Assessment of different pretreatments to breakage dormancy and improve the seed germination in *Elaeocarpus serratus* L. - an underutilized multipurpose fruit tree from South India

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**ABSTRACT**

The seeds of *Elaeocarpus serratus*, a tropical underutilized fruit tree are characterized by hard seed coat and consequent poor water uptake and low germination. To improve the regeneration through seeds, various parameters such as viability of seeds, water uptake, and effect of seed mass on germination and pretreatments were performed using a completely randomized design (CRD). Tetrazolium (TZ) test was conducted using fresh, mature seeds revealed 50 ± 2.56% mean viability. Seeds of different weight classes showed similar pattern of water uptake and the saturation level was achieved at 60 hrs of soaking. Seeds belong to weight class 2.6-3.5g were germinated (12.5 ± 1.26%) with 175 ± 1.75 days (d) of mean time taken for germination (MTG). Germination capacity of seeds varied significantly among different populations and Varkala population gave 12.5 ± 1.1% germination with 174.6 ± 2.5 d MTG. Among various seed treatments, mechanical scarification was superior in germination and significant reduction in MTG (p < 0.05). The mechanical scarification by complete removal of seed coat resulted in 49.2 ± 1.52% germination within a short period of time (9.52 ± 0.89 d MTG). However, the complete removal of seed coat without damaging to embryo is a difficult task. An alternate treatment (Mechanical scarification II) by making cracks on nut faces vertically followed by soaking in distilled water for 24 hrs gave 48.4 ± 1.73% germination with significantly reduced MTG (12.14 ± 0.56 d) over unsoaked, untreated control (6.5 ± 1.84% germination and 197.18 ± 1.79 d MTG; p < 0.05). This treatment (Mechanical scarification II) is therefore recommended for *E. serratus* seeds as it can adopt easily and can achieve 7 fold increases in germination over control. The recorded germination through mechanical scarification is in tune with realized viability percentage of the seeds.

**Introduction**

*Elaeocarpus serratus* L. commonly known as Ceylon olive belongs to family Elaeocarpaceae. It is a medium sized, ever green, multipurpose fruit tree native to Sri Lanka. The plant is also found in East Africa as well as the subtropical and tropical Asia, and tropical Australia (Sriti et al. 2011). The tree is primarily valued for its edible fruits. Sweet-sour, small berry fruits of Ceylon olive are nutrient rich, thus used as seasonal table fruit in the region, and also for the preparation of wide variety of value added products such as squash, jam, jelly, pickles etc. In the Southern states of India, *E. serratus* is semi domesticated in nature. Due to fragmentation of land area and other anthropogenic pressures sustenance and distribution of such underutilized trees are hindered (Hammer et al. 2001; He et al. 2009; Joseph et al. 2010; Yao 2015). Thus there is an urgent need to develop appropriate tree propagation and management methods for their large scale plantations through agro-forestry, social forestry, home gardens and on-farm cultivation (Gebauer et al. 2007; Kim et al. 2016; Sudrajat 2016). Unavailability of planting material is one of the problems that restrict cultivation and popularization of this potential fruit crop. Major constraints in raising seedlings of *E. serratus* are the poor germination coupled with long dormancy, due to the hardness of the nut coat (endocarp) that lead to reduction in the regeneration. The seeds of *E. serratus* are non-orthodox type, despite of its hard seed coat (stone) (Hamilton et al. 2009). Slow and erratic germination of *E. serratus* has been previously attributed to the endocarp needing to soften. Therefore it is presumed that germination of seeds with hard seed coat can be enhanced by pre-sowing treatments, such as physical or chemical treatments (Rouhi et al. 2010; Dewir et al. 2011), softening of the hard seed coat will improve water uptake, enable seeds to overcome dormancy (Yang et al. 1999; Morris et al. 2000; Conversa and Elia 2009; Abari et al. 2012).

