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Seed germination of selected economically important indigenous fruit trees

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ABSTRACT. Indigenous fruit trees are important as they serve as food, nutrition, and income sources for local communities. However, out of more than 300 edible fruit-tree species in the country, only a few are cultivated commercially and considered economically important, and many are underutilized. Hence, this study aimed to determine effective pre-germination treatments for the germination of selected indigenous fruit trees, specifically *kalumpit* [*Terminalia microcarpa* (Decne.)], *tibig* [*Ficus nota* (Blanco) Merr], and *libas* [*Spondias pinnata* (L.f.) Kurz]. Seeds of these species were collected and subjected to 11 different pre-sowing treatments, which include acid treatment and hot water treatment at various concentrations, temperatures, and duration of exposure. All three (3) indigenous species generally achieved more than 50% germination involving HCl acid treatment. The highest germination percentage is observed for *Terminalia microcarpa* seeds soaked in 5% HCl solution, *Ficus nota* in seeds soaked in 10% HCl solution, and *Spondias pinnata* showed a 100% germination in treatments involving extreme conditions, such as higher acid concentrations, longer periods of soaking, and higher water temperature. Hot water treatment hastened germination (31, 46, and 50 days) for *Terminalia microcarpa*, while germination started for most treatments (9 and 13 days) for *Ficus nota* and *Spondias pinnata* (34, 39, and 46 days). Study results can be used as a reference in the mass propagation of these species for plantation and reforestation purposes.

Keywords: indigenous fruit trees, germination, acid treatment, hot water treatment, seed dormancy, tree propagation

INTRODUCTION

The Philippines, considered one of the richest countries in flora and fauna (Coronel, 2011; BMB, 2016), has underutilized most of its estimated 300 edible fruit tree species. Only 20 species are cultivated commercially and considered economically important (Rodeo, 2016). According to Wagan *et al*. (2009), local communities traditionally use underutilized species for food, fiber, animal fodder, oil, or medicine. These species have untapped potential uses for diversifying cropping systems, creating products with added value, preserving the environment, and reclaiming degraded lands. Indigenous fruit-bearing trees should be given importance since they can be grown commercially, and their fruits can be consumed raw and are suitable for processing (Miranda *et al*., 2018).

These fruit-bearing trees species include *kalumpit* [*Terminalia microcarpa* (Decne.)], *tibig* [*Ficus nota* (Blanco) Merr], and *libas* [*Spondias pinnata* (Linn. F.) Kurz]. These fruit trees were chosen because they are indigenous, widely distributed in the country, and underutilized in food processing. Moreover, their fruits are rich in nutrients and phytochemicals that can be used as good sources of natural food colorants, flavoring, and even as medicine (Santiago *et al*., 2007; Bora *et al*., 2014; Mapatac, 2015). Given this, there is a need to explore ways to mass-produce these species to maximize their potential.

T. microcarpa (Decne) is a semi-deciduous fruit-bearing tree species that bears an oval-shaped fruit that has a seed with a thick and hard seed coat (Fern, 2014a; Stuart, 2016). It has a short flowering period of only about 3–4 mo during the dry season (June–September) (Cacatian *et al*., 2013). A previous study for *T. microcarpa* yielded only 56% germination percentage (Coronel, 2002). *Ficus nota* is a shrub or tree with crooked stems that thrives in banks of streams and forests at low and medium altitudes (Fern, 2014b; Stuart, 2018). Its fruit (fig) is subglobose, glabrous, fleshy peduncle, green or brownish, turning yellow (Fernando *et al*., 2004). *S. pinnata*, a tropical fast-growing tree species, has a fleshy fruit, drupe with a finely flavored edible pulp, and yellowish; the seed is hard, ridged, and has a fibrous surface. Depulped fruits (stones/pods) are used for sowing and contain 1–3 viable seeds, and the flowering and fruiting season is from June to October and has only a 5–20% germination percentage (Florido & Cortiguerrra, 2003).

The germination for these species is found to be erratic, poor, and delayed due to their characteristics of thick seed coat that inhibits water absorption, type of seeds, and size. One factor affecting these species' germination is seed dormancy, commonly associated with protective covering, seed coats, or enclosed embryos. The primary basis for the treatments used in this study is the condition by which birds, bats, and mammals eat these fruit trees. As such, the seeds have passed through the digestive tracts, subjected to stomach acids and warm temperatures. Studies mimicking animal digestive practices (*i.e.*, in birds) have shown hydrochloric acid increased germination with little loss to viability (Goddard *et al*., 2009). Immersion of seeds in concentrated acid can disrupt and deteriorate the seed coat and expose the lumen of the macrosleids cells, thus permitting the absorption of water, nutrients, and oxygen for quicker germination (Levitt, 1974; Nikoleave, 1977; Cowlishaw & Dunbar, 2000). Additionally, a sudden dip of dry seeds in boiling or hot water may lead to the rapture of the seed coat tissues causing physiological changes and subsequent germination of the embryo (Agboola & Etejere, 1991; Agboola & Adedore, 1998; Sabongari, 2001).

