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ORIGINAL RESEARCH ARTICLE

Effect of different germination media on seed germination and seedling growth of tomato (*Solanum lycopersicum* L.) in Bhojpur, Nepal

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ABSTRACT

The research was conducted following a Complete Randomized Design (CRD) under plastic tunnel with three replications to investigate the effects of different germination media on seed germination and seedling growth of tomato in Bhojpur Nepal. Nine different compositions of growing media are soil, cocopeat, vermicompost, soil + FYM (1:1), soil + cocopeat (1:1), soil + vermicompost (1:1), cocopeat + vermicompost (1:1), soil + cocopeat + vermicompost (1:1:1) and soil+ cocopeat + vermicompost + FYM (1:1:1:1). Seeds of tomato variety (Srijana) was sown in Plastic tray. Germination parameters such as germination percentage, germination speed, germination energy, and vigor index were recorded for seven consecutive days. Growth parameters including root length, shoot length, number of leaves, stem diameter, fresh seedling weight and dry seedling weight were measured at 20, 25 and 30 days after sowing. There were significant differences in the germination parameters and growth parameters. The maximum germination percentage (100%), maximum seedling vigor index (2329), root length (10.967cm), number of leaves (20.87cm) was recorded in soil + cocopeat + vermicompost + FYM (1:1:1:1) as a growing media. However maximum shoot length (12.847cm), maximum stem diameter (0.310cm) and maximum fresh weight (1.540g) was recorded in soil + cocopeat + vermicompost (1:1:1) as a growing media. Hence, optimum growth of tomato seedlings was observed when soil, cocopeat, vermicompost and FYM were used in equal proportions.

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INTRODUCTION

One of the most well-liked and extensively cultivated vegetable crops worldwide, the tomato, also known as *Solanum lycopersicum*, belongs to the genus Solanum within the family Solanaceae (Lohani *et al*., 2023; Banjade *et al*., 2023). With a weakly woody stem that usually clambers over other plants, tomatoes can reach heights of 1-3 meters (Gama *et al*., 2015). According to botany, tomatoes are fruits, more precisely berries, since they are the ovaries of a blooming plant. Tomatoes (*Solanum lycopersicum* L.) are the most popular home garden and the most consumed vegetable globally, behind potatoes (*Solanum tuberosum L.*) (Banjade *et al*., 2023). It was not until 1800 that the fruit was acknowledged as a beneficial vegetable because it was thought to be toxic (Nicola *et al*., 2009). China is the world's largest tomato producer, contributing 25% of worldwide production, with the US and India coming in second and third, respectively, according to Bhandari *et al.* (2016). Indeterminate, semi-determinate, and determinate are the three main categories into which tomato cultivars can be categorized according to their growth (Swamy, 2023). In Bhojpur, one of the most renowned districts for vegetable production, tomatoes are one of the main vegetable crops farmed, with a total production area and yield of 112.1 ha and 15.63 Mt/ha, respectively (MoALD, 2022). Since the germination rate directly affects the plant's health and vigor and the remainder of the plant life depends on it, germination of the seedlings is a crucial step in the plant life cycle (Gama *et al.*, 2015; Dahal *et al.*, 2024). A tomato nursery can be grown in various settings, from controlled greenhouses to basic plastic shelters. Regardless of the structure, it must shield seedlings from harsh environmental factors such as intense rain, sharp temperature swings, high relative humidity, and exposure to pests and illnesses (Dahal *et al.*, 2024; Banjade *et al.*, 2023). Throughout the nursery stage, growing material directly affects the quality of seedlings as well as the emergence, development, and germination of seeds (Zaller, 2007; Chopra *et al.*, 2017; Kumar *et al.*, 2022). In addition to being a place for sowing and nurturing seedlings, growing media also acts as a source and storage area for plant nutrients. It stabilizes the root system, which helps the plant stay upright (Lohani *et al.*, 2023).

