J. Trop. Agric. and Fd. Sc. 53 (1)(2025): 83 – 93

Peat blocks: An innovative nursery medium vs. peat moss for enhancing chilli (*Capsicum annuum* L.) seedling growth under nursery conditions

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Abstract

The selection of an appropriate nursery medium is crucial for optimising seedling growth and development in chilli (*Capsicum annuum* L.) This study evaluated the influence of peat blocks and peat moss on seedling growth dynamics under nursery conditions. A randomised complete block design (RCBD) with four replications was conducted at the Horticulture Research Centre, MARDI, Serdang, Malaysia. Growth parameters, including plant height, stem diameter, number of leaves, and leaf area, were assessed over 12 weeks after sowing (WAS). Results demonstrated that seedlings grown in peat blocks exhibited significantly greater plant height (52.46 cm), stem diameter (0.65 cm), number of leaves (29.00), and leaf area (524.54 cm^2) compared to those in peat moss. Growth rate modelling using the sigmoidal equation $y = A/(1+be^{-cx})$ revealed that peat blocks-grown seedlings had a higher potential maximum value for all parameters, indicating sustained and accelerated growth. Chlorophyll content and fluorescence measurements further suggested better physiological responses in peat blocks-grown seedlings. These findings highlight the potential of peat blocks as an innovative and efficient alternative to traditional peat moss for enhancing *Capsicum annuum* L. seedling growth in nursery conditions.

Keywords: *chilli, nursery media, peat blocks, peat moss, seedling growth*

Introduction

Chilli (*Capsicum annuum* L.) is a well-known vegetable crop in Malaysia, widely used in local cuisine and commercially cultivated (Razaly et al. 2024). Originally from Mexico and South America, chilli is now grown in many tropical regions. It is an important ingredient in various dishes, especially in Asian countries such as Malaysia, India, and Bangladesh (Singh et al. 2021). Chilli farming contributes significantly to Malaysia's agricultural economy, with red chilli (locally known as Cili Kulai) being one of the main varieties cultivated for both domestic consumption and export markets (Karungi et al. 2013). In Malaysia, chilli is ranked among the top three vegetable crops in terms of cultivation area and production value. However, local production remains insufficient to meet domestic demand, leading to a high dependency on imports. According to the Department of Agriculture Malaysia [Department of Agriculture (DOA) 2024], chilli cultivation covers approximately 3,197 hectares nationwide, with a production volume of 41,949 metric tons, yet the self-sufficiency ratio remains low at 37.1%, highlighting the strategic importance of enhancing local chilli production to improve national food security [Department of Statistics Malaysia (DOSM) 2024].

In Malaysia, chilli cultivation is predominantly carried out using fertigation systems in polybags, particularly within controlled nursery and greenhouse environments, though conventional soil-based planting is still practiced in open-field systems. Given this diversity, the use of effective nursery media is crucial to support early-stage seedling performance, ensuring healthy establishment before transplanting. The choice of nursery media plays an important role in plant development, providing structural support for roots, retaining water, and delivering nutrients during critical growth phases (Tupe et al. 2021; Badreshiya 2024).

In the early development of *Capsicum annuum* L., each growth stage has specific environmental and nutritional requirements. The germination stage (0 – 10 days after sowing, DAS) requires a moist and stable substrate for successful emergence. The seedling stage (10-30 DAS) demands stable root anchorage and moderate nutrient availability, while the vegetative stage (30-60 DAS)

Article history
Received: 12.3.2025
Accepted: 1.7.2025

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involves rapid shoot growth supported by improved aeration and nutrient uptake. Flowering and fruit setting (60-90 DAS) depend on balanced moisture and nutrient supply, followed by the maturity stage beyond 90 DAS. Thus, the nursery medium selected, particularly during germination and early vegetative stages must provide sufficient water holding capacity, aeration, and a conducive structure to facilitate vigorous root growth and overall seedling vigour. (Mandie 2022; Lemma 2022; Nadoda et al. 2023).

Typically, nursery media formulations incorporate a combination of peat soil, decomposed organic matter, bark, wood fibre, and coir to optimise physical and chemical properties (Schmilewski 2008). Among these components, peat moss remains a favoured choice owing to its high water retention ability (68 – 72%) and excellent aeration characteristics, both of which support rapid root proliferation (Kumar 2015; Ab Kahar et al. 2018). Furthermore, the slightly acidic pH (3.5 – 3.8) and low intrinsic nutrient content of peat moss offer flexibility for farmers to customise fertilisation regimes according to specific crop requirements. These properties collectively contribute to peat moss's widespread adoption as a primary constituent of nursery media formulations (Rozas et al. 2023).

As an alternative, the MARDI developed and patented a peat blocks formulation in 2018. These blocks are custom-made from locally sourced peat and are compacted into standardised forms using biodegradable binding agents. They are pre-fertilised with starter nutrients to support early seedling growth, reducing the need for early supplemental fertilisation. In contrast, peat moss is typically imported from countries such as the Netherlands and Canada, where large peatlands are harvested. Although peat moss offers excellent water retention and aeration properties, concerns have been raised over its environmental sustainability due to carbon emissions associated with its extraction and long-distance transportation. Peat blocks, being produced locally, offer a more cost-effective and environmentally sustainable alternative by minimising import dependence and reducing carbon footprint. The structure of the peat blocks encourages strong root development with good aeration, while air pruning at the block edges promotes the formation of fibrous and healthy root systems (Hanim et al. 2018; Sebrina Shahniza et al. 2024).

