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# Optimizing seed storage and treatment for enhanced seedling growth in *Elaeodendron paniculatum Wight & Arn.*: An endemic medicinal tree of Western Ghats

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**Abstract**
The Western Ghats, home to approximately 700 medicinal plant species, face increasing threats from human activities, necessitating urgent conservation efforts. *Eleodendron paniculatum*, a medicinally important species, requires optimized storage and propagation strategies for effective conservation and sustainable utilization. This study, conducted in 2022-2023 at the College of Forestry Nursery, Kodagu, evaluated the effects of seed storage duration and treatments on seedling growth using a split-plot design. Seeds were stored for different durations: freshly collected (S1), 30 days (S2), 60 days (S3), and 90 days (S4), and subjected to four treatments: M1 (Control), M2 (Carbendazim 1%), M3 (Chlorpyriphos 20% EC), and M4 (Carbendazim 1% + Chlorpyriphos 20% EC). Growth parameters, including seedling height, collar diameter, number of leaves, root-shoot ratio, and survival percentage, were recorded fortnightly. Results indicated significant variations in seedling height, with M2 yielding the tallest seedlings (16.14 cm) and M1 the shortest (14.23 cm) after three fortnights. The highest survival percentage (95.45%) was recorded in M4 during the first interval, while M3 exhibited the lowest (76.88%) in the third. The sturdiness quotient peaked at 14.88 in M3 (S1), while the seedling quality index reached 0.31 in M2 (S1). These findings highlight the importance of combining Carbendazim and Chlorpyriphos for improved seedling survival and growth. The study underscores the need for optimized seed storage treatments to enhance propagation efforts and ensure the conservation of this valuable medicinal species.

**Keywords:** Seed storage, seed treatment, seedling growth and conservation

## Introduction
The conservation of endemic tree species is crucial for preserving biodiversity, maintaining ecological balance, and safeguarding valuable genetic resources. *Elaeodendron paniculatum* Wight & Arn., a medicinal tree species native to the Western Ghats, is increasingly threatened by habitat loss, climate change, and anthropogenic pressures. Given its pharmacological significance, economic potential, and ecological role, conservation efforts must go beyond in-situ methods and incorporate efficient ex-situ strategies such as seed banking and vegetative propagation. However, the recalcitrant nature of *E. paniculatum* seeds poses a significant challenge, as these seeds are highly sensitive to dehydration and unsuitable for conventional seed storage techniques. The optimization of seed storage and treatment protocols is, therefore, essential for ensuring seed viability, enhancing germination rates, and supporting large-scale afforestation and restoration initiatives ((Umarani *et al*., 2015) [13].

Proper seed handling, storage conditions, and treatment techniques play a critical role in preserving the genetic integrity and propagation potential of *E. paniculatum*. Factors such as seed maturity at collection, moisture content regulation, and protection against fungal infections significantly influence seed longevity and germination success (Schmidt, 2000) [9]. Given the irregular seed production cycles of the species, developing effective seed storage strategies will help maintain a continuous supply of high-quality seedlings for conservation and commercial applications. This research explores the impact of various seed storage and treatment approaches on the germination and seedling growth of *E. paniculatum*, aiming to establish best practices for its long-term conservation and utilization in medicinal, ecological, and biofuel industries.

## Materials and Methods

The study aimed to determine the optimal storage treatment and duration to enhance the storability and shelf life of *Elaeodendron paniculatum* seeds. A field experiment was conducted from July 2022 to April 2023 at the College of Forestry, Ponnampet, Karnataka, India, using a Split Plot design. Storage treatments were assigned to the main plots and storage durations to the subplots, with four main plots and four subplots, each replicated four times with 100 seeds per replication.

Mature seeds were collected from the Western Ghats (Kodagu district), carefully harvested, and transported to the laboratory for further analysis. Damaged seeds were removed, and the remaining seeds were shade-dried before being treated with a chemical solution for two minutes. The treated seeds were then stored in 100-gauge polythene bags to minimize moisture loss and prevent external damage. Seedling growth parameters, including survival percentage, collar diameter, height, and leaf count, were recorded at 15-day intervals after two months of germination, with data collected from 40 seedlings per treatment.

