



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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NAAS Rating: 5.20
www.agronomyjournals.com
2025; 8(4): 30-36
Received: 08-02-2025
Accepted: 12-03-2025

Manish Kumar Vijay
ICFRE- Tropical Forest Research
Institute, Jabalpur, Madhya
Pradesh, India

Rathod Digvijaysinh.U
ICFRE- Tropical Forest Research
Institute, Jabalpur-482001,
Madhya Pradesh, India

Neelu singh
ICFRE- Tropical Forest Research
Institute, Jabalpur, Madhya
Pradesh, India

Shweta Tiwari
ICFRE- Tropical Forest Research
Institute, Jabalpur, Madhya
Pradesh, India

Lata Kahar
ICFRE- Tropical Forest Research
Institute, Jabalpur, Madhya
Pradesh, India

Deepandra Malviya
ICFRE- Tropical Forest Research
Institute, Jabalpur, Madhya
Pradesh, India

Mithun Aharwar
ICFRE- Tropical Forest Research
Institute, Jabalpur, Madhya
Pradesh, India

Corresponding Author:
Manish Kumar Vijay
ICFRE- Tropical Forest Research
Institute, Jabalpur, Madhya
Pradesh, India

Assessment of germination dynamics through maturity and pre-treatment studies in *Flacourtia indica* (burm.f.) Merr.

Manish Kumar Vijay, Rathod Digvijaysinh U, Neelu Singh, Shweta Tiwari, Lata Kahar, Deepandra Malviya and Mithun Aharwar

DOI: <https://www.doi.org/10.33545/2618060X.2025.v8.i4a.2738>

Abstract

This study investigates the germination dynamics of *Flacourtia indica* (Burm.f.) Merr., a medicinally and economically valuable wild edible fruit species native to Central India. The focus is on understanding the role of seed maturity and the effectiveness of various pre-treatment methods in improving germination. Seed germination in *Flacourtia indica* is often erratic due to seed dormancy and other physiological factors, presenting challenges for cultivation, propagation, and conservation. To address this, we assessed seed viability at different stages of maturity, from the initiation of fruit formation to natural dispersal, and tested various pre-treatments such as soaking, scarification, and hormonal applications. The results show that seeds harvested 80-90 days after anthesis exhibited optimal maturity, with the highest physiological quality and desiccation tolerance. An imbibition assay revealed that the seed coat does not inhibit water uptake in this species. However, the presence of a hard seed coat may restrict embryo expansion, which can negatively impact germination. Pre-treatments using gibberellic acid (GA3) at 500 PPM for 24 hours significantly enhanced germination rates, demonstrating the importance of hormonal stimulation in overcoming seed dormancy and improving seedling establishment. These findings provide valuable insights for developing effective propagation protocols for *Flacourtia indica*, a species with significant potential for reforestation and sustainable agroforestry systems. The use of optimized seed maturity and pre-treatment strategies will improve germination success, contributing to its conservation and large-scale cultivation. Future research should further explore the underlying seed dormancy mechanisms and the role of other growth regulators to enhance germination performance and facilitate the species' use in ecological restoration programs.

Keywords: Conservation, germination, maturity indices, seeds, seedlings

1. Introduction

In the pursuit of achieving Sustainable Development Goals (SDGs), particularly the eradication of hunger and malnutrition, marginal fruits have garnered attention for their potential contributions. These fruits, known for their nutritional richness, climate resilience, and resistance to various stresses, also serve as valuable sources of breeding material for crop improvement, making them essential to global food security. One such underutilized species is the Governor's Plum (*Flacourtia indica*), a tropical and subtropical fruit-bearing shrub or small tree from the Salicaceae family. This resilient plant, native to tropical regions, is prized not only for its tasty fruits but also for its diverse medicinal properties. Its various parts are utilized for therapeutic purposes, reinforcing its reputation as a "nature's pharmacy." *Flacourtia indica* is highly adaptable, thriving in a variety of environments including coastal areas, lowland dry and humid regions, and riverine habitats (Dunlop *et al.* 2005) ^[8]. It is commonly found in tropical dry deciduous and thorn forests, as well as in seasonally dry forests, woodlands, thickets, wooded grasslands, and riparian zones, at elevations ranging from sea level to 2400 meters (Orwa *et al.* 2009; PIER 2014) ^[18]. Its hardiness and ability to thrive in suboptimal conditions make it a promising crop for regions with limited agricultural resources. Its drought resistance and adaptability to tropical climates also make it ideal for home gardens and orchards. However, the species faces challenges in propagation, primarily due to poor seed germination

rates, often below 20%, and the absence of sustainable replenishment strategies (Prins & Maghembe 1994) [22]. Non-deep physiological dormancy (Gomez *et al.* 2019) [11], imposed by the hard endocarp, further complicates propagation efforts. Despite its potential, there is limited scientific literature on the seed biology of *Flacourtia indica*, particularly regarding seed maturity and germination dynamics.