Tomato cultivation is a vital agricultural activity in Bhojpur, Nepal, contributing significantly to the local economy and food security. There is a lack of comprehensive studies examining the comparative effectiveness of different germination media in the specific agro-climatic conditions of Bhojpur. This study seeks to fill this knowledge gap by evaluating the effects of various germination media, including soil, cocopeat, vermicompost, FYM and their combinations, on the germination and growth of tomato seeds in Bhojpur, Nepal. The findings aim to provide evidence-based recommendations for farmers to optimize their germination practices, ultimately contributing to increased agricultural productivity in the region. Due to the rising costs of seeds, different vegetable crops such as tomatoes, eggplants, peppers, and cucurbits are now being transplanted after nurturing in protected environments. This approach ensures maximum germination rates and robust plant establishment (Hazarika *et al.*, 2023). The purpose of this study is to give farmers in Bhojpur, Nepal, useful advice on how to choose the best germination medium, increasing tomato yield and promoting both food security and economic development.

MATERIALS AND METHODS

Experimental site and design of experiment

An experiment on the seed germination and seedling growth of tomato (*Solanum lycopersicum*) was carried out in the plastic house of Agriculture Knowledge Center (AKC), situated in Dandagaun, Bhojpur Municipality-7, Bhojpur Nepal from May 9,2024 to June 8, 2024. The study site is located at 27°10' 0 North, 87°03'0" and is 1,560 meters above sea level. The experiment design is a Complete Randomized Design (CRD) with three replications followed during the research period. The treatment was allocated in the experiment plot was shown in Table 1.

Media preparation and seed sowing

Seeds of tomato variety 'Srijana' were collected from Siddha Kali Agrovet Pvt. Ltd, Bhojpur, near the Agriculture Knowledge Center (AKC). Seeds were placed in trays under plastic tunnels. The tray was used for the seed sowing. Different sizes and shapes of the trays are available in the market. The tray contains 32, 50, 72, 100, and 125 cells in round, square, and truncated pyramid shapes. In this study, seeds were sown in 32 cell trays of 8x4 dimensions. First, the media was half-filled with each cell in the tray, and the seed was sown in each tray cell; again, the seed was filled with media. Each treatment had 16 seeds consisting of seeds in each cell. Trays were placed under the plastic tunnel, and based on the moisture content of the media, watering was done using rose cans.

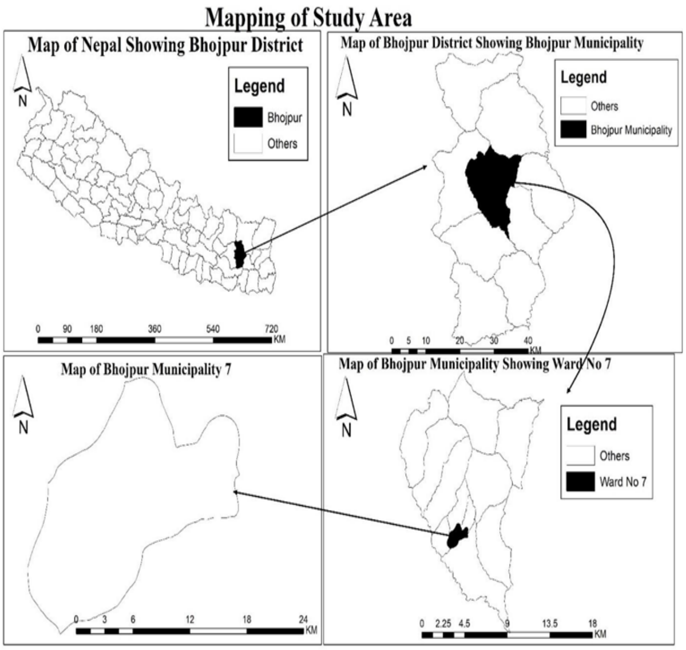

Figure 1. *Location of research site (ArcGIS, Esri, 2024).*

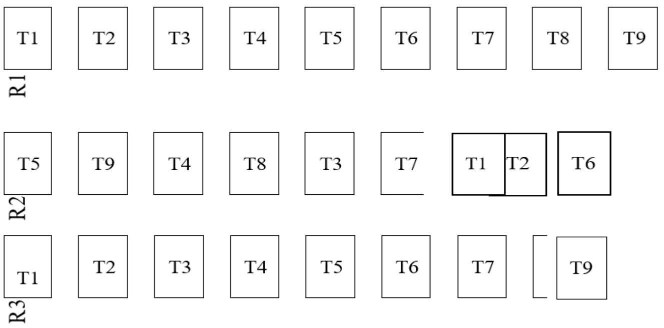

Figure 2. *Experimental design.*

Table 1. Detail of treatments.