Given the critical role of nursery media in early plant development, this study aims to evaluate the effectiveness of locally formulated peat blocks, compared to conventional peat moss, in supporting the growth and physiological performance of chilli (*Capsicum annuum* L.) seedlings under nursery conditions.

Materials and method

Experimental site and design

The experiment was carried out at the nursery of the Horticultural Research Centre, MARDI in Serdang, Selangor, from April 1 – June 24, 2022. A randomised complete block design (RCBD) was implemented, comprising four replications, with each replication containing ten samples. The RCBD was selected to account for possible environmental variability within the nursery setting, thus improving the reliability of treatment comparisons. The study evaluated the growth performance of plants in two different nursery media comprising peat moss and peat blocks over a 12 weeks observation.

Materials used

The chilli variety tested in this study was Kulai 461. The nursery media used included peat moss and peat blocks. The peat moss, imported from the Netherlands, was used to fill 72-hole plug trays (2-inch cells; 3.4 cm diameter × 4.0 cm height). Meanwhile, the peat blocks were custom-made using in-house molders to match the 2-inch size, ensuring uniformity between the two-nursery media. The peat blocks used in this study were a patented formulation developed by MARDI, incorporating local peat and starter fertilisers into a compact structure optimised for tropical nursery conditions. Compared to standard commercial peat blocks, MARDI's peat blocks were specifically designed to enhance water retention, nutrient availability, and promote air pruning, thereby supporting more vigorous seedling growth. The proprietary peat blocks formulation is available for use and procurement through MARDI.

Management practices

Seeds were sown in trays filled with either peat moss or peat blocks and covered with black plastic for four days to promote germination. Once germinated, the seedlings were transferred to planter boxes with a water depth of 2.0 cm. For the first three weeks, they were watered with plain water. From the fourth week onward, a hydroponic nutrient solution (Hydroponics A and B) was introduced gradually, starting with an electrical conductivity (EC) of 0.5 and increasing to 2.5 by the end of the experiment. The nursery was equipped with netted structures, provided a controlled environment that reduced pest and disease pressure, ensuring stable growing conditions.

Analysis of growing media

The physical and chemical characteristics of the growing media (peat moss and peat blocks) were analysed to evaluate their impact on plant growth. Moisture content was assessed using the gravimetric method (Shukla et al. 2014), while pH was measured by saturating 100 g of the substrate with distilled water, shaking for 15 minutes, and filtering before analysis with a pH meter (Singh et al. 2019). Organic matter content was determined using the Walkey-Blacked method (Poudel 2020), whereas total organic carbon was quantified with a carbon analyser (Schumacher, 2002). Mineral nitrogen concentration was measured through potassium chloride extraction (Ma et al. 2005), while phosphorus and potassium were extracted using the Bray method and ammonium acetate, respectively (Dermawan et al. 2024). Calcium and magnesium concentrations were analysed using an inductively coupled plasma atomic emission spectrometer (ICP-AES) (Lance and Bowersox 2019).

Data collection

Plant growth and physiological responses were assessed weekly throughout the experiment. Measurements of plant height, stem diameter, number of leaves, and leaf area/plant were recorded from the first to the twelfth week after sowing (WAS). Plant height was determined using a measuring tape from the base to the apex, while stem diameter was measured at the first node with a vernier caliper. The number of fully expanded leaves was counted to track leaf dvelopment, and leaf area per plant was quantified using a LI-COR LI-300A leaf area meter. Physiological assessments began in the fourth WAP, focusing on chlorophyll content and fluorescence of the fifth fully expanded leaf. Chlorophyll fluorescence parameters were measured using a PAM-2500 Chlorophyll Fluorometer (WALZ, Effeltrich, Germany), while relative chlorophyll content was evaluated with a SPAD502 meter (Konica Minolta Optic Inc. Tokyo, Japan). These measurements provided a comprehensive analysis of the plants' vegetative growth and physiological performance under different treatments.

Statistical analysis

The Logistic Growth Model, used to analyse plant growth parameters such as plant height, stem diameter, number of leaves, and leaf area index (Schacht 1980), models the relationship between these parameters and time (weeks after sowing, WAS). The data are non-linearly regressed using the equation $y = A/(1 + be^{-cx})$, where y represents the growth parameter, A is the potential maximum value, b is a time scale constant, c is the growth rate, x is time, and e is the error term. The model is symmetric around its asymptotes, with the lower asymptote being 0 and the upper asymptote approaching y = A. At the initiation of growth (x = 0), the parameter value is predicted as y = A(1 + b). The growth rate for each parameter is estimated by the derivative of the growth function, $[dy/dx = (Abce^{-cx})/1 + be^{-cx})^2]$, using the variables y, x, A, b, and c. This model offers valuable insights into the dynamic growth patterns of plants, helping to predict growth rates and understand their development stages.