This study seeks to bridge critical knowledge gaps by systematically investigating the criteria and indicators of seed maturity and germination parameters of *Flacourtia indica*. Employing both qualitative and quantitative methodologies, this research aims to provide a comprehensive understanding of the species' germination dynamics.

2. Materials and Methods

2.1 Study Area and Sample Collection

The study was carried out at Jabalpur, Madhya Pradesh, India, located between 21°17' to 26°52' N latitude and 74°08' to 82°49' E longitude. The region experiences a subtropical climate with hot summers (April-June), monsoon rains (July-September), and cool winters. Annual rainfall averages around 1,370 mm, with temperatures ranging from 10°C in winter to 48°C in summer. *Flacourtia indica*, naturally distributed in the region, was sampled from mature trees at various developmental stages after anthesis to evaluate seed maturity and germination.

2.2 Evaluation of Seed Maturity

Seed maturity was assessed using physical and physiological indicators. Observations were made from the start of flowering to fruit development, with seeds collected between 20 and 100 days after anthesis (DAA). The collected fruits were transported in cotton bags, and seeds were extracted through depulping. Evaluations included:

2.2.1 Dimensions: Fruits and seeds were measured for length and width using a digital caliper. Measurements were taken from three replicates of ten fruits and fifty seeds each.

2.2.2 Weight: Fresh and dry weights were recorded using an analytical balance. Fresh mass was determined from three replicates of ten fruits and fifty seeds. Dry mass was measured after drying at 80°C until constant weight was achieved. Data were scaled to represent 100 fruits and 1000 seeds.

2.2.3 Color: Fruit and seed color were recorded using the RHS color chart for 50 samples at each harvest stage.

2.2.4 Germination: Germination was tested by placing three replicates of 50 seeds each on filter paper in petri dishes at 30 ± 2°C with a 16/8 light/dark cycle (ISTA rules). Germination was assessed daily for 28 days, with seeds considered germinated if radicles reached at least 1 cm. The percentage of viable seeds was calculated, and desiccation sensitivity was also tested.

2.2.5 Vigour Index: Seed vigour was calculated as the product of the mean germination percentage and mean seedling length (Abdul-Baki & Anderson, 1973) [1].

2.3 Evaluation of Seed Germination behavior

Germination trials were conducted under controlled conditions to identify optimal pre-treatment methods and assess the role of the seed coat in inhibiting water uptake. The study utilized a completely randomized design with three replicates of 100 seeds each.

2.3.1 Imbibition assays: Seeds were weighed on an analytical balance and immersed in 50 mL of tap water in a beaker for 48 hours. At intervals of 1, 2, 4, 6, 8, 10, 12, 18, 24, and 30 hours, seeds were removed, blotted dry, reweighed, and returned to the water. This process continued until the seeds reached a constant

weight. Water absorption was estimated from the weight gain, with percentage increase in seed mass (Bewley & Black, 1982) [5] calculated using:

Seed mass increase (%) = $[(W_i - W_d) / W_d] \times 100$,

Where, W_i and W_d are the mass of imbibed and dry seeds, respectively.

2.3.2 Pre-treatment: Following pre-treatment methods were employed to find out the suitable pre-sowing treatments for enhancing seed germination (Table 1). Data on seed germination were recorded starting from seed germination till culmination and computed germination-related parameters. Germination-related parameters were determined as follows:

