Acta Biologica Szegediensis

Volume 68(1):31-37, 2024
Acta Biologica Szegediensis
http://abs.bibl.u-szeged.hu/index.php/abs

DOI:10.14232/abs.2024.1.31-37

ARTICLE

# Effect of palm peat as an alternative substrate for coconut peat on the morpho-physiological parameters of *Cucumis sativus* L. (Cucurbitaceae)

Iraj Azizi[1] and Mohammad Asadi[2],*

[1]Department of Horticultural Science, Faculty of Agriculture and Natural Resources, University of Mohaghegh Ardabili, Ardabil, Iran
[2]Kermanshah Agricultural and Natural Resources Research and Education Center, AREEO, Kermanshah, Iran

**ABSTRACT** Soilless cultivation offers a viable alternative to soil-based methods for greenhouse crops. Palm peat has potential as an organic substrate in hydroponic systems, providing an alternative to conventional substrates like coconut peat. *Cucumis sativus* (cucumber) is a widely cultivated plant with significant nutritional value globally. This study evaluated the effects of two substrates—palm peat and coco peat—compared to soil (control) on the morphological and physiological characteristics of cucumber plants under greenhouse conditions in a completely randomized design. Key parameters, including plant height, number of lateral branches, leaf number and diameter, and fruit number and width were assessed at three intervals (15, 45, and 70 days). Additional parameters were measured on the 60th day. Analysis of variance (ANOVA) revealed significant differences in the physical and biochemical properties of the substrates, including EC, BD, pH, CEC, and WHC. Significant treatment effects were also observed on plant height, number of lateral branches, root fresh weight, leaf number and diameter, fruit number, width, and weight, as well as proline content. However, differences in relative water content (RWC), root dry weight, chlorophyll, and carotenoid content were not significant. This study highlights the positive influence of cultivation substrates on cucumber growth and development. Palm peat emerged as a promising cost-effective alternative to coco peat in soilless cultivation systems.
**Acta Biol Szeged 68(1):31-37 (2024)**

**KEY WORDS**
coco peat
cucumber
hydroponic
palm peat
soilless cultivation

**ARTICLE INFORMATION**
**Submitted**
20 August 2024
**Accepted**
28 December 2024
***Corresponding author**
E-mail: assadi20@gmail.com

## Introduction

The field of agriculture has undergone significant transformations in recent years, driven by advancements in science, economics, and technology (Wang et al. 2016). These changes, alongside a growing global population and improved living standards, have increased the demand for food production. As a result, controlled cultivation systems, particularly those prioritizing soilless methods, have emerged as essential strategies to meet this demand efficiently (Karakaş et al. 2017).

Traditional soil-based agriculture, while essential, poses several environmental challenges. Issues such as soilborne pests, increased salinity, chemical residues, and irrigation inefficiencies contribute to reduced crop yields and degraded ecosystems (Olympios 1999). These challenges highlight the need for alternative cultivation methods that mitigate these limitations.

Soilless agriculture offers a promising solution in areas where soil quality is poor or nonexistent. It eliminates problems such as soil fatigue, pests, and diseases while optimizing resource use, including water and fertilizers. By enabling year-round production, soilless systems enhance food security especially in regions unsuitable for traditional farming methods (Putra et al. 2015). This cultivation approach can be categorized into substrate culture (using artificial, mineral, organic, or mixed growing media) and hydroponics (where roots are immersed in nutrient solutions) (Savvas et al. 2013).

Among organic substrates, wood-based materials like pine bark, palm bark, and wood fibers offer advantages such as improved aeration and high water retention capacity, which reduce the need for frequent irrigation (Yang et al. 2023). Two irrigation methods are commonly used in hydroponic systems: open systems, where surplus water and nutrients are discarded (~25%), and closed systems which recirculate water and nutrients. Substrates for soilless systems must be inert and have excellent water-holding and release capacities to maintain optimal water

**Table 1.** Nutritional program of cucumber plants based on the method of Badgery-Parker (2015). Nutrient concentrations are expressed in mg $L^{-1}$ (ppm).

| Week | N-NO3 | N-NH4 | P | K | Ca | Mg | Fe | Mn | Zn | Cu | B | Mo | Expected EC (mS/cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-6 | 72 - 182 | 3 - 30 | 69 - 275 | 275 - 300 | 95 | 25 | 1.4 | 0.4 | 0.08 | 0.02 | 0.26 | 0.012 | 1.3 - 1.95 |
| 6-17 | 182 - 194 | 30 | 69 | 313 -351 | 95 | 25 | 1.4 | 0.4 | 0.08 | 0.02 | 0.26 | 0.012 | 1.95 - 2 |
| 17-end | 170 - 182 | 30 | 69 | 275 - 313 | 95 | 25 | 1.4 | 0.4 | 0.08 | 0.02 | 0.26 | 0.012 | 1.95 |

and nutrient levels, preventing plant stress (Burrage 1998).