Data on media differences for each growth parameter, collected weekly from the first to the twelfth week after sowing, were analysed using a two-sample independent t-test in SAS software (Version 9.4, SAS Institute Inc., Cary, North Carolina, USA) at a significance level of $P \leq 0.05$. The t-test was selected as the appropriate statistical method for comparing means between two treatment groups.

Results and discussion

Physico-chemical properties of growing media

The physical and chemical characteristics of the growing media significantly influenced seedling performance (*Table 1*). Peat moss exhibited a higher moisture content (67.0%) compared to peat blocks (56.0%) ($P \leq 0.05$), which may have contributed to better initial germination. Optimal germination rates are typically observed when soil moisture content ranges between 20 – 40%, and excessive moisture levels can reduce oxygen availability, potentially affecting root development (Hou et al. 2022). Despite high moisture retention, the media were covered during the first week of germination, preventing direct waterlogging and facilitating seed coat softening, which enhances embryo growth.

Both peat moss and peat blocks contained high organic matter content, with no significant difference between peat moss containing (76.02%) and peat blocks (91.3%). High organic matter is beneficial for microbial activity, nutrient retention and moisture balance, contributing to overall seedling growth. The pH values of peat moss (5.83) and peat blocks (6.09) differed significantly ($P \leq 0.05$), with peat blocks exhibiting a slightly acidic conditions, which are generally favourable for chilli seedling growth (Uchida, 2000). The total organic carbon content was comparable between the two media (43.4% for peat moss and 43.7% for peat blocks), with no significant difference, and both exceeding the 12-18% classification threshold for organic growing media [Food Agriculture Organisation (FAO) 2017]. Peat blocks contained significantly higher nitrogen (5,520 mg/kg) compared to peat moss (3,320 mg/kg) ($P \leq 0.05$), exceeding the 2,700 mg/kg threshold required for effective seedling development (Sengxua et al. 2012). Similarly, peat blocks had significantly higher nitrate concentration (13,800 mg/kg vs. 10.2 mg/kg in peat moss), potassium (0.3% vs. 0.1%), calcium (19,800 mg/kg vs. 19,000 mg/kg), and magnesium (3,350 mg/kg vs. 2,380 mg/kg) than peat moss. These differences are

Table 1. Effect of different nursery media on the physico-chemical properties of media

Nursery media	Physical properties			Chemical properties						
	Moisture ontent (%)	Organic matter (%)	pH	Total organic carbon (%)	Total nitrogen as N (mg/kg)	Nitrate (Solution) (mg/kg)	Phosphorus (%)	Potassium (%)	Calcium mg/kg)	Magnesium (mg/kg)
Peat moss	67.0b	91.5a	5.83b	43.4a	3,320b	10.2b	<0.1a	<0.1b	19,000a	2,380b
Peat blocks	56.0a	91.3a	6.09a	43.7a	5,590a	13,800a	<0.1a	0.3a	19,800a	3,350a

Means with different letters within each column is significantly different at $P \leq 0.05$ based on two-sample t-test analysis likely due to the addition of fertilisers in the peat blocks formulation thus enhancing nutrient availability (Ab Kahar et al. 2018).

Growth of plant height

Effect of nursery media on plant height

The plant height of *Capsicum annuum* L. was significantly influenced by the type of nursery media used, as shown in *Table 2*. Plants grown in peat moss were significantly taller from 1 to 3 weeks after sowing (WAS), with peat moss plants reaching 5.20 cm, 8.08 cm, and 13.14 cm at 1, 2, and 3 WAS, respectively, compared to 4.23 cm, 7.68 cm, and 12.21 cm for peat blocks. However, from 4 WAS onwards, seedlings grown in peat blocks exhibited significantly greater height, culminating in a final height of 52.46 cm at 12 WAS compared to 51.45 cm in peat moss.

The initial advantage of peat moss during the early weeks can be attributed to its superior moisture retention, which supported early root establishment and seedling shoot growth. As plants entered the active vegetative growth phase (4-8 WAS and beyond), the superior aeration and nutrient-supply properties of peat blocks, particularly the higher nitrogen and calcium contents, likely became more critical, promoting enhanced shoot elongation and final plant height (Hariyono et al. 2021; Aslam et al. 2022).

This pattern is consistent with the known growth stages of chilli, where early vegetative development (up to approximately 30 DAS) prioritises water availability, whereas later stages (30-60 DAS) increasingly depend on nutrient uptake and root aeration to support rapid vegetative expansion (Balliu et al. 2021; Khedkar et al. 2023).

Growth rate dynamics of plant height

Table 3 illustrates the growth rate dynamics of *Capsicum annuum* L. over 12 WAS, modelled by the equation of $dy/dx = (abce^{-cx})/(1 + be^{-cx})^2$. The results indicate that peat blocks promoted a faster early-stage growth compared to peat moss. The peak growth rate occurred at 2 WAS for peat blocks-grown seedlings (77.84 cm/week) and at 3 WAS for peat moss-grown seedlings (63.00 cm/week). This suggests that peat blocks facilitated early nutrient uptake and root establishment, leading to an initial surge in plant height. However, after the early growth phase, the growth rate declined steadily in both treatments. By 8 WAS, the growth rate had decreased to 3.39 cm/week in peat blocks, while peat moss maintained a relatively higher rate of 10.13 cm/week, indicating prolonged vegetative growth. By 12 WAS, both media exhibited minimal growth, with rates below 2 cm/week, marking the transition to slower height development as seedlings approached maturity.