### Seedling Growth Parameters

After 90 days of germination, the number of seedlings that survived at each fortnight night interval during the observation was estimated and expressed and collar diameter, height and number of leaves observations were recorded at each interval.

**Table 1:** Plant growth parameters

| Plant growth parameters | Methods |
|---|---|
| Survival percentage | $= \frac{Number\ of\ seedlings\ survived\ at\ each\ intervel}{Total\ number\ of\ seedlings\ in\ each\ treatment} \times 100$ |
| Collar diameter (mm) | Collar diameter will be measured at collar region of the seedling by using digital caliper and was expressed in millimeters |
| Seedling height (cm) | Height of seedling will be measured from the base of the shoot to the growing tip of the plant by using measuring scale and was expressed in centimeters |
| Number of leaves | The number of leaves per plant was counted for randomly selected 40 seedlings. |

**Table 2:** Seedling Quality Parameters

| Seedling Quality Parameters | Methods |
|---|---|
| Shoot-to-root dry weight ratio | $= \frac{Shoot\ dry\ weight\ (g)}{Root\ dry\ weight\ (g)}$ |
| Sturdiness Quotient | $= \frac{Seedling\ height\ (cm)}{Collar\ diameter\ (mm)}$ |
| Seedling quality index (Dickson *et al.* (1960)) [4] | $= \frac{Total\ seedling\ dry\ weight\ (g))}{\frac{Seedling\ height\ (cm)}{Collar\ diameter\ (mm)} + \frac{Shoot\ dry\ weight\ (g)}{Root\ dry\ weight\ (g)}}$ |
| Seedling Vigour Index (VI) by Manonmani and Vanangamudi (2002) [8] | Vigour Index = (ASL + ARL) × Percentage of germination Where, ASL= Average Shoot Length, ARL = Average Root Length. |

## Results and Discussion

*Elaeodendron paniculatum* seeds exhibit epigeal germination, with rapid hypocotyl elongation raising the cotyledons above the soil. The presence of paired seedlings suggests polyembryony. Seedling survival percentages were recorded at 15, 30, and 45 days after 90 days of germination across various storage treatments.

Seedling collar diameter showed no significant differences among treatments (Table 3), similar to findings in *Bauhinia purpurea* (Hanumanth *et al.*, 2014) [6] and *Lophopetalum wightianum* (Maheshwarappa *et al*., 2017) [7]. However, storage period significantly influenced collar diameter, with freshly collected seeds exhibiting higher growth due to increased physiological activity (Deepika *et al.*, 2014) [3].

Seedling height was significantly affected by storage treatments (Table 4). M2 (Carbendazim 1%) produced the tallest seedlings (12.43 cm, 14.14 cm, 16.14 cm), followed by M4 (Carbendazim 1% + Chlorpyriphos 20% EC), while M1 (Control) had the shortest (10.54 cm, 12.39 cm, 14.23 cm). The longest seedlings emerged from S3 (90 days storage) and freshly collected seeds (S1), while the shortest resulted from S2 (30 days storage). These results align with Deepika *et al.* (2014) [3] and support the importance of fungicide treatments in promoting seedling growth (Tielborger & Prasse, 2009) [12].

Leaf count showed minimal variation across storage treatments (Table 5). M3 (Chlorpyriphos 20% EC) had the highest first-interval count (5.80), followed by M2 (5.71), while M1 and M4 were lowest (5.42). In the second interval, M2 was highest (7.07), and M1 lowest (6.35). The third interval recorded M2 as highest (7.89) and M3 as lowest (7.07). Leaf number declined with increased storage duration due to reduced seedling vigor, though insect attack in the second interval introduced potential variability.

Seedling survival declined from S1 to S4 and within each storage period from the first to third fortnight due to seedling vulnerability and environmental conditions (Table 6). Emergence order affects competition and long-term plant dominance (Tielborger & Prasse, 2009) [12].