Elaeocarpus seed kernels are relatively large. Therefore viability can be determined by cutting the seeds to examine the condition of the albumen (Bisht and Ahlawat 1999). It has been proven that most of
the Elaeocarpus spp, seeds had physical dormancy mechanisms due to its hard seed coat (Bhuyan et al. 2002; Khan et al. 2003; Shankar and Rawat 2013). The success of on-farm nurseries depends upon the ease of germination under specific controlled condition. To a greater extent it can be achieved by the selection of suitable seed source and development of a dependable germination method. In the present study, we focused on to investigate how germination of *E. serratus* is delayed by possible physiological or physical dormancy. Our plan is to resolve physical dormancy if any operated that restrict *E. serratus* germination by suitably conditioning water resistant nature of seed coat. Therefore present study was carried out with an aim to develop an efficient seed treatment that facilitates rapid and enhanced germination of *E. serratus*.

**Materials and methods**

Fully ripe fruits collected from eight different locations (Table 1 and Figure 1) from multiple plants were used for the germination variability tests. Of these eight collections, the Varkkala (Thiruvananthapuram District) population was used for seed viability, water uptake, and germination experiments viz., - seed mass on germination and seed pretreatments. All the seeds were extracted, shade dried for seven days and pooled for seed tests. The experiments were conducted at the Medicinal plant nursery of Botanic Garden, Department of Botany, University of Kerala (8°33′03.86″ N; 76°52′38.64″ E; 18 m asl). Seed weight class ranging from 2.6-3.5 g was used for the treatments to reduce variation in germination percentage, except seed mass experiments. Prior to various treatments, nuts were cleaned in running tap water, while others were kept intact for using as control. All the seeds after treatment were sown in earthen pots (30x25 cm) filled with a 1:1 (v/v) mix of farmyard manure (FYM) and soil. For each treatment, 40 seeds with three replications were used. The seeds (single seed/pot) were sown upright position and maintained in a shade net house.

**Seed viability**

Outer stony seed coat was removed by using a seed cutter and kernel was dissected out using forceps. The excised kernel were then incubated in 1% solution of 1, 2, 3 triphenyl tetrazolium chloride (pH 7, TZ) (Merck, Germany) for 3 hrs in dark. Viability test was carried out using three replication blocks and each block was composed of 40 dissected embryos. Pink embryos were considered as viable. Accordingly, percentage of viability was determined (ISTA 2015) and mean of three replication blocks was presented as mean seed viability.

**Seed storage and viability**

To determine level of dormancy, seed viability test was conducted using fresh seeds and after 1, 2, 3, 4, 5 and 6 months of storage under normal environmental conditions.

**Water uptake capacity**

Seeds of *E. serratus* were grouped into four categories based on their seed mass (<1.5, 1.5-2.5, 2.6-3.5, >3.5 g) and cumulative mass of 20 seeds were determined prior to water soaking. Each group of seeds was soaked in distilled water at 27°C for 12, 24, 36, 48, 60 and 72 hrs. The imbibed seeds were weighted at the end of each time period and difference in seed weight was duly recorded.

**Seed mass on germination**

Seed mass of four different groups (<1.5, 1.5-2.5, 2.6-3.5, >3.5 g) were soaked in distilled water for 60 hrs at 27°C were subjected to germination on earthen pots. The records on germination percentage and MTG were collected after the definite period of maintenance of pots in the nursery.

**Germination variability**

Seeds collected from geographically different, eight populations were used for germination variability studies (Table 1 and Figure 1). Seeds collected from different populations were soaked in distilled water for 60 hrs (27°C) prior to sowing.

**Seed pretreatments**

Water treatment; To test effect of water soaking on seed germination, at first the two different sets of intact seeds were soaked in distilled water for 48 and 60 hrs respectively and effect of hot water was also determined separately by soaking a set of intact seeds in warm water (45°C) for 60 hrs and brought to room temperature. For the investigation of cold storage on effective germination, intact seeds were soaked in distilled water for 60 hrs (27°C), then excess water blotted. Such seeds were wrapped with paper bags and stored in a walk in cold room (4°C) for 24 hrs.

