*Biological Forum – An International Journal* 14(3): 322-330(2022)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

# Growth Performance of Teak (*Tectona grandis* Linn.) Stump under different Growing Media in Nursery

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*(Received 12 May 2022, Accepted 04 July, 2022)*
*(Published by Research Trend, Website: www.researchtrend.net)*

**ABSTRACT: A study was conducted to obtain low cost and easily available growing media for raising quality seedlings and assess the sprouting and growth attributes of teak (*Tectona grandis* Linn.) stump under different growing media using soil, sand, FYM, sawdust and vermicompost in different proportion in nursery condition. Healthy and vigorous one-year old stumps of 2.5 cm shoot and 12.5 cm root were selected and planted in the polybags of 6” x 12” in size having eleven combinations of growing media for 240 days. The growing media viz., sand: soil: FYM (1:1:1), sand: soil: vermicompost (1:1:1) and, sawdust: soil: FYM (1:1:1) showed highest** sprouting **percentage (100%) indicating better sprouting possibility than solo media like vermicompost (96%), soil (95.33%) and sawdust (91.33%). Highest (20.29 mm and 170.45 cm) and lowest (9.21 mm and height 62.94 cm) collar diameter and height was exhibited in sand: soil: vermicompost (1:2:1) and soil growing media, respectively. After 240 days in the nursery, sturdiness quotient in each and every growing media was cross the limit (6.0) signalling the risk on survival and growth in the field. Therefore, it is recommended to use vermicompost based composite media for the production of healthy and quality seedlings of *T. grandis* for mass scale under nursery condition.**

**Keywords:** Collar diameter, growing media, sprouting, stump, *Tectona grandis*

## INTRODUCTION

Teak (*Tectona grandis* Linn.) is one of the most important widely planted hardwood tropical timber species in the World (Ball *et al*., 1999), increasing subsequently from 2.25 million ha to 6.0 million hectares (Bhat and Hwan, 2004) and distributed at latitudes in the range of $9^0 – 25^0 30$’ N and longitudes of 73°E to 104°30' E (Thaiutsa *et al*., 2001). It is indigenous in both peninsulas of India, in north-eastern drier parts of Java and in other islands of Indian Archipelago (Brandis, 1906). Its natural habitat lies between 10°N and 25°N latitudes with altitudinal range up to 1300 m above sea level on the Indian subcontinent and in South East Asia, especially in India, Burma, Thailand, Cambodia, Vietnam and Indonesia. It is accounted as one of the best economic tree species and mostly highly-valued hardwood due to the dimensional stability, quality, attractiveness, workability and durability of its heartwood (Bermejo *et al*., 2003). It is preferably grown in the areas having at mean annual temperature varies from 14º- 36ºC and annual rainfall ranges from 600 to 4000 mm, but mostly prefer contrasting dry and wet seasons with a wide range of climatic and edaphic conditions (Orwa *et al*., 2009). In India, it grows well in dry and moist deciduous forest and even if extensively planted throughout India both within as well as outside its natural distributional range covering 8.9 million hectare and has the maximum genetic variability of teak (Luna, 1996).

The growth behaviour of teak seedlings ascertains its superiority for its successful establishment either in any plantation programme on in agroforestry system which depends upon its genetic make-up of parent trees as well as environment particularly edaphic and climatic condition. So, planters or farmers are adopting different practices in teak plantation silviculture including regeneration, immediate cuttings and protection for management of teak plantation (Suwannapinant *et al*., 2001). Teak plants are generally raised either by seeds or stumps or vegetative means as grafting, layering and branch cutting. Rapid early growth of seedlings in nursery helps in early establishment in the field. To produce better quality seedlings for achieving maximum productivity, seedlings are either to be fertilized or raised with using proper growing media in nursery. This practice is now quite common in nursery for developing sturdy root system which enables the plant for vigorous growth and survive after transplanting. The works on the growth performance of forest seedlings with the application of different growing media or potting mixtures in nursery have been carried out by different workers (Guleria, 2006; Mhango *et al*., 2008; Sondarva *et al*., 2017; Vidyasagaran and Kumar, 2017 and Mahmoud *et al*., 2019). But the effect of growing media on growth performance of teak stump has not been fully evaluated. Keeping in view the importance of teak, the present study was focussed on the application of low cost and easily available different growing media for raising quality seedlings of teak through stumps in the nursery.

## MATERIALS AND METHODS

The experiment was carried out in the Central Forest Nursery of the Department of Forestry, Uttar Banga Krishi Viswavidyalaya during 2019-2020. The site is located in the plains of *terai* zone of West Bengal with 26°23'45.8"N latitude and 89°23'16.7"E longitude with an elevation of 43 m above mean sea level. The climate is mostly dominated by humid subtropical over the region with a considerable variation in seasonal and diurnal temperature. The minimum and maximum temperature varied from 9.86°C during winter (January) to 34.34°C during summer (August). Average annual rainfall is varied from 2200 to 3000 mm with a relative humidity from 49.66 to 93.10%.

The growing media used were nursery soil, farm yard manure (FYM), vermicompost and saw dust in different proportion. The nursery soils were air-dried, sieved to remove stones, pellets and other foreign materials. Then, approximately 2-3 kg of properly mixed above mentioned growing media was filled up in the polybags of 6" x 12" in size under nursery condition for propagation. One-year old teak stumps i.e. root-shoot cuttings of uniform size and pencil thickness having 2.5 cm shoot and 12.5 cm root was planted in polybags comprising different growing media in different ratio. The experiment was consisting complete randomized design with 11 treatments in three replications namely, $T_1$- soil; $T_2$- sand: soil (1:1); $T_3$- sand: soil: FYM (1:1:1); $T_4$- sand: soil: FYM (1:2:1); $T_5$- Vermicompost; $T_6$- sand: soil: vermicompost: (1:1:1); $T_7$- sand: soil: vermicompost: (1:2:1); $T_8$- sawdust; $T_9$- sawdust: soil (1:1); $T_{10}$- sawdust: soil: FYM (1:1:1) and $T_{11}$- sawdust: soil: FYM (1:2:1). A total of 150 stumps per treatment having with fifty stumps in each replication were taken for study. Weeding and irrigation was done as and when required. At the end of 30 days, data on sprouting percentage and time taken for complete sprouting were recorded, where survival percentage was calculated on monthly basis up to eight months. The observations on growth attributes of seedlings *i.e.* collar diameter, shoot height, number of leaves, fresh and dry weight of leaf, shoot and root, total biomass, leaf area on the basis of area-dry weight relation ($cm^2$) and sturdiness quotient (S.Q.) as outlined by (Thomson, 1985) were assessed at the interval of two months up to the age of eight months by selecting three seedlings randomly per replication of each treatment. All the data were subjected to three-way analysis of variance (ANOVA) for testing the effect of plant species, planting geometry and soil depth individually and interactions among them. Least significant difference ($P \leq 0.05$) values were used to compare the treatment differences.