S. N.	Treatment	Treatment Name
1	T1	Soil
2	T2	Cocopeat
3	T3	Vermicompost
4	T4	Soil + FYM (1:1)
5	T5	Soil + Cocopeat (1:1)
6	T6	Soil + Vermicompost (1:1)
7	T7	Cocopeat + Vermicompost (1:1)
8	T8	Soil + Cocopeat + Vermicompost (1:1:1)
9	T9	Soil + Cocopeat + Vermicompost + FYM (1:1:1:1)

Data collection and observation

Throughout the experiment, a number of germinations, growth, and weight factors were noted. The number of seeds germinated for seven days was counted every day. Additionally, five seedlings from each treatment were chosen at random and physically removed from the cells, and their fresh weight (gm) and dry weight (gm) were assessed along with their growth data, which included the number of leaves, shoot length (cm), root length (cm), and stem diameter (cm). Tomato seedlings that were 20, 25, and 30 days old had their dimensions taken. Measurements were made of the plant height, stem diameter, number of leaves, and root length for each treatment.

Germination parameters

The germination parameters measured in this experiment were vigor index, speed, energy, and germination %. The germination percentage is the proportion of viable seeds that, under optimal growing conditions, effectively sprout and develop into plants. The germination speed is the number of seeds sprouting at a specific time. Germination energy is the proportion of seeds in a sample that sprout during a given time period. The vigor index is the total of the traits of the seed that influence its possible level of activity and performance during germination and emergence (Dahal *et al.*, 2024).

$$\text{Germination percentage (G\%)} = \frac{\text{A number of seeds germinated}}{\text{Total number of seed sown}} \text{x } 100$$

$$\text{Germination Speed (GS)} = \frac{\text{Number of seeds germinated in 72 hours}}{\text{Number of seed germinated in 168 hours}} \text{x } 100$$

Germination Energy (GE) = %of seed germinated in 72 hours

Vigor Index (VI) = Seedling length × Germination Percentage (G%)

Growth parameters

The lengths of their roots and shoots were measured using a measuring scale to assess the tomato seedlings' growth variables. Root length (cm) was measured from the first root's start to the main root's end tip, and shoot length (cm) was measured from the collar area to the apical bud. Five seedlings were randomly selected, removed, and measured on days 20, 25, and 30 after sowing. The diameter of the stem was measured with a vernier caliper. Each of the five fresh seedlings was also weighed using a weighing machine to ascertain their fresh weight. The final dry weight of the seedlings was ascertained by weighing each of the five dry seedlings.

Statistical analysis

The collected data was tabulated and processed using Microsoft Excel. The recorded data on a number of parameters were evaluated using R (version 4.2.3). The normality test was conducted using the statistical software "SPSS". The Duncan Multiple Range Test (DMRT) was used to compare the means of different parametric data sets at a 5% significance level. Before statistical analysis, the germination speed and energy data were transformed using arcsine, and the germination % data was changed using logit.

RESULTS AND DISCUSSION

Effect of germination media on germination percentage and germination speed

The germination percentage of tomato seedlings varied significantly ($p \leq 0.001$) depending on the germination environment. The media with the best physical characteristics and water-holding capacity to support tomato seed germination were soil + cocopeat + vermicompost (93.75%), cocopeat + vermicompost (89.58%), soil (85.42%), soil + FYM (85.42%), and soil + cocopeat (83.33%). The maximum (100%) germination percentage was found in Soil + cocopeat + vermicompost + FYM (1:1:1:1), which was statistically comparable to soil + cocopeat + vermicompost (97.92%). Cocopeat alone had the lowest germination percentage (62.50%), statistically comparable to Vermicompost (68.75%). Tomato and cucumber seed germination and seedling growth were improved by adding a vermicompost extract to the growing media (Arancon *et al.*, 2006). There was a significant difference ($p \leq 0.001$) among the various germination media in the germination speed of tomato seedlings. The highest germination speed (36.26) was recorded for germination media Vermicompost only which was at par with soil + vermicompost (35.52) followed by soil + cocopeat (32.42), soil (29.49), cocopeat (29.44), soil + FYM (27.46), soil + cocopeat + vermicompost (23.47), soil + cocopeat + vermicompost + FYM (22.92). The lowest (20.95) germination speed was recorded in cocopeat + vermicompost (1:1) as shown in Table 2. This might be due to low in nitrogen, calcium, and magnesium but can be relatively high in phosphorus and potassium (Nicola *et al.*, 2009). Cocopeat is a suitable growing medium with acceptable pH, electrical conductivity, and other chemical attributes (Damilola *et al.*, 2022). According to Ghimire *et al.*, (2024) coco peat and vermicompost were the most effective media for tomato seed germination, resulting in higher germination percentages, lower mean germination times, and higher speeds of germination.