The sigmoidal growth model $y = A/(1 + be^{-cx})$ effectively described the plant height development in both nursery media, with a high goodness-of-fit ($R^2 = 0.99$) (*Table 4*). The potential maximum plant height (A) was higher in peat blocks-grown plants (60.98 cm) than in peat moss-grown plants (50.79 cm), reinforcing the long-term growth advantage of peat blocks. The growth constant (b) was lower for peat blocks (17.57) compared to peat moss (21.54), indicating that the two media influenced plant growth differently. Additionally, the growth rate (c) was higher in peat moss (0.6723) than in peat blocks (0.4935), confirming that peat moss initially supported more rapid height expansion, while peat blocks sustained prolonged growth.

These results suggest a clear differentiation in growth dynamics: peat moss promotes steady and prolonged growth, while peat blocks provide a strong initial advantage that ultimately leads to taller plants at maturity. The higher peak growth rate observed earlier in peat blocks supports the hypothesis that they enhance root development, facilitating better nutrient absorption and seedling vigour (Gaikwad et al. 2024). However, the sustained growth observed in peat moss may be attributed to its superior moisture retention, which helps maintain consistent vegetative growth over a longer period.

Table 2. Effect of different nursery media on the plant height (cm) of *Capsicum annuum* L. over 12 weeks after sowing

Nursery media	Week after sowing											
	1	2	3	4	5	6	7	8	9	10	11	12
Peat moss	5.20a	8.08a	13.14a	17.73b	24.50b	31.94b	39.22b	46.20b	48.34b	49.51b	50.13b	51.45b
Peat blocks	4.23b	7.68b	12.21b	20.62a	29.07a	36.77a	42.50a	47.20a	49.34a	50.51a	51.13a	52.46a

Means with different letters within each column is significantly different at $P \leq 0.05$ based on two-sample t-test analysis

Table 3. Growth rates dynamics of plant height of *Capsicum annuum* L. in two types of nursery media modelled by $dy/dx = (abce^{-cx})/(1 + be^{-cx})^2$ over 12 weeks after sowing

Nursery media	Week after sowing											
	1	2	3	4	5	6	7	8	9	10	11	12
Peat moss	42.77	57.28	63.00	54.84	39.80	26.14	14.42	10.13	6.21	3.80	2.32	1.42
Peat blocks	56.78	77.84	70.86	45.46	24.87	12.94	6.64	3.39	1.73	0.89	0.45	0.23

Growth of stem diameter

Effect of ursery media on stem diameter

The stem diameter of *Capsicum annuum* L. was significantly influenced by the type of nursery media used, as shown in *Table 5*. Throughout the 12 weeks after sowing (WAS), plants grown in peat blocks consistently exhibited a larger stem diameter compared to those in peat moss. At 1 WAS, the stem diameter in peat block-grown plants was slightly larger (0.068 mm) than in peat moss (0.065 cm), and this trend persisted throughout the study. By 12 WAS, the final stem diameter in peat blocks (0.65 cm) remained marginally higher than in peat moss (0.62 mm), though the difference was less pronounced at later growth stages.

The most noticeable differences between treatments occurred during the mid-growth phase (3-8 WAS), where peat blocks-grown plants exhibited significantly greater stem thickening. This suggests that peat blocks provided a more favourable environment for structural development at crucial growth stages. The superior aeration of peat blocks may have facilitated better nutrient absorption, particularly calcium, which is essential for cell wall strengthening and vascular development (Bonomelli et al. 2021). Consequently, the increased stem diameter in peat blocks-grown plants may have contributed to improved structural stability, which is crucial for supporting future biomass accumulation and enhancing stress tolerance (Michael Meneghini et al. 2006).

Growth rate dynamics of stem diameter

The sigmoidal growth model, $y = A/(1 + be^{-cx})$ effectively described the stem diameter development in both nursery media, with a high coefficient of determination (R^2 = 0.99) (*Table 6*). The potential maximum stem diameter (A) was higher in peat block-grown plants (0.6883 mm) compared to those in peat moss (0.6539 mm), indicating that peat blocks provided a more favorable environment for long-term stem thickening. The growth constant (b) was significantly lower in peat blocks (15.65) than in peat moss (30.63), reflecting different growth dynamics between the media. Furthermore, the growth rate (c) was higher in peat moss (0.8757) than in peat blocks (0.5985), suggesting that seedlings in peat moss exhibited a more rapid early-stage increase in stem diameter but ultimately achieved a smaller final stem size compared to those in peat blocks.