- First Day of Germination (FDG) (Kader, 1998)
 $FDG = D_g - D_s$
- Where, D_g = First germination day and D_s = Seed sowing day.
- Last Day of Germination (LDG) (Kader, 1998)
 $LDG = D_f - D_s$
- Where, D_f = Final germination day and D_s = Seed sowing day.
- Time Spread of Germination (TSG) (Kader, 1998)
 $TSG = LDG - FDG$
- Where, LDG = Last Day of Germination, FDG = First Day of Germination
- Final Germination Percentage (FGP) (Scott *et al.*, 1984)
 $FGP = G / T \times 100$
- Where G = No. of germinated seeds and T = No. of seeds sown
- 5 Mean germination time (MGT) (Orchard, 1977)
 $MGT = G_t \times D_t / G$
- Where G_t = No. of germinated seeds at day- t , D_t = No. of days at " t " from the day of sowing and G = Total no. of germinated seeds.
- Germination Rate Index (GRI) (Esechi, 1994)
 $GRI = G_1/1 + G_2/2 + \dots + G_x/x$
- Where, G_1 = Germination percentage $\times 100$ at the first day after sowing,
- G_2 = Germination percentage $\times 100$ at the second day after sowing
- Germination Index (GI) (Bench Arnolod *et al.* 1991)
 $GI = (10 \times n_1) + (9 \times n_2) + \dots + (1 \times n_{10})$
- Where, $n_1, n_2 \dots n_{10}$ = No. of germinated seeds on the first, second and subsequent days until the 10th day; 10, 9, ..., and 1 are weights given to the number of germinated seeds on the first, second and subsequent days, respectively
- Germination energy ISTA (2006)
 $GE = X_1 / Y_1 + X_2 / Y_2 + \dots + X_n / Y_n$
- Where X_n = No. of germinant on the n th counting date and Y_n = no. of days from sowing to the n th count.
- Speed of germination (SOG) (Czabator, F. J. 1962).
 $SOG = n_1/d_1 + n_2/d_2 + n_3/d_3 + \dots + n_n/d_n$
- Where, n = Number of germinated seeds, d = Number of days
- Seedling length (cm): Measured with the help of scale.
- Seedling vigour index $I = G\% \times \text{Seedling length (cm)}$ (Abdul-Baki, and Anderson 1973) [1].
- Mean daily germination (MDG) (Czabator, F. J. 1962).
 $MDG = GP / G_d$
- Where GP = Germination percentage and G_d = No. of days to complete germination.

2.4 Statistical Analysis

Data were analysed using ANOVA to test for significant differences in seed size, weight, moisture content, viability, and germination parameters between different developmental stages and pre-treatment methods. Post-hoc tests were conducted where applicable to identify specific differences between groups.

3. Results

3.1 Impact of maturity stages on quality parameters: The maturity assessment of *Flacourtia indica* results are discussed under the following head:

3.1.1 Changes in Fruit and Seed Size: The results of study presented in the Figure 1 showing the growth pattern of fruit and seed dimensions over time, measured in days after anthesis (DAA). The variables observed in the study were fruit length, fruit width, seed length, and seed width. The study observed the growth patterns of fruit and seeds over time. Fruit length (blue line) increased gradually, peaking at 2.13 cm at 90 days after anthesis (DAA), with a notable growth spurt between 70 and 90 DAA before slowing down, likely due to moisture loss and tissue disintegration from the fruit's pulpy nature. Similarly, fruit width (gray line) exhibited significant growth starting around 70 DAA, reaching its maximum at 90 DAA and slightly declining by 100 DAA, suggesting maturity. In contrast, seed length (solid red line) showed a steady increase throughout the period, with a plateau until 70 DAA, while seed width (yellow line) experienced minimal changes after attaining maximum at 40 DAA, reflecting a slower growth rate compared to fruit dimensions.

The graph highlights that both fruit and seed dimensions increase over time, with the most rapid growth in fruit size (length and width) occurring between 70 and 90 days after anthesis (DAA), driven by cell expansion and nutrient accumulation. After 90 DAA, a slight decrease in fruit width suggests the onset of maturation or ripening. Seed growth is steady but slower, without experiencing the same rapid growth phase as the fruit. Pairwise comparisons show significant differences between different stages for both seeds and fruits, emphasizing the contrast in growth dynamics.

3.1.2 Changes in Fresh and Dry Weight of Fruit and Seed

The data presented in the Figure 2 indicate changes in the fresh and dry weights of fruits (mean weight of 100 fruits) and seeds (mean weight of 1000 seeds) over time, measured in days after anthesis (DAA). The fresh weight of fruits (blue line) increased steadily from 20 days after anthesis (DAA), peaking at 83.85 g on 80 DAA before declining, likely due to water loss associated with maturation. In contrast, the fresh weight of seeds (gray line) followed a gradual increase that also peaked around 80 DAA, indicating growth and moisture accumulation. After 80 DAA, seed weight declined slightly, reflecting the onset of maturation. The dry weight of fruits (red line) steadily increased throughout the observation period, peaking around 80-90 DAA, indicating the accumulation of dry matter. Similarly, the dry weight of seeds (yellow line) showed a gradual increase over time, highlighting the ongoing accumulation of nutrients essential for seed development.

3.1.3 Changes in Fruit and Seed Color

The changes in fruit color are good indicator of fruit maturity. The fruit remains green from 20 to 60 DAA, then transitions to deep purplish-red at 70 DAA, darkening to red by 100 DAA, indicating ripening. Seeds are not visible at 20 DAA but begin as strong orange-yellow color at 30 DAA, shifting to light

yellowish-pink by 60 DAA and remaining stable through 100 DAA, signalling gradual seed maturation (Figure 3).

