***Original Research Article***

**Impact of Growth Media on Cucumber Growth and Cost-Benefit Analysis of Treatments in a Greenhouse Environment**

**ABSTRACT**

This research was carried out in a greenhouse located at the Council for Scientific and Industrial Research (CSIR) - Savanna Agricultural Research Institute (SARI), Nyankpala, Northern Region of Ghana from June, 2022 to September, 2022. The study compared the growth of cucumber grown on soil with that grown on cocopeat and soil-biochar and the cost-benefit ratio of the treatments in a greenhouse. The treatments consisted of three irrigation regimes (100 % ETc, 75 % ETc, 50 % ETc) and growth media including Soil (So), Soil plus Charred rice husk biochar (So + CRH), and Cocopeat (CP). The study was a 3 x 3 factorial experiment in a Randomized Complete Block Design (RCBD) with three replications. Data was collected on media physico-chemical properties and growth parameters. Determination of the cost-benefit (CB) of the media was done by using the CBR formula. The result of the Analysis of Variance (ANOVA) showed that CP and So + CRH supported optimum growth of cucumber under greenhouse conditions. Cucumber growth parameters, including plant height and flower count, were maximized on CP. The highest leaf area index was obtained from plants grown on So + CRH; chlorophyll content was highest for cucumber plants grown on So, while the highest flower abortion occurred on plants grown on So + CRH. Use of So proved to be more profitable compared to CP and So + CRH. This could be due to the high cost of production of CP and high flower abortion associated with So + CRH-grown plants, which reduced the yield. More work could be done on the combination of CP and CRH for greenhouse cucumber production.

***Keywords:*** *Cucumber, Cocopeat, Charred, Soil, Biochar, Growth, Physico–chemical properties*

**INTRODUCTION**

Global agricultural productivity faces significant challenges due to shifting weather patterns driven by climate change, which result in reduced rainfall and temperature variability (Garba et al., 2020). Greenhouse cultivation offers a promising adaptation strategy by regulating the macro- and microenvironment of plants, enhancing yield, improving produce quality, and optimizing growth and development (Gruda, 2014).

Cucumber (Cucumis sativus L.), a widely cultivated member of the Cucurbitaceae family, is a high-demand vegetable crop valued for its economic importance (Eifediyi & Remison, 2010). Greenhouse cultivation of cucumbers enhances productivity, improves fruit quality, and supports year-round production, leading to favorable market prices (El-Wanis et al., 2012; Ibeawuchi et al., 2008; Kumar et al., 2015).

While soil remains the most common medium for plant cultivation, providing essential water, nutrients, air, and structural support, its use in greenhouses is associated with challenges. Soil-borne diseases, such as root rots and root-knot nematodes, pose significant risks to cucumber production under greenhouse conditions (Cohen et al., 2015; Elings et al., 2015; Gamliel & Van-Bruggen, 2016). Additionally, access to fertile arable land is often limited. Soilless cultivation systems offer a viable alternative, eliminating the need for frequent soil fumigation, which can leave harmful residues affecting crops and human health (Barrett et al., 2016). Soilless media, such as cocopeat and biochar-amended substrates, are lightweight, uniform, and widely recognized for supporting efficient plant production (Barrett et al., 2016).

This study aims to:

1. Evaluate the growth performance of cucumber cultivated in soil, cocopeat, and soil amended with rice husk biochar under greenhouse conditions.
2. Assess the cost-benefit ratio of these cultivation treatments to determine their economic viability.

**2. MATERIALS AND METHODS**

**2.1 Site Description and Treatments**

A greenhouse experiment was conducted at the Council for Scientific and Industrial Research (CSIR), Savanna Agricultural Research Institute (SARI), Northern Ghana (latitude 9.4066° N, longitude 0.9882° W, and elevation of 169m) during the 2022 planting season (Kareem et al., 2023). Two sets of experimental treatments were applied: the amount of water application and the growth media. The depth of irrigation application included: 100 % crop water requirement (ETc), 75 % ETc, and 50 % ETc. The growth media included: soil, soil plus charred rice husk, and coco peat, respectively.

**2.2 Bulk density**

Dry bulk density was determined using the core method (Blake and Hartage, 1986). Soil samples were collected with core samplers at a depth of 30cm a week before planting. Collected soil samples were taken to the laboratory, and then oven-dried at 105 0C for 48 hours to constant weight. The dry bulk density (ρg) was calculated using the formula below.