The growth rate dynamics of *Capsicum annuum* L. stem diameter over 12 WAS, modelled by the equation $dy/dx = (abce^{-cx})/(1 + be^{-cx})^2$, further supported these observations (*Table 7*). The peak growth rate occurred at 2 WAS for both media, with peat blocks demonstrating a higher rate (1.67 mm/week) than peat moss (0.76 mm/week). Beyond this peak, the growth rate steadily declined, with peat block-grown plants exhibiting a sharper reduction. By 6 WAS, both media showed relatively low growth rates, with peat moss at 0.17 mm/week and peat blocks at 0.10 mm/week. By the later growth stages (8–12 WAS), the growth rates stabilized at minimal levels, indicating that stem thickening had largely plateaued.

Table 4. Growth model of plant height for *Capsicum annuum* L. in two different nursery media using the function $y = A/(1 + be^{-cx})$

Nursery media	Constants			F-value	Approx. Pr >F	Approx. R^2
	A	B	c			
Peat moss	50.7954	21.5428	0.6723	484.06	<.0001	0.99
Peat blocks	60.9841	17.5653	0.4935	245.73	<.0001	0.99

y; Plant height, A; Potential plant height, b; Constant, c; Growth rate, x; Time, e; Error

Table 5. Effect of different nursery media on the stem diameter (cm) of *Capsicum annuum* L. over 12 weeks after sowing

Nursery media	Week after sowing											
	1	2	3	4	5	6	7	8	9	10	11	12
Peat moss	0.065b	0.11b	0.17b	0.26b	0.35b	0.43b	0.50b	0.55b	0.50b	0.60b	0.61b	0.62b
Peat blocks	0.068a	0.11a	0.18a	0.27a	0.37a	0.46a	0.53a	0.58a	0.61a	0.63a	0.64a	0.65a

Means with different letters within each column is significantly different at $p \leq 0.05$ based on two-sample t-test analysis

Table 6. Growth model of plant height for *Capsicum annuum* L. in two different nursery media using the function $y = A/(1 + be^{-cx})$

Treatments	Constants			F-value	Approx. Pr >F	Approx. R^2
	A	B	c			
Peat moss	0.6539	30.6311	0.8757	570.77	<.0001	0.99
Peat blocks	0.6883	15.6508	0.5985	947.15	<.0001	0.99

y; Stem diameter, A; Potential stem diameter, b; Constant, c; Growth rate, x; Time, e; Error

These findings suggest that while peat moss facilitated a faster initial growth rate, likely due to greater water availability, peat blocks provided better long-term structural development, potentially due to enhanced nutrient supply and root anchorage (Hanim et al. 2018). The superior air porosity of peat blocks may have contributed to improved root establishment, leading to stronger and thicker stems. Peat blocks promote a more sustainable growth trajectory, supporting higher final stem diameters and greater structural stability in *Capsicum annuum* L. seedlings (Zhou et al. 2019; Mandie 2022).

Number of leaves

Effect of nursery media on number of leaves

The number of leaves in *Capsicum annuum* L. was significantly influenced by the type of nursery media used, as shown in *Table 8*. Throughout the 12 weeks after sowing (WAS), plants grown in peat blocks consistently exhibited a higher leaf count compared to those in peat moss. At 1 WAS, seedlings in peat blocks had an average of 4.01 leaves, significantly more than those in peat moss (3.77 leaves). This trend persisted throughout the growth period, with peat block-grown plants reaching 29.00 leaves at 12 WAS, compared to 28.54 leaves in peat moss.

The difference in leaf production was most pronounced during the early to mid-growth stages (3–8 WAS), suggesting that peat blocks provided a more conducive root environment for vegetative growth. The enhanced leaf expansion observed in peat block-grown plants may be attributed to better nutrient availability, particularly nitrogen, which is essential for chlorophyll synthesis and amino acid production, both of which are critical for leaf development (Lob et al. 2023; Abd Rahim et al. 2024). These findings indicate that peat blocks support superior vegetative growth, potentially leading to improved overall plant vigour and productivity.

Growth rate dynamics of number of leaves

The sigmoidal growth model, $y = A/(1 + be^{-cx})$ effectively described the leaf development pattern in both nursery media, with a high coefficient of determination ($R^2 = 0.99$) (*Table 9*). The potential maximum number of leaves (A) was higher in peat block-grown plants (45.02) compared to those in peat moss (36.85), indicating a greater leaf-bearing capacity. The growth rate constant (c) was also higher in peat blocks (0.3099) than in peat moss (0.2674), suggesting a faster rate of leaf formation. Meanwhile, the growth constant (b) was lower in peat blocks (11.16) compared to peat moss (14.29), reflecting differences in the initial growth trend and suggesting that peat blocks supported more efficient early-stage leaf development.

The growth rate dynamics of *Capsicum annuum* L. leaf development over 12 WAS, modelled by the equation $dy/dx = (abce^{-cx})/(1 + be^{-cx})^2$, further illustrate these differences (*Table 10*). The peak leaf growth rate occurred at 5 WAS for peat blocks-grown plants (22.75 leaves/week), whereas peat moss-grown plants peaked earlier at 4 WAS (19.06 leaves/week). This suggests that peat blocks promoted more sustained leaf production in the early stages of growth. Beyond this peak, leaf formation gradually declined in both treatments. At 8 WAS, the growth rate in peat moss was 9.90 leaves/week, where as peat blocks maintained a higher rate of 16.90 leaves/week, indicating continued growth advantages. By 12 WAS, the growth rate had slowed significantly in both treatments, reaching 3.07 leaves/week in peat moss and 6.79 leaves/week in peat blocks, signifying the transition to later growth phases.

