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Soilless culture of tomato in naturally ventilated polyhouse under Assam conditions, India

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ABSTRACT

In 2022, an experiment was conducted at the Experiment Farm, Department of Horticulture, Assam Agricultural University, Jorhat, to explore tomato cultivation possibilities using soilless media in a naturally ventilated polyhouse. Employing a randomized block design with 5 treatments and 4 replications, various media compositions, including cocopeat, vermiculite, perlite, sand, and loam soil in different ratios, were tested. The study uncovered that optimal tomato growth occurred in Loam soil: Sand: Vermicompost (1:1:1), showing maximum plant height (140.68 cm), primary branches (6.19), plant fresh weight (177.90 g), fruit weight (70.80 g), and a shorter time to flowering (42.5 days). This medium also resulted in higher residual N, P, K contents (2.58%, 2.51%, 2.64%, respectively) in the spent growing medium. Cocopeat: Sand: Vermicompost (5:2:3) yielded the highest plant dry weight (25.80 g), fruit set (48.24%), fruits/cluster (8.36), fruits/plant (71.74), yield/plant (4.88 kg), total yield (66.26 q/500sqm), and harvesting latitude (48.31 days). Meanwhile, Cocopeat: Vermiculite: Perlite (3:1:1) recorded the longest days to first harvest (83.75 days). Sand: Vermicompost (1:1) exhibited the highest chlorophyll content (2.50 mg/100 g), and fruit volume (73.10 cc), while Cocopeat: Vermicompost (1:1) had the maximum flowers per cluster (3.91). Economically, the analysis favored Loam soil: Sand: Vermicompost (1:1:1) with a maximum benefit-cost ratio of 2.20. In conclusion, while Cocopeat: Sand: Vermicompost (5:2:3) seems optimal for growth and yield, the economic advantage lies with Loam soil: Sand: Vermicompost (1:1:1).

Key words: *Tomato, Soilless cultivation, Growing media, Plant nutrition*

Introduction

Soilless culture, a method of growing plants without traditional soil, involves cultivating plants in controlled environments with their roots in contact with a non-soil growing medium providing support, nutrition, and airflow. This technique facilitates precise control over water availability, pH, and nutrient levels, leading to efficient plant development and increased agricultural yields. According to VanOs (1999) and Savvas *et al.* (2013), soilless systems typically exhibit superior water and fertilizer use efficiency, along with additional benefits such as reduced crop duration, minimized pest and disease stress, fewer weeds, and ease of spraying and irrigation (Prakash *et al.,* 2020). Hydroponics, a form of soilless culture, has been widely adopted on a commercial scale in various countries, including Israel,

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France, Canada, and the Netherlands. The Center for Protected Cultivation Technology (CPCT), established by the National Horticulture Board (NHB) under the Indian Council of Agricultural Research (ICAR) in New Delhi, actively promotes sustainable farming practices like soilless culture (hydroponics, aeroponics, etc.). This initiative significantly contributes to increased agricultural output, particularly in horticulture (Gowda *et al.,* 2022). Soilless culture is now integral to polyhouse breeding and multiplication programs for crop improvement (Gosal *et al*., 2010), and top-tier institutes, including IARI, employ it for hardening and multiplying transgenic plants created using CRISPR/Cas 9 in both horticulture and field crops, such as transgenic tomatoes (Nandhakumar *et al*., 2018). Traditional crop cultivation using soil faces inherent challenges, including difficulties in disease and pest management, extensive land requirements, substantial labor needs, and high water consumption. In urban and semi-urban areas, where land is often scarce or unfit for cultivation, soilless culture, particularly hydroponics, emerges as a promising solution. With global consumer demands for quality foods, soilless cultivation is practiced in densely populated areas like Delhi, utilizing rooftops for small polyhouses or highways for vertical gardens, contributing to pollution control and aesthetics. Soilless culture allows for precise control of environmental parameters, promising higher crop yields with better quality and safer foods.

Tomatoes, scientifically known as *Solanum lycopersicon*, are widely cultivated in India, with production challenges in open-field conditions. High-tech approaches, such as greenhouse cultivation, offer a solution, especially in areas with limited agricultural land, like Assam's urban and semi-urban regions. Soilless culture proves advantageous in overcoming soil-related constraints, including low fertility, excessive acidity, and soil-borne diseases. In regions like Assam with unique climatic conditions, soilless farming provides controlled environments, allowing for year-round cultivation and optimal growing conditions. This method contributes to better yields, lower production costs, reduced pesticide use, and superior product quality. Soilless culture, particularly with substrates like rock wool or coco coir in naturally ventilated polyhouses, enhances tomato growth, yield, and nutrient content, offering a sustainable and efficient alternative to traditional soil-based agriculture.

