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PHYSIOLOGICAL MATURITY AND CRITICAL MOISTURE CONTENT OF TERAP (*ARTOCARPUS ELASTICUS* REINW. EX BLUME) FOR EFFECTIVE SEED BANKING

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SUMMARY

Terap (*Artocarpus elasticus* Reinw. ex Blume) is a native Indonesian plant that can be a functional and medicinal food source. The conservation of terap has focused on implementing the field gene bank at botanical gardens. These methods presented risks, such as aging, pest and disease susceptibility, and weather-related threats; thus, diversifying conservation strategies, notably through seed banking, is imperative to mitigate these challenges. This study aimed to determine the physiological maturity level and critical moisture content crucial for effective terap seed banking. When harvested, physiological maturity determination used three fruit colors: green, orange, and orange-fall fruits. The critical moisture content identification of seeds had seeds dried for 0, 2, 4, 6, and 8 days in a room at 18 °C ± 2 °C and 55%–65% relative humidity, as predicted by regression analysis. The results indicated optimal quality and viability from physiologically mature orange fruits harvested 100–120 days after anthesis, with 35.31 g 100-seed dry weight and 75%–80% germination percentage. The germination evaluation revealed that the first count was 35 days after sowing, and the final count was 50 days after sowing. The seeds had 0.63% per 24 h germination rate, 64% germination uniformity, and more than 82% emergence ability. The critical moisture content was 36.93%, suggesting terap seeds are recalcitrant; hence, seed banking requires storage conditions to be moist. In addition, storing seeds can also proceed by in vitro techniques, using tissue culture and cryopreservation.

Keywords: Germination, moisture content, recalcitrant, seed banking, seed characteristic

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Key findings: Terap fruits colored orange were physiologically mature fruits with physiologically mature seeds. The critical moisture content was 36.93%, suggesting terap seeds are recalcitrant. These findings will benefit terap germplasm conservation. Proper germplasm conservation will maintain the genetic diversity of terap and make it easier for breeders to manage the germplasms for their future work.

INTRODUCTION

Terap (*Artocarpus elasticus* Reinw. ex Blume) is a native Indonesian plant belonging to the Moraceae family. The proximate tests have revealed that fruit flesh and seeds are rich in protein and carbohydrates, indicating their potential as functional food sources (Susiarti *et al*., 2020). Additionally, phytochemical tests have identified various active compounds in young leaves and wood, indicating medicinal potential, including rifampicin, isoniazid, kanamycin sulfate, oxepinoflavones (Artoindonesianin E1), and artelastin (Bailly, 2021). The potential for these applications requires ex-situ conservation to ensure the maintenance and sustainable use of populations in their natural habitats.

Ex-situ conservation is a set of techniques applied outside the natural habitat of target species, focusing on captive breeding in addition to sampling, transfer, and storage of species (Mestanza-Ramon *et al*., 2020). For terap, ex-situ conservation has centered at two locations: Bogor Botanical Gardens (BBG) (Ariati *et al*., 2019) and Mulawarman University Botanical Gardens, Samarinda (MUBGS) (Megawati *et al*., 2015), utilizing the field gene bank method. However, relying solely on this method poses risks such as aging, susceptibility to pests and diseases, and vulnerability to adverse weather conditions (Chauhan *et al*., 2019).

Complementary strategies, such as seed banking, are essential to mitigate these risks (O’Donnell and Sharrock, 2017). Seed banking involves storing seeds in a room with low humidity and temperature settings to enhance longevity (O’Donnell and Sharrock, 2017). This method proved cost-effective, conserving higher genetic diversity in a smaller space for extended periods, potentially reaching hundreds of years (O'Donnell and Sharrock, 2018).

Ensuring high-quality seeds for banking involves considering factors like physiological seed maturity (Vidya and Jose, 2023). Physiological seed maturity is a dynamic stage that determines the quality of a particular seed for its harvest with higher germinative capacity, energy, and subsequent long-term storage (Vidya and Jose, 2023). Protein and RNA production also occurs in the seed maturation process, which is crucial for subsequent seed longevity and successful completion of the seed germination process upon imbibition after banking (Dirk and Downie, 2018). Determining physiological maturity relies on various criteria, including physical quality, physiological quality, and biochemical content (Yuniarti *et al*., 2016). The easiest way to determine the physiological maturity was by observing changes in the fruit color (Bareke, 2018), as in chili (Suharsi *et al*., 2015) and tomato (Zebua *et al*., 2019), which changed from green to red and Mindi, from green to yellow (Aminah and Siregar, 2019).