$\frac{m\_{1} - m\_{2}}{πr^{2}h}$……………………………………………. Equation 1

Where:

m1= mass of oven-dried soil + core ring (g)

m2 = mass of empty core ring (g)

h = length of core sampler (cm)

r = internal radius of core sampler (cm)

**2.3 Moisture content**

The different media were collected into weighed moisture cans, which were immediately covered with polythene bags to prevent moisture loss. The cans were immediately transferred to the laboratory, weighed, and transferred into an oven set at 105 °C for 48 hours. Gravimetric moisture content (ω) was calculated thus:

 $\frac{m\_{1} – m \_{2}}{m\_{2} - m\_{3}}$………………………………………………………. Equation 2

Where: m1 = mass of moist sample + moisture can (g)

m2= mass of oven-dried sample + moisture can (g)

m3 = mass of empty moisture can (g)

**2.4 Moisture constants**

Soil moisture constants, including field capacity (FC), permanent wilting point (PWP), and available water capacity (AWC), were calculated for each of the media. To determine the FC, the pressure plate apparatus method was used. Collected soil samples in core rings were saturated overnight for 24 hours by covering one end of the rings with pieces of cloth and holding the cloth in place using rubber bands. These rings were then transferred into an empty water trough with the covered side placed at the base of the water trough, water was poured into the trough so that the rings were not submerged. After 24 hours, the saturated samples were removed from the trough, the cloth and rubber tied over one end were replaced with filter paper, after which the samples were placed in the pressure plate extractor for 24 hours, set to 0.33 bar to release water until field capacity was attained. It was then removed from the pressure plate, weighed and recorded as $m1$ and oven-dried at 105°C for 24 hours to constant weight, and recorded as m2. FC was then calculated thus:

$\frac{m\_{1} – m \_{2}}{m\_{2}} ×100$ ………………………………..…………………… Equation 3

Where, m1 = mass of saturated soil before oven-drying (g) m2 = mass of oven-dried soil (g)

The PWP of the different media was calculated using the membrane apparatus. The samples were saturated for 24 hours, then placed in the pressure membrane apparatus where a pressure of 15 bar was applied for 7 days. After extraction, samples were removed and weighed, the weight was recorded as M1. Samples were then oven–dried at 105oC, the weight was then recorded as M2.

PWP = M1 – M2……………………………….……………….………Equation 4

Where:

PWP = Permanent wilting point (%)

M1 = Mass of soil before oven drying (g)

M2 = Mass of soil after oven drying at 105oC (g).

The AWC was calculated as the difference between water contents at FC and PWP.

AWC = FC – PWP……………………………………….…………… Equation 5

**2.5 pH and Electrical conductivity (EC)**

The pH of the media was determined following the procedure reported by Miaomiao *et al.* (2009). Collected soil samples were air-dried for 24 hours, after which the soil samples were passed through a 2 mm sieve before the test. The pH of the media was then determined using the electrometric method, where 10 grams of the different media were suspended in 50 ml of distilled water. The mixture was shaken for 30 minutes and left standing for another 30 minutes. After this, the pH meter was dipped into it for pH determination. The EC of the different media was determined using the Jenway conductivity meter inserted into the saturated paste used in the pH determination.

**2.6 Growth Parameters**

Chlorophyll content was measured using a chlorophyll meter at 2 and 4 weeks after transplanting (WAT), and leaf area index was measured at 2, 4, and 6 WAT following the formula (equations 6 and 7) reported by Xiaolei and Zhifeng (2004). Flower count was done by hand counting of the flowers present on the plant at 3 and 4 WAT. Flower Abortion was done using a clipper to cut off the flower at 4 and 5 WAT.

LAI$ =\frac{LA}{Area occupied by plant}$ ………………………………. Equation 6

Where LA = Maximum length ×Maximum width ×0.89 ………………. Equation 7

**2.7 Cost-Benefit Analysis**

To determine which treatment gave the largest profit, the economics of each of the treatments were calculated based on the input and output. The difference between the revenue and cost thus gives the profit

Benefit-cost ratio $=\frac{Benefit}{Cost}$ …………………………….... Equation 8

**2.8 Statistical Analysis**

The experiment was a 3 x 3 factorial study in a Randomized Complete Block Design (RCBD) with three replications. All data collected were subjected to analysis of variance (ANOVA) using the PROC GLM procedure in GenStat software. When global F-values were found to be significant, means were separated using least significant difference (LSD) at a 5% probability level.

