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Effect of substrate media on tomato growth, yield, and economic viability in soilless cultivation

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Abstract

A field experiment was conducted at the Precision Farming Development Centre (PFDC), Dr. RPCAU, Pusa, Bihar, to evaluate the effects of different soilless substrate media on tomato (*Solanum lycopersicum* L.) growth, yield, and economic performance. The study was laid out in a Completely Randomized Design (CRD) with three substrate treatments: M_1 (Cocopeat + Perlite + Vermicompost, 3:1:1 by weight), M_2 (Cocopeat + Perlite + Sand, 3:1:1), and M_3 (Cocopeat + Vermiculite + Perlite, 3:1:1). Seasonal crop water requirement was recorded as 15.90 cm. Among the tested media, M_1 significantly enhanced vegetative growth and yield attributes, achieving a maximum average plant height of 95.7 cm, fruit number of 48.1 per plant, average fruit weight of 77.9 g, and yield of 3.9 kg per plant, while the lowest yield (2.5 kg/plant) was observed in M_2. Economic analysis indicated that M_1 provided the highest benefit-cost (B:C) ratio of 2.55 and net return of Rs 169,936/-per 1000 m², whereas M_2 recorded the lowest B:C ratio of 1.79. These results demonstrate that the combination of Cocopeat + Perlite + Vermicompost is the most effective substrate medium for optimizing growth, yield, and profitability in soilless tomato cultivation under open-field conditions.

Keywords: Soilless cultivation, tomato, Pan Evaporation (PE)

Introduction

Soil, the most widely used natural growing medium, plays a crucial role in supporting plant growth by providing essential nutrients, aeration, and water. However, its effectiveness is often limited by various constraints, including soil-borne pathogens and nematodes, unsuitable pH levels, compaction, poor drainage, and degradation caused by erosion. Traditional soil-based agriculture further faces challenges such as high land and labor requirements, vulnerability to climatic fluctuations, and excessive water consumption. In urban and peri-urban regions, access to fertile arable land is increasingly restricted due to adverse environmental and geographical conditions. These challenges emphasize the need for alternative, resource-efficient cultivation systems.

Soilless culture, as described by Butler and Oebker (2006) [2], offers a promising alternative that enables crop production independent of natural soil. This approach effectively addresses issues of land scarcity, soil degradation, and resource inefficiency, while providing greater control over nutrient and water management. In regions where arable soil is either limited or unsuitable, soilless cultivation serves as a viable and sustainable production strategy. A wide variety of crops—including cereals such as rice and maize, vegetables like tomato, chilli, and brinjal, leafy greens such as lettuce, ornamentals like rose and marigold, and fodder crops including sorghum and barley—can be successfully grown in soilless systems (Sardare and Admane, 2013) [10].

With increasing constraints on land and water resources, modern agriculture must enhance productivity per unit of resource input to remain sustainable and profitable (Barnali Saha *et al.* 2025) [9]. In this context, the present study was conducted to assess the impact of different substrate media on the growth, yield, and economic performance of tomato under soilless cultivation.

2. Materials and Methods

2.1 Experimental site and climate

The research experiments were conducted at PFDC, Dr. RPCAU, Pusa, Samastipur, Bihar, during the season of 2019-20. The experimental site is situated at 25^0 59' N latitude and $85^0$48'E longitudes at 52.92 m above MSL.

2.2 Experimental Setup and Treatment Details

The experiment was conducted to assess the impact of soilless growing media on the growth performance, yield potential, and economic viability of tomato cultivation under open-field conditions. The experiment was structured as a Completely Randomized Design (CRD), using the tomato hybrid *Avinash-2* as the test crop. Five main substrates—cocopeat, perlite, vermiculite, sand, and vermicompost—and their selected mixtures were used, resulting in three substrate combinations: M_1 (cocopeat + perlite + vermicompost, 3:1:1 by weight), M_2 (cocopeat + perlite + sand, 3:1:1), and M_3 (cocopeat + vermiculite + perlite, 3:1:1). The daily irrigation water requirement was determined based on evaporation data recorded from a Class-A open pan evaporimeter. Polyethylene black plastic bags with a capacity of 3 L were used for filling the culture materials. Soilless media were put in plastic grow bags, and seedlings (one per bag) were planted in it. The plants were irrigated daily using a drip irrigation system, with one dripper assigned to each plant. Online emitters with 0.40 m spacing on the lateral and a discharge rate of 2.0 L/h were used. Irrigation was maintained up to one week prior to final harvest. Water-soluble fertilizers were applied throughout the experiment, with the required amount evenly distributed across the plots via fertigation using a venturi-type injection system.