Hormonal treatment: To examine the efficacy of hormonal treatment on seed germination, GA3 (100ppm, 500ppm) and IAA (100ppm, 500ppm) for 60 hrs were treated separately on different seed sets.

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**Table 1. Geographical description of seed collection sites in Kerala State of South India**

| Location               | Altitude(m asl) | Latitude(N) | Longitude(E) |
|------------------------|-----------------|-------------|--------------|
| Puthoorvayal           | 757             | 11°35′08.68″ | 76°05′59.26″ |
| Cherthala              | 10              | 9°41′01.09″  | 76°20′11.54″ |
| Ulyyakovil             | 18              | 8°54′07.58″  | 76°36′08.20″ |
| Varkkala               | 48              | 8°44′16.33″  | 76°42′58.81″ |
| Vazhachal              | 223             | 10°18′07.33″ | 76°35′36.14″ |
| Karjavattom            | 128             | 8°33′50.14″  | 76°53′11.82″ |
| Kulathoopuzha          | 174             | 8°54′41.39″  | 77°30′32.61″ |
| Bonacadu               | 551             | 8°40′50.14″  | 77°10′3.98″  |
Acid treatment: The effect of acid scarification on germination was tested by intact seeds sets were treated with conc. sulphuric acid for 10, 20 or 30 minutes. After treatment, seeds were thoroughly washed in running water for 45 minutes.

Mechanical scarification: Three different methods of mechanical scarifications were adopted separately on three seed sets. At first, seed coat was thinned using secateurs followed by soaking in distilled water for 60 hrs at 27°C (Mechanical scarification I). Second scarification treatment was carried out by creating cracks on the nut faces vertically by using a seed cutter followed by soaking in distilled water for 24 hrs at 27°C (Mechanical scarification II). Third method was done with complete removal of seed coat and excised kernel soaked in distilled water for 24 hrs at 27°C (Mechanical scarification III).

Growth performance of seedlings raised through mechanical scarification

To evaluate the pre-sowing treatment on growth pattern, seedling growth was monitored. After the successful completion of seed germination experiment, the seedlings were monitored for 2 years under natural growth conditions.
habitat. All the seedlings were measured for total shoot height and collar diameter, once in a year and compared with a control group of germinated seedlings. Total shoot height was measured by using ruler and collar diameter by using electronic digital vernier caliper. The vigor index was calculated according to the following formula:

\[
V = \frac{\text{seedling length(cm)} \times \text{germination percentage}}{\text{N}}
\]

(Moradi Dezfuli et al. 2008).

The experiment was carried out during July 2014 to August 2016.

**Experimental design and data collection**

A Completely Randomized Design (CRD) was adopted for all the experiments. For each experiment and control, 40 seeds were used with three replications. The collected data were subjected to statistical analysis using statistical software SPSS package version 20 (IBM Crop). Data on percentage germination and mean time taken for germination were subjected to one way analysis of variance (ANOVA) to test the null hypothesis. Mean separation test was performed using Duncan’s Multiple Range Test (DMRT; \( p < 0.05; \) Duncan 1955). Data on percentage germination was arc sine transformed prior to performing analysis of variance (ANOVA) and then converted back to percentages for presentation in the table.

\[
Gc(\%) = \frac{\sum ni}{N} \times 100
\]

\[
MTG(\text{days}) = \frac{\sum (ti \times ni)}{\sum ni}
\]

Where \( Gc \) is the germination capacity, \( \sum ni \) is the number of germinated seed after 210 days, and \( N \) is the total numbers of seed sown; \( ti \) is the number of days starting from the date of sowing and ‘ni’ is the number of seeds germinated at each day (Bewley and Black 1994). In the present study, time interval of 7 days was considered for scoring germination. The maximum time duration for germination was 240 days. Seeds were considered germinated when the radicle measured >1mm in length.