Inorganic substrates, such as vermiculite and perlite, are valued for their high porosity but are more costly compared to organic options (Goddek et al. 2019). A sustainable alternative is the use of agricultural waste, such as date palm residues, which are abundant in many countries, including Iran. These residues—leaves, branches, stem bark, and fronds—have suitable physicochemical properties for soilless culture systems. Repurposing this waste as a substrate could reduce costs and environmental impact while providing a valuable resource for greenhouse crops (Mohammadi Ghehsareh et al. 2012).

*Cucumis sativus* L. (cucumber), a member of the Cucurbitaceae family, is an important crop globally, ranking as the third most cultivated vegetable. Native to southern Asia and northern Africa, it thrives in warm and humid conditions but is sensitive to environmental stressors, which can limit its yield and quality (Wdowikowska et al. 2023; Wang et al. 2015). Hydroponic systems have proven effective in mitigating these challenges.

This study aimed to compare the morpho-physiological responses of cucumber plants grown in two organic substrates—coco peat and palm peat—under greenhouse conditions, with soil used as the control. By evaluating the performance of these substrates, we aim to highlight the potential of palm peat as a cost-effective sustainable alternative in soilless cultivation systems.

## Materials and methods

### Experimental design

This research was conducted in the industrial greenhouse of Kowsar Pishgaman Agricultural Development Co., located in Eslamabad-e-Gharb, Iran (34.1132° N, 46.5279° E). The experiment followed a completely randomized design (CRD) with three treatments and sixteen replications. The treatments were:

1. Soil (control) consisting of a loam and sand mixture (3:1),
2. A combination of coco peat and perlite (3:1), and
3. A combination of palm waste and perlite (3:1).

Greenhouse cucumber seeds (F1 generation, Nagene variety) were purchased from Enza Zaden Company, Netherlands. Environmental conditions in the greenhouse, including temperature (18–30 °C), relative humidity (40–60%), and light, were controlled using an intelligent climate control system.

Cucumber seeds were first planted in seed trays filled with a mixture of coco peat and peat moss (3:1). After two weeks of optimal watering and environmental conditions, seedlings with two true leaves were transplanted to the main substrates (Fig. 1A-B). Each 35-liter bag of substrate contained four seedlings. The plants were fed according to the nutritional program outlined by Badgery-Parker et al. (2015) (Table 1). An open irrigation system with an intelligent feeding system delivered 60 cc of water per pot every 30 min.

### Plant growth parameters

During the growth period, various growth parameters were measured, including plant height, leaf diameter, leaf number, fruit number, root fresh and dry weight, and fruit weight. Seedling dry weight was determined

**Table 2.** Physical and biochemical properties of different substrates used in the study. Data are expressed as mean ± standard error (SE). Significant differences among treatments are indicated by different letters ($p < 0.05$).

| Cultivation substrate | EC (ds/m) | BD (gr/cm³) | pH | CEC (Cmol/kg) | WHC (%) |
|---|---|---|---|---|---|
| Soil | 2.38 ± 0.05 [a] | 1.45 ± 0.03 [a] | 7.35 ± 0.09 [a] | 46.50 ± 1.70 [b] | 70.75 ± 2.21 [b] |
| Palm peat | 1.78 ± 0.04 [b] | 0.16 ± 0.00 [b] | 6.90 ± 0.09 [b] | 88.25 ± 1.93 [a] | 89.00 ± 0.91 [a] |
| Coco peat | 0.84 ± 0.04 [c] | 0.14 ± 0.00 [b] | 6.25 ± 0.10 [c] | 93.25 ± 1.54 [a] | 90.00 ± 0.91 [a] |
| F value | 242.06 [s] | 1759.46 [s] | 32.38 [s] | 218.63 [s] | 53.68 [s] |