These findings highlight that while both nursery media supported continuous leaf development, peat blocks provided superior conditions for higher leaf production and sustained growth over time. The higher potential leaf number (45.02) and growth rate constant (0.3099) in peat blocks-grown plants further reinforce its effectiveness in promoting vegetative development. The rapid increase in leaf number between three and seven WAS in peat

Table 7. Growth rates dynamics of stem diameter of *Capsicum annuum* L. in two types of nursery media modelled by $dy/dx = (abce^{-cx})/(1 + be^{-cx})^2$ over 12 weeks after sowing

Nursery media	Week after sowing											
	1	2	3	4	5	6	7	8	9	10	11	12
Peat moss	0.59	0.76	0.71	0.50	0.30	0.17	0.10	0.05	0.03	0.02	0.01	0.01
Peat blocks	1.22	1.67	1.15	0.54	0.23	0.10	0.04	0.02	0.010	0.01	0.01	0.01

Table 8. Effect of nursery number of leaves of *Capsicum annuum* L. at 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12 weeks after sowing

Nursery media	Week after sowing											
	1	2	3	4	5	6	7	8	9	10	11	12
Peat moss	3.77b	4.81b	6.08b	7.63b	9.47b	11.63b	14.08b	16.79b	19.68b	22.68b	25.67b	28.54b
Peat blocks	4.01a	5.26a	6.82a	8.71a	10.94a	13.46a	16.20a	19.04a	21.86a	24.52a	26.92a	29.00a

Means with different letters within each column is significantly different at $p \leq 0.05$ based on two-sample t-test analysis

Table 9. Constants of number of leaves of *Capsicum annuum* L. at two types of media using a function $y = A/(1 + be^{-cx})$

Treatments	Constants			F-value	Approx. Pr>F	Approx. R^2
	A	b	c			
Peat moss	36.8503	14.285	0.2674	314.39	<.0001	0.99
Peat blocks	45.0206	11.1573	0.3099	378.74	<.0001	0.99

y; Number of leaves, A; Potential number of leaves, b; Constant, c; Growth rate, x; Time, e; Error

Table 10. Growth rates dynamics of number of leaves of *Capsicum annuum* L. in two types of nursery media modelled by $dy/dx = (abce^{-cx})/(1 + be^{-cx})^2$ over 12 weeks after sowing

Nursery media	Week after sowing											
	1	2	3	4	5	6	7	8	9	10	11	12
Peat moss	13.35	16.21	18.37	19.06	18.00	15.62	12.71	9.90	7.52	5.62	4.16	3.07
Peat blocks	14.05	17.07	19.92	22.00	22.75	21.92	19.77	16.90	13.89	11.11	8.73	6.79

blocks-grown plants suggests that peat blocks enhanced nutrient availability and photosynthetic activity, both of which are critical for sustained leaf numbers (Ikkonen et al. 2021).

Leaf area per plant

Effect of nursery media on leaf area per plant

The leaf area per plant in *Capsicum annuum* L. was significantly influenced by the type of nursery media used, as shown in *Table 11*. Throughout the 12 weeks after sowing (WAS), plants grown in peat blocks consistently exhibited a larger leaf area compared to those in peat moss. At 1 WAS, the leaf area of peat blocks-grown plants (19.05 cm^2) was significantly higher than that of peat moss-grown plants (16.67 cm^2). This trend continued throughout the study, with peat blocks-grown plants reaching a final leaf area of 524.54 cm^2 at 12 WAS, nearly 60% larger than the 330.10 cm^2 recorded in peat moss-grown plants. The difference in leaf area expansion became more pronounced from 3 WAS onwards, where peat blocks-grown plants exhibited a faster and more sustained increase in leaf area. The most rapid expansion occurred between 3 and 7 WAS, with leaf area increasing from 103.46 cm^2 to 479.04 cm^2 in peat blocks-grown plants, while in peat moss-grown plants, it increased from 85.46 cm^2 to only 290.50 cm^2. This suggests that peat blocks provided a more favourable environment for leaf expansion, likely due to improved water retention, aeration, and nutrient availability.

The superior substrate properties of peat blocks may have enhanced stomatal conductance and photosynthetic efficiency, ultimately leading to larger leaf areas (Tewodros 2014). These findings highlight the importance of selecting an appropriate nursery medium, as peat blocks appear to offer significant advantages in promoting optimal vegetative growth in *Capsicum annuum* L.