Shoot and root lengths were unaffected by storage chemicals (Table 7). M2 had the longest shoots (24.45 cm), while M4 had the longest roots (7.53 cm). The shortest shoot (22.13 cm) and root (6.40 cm) lengths were observed in M3 and M4, respectively, supporting Aldhous (1972) [1]. Storage duration significantly impacted seedling growth, with the longest shoots and roots recorded in freshly sown seeds (26.76 cm and 8.59 cm) and decreasing with prolonged storage (Garoma *et al.*, 2019) [5].

**Table 3:** Impact of Seed Storage Treatments and Duration on Seedling Collar Diameter Across Three Fortnight Intervals

| Plots | | Collar diameter (mm) | | |
|---|---|---|---|---|
| | | First interval | Second interval | Third interval |
| Seed storage treatments | M1 | 2.25 | 2.54 | 2.84 |
| | M2 | 2.42 | 2.68 | 2.94 |
| | M3 | 2.12 | 2.45 | 2.78 |
| | M4 | 2.28 | 2.60 | 2.92 |
| | S.Em ± | 0.14 | 0.16 | 0.18 |
| | CD (0.05) | NS | NS | NS |
| Storage periods | S1 | 2.66[a] | 3.02[a] | 3.38[a] |
| | S2 | 2.29[ac] | 2.53[ac] | 2.76[b] |
| | S3 | 2.48[a] | 2.73[a] | 2.99[b] |
| | S4 | 1.65[b] | 2.09[b] | 2.36[c] |
| | S.Em ± | 0.086 | 0.10 | 0.12 |
| | CD (0.05) | 0.25 | 0.32 | 0.38 |
| Storage treatments × Storage periods | M1S1 | 2.59 | 2.89 | 3.11 |
| | M1S2 | 2.53 | 2.84 | 3.16 |
| | M1S3 | 2.32 | 2.55 | 2.78 |
| | M1S4 | 1.55 | 1.93 | 2.33 |
| | M2S1 | 2.75 | 3.11 | 3.48 |
| | M2S2 | 2.30 | 2.53 | 2.75 |
| | M2S3 | 2.70 | 2.97 | 3.24 |
| | M2S4 | 1.95 | 2.10 | 2.27 |
| | M3S1 | 2.63 | 2.99 | 3.36 |
| | M3S2 | 2.22 | 2.43 | 2.63 |
| | M3S3 | 2.25 | 2.49 | 2.73 |
| | M3S4 | 1.39 | 1.89 | 2.40 |
| | M4S1 | 2.67 | 3.11 | 3.56 |
| | M4S2 | 2.12 | 2.31 | 2.50 |
| | M4S3 | 2.65 | 2.93 | 3.21 |
| | M4S4 | 1.70 | 2.06 | 2.43 |
| | S.Em± | 0.15 | 0.15 | 0.23 |
| | CD (0.05) | NS | NS | NS |