## RESULTS AND DISCUSSION

The mean sprouting percentage and time taken for completion of sprouting in the different growing media was significantly different (Fig. 1). Irrespective of the growing media, the sprouting of teak stumps was ranged from 91.33 to 100% with an average value of 97.82%. Highest sprouting (100%) was observed in media comprising sand: soil: FYM (1:1:1), sand: soil: vermicompost (1:1:1) and sawdust: soil: FYM (1:1:1) whereas lowest sprouting (91.33%) was in sawdust followed by soil (95.33%) which was significantly different with each other. It might be due to more compactness and binding property with highest Ca content in vermicompost and acidic nature of soil (Nurhidayati *et al*., 2017). The sprouting percentage in composite media with vermicompost showed 96 to 100%, indicating superiority over the growing media composite with sawdust (91.33 to 100%) and other composite media (95.33 to 100%) after 30 days. The performance of composite media provided better condition for sprouting as compared to sole media, particularly sawdust (91.33%), soil (95.33%) and vermicompost (96.00%), respectively. Though, the teak stumps were prepared from the same batch of seedlings, the variation in sprouting percentage might be due to the presence of plant hormones which regulate the development of buds into sprouts and stored reserves foods which enable sprouts to expand. Particularly endogenous cytokinin and inherent potential for mobilizing and utilizing of stored reserves in teak stump are likely to be sufficient for stump sprouting. This finding is consonance with the findings of Kaosa-ard *et al*. (1977); Zaller (2007) as vermicompost as a substrate positively effect on sprouting of *Lycopersicon esculentum* whereas Omokhua *et al*. (2015) noticed that sawdust enhanced sprouting percentage in *T. ivorensis* which is contradictory with our findings. Sood and Ram (2019) assessed that soil: sand: vermicompost (1:1:1) was observed significantly higher germination than that of soil: sand: FYM (1:1:1) in *Oroxylum indicum*. This result is closely agreement with the findings of Khadijah *et al*. (2020); Panda *et al*. (2021).

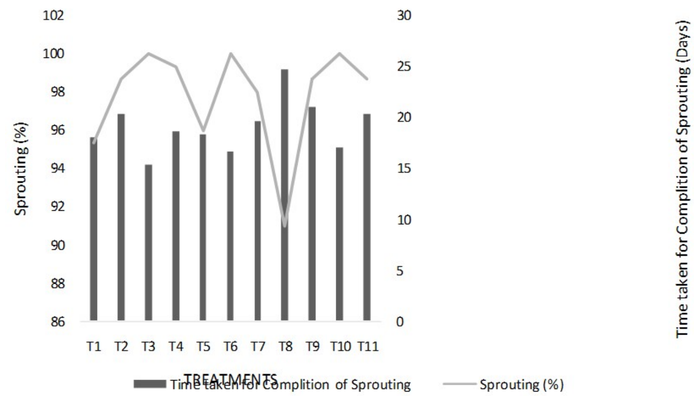


**Fig. 1.** Sprouting (%) and Time taken for completion of sprouting (days) of teak sumps in different growing media.

The longest time span (24.67 days) was recorded in sawdust for complete sprouting whereas the least (15.33 days) was found in soil: sand: FYM (1:1:1) followed by 16.67 and 17.0 days in soil: sand: vermicompost (1:1:1) and sawdust: soil: FYM (1:1:1), respectively which was not significantly different with other. The rest of growing media such as soil; sand: soil (1:1); sand: soil: FYM (1:2:1); vermicompost; sand: soil: vermicompost: (1:2:1); sawdust: soil (1:1) and sawdust: soil: FYM (1:2:1) with respect to the number of days taken for complete sprouting was not significantly different with each other. The time span varied between 17.00 to 24.67 days in sawdust composition 16.67 to 19.67 in vermicompost composition while other media showed 15.33 to 20.33 days, which clearly indicated that, the superiority of vermicompost as a better media to take lesser time for completion of sprouting. It might be due to the available of higher N content in vermicompost composite mixture than sole media which influenced the germination period (Lazcano *et al*., 2010). Sondarva *et al.* (2017) observed the similar findings that the media composition vermicompost and red soil took minimum 7.58 days for germination in *Khaya senegalensis*.

The survival percentage was showed decreasing trend with increasing the age of the seedlings with significant difference among the treatment (Fig. 2). After 240 days of growth, the maximum survival (95.33%) was observed in sand: soil: vermicompost (1:1:1) which was statistically at par with 88.67% in sawdust: soil: FYM (1:1:1) followed by 86.67% in both, sand: soil: FYM (1:1:1) and sawdust: soil: FYM (1:2:1) growing media, respectively whereas the minimum (62.67%) was in sawdust followed by 71.33 and 80.00% in soil and sand: soil: FYM (1:2:1) growing media, respectively. The vermicompost as component of growing media ranged from 84 to 95.33% which proved the best performing in terms of survival percentage followed by sawdust composite media (62.67 to 88.67%) and other composite media (71.33 to 86.67%) after 240 days. The results presented in this study are well in line with the results obtained earlier by Masilamani *et al.* (2010) in teak stumps as maximum survival (98%) was observed with red earth: sand: farm yard manure (2:1:1) and the probability of plant mortality was significantly higher in *Uapaca kirkiana* seedling with saw dust media which may be due to the tannin and low nutrient content (Sileshi *et al*., 2007).