Effect of germination media on germination energy and seedling vigor index

The germination energy of the investigated germination media varied significantly ($p \leq 0.1$). soil + vermicompost (33.33) had the highest germination energy, making it comparable to soil + cocopeat (27.08), vermicompost (25.00), soil (25.00), soil + FYM (22.92), Soil + cocopeat + vermicompost (22.92), and soil + cocopeat + vermicompost + FYM (22.92). Germination media Cocopeat had the lowest germination energy (18.75), comparable to cocopeat + vermicompost (18.75) as shown in figure 4. The vigor index of tomato seedlings showed highly significant ($p \leq 0.001$) differences across growing conditions. Treatment soil + cocopeat + vermicompost + FYM (1:1:1:1) had the highest seedling vigor index (2329), which was comparable to treatment soil + cocopeat + vermicompost (2123), soil + vermicompost

Table 2. Effect of germination media on germination percentage and germination speed of tomato seedlings.

Treatments	Germination percentage	Germination speed
T1	85.42[b]	29.49[abc]
T2	62.50[c]	29.44[abc]
T3	68.75[c]	36.26[a]
T4	85.42[b]	27.46[abc]
T5	83.33[b]	32.42[abc]
T6	93.75[ab]	35.52[ab]
T7	89.58[ab]	20.95[c]
T8	97.92[a]	23.47[abc]
T9	100.0[a]	22.92[bc]
Grand mean	85.2	28.7
CV%	7.6	13.3
SEM (±)	5.29	5.46
LSD $_{(0.05)}$	11.11	11.47
F test	***	**

**significance at 1% level of significance, ***significance at 0.1% level of significance, LSD: Least significant difference, SEM: Standard error of the mean, CV: Coefficient of differences.

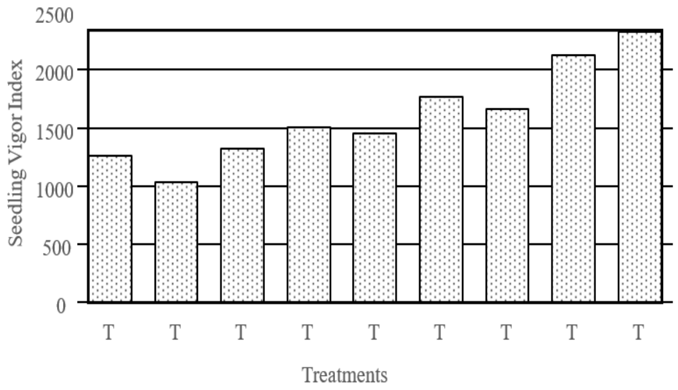

Figure 3. *Effect of germination media on seedling vigor index of tomato seedlings.*

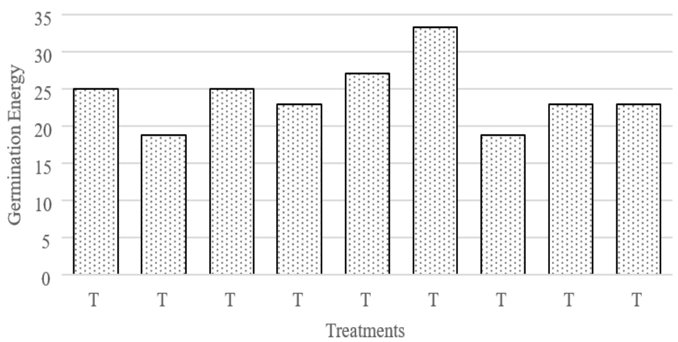

Figure 4. *Effect of germination media on germination energy of tomato seedlings.*

