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# Larger drupe size and earlier geminants for better seedling attributes of teak (*Tectona grandis* Linn. f.)

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**Abstract.** Massive plantation establishment programme in the tropics has led to an ever-increasing demand for good quality planting stock of teak (*Tectona grandis* L. f.). Although drupe size in teak is positively correlated with seedling growth much less is known about the combined effect of drupe size and time of emergence on the performance of the seedlings. The drupes were divided in 3 diameter categories (i.e. 9-12, 12-15 and 15-18 mm) and the number of germinants were weekly counted for four weeks. The resulted seedlings were planted in poly bags containing rooting medium of soil and sand (1:1 ratio). Results of the study indicated that the seedling emergence was largest during second week irrespective of drupe size. Seedlings from 15-18 mm diameter class drupes recorded the highest seedling attributes followed by 12-15 mm and 9-12 mm classes. However, net assimilation rate and relative growth rate were highest in the seedlings obtained from 9-12 mm class drupes. With a few exceptions, first week emergents recorded the highest seedling attributes followed by second, third and fourth week germinants. Cluster analysis of the seedling attributes identified the seedlings belonging to 15-18 mm drupe size and emerging during first week as superior. But, considering the largest number of drupes in 12-15 mm size class, peak germination during second week after sowing, price of planting stock and cost of nursery operation per unit of planting, second week germinants of 12–15 mm size drupes can also be recommended for raising seedlings in plantation programmes of teak.
**Keywords** Net assimilation rate, relative growth rate, teak nursery, teak plantation.

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## Introduction

Seed germination and seedling establishment are high risk phases in the life cycle of most plants (Harper 1977). Seed size or seed mass plays pivotal role in plantation establishment. Larger seeds generally result in larger seedlings having a higher probability of survival. A close relationship between drupe size and germination and subsequent plant development of teak has been observed by several scientists (Kumar 1979, Viswanath et al. 1995, Manonmani & Vanangamudi 2003). The variation in number and physical characteristics of five size grades of teak drupes belonging to Nilambur Forest Division, Kerala, India have been described by Jijeesh and Sudhakara (2007). A positive correlation of drupe size was observed with germination parameters (Sudhakara & Jijeesh 2008), chlorophyll content and chlorophyll stability index of the seedlings (Jijeesh & Sudhakara 2006). However, it was also observed that the drupe size characteristics had no or weak correlation with germination percentage of teak drupes (Jayasankar et al. 1999b) and on seedling survival and growth (Indira et al. 2000).

Generally, teak seedlings emerge over a period of time when pretreated drupes are sown in nursery beds. Timing of emergence of seedling has important consequences for the subsequent survival and fitness (Bush & Van Auken 1991). A few days delay in emergence can be magnified into large differences in final biomass and reproduction, especially under competitive situations (Ross & Harper 1972). Not much information is available on the influence of drupe size and time of emergence on seedling performance of teak.

Therefore, we conducted a study on the effects of drupe size (three diameter classes viz., 15-18 mm, 12-15 mm and 9-12 mm) and time of emergence (seedlings emerging during first to fourth week) on seedling performance of *Tectona grandis* Linn. f.

## Materials and methods

The study was conducted at the College of Forestry, Kerala Agricultural University, Thrissur, Kerala, India during June 2002 to June 2003. The nursery area is located 40 meters above msl at 10°32’N latitude and 76°26’E longitude. The area experiences a warm and humid climate with distinct rainy season. The drupes were collected during January - February of 2002, from the Nilambur Forest Division of Kerala.

The drupes were graded using the sieves of diameter 9, 12 and 15 mm and designated as 9-12 mm, 12-15 mm and 15-18 mm classes respectively. The drupes were pre-treated by termites to remove the mesocarp (Chacko 1998) and sown in standard nursery beds (2000 drupes x 4). The germinants emerging from the drupes were recorded at weekly interval up to four weeks and each week’s emergence was recorded as the percentage of the total germinants obtained. These germinants were planted in polythene bags (gauge 300) of size 43 cm x 35 cm, containing rooting medium (mixture of sand: soil in the ratio of 1:1) and arranged in split plot design with drupe size grade as main-plot and time of emergence as the subplots. Observations were taken (12 plants per treatment) on seedling height, collar diameter and number of functional leaves at 30, 90, 120, 180, 270 and 360 days after planting. Another set of 12 seedlings were destructively sampled simultaneously to determine the leaf area ($cm^2$) (measured using an area meter, Model LI 3100 LI-COR, Nebraska, USA), length of the tap root, number of lateral roots, and biomass of the shoot and root (dried to constant weight in oven at 70°C + -2°C). Specific leaf area was calculated (Hunt 1990) by dividing total leaf area by leaf dry weight per plant and the average value was expressed in $cm^2\ g^1$. Root: shoot ratio of the seedlings was calculated (Hunt 1990) by dividing the average value of root weight by shoot weight. Relative growth rate *(RGR)* was calculated from the formula given of Hunt (1990):

$$RGB = (\log_e W_2 - \log_e W_1) / (t_2 - t_1)$$

where, $W_1$ and $W_2$ are the dry weight determined at time $t_1$ and $t_2$ respectively, [expressed in % month$^{-1}$].