Critical moisture content is also crucial for seed banking, marking the onset of imbibitional chilling injury, termed the breakpoint (Taylor, 2020; Vitis *et al*., 2020). The seed viability maintenance in banking remains when the moisture content is above the breakpoint (Vitis *et al*., 2020). Critical moisture content determination can proceed by drying seeds at ambient temperatures for some hours or days (Indraeni *et al*., 2019; Gawankar *et al*., 2020a). The critical moisture content of jamblang seed (41.61%) resulted from drying them in a room with 27 °C–28 °C temperature and 74%–81% relative humidity for 100–120 hours (Indraeni *et al*., 2019). Obtaining the critical moisture content of jackfruit seeds (37.71%) had them dried at an ambient temperature (32 °C ± 2 °C) for 15 days (Gawankar *et al*., 2020a).

This study aimed to contribute to the ongoing conservation by investigating the physiological maturity level of terap seeds through fruit color changes and determining the critical moisture content by correlating moisture to decreasing seed viability. Understanding these aspects was essential for refining seed banking protocols and ensuring the long-term success of ex-situ conservation of terap.

MATERIALS AND METHODS

Study area

This research commenced in January to December 2022 at the Integrated Laboratory of Bogor Botanical Gardens - National Research and Innovation Agency (BRIN), Bogor, West Java. The fruit came from the Bogor Botanical Gardens (BBG), Bogor, West Java, planted in Block XIX.F.126 (Figure 1).

Determination of seed physiological maturity

This study employed a randomized complete block design (RCBD) with one factor: fruit color at harvest. Blocks relied on harvest timings, including green fruit, orange fruit on the tree (orange fruit), and fallen orange fruit (orange-fall fruit) (Figure 2). Harvesting green, orange, and orange-fall fruits transpired at 75–100, 100–120, and over 120 days after anthesis (DAA). Characterization of fruits from the BBG was by color, weight, length, width, and diameter. Seed assessment probed moisture content, color, length, diameter, 100-seeds fresh weight, and 100-seeds dry weight. The dry weight determination used oven drying at 60 °C. Each level had three repeats, totaling nine experimental units with 10 seeds each for moisture content and 30 for viability testing, resulting in 360 seeds for determining seed physiological maturity.

Moisture content (MC) measurement used the constant-temperature oven method at 105 °C for 17 h (ISTA, 2018). The formula employed was:

$$MC = \frac{M2-M3}{M2-M1} \times 100\%$$

Where M_1 = the weight of the container and its cover (g), M_2 = the weight of the container, its cover, and seed before drying (g), and M_3 = the weight of the container, its cover, and seed after drying (g).

Viability testing involved planting seeds in sterilized sand within a controlled greenhouse environment at 25 °C – 30 °C and 50%–80% relative humidity. Daily observations recorded the germination process, facilitating the calculation of germination percentage (GP), vigor index (VI), germination rate (GR), germination uniformity (GU), and emergence ability (EA).

GP was counted by the number of seeds that germinated normally. The criteria for normal seedlings are that the hypocotyl grows straight and healthy, with fully opened cotyledons and healthy shoots. The GP calculation depended on the total number of normal seedlings in the first count (NS I) and the second or final count (NS II). NS I and NS II computations followed Sadjad's (1994) method, which involved plotting seed germination data on a curve with the X-axis being days after sowing and the Y-axis being the number of germinated seeds. NS I establishment used the daily normal maximum seedling curve, with NS II determined using the normal cumulative maximum seedling curve. Once confirming NS I and NS II, the percentage of GP can proceed using the formula (ISTA, 2018):

$$GP = \frac{\sum \text{NS I} + \sum \text{NS II}}{\textit{total number of seeds sown}} \times 100\%.$$

VI checking continued by counting the number of normal seedlings in the first count (NS I). VI calculation used the formula (Copeland and McDonald, 2001):

$$VI = \frac{\sum NS\ I}{\textit{total number of seeds sown}} \times 100\%$$

Figure 1. Location of terap in block XIX.F.126 at Bogor Botanic Gardens.