**Results and discussion**

**Viability test**

Seed viability test using tetrazolium revealed 50 ± 2.56% viable seeds in randomly sampled seeds of E. serratus. Excised seed kernel after incubation in tetrazolium chloride solution turned purple to pink colour and were considered as viable. Our result on viability of E. serratus is in conformity with previous report on other species of Elaeocarpus (Murali 1997; Bisht and Ahlawat 1999).

**Seed storage and viability**

Seed storage had significant effect on seed viability \((p \leq 0.05)\). The fresh seeds showed significantly \((p \leq 0.05)\) highest viability percentage \((50 \pm 2.56\%)\). Viability reduced after few months of seed storage under normal environmental conditions (Figure 2). One month seed storage leads to 2.5% reduction in viability (Figure 2). Seeds stored for two month duration showed 40 ± 1.26% viability. Viability was significantly declined to 35 ± 2.84% due to four month storage under normal temperature conditions (Figure 2). Six month storage caused significant \((p \leq 0.05)\) reduction in viability by 11.6 ± 0.56%. Thus, viability test signify that storability of E. serratus seed is limited under normal conditions and recommended germination at an early period of collection. As per the previous report (Murali 1997), the proportion of viable seeds was 60% in E. tuberculatus. The viability data of seeds stored at normal environmental conditions for different durations suggest that viability of E. serratus seeds reduce with period of seed storage.
germination capacity of *E. serratus* seeds. Low weight class (<1.5) of seeds showed least germination (8.1 ± 1.26%). Reduced germination capacity of the low seed weight group is possibly due to the presence of hard, thick seed coat, which reduces gas exchange along with reduced imbibition (Khan et al. 1999). Among the four seed weight classes, medium sized seeds (2.6-3.5g) had significantly (*p* ≤ 0.05) greater capacity for germination than other weight classes (Figure 4). Selection of heavier seeds reported to increase germination success in other tree species also (Harrison et al. 2014).

### Germination variability

Germination capacity of seeds collected from different populations varied (1.10–12.5%) significantly (*p* ≤ 0.05). Seeds collected from Varkala population gave 12.5 ± 1.1% germination within 174.6 ± 2.5 d MTG. Seeds collected from Pathoorvayal recorded least germination and maximum MTG (Table 2). Seed source of present investigation are from different habitats and altitudinal regimes. Variability in germination is possibly attributes to edaphic and climatic conditions (Joshi and Dhar 2003), or due to possible genetic differences as reported in other perennial crops such as *Sapium sebiferum* (Siril et al. 1998), *Erica australis* (Cruz et al. 2003); *Bixa orellana* (Joseph et al. 2011). Uniyal et al. (2000) and Fredrick et al. (2017) have reported that seed source is as important as pretreatment in seeds of *Grewia oppositifolia* and *Faidherbia albida* respectively.

### Seed Pre treatments

#### Water soaking

Water soaking treatments produced more or less similar pattern of germination. Water soaking for prolonged periods (48 and 60 hrs) gave 7.4 ± 1.59 and 12.5 ± 1.26% of germination and 187.27 ± 2.19 d and 178.42 ± 1.75 d MTG respectively. However, water soaking treatment irrespective of duration of treatment, germination did not improve significantly. Hot water (45°C) soaking for 60 hrs resulted in 13.4 ± 0.7% germination with 176.08 ± 1.52 d MTG. Seed treatment in cold water (4°C) for 60 hrs did not improve germination or reduced MTG (Table 3).

#### Acid scarification

Least germination was occurred in seeds subjected to acid scarification (Table 3). The conc. sulfuric acid treatment for different time durations adversely affected germination capacity of seeds. An extended acid treatment for 30 minutes significantly (*P* ≤ 0.001) inhibited germination of seeds, indicating possible damage to embryo or dehydration due to strong acid. Treatment using conc. sulfuric acid caused reduction in germination. Adverse effect of strong and prolonged acid treatment also reported many perennial

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**Table 1.** Germination capacity (%). Means with same alphabets are not significantly (*p* ≤ 0.05) different as determined by Duncan’s Multiple Range test.