Net assimilation rate (*NAR*) is an index of the productive efficiency of plant calculated in relation to the total leaf area, after Hunt (1990):

$$NAR = (V_2-W_1)(\log_e LA_2-\log_e LA_1) / (LA_2-LA_1)(t_2-t_1)$$

where: $W_2$ and $W_1$ are the dry weights at time $t_2$ and $t_1$ respectively, $LA_2$ and $LA_1$ are the leaf area at time $t_2$ and $t_1$ respectively [expressed in g cm$^{-2}$ month$^{-1}$].

Bartlett's test of sphericity on the matrix of correlation coefficients among the variables (seedling attributes) was significant at 1% level ($\chi^2$ = 7131.29), indicating the suitability of factor analysis for data.

Analysis was conducted using SPSS (Norusis 1988). Principal component analysis was the method of factor extraction and the factors were subjected to oblique rotation with Kaiser Normalisation (Kaiser 1958) using Direct OBLIMIN option. Factor scores were subjected to analysis of variance. The treatment means were compared against 'lsd' (least significant difference) wherever necessary. Cluster analysis was carried out using average linkage method and squared Euclidian distance as distance measure (Hair et al. 2005), taking drupe size and earliness of germination as entities and different seedling parameters as characters to find the best treatment combination.

## Results

### Influence of drupe size on the percentage of the germinants emerging at weekly intervals

Data pertaining to the emergence of germinants belonging to different size categories (Table 1) indicated that the largest number of germinants emerged during the second week after sowing in all the size classes which varied from 34.54% to 41.84%. Second highest percentage of emergence was observed during third week after sowing in the case of 15-18 mm and 12-15 mm classs drupes (24.87% and 24.8% respectively) and during fourth week in the case of 9-12 mm grade drupes (25.93%).

While the drupes from 9-12 mm class had the lowest percentage of the germinants during the first week (12.74 %), the drupes from 15-18 mm and 12-15 mm size grade had lowest of germination percentages during fourth week (19.03 and 18.29 % respectively).

### Seedling attributes as affected by drupe size and time of emergence

Factor analysis identified two factors, of which the first factor explained 51.88 per cent and the second factor explained only 16.45% of the total variance. More than 85% of the variance in seedling height, collar diameter and total dry weight, more than 75% of the variance in leaf area, root dry weight, shoot biomass and number of lateral roots was explained by the first factor. Therefore, analysis of variance of factor scores for the factor one was carried out. The analysis of variance indicated that the ef-

**Table 1** Variation in emergence percentage of teak germinants in different drupe size grades

| Timing of emergence (week) | Emergence percentage by drupe size class (in %) | | |
|---|---|---|---|
| | 15-18 mm | 12-15 mm | 9-12 mm |
| First | 21.56$^b$ | 20.95$^b$ | 12.74$^d$ |
| Second | 34.54$^a$ | 35.96$^a$ | 41.84$^a$ |
| Third | 24.87$^b$ | 24.80$^b$ | 19.49$^c$ |
| Fourth | 19.03$^c$ | 18.29$^c$ | 25.93$^b$ |

fect of drupe size and time of emergence on seedling attributes were significant ($p$ = 0.01). But, their interaction effects were not significant.

## Influence of drupe size on seedling attributes

Seedling growth measured in terms of height, collar diameter, leaf area, tap root length, number of lateral roots, biomass yield and growth analysis indices (Tables 2,3) was significantly influenced by drupe size ($p$ = 0.01).

**Table 2** Growth parameters of teak seedlings at different growth stages as affected by drupe size

| Days after planting | Drupe size class (mm) | Height (cm) | Collar diameter (mm) | No. of leaves | Leaf area ($cm^2$) | Tap root length (cm) | No. of lateral roots |
|---|---|---|---|---|---|---|---|
| 30 | 15-18 | $5.20^a$ | $15.5^a$ | 4.10 | $17.47^a$ | $4.74^a$ | $8.81^a$ |
| | 12-15 | $4.28^a$ | $12.3^b$ | 3.88 | $12.92^a$ | $4.17^a$ | $7.65^a$ |
| | 9-12 | $3.57^a$ | $11.3^b$ | 3.90 | $9.28^a$ | $3.31^a$ | $6.17^a$ |
| 90 | 15-18 | $7.42^a$ | $22.6^a$ | 8.46 | $39.82^a$ | $21.59^a$ | $22.25^a$ |
| | 12-15 | $7.19^a$ | $20.4^{ab}$ | 8.08 | $32.32^a$ | $19.57^b$ | $18.63^b$ |
| | 9-12 | $6.50^a$ | $19.3^b$ | 7.88 | $25.33^a$ | $15.57^c$ | $18.44^b$ |
| 180 | 15-18 | $15.52^a$ | $41.0^a$ | 6.58 | $164.50^a$ | $31.30^a$ | $29.97^a$ |
| | 12-15 | $12.89^b$ | $36.1^b$ | 6.25 | $137.24^a$ | $28.55^b$ | $27.10^a$ |
| | 9-12 | $10.29^c$ | $32.9^c$ | 6.33 | $110.72^a$ | $28.20^b$ | $23.90^b$ |
| 270 | 15-18 | $16.66^b$ | $57.6^a$ | 7.08 | $510.29^a$ | $33.54^a$ | $51.77^a$ |
| | 12-15 | $16.28^b$ | $47.4^b$ | 6.98 | $312.88^b$ | $32.82^a$ | $44.65^b$ |
| | 9-12 | $19.78^a$ | $49.1^b$ | 6.65 | $256.61^b$ | $33.48^a$ | $41.29^c$ |
| 360 | 15-18 | $43.91^b$ | $78.8^a$ | 9.28 | $1529.89^a$ | $36.99^a$ | $59.46^a$ |
| | 12-15 | $47.29^a$ | $71.3^b$ | 9.02 | $1318.21^b$ | $36.56^a$ | $52.33^b$ |
| | 9-12 | $38.81^c$ | $61.8^c$ | 9.73 | $905.75^c$ | $32.35^b$ | $41.69^c$ |

Note. Means with same letter as superscript are homogeneous within a column for each growth period.