The lack of adequate research on their cultivation limits the potential of these indigenous fruit trees for higher yield and utilization. Hence, this study tested selected pre-germination treatments to improve germination and to develop methods or techniques for mass cultivation through seeds of the three species. It is the overall goal that these techniques can be adopted in local nurseries to enhance the species' potential and utilization in local and foreign markets, as underutilized fruit trees can play an important role in the country's future food security.

METHODOLOGY

Location and duration of the study

The study was conducted at the Soils Laboratory (Soils Lab) and Forest-Agroforest Nursery Learning Laboratory (FANLL) of the Institute of Renewable Natural Resources, College of Forestry and Natural Resources, University of Baños (UPLB) from October 2021 to April 2022. The application of the pre-germination treatments was made in the Soils Lab, as the laboratory contains the necessary chemicals and equipment for the experiment, while the germination study was done at FANLL to achieve the necessary growing conditions for the seeds.

Seed sourcing and seed collection

The seeds of *T. microcarpa*, *F. nota*, and *S. pinnata* were acquired from various sources (**Table 1**). *T. microcarpa* seeds were from the Ecosystems Research and Development Bureau of the Department of Environment and Natural Resources (DENR-ERDB) and collected from a natural stand in Quezon Protected Landscape (QPL). *F. nota* seeds were sourced from the fruits that fell at the base of its trees within the UPLB campus. These fruits were preferred for their ripeness and seed maturity (**Figure 1**). Seeds were macerated, dried, and stored in an airtight container until pre-sowing treatments were started. *S. pinnata* seeds were from Mindanao suppliers, as the study's timing did not coincide with its fruiting season in Luzon.

Table 1. Seed location and sources of the seeds used in the study.

Seed	Seed source	Location of seed collection
Kalumpit	DENR-ERDB	Quezon Protected Landscape
Tibig	Direct collection	University of the Philippines Los Baños (lower campus)
Libas	Seed supplier	Agusan del Sur

Figure 1. Collected *Ficus nota* fruit before and after seed extraction. The yellowish-brown color indicates fruit maturity.

Seed characterization

The fruits of *T. microcarpa* are arranged on an unbranched axis, 11–14 mm long, red in color, not shiny, fleshy, simple, indehiscent, and drupe. Seeds are about 10 mm long, not winged, broad (as wide as long), 1–10 mm in diameter, are very hard and stony. It flowers during summer, and fruits ripen around May to June. *F. nota* fruits (fig) are subglobose, glabrous, fleshy peduncle, green or brownish, turning yellow when ripe. The seeds, when dried, feel like loose sands. It flowers throughout the year. *S. pinnata* has a fleshy drupe fruit, ovoid or oblong, 30–50 mm long, yellow depulped fruits (stone) is semi-woody, surrounded by longitudinal interwoven fibers and pitted with a cavity that contains 1–3 viable seeds, but only one is perfect (**Figure 2**). Flowering and fruiting occur from June to October.

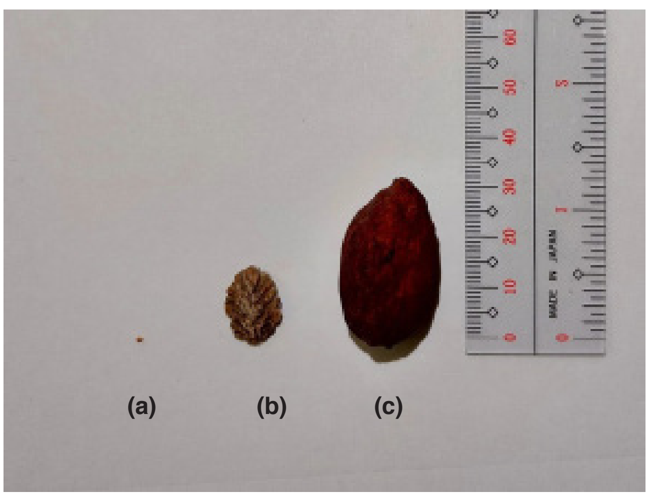


Figure 2. (a) *Ficus nota*, (b) *Terminalia microcarpa*, and (c) *Spondias pinnata* seeds (from left to right) used in the study.