Therefore, keeping in view all these factors, this investigation was carried out at Assam Agricultural University, Jorhat with the use of the soilless media in the form of cocopeat, vermiculite, vermicompost, perlite, sand and loam soil for the production of tomato under ventilated polyhouse in Assam condition with the objective to find out suitable growing media combination for soil-less cultivation of tomato.

Materials and Methods

In 2022, the study was carried out within the naturally ventilated polyhouse situated at the Experimental Farm of the Department of Horticulture. The polyhouse, covering an expanse of 300 m², was aligned in the East-West direction. Jorhat experiences a humid subtropical climate, characterized by hot summers from May to August and cold winters spanning September to January, succeeded by spring from February to April. The locale maintains high relative humidity, and the monsoon season typically prevails from the initial week of June through September. Annually, Jorhat receives an average rainfall of 2244 mm.

The field experiment was laid by the Randomized Block Design with 5 treatments in 4 replications.T_1 (Cocopeat: vermiculite: perlite (3:1:1), T_2 (Cocopeat: sand: vermicompost (5:2:3), T_3 (Cocopeat: vermicompost (1:1), T_4 (Sand: vermicompost (1:1) and T_5 (Loam soil: sand: vermicompost (1:1:1). The seeds of tomato variety PH-1were sown on 24th December 2021 in protrays. Seedlings of 3-4 weeks age were transplanted into the bags. Transplanting was done on 20 January 2022. There were 12 plants in each treatment. The total plant population was 240 numbers. Fertilizer dose recommendations were applied to each treatment. Water soluble fertilizer N:P:K (19:19:19) was applied as a source of nutrients to the crop. This was applied with a dose of 0.25% in media and 0.2% over the canopy. Lime, as a source of calcium, was mixed @ 2.5g per 5 kg media. The experimental bags and the field were made free from weeds throughout the crop growth period by hand weeding. Staking of the growing tomato plant was done by using bamboo sticks in each plant and tied with plastic thread to prevent lodging. Leaf miner attack was managed by spraying Rogor @1 ml/l.

The observations on plant growth, yield and yield attributing characters viz., plant height, primary branches per plant, days to first flowering, plant fresh weight at flowering, plant dry weight at flowering, chlorophyll content at flowering (mg/100gm), flowers per cluster, fruit set per cluster, fruit per cluster, days to first harvest, fruit weight (g), fruits per plant, fruit volume (cc), fruit yield per plant, total yield, crop duration, harvesting latitude and NPK content in media after harvest (kg/100 kg media) in keeping with their standard processes. The chlorophyll content of tomato leaf was estimated following the procedure described by Arnon (1949). About 0.2 g of fresh leaf sample was crushed in a mortar pastle with addition of 80% acetone. The extract was centrifuged (5000 rpm), the supernatant transferred to a 25 ml volumetric flask and the volume was made up to the mark with 80% acetone. The absorbance was recorded at 663 and 645 nm in a Spectrophotometer with a blank containing 80% acetone.

Total Chlorophyll $= (20.2(A_{645}) + 8.02(A_{663}) \, {}^{V}/_{100W}$ mg g^{-1}fw,

Chlorophyll a $= 12.7(A_{663}) - 2.69(A_{645}) \, {}^{V}/_{100W}$ mg g^{-1}fw and

Chlorophyll b $22.9(A_{645}) - 4.68(A_{663})$ mg g^{-1}fw

Where, V Final volume of extract (ml) fw Fresh weight of leaf sample (g), A645 and A663 are the absorbances at 645 and 663 nm wavelength respectively. The NPK content in media after harvest N content in media was determined by using methods given by Jackson and Kjeldahl, P in media was using method developed by Bray and Kurtz and K in media was estimated using method outlined by Skoog and Jackson. Following Panse and Sukhatme guidelines, the data were statistically examined using the analysis of variance.