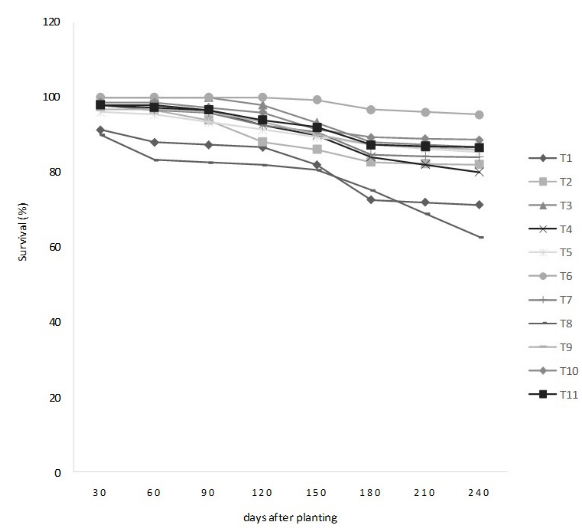


**Fig. 2.** Survival percentage (%) of teak stumps in different growing media.

The effect of growing media on growth attributes like collar diameter, height and number of leaves was showed with significant difference among the growing media throughout the growing period. Irrespective of growing media, the collar diameter ranged from 5.70 to 8.94 mm with a mean value of 6.99 mm at 60 days; 7.32 to 11.04 mm with an average of 9.88 mm at 120 days; 9.08 to 14.38 mm with an average of 12.54 mm at 180 days and 9.21 to 20.29 mm with a mean value of 14.60 mm at 240 days of growth, respectively (Table 1). The collar diameter was showed increasing trend during the growth period. After 60 days of growth, sawdust: soil (1:1) exhibited highest (8.94 mm) collar diameter followed by sawdust (7.89 mm) and 7.82 mm in sand: soil: FYM (1:2:1), respectively whereas the growing media sawdust and sand: soil: FYM (1:1:1) recorded maximum collar diameter (11.04 and 14.38 mm) in at 120 and 180 days, respectively while the sole media soil showed minimum (5.71, 7.32 and 9.08 mm) at 60, 120 and 180 days, respectively. Similarly, highest (20.29 mm) collar diameter was found in sand: soil: vermicompost (1:2:1) followed by 15.79 mm in sawdust: soil: FYM (1:2:1) which was closely at par with sawdust (15.53 mm) whereas the lowest (9.21 mm) was found in soil at 240 days of growth. The collar diameter varied from 14.91 to 20.29 mm in the vermicompost based growing media which proved the best performing growing media in terms of collar diameter followed by sawdust composite media (12.40 to 15.79 mm) and other composite media (9.21 to 15.13 mm) after 240 days. This finding is similar with the result of Mwadalu *et al*. (2020) in seedling of *Casuarina equisetifolia*: highest collar diameter with 10% manure as it enhanced the nitrogen and phosphorus availability and Murugesan *et al*. (2014) in *Pongamia pinnata*, treated with flyash: vermicompost: soil (1:1:2) by catalysing the uptake of NPK and micro nutrients (Fe, Mn, Cu and Zn) at all growth stages.

**Table 1: Effect of growing media on collar diameter, height and number of leaf of *Tectona grandis* stump.**

| Treatments | Collar diameter (mm) | | | | Height (cm) | | | | Number of leaves | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 60DAP | 120DAP | 180DAP | 240DAP | 60DAP | 120DAP | 180DAP | 240DAP | 60DAP | 120DAP | 180DAP | 240DAP |
| $T_1$: Soil | $5.7^{f}$ | $7.32^{e}$ | $9.08^{f}$ | $9.21^{e}$ | $24.95^{g}$ | $51.43^{g}$ | $56.99^{g}$ | $62.94^{g}$ | $6.7^{c}$ | $9.0^{c}$ | $7.2^{e}$ | $6.0^{c}$ |
| $T_2$: Sand: soil (1:1) | $6.19^{def}$ | $10.05^{bc}$ | $13.05^{bcd}$ | $13.73^{cd}$ | $25.12^{g}$ | $59.30^{f}$ | $93.91^{f}$ | $103.36^{f}$ | $7.5^{b}$ | $9.3^{bcd}$ | $8.0^{bcde}$ | $6.3^{bc}$ |
| $T_3$: Sand: soil: FYM (1:1:1) | $7.03^{bcd}$ | $10.26^{abc}$ | $14.38^{a}$ | $15.13^{bc}$ | $35.78^{ef}$ | $76.02^{d}$ | $109.71^{cde}$ | $118.72^{de}$ | $7.2^{b}$ | $10.3^{b}$ | $9.2^{a}$ | $6.7^{abc}$ |
| $T_4$: Sand: soil: FYM (1:2:1) | $7.82^{bc}$ | $10.78^{ab}$ | $13.05^{bcd}$ | $14.04^{bcd}$ | $49.06^{b}$ | $88.56^{c}$ | $113.08^{bcd}$ | $132.40^{c}$ | $9.7^{a}$ | $11.6^{a}$ | $8.8^{abc}$ | $7.4^{a}$ |
| $T_5$: Vermicompost | $6.09^{ef}$ | $10.14^{bc}$ | $13.65^{ab}$ | $14.99^{bc}$ | $39.37^{d}$ | $91.58^{bc}$ | $120.41^{a}$ | $150.96^{b}$ | $7.2^{b}$ | $9.7^{bc}$ | $8.3^{abcd}$ | $7.0^{abc}$ |
| $T_6$: Sand: soil: vermicompost (1:1:1) | $6.95^{cde}$ | $9.44^{c}$ | $13.04^{bcd}$ | $14.91^{bc}$ | $32.62^{f}$ | $66.12^{e}$ | $107.06^{de}$ | $109.18^{e}$ | $7.9^{b}$ | $9.3^{bcd}$ | $7.8^{cde}$ | $6.6^{abc}$ |
| $T_7$: Sand: soil: vermicompost (1:2:1) | $6.81^{de}$ | $10.55^{ab}$ | $12.97^{bcd}$ | $20.29^{a}$ | $44.94^{c}$ | $89.9^{c}$ | $117.70^{ab}$ | $170.45^{a}$ | $8.0^{b}$ | $10.0^{bc}$ | $8.1^{bcde}$ | 7.4a |
| $T_8$: Sawdust | $7.89^{b}$ | $11.04^{a}$ | $13.43^{ac}$ | $15.53^{b}$ | $43.56^{c}$ | $89.82^{c}$ | $103.82^{e}$ | $120.37^{cde}$ | $7.6^{bc}$ | $10.3^{b}$ | $9.2^{a}$ | $4.7^{d}$ |
| $T_9$: Sawdust: soil (1:1) | $8.94^{a}$ | $10.35^{ab}$ | $12.44^{cd}$ | $14.56^{bc}$ | $54.41^{a}$ | $103.61^{a}$ | $115.40^{abc}$ | $146.91^{b}$ | $7.0^{b}$ | $9.6^{bc}$ | $9.0^{ab}$ | $7.1^{ab}$ |
| $T_{10}$: Sawdust: soil: FYM (1:1:1) | $6.96^{cde}$ | $10.38^{ab}$ | $11.90^{de}$ | $12.40^{d}$ | $38.31^{de}$ | $94.66^{b}$ | $104.74^{e}$ | $121.49^{cd}$ | $7.1^{b}$ | $8.2^{d}$ | $7.6^{de}$ | $7.4^{a}$ |
| $T_{11}$: Sawdust: soil: FYM (1:2:1) | $6.56^{def}$ | $8.39^{d}$ | $11.02^{e}$ | $15.79^{b}$ | $33.48^{f}$ | $65.72^{e}$ | $90.32^{f}$ | $118.79^{de}$ | $6.7^{c}$ | $9.8^{bc}$ | $7.2^{e}$ | $7.1^{ab}$ |
| Mean | 6.99 | 9.88 | 12.54 | 14.60 | 38.33 | 79.70 | 103.01 | 123.23 | 7.50 | 9.74 | 8.22 | 6.71 |
| Sem± | 0.299 | 0.301 | 0.391 | 0.598 | 1.155 | 1.512 | 2.214 | 4.194 | 0.353 | 0.391 | 0.324 | 0.335 |
| CD (0.05) | 0.88 | 0.88 | 1.15 | 1.75 | 3.39 | 4.44 | 6.49 | 12.3 | 1.0 | 1.2 | 1.0 | 1.0 |