s: significant

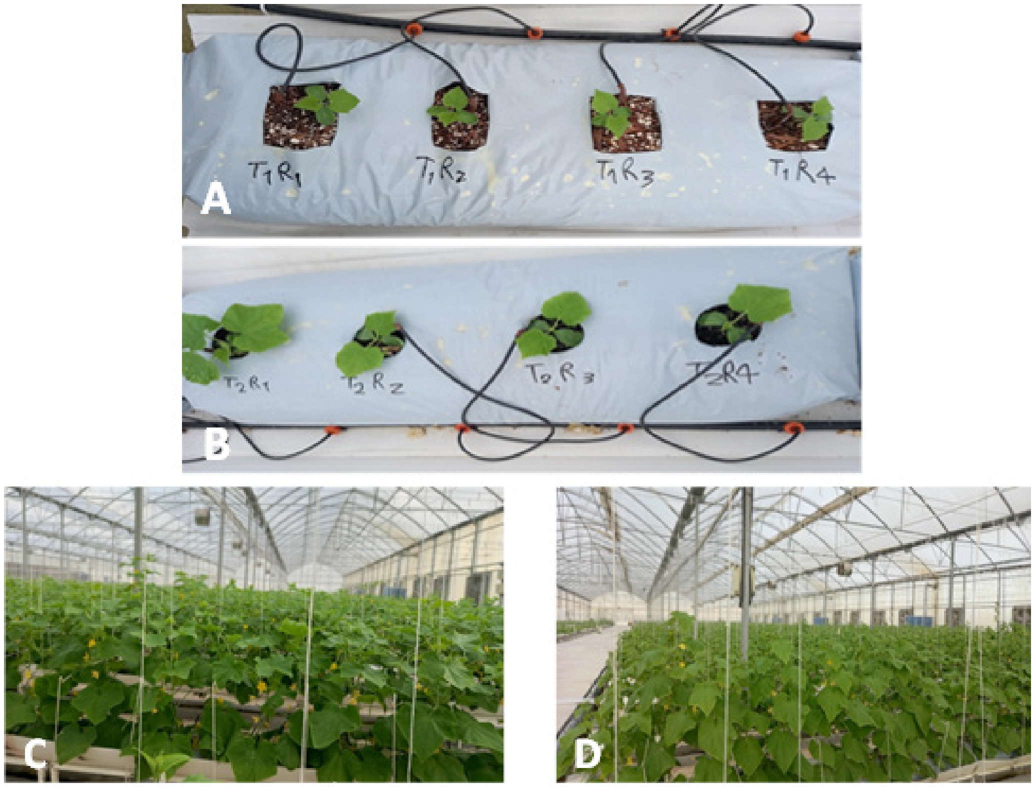


**Figure 1.** Growth stages of cucumbers in palm and coco peat substrates: (A) Seedlings in palm peat; (B) Seedlings in coco peat; (C) Cucumbers grown in palm peat after 45 days; (D) Cucumbers grown in coco peat after 45 days. Nutritional program adapted from Badgery-Parker et al. (2015).

by drying fresh seedlings in an oven at 70 °C for 72 h. After drying, a digital scale with an accuracy of 0.01 g was used to measure the dry weight.

#### *Physico-chemical analysis of substrates*

The pH and electrical conductivity (EC) of the substrates were measured using a Milwaukee pH55 PRO and EC60 PRO (Australia), respectively. Measurements were taken from a 1:5 (v/w) slurry of substrate and distilled water after stirring for 1 h. Cation exchange capacity (CEC) was determined using ammonium acetate at pH 7, as described by Masmoudi et al. (2013). Bulk density (BD) was calculated as the dry weight of the substrate divided by its total volume, including both particle and pore volumes.

#### *Relative water content (RWC)*

The relative water content of plants was determined following the method of Ritchie et al. (1990). A 0.5 g sample was taken from the youngest leaf of each plant to measure fresh weight (FW). The sample was floated in distilled water for 24 h to determine turgid weight (TW) and then dried in oven at 70 °C for 24 h to measure dry weight (DW). The RWC was calculated using the following equation:

$$\text{RWC (\%)} = \text{FW-DW/TW-DW}$$

**Table 3.** Plant height and lateral branch number of cucumbers grown in different substrates. Measurements were taken at 14, 45, and 70 days after planting. Values are presented as mean ± SE. Significant differences are denoted by different letters ($p < 0.05$).