**Table 3** Biomass and growth analysis indices of teak seedlings at different growth stages as affected by drupe size

| Days after planting | Drupe size class (mm) | Biomass(g) | | | Growth analysis indices | | | |
|---|---|---|---|---|---|---|---|---|
| | | Shoot | Root | Total | Specific leaf area ($cm^2$ $g^1$) | Root: shoot ratio | NAR (($g$ $cm^{-2}$) $month^{-1}$) | RGR (% $month^{-1}$) |
| 30 | 15-18 | $0.08^a$ | $0.02^a$ | $0.13^a$ | $415.95^a$ | $0.36^a$ | - | - |
| | 12-15 | $0.07^a$ | $0.03^a$ | $0.10^a$ | $370.46^b$ | $0.46^a$ | - | - |
| | 9-12 | $0.05^a$ | $0.03^a$ | $0.08^a$ | $391.38^{ab}$ | $0.46^a$ | - | - |
| 90 | 15-18 | $0.20^a$ | $0.35^a$ | $0.54^a$ | $356.86^a$ | $1.97^a$ | $0.0047^b$ | $0.5688^c$ |
| | 12-15 | $0.20^a$ | $0.30^a$ | $0.52^a$ | $322.09^{ab}$ | $1.53^a$ | $0.0048^b$ | $0.6342^b$ |
| | 9-12 | $0.20^a$ | $0.29^a$ | $0.49^a$ | $282.94^b$ | $1.57^a$ | $0.0068^a$ | $0.6774^a$ |
| 180 | 15-18 | $0.98^a$ | $0.92^a$ | $1.89^a$ | $304.11^a$ | $0.98^a$ | $0.0062^b$ | $0.5745^b$ |
| | 12-15 | $0.86^a$ | $0.78^a$ | $1.64^a$ | $293.76^a$ | $0.91^a$ | $0.0072^a$ | $0.5928^b$ |
| | 9-12 | $0.65^a$ | $0.67^a$ | $1.39^a$ | $307.81^a$ | $1.08^a$ | $0.0089^a$ | $0.6104^a$ |
| 270 | 15-18 | $3.61^a$ | $6.73^a$ | $10.30^a$ | $285.55^a$ | $2.61^b$ | $0.0090^b$ | $0.5307^a$ |
| | 12-15 | $2.34^b$ | $5.26^b$ | $6.73^b$ | $283.43^a$ | $2.49^b$ | $0.0094^b$ | $0.4836^a$ |
| | 9-12 | $1.36^c$ | $3.01^c$ | $4.60^c$ | $321.54^a$ | $2.84^a$ | $0.0117^a$ | $0.3417^b$ |
| 360 | 15-18 | $7.43^a$ | $7.97^a$ | $15.61^a$ | $306.60^a$ | $1.09^b$ | $0.0020^b$ | $0.1462^b$ |
| | 12-15 | $5.76^b$ | $5.66^b$ | $11.46^b$ | $307.25^a$ | $1.27^a$ | $0.0022^b$ | $0.1500^b$ |
| | 9-12 | $4.35^b$ | $3.72^c$ | $8.03^c$ | $322.27^a$ | $1.10^b$ | $0.0222^a$ | $0.1810^a$ |

Note. Means with same letter as superscript are homogeneous within a column for each growth period.

No significant variation due to drupe size was observed in number of functional leaves throughout the different growth stages. At 30 days after planting, only the collar diameter and specific leaf area of the seedlings varied significantly and the highest values were due to the largest drupe size. At 90 days, collar diameter, tap root length, number of lateral roots and specific leaf area of the seedlings varied significantly among different drupe size classes and the highest values were obtained for seedlings obtained from 15-18 mm class drupes followed by those of 12-15 mm and 9-12 mm size class drupes. However, NAR and RGR were significantly higher in seedlings obtained from 9-12 mm drupes.

Obvious and significant variation in seedling height was observed only from 180 days of planting and at this stage, seedlings obtained from 15-18 mm class recorded the highest height followed by 12-15 mm and 9-12 mm size classes; this increase was more than 1.5 times that of seedlings obtained from 9-12 mm size class drupes. However, this trend was not retained at later stages of growth. At 270 days after planting, seedlings obtained from 9-12 mm class and at 360 days after planting, seedlings obtained from 12-15 mm size class drupes had the highest height.