3.1.4 Seed Germination and vigour: The study analysed seed germination percentages at different developmental stages (Table 3). Fresh seeds showed no germination from 20 to 60 DAA, with only a low percentage (1.83 ± 3.18) at 70 DAA, marking the initial stage of mature seed production. Germination significantly increased at 80 DAA (20.42 ± 2.14) and peaked at 90 DAA (40.14 ± 3.28), indicating optimal seed maturity for collection. A similar trend was observed in desiccated seeds, with no germination at 20 to 60 DAA and a maximum germination percentage of 41.72 ± 3.10 at 90 DAA. After this peak, germination declined to 38.20 ± 2.46 , reinforcing that 90 DAA is the ideal time for both seed collection and storage. The significantly higher value of seedling vigour index was recorded at 90 DAA (279.90 ± 38.00). It indicated that seed collected at 90 DAA were able to produce healthy seedlings which are develop quickly and robustly.

The F-values for fresh seed germination, germination after desiccation, and seedling vigour index were 161.8253, 268.81, and 66.4932, respectively. The probability values (Pr (>F)) for all three parameters were less than 0.001 (denoted by ***), indicating that the differences in germination percentage and vigour index across different DAA are highly significant. Seeds show no germination until 70 DAA, suggesting they are not viable at earlier stages. Optimal seed maturity for germination and seedling vigour is observed around 80-90 DAA. The desiccation process appears to enhance germination percentages slightly compared to fresh seeds, especially at later stages of seed development. The data implies that harvesting seeds at around 80 to 90 DAA is ideal for achieving high germination rates and healthy seedlings.

3.2 Imbibition Assays: Figure 4 illustrates the changes in seed fresh weight (% increase) during various periods of imbibition time (in hours) for *Flacourtia indica* seeds, showing a consistent increase over a 30-hour period that indicates effective water uptake. The imbibition process follows a triphasic pattern. In the initial phase (0-8 hours), seed fresh weight increases steadily to approximately 50%, reflecting rapid water absorption as the seeds swell. During the steady rise phase (8-12 hours), fresh weight reaches about 55%, indicating continued active water uptake. After 12 hours, the rate of increase slows, leading to a plateau phase (12-30 hours) where fresh weight stabilizes at around 60% increase by 24 hours, suggesting that the seeds have reached their maximum water absorption capacity. This pattern indicates that imbibition is a rapid process initially, reaching saturation by 24 hours. The fresh weight percentage increase serves as a key indicator of water uptake, which is essential for initiating germination and supporting further developmental processes.

3.3 Impact of pre-treatment methods on seed quality parameters: Table 4 presents the effects of various pre-treatments on germination parameters of *Flacourtia indica* seeds. The first day of germination (FDG) was observed to start on day 4 for treatments T3, T5, T6, T7, T8, T9, and T12, significantly earlier than the control treatments (T0 and T1), which germinated on day 7. The last day of germination (LDG) was for T0 and T1 (18 days) and earliest for T4, T5, T9, T10, and T12 (10 days). Time spread of germination showed that T4, T10, and T12 had the shortest range (3.0-6.0 days), while T0 and T1 had the longest (11 days). The highest final germination percentage (FGP) was found in T9 (47.2%), while T4, T10, T11,

and T12 exhibited lower percentages (11-13%). Mean germination time (MGT) was shortest in T12 (7.7 days) and longest in T0 (10.1 days). The germination rate index (GRI) was highest in T9 (6.5/day) and lowest in T4 (1.4/day). The germination index (GI) also favored T9 (602.3), indicating rapid and consistent germination, while T4 and T11 had lower GIs (136.8 and 142.7, respectively). Germination energy was highest in T9 (39.0), and seedling length measured longest in T9 (7.73 cm) compared to T7 (4.28 cm). The vigor index was also highest for T9 (399.93), suggesting strong seedling health, while T4 had the lowest vigour index (46.87).

The significant F-values and p-values ($<0.001^{***}$) indicate that all germination parameters were significantly affected by the pre-treatments. Pre-treatment T9 (Soaking in GA₃ 500 PPM for 24 hr) was the most effective, showing the highest germination rate, vigor, and fastest mean germination time, thereby enhancing both the rate and success of germination. In contrast, treatments T4, T10, and T12, resulted in lower germination percentages, indicating less successful germination. Overall, T9 promoted robust germination and early seedling growth in *Flacourtia indica*. These findings emphasize the importance of selecting appropriate pre-treatments to optimize germination and seedling quality in *Flacourtia indica*.