**3. RESULTS**

## **3.1 Characteristics of The Growth Media**

The physical properties of the different growth media indicate that So had the highest bulk density of 1.41 g/cm3, followed by So + CRH (1.03 g/cm3), and CP had the lowest value of 0.1 g/cm3 (Table 1). Gravimetric moisture content revealed CP was highest with a value of 39%, followed by So + CRH (12.6%), with So having the lowest value of 6.5%. The moisture content at FC varied from 12.9% for So, followed by So + CRH at 23.87%, with CP having the highest value of 33.5%. The moisture content at permanent wilting point also varied from 4.0% for So, followed by So + CRH with a value of 8.7%, with CP recording the highest value of 10.8%. Thus, the available water content of the different media varied from 8.9% to 15.17% and 22.5% for So, So + CRH, and CP, respectively.

The chemical properties of the growth media showed CP had the highest pH (6.48), followed by So + CRH (6.10), whereas So had the lowest pH (5.99) (Table 2). The highest EC was observed in CP (1878 μS/cm), followed by So + CRH (95.05 μS/cm), whereas EC was lowest in So (76.9 μS/cm).

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| Table 1. Properties of the growth media and irrigation water |
| Growth media | Bulk density(g/cm3) | Moisture content (%) | Field capacity (%) | Permanent wilting point (%) | Available water capacity (%) | pH (1:5) | EC (μS/cm) |
| So | 1.43 | 6.50 | 12.90 | 4.00 | 8.90 | 5.99 | 76.90 |
| So + CRH | 1.03 | 12.60 | 23.87 | 8.70 | 15.17 | 6.10 | 95.05 |
| CP | 0.10 | 39.00 | 33.50 | 10.80 | 22.50 | 6.48 | 18.78 |
| So: Soil; So + CRH: Soil + Biochar (75:25); CP: CocopeatMeans with similar letters down the column are not significantly different  |

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## **3.2 Cucumber plant growth parameters**

From the analysis of variance results, significant variations were observed in the main effects of growth media on chlorophyll content at 2 and 4 WAT at p ≤ 0.001 and p ≤ 0.05, respectively (Table 2). Cucumber LAI was significantly affected by the main effects of growth media at 2, 4, and 6 WAT at p≤ 0.01and p ≤ 0.05 (Table 2). Significant differences (p ≤ 0.01) were noted for the main effect of growth media on flower count at 3 and 4 WAT (Table 3). At 4 WAT, flower abortion was significantly altered by the main effects of the growth media (Table 3). At 5 WAT, Flower abortion was significantly affected by the interactive effects of irrigation regimes by growth media (p ≤ 0.05) and the main effects of growth media (p≤ 0.001) (Table 3).

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| Table 2. Main effect of growth media on chlorophyll and leaf area index (LAI) |
| Treatments | Chlorophyll (spad)  |  | Leaf area index (LAI) |
| 2 WAT | 4 WAT |  | 2 WAT | 4WAT | 6WAT |
| So | 60.00a | 62.10a |  | 0.0511ab | 0.0544ab | 0.058b |
| So+CRH | 49.30ab | 53.90ab |  | 0.0544a | 0.0606a | 0.0626a |
| CP | 29.70c | 40.60b |   | 0.0444b | 0.0517b | 0.0533c |
| So: Soil; So + CRH: Soil + Biochar (75:25); CP: CocopeatMeans with similar letters down the column are not significantly different |
| Table 3. The main effect of growth media on flower count and flower abortion  |
| Treatments | Flower count |  | Flower Abortion |
| 3 WAT | 4 WAT |  | 4 WAT | 5 WAT |
| So | 2.74b | 3.08b |  | 1.12ab | 2.82b |
| So+CRH | 2.89ab | 3.12ab |  | 1.42a | 3.20a |
| CP | 2.95a | 3.48b |   | 0.95b | 3.04ab |
| So: Soil; So + CRH: Soil + Biochar (75:25); CP: CocopeatMeans with similar letters down the column are not significantly different  |

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## **3.3 Cost-Benefit-Analysis**

The total cost incurred in obtaining the different media and the benefits accrued are shown in Table 4. CP (GH₵ 584) had the highest cost incurred, followed by So + CRH (GH₵464) and So (GH₵434). The benefit accrued was in the order CP> So> So + CRH at GH₵702, GH₵551.9, and GH₵503.8, respectively. The benefit cost ratio thus ranges from 1.10 for So + CRH to 1.20 for CP and 1.27 for So (Table 4).