The height, collar diameter, leaf area, number of lateral roots, biomass and root: shoot ratio of the seedlings varied significantly due to drupe size at 270 days; compared to the seedlings of 9-12 mm size class drupes, the leaf area was almost double and the biomass was 2.2 times higher in the seedlings of 15-18 mm size class drupes. However, the seedlings obtained from 9-12 mm class drupes recorded the largest seedling height and root to shoot ratio. At 360 days after planting, seedlings belonging to 15-18 mm size class drupes recorded the highest mean value for collar diameter (7.88 mm), leaf area (1529.89 $cm^2$), tap root length (36.99 cm), number of lateral roots (59.46), shoot biomass (7.43 g), root biomass (7.97 g) and total biomass (15.61 g). Whereas, the seedlings obtained from 12-15 mm drupe size grade recorded highest seedling height (47.29 cm), specific leaf area (307.25 $cm^2g^{-1}$) and root to shoot ratio (1.27). Meanwhile, the seedlings obtained from 9-12 mm class drupes recorded the lowest mean value for seedling height (38.81 cm), collar diameter (6.18 mm), leaf area (905.75 $cm^2$), tap root length (32.35 cm), number of lateral roots(41.69), shoot biomass (4.35 g), root biomass and (3.72 g) total biomass (8.03 g) at 360 days after planting.

Lowest root to shoot ratio (1.09) was observed in seedlings obtained from 15-18 mm class. The variation in specific leaf area of the seedlings due to drupe size was not significant at the same period. Variation in NAR and RGR at different stages of growth was significant and showed inverse trend with 9-12 mm class seedlings recording the highest value of 0.0222 g $cm^{-2}$ $month^{-1}$ and 0.2950% $month^{-1}$ respectively and 15-18 mm class seedlings showing the lowest NAR and RGR of 0.0020 g $cm^{-2}$ $month^{-1}$ and 0.1462% $month^{-1}$ respectively at 360 days after planting.

**Influence of time of emergence on seedling attributes**

At 30 days after planting, significant variation due to time of emergence was absent in most of the seedling attributes except for specific leaf area, where the first week germinants recorded the maximum value and decreased to fourth week (Tables 4,5). At 90 days, collar diameter, number of functional leaves, tap root length, NAR and RGR of the seedlings significantly varied. The second week germinants recorded the highest value for collar diameter, number of functional leaves, tap root length, NAR and RGR, and first week germinants had the highest specific leaf area.

The height and number of lateral roots of the seedling varied significantly from 180 days and the first week germinants recorded the maximum value. The number of functional leaves, tap root length and specific leaf area were also

**Table 4** Growth parameters of teak seedlings at different growth stages as affected by time of germination

| Days after planting | Time of germination (week) | Height (cm) | Collar diameter (mm) | No.of leaves | Leaf area ($cm^2$) | Tap root length (cm) | No. of lateral roots |
|---|---|---|---|---|---|---|---|
| 30 | First | 5.05$^{a}$ | 15.1$^{a}$ | 3.89$^{a}$ | 16.37$^{a}$ | 4.23$^{a}$ | 8.86$^{a}$ |
| | Second | 4.55$^{a}$ | 13.9$^{a}$ | 4.00$^{a}$ | 13.42$^{a}$ | 4.05$^{a}$ | 7.69$^{a}$ |
| | Third | 3.87$^{a}$ | 12.9$^{a}$ | 4.00$^{a}$ | 12.13$^{a}$ | 4.23$^{a}$ | 7.40$^{a}$ |
| | Fourth | 3.84$^{a}$ | 09.9$^{b}$ | 4.00$^{a}$ | 10.69$^{a}$ | 3.76$^{a}$ | 6.29$^{a}$ |
| 90 | First | 6.82$^{a}$ | 20.6$^{a}$ | 6.94$^{b}$ | 40.20$^{a}$ | 17.33$^{b}$ | 16.68$^{a}$ |
| | Second | 7.51$^{a}$ | 22.5$^{a}$ | 9.14$^{a}$ | 33.78$^{a}$ | 19.59$^{ab}$ | 19.40$^{a}$ |
| | Third | 6.43$^{a}$ | 18.0$^{ab}$ | 7.89$^{b}$ | 26.39$^{a}$ | 18.39$^{ab}$ | 19.00$^{a}$ |
| | Fourth | 6.35$^{a}$ | 17.7$^{b}$ | 7.43$^{b}$ | 23.41$^{a}$ | 16.90$^{b}$ | 17.91$^{a}$ |
| 180 | First | 14.81$^{a}$ | 36.6$^{a}$ | 8.57$^{a}$ | 164.98$^{a}$ | 30.62$^{a}$ | 30.11$^{a}$ |
| | Second | 13.58$^{ab}$ | 36.8$^{a}$ | 7.06$^{b}$ | 142.11$^{a}$ | 28.93$^{ab}$ | 25.51$^{b}$ |
| | Third | 11.79$^{b}$ | 37.3$^{a}$ | 4.97$^{c}$ | 129.04$^{a}$ | 29.63$^{ab}$ | 26.89$^{ab}$ |
| | Fourth | 11.58$^{b}$ | 36.3$^{a}$ | 4.71$^{c}$ | 114.31$^{a}$ | 28.41$^{b}$ | 25.66$^{b}$ |
| 270 | First | 17.77$^{a}$ | 54.0$^{a}$ | 4.69$^{a}$ | 402.91$^{a}$ | 33.75$^{a}$ | 54.37$^{a}$ |
| | Second | 16.87$^{a}$ | 50.9$^{b}$ | 8.17$^{b}$ | 327.02$^{ab}$ | 34.13$^{a}$ | 44.34$^{b}$ |
| | Third | 16.67$^{a}$ | 50.5$^{b}$ | 7.03$^{c}$ | 293.27$^{b}$ | 33.59$^{a}$ | 43.54$^{b}$ |
| | Fourth | 15.50$^{a}$ | 47.3$^{c}$ | 7.51$^{b}$ | 289.44$^{b}$ | 31.41$^{b}$ | 40.49$^{b}$ |
| 360 | First | 50.37$^{a}$ | 76.4$^{a}$ | 8.86$^{a}$ | 1444.95$^{a}$ | 35.41$^{a}$ | 55.46$^{a}$ |
| | Second | 44.48$^{b}$ | 72.2$^{b}$ | 9.37$^{a}$ | 1342.26$^{b}$ | 35.42$^{a}$ | 51.20$^{b}$ |
| | Third | 42.55$^{b}$ | 69.3$^{b}$ | 9.49$^{a}$ | 1183.74$^{c}$ | 35.36$^{a}$ | 51.49$^{b}$ |
| | Fourth | 37.60$^{c}$ | 66.0$^{c}$ | 9.74$^{a}$ | 1069.49$^{d}$ | 34.30$^{a}$ | 47.06$^{c}$ |