4. Discussion

The maturity assessment of *Flacourtia indica* is critical for determining the optimal harvesting stage of its fruits, which directly impacts seed germination and seedling quality. This knowledge can significantly save time and costs for tree nursery growers by identifying the ideal maturity stage to collect fruits before they fall and deteriorate. As seen in the data, the transition from green to red and eventually dark red in fruit color serves as a reliable visual indicator of maturation. The findings show that both fruit and seed size and weight increase significantly over time, peaking around 80-90 days after anthesis (DAA). This period corresponds with the highest fresh and dry

weights, alongside a notable decrease in moisture content, suggesting that seeds collected during this window are most viable for propagation.

In the growth phase (20-80 DAA), substantial increases in fresh weight of both fruits and seeds indicate active growth and water uptake, accompanied by increases in dry weight, reflecting the accumulation of essential dry matter. The maturation phase (80-100 DAA) marks a shift, as fresh weight declines due to moisture loss while dry weight stabilizes, indicating hardening and maturation of the seeds and fruits. This pattern aligns with typical fruit and seed development cycles, highlighting the importance of proper timing for harvesting (Adams-Phillips *et al.* 2004; Giovannoni 2001; Pott *et al.* 2019; Kasunmala *et al.* 2019; Attallah *et al.* 2022) [12].

The study's results indicate that seed germination rates significantly improve after drying, particularly for seeds harvested at 90 DAA, which exhibited germination rates exceeding 40% after desiccation. This emphasizes the critical importance of timing in harvesting *Flacourtia indica* seeds to ensure maximum viability and successful propagation. Similar observations have been reported in other species within the *Flacourtia* genus, underscoring the relevance of these findings across different contexts (Orwa *et al.* 2009; PROTA 2014; Kumar 2003; Gomez *et al.* 2019) [18].

Pre-treatment methods significantly influenced germination rates, with soaking in GA₃ at 500 PPM for 24 hours (T9) demonstrating remarkable efficacy. This treatment yielded the highest final germination percentage, seedling vigour, and overall germination performance, corroborating findings from previous studies on the *Flacourtia* genus (Janick and Paull 2008; Orwa *et al.* 2009; Gomez *et al.* 2019) [12]. Treatments involving KNO₃ (T7) and thiourea (T6) also showed improved metrics compared to controls, while mechanical scarification (T5) and soaking in water (T1, T2) yielded positive but lesser effects. Conversely, treatments involving H₂SO₄ were generally less effective, indicating their unsuitability for *Flacourtia indica*.

Table 1: List of Seed Pre-treatments

Treatment	Code
Control	T0
Cold water soaking (24 hr)	T1
Cold water soaking (48 hr)	T2
Incubation at 50 °c for 24 h in water	T3
Scarification using h ₂ so ₄ for 2 min followed by 24 hrs water soaking	T4
Mechanical scarification	T5
Soaking in 0.5 % thiourea for 24 hrs	T6
Soaking in 0.5% kno ₃ for 24 hrs	T7
Soaking in GA ₃ 250 ppm for 24 hrs	T8
Soaking in GA ₃ 500 ppm for 24 hrs	T9
Soak in H ₂ SO ₄ 2 min + ga ₃ 500 ppm for 24 hrs	T10
Soak in H ₂ SO ₄ 2 min + 0.5 % thiourea for 24 hrs	T11
Soak in H ₂ SO ₄ 2 min + 0.5% kno ₃ for 24 hrs	T12

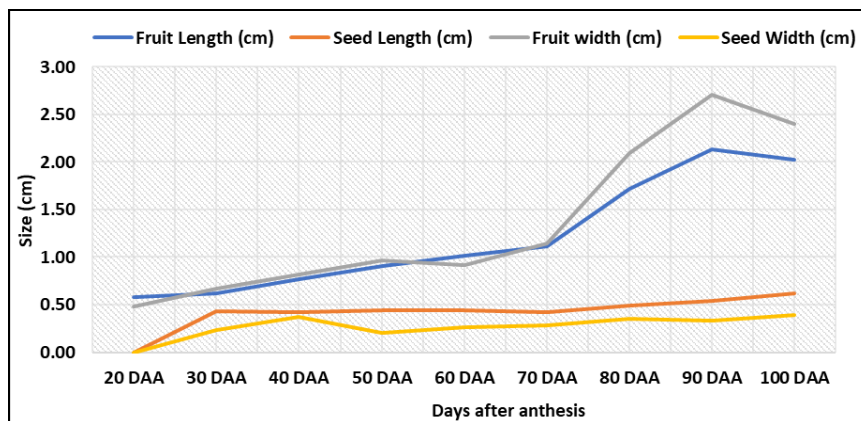


Fig 1: Changes in the fruit and seed dimension with maturity (Days after anthesis)