Means with same letters are not significantly different.

Height of the seedlings showed increasing trend with age in all growing media during the period of study. Irrespective of growing media, the average height was 38.33, 79.70, 103.01 and 123.23 cm at 60, 120, 180 and 240 days of growth, respectively (Table 1). The maximum height (170.45 cm) was observed in sand: soil: vermicompost (1:2:1) followed by 150.96 cm in vermicompost which statistically at par with sawdust: soil (1:1) indicating 146.91 cm whereas minimum (62.94 cm) was recorded in soil at 240 days. The vermicompost based composite media influenced the height from 109.18 to 170.45cm and proved the best performing in terms of height followed by sawdust composite media (118.79 to 146.91cm) and other composite media (62.94 to 132.40cm) after 240 days. It might be due to the effect of the combination of high moisture retention and significant air space in growing media. The present study is close agreement with Dao *et al*. (2020) that vermicompost enhanced the relative height growth (132% in *Betula platyphylla*, 114% in *Larix kaempferi* and 57% in *Chamaecyparis obtuse*) with significant increased N concentration. The vermicompost growing media was not only improved health but also promoted plant growth because of higher microbial load (Emperor and Kumar, 2015) while sawdust was recorded lowest seedling growth in height and root collar diameter in seedlings (Ashiono *et al*., 2017) due to slow rate of decomposition and temporary depression in nitrogen release tendency (Garner, 2014).

The number of leaves per plant showed an increasing trend up to 120 days and thereafter declined due to the starting of leaf fall in winter (Table 1). The number of leaves per plant varied from 6.7 to 9.7 with a mean of 7.50; 8.2 to 11.6 with an average value of 9.74; 7.2 to 9.2 with a mean of 8.22 and 4.7 to 7.4 with an average value of 6.71 at 60, 120 180 and 240 days of growth, respectively. Maximum number of leaves per plant (7.4) was recorded in three growing media, particularly in sand: soil: FYM (1:2:1); sand: soil: vermicompost (1:2:1) and sawdust: soil: FYM (1:1:1) whereas minimum (4.7) was in sawdust at the end of 240 days of growth. The vermicompost composite media showed the best performing in terms of number of leaves than sawdust composite media and other composite media after 240 days. In another study, the highest number of leaves per stump were enumerated in composition of vermicompost and red soil (1:1) in *Khaya senegalensis* as organic media were generally rich in essential plant nutrients including vitamins, enzymes and hormones (Sondarva *et al*., 2017); whereas sand and sawdust: sand (1:1) were enhanced the number of leaves of *Cordia africana* branch cuttings due to the physical characteristic of the media in regard to the porosity and air water balance (Ambebe *et al*., 2018).

The results pertaining to fresh weight of leaves, root and shoot are presented in Table 2 and showed significant difference (p = 0.05) among the different growing media throughout the growing period for all traits. An increasing trend in the leaf fresh weight was exhibited with age up to 180 days and then showed declining trend afterwards but increasing trend was observed in both root and shoot fresh weight throughout the growing periods. The range among the different growing media for fresh weight of leaves was observed to be 13.66 – 37.81 g/plant, 15.59 – 40.77 g/plant, 46.87 – 103.45 g/plant and 37.82 – 63.12 g/plant at 60, 120, 180 and 240 days of growth, respectively. The maximum leaf fresh weight (63.12 g/plant) was recorded in sand: soil: vermicompost (1:2:1) followed by 58.49 g/plantin sawdust: soil (1:1) and 56.15 g/plant in sawdust: soil: FYM (1:1:1) whereas minimum (37.82 g/plant) was recorded in sawdust: soil: FYM (1:2:1) followed by soil (46.87 g/plant) at the end of 240 days of growth. After 60 days of growth of stumps, the maximum leaf fresh weight (37.81 g/plant) was recorded in sand: soil: FYM (1:2:1) statistically at par with sand: soil: FYM (1:1:1) and sawdust: soil (1:1) indicating 33.90 and 30.47 g/plant, respectively. It is clearly stated that organic manures effectively enhanced the vegetative growth of the plant and helped to produce the heaviest fresh weight of leaves. This study is well in line with the findings of Mohapatra and Das (2009); Quasni *et al*. (2014).

**Table 2: Effect of growing media on leaf fresh weight, shoot fresh weight and root fresh weight of *Tectona grandis* stump.**