Note. Means with same letter as superscript are homogeneous within a column for each growth period.

**Table 5** Biomass and growth analysis indices of teak seedlings at different growth stages as affected by time of germination

| Days after planting | Time of germination (week) | Biomass (g) | | | Growth analysis indices | | | |
|---|---|---|---|---|---|---|---|---|
| | | Shoot | Root | Total | Specific leaf area ($cm^2$ $g^1$) | Root: shoot ratio | NAR (($g\ cm^{-2}$) $month^{-1}$) | RGR (($g\ g^{-1}$) $month^{-1}$) |
| 30 | First | 0.08$^{a}$ | 0.03$^{a}$ | 0.15$^{a}$ | 476.89$^{a}$ | 0.32$^{a}$ | - | - |
| | Second | 0.06$^{a}$ | 0.02$^{a}$ | 0.10$^{a}$ | 387.69$^{b}$ | 0.48$^{a}$ | - | - |
| | Third | 0.09$^{a}$ | 0.03$^{a}$ | 0.09$^{a}$ | 375.72$^{bc}$ | 0.47$^{a}$ | - | - |
| | Fourth | 0.09$^{a}$ | 0.02$^{a}$ | 0.07$^{a}$ | 331.97$^{c}$ | 0.42$^{a}$ | - | - |
| 90 | First | 0.25$^{a}$ | 0.29$^{a}$ | 0.50$^{a}$ | 379.94$^{a}$ | 1.67$^{a}$ | 0.0050$^{b}$ | 0.5396$^{b}$ |
| | Second | 0.22$^{a}$ | 0.36$^{a}$ | 0.58$^{a}$ | 322.47$^{b}$ | 1.72$^{a}$ | 0.0063$^{a}$ | 0.6634$^{a}$ |
| | Third | 0.17$^{a}$ | 0.27$^{a}$ | 0.44$^{a}$ | 332.95$^{ab}$ | 1.73$^{a}$ | 0.0051$^{b}$ | 0.5656$^{b}$ |
| | Fourth | 0.17$^{a}$ | 0.24$^{a}$ | 0.40$^{a}$ | 262.51$^{c}$ | 1.65$^{a}$ | 0.0047$^{b}$ | 0.4631$^{c}$ |
| 180 | First | 0.83$^{a}$ | 0.82$^{a}$ | 1.72$^{a}$ | 332.54$^{a}$ | 0.88$^{a}$ | 0.0051$^{c}$ | 0.4820$^{b}$ |
| | Second | 0.89$^{a}$ | 0.86$^{a}$ | 1.76$^{a}$ | 306.74$^{ab}$ | 1.00$^{a}$ | 0.0068$^{b}$ | 0.5261$^{a}$ |
| | Third | 0.94$^{a}$ | 0.83$^{a}$ | 1.62$^{a}$ | 274.23$^{b}$ | 1.05$^{a}$ | 0.0083$^{a}$ | 0.6410$^{a}$ |
| | Fourth | 0.69$^{a}$ | 0.69$^{a}$ | 1.52$^{a}$ | 300.06$^{ab}$ | 1.11$^{a}$ | 0.0069$^{b}$ | 0.5902$^{a}$ |
| 270 | First | 2.59$^{a}$ | 6.71$^{a}$ | 8.84$^{a}$ | 377.33$^{a}$ | 2.06$^{b}$ | 0.0040$^{b}$ | 0.3408$^{c}$ |
| | Second | 2.31$^{a}$ | 4.46$^{bc}$ | 6.37$^{b}$ | 278.04$^{b}$ | 1.96$^{b}$ | 0.0113$^{a}$ | 0.4994$^{b}$ |
| | Third | 2.18$^{a}$ | 5.46$^{b}$ | 7.88$^{a}$ | 277.41$^{b}$ | 2.68$^{a}$ | 0.0107$^{a}$ | 0.4640$^{b}$ |
| | Fourth | 2.17$^{a}$ | 3.74$^{c}$ | 5.93$^{b}$ | 263.23$^{b}$ | 2.82$^{a}$ | 0.0099$^{a}$ | 0.5038$^{a}$ |
| 360 | First | 5.24$^{b}$ | 6.85$^{a}$ | 13.50$^{a}$ | 306.40$^{a}$ | 1.54$^{a}$ | 0.0028$^{b}$ | 0.3356$^{a}$ |
| | Second | 6.68$^{a}$ | 5.90$^{a}$ | 12.64$^{a}$ | 307.32$^{a}$ | 1.30$^{b}$ | 0.0024$^{a}$ | 0.1633$^{b}$ |
| | Third | 5.57$^{b}$ | 6.42$^{a}$ | 11.44$^{b}$ | 307.00$^{a}$ | 1.22$^{b}$ | 0.0020$^{a}$ | 0.1330$^{c}$ |
| | Fourth | 5.96$^{ab}$ | 4.20$^{c}$ | 9.67$^{b}$ | 307.03$^{a}$ | 0.89$^{c}$ | 0.0022$^{a}$ | 0.1635$^{b}$ |