| | Height of plant (cm) | | | Lateral branch number | | |
|---|---|---|---|---|---|---|
| **Cultivation substrate** | **14 days** | **45 days** | **70 days** | **14 days** | **45 days** | **70 days** |
| Soil | 12.93 ± 0.62 $^{c}$ | 85.43 ± 1.29 $^{c}$ | 169.43 ± 1.09 $^{b}$ | 0.00 ± 0.00 $^{b}$ | 9.56 ± 0.36 $^{c}$ | 16.50 ± 0.56 $^{b}$ |
| Coco peat | 21.87 ± 0.45 $^{a}$ | 121.62 ± 1.70 $^{a}$ | 191.18 ± 2.53 $^{a}$ | 0.93 ± 0.43 $^{a}$ | 15.62 ± 0.45 $^{a}$ | 27.62 ± 0.85 $^{a}$ |
| Palm peat | 17.25 ± 0.44 $^{b}$ | 110.68 ± 3.35 $^{b}$ | 193.06 ± 2.12 $^{a}$ | 0.00 ± 0.00 $^{b}$ | 13.81 ± 0.67 $^{b}$ | 25.25 ± 1.08 $^{a}$ |
| F value | 66.68 $^{s}$ | 65.38 $^{s}$ | 42.62 $^{s}$ | 4.69 $^{s}$ | 36.29 $^{s}$ | 46.22 $^{s}$ |

s: significant

**Table 4.** Root fresh weight and root dry weight of cucumbers grown in different substrates. Data are shown as mean ± SE. Significant differences among treatments are marked with different letters (p < 0.05).

| Cultivation substrate | Root fresh weight (gr) | Root dry weight (gr) |
|---|---|---|
| Soil | 4.72 ± 0.14 [a] | 1.40 ± 0.11 [a] |
| Palm peat | 4.14 ± 0.12 [b] | 1.18 ± 0.08 [a] |
| Coco peat | 4.43 ± 0.13 [ab] | 1.51 ± 0.08 [a] |
| F value | 4.70 [s] | 2.86 [ns] |

s: significant; ns: non-significant

### *Photosynthetic pigments*

Pigment extraction followed the method described by Najar et al. (2019). Fresh leaf material (0.5 g) was ground in 10 mL of 80% acetone and centrifuged at 5000 rpm for 15 min. The supernatant was used for pigment analysis, and absorbance was measured at 460, 645, and 663 nm using a UV spectrophotometer (Jenway, Italy). Acetone (80%) served as the blank. Pigment concentrations (mg $g^{-1}$ FW) were calculated based on absorbance values.

### *Proline content*

Proline content was determined following the method of Bates et al. (1973). A 0.5 g sample of the youngest leaves was homogenized in 2 mL of 3% sulfosalicylic acid. The homogenate was centrifuged at 2000 g for 5 min, and the filtrate was mixed with equal volumes of ninhydrin and glacial acetic acid in a test tube. The mixture was incubated in a water bath at 100 °C for 1 h, and the reaction was terminated by cooling the tube in an ice bath. The solution was extracted with toluene, and absorbance was measured at 520 nm using a spectrophotometer. Proline content was calculated from a standard curve of L-proline and expressed as µg per g of fresh leaf weight.

### *Statistical analysis*

Sixteen replications were conducted for each cultivation substrate. Data were tested for normality before analysis. Normally distributed data were analyzed using one-way ANOVA, and means were compared using Tukey's test at a significance level of $p < 0.05$. Statistical analyses were performed using SPSS software (version 22).

## Results

The results of the physical and biochemical properties of the three substrates are presented in Table 2. Significant differences were observed in EC among all substrates, while the BD values for palm peat and coco peat were not significantly different. Regarding pH, soil exhibited the highest value, and all differences were significant. The CEC values of palm peat and coco peat showed no significant difference, while both were higher than soil. For WHC, palm peat and coco peat demonstrated similar capacities.

Table 3 presents data on plant height and lateral branch number for cucumbers grown in different substrates across three time points. On day 14, the plant height was highest in coco peat and lowest in soil. This trend was consistent on day 45; however, by day 70, no significant difference in plant height was observed between coco peat and palm peat. Lateral branch numbers were higher in coco peat on days 14 and 45. By day 70, there was no significant difference between coco peat and palm peat.

Table 4 displays the results for root fresh and dry weight. Root fresh weight differed significantly among all substrates, with soil showing the highest value and palm peat the lowest. For root dry weight, no significant differences were observed among the substrates.