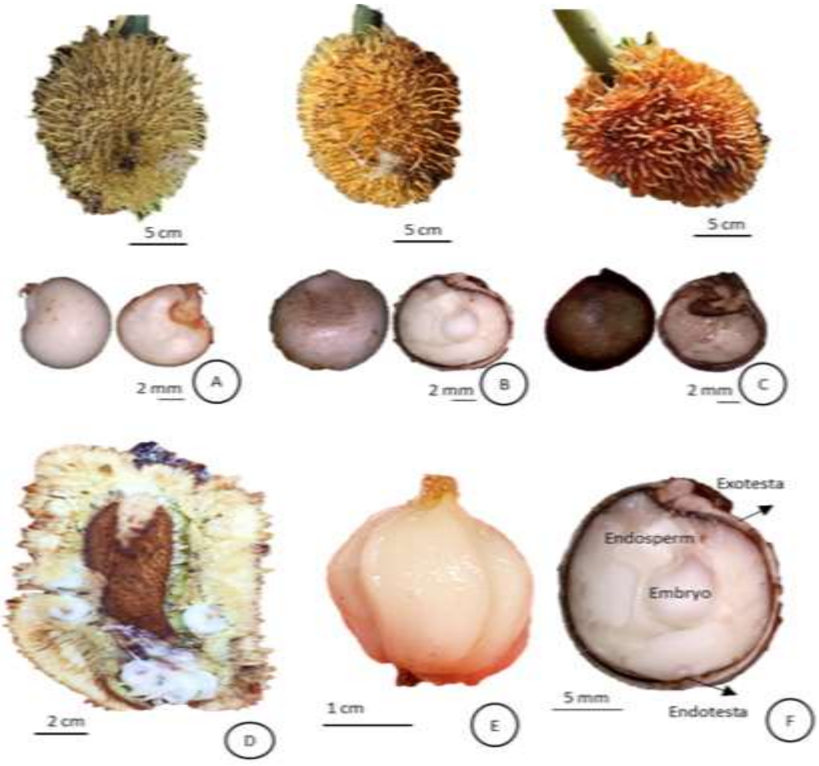

Figure 2. A. Green compound fruit and seeds, B. Orange compound fruit and seeds, C. Orange-fall compound fruit and seeds, D. Split compound fruit, E. Single-white fruit, F. Split seed and its parts (Figures D, E, and F were from the orange compound fruit).

GR ascertained and counted the number of normal seedlings that appeared every day from the first day until the final recorded count. GR calculation can use the formula (Sadjad, 1994):

$$\mathrm{GR} = \sum_{i=1}^{n} d$$

Where d is the addition of the percentage of normal seedlings per etmal (1 etmal = 24 hours).

Calculating GU depended on the number of normal seedlings between the first count (NS I) and the final count (NS II), with the strongest seedling calculated as (Sadjad, 1994):

$$GU = \frac{total\ number\ of\ normal\ seedlings\ at\ x\ days}{total\ number\ of\ seeds\ sown} \times 100\%$$

EA verification relied on germination criteria related to physiological aspects, considering a seed germinated even if the new embryo produced a radicle (potential root). The calculation utilized the final count of germination observations (NS II) with the formula (ISTA, 2018):

$$EA = \frac{total\ number\ of\ germinating\ seeds}{total\ number\ of\ seeds\ sown} \times 100\%$$

Determination of seed critical moisture content

Seeds from physiologically mature fruits were samples to determine the critical moisture content of seeds. The experimental design employed a completely randomized design (CRD), with seed drying time as the factor (2, 4, 6, and 8 days). Seeds dried in a room had 18 °C ± 2 °C temperature and 55%–65% relative humidity. Each drying time level had three replicates, resulting in 12 experimental units. Each experimental unit comprised 40 seeds, making the overall sample size 480. The observed variables consistent with those in the previous experiment were MC, GP, GR, VI, GU, and EA. Regression analysis helped predict the critical moisture content by establishing a correlation between moisture content and germination percentage.