Growth rate dynamics of leaf area per plant

The sigmoidal growth model, $y = A/(1 + be^{-cx})$, effectively described the leaf area development in both nursery media, with a high coefficient of determination (R2 = 0.99) (*Table 12*). The potential maximum leaf area (A) was significantly higher in peat blocks-grown plants (525.0 cm^2) compared to those in peat moss (327.8 cm^2), indicating a greater capacity for leaf expansion. The growth constant (b) was also higher in peat blocks (67.78) than in peat moss (29.57), reflecting a steeper growth progression in plants grown in peat blocks. Additionally, the growth rate (c) was higher in peat blocks (0.9372) compared to peat moss (0.7435), suggesting a more rapid expansion of leaf area.

The growth rate dynamics of *Capsicum annuum* L. leaf area over 12 WAS, modelled by the equation $dy/dx = (abce^{-cx})/(1 + be^{-cx})^2$, further supported these observations (*Table 13*). The highest growth rate was recorded at 2 WAS in both media, with peat block-grown plants exhibiting a significantly higher rate (1971.35 cm^2/week) compared to peat moss-grown plants (648.72 cm^2/week). Following this peak, the growth rate declined steadily in both treatments, though peat blocks-grown plants consistently maintained higher rates across all growth stages. By 6 WAS, the growth rate in peat blocks had reduced to 120.40 cm^2/week, whereas in peat moss, it had declined to 82.90 cm^2/week. From 8 WAS onwards, both treatments exhibited a much slower rate of increase, with peat moss at 18.81 cm^2/week and peat blocks at 18.49 cm^2/week. By 12 WAS, leaf area expansion had nearly plateaued, with minimal increments of 0.6 cm^2/week in peat moss and 0.44 cm^2/week in peat blocks.

These results highlight that peat blocks not only promote a larger overall leaf area but also support a more sustained and accelerated expansion of leaf development throughout the growth period. The higher potential maximum leaf area in peat blocks (525.0 cm^2) compared to peat moss (327.8 cm^2) suggests that peat blocks provide a more favourable growth environment. The enhanced growth rate in peat blocks-grown plants indicates more efficient resource allocation towards leaf expansion, which is crucial for maximising light interception and biomass accumulation (Hematharshini and Seran 2019; Shakhidar et al. 2025).

Relative chlorophyll content and chlorophyll fluorescence

Relative chlorophyll content

The relative chlorophyll content (%) exhibited a decreasing trend over the 12-week growth period for both media types, with peat blocks consistently recording higher values than peat moss (*Figure 1*). At week 4, the relative chlorophyll content in peat moss and peat blocks was 37.13% and 38.52%, respectively. This trend continued, and by week 12, the relative chlorophyll content had declined to 34.68% in peat moss and 36.68% in peat blocks.

The reduction in chlorophyll content over time is a natural physiological response, commonly associated with plant maturation and leaf senescence. As plants grow, chlorophyll degradation occurs due to oxidative stress, nutrient redistribution, and reduced photosynthetic activity in older leaves (dos Santos et al. 2013; Nour et al. 2024). The consistently higher chlorophyll content in peat blocks compared to peat moss suggests that peat blocks may provide better nutrient retention or moisture availability, which could positively impact chlorophyll synthesis. Peat blocks' structural stability and aeration may have contributed to improved root function, leading to more efficient water and nutrient uptake, which are critical for chlorophyll production (Ab Kahar et al. 2018).

Previous studies have shown that substrate composition significantly affects plant physiological traits, particularly chlorophyll retention. Peat-based media with high water-holding capacity and better aeration enhance root activity, promoting nitrogen uptake, which is essential for chlorophyll biosynthesis (Kavipriya et al. 2019; Sardar et al. 2022). These results align with findings from earlier research on peat-based substrates, where superior growth performance was observed in media with optimized moisture and aeration properties.

Chlorophyll fluorescence (Fv/Fm ratio)

Chlorophyll fluorescence (Fv/Fm), an indicator of photosynthetic efficiency, exhibited a gradual decline over the study period for both media types (*Figure 2*). At week 4, the Fv/Fm ratio was 0.8100 in peat moss and 0.81 in peat blocks, and this value declined progressively to 0.75 and 0.76 by week 12, respectively.

The decline in Fv/Fm values suggests a reduction in the maximum quantum efficiency of PSII, possibly due to increasing stress conditions such as nutrient limitations, water availability, or plant maturity. Generally, an optimal Fv/Fm ratio for unstressed plants ranges between 0.80 and 0.85, whereas values below this threshold indicate stress-related impairments in photosystem II (Kumagai et al. 2009). The gradual reduction in Fv/Fm observed in both treatments suggests that as the seedlings aged, they experienced mild stress, potentially due to nutrient depletion or environmental factors.

