sarath (2017), who observed better fruit yields in cocopeat. Also, the media significantly influenced the fruit quality of tomato, with soilless culture typically enhancing the quality of vegetable crops more (Savvas and Gruda, 2018). While some parameters varied significantly across the media, all nutritional values remained within acceptable ranges. For instance, tomatoes grown in rice husk had higher vitamin C content than those grown in cocopeat, contrary to findings by Suvo *et al*. (2017). The moisture content of the tomatoes fell within the range reported by Agbemafle *et al*. (2015), contributing to the good shelf life observed in this study.

For protein content, all media yielded protein values within the expected range, between 0.93% and 1.02%, aligning with USDA data (2005). Carbohydrate content was low across all media, this is consistent with the nature of tomatoes as a low-calorie vegetable (Adubofuor *et al*., 2010). The crude fiber content was notably higher in tomatoes grown in r,ice husk, and this reflects the medium's high fiber content, which is beneficial for digestion and cholesterol management (Papas *et al.,* 2004), tomatoes grown in rice husk biochar had the highest ash content, indicating a higher mineral content, with significant levels of essential minerals such as iron, magnesium, copper, manganese, and zinc.

Consequently, the choice of growing media has a profound effect on tomato growth, yield, and nutritional quality, with soilless media, particularly cocopeat and rice husk, offering advantages in terms of plant performance and nutritional content.

**5.CONCLUSION**:

The results revealed that for the different growing media, using cocopeat as growing medium resulted in the highest plant height, number of leaves, and stem girth. With the media performance, rice husk biochar, cocopeat, and rice husk outperformed soil in yield production. The study concludes that soilless farming using various media supports sustainability by repurposing agricultural waste and enabling year-round production. Soilless farming not only ensures sustainable practices but also improves crop performance and efficiency.

**REFERENCES**

Adegbola, J. A., Awagu, F., Adu, E.A., Anugwom, U.D., Ishola, D.T., & Bodunde, A.A. (2012). Investment Opportunities in Tomato Processing in Kano, Northern Nigeria. Global Adv. Res. *Journal of Agricultural Science,* 1(10): 2882-97.

Adubofuor, J., Amankwah, E. A., Arthur, B. S., & Appiah, F. (2010*).* Comparative study related to physico-chemical properties and sensory qualities of tomato juice and cocktail juice produced from oranges, tomatoes and carrots*. African Journal of Food Science, 4(7), 427-433.*

Agbemafle, R., Owusu-Sekyere, J. D. & BartPlange, A. (2015). Effect of deficit irrigation and storagSe on the nutritional composition of tomato (*Lycopersicum esculentum* Mill. cv. Pectomech). Croatian *Journal of Food Technology, Biotechnology and Nutrition*, 10(1-2): 59- 65

Balqiah, T. E., Pardyanto, A., Astuti, R. D., & Mukhtar, S. (2020). Understanding how to increase hydroponic attractiveness: economic and ecological benefit. E3S Web of Conferences, 211, 01015. https://doi.org/10.1051/e3sconf/202021101015

Bhatia, P., Ashwath N, Senaratna T., & Midmore, D (2004). Tissue culture studies of tomato (*Lycopersicon escuelentum*). Plant Cell Tissue Organ Cult 78:1-21

Bihari, C., Ahamad, S., Kumar, M., Kumar, A., Kamboj, A. D., Singh, S., & Gautam, P. (2023). Innovative Soilless Culture Techniques for Horticultural Crops: A Comprehensive Review. *International Journal of Environment and Climate Change*, *13*(10), 4071-4084.

Butler J. D., & Oebker N. F. (2006). Hydroponics as a Hobby— Growing Plants Without Soil. Circular 844. Information Office, College of Agriculture, University of Illinois, Urbana, IL 61801

Cherrybel O., & Prisca B. (2017) Tomato production guide a Publication of the Department of Agriculture, Regional Field Office No. 02, High Value Crops Development Program

Dias, J. S., & Ryder EJ (2011). World vegetable industry: production, breeding, trends. *Horticultural Reviews*; 38: 299-356.

Ellis, N.K., Jensen, M., Larsen, J., & Oebker, N. (1974). Nutriculture Systems—Growing Plants Without Soil. Station Bulletin No. 44. Purdue University, Lafayette, *Indiana*

Fascella, G., & Zizzo, G.V. (2004). Effect of growing media on yield and quality of soilless cultivated rose. In *International Symposium on Soilless Culture and Hydroponics*.;697:133-138.

FAOSTAT 2019. Food and Agriculture Organization of the United Nations

Fujiwara, K., Aoyama, C., Takano, M., & Shinohara M. (2012). Suppression of *Ralstonia solanacearum* bacterial wilt disease by an organic hydroponic system. *J. Gen. Plant Pathol*. 78:217–220

Ghimire, S., Acharya, S., Adhikari, C., Chaurel, S., & Paudel, R. (2024). Effect of Growing media on Germination and Seedling Growth of Four Different Varieties of Tomato [Solanum lycopersicum (L.)] in Khumaltar Lalitpur, Nepal. Asian Journal of Agricultural and Horticultural Research, 11(4), 49–61. https://doi.org/10.9734/ajahr/2024/v11i4339

Golberg, G. (2003). Plants: diet and health. The Report of a British Nutrition Foundation Task Force, Blackwell Science, Oxford.,152-163.