Seed pre-sowing treatments and experimental materials

The seeds were subjected to 10 treatments except for *F. nota*; with 11 treatments (**Table 2**). For each treatment, 50 seeds were used and replicated three times (except for *S. pinnata* where 20 seeds were used due to limited quantity). Also, 1,500 seeds were used for *T. microcarpa* (50 seeds x 10 treatments x 3 replicates), 1,650 seeds for *F. nota* (50 seeds x 11 treatments x 3 replicates), and 600 seeds for *S. pinnata* (20 seeds x 10 treatments x 3 replicates). Treatment 2 (T2), which involves soaking in 1% HCl solution for 1 min, was applied *F. nota* seeds due to their very small size. Additional treatment with a lower HCl concentration was applied.

Table 2. The different pre-germination treatments tested for improving the germination of *T. microcarpa*, *F. nota*, and *S. pinnata*.

Code	Description
T1	Control
T2	Soaked in 1% HCl solution for 1 min
T3	Soaked in 3% HCl solution for 1 min
T4	Soaked in 5% HCl solution for 1 min
T5	Soaked in 10% HCl solution for 1 min
T6	Soaked in 50°C water for 30 sec
T7	Soaked in 50°C water for 1 min
T8	Soaked in 50°C water for 3 min
T9	Soaked in 75°C water for 30 sec
T10	Soaked in 75°C water for 1 min
T11	Soaked in 75°C water for 3 min

For each seed, the quality was visually checked. Rotten, damaged, or otherwise infected seeds were discarded. Seeds were soaked in a wire mesh and dipped in a beaker containing the treatment (**Figure 3**). For T2 to T5, hydrochloric acid (HCl) was prepared using laboratory-grade pure HCl. While the water temperature for T7 to T11 was set through a thermometer placed in cooling boiled water (**Figure 4**). The seeds were then rinsed thoroughly with distilled water to remove any residues that could damage the seeds, especially the embryo.

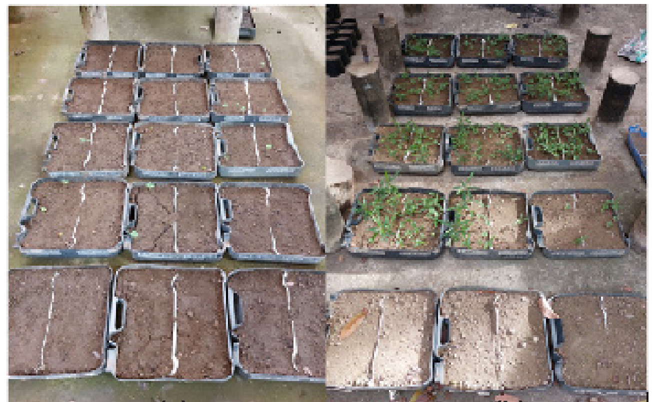
Figure 3. *Terminalia microcarpa* seeds soaked in varying concentrations of HCL acid for 1 min.

After applying the pre-germination treatments, the seeds were directly sowed in a germination box (40 cm x 35 cm x 8 cm) with sterilized garden soil with spacing and depth of approximately 0.5–1 cm covered with a thin layer of soil (**Figure 5**). The germination boxes were divided depending on the seeds' sizes, as the boxes' quantity was limited. Fifteen germination boxes (2 observational units per 1 germination box)

Figure 4. *Spondias pinnata* seeds subjected to hot water treatment monitored using a thermometer.

were used for the experimental units *T. microcarpa* (**Figure 6**) and *S. pinnata*, and 5 ½ germination boxes (6 observational units per 1 germination box) for *F. nota*. The germination setup of the three species was placed under shade in the nursery and was monitored and observed daily. Watering was done twice or thrice a week to ensure that the soil was moist, and weeds were manually uprooted from time to time. A seed was considered germinated when the cotyledons had emerged above the soil surface and were recorded.

Figure 5. Germination box used in the study.



(a) (b)

Figure 6. *Terminalia microcarpa* germination setup at days (a) 57 and (b) 132.

Data analysis

All data were subjected to Analysis of Variance (ANOVA) for Completely Randomized Design (CRD) and Tukey's Honest Significant Difference Test at a 95% confidence interval ($P<0.05$) using the Microsoft Excel Software. For analysis, germination percentage (GP) and cumulative germination percentage (CGP) were calculated and compared across all treatments. Germination percentage was determined by the number of germinated seeds (SNG) over the total number of sowed seeds (SN0) multiplied by 100 (Scott *et al*. 1984), and cumulative germination percentage by adding the germination percentage per day since sowing (Djavanshir & Pourbeik, 1976).