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**Figure 4.** Germination response in *E. serratus* seeds of four different seed mass groups (<1.5, 1.5–2.5, 2.6–3.5, >3.5g). Means with same alphabets are not significantly (*p* ≤ 0.05) different as determined by Duncan’s Multiple Range test.
species such as *Macaranga peltata* (Rodrigues and Rodrigues 2014).

**Hormonal treatment**

Hormonal treatments by using GA3 (100 ppm, 500 ppm) and IAA (100 ppm, 500 ppm) for 60 hrs showed more or less germination (*p* ≤ 0.05) to 60 hrs water soaked seeds. One way ANOVA revealed that seeds treated with 100 ppm GA3 results slight improvement in germination (13.2 ± 0.79%) against 6.5 ± 1.84% germination in unsoaked control. IAA (100 ppm) treatment for 60 hrs gave 12.3 ± 2.43% germination. Role of hormones to relive dormancy of forest tree seeds are well established (Ahmadloo et al. 2015; Daneshvar et al. 2016). Exogenous applications of GA3 have been widely used to break physiological dormancy of hard seeds and hence can be classified as physiologically non-dormant (Baskin et al. 2004). The higher mortality rates of seeds during the incubation can be explained by requirement of prolonged period of time for the seed coat to soften or to lose their toxic compounds that inhibits the seed germination (Gardarin et al. 2010; Missanjo et al. 2014).

**Effect of mechanical scarification**

Mechanical scarifications had significant (*p* ≤ 0.05) effect on germination capacity (GC). The dormancy of *E. serratus* seeds were considerably relieved by different mechanical scarifications (Table 3). The speed of germination, as determined by MTG varied significantly among mechanically scarified seeds. All the mechanically scarified seeds started germination much earlier than all other treatments. Mechanical scarification by thinning seed coat using secateurs followed by soaking in distilled water for 60 hrs at 27 °C improved germination to 28.3 ± 1.07% and reduced MTG (12.14 ± 0.56 d). Mechanical treatment by making cracks on the nut faces vertically by using a seed cutter followed by soaking in distilled water for 24 hrs at 27 °C resulted in significantly (*p* ≤ 0.05) high germination (48.4 ± 1.73%) and reduced MTG (12.14 ± 0.56 d). Mechanical treatment by soaking in distilled water for 60 hrs at 27 °C improved the incubation can be explained by requirement of prolonged period of time for the seed coat to soften or to lose their toxic compounds that inhibits the seed germination (Gardarin et al. 2010; Missanjo et al. 2014).

### Table 2. Variation in mean germination capacity among eight populations of *E. serratus* L.

| Population          | Germination Capacity (%) Mean time taken for germination (days) |
|---------------------|-----------------------------------------------------------------|
| Puthoonnayal       | 13.4 ± 0.70 / 176.08 ± 1.52                                      |
| Cherthala          | 12.5 ± 1.26 / 178.42 ± 1.75                                      |
| Ullyakovil         | 10.3 ± 2.6 / 179.4 ± 0.7                                         |
| Varkkala           | 11.5 ± 1.4 / 177.9 ± 1.2                                         |
| Vazhachal          | 12.5 ± 1.1 / 174.6 ± 2.5                                         |
| Kariyavattom       | 7.4 ± 1.59 / 176.8 ± 2.4                                         |
| Kulathoozhuza      | 9.0 ± 1.3 / 177.4 ± 1.9                                          |
| Bonacudu           | 2.1 ± 4.1 / 187.7 ± 4.1                                          |
| Population          | Germination Capacity (%) Mean time taken for germination (days) |
| Population          | Germination Capacity (%) Mean time taken for germination (days) |
| Puthoonnayal       | 2.1 ± 3.0 / 189.1 ± 3.4                                          |
| Cherthala          | 10.3 ± 2.6 / 179.4 ± 0.7                                         |
| Ullyakovil         | 11.5 ± 1.4 / 177.9 ± 1.2                                         |
| Varkkala           | 12.5 ± 1.1 / 174.6 ± 2.5                                         |
| Vazhachal          | 7.4 ± 1.59 / 176.8 ± 2.4                                         |
| Kariyavattom       | 9.0 ± 1.3 / 177.4 ± 1.9                                          |
| Kulathoozhuza      | 2.1 ± 4.1 / 187.7 ± 4.1                                          |
| Bonacudu           | 5.8 ± 1.00 / 186.2 ± 2.0                                         |