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| Table 4. Cost-Benefit Analysis (CBA) of the growth media |
| Items | Growth Media Quantity |  | Growth Media Cost (GH₵) |
| So | So + CRH | CP |   | So | So + CRH | CP |
| Purchase | 260 kg | 260 kg | 120 kg |  | 0.0 | 0.0 | 150.0 |
| Transport | Field to GH | Field to GH | Accra to GH | 50.0 | 50.0 | 100.0 |
| Charring | 0 kg  | 30 kg | 0 kg |  | 0.0 | 20.0 | 0.0 |
| Seed | 65 pieces | 65 pieces | 65 pieces |  | 35.0 | 35.0 | 35.0 |
| Pots | 54 pieces | 54 pieces | 54 pieces |  | 54.0 | 54.0 | 54.0 |
| Water | 305 L | 305 L | 305 L |  | 250.0 | 250.0 | 200.0 |
| Fertilizer | 1 kg | 1 kg | 1 kg |  | 30.0 | 30.0 | 30.0 |
| Fungicide | 50 g | 50 g | 50 g |  | 15.0 | 15.0 | 15.0 |
| Total Cost |  |  |  |  | 435.0 | 454.0 | 584.0 |
| Benefit Accrued |  |  |  |  | 551.9 | 503.8 | 702.0 |
| Benefit Cost Ratio (BCR) |   |   |   | 1.3 | 1.1 | 1.2 |
| So: Soil; So + CRH: Soil + Biochar (75:25); CP: Cocopeat; GH: Greenhouse; GH₵: Ghana cedis |

**4. DISCUSSION**

**4.1 Properties of Growth Media and Irrigation Water**

The reduction in bulk density value of So + CRH as compared to So could be attributed to the amending effects of the CRH, which improves aeration through an increase in organic matter content of the soil (Lehmann and Rondon, 2006). Kareem et al. (2025), also reported that addition of biochar increases the soil organic matter, which will improve soil aeration. Hence, the value agrees with the findings of Blanco-Canqui (2017), who stated biochar reduces soil bulk density by 3 to 31%. Another Study by Liman (2024a), stated that biochar has the ability to reduce bulk density. Although the bulk densities of So + CRH and So, fall within appropriate values desired for adequate flow of air and moisture circulation for optimum growth of the plant, as pointed out by Waller and Yitayew (2016). The low bulk density of CP (0.10 g/cm3) in this study falls within acceptable options for crops grown hydroponically, ranging from 0.1 – 0.3 g/cm3 as demonstrated by Kämpf *et al.* (1997).

The available water capacity of the media was not outside expectations, as Awang *et al.* (2009), and Bunt (1988), explained differences in size and number of pore spaces of media to play a key role in their water holding capacities (WHC). The mixture of So + CRH has a higher available water content (15.17%) as compared to the soil (8.9%), attributable to the fact that CRH reduces the bulk density of soil, by loosening up the soil and increasing the total porosity which means more available pores for water storage and having a direct impact on the available water content of the soil (Nyle and Ray, 1999). This agrees with the work of Kareem et al, (2023), Liman et al (2024b) and Sosu (2014), who confirmed that adding organic materials such as CRH, CP, amongst others to soil leads to a significant increase in the soil WHC. The CP, however had the highest available water capacity value in this study. This goes in line with the work of Carlie et al. (2019) where it is stated that the favorable physical characteristics of CP is associated to its high available water, slow biodegradation, low shrinkage ability and low bulk density.

The media pH, as confirmed in the classification of soil reaction done by Motsara (2015), are classified as being moderately acidic (5.6 – 6.5). The increased pH of So + CRH (6.1) in this work as compared to soil (5.99) agrees with the findings of Wang et al. (2018), who made a point on rice husk biochar having the ability to increase the pH of soils during his work on tea garden soil where the pH increased from 3.33 to 3.63 due to rice husk biochar addition.