Data analysis

All obtained data processing used Microsoft Excel 2019 and analyzed with the F test (ɑ = 5%) using the Statistical Tool for Agricultural Research (STAR) Nebula. Data exhibiting significant differences underwent additional testing through Duncan's multiple-range test (DMRT) with ɑ = 5%.

RESULTS AND DISCUSSION

Fruit and seed traits at physiological maturity

Terap had a compound fruit (Figure 2A) consisting of single white fruits (Figure 2B). Each single fruit had one seed (Figure 2C). The result of the characteristics of terap fruits and seeds, as a function of color fruit at harvest time, is visible in Figure 3. The fruit maturation stage significantly affected all evaluated variables. The diameter and length of compound fruit increased during development, reaching 14.76 cm (orange fruits) and decreasing when the fruit fell (orange-fall fruit). However, it did not differ significantly (Figure 3A). Recent studies have demonstrated that fruit growth and development can strongly determine the physiological maturity of fruits (Ramos *et al*., 2021). In parallel with the study, Mohammed and Wickham (2021) also observed that the width and length of the compound fruit of breadnut increased during the physiological maturity period.

The compound fruit weight also increased from the green fruit (619.33 g) to the orange (1,125 g), then decreased at the orange-fall fruit (901.5 g). The rise in compound fruit weight had links with development and maturation, as well as the increase in dry matter and accumulation of sugars (Barbedo *et al*., 2013). The decrease in orange-fall fruit weight was due to the water loss from the fruit transpiration and respiration process (Pah *et al*., 2020).

The total number of seeds per compound fruit among orange and orange-fall fruits was not significantly different (29.83 and 24.33, respectively) but relatively higher than