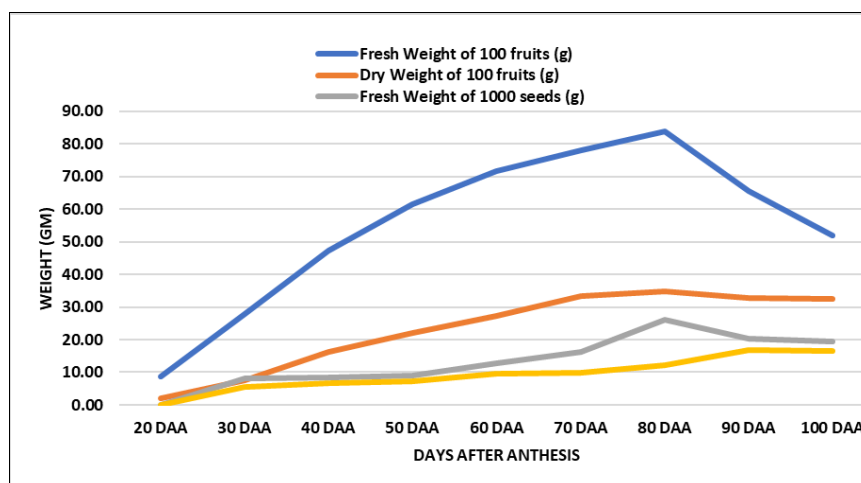


Fig 2: Changes in the fruit and seed weight with maturity (Days after anthesis)



Fig 3: Fruits of *Flacourtia indica* at different Maturity stages

Table 2: Changes in the Fruit and Seed colour with maturity

Days After Anthesis	Fruit colour	Seed colour
20 DAA	Green Group 143 (Yellow Green A)	Nil
30 DAA	Green Group 143 (Yellow Green A)	Yellow Orange Group 22 (Strong Orange Yellow Colour A)
40 DAA	Green Group 143 (Yellow Green A)	Yellow Orange Group 22 (Strong Orange Yellow Colour A)
50 DAA	Green Group 143 (Yellow Green A)	Yellow Orange Group 22 (Strong Orange Yellow Colour A)
60 DAA	Green Group 143 (Yellow Green A)	Yellow Orange Group 19 (Light Yellowish Pink B)
70 DAA	Red Purple Group 59 (Deep Purplish Red B)	Yellow Orange Group 19 (Light Yellowish Pink B)
80 DAA	Red Purple Group 59 (Deep Purplish Red B)	Yellow Orange Group 19 (Light Yellowish Pink B)
90 DAA	Red Purple Group 59 (Deep Purplish Red B)	Yellow Orange Group 19 (Light Yellowish Pink B)
100 DAA	Red Purple Group 59 (Dark Red A)	Yellow Orange Group 19 (Light Yellowish Pink B)

Table 3: Variation in fresh seed and desiccated seed germination percentage and seed vigour Index (SVI) with maturity

Days After Anthesis	Germination (%)		SVI
	Fresh Seed	Desiccated Seed (5.28% moisture content)	
20 DAA	0.00	0.00	0.00
30 DAA	0.00	0.00	0.00
40 DAA	0.00	0.00	0.00
50 DAA	0.00	0.00	0.00
60 DAA	0.00	0.00	0.00
70 DAA	1.83±3.18	2.35±2.26	36.19±62.69
80 DAA	20.42±2.14	26.04±3.41	245.87±25.48
90 DAA	40.14±3.28	41.72±3.10	279.90±38.00
100 DAA	36.86±4.74	38.20±2.46	250.05±23.31
F Value	161.8253	268.81	66.4932
Pr (>F)	<.001***	<.001***	<.001***

Table 4: Effects of different pre-treatments on germination parameters in *Flacourtia indica*