Means within a column followed by same letters are not significantly (*p* ≤ 0.05) different as determined by Duncan’s Multiple Range test.

### Table 3. Effect of various seed treatments on germination of *E. serratus*.

| Treatment                          | Germination capacity (%) Mean time taken for germination (days) |
|------------------------------------|-----------------------------------------------------------------|
| Control (without soaking)          | 6.5 ± 1.84 / 197.18 ± 1.79                                      |
| Water soaking (48 hrs)             | 7.4 ± 1.59 / 187.27 ± 2.19                                      |
| Water soaking (60 hrs)             | 12.5 ± 1.26 / 178.42 ± 1.75                                      |
| Hot water (45 °C) for 60 hrs       | 13.4 ± 0.70 / 176.08 ± 1.52                                      |
| Cold storage (4 °C) for 60 hrs     | 10.8 ± 0.76 / 182.87 ± 2.50                                      |
| 100ppm GA3 for 60 hrs              | 13.2 ± 0.79 / 178.13 ± 2.05                                      |
| 500ppm GA3 for 60 hrs              | 12.5 ± 1.84 / 178.38 ± 2.82                                      |
| 100ppm IAA for 60 hrs              | 12.3 ± 2.43 / 176.59 ± 2.23                                      |
| 500ppm IAA for 60 hrs              | 11.7 ± 1.26 / 180.60 ± 1.56                                      |
| Conc. H2SO4 10 minutes             | 6.5 ± 1.84 / 192.95 ± 1.46                                      |
| Conc. H2SO4 20 minutes             | 4.8 ± 1.97 / 198.99 ± 1.25                                      |
| Conc. H2SO4 30 minutes             | 1.7 ± 3.83 / 200.37 ± 1.11                                      |
| Mechanical scarification I - Seed coat was thinned using secateurs followed by soaking in distilled water for 60 hrs at 27 °C | 28.3 ± 1.07 / 93.45 ± 2.68 |
| Mechanical scarification II - Cracks were made on the nut faces vertically by using a seed cutter followed by soaking in distilled water for 24 hrs at 27 °C | 48.4 ± 1.73 / 12.14 ± 0.56 |
| Mechanical scarification III - Complete removal of seed coat followed by soaking in distilled water for 12 hrs at 27 °C | 49.2 ± 1.26 / 9.52 ± 0.89 |

Treatment F value Df (n-1) = 14

Means within column followed by same letters are not significantly (*p* ≤ 0.05) different as determined by Duncan’s Multiple Range test.

***Significant F value at p ≤ 0.001 level; Means within column followed by same letters are not significantly (*p* ≤ 0.05) different as determined by Duncan’s Multiple Range test.***
workers as the best treatment to overcome seed coat impermeability (He et al. 2009; Maina et al. 2011; Fredrick et al. 2017). By facilitating water uptake and gas exchanges through vertical cracks on seed coat, germination was improved. This indicates that the hard seed coat caused a major physical restraint to seed germination. This observation is in conformity with previous reports on different hard seed coat perennials (Morris et al. 2000; Wang et al. 2008; Dewir et al. 2011; Rodrigues and Rodrigues 2014). In general, seeds of genus Elaeocarpus have hard seed coat that restricts radicle protrusion. In the previous reports on germination study of E. ganitrus, physical dormancy breaking treatments that facilitating removal of the seed coat was recommended (Khan et al. 2003; Bhuyan et al. 2004). Das (2014) found that in E. floribundus scarification by seed coat thinning using sand paper leads to 78% germination with an MTG of 20 days.