According to Harmann *et al.* (2011), and Sonneveld and Voogt (2009), the ideal pH for optimum growth of crops in a soilless substrate should range from 5.4 to 6.0. This point was reiterated by Adams (2002), who mentioned that the best pH for hydroponically grown crops to ensure optimum production is between 5.5 to 6.5, the pH of CP (6.48) used in this research falls within this range. Generally, a high number of nutrients are available to crops within the range of 5.5 – 6.5 (Motsara, 2015). The values of all the media were in this range, the pH can therefore be said to be acceptable and not have an impact on the results obtained. CP had the highest EC, whereas So had the lowest. Motsara (2015), classified EC values > 4 dS/m as being saline and values < 4 dS/m as being non – saline. This indicates that the EC of the three media (So, So + CRH, and CP) are non–saline and are suitable for cucumber production (He et al., 2003).

**4.2 Cucumber Plant Growth Parameters**

At both 2 and 4 WAT, plants grown on So had the highest chlorophyll content, while those in CP had the lowest chlorophyll content. This is similar to the result of Ameho (2017), who obtained a higher chlorophyll content with cucumber plants grown on soil as compared to those grown on CP and CP plus palm fiber mixture. The higher chlorophyll content of So + CRH as compared to the CP in this experiment could be linked to the leaf area index. Plants grown on So + CRH had the highest leaf length and longer leaf lengths suggest more provision for plant chlorophyll to trap light for photosynthetic processes (Varela et al., 2013).

The lowest LAI in terms of growth media was observed with cucumber plants grown on CP. This agrees with the work of Sosu (2014), who found an increase with soil mixed with charred rice husk as compared to soil and soilless media as regards leaf area, plant stem girth, plant height, root dry weight and total dry weight. The result does not however agree with that of Nikrazm *et al.* (2011), who stated that, cocopeat was better than inorganic substrates as regards lily flower leaf area. Mends–Cole et al. (2019), mentioned that flower abortion is seriously affected by genotype and environmental conditions. During the period of the research, the temperature and relative humidity remained within the normal range required for cucumber productivity, ranging from 29.3 – 35.9oC and 54% - 73.4% respectively. The high rate of abortion in plants grown on So + CRH could however be linked to disease infestation.

**4.3 Cost-Benefit-Analysis**

The highest profitability associated with So was due to the low production cost. CP had the highest benefit as it produced the highest number of fruit, although the BCR was lower than So. The low BCR as compared to that of soil is due to high initial cost as compared to the other media. Although, the cost incurred in availing So + CRH for the research is a bit higher than that of So due to the labour involved and cost of fuel for the process of charring, it however accounted for the lowest profit which lead to low BCR, this might be due to the high rate of flower abortion associated with it in this research. The flower abortion had an effect on the total number of fruits harvested as part of the fruits that could have been harvested were lost through flower dropping. The low cost incurred in getting the rice husk conforms to the findings of Acuna *et al.* (2004), that the production cost of soilless media can be reduced if local materials are utilized. This result agrees with Ameho (2017), who obtained the lowest profit from CP and CRH grown cucumber. All media, however, had a BCR greater than one, which means making use of any of the media is profitable, and this agrees with the findings of Due (1973).

## **CONCLUSIONS AND RECOMMENDATIONS**

CP highly facilitated plant growth as it accounted for the highest plant height and number of flowers. However, So + CRH had the best performance in terms of leaf area index. Plants grown on So had the highest chlorophyll content. Although So + CRH did relatively well for some of the growth indices, it gave the highest flower abortion. Plants grown on So accounted for the highest benefit–cost ratio. CP and So + CRH grown cucumber performed best in terms of most of the growth indices, Soil is better used in greenhouses when it is mixed with charred rice husk (75:25), most importantly in areas like Northern Ghana, where rice husk is readily available. Due to the cost implication of availing CP and the ease of assessing CRH in Ghana, more work could be done on combining CP or other soilless media with CRH as a media for cucumber cultivation, as CRH can increase the nutrient status of the plant when mixed with other media in contrast to when used alone. Hence, comparative research may be conducted in the field and greenhouse to confirm their effects in cucumber production in Ghana.