Gruda, N. S. (2019). Increasing sustainability of growing media constituents and standalone substrates in soilless culture systems. Agronomy 9(6), 298. doi .org /10 .3390 / agronomy90602 98.

Gruda, N. (2022). Advances in soilless culture and growing media in today’s horticulture—an editorial. *Agronomy,* 12(11), 2773.

Gül, A., Kıdoğlu, F., & Anaç, D. (2007). Effect of nutrient sources on cucumber production in different substrates. *Scientia Horticulturae*, *113*(2), 216-220

Harjoko, D. (2009). Studi macam media dan debit aliran terhadap pertumbuhan dan hasil tanaman sawi (Brassica juncea L.) secara hidroponik NFT. *Jurnal Agrosains*, *11*(2), 58-62.

Lakhiar I.A., Gao J.M., Syed T N, Chandio F A, Tunio M H, & Ahmad., F.(2020). Overview of the aeroponic agriculture – An emerging technology for global food security. *Int J Agric and Biol Eng,;* 13(1): 1–10.

Li, Q., Li, X., Tang, B., & Gu, M. (2018). Growth responses and root characteristics of lettuce grown in aeroponics, hydroponics, and substrate culture. *Horticulturae,* 4(4), 35. <https://doi.org/10.3390/horticulturae4040035>

Llorach-Massana, P., Muñoz, P., Riera, M., Gabarrell, X., Rieradevall, J., Montero, J., & Villalba, G. (2017). N2o emissions from protected soilless crops for more precise food and urban agriculture life cycle assessments. Journal of Cleaner Production, 149, 1118-1126. <https://doi.org/10.1016/j.jclepro.2017.02.191>

Marti R., Rosello, S., & Cebolla-Cornejo, J.(2016). Tomato as a source of carotenoids and polyphenols targeted to cancer prevention. Cancers (Basel) 8:58. doi: 10.3390/cancers8060058

Meseret, D., Ali, M., & Kassahun, B. (2012) Evaluation of tomato (*Lycopersicon esculentum* Mill.) Genotypes for yield and yield components. *The Africa Journal of plant science and Bioltechnology* 6 (special issue 1), 45-49

Olubanjo, O.O., & Alade, A .E. (2019). Growth and yield response of African spinach plant grown in different substrates culture of drip hydroponic farming method. VOL. 5, 2019 Agriculture ISSN 2347–3819 EISSN 2347–386X discovery

Papas, M., Giorannuli,, E., & Platze, E. (2004). Fibre from fruit and colorectal Neoplasia. *Journal of cancer Epidemiology Biomarker and prevention*, 13: 1267-1270.

Ramsari, N., & Hidayat, T. (2022). Monitoring system and hydroponic plant automation using microcontroller internet of things based (iot). Compiler, 11(2).

Rodríguez-Ortega, W. M.., Martı́nez, V., Nieves, M., Simón, I., Lidón, V., Fernández-Zapata, J. C., & Garcı́a-Sánchez, F. (2019). Agricultural and physiological responses of tomato plants grown in different soilless culture systems with saline water under greenhouse conditions. *Scientific Reports*, 9(1).

Savvas, D., & Gruda, N. (2018). Application of soilless culture technologies in the modern greenhouse industry – a review. *European Journal of Horticultural Science*, 83(5), 280-293. https://doi.org/10.17660/ejhs.2018/83.5.2

Sepehri, A., & Sarrafzadeh M.H (2018) Effect of nitrifiers community on fouling mitigation and nitrification efficiency in a membrane bioreactor. *Chem Eng Process*. 128, 10-18.

Sharma, N., Acharya, S., Kumar, K.,Singh, N., & Chaurasia, O.P.(2018) Hydroponics as an Advanced Technique for Vegetable Production: An Overview. *J. Soil. Water Conserv*. 17, 364.

Southon, S. (2000). Increased fruit and vegetable consumption within EU: potential health benefits. Food Res Intl 33211217

Suhaimi, Y. M., Mohamad, A.M., Mahamud,S., & Khadzir D. (2012). Effects of substrates on growth and yield of ginger cultivated using soilless culture. *J Trop Agric and Food Sc*;40(2):159-168.

Sundari, R. S., Sulistyowati, L., Noor, T. I., & Setiawan, I. (2023). Soilless culture for agribusiness throughout urban farming in Indonesia. *Recent Research and Advances in Soilless Culture.*

Suvo, T. P., Biswas, H., Jewel, M. H., Islam, M. S., & Khan, M. S. I. (2017). Impact of substrate on soilless tomato cultivation. *International Journal of Agricultural Research, Innovation and Technology (IJARIT)*, *6*(2), 82-86.

Truong H D, Wang C H & Kien TT. (2018). Effect of vermicompost in media on growth, yield and fruit quality of cherry tomato (*Lycopersicon esculentum* Mill.) under net house conditions. *Compost Science and Utilization* 26(1): 52–8

UN (2019). Growing at a slower pace, world population is expected to reach 9.7 billion in 2050 United nation department of Economic and Social Affairs

Yasmeen, S., Younis, A., Rayit, A., Riaz, A., & Shabeer, S. (2012). Effect of different substrates on growth and flowering of Dianthus caryophyllus cv.‘Chauband Mixed’. *American-Eurasian Journal of Agriculture and Environmental Science*, *12*(2), 249-258.