Germination Percentage (GP) = SNG/SN0 x 100 (1)

RESULTS AND DISCUSSION

The three species showed different reactions to the pre-sowing treatments (acid and hot water) applied to break seed dormancy and induce germination.

Terminalia microcarpa

After 180 days of observation, the seeds soaked in 5% HCl solution for 1 min (T4) gave the highest germination percentage at 51.33%. The results were relatively low compared to the 56% germination of *T. microcarpa* seeds by Coronel (2002), wherein a decrease of 8.70% was observed. The three treatments that yielded the highest germination percentage were T4 (51.33%), T5 (47.33%), and T8 (44.67%). Although T4 gave the highest germination percentage, it was not significantly different (α =0.05) from T5, and T8, with a mean difference of 4, and 6.66, respectively, based on Tukey's HSD test. The Tukey critical value computed at 180 days was 13.06; thus, only those with a higher treatment mean difference than the critical value were considered significant (**Table 3**).

The controlled seeds (T1) germinated only about 35.33% after observation, which was 36.93% lower than the study's highest percent germination (51.33%). Similar findings where poor germination of untreated seeds was also reported in *Terminalia sericea* (Likoswe *et al*., 2008) and *Terminalia chebula* (Saleem *et al*., 2014). These can be attributed to the hard seed coats of the *Terminalia* species (Likoswe *et al*., 2008).

The fastest germination based on the cumulative daily germination of *T. microcarpa* was observed in seeds soaked in 50°C hot water for 30 seconds (T6) at 31 days, while the slowest germination was observed on seeds soaked in 75°C hot water for 30 seconds (T9) at 100 days. Seeds soaked in water with higher temperatures (T9, T10, and T11) had the lowest (7.33%), slowest, and no germination after 180 days (**Table 4**; **Figure 7**). The results showed a longer germination period and lower germination percentage compared with the previous study by Coronel (2002). It seemed that

Table 3. Presentation of Tukey's test results for the germination of *Terminalia microcarpa* at 180 days.

	Experimental group									
	T1	T3	T4	T5	T6	T7	T8	T9	T10	T11
	35.33	36.00	51.33	47.33	40.00	42.67	44.67	7.33	0	0
M_{T1} = 35.33	0	0.67^{ns}	16.00^{s}	12.00^{s}	4.67^{ns}	7.34^{ns}	9.34^{s}	28.00^{s}	35.33^{s}	35.33^{s}
M_{T3} = 36.00		0	15.33^{s}	11.33^{s}	4.00^{ns}	6.67^{ns}	8.67^{ns}	28.67^{s}	36.00^{s}	36.00^{s}
M_{T4} = 51.33			0	4.00^{ns}	11.33^{s}	8.66^{ns}	6.66^{ns}	44.00^{s}	51.33^{s}	51.33^{s}
M_{T5} = 47.33				0	7.33^{ns}	4.66^{ns}	2.66^{ns}	40.00^{s}	47.33^{s}	47.33^{s}
M_{T6} = 40.00					0	2.67^{ns}	4.67^{ns}	32.67^{s}	40.00^{s}	40.00^{s}
M_{T7} = 42.67						0	2.00^{ns}	35.34^{s}	42.67^{s}	42.67^{s}
M_{T8} = 44.67							0	37.34^{s}	44.67^{s}	44.67^{s}
M_{T9} = 7.33								0	7.33^{ns}	7.33^{ns}
M_{T10} = 0									0	0
M_{T11} = 0										0

**ns = not significant, s = significant at p<0.05*
**Absolute values of the treatment mean differences were computed and compared with the Tukey critical value of 13.06 at α = 0.05.*

Table 4. Germination percentage of *Terminalia microcarpa* seeds as a result of various pre-sowing treatments.