Note. Means with same letter as superscript are homogeneous within a column for each growth period.

significantly highest in the case of first week emergents. But the NAR and RGR were lowest in the case of first week emergents. At 270 days after planting, collar diameter, number of functional leaves, leaf area, number of lateral roots, root biomass, total biomass and specific leaf area were highest in second week emergents; even though the root: shoot ratio and NAR were highest in second week emergents, RGR was highest in fourth week emergents. At 360 days after planting, seedlings emerged during the first week recorded the highest mean value for seedling height (50.37 cm), collar diameter (7.64 mm), leaf area (1444.95 $cm^2$), number of lateral roots (55.46), root biomass (6.85 g), total biomass (13.50 g), root to shoot ratio (1.54), NAR (0.0028 g $cm^{-2}$ $month^{-1}$) and RGR (0.3356% $month^{-1}$). However, the seedlings emerged during second week recorded the largest shoot biomass (6.68 g) and those emerged in fourth week recorded the highest number of functional leaves (9.74). Meanwhile, seedlings emerged during fourth week recorded the lowest seedling height (37.60 cm), collar diameter (6.60 mm), leaf area (1.069.49 $cm^2$), number of lateral roots (47.06), root biomass (4.20 g), total biomass (9.67 g) and root to shoot ratio (0.89). With regards to shoot biomass, first week germinants recorded the lowest value (5.24 g). Lowest mean value for NAR (0.0020 g $cm^{-2}$ $month^{-1}$) and RGR (0.1330 % $month^{-1}$) was recorded by third week emergents. Significant variation due to time of emergence was absent in number of functional leaves, taproot length, and specific leaf area of the seedlings at 360 days after planting.

## Cluster analysis

The dendrogram of the cluster analysis is presented Figure 1. Cluster analysis identified three clusters. First cluster contained the seedlings belonging to 15-18 mm size class emerging at first to fourth week and second week germinants of 12-15 mm size grade (treatments 1 to 4 and 6). The second cluster contained the seedlings belonging to 12-15 mm class that emerged during first, third and fourth week and second week germinants of 9-12 mm size class (treatments 5, 7, 8 and 10) and third cluster contained first, third and fourth week emergents of 9-12 mm grade (treatments 9, 11 and 12). Cluster analysis identified the seedlings emerged during first week of germination, belonging to 15-18 mm size class as the superior cluster and the fourth week germinants belonging to 9-12 mm size class as the inferior one.

## Discussion

It is generally agreed that larger seeds tend to produce larger seedlings (Weis 1982, Zhang & Maun, 1990). A very significant and positive influence of drupe size on seedling attributes in teak seedlings was obtained in present in-

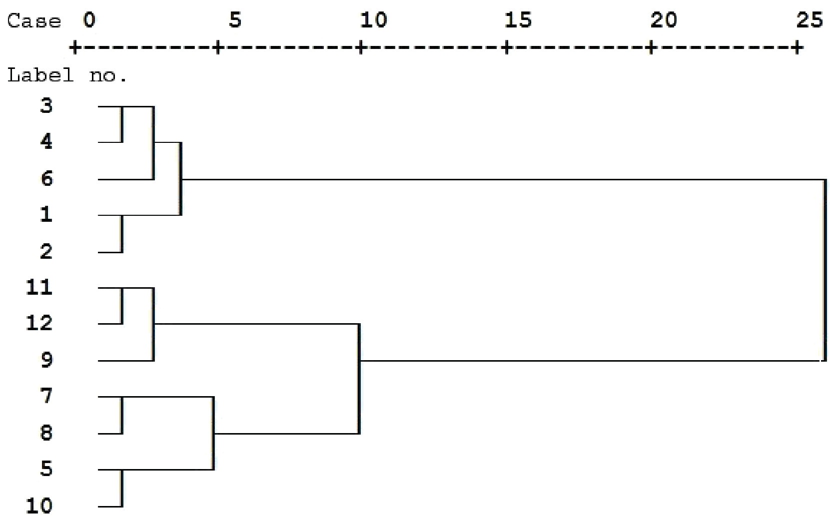


**Figure 1** Dendrogram of the cluster analysis at 25 percent variance level

vestigation. Larger drupes (15-18 mm size grade) produced superior seedlings in growth attributes compared to those of smaller drupes (9-12 and 12-15 mm size classes). With a few exceptions, the growth and biomass attributes of the seedlings decreased from the largest drupe class (15-18 mm) to the smallest drupes class (9-12 mm) at different stages of growth.