**Table 4:** Impact of Seed Storage Treatments and Duration on Seedling Height Across Three Fortnight Intervals

| Plots | | Height (cm) | | |
|---|---|---|---|---|
| | | First interval | Second interval | Third interval |
| Seed storage treatments | M1 | 10.54[a] | 12.39[a] | 14.23[a] |
| | M2 | 12.43[b] | 14.14[b] | 16.14[b] |
| | M3 | 11.40[ab] | 13.54[ab] | 15.45[ab] |
| | M4 | 11.55[ab] | 13.55[ab] | 15.54[ab] |
| | S.Em ± | 0.42 | 0.41 | 0.44 |
| | CD (0.05) | 1.26 | 1.24 | 1.34 |
| Storage periods | S1 | 12.00[ab] | 14.01[b] | 16.02[ab] |
| | S2 | 9.56[a] | 11.63[a] | 13.67[a] |
| | S3 | 12.34[b] | 13.99[ab] | 15.63[ab] |
| | S4 | 11.99[ab] | 13.98[ab] | 16.04[b] |
| | S.Em ± | 0.61 | 0.36 | 0.41 |
| | CD (0.05) | 1.85 | 1.09 | 1.25 |
| Storage treatments × Storage periods | M1S1 | 10.15 | 11.83 | 13.51 |
| | M1S2 | 9.70 | 11.37 | 13.05 |
| | M1S3 | 10.89 | 12.62 | 14.35 |
| | M1S4 | 11.37 | 13.73 | 16.02 |
| | M2S1 | 12.69 | 14.63 | 16.57 |
| | M2S2 | 10.99 | 12.99 | 15.00 |
| | M2S3 | 13.16 | 14.36 | 16.41 |
| | M2S4 | 12.87 | 14.59 | 16.60 |
| | M3S1 | 12.84 | 14.64 | 16.45 |
| | M3S2 | 9.37 | 11.71 | 14.04 |
| | M3S3 | 12.15 | 14.34 | 15.59 |
| | M3S4 | 11.25 | 13.47 | 15.71 |
| | M4S1 | 12.33 | 14.94 | 17.56 |
| | M4S2 | 8.30 | 10.45 | 12.61 |
| | M4S3 | 13.17 | 14.66 | 16.16 |
| | M4S4 | 12.42 | 14.13 | 15.84 |
| | S.Em± | 0.55 | 0.54 | 0.75 |
| | CD (0.05) | NS | NS | NS |

**Table 5:** Effect of seed storage treatments and storage period on the number of leaves of the seedlings for three-fortnight intervals after each sowing

| Plots | | Number of leaves | | |
|---|---|---|---|---|
| | | First interval | Second interval | Third interval |
| Seed storage treatments | M1 | 5.42 (2.33) | 6.35 (2.52) | 7.34 (2.71) |
| | M2 | 5.71 (2.39) | 7.07 (2.66) | 7.89 (2.81) |
| | M3 | 5.80 (2.41) | 6.40 (2.53) | 7.07 (2.66) |
| | M4 | 5.42 (2.33) | 6.55 (2.56) | 7.61 (2.76) |
| | S.Em ± | 0.03 | 0.05 | 0.05 |
| | CD (0.05) | NS | NS | NS |
| Storage periods | S1 | 5.38 (2.32) | 6.33 (2.53)$^{c}$ | 7.23 (2.69) |
| | S2 | 5.71 (2.39) | 6.55 (2.56)$^{b}$ | 7.56 (2.75) |
| | S3 | 5.95 (2.44) | 7.23 (2.69)$^{a}$ | 8.06 (2.84) |
| | S4 | 5.38 (2.32) | 6.25 (2.50)$^{d}$ | 7.07 (2.66) |
| | S.Em ± | 0.03 | 0.05 | 0.05 |
| | CD (0.05) | NS | 0.15 | NS |
| Storage treatments × Storage periods | M1S1 | 5.06 (2.25) | 6.00 (2.45)$^{d}$ | 7.07 (2.66) |
| | M1S2 | 6.05 (2.46) | 7.07 (2.66)$^{c}$ | 8.06 (2.84) |
| | M1S3 | 5.47 (2.34) | 6.45 (2.54)$^{d}$ | 7.61 (2.76) |
| | M1S4 | 5.19 (2.28) | 5.95 (2.44)$^{d}$ | 6.70 (2.59) |
| | M2S1 | 5.01 (2.24) | 5.95 (2.44)$^{d}$ | 6.65 (2.58) |
| | M2S2 | 6.35 (2.52) | 8.35 (2.89)$^{a}$ | 9.36 (3.06) |
| | M2S3 | 6.10 (2.47) | 7.84 (2.80)$^{b}$ | 8.88 (2.98) |
| | M2S4 | 5.33 (2.31) | 6.35 (2.52)$^{d}$ | 6.91 (2.63) |
| | M3S1 | 5.95 (2.44) | 7.07 (2.66)$^{c}$ | 7.45 (2.73) |
| | M3S2 | 5.47 (2.34) | 5.01 (2.24)$^{f}$ | 6.10 (2.47) |
| | M3S3 | 6.30 (2.51) | 7.05 (2.74)$^{c}$ | 7.56 (2.75) |
| | M3S4 | 5.56 (2.36) | 6.15 (2.48)$^{d}$ | 7.23 (2.69) |
| | M4S1 | 5.42 (2.33) | 6.65 (2.58)$^{e}$ | 7.67 (2.77) |
| | M4S2 | 4.92 (2.22) | 5.95 (2.44)$^{d}$ | 6.96 (2.64) |
| | M4S3 | 5.90 (2.43) | 7.18 (2.68)$^{c}$ | 8.23 (2.87) |
| | M4S4 | 5.47 (2.34) | 6.50 (2.55)$^{d}$ | 7.56 (2.75) |
| | S.Em± | 0.08 | 0.08 | 0.07 |
| | CD (0.05) | NS | 0.24 | NS |