| Treatments | Leaf fresh weight (g/plant) | | | | Root fresh weight (g/plant) | | | | Shoot fresh weight (g/plant) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 60DAP | 120DAP | 180DAP | 240DAP | 60DAP | 120DAP | 180DAP | 240DAP | 60DAP | 120DAP | 180DAP | 240DAP |
| $T_1$: Soil | 21.33$^{de}$ | 25.84$^{e}$ | 46.87$^{g}$ | 43.42$^{def}$ | 23.27$^{def}$ | 31.81$^{e}$ | 48.57$^{cd}$ | 65.16$^{d}$ | 7.78$^{g}$ | 20.71$^{g}$ | 52.39$^{g}$ | 67.85$^{e}$ |
| $T_2$: Sand: soil (1:1) | 23.85$^{d}$ | 27.82$^{de}$ | 64.76$^{ef}$ | 48.81$^{cde}$ | 26.43$^{cd}$ | 32.21$^{ef}$ | 43.74$^{de}$ | 70.54$^{cde}$ | 13.06$^{ef}$ | 33.96$^{ef}$ | 71.62$^{cde}$ | 76.15$^{e}$ |
| $T_3$: Sand: soil: FYM (1:1:1) | 33.90$^{ab}$ | 37.07$^{bc}$ | 85.06$^{b}$ | 55.80$^{abc}$ | 29.16$^{bc}$ | 37.01$^{de}$ | 55.65$^{bc}$ | 72.29$^{cd}$ | 16.81$^{cd}$ | 41.52$^{cde}$ | 90.29$^{b}$ | 101.29$^{d}$ |
| $T_4$: Sand: soil: FYM (1:2:1) | 37.81$^{a}$ | 40.77$^{ab}$ | 74.84$^{c}$ | 55.78$^{ab}$ | 33.77$^{ab}$ | 48.26$^{ab}$ | 60.86$^{ab}$ | 73.60$^{cd}$ | 21.86$^{a}$ | 57.53$^{a}$ | 104.79$^{a}$ | 113.30$^{bcd}$ |
| $T_5$: Vermicompost | 16.76$^{fg}$ | 33.07$^{cd}$ | 83.74$^{b}$ | 49.88$^{bcde}$ | 18.07$^{f}$ | 37.32$^{de}$ | 44.81$^{d}$ | 87.47$^{b}$ | 18.92$^{bc}$ | 38.53$^{de}$ | 70.45$^{cde}$ | 122.76$^{b}$ |
| $T_6$: Sand: soil: vermicompost (1:1:1) | 19.04$^{ef}$ | 36.70$^{bc}$ | 70.76$^{cd}$ | 41.08$^{e}$ | 24.88$^{cde}$ | 40.12$^{cd}$ | 44.93$^{d}$ | 80.50$^{bc}$ | 21.40$^{ab}$ | 44.93$^{cd}$ | 72.67$^{cd}$ | 123.81$^{b}$ |
| $T_7$: Sand: soil: vermicompost (1:2:1) | 18.43$^{ef}$ | 44.36$^{a}$ | 103.45$^{a}$ | 63.12$^{a}$ | 18.72$^{f}$ | 32.13$^{e}$ | 63.83$^{a}$ | 108.08$^{a}$ | 16.08$^{d}$ | 49.03$^{bc}$ | 76.55$^{c}$ | 144.93$^{a}$ |
| $T_8$: Sawdust | 28.84$^{c}$ | 35.89$^{bc}$ | 65.71$^{de}$ | 51.73$^{bcd}$ | 37.97$^{a}$ | 55.33$^{a}$ | 58.50$^{ab}$ | 107.20$^{a}$ | 15.15$^{de}$ | 55.89$^{ab}$ | 65.52$^{de}$ | 120.53$^{bc}$ |
| $T_9$: Sawdust: soil (1:1) | 30.47$^{bc}$ | 36.03$^{bc}$ | 102.60$^{a}$ | 58.49$^{ab}$ | 19.94$^{ef}$ | 27.60$^{f}$ | 53.76$^{bc}$ | 69.62$^{cd}$ | 21.07$^{a}$ | 54.17$^{ab}$ | 76.35$^{c}$ | 121.47$^{bc}$ |
| $T_{10}$: Sawdust: soil: FYM (1:1:1) | 18.43$^{ef}$ | 26.74$^{e}$ | 101.50$^{a}$ | 56.15$^{abc}$ | 29.23$^{bc}$ | 46.84$^{bc}$ | 43.48$^{d}$ | 106.87$^{a}$ | 11.08$^{f}$ | 46.35$^{c}$ | 55.44$^{fg}$ | 105.82$^{cd}$ |
| $T_{11}$: Sawdust: soil: FYM (1:2:1) | 13.66$^{g}$ | 15.59$^{f}$ | 59.95$^{f}$ | 37.82$^{f}$ | 17.64$^{f}$ | 31.34$^{e}$ | 37.18$^{e}$ | 59.95$^{e}$ | 10.82$^{f}$ | 27.99$^{fg}$ | 63.23$^{ef}$ | 79.77$^{e}$ |
| Mean | 23.87 | 32.72 | 78.11 | 51.10 | 25.37 | 38.18 | 50.48 | 81.93 | 15.82 | 42.78 | 72.66 | 107.06 |
| Sem± | 1.50 | 1.91 | 3.79 | 3.04 | 1.97 | 2.67 | 2.46 | 3.93 | 0.90 | 2.60 | 3.12 | 5.64 |
| CD (0.05) | 4.39 | 5.60 | 5.36 | 8.93 | 5.77 | 7.83 | 7.21 | 11.51 | 2.65 | 7.63 | 9.16 | 16.55 |

Means with same letters are not significantly different.

The average root fresh weight was found to be 25.37, 38.18, 50.48 and 81.93 g/plant at the age 60, 120, 180 and 240 days, respectively with irrespective of the growing media. The maximum root fresh weight (108.08 g/plant) was recorded in sand: soil: vermicompost (1:2:1) which was statistically at par with 107.20 g/plant in sawdust and 106.87 g/plant in sawdust: soil: FYM (1:1:1) whereas the minimum root fresh weight (59.95 g/plant) was observed in sawdust: soil: FYM (1:2:1) followed by 65.16 g/plant in soil. The present findings are showed similar result of Sood *et al*. (2018) as: soil: sand: vermicompost (1:1:1) induced highest root weight in *Terminalia bellirica* seedling and another finding, soil: sand: FYM (1:1:1) had more aeration than other media which provide adequate nutrients to promote better root growth of *Oroxylum indicum* seedlings (Sood and Ram, 2019).

Irrespective of the growing media, the mean value of shoot fresh weight was 15.82, 42.78, 72.66 and 107.06 g/plant at the age of 60, 120, 180 and 240 days, respectively. The maximum shoot fresh weight (144.93 g/plant) was recorded in sand: soil: vermicompost (1:2:1) followed by 123.81 g/plant in sand: soil: vermicompost (1:1:1) which was at par with 122.76g in vermicompost whereas the minimum (67.85 g) was in soil at the age of 240 days. The vermicompost based growing media influenced shoot fresh weight better than other growing media. The study is close agreement with Mathowa *et al*. (2014) that the combination of garden soil, forest soil and commercial compost significantly increased total shoot fresh weight in *Adansoni digitata* seedlings which may be attributed to the general improvement in the soil physical and chemical properties and also Sood *et al*. (2018) found that soil: sand: vermicompost (1:1:1) had highest fresh shoot weight in *Terminalia bellerica* seedling.