**References**

1. Acuna, R., Bonachela, S., & Magan, J. J. (2004). Response of a sweet pepper crop grown in new and two-year-old reused rockwool slabs in greenhouse on the Mediterranean coast of south-east Spain. *International Symposium on Soilless Culture and Hydroponics 697*, 189–194.
2. Adams, P. (2002). Nutritional Control in Hydroponics. In D. Savvas & H.C. Passam, eds. Hydroponic Production of Vegetables and Ornamentals, p. 211–261. EmbryoPublications, Athens, Greece
3. Ameho, C. S. (2017). Comparative effect of soilless substrates on growth, yield and fruit quality of greenhouse grown cucumber *( Cucumis sativus L .). University of Ghana http://ugspace.ug.edu.gh*. *10104146*.
4. Awang, Y., Shaharom, A. S., Mohamad, R. B., & Selamat, A. (2009). Chemical and physical characteristics of cocopeat-based media mixtures and their effects on the growth and development of Celosia cristata. *American Journal of Agricultural and Biological Sciences*, *4*(1), 63–71.
5. Barrett, G. E., Alexander, P. D., Robinson, J. S., & Bragg, N. C. (2016). Achieving environmentally sustainable growing media for soilless plant cultivation systems – A review. *Scientia Horticulturae*, *212*, 220–234. <https://doi.org/10.1016/j.scienta.2016.09.030>
6. Blanco-Canqui, H. (2017). Biochar and soil physical properties. *Soil Science Society of America Journal*, *81*(4), 687–711. <https://doi.org/10.2136/sssaj2017.01.0017>
7. Bunt, A. C. (1988). A manual on the preparation and use of growing media for pot plants. *Media and Mixes for Container Grown Plants*.
8. Carlile, W. R., Raviv, M., & Prasad, M. (2019). Organic soilless media components. *Soilless culture*, 303-378.
9. Cohen, R., Orgil, G., Burger, Y., Saar, U., Elkabetz, M., Tadmor, Y., Edelstein, M., Belausov, E., Maymon, M., & Freeman, S. (2015). Differences in the responses of melon accessions to fusarium root and stem rot and their colonization by F usarium oxysporum f. sp. radicis‐cucumerinum. *Plant Pathology*, *64*(3), 655–663.
10. Due, J. M. (1973). Project Evaluation-Economic Analysis of Agricultural Projects. J. Price Gittinger. Economic Development Institute, International Bank for Reconstruction and Development. Baltimore: John Hopkins University Press, 1972. 221 pp. $3.00. *African Studies Review*, *16*(2), 298-299.
11. Eifediyi, E. K., & Remison, S. U. (2010). Growth and yield of cucumber (Cucumis sativus L.) as influenced by farmyard manure and inorganic fertilizer. *Journal of Plant Breeding and Crop Science*, *2*(7), 216–220
12. Elings, A., Speetjes, B., & Victoria, N. G. (2015). Greenhouse designs for Mexico . Aguascalientes , Querétaro and Sinaloa. Foundation Stichting Dienst Landbouwkundig Onderzoek (DLO) research institute Wageningen UR Greenhouse Horticulture (Wageningen UR Glastuinbouw)
13. El-Wanis, M. M. A., Abdel-Baky, M. H., & Salman, S. R. (2012). Effect of grafting and salt stress on the growth, yield and quality of cucumber grown in NFT system. *Journal of Applied Sciences Research*, *October*, 5059–5067.
14. Gamliel, A., & Van Bruggen, A. H. C. (2016). Maintaining soil health for crop production in organic greenhouses. *Scientia Horticulturae*, *208*, 120–130.
15. Garba, I. I., Buhari, F. Z., & Samaila, B. K. (2020). Response of cucumber *( Cucumis sativus L .)* to differential pruning under greenhouse. *6*(March), 10–16. <https://doi.org/10.5897/JODA2020.0038>
16. Gruda, N. (2014). Impact of environmental factors on product quality of greenhouse vegetables for fresh consumption. *May*. <https://doi.org/10.1080/07352680591008628>
17. Harmann, H. T., Kester, D. E., Davies, F. T., & Geneve, R. L. (2011). *Plant propagation, principles and practices*.
18. He, M., Chen, Z., Sakurai, K., Iwasaki, K., Shen, Y., & Zhou, J. (2003). Effect of differences in substrate formulations on cucumber growth under soilless bag culture in greenhouse. *Soil Science and Plant Nutrition*, *49*(5), 763–767.