**Table 6:** Effect of seed storage treatments and storage period on the survival percentage of the seedlings for three-fortnight intervals after each sowing

| Plots | | Survival percentage | | |
|---|---|---|---|---|
| | | First interval | Second interval | Third interval |
| Seed storage treatments | M1 | 94.17 (76.03) | 91.25 (72.8) | 90.36 (71.91) |
| | M2 | 93.50 (75.23) | 90.46 (72.01) | 89.93 (71.50) |
| | M3 | 93.18 (74.87) | 83.66 (66.16) | 76.88 (61.26) |
| | M4 | 95.45 (77.69) | 86.41 (68.37) | 77.13 (61.43) |
| | S.Em ± | 3.025 | 3.01 | 2.67 |
| | CD (0.05) | NS | NS | 8.03 |
| Storage periods | S1 | 92.35 (73.95)$^{a}$ | 86.24 (68.23)$^{a}$ | 82.62 (65.36)$^{a}$ |
| | S2 | 88.13 (69.85)$^{ab}$ | 81.89 (64.82)$^{a}$ | 78.86 (62.63)$^{ab}$ |
| | S3 | 92.39 (73.99)$^{ab}$ | 86.67 (68.59)$^{a}$ | 82.35 (65.16)$^{b}$ |
| | S4 | 99.52 (86.03)$^{b}$ | 95.45 (77.69)$^{b}$ | 91.38 (72.93)$^{b}$ |
| | S.Em ± | 2.55 | 2.86 | 2.87 |
| | CD (0.05) | 7.66 | 8.59 | 8.62 |
| Storage treatments × Storage periods | M1S1 | 86.85 (68.74) | 80.50 (63.8) | 78.39 (62.30) |
| | M1S2 | 94.28 (76.17) | 92.53 (74.14) | 90.55 (72.10) |
| | M1S3 | 97.43 (80.78) | 94.28 (76.17) | 94.29 (76.17) |
| | M1S4 | 96.19 (78.75) | 95 (77.08) | 95 (77.08) |
| | M2S1 | 97.43 (80.78) | 94.28 (76.17) | 94.29 (76.17) |
| | M2S2 | 85.80(67.87) | 83.23 (65.83) | 83.24 (65.83) |
| | M2S3 | 84.60 (66.9) | 82.45 (65.24) | 82.46 (65.24) |
| | M2S4 | 99.35 (85.39) | 97.43 (80.78) | 96.19 (78.75) |
| | M3S1 | 87.76 (69.53) | 82.75 (65.46) | 80.51 (63.80) |
| | M3S2 | 83.23 (65.83) | 76.27 (60.85) | 73.20 (58.82) |
| | M3S3 | 92.53 (74.14) | 81.01 (64.17) | 72.85 (58.60) |
| | M3S4 | 100 (90) | 92.53 (74.14) | 80.51 (63.80) |
| | M4S1 | 95 (77.08) | 85.35 (67.5) | 73.77 (59.19) |
| | M4S2 | 87.76 (69.53) | 72.62 (58.45) | 65.07 (53.77) |
| | M4S3 | 92.53 (74.14) | 86.89 (68.78) | 75.95 (60.63) |
| | M4S4 | 100 (90) | 96.19 (78.75) | 90.55 (72.10) |
| | S.Em± | 4.54 | 5.40 | 4.90 |
| | CD (0.05) | NS | NS | NS |