An appraisal of data in Table 3 it was found that the dry weight of root and shoot increased gradually at all periodic intervals among all growing media except leaf dry weight. The leaf, root and shoot dry weight of seedlings in different growing media showed wide range of variations with significant difference throughout the growing period in nursery. Leaf dry weight in different growing media ranged between 2.65 g/plant to 7.34 g/plant with an average of 4.63 g/plant at 60days; 3.51 to 9.98 g/plant with an average of 7.36 g/plant at 120 days; 17.87 g/plant to 30.83 g/plant with a mean of 23.28 at 180 days and 9.87 g/plant to 16.47 g/plant with average of 13.34 g/plant at the end of 240 days of growth. Maximum leaf dry weight (16.47 g/plant) was exhibited in sand: soil: vermicompost (1:2:1) which at par with 15.26 g/plant in sawdust: soil (1:1) whereas minimum (13.97 g/plant) was in soil growing media at 240 days of growth in nursery. The results indicating media close to neutral pH may supply nutrients in adequate quantities to container-grown trees for cell turgidity and enlargement within plant tissues. The study is closely similar with Quasni *et al*. (2014) in *Magnolia grandiflora* and Mahmoud *et al*. (2019) in *Pistacia vera*.

**Table 3: Effect of growing media on leaf dry weight, shoot dry weight and root dry weight of *Tectona grandis* stump.**

| Treatments | Leaf dry weight (g/plant) | | | | Root dry weight (g/plant) | | | | Shoot dry weight (g/plant) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 60DAP | 120DAP | 180DAP | 240DAP | 60DAP | 120DAP | 180DAP | 240DAP | 60DAP | 120DAP | 180DAP | 240DAP |
| $T_1$: Soil | $4.14^{de}$ | $5.81^{e}$ | $13.97^{e}$ | $11.33^{def}$ | $4.56^{def}$ | $8.27^{e}$ | $12.87^{cd}$ | $18.83^{de}$ | $1.51^{g}$ | $4.51^{g}$ | $13.52^{g}$ | $19.13^{e}$ |
| $T_2$: Sand: soil (1:1) | $4.63^{d}$ | $6.26^{de}$ | $19.30^{cd}$ | $12.74^{cde}$ | $5.18^{cd}$ | $8.37^{ef}$ | $11.59^{de}$ | $20.39^{cde}$ | $2.53^{ef}$ | $7.40^{ef}$ | $18.48^{cde}$ | $21.48^{e}$ |
| $T_3$: Sand: soil: FYM (1:1:1) | $6.58^{ab}$ | $8.34^{bc}$ | $25.35^{b}$ | $14.56^{abc}$ | $5.71^{bc}$ | $9.62^{de}$ | $14.75^{bc}$ | $20.89^{cd}$ | $3.26^{cd}$ | $9.05^{cde}$ | $23.29^{b}$ | $28.56^{d}$ |
| $T_4$: Sand: soil: FYM (1:2:1) | $7.34^{a}$ | $9.17^{ab}$ | $22.30^{bc}$ | $14.56^{abc}$ | $6.62^{ab}$ | $12.55^{ab}$ | $16.13^{ab}$ | $21.27^{cd}$ | $4.24^{a}$ | $12.54^{a}$ | $27.04^{a}$ | $31.95^{bcd}$ |
| $T_5$: Vermicompost | $3.25^{fg}$ | $7.44^{cd}$ | $24.95^{b}$ | $13.02^{bcde}$ | $3.54^{f}$ | $9.70^{de}$ | $11.87^{d}$ | $25.28^{b}$ | $3.67^{bc}$ | $8.40^{de}$ | $18.18^{cde}$ | $34.62^{b}$ |
| $T_6$: Sand: soil: vermicompost (1:1:1) | $3.69^{ef}$ | $8.26^{bc}$ | $21.09^{cd}$ | $10.72^{e}$ | $4.88^{cde}$ | $10.43^{cd}$ | $11.91^{d}$ | $23.26^{bc}$ | $4.15^{ab}$ | $9.80^{cd}$ | $18.75^{cd}$ | $34.92^{b}$ |
| $T_7$: Sand: soil: vermicompost (1:2:1) | $3.58^{ef}$ | $9.98^{a}$ | $30.83^{a}$ | $16.47^{a}$ | $3.67^{f}$ | $8.35^{ef}$ | $16.92^{a}$ | $31.23^{a}$ | $3.12^{d}$ | $10.69^{bc}$ | $19.75^{c}$ | $40.87^{a}$ |
| $T_8$: Sawdust | $5.60^{c}$ | $8.08^{bc}$ | $19.58^{cd}$ | $13.50^{bcd}$ | $7.44^{a}$ | $14.39^{a}$ | $15.50^{ab}$ | $30.98^{a}$ | $2.94^{de}$ | $12.18^{ab}$ | $16.90^{de}$ | $33.99^{bc}$ |
| $T_9$: Sawdust: soil (1:1) | $5.91^{bc}$ | $8.11^{bc}$ | $30.57^{a}$ | $15.26^{ab}$ | $3.91^{ef}$ | $7.18^{f}$ | $14.25^{bc}$ | $20.12^{cde}$ | $4.09^{ab}$ | $11.81^{ab}$ | $19.70^{c}$ | $34.26^{bc}$ |
| $T_{10}$: Sawdust: soil: FYM (1:1:1) | $3.58^{ef}$ | $6.02^{e}$ | $30.25^{a}$ | $14.66^{abc}$ | $5.73^{bc}$ | $12.18^{bc}$ | $11.52^{de}$ | $30.88^{a}$ | $2.15^{f}$ | $10.10^{c}$ | $14.30^{fg}$ | $29.84^{cd}$ |
| $T_{11}$: Sawdust: soil: FYM (1:2:1) | $2.65^{g}$ | $3.51^{f}$ | $17.87^{d}$ | $9.87^{f}$ | $3.46^{f}$ | $8.15^{ef}$ | $9.85^{e}$ | $17.32^{e}$ | $2.10^{f}$ | $6.10^{fg}$ | $16.31^{ef}$ | $22.49^{e}$ |
| Mean | 4.63 | 7.36 | 23.28 | 13.34 | 4.97 | 9.93 | 13.38 | 23.68 | 3.07 | 9.33 | 18.75 | 30.19 |
| Sem± | 0.291 | 0.429 | 1.129 | 0.794 | 0.385 | 0.694 | 0.651 | 1.134 | 1.175 | 0.567 | 0.81 | 1.591 |
| CD (0.05) | 0.85 | 1.26 | 3.31 | 2.33 | 1.13 | 2.04 | 1.91 | 3.33 | 0.52 | 1.66 | 2.36 | 4.67 |

Means with same letters are not significantly different.