Table 11. Effect of nursery media on leaf area per plant (cm^2) of *Capsicum annuum* L. at 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12 weeks after sowing

Nursery media	Week after sowing											
	1	2	3	4	5	6	7	8	9	10	11	12
Peat moss	16.67b	42.22b	85.46b	135.55b	179.49b	242.73b	290.50b	306.17b	315.99b	319.17b	320.92b	330.10b
Peat blocks	19.05a	46.05a	103.46a	202.23a	323.04a	421.72a	479.04a	505.99a	517.38a	521.99a	523.82a	524.54a

Means with different letters within each column is significantly different at P ≤ 0.05 based on two-sample t-test analysis

Table 12. Constants of leaf area per plant (cm^2) of *Capsicum annuum* L. at two types of media using a function $y = A/(1+be^{-cx})$

Nursery media	Constants			F-value	Approx. Pr>F	Approx. R^2
	A	b	c			
Peat moss	327.8	29.5691	0.7435	6.4144	<.0001	0.99
Peat blocks	525.0	67.7836	0.9372	3.491	<.0001	0.99

y; Number of leaves, A; Potential number of leaves, b; Constant, c; Growth rate, x; Time, e; Error

Table 13. Growth rates dynamics of leaf area /plant (cm^2) of *Capsicum annuum* L. in two types of nursery media modelled by $dy/dx = (abce^{-cx})/(1+be^{-cx})^2$ over 12 weeks after sowing

Nursery media	Week after sowing											
	1	2	3	4	5	6	7	8	9	10	11	12
Peat moss	445.89	648.72	577.23	341.78	172.04	82.90	39.53	18.81	8.94	4.25	2.02	0.6
Peat blocks	1145.90	1971.35	1610.34	756.83	305.86	120.40	47.20	18.49	7.24	2.84	1.11	0.44

Interestingly, peat blocks maintained slightly higher Fv/Fm values compared to peat moss throughout the experiment, indicating a marginally better photosynthetic performance in peat blocks grown seedlings. This finding is consistent with previous studies that reported improved chlorophyll fluorescence in media with enhanced water retention and nutrient availability (Masoudi et al. 2017; Pagoto et al. 2022). The improved performance of peat blocks may be attributed to its better aeration and moisture retention, which support root respiration and nutrient transport, thereby sustaining photosynthetic efficiency for a longer duration.

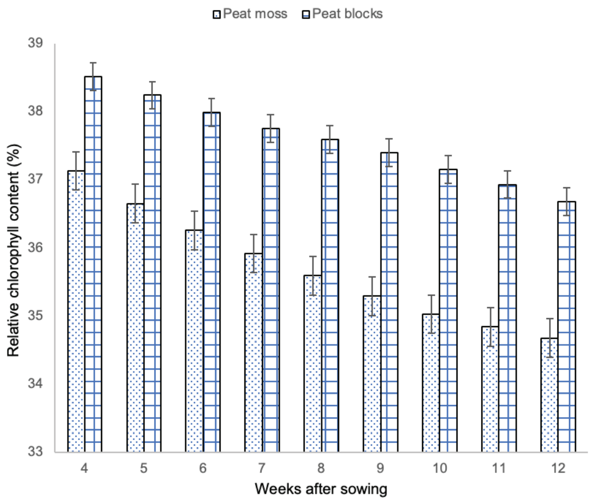

Figure 1. Changes in relative chlorophyll during 12 weeks of growing duration. The bar; standard error

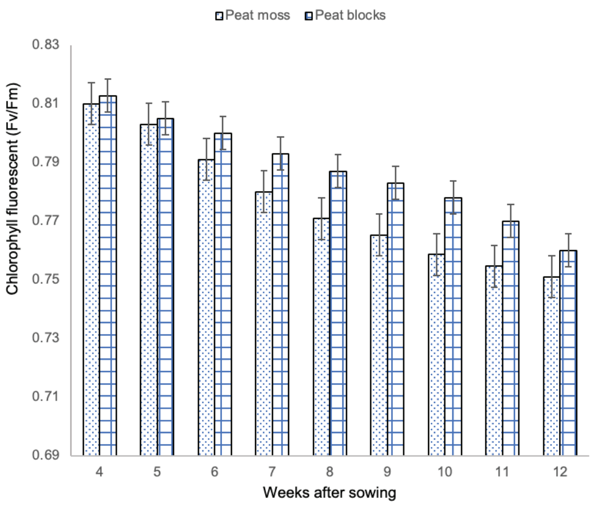

Figure 2. Changes chlorophyll fluorescence during 12 weeks of growing duration. The bar; standard error

Economic potential

In addition to the agronomic advantages, the economic potential of peat blocks is also noteworthy. Although the production of peat blocks involves slightly higher initial costs due to compaction and fertilizer integration, their ability to promote stronger root development and enhance early vegetative growth may offset these costs. In a commercial nursery setting, improved seedling vigor and growth performance during the early stages are critical for ensuring healthy plant establishment. Thus, peat blocks offer not only an effective but also an economically viable alternative to traditional peat moss for nursery seedling production.

Conclusion

This study demonstrated that the type of nursery media significantly influenced the growth and physiological performance of chilli (*Capsicum annuum* L.) seedlings. Seedlings grown in peat blocks exhibited superior growth in plant height, stem diameter, number of leaves, leaf area per plant, relative chlorophyll content and chlorophyll fluorescence compared to those grown in peat moss, particularly after the early growth stages. The improved performance of peat blocks is attributed to their enhanced physical properties, such as better water retention, nutrient availability, and aeration capacity, which are critical for early root and shoot development under nursery conditions. These findings suggest that locally formulated peat blocks by MARDI can effectively support vigorous seedling growth and offer a promising medium for commercial chilli production.

Conflict of interest

The authors declare no conflict of interest.

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