Table 5 summarizes the leaf number and diameter for cucumbers grown in different substrates across three time points. On day 14, coco peat yielded the highest leaf number, while soil had the lowest. This pattern persisted on day 45. By day 70, no significant difference in leaf number was observed between coco peat and palm peat. Leaf diameter was higher in coco peat across all three time points, though no significant differences were detected between coco peat and palm peat on days 45 and 70.

**Table 5.** Leaf number and diameter of cucumber plants grown in different substrates at three growth stages (14, 45, and 70 days after planting). Data represent mean ± SE, with significant differences indicated by different letters (p < 0.05).

| | Leaf number | | | Leaf diameter (cm) | | |
|---|---|---|---|---|---|---|
| Cultivation substrate | 14 days | 45 days | 70 days | 14 days | 45 days | 70 days |
| Soil | 2.68 ± 0.19 [b] | 12.62 ± 0.32 [c] | 16.00 ± 0.50 [b] | 4.00 ± 0.17 [c] | 15.06 ± 0.34 [b] | 18.31 ± 0.26 [b] |
| Coco peat | 4.25 ± 0.32 [a] | 17.93 ± 0.46 [a] | 21.93 ± 0.51 [a] | 7.75 ± 0.45 [a] | 20.62 ± 0.60 [a] | 22.93 ± 0.52 [a] |
| Palm peat | 2.81 ± 0.20 [b] | 15.75 ± 0.58 [b] | 22.31 ± 0.47 [a] | 5.56 ± 0.30 [b] | 18.87 ± 0.55 [a] | 21.93 ± 0.60 [a] |
| F value | 12.09 [s] | 32.55 [s] | 50.61 [s] | 32.77 [s] | 30.58 [s] | 24.88 [s] |

s: significant

**Table 6.** Fruit number, length, and weight of cucumbers grown in various substrates at 14, 45, and 70 days after planting. Values are shown as mean ± SE. Different letters signify statistically significant differences ($p < 0.05$).

| | Fruit number | | | Fruit length (cm) | | | |
|---|---|---|---|---|---|---|---|
| **Cultivation substrate** | **14 days** | **45 days** | **70 days** | **14 days** | **45 days** | **70 days** | **Fruit weight (gr)** |
| Soil | 0.00 ± 0.00 $^{a}$ | 0.56 ± 0.20 $^{c}$ | 30.31 ± 0.71 $^{b}$ | 0.00 ± 0.00 $^{a}$ | 10.75 ± 0.28 $^{b}$ | 15.12 ± 0.30 $^{b}$ | 87.50 ± 2.32 $^{b}$ |
| Coco peat | 0.00 ± 0.00 $^{a}$ | 2.81 ± 0.26 $^{a}$ | 37.87 ± 0.83 $^{a}$ | 0.00 ± 0.00 $^{a}$ | 13.75 ± 0.23 $^{a}$ | 17.06 ± 0.35 $^{a}$ | 108.12 ± 2.40 $^{a}$ |
| Palm peat | 0.00 ± 0.00 $^{a}$ | 1.75 ± 0.19 $^{b}$ | 38.93 ± 0.76 $^{a}$ | 0.00 ± 0.00 $^{a}$ | 13.12 ± 0.25 $^{a}$ | 16.50 ± 0.27 $^{a}$ | 108.75 ± 2.39 $^{a}$ |
| F value | 0.00 $^{ns}$ | 25.78 $^{s}$ | 36.85 $^{s}$ | 0.00 $^{ns}$ | 37.75 $^{s}$ | 10.11 $^{s}$ | 25.87 $^{s}$ |

s: significant; ns: non-significant

Table 6 provides data on fruit number, length, and weight. On day 14, differences in fruit numbers were not significant. By day 45, significant differences emerged, while on day 70, fruit numbers were not significantly different between palm peat and coco peat. Fruit length was consistently higher in coco peat across all time points, though differences between coco peat and palm peat were not significant. Fruit weight was highest in palm peat and lowest in soil.

Table 7 outlines biochemical characteristics, including RWC, chlorophyll a and b, carotenoids, and proline content. RWC showed no significant differences among treatments. Chlorophyll a, chlorophyll b, and carotenoid content were highest in coco peat and lowest in soil, though differences were not statistically significant. Proline content, however, differed significantly, with coco peat and palm peat showing higher values than soil.