<https://doi.org/10.37421/2168-9768.2023.14.365>

1. Ibeawuchi, I. I., Iheoma, O. R., Obilo, O. P., & Obiefuna, J. C. (2008). Effect of time of mulch application on the growth and yield of cucumber (Cucumis sativus) in Owerri, Southeastern Nigeria. *Life Science Journal*, *5*(1), 68–71.
2. Kämpf, A. N., Allen Hammer, P., & Kirk, T. (1997). Effect of the packing density on the mechanical impedance of root media. *International Symposium on Growing Media and Hydroponics 481*, 689–694.
3. Kareem, M. O., Liman, A. H., Odofin, A. J., Azeez, B. A., Musa, B. M., & Jimoh, L. T. (2025). Soil Organic Carbon, Cation Exchange Capacity, and Maize (Zea mays) Response to Biochar and Nitrogen Fertilizer Amendments. *Journal of Scientific Research and Reports*, *31*(5), 278–283. <https://doi.org/10.9734/jsrr/2025/v31i53025>
4. Kareem, M.O, AG Shaibu, M Samoura, & IK Dzomeku. (2023). Yield and Yield Components of Greenhouse Cucumber as Affected by irrigation Regimes and Growth Media. *Irrigation & Drainage Systems Engineering*, *12*(1), 1–4. https://doi.org/10.37421/2168-9768.2023.14.365
5. Kumar, P., Chauhan, R. S., & Grover, R. K. (2015). Comparative economics of cucumber cultivation under polyhouses and open field conditions in Haryana. *Indian Journal of Economics and Development*, *3*(7), 1–4.
6. Lehmann, J., & Rondon, M. (2006). *Bio-Char Soil Management on Highly Weathered Soils in the Humid Tropics*. 517–529. <https://doi.org/10.1201/9781420017113.ch36>
7. Liman, A. H. (2024a). Effect of Biochar Application Rates on Crop Performance and Soil Quality. New Mexico State University ProQuest Dissertations & Theses,  2024. 31635133. <https://www.proquest.com/openview/a435324bd23e873e1cb5d6f650a37777/1?cbl=18750&diss=y&pq-origsite=gscholar>
8. Liman, A., Darapuneni, M., Angadi, S. V., Idowu, O. J., Steiner, R., & Lauriault, L. M. (2024b). Effect of Biochar Application Rates on Winter Canola (Brassica napus L) Growth, Yield, and Soil Quality Under Controlled Environmental Conditions. [Abstract]. ASA, CSSA, SSSA International Annual Meeting, San Antonio, TX. <https://scisoc.confex.com/scisoc/2024am/meetingapp.cgi/Paper/163899>
9. Mends-Cole, M. T., Banful, B. K., & Tandoh, P. K. (2019). Flower abortion and fruit yield responses of two varieties of chilli pepper (Capsicum frutescens L.) to different planting dates and plant densities. *Archives of Current Research International*, *16*(1), 1-11.
10. Motsara, M. R. (2015). Guide to laboratory establishment for plant nutrient analysis. Scientific Publishers.
11. Nikrazm, R., Ajirlou, S. A., Khaligy, A., & Tabatabaei, S. J. (2011). Effects of different media on vegetative growth of two Lilium cultivars in soilless culture. *Journal of Science and Technology of Greenhouse Culture*, *2*(6), 1–9.
12. Nyle, C. B., & Ray, R. W. (1999). The nature and properties of soils.(12) th. *Pren. Hall. New Jersey*, 881.
13. Sonneveld, C., & Voogt, W. (2009). Plant nutrition in future greenhouse production. In *Plant nutrition of greenhouse crops* (pp. 393–403). Springer.
14. Sosu, G. (2014). Growth of cocoa seedlings as affected by different growth media and different polybag sizes. *For the award of MPHIL ( Crop Science ) degree*. *University of Ghana http://ugspace.ug.edu.gh 10396680*.
15. Varela, O., Rivera, E. B., Huang, W.-J., Chien, C., & Wang, Y.-M. (2013). Agronomic properties and characterization of rice husk and wood biochars and their effect on the growth of water spinach in a field test. *Journal of Soil Science and Plant Nutrition*, *13*(2), 251–266.
16. Waller, P., & Yitayew, M. (2016). Open Channel Flow. *Irrigation and Drainage Engineering*, 185-207.
17. Wang, S., Guo, W., Gao, F., Wang, Y., & Gao, Y. (2018). Lead and uranium sorptive removal from aqueous solution using magnetic and nonmagnetic fast pyrolysis rice husk biochars. *RSC advances*, *8*(24), 13205-13217.