Treatment	Onset of germination (Day)	Percent germination (%)									
		45 days	60 days	75 days	90 days	105 days	120 days	135 days	150 days	165 days	180 days
T1 (Control)	97	0	0	0	0	7.33 ± 9.24	23.33 ± 16.17	28.67 ± 15.53	32.00 ± 14.00	34.67 ± 13.31	35.33 ± 14.47
T3 (HCl3%)	57	0	0.67 ± 1.15	2.00 ± 2.00	2.00 ± 2.00	5.33 ± 4.62	22.67 ± 7.57	31.33 ± 6.43	33.33 ± 9.02	34.67 ± 9.45	36.00 ± 10.39
T4 (HCl5%)	62	0	0	0.67 ± 1.15	0.67 ± 1.15	1.33 ± 1.15	30.00 ± 3.46	40.67 ± 6.43	46.67 ± 6.11	51.33 ± 8.08	51.33 ± 8.08
T5 (HCl10%)	45	0.67 ± 1.15	2.67 ± 3.06	5.33 ± 4.62	5.33 ± 4.62	8.00 ± 5.29	38.67 ± 8.08	42.00 ± 12.00	44.67 ± 12.06	46.00 ± 12.49	47.33 ± 13.32
T6 (50'30s)	31	0.67 ± 1.15	1.33 ± 1.15	2.00 ± 0.00	2.67 ± 1.15	7.33 ± 2.31	26.67 ± 9.24	34.00 ± 9.17	38.00 ± 6.93	40.00 ± 5.29	40.00 ± 5.29
T7 (50'1m)	48	0	2.67 ± 1.15	3.33 ± 1.15	3.33 ± 1.15	6.67 ± 3.06	28.67 ± 7.02	37.33 ± 7.02	40.00 ± 5.29	42.00 ± 3.46	42.67 ± 4.16
T8 (50'3m)	50	0	3.33 ± 3.06	4.00 ± 4.00	4.00 ± 4.00	6.67 ± 3.06	27.33 ± 3.06	37.33 ± 8.08	41.33 ± 6.11	43.33 ± 6.11	44.67 ± 8.33
T9 (75'30s)	100	0	0	0	0	0.67 ± 1.15	4.00 ± 2.00	4.67 ± 3.06	6.00 ± 3.46	6.67 ± 3.06	7.33 ± 2.31
T10 (75'1m)	0	0	0	0	0	0	0	0	0	0	0
T11 (75'3m)	0	0	0	0	0	0	0	0	0	0	0
CV		387.30	141.14	121.02	118.29	92.69	36.63	32.12	27.13	25.38	27.07

**± indicates the standard deviation of means.*

soaking the seeds in acid concentrations is favorable to breaking the seed coat and inducing germination of *T. microcarpa*, and soaking at a higher temperature was contrary since there was no germination recorded at 1 min and 3 min of soaking at 75°C.

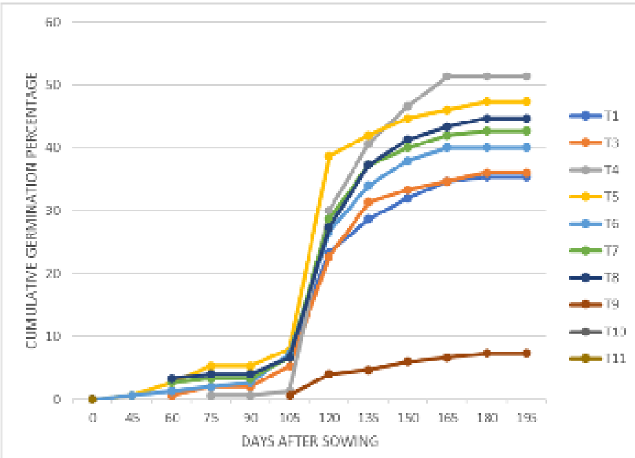


Figure 7. Cumulative germination percentage of *Terminalia microcarpa* seeds.

Ficus nota

The highest germination percentage for *F. nota* seeds was observed in the seeds soaked in 10% HCl solution for 1 min (T5) at 54.67% germination (**Figure 8**). A difference of 122% germination compared with the controlled treatment, with only 24.67% germination. This contrasts with Lucero (1994), which concluded that *F. nota* seeds have better germination without any pre-germination treatments. T5 was the most significant treatment based on Tukey's test at α =0.05 level after 120 days (**Table 5**), exceeding the computed Tukey critical value of 14.64 with all other treatment mean differences.

Figure 8. *Ficus nota* germination setup at day 100 after sowing.

Ficus seeds are dispersed internally by frugivores (Traveset *et al*., 2007). When birds ingest the seeds, it introduces them to corrosive digestive acids and enzymes such as hydrochloric acid which may alter the seed coat and subsequently, germination. Studies mimicking animal digestive practices (*i.e.*, in birds) have shown HCl increased germination with little loss to viability (Goddard *et al*., 2009). Seed germination started 9 days after sowing for most treatments and 13 days for the treatments involving higher temperatures (T9 and T10). This is also in contrast to the study of Fernando (2004), which showed that *F. nota* seeds germinate within 5–7 days after sowing.