## Discussion

Soilless culture offers an innovative approach to plant cultivation, eliminating the need for soil as a rooting medium. This method ensures a controlled environment where essential nutrients are delivered through irrigation (Putra and Yuliando 2015). Horticultural products grown under soilless conditions often exhibit superior quality compared to those grown in conventional soil-based systems. For high-value crops such as cucumbers, tomatoes, and peppers, soilless culture presents a viable alternative to traditional methods (Asaduzzaman 2015).

The physicochemical parameters analyzed in this study revealed that palm peat and coco peat substrates offer significant advantages over soil. Both substrates demonstrated lower BD and higher WHC compared to soil, indicating improved water and air penetration around the roots. These findings align with Mohammadi Ghehsareh et al. (2012), who also reported enhanced water retention and aeration in palm peat substrates. A suitable substrate should provide adequate anchorage, moisture, oxygen, and nutrients, facilitating optimal plant growth.

Substrate pH plays a crucial role in nutrient availability. Optimal pH levels for nutrient uptake range from 5.5 to 6.0 (Krumrei 2019). In this study, soil had the highest pH (7.35), while palm peat and coco peat fell within the optimal range (6.9 and 6.25, respectively). High pH levels can reduce the availability of micronutrients such as Mn, Cu, Zn, and Fe, potentially impacting plant growth. Similarly, EC values, indicative of nutrient supply and salt stress risk, were highest in soil and lowest in coco peat. These results align with Elabed et al. (2022), who observed similar trends in melon cultivation.

The higher CEC values of palm peat and coco peat compared to soil suggest superior nutrient retention and availability. This characteristic is essential for sustained nutrient supply in soilless systems. Enhanced vegetative

**Table 7.** Relative water content (RWC), chlorophyll a and b, carotenoid, and proline content in cucumber plants grown under different substrate treatments. Data are expressed as mean ± SE. Significant differences ($p < 0.05$) are indicated by different letters.

| **Cultivation substrate** | **RWC (%)** | **Chlorophyll a (mg.100g FW$^{-1}$)** | **Chlorophyll b (mg.100g FW$^{-1}$)** | **Carotenoid (mg.100g FW$^{-1}$)** | **Proline (µg.100g FW$^{-1}$)** |
|---|---|---|---|---|---|
| Soil | 73.18 ± 1.86 $^{a}$ | 29.61 ± 0.47 $^{a}$ | 9.66 ± 0.22 $^{a}$ | 6.93 ± 0.16 $^{a}$ | 2.40 ± 0.10 $^{b}$ |
| Coco peat | 73.56 ± 1.94 $^{a}$ | 30.20 ± 0.46 $^{a}$ | 10.32 ± 0.23 $^{a}$ | 7.34 ± 0.18 $^{a}$ | 3.04 ± 0.12 $^{a}$ |
| Palm peat | 70.06 ± 1.23 $^{a}$ | 29.62 ± 0.48 $^{a}$ | 10.05 ± 0.20 $^{a}$ | 7.10 ± 0.15 $^{a}$ | 2.71 ± 0.13 $^{ab}$ |
| F value | 1.46 $^{ns}$ | 0.50 $^{ns}$ | 2.26 $^{ns}$ | 1.50 $^{ns}$ | 7.28 $^{s}$ |

s: significant; ns: non-significant

growth parameters—such as plant height, leaf number, and fruit weight—observed in palm peat and coco peat substrates further support their suitability as alternatives to soil. Notably, the differences in vegetative growth parameters between palm peat and coco peat were not significant by day 70, indicating that palm peat is a viable, cost-effective alternative.

Proline content, an important osmolyte, was significantly higher in palm peat and coco peat substrates compared to soil. Proline aids in water balance regulation, root and shoot growth, and oxidative stress mitigation. The findings of this study corroborate those of Aydi et al. (2023), who reported enhanced growth characteristics in melon plants cultivated in palm peat and coco peat substrates. Conversely, photosynthetic pigments and RWC did not show significant differences among treatments, consistent with Islam et al. (2002).

## Conclusion

This study demonstrates the potential of palm peat as a soilless substrate for cucumber cultivation. Compared to soil, palm peat significantly enhanced growth parameters, including plant height, leaf number, and fruit weight. While coco peat exhibited slightly better performance in some aspects, the differences were not statistically significant, suggesting that palm peat is a viable, cost-effective alternative for soilless cultivation systems.