Mechanical scarification by complete removal of seed coat and extraction of kernel resulted in 49.2 ± 1.26% germination with at least 9.52 ± 0.89 d MTG compared to control treatment (Table 3). Nevertheless, the complete removal of seed coat without injuring kernel is a difficult task. Also efforts to germinate the extracted kernel directly in the soil were discouraging due to microbial attack. Several studies on hard seed coated woody species suggests that kernel extraction have not been common due to the rotting from microbial action and the difficulty of extracting them from the hard endocarp without damage (Tiwari et al. 2004; Slator et al. 2013). Thus, through the present study it is evident that most reliable method to relieve dormancy of E. serratus is by making cracks on nut faces vertically followed by soaking in distilled water for 24 hrs (Mechanical Scarification II). This treatment improved germination by 7.4 fold coupled with quick germination (12.14 ± 0.56 d MTG) and is in tune with realized viability percentage of the seeds.

**Growth performance of seedlings raised through mechanical scarification**

Heights of the seedlings of E. serratus raised through mechanical scarification were determined at nursery stages (Table 4). At the end of 2 year of planting, height of seedlings was significantly (p ≤ 0.05) higher than control treatments. ANOVA showed significant difference of height of seedlings (p ≤ 0.05) originated from seeds among the mechanical treatments. Collar diameter of the seedlings of E. serratus from the seeds treated with different pre-sowing treatments was also determined at nursery stages (Table 4). At the nursery conditions for I year growth, it was found that collar diameter of seedlings raised through mechanical scarification treatments were significantly (p ≤ 0.05) higher than that of control. Leaf number as well as calculated vigor index increased in germination (48.4 ± 1.73%) success over all other pretreatments. The most suitable mechanical scarification method for E. serratus was the making cracks on the seed vertically through lateral suture of seed coat using a seed cutter followed by soaking in distilled water for 24 hrs at 27°C without exposing embryo is significantly efficient to 7.4 fold increase in germination (48.4 ± 1.73%) success over control treatments (6.5 ± 1.84%). The achieved germination is in tune with viability of the seed lot realized. The forwarded method is easy and simple to follow among different methods studied. Eliminating lightweight seeds can further enhance germination in the seed lot. The population wise germination variability realized through the study is useful to screen adaptable populations of E. serratus. Also germination process of mechanically scarified seeds was significantly fast (12.14 ± 0.56 d MTG) compared to control (197.18 ± 1.79 d MTG), thus facilitate early establishment of plants and reduce the cost of nursery operations related to seedling production of E. serratus. In brief, the improved germination method evolved through the study can be applied to large scale propagation and conservation of E. serratus.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

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**Table 4. Growth performance of seedlings of E. serratus raised through various mechanical seed treatments along with control.**

| Treatment | Mean Height Growth (cm) | Mean Collar Diameter (cm) | Leaf number | Vigor index |
|-----------|-------------------------|---------------------------|-------------|-------------|
| Control   | 10.81 ± 0.76            | 0.71 ± 0.03               | 30.68 ± 0.51| 70.24 ± 4.92|
| Mechanical I | 13.54 ± 0.62            | 0.79 ± 0.03               | 28.40 ± 0.95| 383.18 ± 17.63|
| Mechanical II | 14.40 ± 0.77            | 0.87 ± 0.04               | 34.33 ± 0.35| 696.96 ± 37.39|
| Mechanical III | 11.19 ± 0.90          | 0.69 ± 0.05               | 19.83 ± 1.13| 19.03 ± 1.53|
| Treatment F | 5.212 ± 4.59           | 59.095 ± 227.398         |

*Significant at p < 0.05 level of means within a column followed by same letters are not significantly (p < 0.05) different as determined by Duncan’s Multiple Range test.

***Significant F value at p < 0.001 level.
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