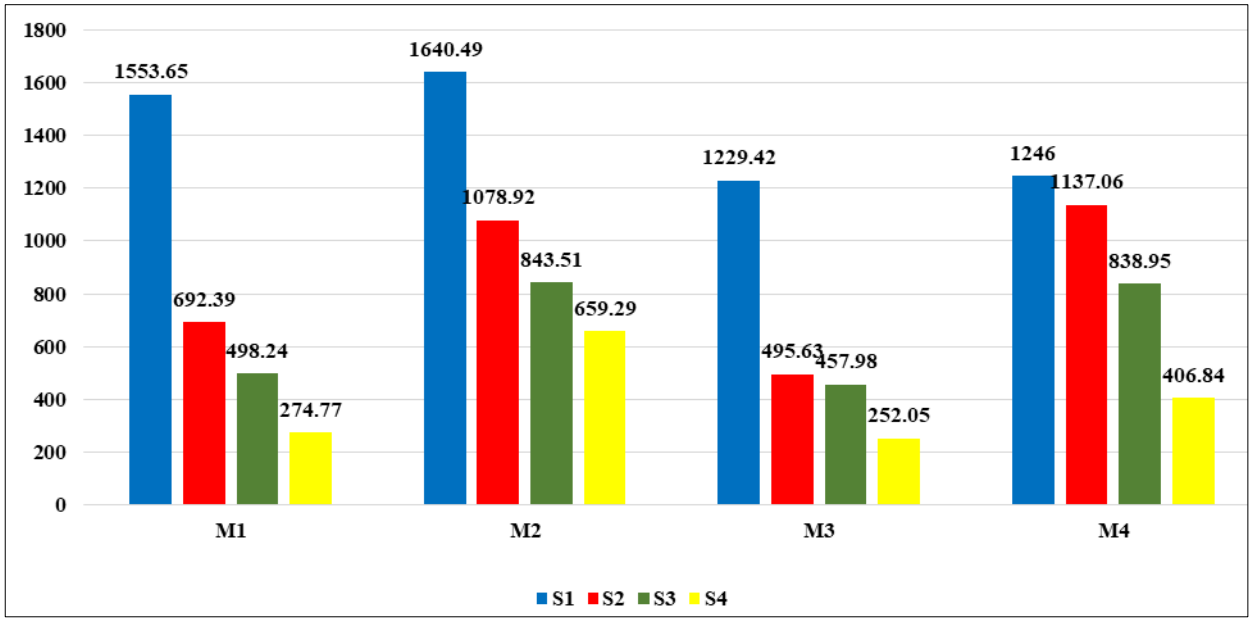
**Table 7:** Effect of seed storage treatments and storage period on shoot length and root length

| Plots | | Shoot length | Root length |
|---|---|---|---|
| Seed storage treatments | M1 | 23.11 | 6.72 |
| | M2 | 24.45 | 7.53 |
| | M3 | 22.13 | 6.74 |
| | M4 | 22.18 | 6.40 |
| | S.Em ± | 1.02 | 0.67 |
| | CD (0.05) | NS | NS |
| Storage periods | S1 | 26.76[b] | 8.59[a] |
| | S2 | 22.76[ab] | 6.88[a] |
| | S3 | 21.35[ab] | 6.11[ab] |
| | S4 | 20.99[a] | 5.82[ab] |
| | S.Em ± | 0.88 | 0.63 |
| | CD (0.05) | 2.65 | 1.91 |
| Storage treatments × Storage periods | M1S1 | 24.06 | 7.25 |
| | M1S2 | 23.06 | 6.71 |
| | M1S3 | 21.46 | 6.21 |
| | M1S4 | 22.96 | 6.74 |
| | M2S1 | 24.42 | 7.9 |
| | M2S2 | 25.21 | 7.98 |
| | M2S3 | 25.10 | 7.33 |
| | M2S4 | 23.06 | 6.90 |
| | M3S1 | 30.7 | 10.62 |
| | M3S2 | 19.43 | 5.66 |
| | M3S3 | 19.43 | 5.66 |
| | M3S4 | 18.97 | 5.03 |
| | M4S1 | 27 | 8.6 |
| | M4S2 | 23.35 | 7.17 |
| | M4S3 | 19.43 | 5.24 |
| | M4S4 | 18.97 | 4.61 |
| | S.Em± | 1.42 | 1.25 |
| | CD (0.05) | 4.28 | NS |