2.3 Data collection

2.3.1 Crop Water Requirement

The daily water requirement to be applied for irrigation of tomatoes was calculated using the following formula (Anonymous 1997)

$$WR = E_P \times K_P \times K_C \times W_P \qquad \text{... (3.1)}$$

Where,

WR = Crop Water Requirement (Lit/day/plant)

E_P = Pan evaporation in (mm/day)

K_P = Pan coefficient

K_C = Crop coefficient

W_P = Wetted area factor m^2 (total area of grow bags was taken

The data on daily pan evaporation was collected from the meteorological observatory of the Department of Meteorology, Dr. RPCAU Pusa, for the period October 2019 to April 2020. The value of K_P varies from 0.6 to 0.8, but for the USWB Class-A pan evaporimeter, it is recommended to be 0.7. The value of K_C depends on the crop, growing stage, and meteorological conditions, mainly its value for the Tomato crop for different growing stages is considered as per follows.

2.3.2 Crop growth and yield parameters

Crop growth attributes and yield parameters, such as height, number of branches, fruit weight (g), number of fruits per plant, and yield per plant, were measured.

2.3.3 Cost Economics

The economics of tomato cultivation will be evaluated under different treatments. The cost includes paid out cost on hired laborers, grow bags, seeds, fertilizers, and growing media. Gross returns will be worked out by multiplying the yield by the market rate of produce, and based on these two, net returns and the B:C ratio under different treatments will be worked out.

3. Results and Discussion

3.1 Crop Water Requirement (cm)

The seasonal crop water requirement (ETc) of tomato plants under the experimental conditions was observed to be 15.90 cm, which was determined based on daily irrigation schedules calculated from Class-A pan evaporation data and adjusted using an appropriate crop coefficient (Kc) for tomato.

3.2 Response of tomato under different treatments

3.2.1 Growth parameters

The pooled data on the influence of soilless media on plant height and number of branches are presented in Table 1. The results indicate that both plant height and the number of branches at harvest responded significantly to the type of soilless media. The highest average plant height and number of branches were recorded under M_1 (95.7 cm and 9.3 branches, respectively), whereas the lowest values were observed under M_2 (Fig. 1). The significantly enhanced growth parameters under M_1 (Cocopeat + Perlite + Vermicompost) can be attributed to the synergistic effects of nutrient-rich vermicompost combined with the superior water-holding capacity and aeration properties of cocopeat. These findings are in agreement with previous reports by Rajiv *et al.* (2004) [8], Umashanker *et al.* (2025) [12], and Bohme *et al.* (2001) [1].

Table 1: Growth and yield attributes of tomato as influenced by different substrates

Treatments	Plant height			No. of. branches			Number of fruits per plant
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	
M1	44.8	81.6	95.7	2.9	7.1	9.3	48.1
M2	41.7	78.2	91.2	2.5	6.7	8.9	36.7
M3	42.5	79.4	94.3	3.1	6.8	9.3	43.6
S.Em ±	0.70	0.62	0.46	0.12	0.06	0.05	0.52
C.D. at 5%	2.04	1.79	1.32	0.33	0.17	0.16	1.48