Seeds soaked in water with high temperatures (50°C and 75°C – T6, T7, T8, T9, T10, and T11) showed a decreasing germination percentage pattern; the higher the temperature and the longer it is soaked, the lower its germination percentage. Results suggest that the embryo may likely get damaged upon contact with hot or boiling water for a prolonged period (Abubakar & Maimuna, 2013) (**Table 6**; **Figure 9**).

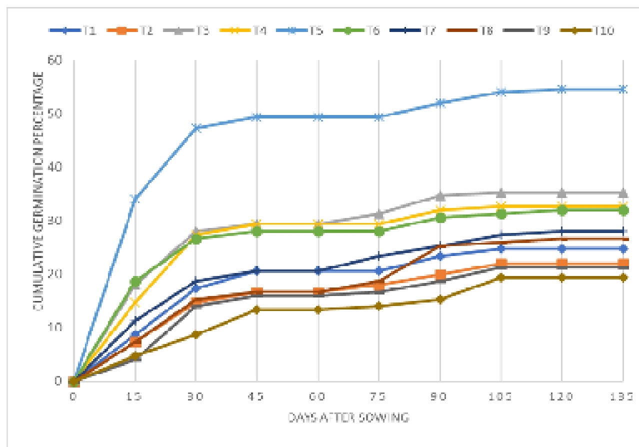


Figure 9. Cumulative germination percentage of *Ficus nota* seeds.

Spondias pinnata

Seeds subjected to treatments involving the longer duration of soaking in either high-water temperature or acid concentration such as T11 - seed soaked in 75°C water for 3 min, T8 – seeds soaked in 50°C water for 3 min, and T5 – seeds soaked in 10% HCl solution for 1 min yielded a perfect germination percentage after 120 days. However, they do not differ significantly within and among other treatments except for T10 according to Tukey's HSD tests at α =0.05 level, as the computed Tukey critical value was 8.31 (**Table 7**).

Table 5. Presentation of Tukey's test results for the germination of *Ficus nota* at 120 days.

	Experimental group										
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
	24.67	22.00	35.33	32.67	54.67	32.00	28.00	26.67	21.33	19.33	0
M_{T1} = 24.67	0	2.67^{ns}	10.67^{ns}	8.00^{ns}	30.00^{s}	7.33^{ns}	3.33^{ns}	2.00^{ns}	3.33^{ns}	5.33^{ns}	24.67^{s}
M_{T2} = 22.00		0	13.33^{ns}	10.67^{ns}	32.67^{s}	10.00^{ns}	6.00^{ns}	4.67^{ns}	0.67^{ns}	2.67^{ns}	22.00^{s}
M_{T3} = 35.33			0	2.67^{ns}	19.33^{s}	3.33^{ns}	7.33^{ns}	8.67^{ns}	14.00^{ns}	16.00^{s}	35.33^{s}
M_{T4} = 32.67				0	22.00^{s}	0.67^{ns}	4.67^{ns}	6.00^{ns}	11.33^{ns}	13.33^{ns}	32.67^{s}
M_{T5} = 54.67					0	22. 67^{s}	26. 67^{s}	28.00^{s}	33.33^{s}	35.33^{s}	54.67^{s}
M_{T6} = 32.00						0	4.00^{ns}	5. 33^{ns}	10.67^{ns}	12.67^{ns}	32.00^{s}
M_{T7} = 28.00							0	1.33^{ns}	6.67^{ns}	8.67^{ns}	28.00^{s}
M_{T8} = 26.67								0	5.33^{ns}	7.33^{ns}	26.67^{s}
M_{T9} = 21.33									0	2.00^{ns}	21.33^{s}
M_{T10} = 19.33										0	19.33^{s}
M_{T11} = 0											0

**ns = not significant, s = significant at p<0.05*
***Absolute values of the treatment mean differences were computed and compared with the Tukey critical value of 14.64 at α =0.05.*

Table 6. Germination percentage of *Ficus nota* seeds as a result of various pre-sowing treatments.