Treatments	First Day of Germination (FDG) Days	Last Day of Germination (LDG) Days	Time Spread of Germination (days)	Final Germination Percentage (FGP) (%)	Mean Germination Time (MGT) Days	Mean Germination Time (MGT) Days	Germination Rate Index (GRI) %/day	Germination Index (GI)	Germination energy	Speed of germination	Mean Daily Germination	Seedling length (cm)	Vigour index I
T0	7.0±0.0	18.0±0.0	11.0±0.0	28.8±2.7	10.1±0.1	10.1±0.1	3.1±0.2	300.3±26.0	26.6±2.5	3.07±0.21	1.63±0.2	5.23±0.3	150.03±6.43
T1	7.0±0.0	18.0±0.0	11.0±0.0	31.4±1.0	9.9±0.1	9.9±0.1	3.4±0.2	335.1±12.5	29.0±1.0	3.40±0.17	1.73±0.1	5.50±0.4	172.73±17.14
T2	6.0±1.7	14.0±0.0	8.0±1.7	31.2±5.1	9.1±0.2	9.1±0.2	3.7±0.5	360.1±51.5	28.3±5.0	3.67±0.47	2.20±0.4	5.57±0.4	186.87±31.91
T3	4.0±0.0	11.3±2.3	7.3±2.3	17.1±2.8	7.8±0.2	7.8±0.2	2.4±0.4	222.3±33.7	13.4±2.3	2.43±0.35	1.57±0.4	5.48±0.5	106.07±15.70
T4	7.0±0.0	10.0±0.0	3.0±0.0	11.0±0.5	8.1±0.3	8.1±0.3	1.4±0.1	136.8±5.3	10.0±0.5	1.37±0.06	1.10±0.0	5.00±0.2	46.87±8.28
T5	4.0±0.0	10.0±0.0	6.0±0.0	26.4±4.3	7.9±0.2	7.9±0.2	3.6±0.5	337.8±46.5	21.8±4.5	3.60±0.46	2.67±0.4	6.00±0.3	135.37±29.75
T6	4.0±0.0	12.7±2.3	8.7±2.3	31.8±2.1	8.4±0.3	8.4±0.3	4.1±0.4	391.5±31.4	27.3±1.5	4.13±0.40	2.57±0.3	6.21±0.3	245.90±25.46
T7	4.0±0.0	14.0±0.0	10.0±0.0	35.3±2.3	8.0±0.1	8.0±0.1	4.9±0.4	454.9±29.7	28.3±1.5	4.93±0.35	2.53±0.2	4.28±0.8	279.90±38.02
T8	4.0±0.0	14.0±0.0	10.0±0.0	30.6±1.7	8.9±0.3	8.9±0.3	3.9±0.3	362.7±27.0	25.9±1.6	3.87±0.29	2.17±0.1	5.10±0.3	250.07±23.32
T9	4.0±0.0	10.0±0.0	6.0±0.0	47.2±2.3	7.9±0.2	7.9±0.2	6.5±0.5	602.3±40.0	39.0±1.3	6.47±0.47	4.73±0.2	7.73±0.3	399.93±37.95
T10	5.0±1.7	10.0±0.0	5.0±1.7	13.6±1.7	7.9±0.5	7.9±0.5	1.9±0.4	173.9±30.4	11.6±0.8	1.87±0.38	1.40±0.2	7.90±0.6	75.97±13.80
T11	5.0±1.7	11.3±2.3	6.3±0.6	11.7±0.6	8.4±0.6	8.4±0.6	1.5±0.2	142.7±14.0	10.1±0.1	1.50±0.17	1.07±0.2	8.17±0.3	63.77±4.81
T12	4.0±0.0	10.0±0.0	6.0±0.0	11.0±1.6	7.7±0.2	7.7±0.2	1.6±0.2	144.3±21.1	9.0±1.5	1.57±0.21	1.13±0.2	8.47±0.4	54.77±6.25
F Value	7.22	20.56	13.99	59.59	25.31	25.31	60.13	59.75	52.18	60.13	50.05	33.1344	62.0909
Pr (>F)	<.001***	<.001***	<.001***	<.001***	<.001***	<.001***	<.001***	<.001***	<.001***	<.001***	<.001***	<.001***	<.001***

5. Conclusion

The study highlights the critical importance of maturation timing and pre-treatment methods in enhancing the germination and vigour of *Flacourtia indica* seeds. Seeds collected at 80-90 DAA demonstrated optimal maturity, physiological quality, and desiccation tolerance. Pre-treatments involving in GA₃ at 500 PPM for 24 hours significantly improved germination performance, making them recommended practices for *Flacourtia indica* seed propagation and conservation efforts. This information is vital for conservation efforts and can significantly improve propagation practices in nursery settings, thereby supporting sustainable management of this valuable species.

6. Conflict of interest

The authors declare no conflicts of interest.

7. Acknowledgment

The present work is the outcome of an ongoing project focused on the conservation and sustainable management of wild edible fruiting species, generously sponsored by the CAMPA, Ministry of Environment, Forests & Climate Change, Government of India, New Delhi. We extend our sincere gratitude to this funding agency for their invaluable support.