Superiority of the seedlings from large drupes (above 15 mm diameter) of teak to other sizes with respect to growth parameters like mean height, mean collar diameter, tap root length, number of lateral roots and length of the longest lateral root have been established by Viswanath et al. (1995). Manonmani & Vanangamudi (2003) also reported enhanced germination and seedling characters with increase in drupe size. The positive correlation between drupe size and seedling growth in our study might be ascribed to the higher leaf area for the seedlings of larger drupe size grade. The larger leaf area of these seedlings, which provided more photosynthetic surface, also might have enhanced the biomass accumulation. Jijeesh & Sudhakara (2006) have obtained a positive relation among drupe size, chlorophyll content and seedling performance.

The leaf chlorophyll content is an index of biomass accumulation and seedling growth (Lahai et al. 2003). Hence, the superior performance of seedlings from 15-18 mm class drupes might be due to the higher root surface area for the absorption of water and mineral nutrients and a higher leaf area with high chlorophyll content for greater biomass accumulation. However, a reverse trend was obtained for RGR values with seedlings obtained from larger drupe size grade showing the lower growth rate. A higher RGR indicates of faster seedling growth. Hence, the greater seedling growth and biomass accumulation of the seedlings from larger drupe size class might be attributed to large reserves of nutritive substances in the drupes Khan et al. 1999, Khan et al. 2002, Khan & Uma Shankar 2001) than higher growth rate. More likely explanation for decreasing RGR with seed mass among closely related individuals of the same species is that, as seedlings get larger, the fraction of mass in photosynthetic tissue declines (i.e., leaf mass ratio declines), leading to decreasing RGR (Walters et al. 1993). In growth analysis, RGR is split into NAR and leaf area ratio (Evans 1972, Causton & Venus 1981). LAR reflects the amount of leaf area a plant develops per unit total plant mass and, therefore, depends on the proportion of biomass allocated to leaves relative to total plant mass (leaf mass ratio) and how much leaf area a plant develops per unit leaf biomass (specific leaf area). Even though, the specific leaf area was significantly higher for larger seedlings initially, at later stages smaller seedlings showed a slightly higher value. NAR showed similar trend in variation as in the case of RGR. The higher NAR and RGR for the seedlings of 9-12 mm size class were not adequate to outgrow those from 15-18 mm class in the first year of growth. Hence, further research is required to ensure whether the increased seedling performance due to bigger drupes will be confirmed for the later stages of life cycle, or seedlings higher NAR and RGR will equalize their performance when exposed to field conditions. The present results are contrary to some other studies on drupe size of teak; Jayashankar et al. (1999a) have reported that the drupe size characteristics had no or weak correlation with germination percentage. Indira et al. (2000) also could not obtain any correlation between drupe size and germination.

In general, the pretreated teak drupes sown in nursery beds germinate over a period of three to six weeks.  In our study, the drupes belonging to different size grades completed the germination over a period of four weeks in which the highest percentage of seedlings (31.54 to 41.84 % of the total seedlings emerged) emerged during second week (Table 1). It is generally accepted that biomass is much higher for earlier emerging seedlings than late-emerging seedlings (Ross & Harper 1972, Howell 1981). Black & Wilkinson (1963) found that the growth of *Trifolium subterraneum* in dense stands was strongly affected by emergence time. They found that a 5-day difference in emergence time led to 50% yield reduction; and 8-day difference caused a 75% reduction in biomass in this annual plant. In our study also the seedling growth parameters were significantly influenced by the time of emergence ($p$ = 0.01) and with a few exceptions, decreased from first to fourth. This variation was very obvious at 360 days after planting compared to early growth stages. The height, collar diameter, leaf area, number of lateral roots, root biomass, shoot biomass and total biomass of the first week germinants was 1.33, 1.15, 1.35, 1.17, 1.34, 1.60, 1.37 times higher respectively compared to fourth week germinants. So, during the selection of the planting stock the early emerging individuals can be preferred over late germinating individuals.

Clustering of the seedlings based on drupe size and time of emergence indicated that seedlings obtained from 15-18 mm size grade, emerging in the first week of germination period, had superior growth. Hence, they can be recommended for selection during plantation programmes. However, teak drupe size varies from less than 6 mm to more than 18 mm and 12-15 mm class drupes are largest in number (Jijeesh & Sudhakara 2007). Since, the teak germination percent is very poor, selecting only the seedlings obtained from 15-18 mm size class, which emerged in the first week for raising planting stock, may result in a very high degree of rejection percent.

Thereby, the availability of superior quality planting stock will be very scarce, the price of planting stock might escalate exorbitantly and also cost of nursery operation per unit of planting stock produced might be disproportionately high. Moreover, the highest percentage of germinates emerged in the second week of sowing. As a compromise we should strike some balance by selecting first and second week germinants for 15-18 mm size class and first and second week germinants for 12-15 mm size grade (dendrogram Figure 1) also as planting stock.

## Conclusions

The present investigations revealed that the drupe categories (or classes) and earliness of germination significantly influenced the seedling the growth parameters. With regards to seed size, seedlings obtained from 15-18 mm size class recorded the highest seedling attributes. The seedling growth parameters were significantly influenced by the time of emergence and, with a few exceptions, decreased from the first to the fourth week. Seedlings obtained from 15-18 mm size category emerging in the first week of germination period recorded the superior growth and therefore they are recommended for selection during plantation programmes. Since the teak germination percent is very poor, we recommend selection from first and second week emergents from 15-18 mm size class and first and second week emergents for 12-15 mm size class.