Treatment	Onset of germination (Day)	Percent germination (%)							
		15 days	30 days	45 days	60 days	75 days	90 days	105 days	120 days
T1 (Control)	9	8.67 ± 9.87	17.33 ± 14.05	20.67 ± 14.19	20.67 ± 14.19	20.67 ± 14.19	23.33 ± 13.32	24.67 ± 11.72	24.67 ± 11.72
T2 (HCL1%)	9	7.33 ± 1.15	14.67 ± 4.16	16.67 ± 6.11	16.67 ± 6.11	18.00 ± 4.00	20.00 ± 3.46	22.00 ± 2.00	22.00 ± 2.00
T3 (HCl3%)	9	18.00 ± 2.00	28.00 ± 0.00	29.33 ± 2.31	29.33 ± 2.31	31.33 ± 4.16	34.67 ± 3.06	35.33 ± 4.16	35.33 ± 4.16
T4 (HCl5%)	9	14.67 ± 6.11	27.33 ± 3.06	29.33 ± 3.06	29.33 ± 3.06	29.33 ± 3.06	32.00 ± 4.00	32.67 ± 5.03	32.67 ± 5.04
T5 (HCl10%)	9	34.00 ± 8.72	47.33 ± 15.28	49.33 ± 17.24	49.33 ± 17.24	49.33 ± 17.24	52.00 ± 19.08	54.00 ± 19.08	54.67 ± 20.03
T6 (50'30s)	9	18.67 ± 9.45	26.67 ± 11.02	28.00 ± 12.49	28.00 ± 12.49	28.00 ± 12.49	30.67 ± 9.45	31.33 ± 8.33	32.00 ± 8.72
T7 (50'1m)	9	11.33 ± 1.15	18.67 ± 4.16	20.67 ± 6.11	20.67 ± 6.11	23.33 ± 9.02	25.33 ± 10.26	27.33 ± 10.26	28.00 ± 11.14
T8 (50'3m)	9	7.33 ± 6.11	15.33 ± 7.02	16.67 ± 7.02	16.67 ± 7.02	18.67 ± 8.33	25.33 ± 8.08	26.00 ± 7.21	26.67 ± 7.02
T9 (75'30s)	13	4.00 ± 4.00	14.00 ± 8.72	16.00 ± 8.72	16.00 ± 8.72	16.67 ± 9.87	18.67 ± 9.02	21.33 ± 8.08	21.33 ± 8.08
T10 (75'1m)	13	4.67 ± 1.15	8.67 ± 1.15	13.33 ± 4.16	13.33 ± 4.16	14.00 ± 3.46	15.33 ± 4.16	19.33 ± 4.62	19.33 ± 4.62
T11 (75'3m)	0	0	0	0	0	0	0	0	0
CV		46.72	39.00	39.23	39.23	39.24	34.91	31.57	32.35

**± indicates the standard deviation of means.*

Depulped *S. pinnata* fruit contains 2–5 viable seeds (Singh *et al*., 2003), which is likely the reason for having high seed germination percentage for all the treatments applied since one sowed pod/stone germinated up to four seedlings (**Figure 10**). The fastest treatment that induced germination within the seeds was observed in T3 (seeds soaked in 3% HCl solution for 1 min) at 34 days, while the slowest was in T9 and T11, both at 56 days. However, T11 was the fastest to reach 100% germination within 75 days after sowing (**Table 8**; **Figure 11**; **Figure 12**).

The results indicate that *S. pinnata* seeds have faster and higher germination when exposed to extreme conditions, as these conditions are likely to soften the hard seed coat and facilitate water imbibition and gaseous exchange in the seeds, which leads to a higher germination percentage. This is in contrast with the findings of Fadimu *et al*. (2014) in *Spondias mombin*, where an increase in hot water treatment temperature decreased germination percentage.

Table 7. Presentation of Tukey's test results for the germination of *Spondias pinnata* at 120 days.

	Experimental group									
	T1	T3	T4	T5	T6	T7	T8	T9	T10	T11
	93. 33	96. 67	96.67	100	98. 33	93.33	100	98.33	90	100
M_{T1} = 93.33	0	3.33^{ns}	3.33^{ns}	6.67^{ns}	5.00^{ns}	0	6.67^{ns}	5.00^{ns}	3.33^{ns}	6.67^{ns}
M_{T3} = 96.67		0	0	3.33^{ns}	1.67^{ns}	3.33^{ns}	3.33^{ns}	1.67^{ns}	6.67^{ns}	3.33^{ns}
M_{T4} = 96.67			0	3.33^{ns}	1.67^{ns}	3.33^{ns}	3.33^{ns}	1.67^{ns}	6.67^{ns}	3.33^{ns}
M_{T5} = 100.00				0	1.67^{ns}	6.67^{ns}	0	1.67^{ns}	10.00^{s}	0
M_{T6} = 98.33					0	5.00^{ns}	1.67^{ns}	0	8.33^{s}	1.67^{ns}
M_{T7} = 93.33						0	6.67^{ns}	5.00^{ns}	3.33^{ns}	6.67^{ns}
M_{T8} = 100.00							0	1.67^{ns}	10.00^{s}	0
M_{T9} = 98.33								0	8.33^{s}	1.67^{ns}
M_{T10} = 90.00									0	10.00^{s}
M_{T11} = 100.00										0

**ns = not significant, s = significant at p<0.05*

***Absolute values of the treatment mean differences were computed and compared with the Tukey critical value of 8.31 at α =0.05.*

Table 8. Germination percentage of *Spondias pinnata* pods/stones as a result of various pre-sowing treatments.