Results and Discussion

Growth and development of tomatoes in soilless culture

In the present investigation, Table 1 reveals that T2 recorded the highest mean value for plant height at 30 days (37.04 cm) followed by T3 (31.32 cm). The treatments did not show any significant difference in plant height on 45 days and T5 showed the maximum plant height at first harvest. The growing media comprising of cocopeat: sand: vermicompost and loam soil: sand: vermicompost recorded highest plant height (37.04 cm and 140.68 cm) due to high water holding capacity, aeration, decreased bulk density, slightly higher potassium content and also superior physico-chemical qualities and maintenance of the necessary biological balance, both of which have contributed to the plants' greater growth when compared to other growing media. The results of the investigation closely matched those of Subramani *et al*. (2020), Kaushal *et al*. (2019) and Spehia *et al*. (2020) in tomato and Thapa *et al*. (2016) in sweet pepper.No significant effect was noticed in number of primary branches at 30 days and 45 days. The T5 (loam soil: sand: vermicompost, 1:1:1) produced maximum number of branches due to contribution of high concentrations of minerals like nitrogen, phosphorous, and potassium in vermicompost for the growth and development of plants. Vermicompost can increase the availability of nutrients in the soil, which can encourage plant growth, development and primary branches when added to a growing medium. This result was in close conformity with the findings of Natarajan and Kothandaraman (2018).

Table 2 shows that T5 (loam soil: sand: vermicompost, 1:1:1) took minimum days to first flowering due to the presence of more useful micro-organisms particularly phosphate-solubilizing and other useful microbes, hormones, and enzymes, present in vermicompost and appropriate nutritional supply. The significant difference among the treatments for days to first flowering was also reported by Vamsi *et al.* (2021) and Lata *et al.* (2018) in cucumber.

Treatments did not influence the number of flowers per cluster during the investigation. Similar results were reported by Erabadupitiya *et al.* (2021) in tomato. T2 (cocopeat: sand: vermicompost, 5:2:3) recorded the highest fruit set percentage (48.24%) probably due to abundance of nitrogen, phosphorus, and potassium in vermicompost through breakdown of organic materials by earthworms. The similar results are reported by Kýlýç *et al.* (2018) in tomato.

The T5 comprising loam soil: sand: vermicompost recorded the highest plant fresh weight (177.90 g) because tomatoes are heavy feeders and need a lot of resources to grow and bear fruit. Vermicompost, being a nutrient-rich organic manure that enhanced soil quality and supplied vital plant nutrients, while sand and soil supplied physical support for the roots of plants. These three elements combined to make a good growing medium that was able to provide the most favorable conditions for tomato growth and, as hence, produced plants with higher fresh weights. Results of Haddad (2007) in tomato are in consonance with the present findings.

T2, the growing media comprising of cocopeat: sand: vermicompost in ratio 5:2:3, recorded highest plant dry weight (25.80 g) due to an ideal growing environment for tomato plants created by the mixture of cocopeat, sand, and vermicompost, which led to higher plant dry weight. This was because the growing medium offered a mix of nutrients available, drainage, moisture retention, and aeration, all of which were necessary for plant growth and development. Teo and Hoe (1993) also reported that a medium with the above qualities could support positively for optimum growth and development of tomato plants.

Yield and Yield Attributing Characters

The study revealed that T2 growing media comprising of cocopeat: sand: vermicompost in ratio 5:2:3 recorded higher number of fruits per cluster (3.91) due to vermicompost, which had the ability to increase protein production, ultimately led to larger levels of meristem cells and cell division. Similar results were reported by Lata *et al.* (2018). The growing media T2 also produced the highest number of fruits per plant (71.74) due to medium structure and aeration, which allowed plant roots to grow more quickly and efficiently to absorb water and nutrients. This had led to stronger, healthier plants that produced more fruits per plant. These findings are in consonance with the reports of Lata *et al.* (2018) in cucumber and Spehia *et al.* (2020) in tomato.