**Table 8:** Seedling quality parameters of seedlings in different seed treatments under different storage periods

| Treatments | | Sturdiness quotient | Seedling quality index | S: R Ratio |
|---|---|---|---|---|
| Control | S1 | 10.92 | 0.16 | 2.21 |
| | S2 | 8.74 | 0.19 | 2.08 |
| | S3 | 7.18 | 0.21 | 2.22 |
| | S4 | 7.54 | 0.19 | 2.42 |
| Carbendazim (1%) | S1 | 9.56 | 0.29 | 2.25 |
| | S2 | 8.98 | 0.31 | 2.23 |
| | S3 | 8.20 | 0.31 | 1.85 |
| | S4 | 7.29 | 0.31 | 1.99 |
| Chlorpyriphos 20% EC | S1 | 14.88 | 0.20 | 2.14 |
| | S2 | 8.15 | 0.17 | 2.35 |
| | S3 | 7.18 | 0.19 | 2.35 |
| | S4 | 6.79 | 0.15 | 2.41 |
| Carbendazim (1%) + Chlorpyriphos 20% EC | S1 | 11.06 | 0.16 | 2.83 |
| | S2 | 8.50 | 0.17 | 2.71 |
| | S3 | 6.36 | 0.16 | 2.60 |
| | S4 | 6.10 | 0.18 | 2.77 |

*Parenthetical values are arc sine transformed; CD- Critical Difference;
Figures with similar letters as superscript do not differ significantly
freshly collected - S1, 30 days after collection - S2,
60 days after collection - S3 and 90 days after collection - S4.
M1- Control, M2- Carbendazim (1%), M3- Chlorpyriphos 20% EC, and M4- Carbendazim (1%) + Chlorpyriphos 20% EC




**Note:** M1= Control, M2= Carbendazim (1%), M3=Chlorpyriphos 20% EC, M4= Carbendazim (1%) + Chlorpyriphos 20% EC

S1= Freshly collected seeds, S2= 30 Days after collection (DAS), S3= 60 DAS, S4= 90 DAS

**Fig 1:** Vigour Index of seedlings with different storage treatments at different storage periods

Seedling quality parameters, including the sturdiness quotient, quality index, and shoot-to-root ratio, declined with increased storage (Table 8). The highest sturdiness quotient was in M3-treated fresh seeds (S1), while M2-treated fresh seeds had the best seedling quality index. M4-treated fresh seeds had the highest shoot-to-root ratio, confirming the importance of robust root development. Vigour Index declined with prolonged storage. The highest index (1640.49) was observed in M2-treated fresh seeds, while the lowest (274.77) was recorded for M1 under S4 conditions. Similar trends were reported in *Lophopetalum wightianum* (Chandra *et al*., 2014) [2], *Calamus thwaitesii* (Patil & Krishna, 2016), and Garcinia gummi-gutta (Shankar *et al.*, 2016) [10]. Chlorpyrifos application reduced germination rates, consistent with Srinivas *et al*. (2016) [11], who found enzyme inhibition led to reduced seedling vigor in radish and green gram.These findings highlight the critical role of seed storage duration and fungicide treatments in optimizing seedling growth and survival.

## Conclusion

The study underscores the importance of optimizing seed storage and treatment protocols for enhancing the viability and seedling growth of *Elaeodendron paniculatum*, an endemic tree of the Western Ghats. Freshly stored seeds exhibited the best performance, with viability decreasing as storage time increased. The use of Carbendazim and Chlorpyriphos treatments significantly improved seedling survival, quality, and vegetative growth, making them effective in preserving seed viability and enhancing propagation. Combining these chemical treatments with controlled storage conditions is recommended for the successful propagation and conservation of *E. paniculatum*, supporting biodiversity conservation and afforestation efforts.

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