Treatment	Onset of germination (Day)	Percent germination (%)					
		45 days	60 days	75 days	90 days	105 days	120 days
T1 (Control)	39	5.00 ± 8.66	28.33 ± 10.41	85.00 ± 13.23	90.00 ± 10.00	93.33 ± 7.64	93.33 ± 7.64
T3 (HCl3%)	34	1.67 ± 2.89	35.00 ± 15.00	85.00 ± 13.23	96.67 ± 5.77	96.67 ± 5.77	96.67 ± 5.77
T4 (HCl5%)	39	1.67 ± 2.89	56.67 ± 12.58	83.33 ± 2.89	93.33 ± 11.55	96.67 ± 5.77	96.67 ± 5.77
T5 (HCl10%)	46	0	31.67 ± 7.64	98.33 ± 2.89	100.00 ± 0.00	100.00 ± 0.00	100.00 ± 0.00
T6 (50'30s)	39	1.67 ± 2.89	43.33 ± 5.77	86.67 ± 5.77	95.00 ± 5.00	98.33 ± 2.89	98.33 ± 2.89
T7 (50'1m)	50	0	18.33 ± 7.64	88.33 ± 12.58	91.67 ± 10.41	93.33 ± 7.64	93.33 ± 7.64
T8 (50'3m)	53	0	26.67 ± 17.56	96.67 ± 2.89	100.00 ± 0.00	100.00 ± 0.00	100.00 ± 0.00
T9 (75'30s)	56	0	28.33 ± 7.64	81.67 ± 27.54	95.00 ± 5.00	98.33 ± 2.89	98.33 ± 2.89
T10 (75'1m)	53	0	16.67 ± 12.58	55.00 ± 40.93	83.33 ± 17.56	90.00 ± 8.66	90.00 ± 8.66
T11 (75'3m)	56	0	41.47 ± 22.55	100.00 ± 0.00	100.00 ± 0.00	100.00 ± 0.00	100.00 ± 0.00
CV		316.23	39.62	20.14	9.06	5.42	5.42

**± indicates the standard deviation of means.*

Figure 10. One to four germination seedlings from a single pod/stone of *Spondias pinnata*.

(a) **(b)** **(c)**

Figure 11. *Spondias pinnata* germination setup at days (a) 50, (b) 70, and (c) 88.

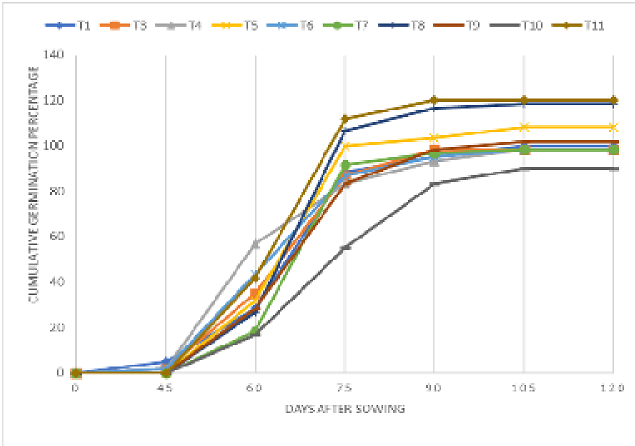


Figure 12. Cumulative germination percentage of *Spondias pinnata* seeds.

CONCLUSION

Spondias pinnata, *Terminalia microcarpa*, and *Ficus nota* are indigenous fruit species that are underutilized and undervalued. When given due recognition, its value and potential for food processing and security can be maximized. These species can be considered in the list of priority species for reforestation activities addressing food security. If considered, knowledge of the germination methods for mass propagation of the species must be carefully examined. The study looked into the different germination methods, and results revealed that *S. pinnata* showed a perfect germination percentage in the treatments exhibiting extreme conditions such as higher acid concentrations, longer periods of soaking, and higher water temperatures. Exposure to 5% and 10% HCl concentrations for 1 min was found to be the effective pre-germination treatment for *T. microcarpa* and *F. nota*, respectively. With this, it can be concluded that the different pre-germination treatments have varying effects on the germination of the three selected indigenous fruit trees. It could also be inferred that HCl and hot water treatment effectively break and soften the selected species' hard seed coat, thus inducing seed germination. The results of the germination study can aid in the mass production of these species for reforestation and plantation development.

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