8. References

- Abdul-Baki AA, Anderson JD. Vigor determination in soybean seed by multiple criteria. *Crop Sci.* 1973;13(6):630-3.
- Adams-Phillips L, Barry B, Giovannoni J. Signal transduction systems regulating fruit ripening. *Trends Plant Sci.* 2004;9(7):331-8. doi:10.1016/j.tplants.2004.05.004
- Attallah OMAK, Delgoda R, Benkeblia N. Profiling primary metabolites of Governor's Plum (*Flacourtia indica* (Burm.f.) Merr.) at two different ripe stages. *Trop Agric Sci.* 2022;46(1):1. doi:10.47836/pjtas.46.1.01
- Bench AR, Fenner M, Edwards P. Changes in germinability, ABA content, and ABA embryonic sensitivity in developing seeds of *Sorghum bicolor* (L.) Moench induced by water stress during grain filling. *New Phytol.* 1991;118:339-47.
- Bewley JD, Black M. Physiology and biochemistry of seeds in relation to germination. Vol. 2: Viability, dormancy and environmental control. Berlin: Springer-Verlag; 1982.
- Czabator FJ. Germination value: An index combining speed and completeness of pine seed germination. *For Sci.* 1962;8:386-95.
- Dathan AK, Singh D. Structure and development of ovule and seed in *Flacourtia indica* (Burn. F.) Merrill. *Proc Indian Natl Sci Acad B.* 1973;39:172-9.
- Dunlop E, Hardcastle J, Shah NJ. Cousin and Cousine Islands status and management of alien invasive species. 2005.
- Esechie H. Interaction of salinity and temperature on the germination of sorghum. *J Agron Crop Sci.* 1994;172:194-9.
- Giovannoni J. Molecular biology of fruit maturation and ripening. *Annu Rev Plant Biol.* 2001;52(1):725-49. doi:10.1146/annurev.arplant.52.1.725
- Gomez Barreiro P, Otieno V, Mattana E, Castillo Lorenzo E, Omondi W, Ulian T. Interaction of functional and environmental traits on seed germination of the multipurpose tree *Flacourtia indica*. *South Afr J Bot.* 2019;125:427-33. doi:10.1016/j.sajb.2019.08.013
- Janick J, Paull RE. The encyclopedia of fruit and nuts. Wallingford, UK: CABI International Publications; 2008.

13. Kader (Al-Mudaris) M. Notes on various parameters recording the speed of seed germination. *J Agric Trop Subtrop*. 1998;99:147-54.
14. Kader (Al-Mudaris) M, Omari M, Hattar B. Maximizing germination percentage and speed of four Australian indigenous tree species. *Dirasat Agric Sci*. 1998;25:157-69.
15. Kasunmala IGG, Navarathne SB, Wickramasinghe I. Antioxidant activity and physicochemical properties of *Flacourtia indica* (Uguressa) at different maturity stages. In: *Proceedings of the 4th International Research Symposium on Pure and Applied Sciences*; 2019; Kelaniya, Sri Lanka. Abstract No: BP-15.
16. Kumar CS, Naresh G, Sudheer V, Veldi N. A short review on therapeutic uses of *Couroupita guianensis* Aubl. *Int Res J Pharm Appl Sci*. 2011;1(1):105-8.
17. Orchard T. Estimating the parameters of plant seedling emergence. *Seed Sci Technol*. 1977;5:61-9.
18. Orwa C, Mutua A, Kindt R, Jamnadass R, Anthony S. Agroforest tree database: A tree reference and selection guide. *Res J Pharmacogn Phytochem*. 2009;9(1):7-10.
19. Pandey SK, Shukla RP. Regeneration strategy and plant diversity status in degraded sal forests. *Curr Sci*. 2001;81:951-62.
20. PIER. Pacific Islands Ecosystems at Risk. Honolulu, HI: HEAR, University of Hawaii; 2014 [cited 2025 Mar 17]. Available from: <http://www.hear.org/pier/index.html>
21. Pott DM, Osorio S, Vallarino JG. From central to specialized metabolism: An overview of some secondary compounds derived from the primary metabolism for their role in conferring nutritional and organoleptic characteristics to fruit. *Front Plant Sci*. 2019;10:835. doi:10.3389/fpls.2019.00835
22. Prins H, Maghembe JA. Germination studies on seed of fruit trees indigenous to Malawi. In: Maghembe JA, editor. Special Issue: Agroforestry research in the African miombo ecozone. *Proceedings of a regional conference held in Lilongwe, Malawi, 16–22 June 1991*. For *Ecol Manage*. 1994;64(2/3):111-25.
23. PROTA. PROTA4U web database. Grubben GJH, Denton OA, editors. Wageningen, Netherlands: Plant Resources of Tropical Africa; 2014 [cited 2025 Mar 17]. Available from: <http://www.prota4u.org/search.asp>
24. Scott S, Jones R, Williams W. Review of data analysis methods for seed germination. *Crop Sci*. 1984;24:1192-9.