(1768), cocopeat + vermicompost (1667), soil + FYM (1508), soil + cocopeat (1456), and vermicompost (1319), soil (1262) as shown in figure 3. Similarly, the result was supported by Panthi *et al*. (2023). A minimum (1031) seedling vigor index was recorded in treatment cocopeat only. Vermicompost contains macro and micronutrients. Cocopeat is an agricultural by-product obtained after fiber extraction from the coconut husk (Bhardwaj, 2013).

Effect of germination media on root length and shoot length

The germination media significantly (p≤0.001) affected the root length of 20, 25, and 30 days old seedlings. The growth media had the longest reported root length. Soil + cocopeat + vermicompost + FYM (10.967 cm) was followed by the following treatments: soil + cocopeat (8.530 cm), soil + FYM (8.460 cm), cocopeat (8.420 cm), soil + vermicompost (9.487 cm), vermicompost (9.340 cm), soil + cocopeat + vermicompost (8.920 cm), cocopeat + vermicompost (8.873 cm), and soil (7.367 cm) at 30 DAS. At 20 DAS, the germination media Soil had the shortest root length (3.353 cm). The germination media soil + cocopeat + vermicompost (1:1:1) had the most extended shoot length (12.847 cm), which was statistically comparable to treatments soil + cocopeat + vermicompost + FYM (12.323 cm). at 30 das, vermicompost (9.850 cm), cocopeat + vermicompost (9.713 cm), soil + vermicompost (9.387 cm), soil + FYM (9.250 cm), soil + cocopeat (8.953 cm), cocopeat (8.103 cm), and soil (7.397 cm) were next in order. At 20 DAS, soil had the shortest shoot length (5.520 cm), which was statistically comparable to soil + cocopeat (6.397 cm) and cocopeat alone (6.493 cm) as shown in Table 3. The results revealed that the stem diameter was significantly high in the growth medium with cocopeat, vermicompost, and FYM. Similar results were obtained by Goel & Kaur (2012). This might be due to the vermicompost has the potential to make a valuable contribution to soilless potting media (Paul & Metzger, 2005). Organic matter in the vermicompost may also improve nutrient availability and phosphorus absorption (Kaur, 2017).

Effect of germination media on stem diameter and number of leaves

The stem diameter of the seedling was found to be non-significant among tested different germination media at 25 and 30 DAS and found significant at 20 DAS. At 30 DAS, the soil + cocopeat + vermicompost (1:1:1) produced the largest stem diameter (0.310 cm), while at 20 DAS, the soil + cocopeat (1:1) produced the smallest stem diameter (0.110 cm), which was comparable to the growing media cocopeat (0.123 cm). According to the study, the number of leaves per seedling varied significantly (p<0.001) throughout the investigated germination media. In comparison to soil + cocopeat + vermicompost (19.70), the soil + cocopeat + vermicompost + FYM (1:1:1:1) had the maximum number of leaves per seedling (20.87), followed by soil + vermicompost (16.10) and soil + FYM (15.47) at 30DAS as illustrated in Table 4. At 20DAS, the lowest leaf count (4.400) was noted for soil. Jeevitha *et al*. (2019) reported that among the different growing media used 75% Vermicompost +25% FYM media was found to be significantly superior for seedling production of tomatoes in terms of seedling height, seedling girth, leaf area, shoot length and root length. The highest number of leaves per seedling (20.87) was recorded for the soil + cocopeat + vermicompost + FYM (1:1:1:1) which was at par with soil + cocopeat + vermicompost (19.70) followed by soil + vermicompost (16.10), Soil +FYM (15.47) at 30DAS. The lowest number of leaves (4.400) recorded for soil at 20DAS. The same findings were obtained by Song *et al*. (2022).

Table 3. Effect of different germination media on the root length and shoot length at 20, 25, and 30 DAS of tomato.