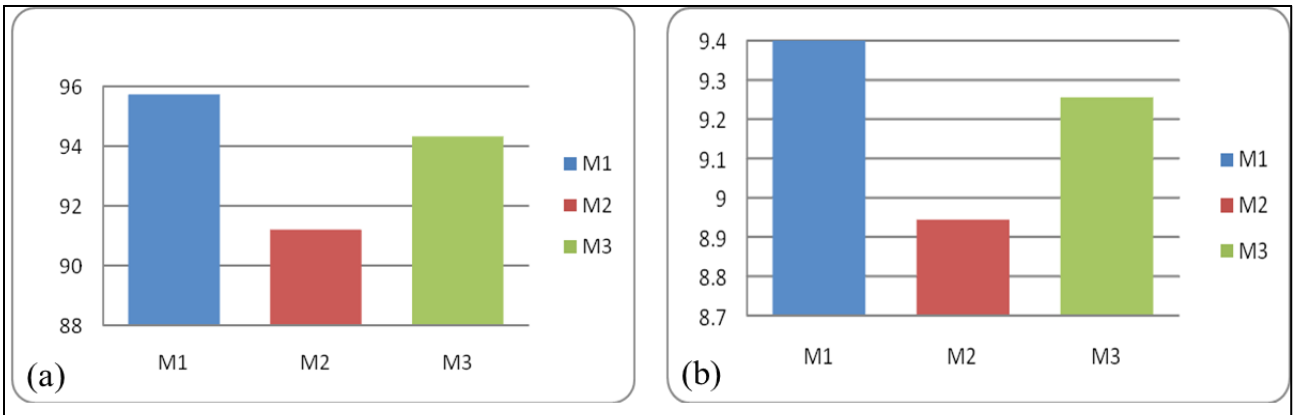

Fig 1: Effect of growing media on (a) Plant height, (b) Number of branches

3.2.1 Yield parameters

The influence of soilless media on the number of fruits per plant, fruit weight, and yield per plant is presented in Tables 1 and 2. The data indicate that the number of fruits per plant, fruit weight, and yield per plant were significantly higher under M_1 (48.1 fruits, 77.9 g, and 3.9 kg, respectively), whereas the minimum averages for these parameters were observed under M_2 (Fig. 2). The enhanced yield and yield-related attributes of tomatoes grown in media supplemented with vermicompost may be attributed to the regulated and balanced nutrient release, as well as the favorable modulation of microbial activity that promotes plant growth. These findings are consistent with previous reports by Ten and Kirienko (2002) [11], Natarajan and Kothandaraman (2018) [5], and Padem and Alan (1994) [6].

Table 2: Yield and economics as influenced by different substrates

Treatments	Fruit weight (g)	Fruit yield (kg per plant)	Gross income (Rs/1000 m^2)	Net income (Rs/1000 m^2)	B:C ratio
M1	77.9	3.9	236806	169936	2.55
M2	65.8	2.5	194084	123979	1.79
M3	72.7	3.3	219356	149947	2.14
S.Em ±	0.82	0.04	2715	2715	0.04
C.D. at 5 %	2.34	0.11	7787	7787	0.11

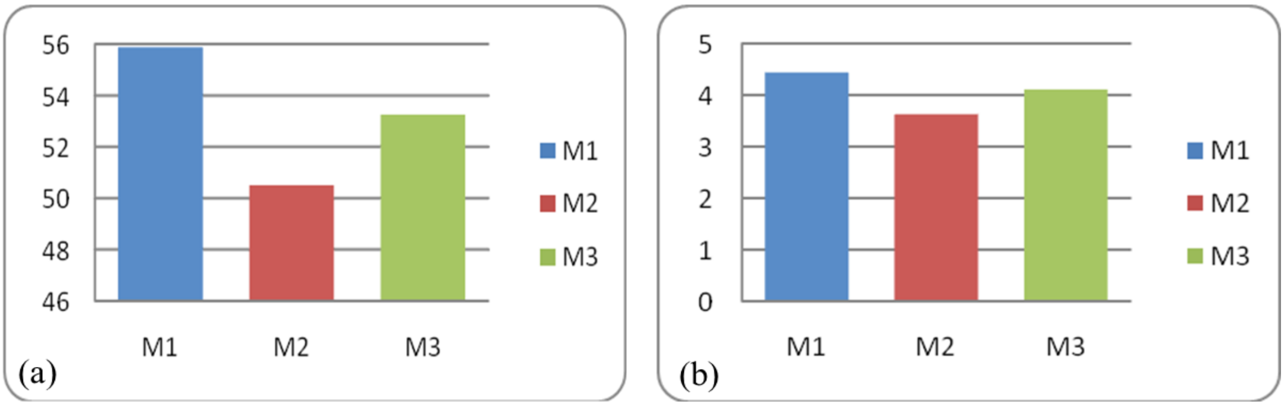

Fig 2: Effect of growing media on (a) Number of fruits per plant, (b) Fruit yield per plant

3.3 Economics

The choice of soilless growing media had a significant effect on the economic performance of tomato cultivation. Among the treatments, the substrate combination of Cocopeat + Perlite + Vermicompost (3:1:1) produced the highest economic returns, with gross returns of Rs 236806/- and net returns of Rs 169936/-per 1000 m², as well as a superior benefit-cost (B:C) ratio of 2.55, compared to the other media combinations.

4. Conclusions

- Total Crop Water Requirement was found as 15.90 cm at 100% ETc for tomato cultivated in soilless medium.
- Growing media of a combination of cocopeat + perlite + vermicompost (3:1:1) was found to be better in terms of growth and yield.
- From the economics point of view, the use of cocopeat + perlite + vermicompost (3:1:1) was found to be best over all other treatments, having a maximum B: C ratio of 2.55 and maximum net income of Rs 169936/-per 1000 m^2.

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