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## References

Black J., Wilkinson J.N., 1963. The role of time of emergence in determining the growth of individual plants in swards of subterranean clover (*Trifolium subterraneum L.)*. Australian Journal of Agricultural Research 14: 628–638.

Bush J.K., Van Auken O.W., 1991. Importance of time of germination and soil depth for *Prosopis glandulosa* seedling growth. American Journal of Botany 87:247-257.

Causton D.R., Venus J.C., 1981. The biometry of plant growth. Edward Arnold, London, 307 p.

Chacko K.C., 1998. Termite aided mesocarp removal of teak (*Tectona grandis* Linn. f.) fruits for germination and cost effective seed handling. Indian Forester 124: 134-140.

Evans G.C., 1972. The quantitative analysis of plant growth. Blackwell Scientific, Oxford. 734 p.

Hair J.F., Anderson R., Tatham R., Black W., 2005. Multivariate data analysis. New Delhi: Pearson Education 730 p.

Harper J.L., 1977. Population biology of plants. Academic press, London 892 p.

Howell N., 1981. The effect of seed size and relative emergence time on fitness in a natural population of *Impatiens capensis* Meerb. (Balsaminaceae) The American Midland Naturalist 105: 312–320.

Hunt R., 1990. Basic growth analysis. Academic division, Unwin Hyman Limited, London 112 p.

Indira E.P., Basha S.C., Chacko K.C., 2000. Effect of seed size grading on germination and growth of teak (*Tectona grandis*) seedlings. Journal of Tropical Forest Science 12: 21-27.

Jayasankar S., Babu, L.C., Sudhakara K., Kumar P.D., 1999a. Evaluation of provenances for seedling performance of teak (*Tectona grandis* Linn. f.). Silvae Genetica 48: 115-122.

Jayasankar S., Babu L.C., Sudhakara K., Unnithan V.K.G., 1999b. Provenance variation in seed germination characteristics of teak (*Tectona grandis* L. f). Seed Science and Technology 27: 131-139.

Jijeesh C.M., Sudhakara K., 2006. Effect of drupe size and earliness of germination on the chlorophyll content and chlorophyll stability index of teak (*Tectona grandis* Linn. f.) seedlings. In: National Seminar on Plant Physiology "Physiological and molecular approaches for the improvement of agricultural, horticultural and forestry crops", 28-30 November 2006 Kerala Agricultural University, Thrissur – 680 656, India. p. 152.

Jijeesh C.M., Sudhakara K., 2007. Variations in the number of seeds and physical characteristics of teak fruits of Nilambur Forest Division, Kerala. Seed Research 35: 25-33.

Kaiser H.F., 1958. The varimax criterion for analytic rotation in factor analysis. Psychometrika 23: 187-200.

Khan M.L., Bhuyan P., Singh N.D., Todaria N.P., 2002. Fruit set, seed germination and seedling growth of *Mesua ferrea* Linn. (Clusiaceae) in relation to light intensity. Journal of Tropical Forest Science 14: 35–48.

Khan M.L., Bhuyan P., Uma Shankar, Todaria N.P., 1999. Seed germination and seedling fitness in *Mesua ferrea* L. in relation to fruit size and seed number per fruit. Acta Oecologica 20: 599–606.

Khan M.L, Uma Shankar., 2001. Effect of seed weight, light regime, and substratum microsite on germination and seedling growth of *Quercus semiserrata* Roxb. Tropical Ecology 42: 117–125.

Kumar A., 1979. Effect of seed size and source on germination of teak seeds. Srilankan Forester 14: 56-63.

Lahai M.T., Ekanayake I.J., George J.B., 2003. Leaf chlorophyll content and tuberous root yield of cassava in inland valley. African Crop Science Journal 11: 107-117.

Manonmani V., Vanangamudi K., 2003. Effect of seed source and size on seed and stump quality of teak (*Tectona grandis* Linn. f.). Seed Research 31: 180-185.

Maranon T., Grubb P.J., 1993. Physiological basis and ecological significance of the seed size and relative growth rate relationship in Mediterranean annuals. Functional Ecology 7: 591–599.

Norusis M.J., 1988. SPSS-X Introductory statistics guide. Chicago, SPSS Inc.

Ross M.A., Harper J.L., 1972. Occupation of biological space during seedling establishment. Journal of Ecology 60: 77–88.

Sudhakara K., Jijeesh C.M., 2008. Effect of germination conditions, grading and storage of teak (*Tectona grandis* Linn. f.) drupes on the germination parameters. Indian Forester 134: 241-249.

Viswanath S., Surendran T., Chacko K.C., Basha S.C., 1995. Effect of fruit grading, presowing treatments and media on germination and growth of *Tectona grandis* Linn. f. Journal of Tropical Forest 11: 99-109.

Walters M.B., Kruger E.L., Reich P.B., 1993. Growth, biomass distribution and $CO_2$ exchange of northern hardwood seedlings in high and low light: relationships with successional status and shade tolerance. Oecologia 94: 7–16.

Weis I.M., 1982. The effects of propagule size on germination and seedling growth in *Mirabilis hirsuta*. Canadian Journal of Botany 60: 959–971.

Zhang J., Maun M.A., 1990. Effects of sand burial on seed germination, seedling emergence, survival, and growth of *Agropyron psammophilum*. Canadian Journal of Botany 68: 304-310.