Treatments	20 DAS	Root length (cm) 25DAS	30DAS	20DAS	Shoot length (cm) 25DAS	30DAS
T1	3.353^{e}	5.567^{f}	7.367^{d}	5.520^{c}	6.800^{d}	7.397^{b}
T2	4.660^{d}	7.453^{d}	8.420^{c}	6.493^{bc}	7.403^{cd}	8.103^{b}
T3	6.647^{b}	8.100^{bc}	9.340^{bc}	7.230^{b}	8.850^{b}	9.850^{b}
T4	6.320^{b}	7.540^{d}	8.460^{c}	7.353^{b}	8.443^{bc}	9.250^{b}
T5	5.513^{c}	6.530^{e}	8.530^{bc}	6.397^{bc}	7.893^{bcd}	8.953^{b}
T6	6.803^{b}	7.620^{cd}	9.487^{b}	7.173^{b}	8.357^{bc}	9.387^{b}
T7	6.390^{b}	8.360^{b}	8.873^{bc}	7.013^{b}	8.093^{bcd}	9.713^{b}
T8	6.787^{b}	7.823^{cd}	8.920^{bc}	8.633^{a}	10.100^{a}	12.847^{a}
T9	8.523^{a}	9.480^{a}	10.967^{a}	9.007^{a}	10.747^{a}	12.323^{a}
Grand mean	6.111	7.608	8.929	7.20	8.52	9.76
CV%	4.3	3.6	5.8	8.3	8.4	13.3
SEM(±)	0.2153	0.2213	0.4240	0.489	0.586	1.062
$LSD_{(0.05)}$	0.452	0.464	0.890	1.028	1.231	2.232
F test	***	***	***	***	***	***

*Significance at 5% level of significance, **Significance at 1% level of significance, ***Significance at 0.1% level of significance, LSD: Least significant difference, SEM: Standard error of the mean, CV: Coefficient of differences.

Table 4. Effect of different germination media on the stem diameter and number of leaves at 20, 25 and 30 DAS of tomato.

Treatments	Stem diameter (cm)			Number of leaves		
	20DAS	25DAS	30DAS	20DAS	25DAS	30DAS
T1	0.186^{a}	0.250^{ab}	0.290^{a}	4.400^{g}	6.47^{f}	8.93^{e}
T2	0.123^{b}	0.170^{b}	0.270^{a}	5.200^{f}	7.50^{e}	11.40^{de}
T3	0.163^{ab}	0.210^{ab}	0.286^{a}	6.433^{e}	8.47^{d}	11.60^{de}
T4	0.140^{ab}	0.236^{ab}	0.300^{a}	8.600^{c}	10.60^{c}	15.47^{cd}
T5	0.110^{b}	0.193^{ab}	0.280^{a}	5.500^{f}	8.40^{d}	15.00^{cd}
T6	0.183^{a}	0.243^{ab}	0.283^{a}	7.533^{d}	11.47^{b}	16.10^{bc}
T7	0.156^{ab}	0.233^{ab}	0.283^{a}	7.133^{d}	8.83^{d}	13.60^{cd}
T8	0.166^{ab}	0.290^{a}	0.310^{a}	11.10^{a}	14.77^{a}	19.70^{ab}
T9	0.156^{ab}	0.243^{ab}	0.293^{a}	9.400^{b}	15.03^{a}	20.87^{a}
Grand mean	0.154	0.230	0.289	7.256	10.170	14.74
CV%	19.70	24.80	19.70	4.60	4.20	15.0
SEM(±)	0.024	0.0465	0.046	0.2722	0.3496	1.802
$LSD_{(0.05)}$	0.052	0.097	0.097	0.571	0.734	3.786
F test	*	NS	NS	***	***	***

*significance at 5% level of significance, **significance at 1% level of significance, ***significance at 0.1% level of significance, NS, Non-significant, LSD: Least significant difference, SEM: Standard error of the mean, CV: Coefficient of differences.

Table 5. Effect of different germination media on the fresh weight and dry weight at 20, 25, and 30 DAS of tomato.