The T5 comprising loam soil: sand: vermicompost gave the maximum fruit weight (70.80g. Sandy soil includes larger particles, which promote greater aeration and drainage. This may promote more rapid root development in tomato plants, resulting

Table 3. Effect of growing media on growth attributes of tomato fruits

Treatments	Fruits per cluster	Fruits per plant	Fruit weight (g)	Fruits volume (cc)
T1	3.16	39.63	60.95	65.03
T2	3.91	71.74	68.18	65.38
T3	3.69	60.24	64.48	70.35
T4	3.78	53.63	68.03	73.1
T5	3.63	59.89	70.80	68.63
SEd (±)	0.20	6.49	1.52	5.89
CD(0.05)	0.43	14.13	3.31	NS

Table 1. Effect of growing media on growth attributing characters of tomato

Treatment	Plant height (cm)			No of primary branches		
	30 days	45 days	1st Harvest	30 days	45 days	1stHarvest
T1	21.94	65.55	130.26	3.53	3.83	4.25
T2	37.04	83.10	134.2	3.83	4.21	5.12
T3	31.32	74.51	137.39	3.75	4.21	4.93
T4	33.82	80.03	136.62	3.54	4.00	5.25
T5	33.48	75.57	140.68	3.54	4.21	6.19
SEd (±)	3.12	5.60	2.13	0.30	0.30	0.30
CD (0.05)	6.80	NS	4.63	NS	NS	0.65

Table 2. Effect of growing media on flowering and weight of plant parts in tomato

Treatment	Days to first flowering	No. of flowers per cluster	Fruit set (%)	Plant fresh weight (g)	Plant dry weight (g)	Leaf chlorophyll content at flowering
T1	56.00	7.85	40.24	116.80	11.03	2.46
T2	43.00	8.10	48.24	144.30	25.80	2.40
T3	48.50	8.36	41.66	136.60	19.78	2.26
T4	43.00	8.24	45.74	150.30	18.70	2.50
T5	42.50	8.15	44.49	177.90	23.55	2.18
SEd (±)	1.93	0.25	2.33	8.05	1.65	0.19
CD (0.05)	4.20	NS	5.08	17.53	3.59	NS

in bigger, healthier plants and, ultimately, bigger fruits. Vermicompost is high in nutrients including nitrogen, phosphorous, and potassium as well as advantageous microorganisms that can assist improves the health of the soil. These nutrients could play a role in the plants increasesize and fruit size. Similar results were represented by Lata *et al.* (2018) in cucumber.

Yield per plant was highest in the T2 (4.88 kg). T2 comprised of cocopeat: sand: vermicompost in ratio (5:2:3) which improved soil structure and supplied essential nutrients to plants. Environmental conditions, the control of pests and diseases, and horticultural techniques like fertilization and pruning are a few other variables that might influence tomato fruit yield. The similar results were reported by Lata *et al.* (2018) in cucumber and Bijeta *et al.* (2020) in capsicum. Per plant higher yield per plant in T2 ultimately resulted in higher total yield per ha.

Table 4. Effect of growing media on yield and yield attributes of tomato

Treatments	Days to first harvest	Fruit yield per plant (kg)	Crop duration (days)	Harvesting latitude (days)
T1	83.75	2.42	115.75	32.03
T2	78.75	4.88	121.83	43.08
T3	77.50	3.89	119.05	41.55
T4	77.75	3.65	111.81	34.06
T5	76.25	4.24	124.56	48.31
SEd (±)	2.34	0.43	3.05	3.59
CD (0.05)	NS	0.93	6.64	7.82

Production economics

In the present inquisition, T5 recorded the highest benefit cost ratio (2.20). Amongst the medium comprising loam soil: sand: vermicompost (1:1:1) improved soil fertility, stabilized soil, recovered soil nutrients, and functioned as biofertilizer and hence it increased production ultimately positively affecting the benefit-cost ratio. Similar results were reported by Mehta *et al.* (2022) in tomato.

Table 5. Economics of various treatments

Treatment	Total fruit yield (q/500 sqm)	Gross return (₹/ha)	Cost of cultivation (₹/ha)	Net Return (₹/ha)	B:C ratio
T1	39.85	239100.00	447353.00	(-)208253.00	(-)0.47
T2	66.26	397560.00	282023.00	115537.00	0.41
T3	57.20	366540.00	307103.00	59437.00	0.19
T4	54.17	325020.00	104153.00	220867.00	2.12
T5	43.86	263160.00	82224.50	180935.50	2.20

Conclusion

Cocopeat: Sand: Vermicompost (5:2:3) demonstrated the best overall performance in terms of plant growth, yield, and yield attributing characteristics. On the other hand, treatment Loam soil: Sand: Vermicompost (1:1:1) exhibited the highest (2.20) benefit cost ratio among all the treatments. This indicated that the financial returns obtained from Treatment T_5(Loam soil: sand: vermicompost (1:1:1) were the highest relative to the cost incurred.

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