As far as root dry weight per seedling is concerned, the average values varied from 4.97 to 23.68 g/plant from 60 to 240 days. The maximum root dry weight (16.92 and 31.23 g/plant) was recorded in sand: soil: vermicompost (1:2:1) at 180 and 240 days where as the growing media sawdust exhibited highest root dry weight (7.44 and 14.39 g/plant) in 60 and 120 days of growth of seedlings, respectively. The minimum root dry weight was recorded in sawdust: soil: FYM (1:2:1) in all growing periods in all growing media. The present findings are similar with the findings of Tallini *et al*. (1991); Daldoum and Hammad (2015) indicating humic acid in the vermicompost enhanced root growth parameter which organically is a bio-stimulant that boost up crop growth (Noory *et al*., 2022).

The maximum shoot dry weight (40.87 g/plant) was recorded in sand: soil: vermicompost (1:2:1) followed by 34.92 g/plant in sand: soil: vermicompost (1:1:1) which was statistically at par with vermicompost (34.62 g/plant) whereas the minimum (19.13 g/plant) in soil was not significantly different with 21.48 g/plant in sand: soil (1:1) and 22.49 g/plant in sawdust: soil: FYM (1:1:1) at the end of 240 days. Overall, the vermicompost composite media showed highest shoot dry weight (34.62 to 40.87 g/plant) in comparison to sawdust media (22.49 to 34.26 g/plant) and other composite media (19.13 to 31.95 g/plant) after 240 days. Singh *et al*. (2018) reported somewhat similar results in growing medium of soil: sand: FYM: dalweed (1:2:3:3) showed high dry shoot weight in *Pinus halepensis* due to more nitrogen from the FYM narrower C: N ratio which promote better shoot growth.

Different growing media had significant effect on the total biomass throughout the growing period (Table 4). The maximum total biomass (88.57 g/plant) was recorded in sand: soil: vermicompost (1:2:1) followed by 78.47 g/plant in sawdust which was statistically at par with sawdust: soil: FYM (1:1:1) with 75.38 g/plant whereas the minimum total biomass (49.29 g/plant) was recorded in soil closely followed by 49.68 g/plant in sawdust: soil: FYM (1:2:1) at 240 days. Similar trend was followed at 180 days whereas the maximum total biomass (18.20 and 34.65 g/plant) was exhibited in sand: soil: FYM (1:2:1) and sawdust at the age of 60 and 120 days, respectively while the minimum (8.21 and 17.76 g/plant) was observed in sawdust: soil: FYM (1:2:1). The study showed close agreement with Saqib *et al*. (2019) in *Acacia nilotica* seedlings with 75% compost level and sawdust alone had recorded the lowest total biomass in *Eucalyptus saligna* seedlings due to the decomposition environment associated with mineralization of the growth media (Ashiono *et al*., 2017). Not only the nutrient content in growing medium are affecting plant growth but also other indirect effect via the inhibition of plant pathogen infection (Masilamani *et al.*, 2010) or effects of on the rhizospehere microflora might dominate sole growing media effects (Suwannapinant *et al*., 2001; Guleria, 2006).

**Table 4: Effect of growing media on total biomass, leaf area and sturdiness quotient of *Tectona grandis* stump.**

| Treatments | Total biomass (g/plant) | | | | Leaf area (sq.cm) | | | | Sturdiness quotient | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 60DAP | 120DAP | 180DAP | 240DAP | 60DAP | 120DAP | 180DAP | 240DAP | 60DAP | 120DAP | 180DAP | 240DAP |
| $T_1$: Soil | 10.21$^{g}$ | 18.60$^{de}$ | 40.36$^{f}$ | 49.30$^{f}$ | 715.93$^{de}$ | 1141.51$^{bc}$ | 2623.22$^{a}$ | 2057.92$^{b}$ | 4.38$^{de}$ | 7.05$^{e}$ | 6.28$^{e}$ | 6.84$^{d}$ |
| $T_2$: Sand: soil (1:1) | 12.34$^{def}$ | 22.04$^{cd}$ | 49.37$^{e}$ | 54.60$^{f}$ | 800.47$^{d}$ | 1228.89$^{bc}$ | 2948.98$^{a}$ | 2843.81$^{ab}$ | 4.06$^{e}$ | 5.90$^{f}$ | 7.20$^{d}$ | 7.57$^{bcd}$ |
| $T_3$: Sand: soil: FYM (1:1:1) | 15.55$^{bc}$ | 27.01$^{b}$ | 63.39$^{b}$ | 64.02$^{e}$ | 1137.70$^{ab}$ | 1637.90$^{ab}$ | 3371.06$^{a}$ | 3734.89$^{ab}$ | 5.11$^{bc}$ | 7.42$^{de}$ | 7.63$^{cd}$ | 7.86$^{bc}$ |
| $T_4$: Sand: soil: FYM (1:2:1) | 18.20$^{a}$ | 34.26$^{a}$ | 65.47$^{ab}$ | 67.78$^{de}$ | 1246.79$^{a}$ | 1801.12$^{a}$ | 3369.85$^{a}$ | 3286.37$^{ab}$ | 6.28$^{a}$ | 8.22$^{c}$ | 8.68$^{ab}$ | 9.42$^{a}$ |
| $T_5$: Vermicompost | 10.46$^{fg}$ | 25.54$^{bc}$ | 55.00$^{cd}$ | 72.92$^{bcd}$ | 562.38$^{fg}$ | 1461.18$^{ab}$ | 3013.35$^{a}$ | 3676.73$^{ab}$ | 6.46$^{a}$ | 9.06$^{b}$ | 8.84$^{ab}$ | 10.09$^{a}$ |
| $T_6$: Sand: soil: vermicompost (1:1:1) | 12.72$^{de}$ | 28.49$^{b}$ | 51.74$^{de}$ | 68.90$^{de}$ | 639.25$^{ef}$ | 1621.55$^{ab}$ | 2481.52$^{a}$ | 3107.07$^{ab}$ | 4.73$^{cd}$ | 7.03$^{e}$ | 8.23$^{bc}$ | 7.38$^{cd}$ |
| $T_7$: Sand: soil: vermicompost (1:2:1) | 10.37$^{g}$ | 29.02$^{b}$ | 67.49$^{a}$ | 88.58$^{a}$ | 618.70$^{ef}$ | 1959.87$^{a}$ | 3124.98$^{a}$ | 4542.39$^{a}$ | 6.61$^{a}$ | 8.53$^{bc}$ | 9.11$^{ab}$ | 8.41$^{b}$ |
| $T_8$: Sawdust | 15.98$^{b}$ | 34.65$^{a}$ | 51.99$^{de}$ | 78.47$^{b}$ | 968.08$^{c}$ | 1585.52$^{ab}$ | 3533.30$^{a}$ | 2885.42$^{ab}$ | 5.52$^{b}$ | 8.14$^{cd}$ | 7.73$^{cd}$ | 7.78$^{bcd}$ |
| $T_9$: Sawdust: soil (1:1) | 13.91$^{cd}$ | 27.09$^{b}$ | 64.52$^{ab}$ | 69.64$^{cde}$ | 1022.72$^{bc}$ | 1591.85$^{ab}$ | 3813.21$^{a}$ | 4505.02$^{a}$ | 6.10$^{a}$ | 10.03$^{a}$ | 9.28$^{a}$ | 10.11$^{a}$ |
| $T_{10}$: Sawdust: soil: FYM (1:1:1) | 11.46$^{efg}$ | 28.30$^{b}$ | 56.07$^{c}$ | 75.38$^{bc}$ | 618.70$^{ef}$ | 1181.28$^{bc}$ | 3392.13$^{a}$ | 4456.87$^{a}$ | 5.52$^{b}$ | 9.13$^{b}$ | 8.84$^{ab}$ | 9.79$^{a}$ |
| $T_{11}$: Sawdust: soil: FYM (1:2:1) | 8.21$^{h}$ | 17.76$^{e}$ | 44.03$^{f}$ | 49.69$^{f}$ | 458.55$^{g}$ | 688.86$^{c}$ | 2284.51$^{a}$ | 2632.45$^{ab}$ | 5.13$^{bc}$ | 7.86$^{cd}$ | 8.22$^{bc}$ | 7.54$^{bcd}$ |
| Mean | 12.67 | 26.62 | 55.40 | 67.21 | 799.02 | 1445.41 | 3086.92 | 3429.90 | 5.44 | 8.03 | 8.19 | 8.44 |
| Sem± | 0.67 | 1.29 | 1.37 | 2.14 | 147.5 | 190.719 | 628.552 | 715.944 | 0.178 | 0.226 | 0.309 | 0.332 |
| CD (0.05) | 1.96 | 3.77 | 4.01 | 6.28 | 132.60 | 559.36 | 1843.48 | 2099.79 | 0.52 | 0.76 | 0.91 | 0.97 |