Treatments	Fresh weight (g)			Dry weight (g)		
	20DAS	25DAS	30DAS	20DAS	25DAS	30DAS
T1	0.113^{d}	0.340^{c}	0.526^{b}	0.005^{d}	0.013^{d}	0.022^{d}
T2	0.310^{bc}	0.423^{c}	0.783^{b}	0.014^{c}	0.021^{cd}	0.034^{bcd}
T3	0.386^{b}	0.560^{bc}	0.836^{ab}	0.019^{bc}	0.026^{bc}	0.041^{bc}
T4	0.386^{b}	0.563^{bc}	0.880^{ab}	0.022^{b}	0.033^{b}	0.044^{b}
T5	0.200^{cd}	0.463^{bc}	0.640^{b}	0.034^{a}	0.050^{a}	0.066^{a}
T6	0.436^{b}	0.653^{abc}	0.903^{ab}	0.017^{c}	0.024^{c}	0.033^{bcd}
T7	0.323^{bc}	0.613^{bc}	0.966^{ab}	0.014^{c}	0.021^{c}	0.031^{cd}
T8	0.736^{a}	0.943^{a}	1.540^{a}	0.015^{c}	0.022^{c}	0.031^{cd}
T9	0.616^{a}	0.763^{ab}	1.070^{ab}	0.016^{c}	0.022^{c}	0.029^{bc}
Grand mean	0.390	0.591	0.905	0.0176	0.026	0.038
CV%	19.10	27.7	42.0	16.30	18.0	14.1
SEM (±)	0.060	0.133	0.310	0.002	0.003	0.005
LSD (0.05)	0.1278	0.2808	0.6520	0.0049	0.0081	0.0117
F test	***	**	NS	***	***	***

*Significance at 5% level of significance, **significance at 1% level of significance, ***significance at 0.1% level of significance, NS, Non-significant, LSD: Least significant difference, SEM: Standard error of the mean, CV: Coefficient of difference

Effect of germination media on fresh weight and dry weight of tomato seedling

At 30 DAS, soil + cocopeat + vermicompost (1:1:1) had the highest fresh weight (1.540 g), which was comparable to soil + cocopeat + vermicompost + FYM (1.070 kg), cocopeat + vermicompost (0.966 g), soil + vermicompost (0.903 g), soil + FYM (0.880 g), and vermicompost (0.836 g). The same results were obtained by Wang *et al*. (2017). At 20DAS, treated soil had the lowest fresh weight (0.113 mg), comparable to soil + cocopeat (0.200 gm). The study found that the growth conditions had substantial ($p<0.001$) differences in seedling dry weights at 20, 25, and 30 DAS as shown in Table 5. Jawaad *et al*. (2016) demonstrated that a balanced combination of peat, compost, and traditional farming methods yielded the most substantial improvements in these growth parameters. According to Song *et al*. (2022) showed moderate light with a controlled cool-night temperature improved biomass accumulation and growth efficiency, enhancing the photosynthetic rate under non-stressful conditions.

Conclusion

Germination media significantly influence the germination and growth parameters of tomato seedlings. Tomato seed sown in growth media soil + cocopeat + vermicompost (1:1:1) is best for maximum shoot length, stem diameter, fresh weight. Maximum germination speed was recorded in growth media vermicompost only and maximum germination energy was recorded in treatment soil + vermicompost (1:1). The maximum dry weight was recorded in treatments soil + cocopeat. The superiority of above mention parameter was recorded in treatment of all mixtures soil + cocopeat + vermicompost + FYM in equal proportion followed by treatment soil + cocopeat + vermicompost (1:1:1) except germination speed, germination energy and dry weights. Therefore, it is concluded that the combination of soil + cocopeat + vermicompost + FYM were found most suitable for better growth of tomato seedlings.

DECLARATIONS

Author contribution statement

Conceptualization: D.B. and S.K.; Methodology: D.B., S.K., and D.K.; software and validation: D.B. and D.K.; Formal analysis and investigation: D.B., D.K., S.K., and A.S.; Resources: S.K., D.B., and A.S.; Data curation: D.K., D.B., and S.K.; Writing-original draft preparation: D.B., D.K., S.K., and A.S.; writing-review and editing: D.B., D.K., S.K., and A.S; Visualization: D.B., D.K., S.K., and A.S; Supervision: D.K., Funding acquisition: D.K., D.B., A.S., and S.K. All authors have read and agreed to the published version of the manuscript.

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