## References


Asaduzzaman M (2015) Soilless culture: use of substrates for the production of quality horticultural crops. BoD – Books on Demand, InTech Publisher, Rijeka, Croatia.

Aydi S, Sassi Aydi S, Rahmani R, Bouaziz F, Souchard JP, Merah O, Abdelly C (2023) Date-palm compost as soilless substrate improves plant growth, photosynthesis, yield and phytochemical quality of greenhouse melon (*Cucumis melo* L.). Agronomy 13(1):212.

Badgery-Parker J, James L, Jarvis J, Parks S (2015) Commercial Greenhouse Cucumber Production, 2010 Edition, NSW Agriculture.

Bates LS, Waldren RPA, Teare ID (1973) Rapid determination of free proline for water-stress studies. Plant Soil 39:205-207.

Burrage SW (1998) Soilless culture and water use efficiency for greenhouses in arid, hot climates. In: International Workshop on Protected Agriculture in the Arabian Peninsula, Doha (Qatar), 15-18 Feb 1998, ICARDA.

Elabed N, Bouaziz F, Bouri M, Boukhris A, Aydi S, Belkadhi MS (2022) Date palm waste compost: a promising alternative for coconut fiber as growing media of melon. Ital Hort 29:26-34.

Goddek S, Joyce A, Kotzen B, Burnell GM (Eds.) (2019) Aquaponics food production systems: Combined aquaculture and hydroponic production technologies for the future. Springer Cham, pp. 619.

Islam S, Khan S, Ito T, Maruo T, Shinohara Y (2020) Characterization of the physico-chemical properties of environmentally friendly organic substrates in relation to rockwool. J Horti Sci Biotech 77(2):43-148.

Karakaş C, Özçimen D, İnan B (2017) Potential use of olive stone biochar as a hydroponic growing medium. J Analyt Appl Pyrolys 125:17-23.

Krumrei M (2019) Hydroponics: Effect of pH on Different Cucumber Varieties. Undergraduate Thesis, University of Nebraska, Lincoln, USA.

Masmoudi S, Jarboui R, El Feki H, Gea T, Medhioub K, Ammar E (2013) Characterization of olive mill wastes composts and their humic acids: stability assessment within different particle size fractions. Enviro Techn 34(6):787-797.

Mohammadi Ghehsareh A, Hematian M, Kalbasi M (2012) Effect of date palm wastes and rice hull mixed with soil on growth and yield of cucumber in greenhouse culture. Int J Recycl Org Waste Agric 2:17.

Najar R, Aydi S, Sassi-Aydi S, Zarai A, Abdelly C (2019) Effect of salt stress on photosynthesis and chlorophyll fluorescence in *Medicago truncatula*. Plant Biosys 153(1):88-97.

Olympios CM (1999).Overview of soilless culture: advantages, constraints, and perspectives. In Choukr-Allah R (Ed.), Protected Cultivation in the Mediterranean Region, CIHEAM/IAV Hassan II, Paris, Europe, pp. 307 -324.

Putra PA, Yuliando H (2015) Soilless culture system to support water use efficiency and product quality: a review. Agri Sci Proc 3:283-288.

Ritchie SW, Nguyen HT, Holaday AS (1990) Leaf water content and gas-exchange parameters of two wheat genotypes differing in drought resistance. Crop Sci 30(1):105-111.

Savvas D, Gianquinto G, Tuzel Y, Gruda N (2013) Soilless culture. In Good Agricultural Practices for Greenhouse Vegetable Crops. FAO Plant Production and Protection Paper 217 (Rome, Italy: FAO), 303-354.

Wang D, Gabriel MZ, Legard D, Sjulin T (2016) Characteristics of growing media mixes and application for open-field production of strawberry (*Fragaria ananassa*). Sci Horti 198:294-303.

Wang SL, Ku SS, Ye XG, HE CF, Kwon SY, Choi PS (2015) Current status of genetic transformation technology developed in cucumber (*Cucumis sativus* L.). J Integ Agri 14(3):469-482.

Wdowikowska A, Reda M, Kabała K, Chohura P, Jurga A, Janiak K, Janicka M (2023) Water and nutrient recovery for cucumber hydroponic cultivation in simultaneous biological treatment of urine and grey water. Plants 12(6):1286.

Yang T, Altland JE, Samarakoon UC (2023) Evaluation of substrates for cucumber production in the Dutch bucket hydroponic system. Sci Horti 308:111578.