Means with same letters are not significantly different.

The effect of growing media on leaf area was showed increasing trend with age up to 180 days and then no systematic trend was followed afterwards because of the starting of leaf fall. The leaf area showed significant difference among treatments from 60 to 120 days and became non-significant after 180 and 240 days of growth (Table 4). The maximum leaf area (4542.39 $cm^2$) was recorded in sand: soil: vermicompost (1:2:1) followed by 4505.02 $cm^2$ in sawdust: soil (1:1) and 4456.87 $cm^2$ in sawdust: soil: FYM (1:1:1) whereas the minimum leaf area (2057.92 $cm^2$) was recorded in soil after 240 days of planting. The growing media containing vermicompost increased the P, K and total soluble solid which may improve the leaf area in the plant (Peyvast *et al*., 2008). These findings are in close conformity with earlier observation of Aderounmu *et al*. (2020) in *Vitellaria paradoxa* and differ with the views of Amonum *et al*. (2019) in *Dacryodes edulis* on sawdust and river sand.

The stocky or spindly nature of the seedlings depends upon the sturdiness quotient of the plant. The effect of growing media on sturdiness quotient was represented with significant difference among the treatments throughout the experimental period (Table 4). The sturdiness quotient was recorded above 6.0 after 120 days of growth in all growing media which might be due to the fast-growing nature of the species over the initials except sand: soil (1:1) indicating 5.90. Irrespective of the growing media the sturdiness quotient ranged from 4.06 to 6.61 with an average value of 5.44 at 60 days. It is generally agreed that if SQ increases, the seedlings will be less sturdy and intolerant to strong wind, drought, and frost resulting in substantial losses compared to seedlings with lower SQ values. The seedlings raised in compost growing media with significantly higher sturdiness quotient as compared to both soil and sand due to the effect of organic and nitrogen availability of the media (Kihara, 2002). This study is close agreement with the results of Mwadalu *et al*. (2020) in *Casuarina equisetifolia* seedling and Sood *et al*. (2018) in *Terminalia bellirica* seedlings.

It reveals from the study that the media comprising of sand: soil: FYM (1:1:1) proved the best for sprouting of stumps, number of days for completion of sprouting and survival rate among the different media whereas sand: soil: vermicompost (1:2:1) showed maximum growth in terms of collar diameter, height, number of leaves, leaf fresh weight, root fresh weight, shoot fresh weight, leaf dry weight, root dry weight, shoot dry weight, total biomass and leaf area. Over all the growing medium comprising vermicompost was superior for growth of teak seedlings. Therefore, it is recommended to use vermicompost based composite media for the production of healthy and quality seedlings of *Tectona grandis* for mass scale under nursery condition. However, further study regarding the nutrient uptake and genetic characteristics is also needful.

## CONCLUSION

It reveals from the study that the media comprising of sand: soil: FYM (1:1:1) proved the best for sprouting of stumps, number of days for completion of sprouting and survival rate among the different media whereas sand: soil: vermicompost (1:2:1) showed maximum growth in terms of collar diameter, height, number of leaves, leaf fresh weight, root fresh weight, shoot fresh weight, leaf dry weight, root dry weight, shoot dry weight, total biomass and leaf area. Over all the growing medium comprising vermicompost was superior for growth of teak seedlings. Therefore, it is recommended to use vermicompost based composite media for the production of healthy and quality seedlings of *Tectona grandis* for mass scale under nursery condition. However, further study regarding the nutrient uptake and genetic characteristics is also needful.

**Acknowledgement:** Authors are thankful to Dean, Faculty of Horticulture, UBKV for providing necessary facility to conduct this experiment.

**Conflict of interest.** Authors declare there is no conflict of interests.

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**How to cite this article:** Kamal Ghising, Amarendra Nath Dey, Sumit Chakravarty, Mihir Ranjan Panda, Nilesh Bhowmick and Dibyendu Mukhopadhyay (2022). Growth Performance of Teak (*Tectona grandis* Linn.) Stump under different Growing Media in Nursery. *Biological Forum – An International Journal*, *14*(3): 322-330.