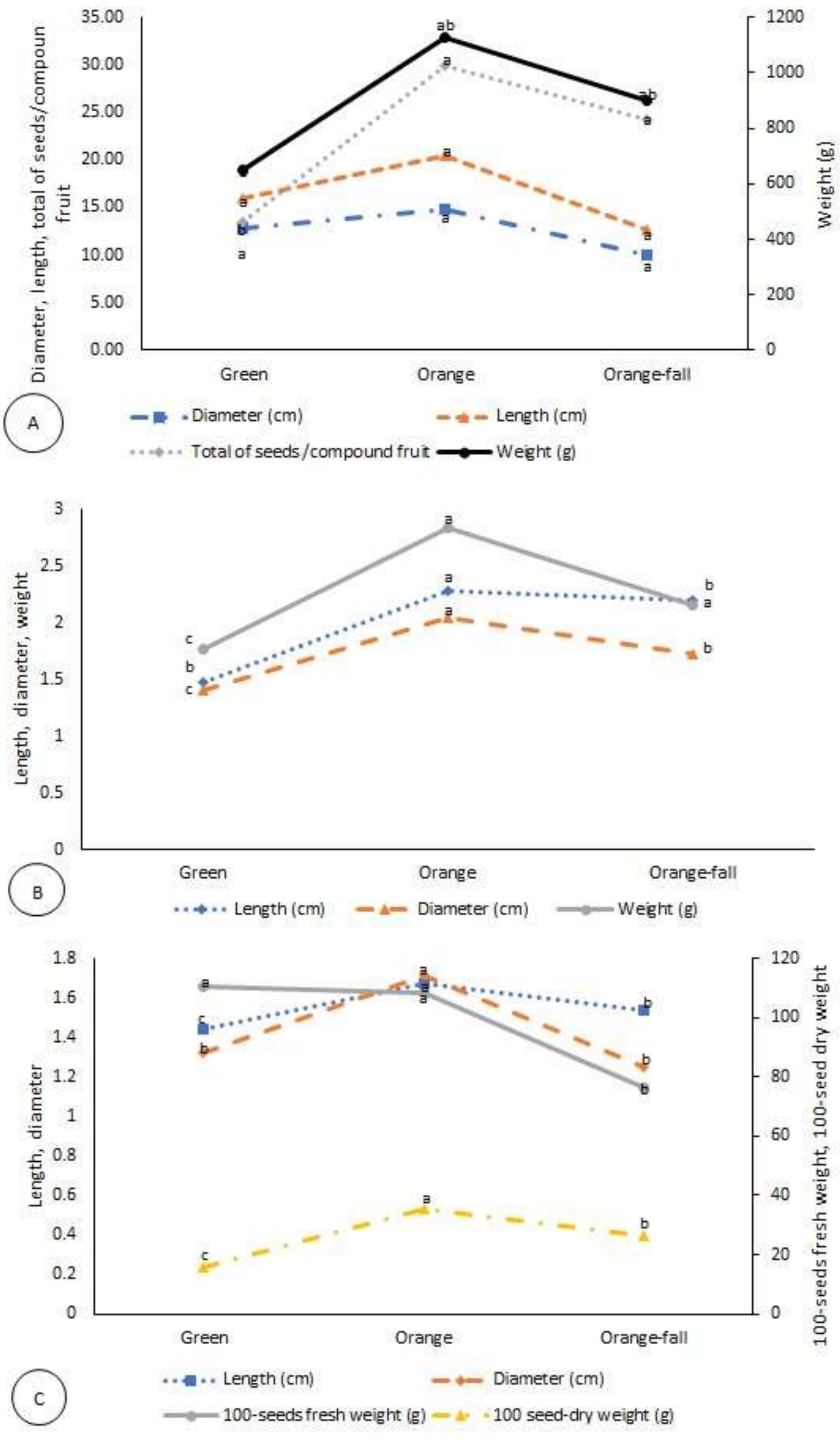

Figure 3. Size of terap compound fruits (A), single fruits (B), and seeds (C) based on the fruit color (the different letter above the marker indicates that fruit color gave a significant effect at the DMRT test [α 5%]).

the green fruit (13.50). The total seeds of terap fruit have a high variation, depending on the observed fruit. Susiarti *et al*. (2020) observed that the total seed per compound fruit was four to 207. In *Physalis angulata,* the total number of seeds was also notably different ($P < 0.05$) during the development and maturation of fruit (Ramos *et al*., 2021). Amali *et al*. (2013) reported that increasing the total seed per fruit was parallel with the total days after anthesis.

The single fruit of terap was white, similar to the three observed maturities, but flesh firmness differed among them (Figure 2E). A single fruit from green fruit had the highest flesh firmness, followed by orange and orange-fall fruits. It was because the terap fruit is climacteric. An increase in respiration and ethylene production marks the beginning of the ripening and softening of climacteric fruits (Morelos-Flores *et al*., 2022). Moreover, the firmness of the fruit flesh decreases after reaching physiological maturity (Alenazi *et al*., 2020). It reflects chemical and physical changes in cell walls, which correlate with the action of hydrolytic enzymes on the cell wall, especially the enzymatic breakdown of pectin and related substances (Alenazi *et al*., 2020). Likewise, the single fruit differed considerably in lengths, diameters, and weights (Figure 3). The maximum fruit length was in the orange fruits (2.28 cm) and orange-fall fruits (2.20 cm). The fruit with the highest diameter (2.04 cm) and weight (2.83 cm) was the orange fruit (Figure 3). Bareke (2018) stated that fruit size changes relatively when the seed physiologically matures.

Figure 2F shows a vertically split terap seed. The section showed different parts of the terap seed: exotesta, endotesta, endosperm, and embryo. Its exotesta was yellowish white with 0.42–0.53 cm thickness. The endotesta color was light brown, attaching directly to the endosperm. The endosperm was milky white and sticky. The embryo was in the middle of the endosperm. According to Sliwinska and Bewley (2014), the embryo of terap was axial, ranging from small to occupying the entire seed interior, with a location at the center of the endosperm.

The seed shape was spherical, with visible significant differences in seed sizes among the three maturities (Figure 3C). Seeds of the orange fruit had the highest length and diameter, measuring 1.67 and 1.71 cm, respectively. The 100-seed fresh weight from green and orange fruits differed nonsignificantly but was heavier than the orange-fall fruits. The 100-seed dry weight showed that seeds from orange fruit had the maximum weight because an orange fruit had reached physiological maturity. Physiological maturity corresponds with maximum seed dry matter accumulation (Bareke, 2018). Ellis (2019) also reported that physiological maturity is a period of cell division, cell enlargement, and histodifferentiation as the embryo develops; hence, the seed size and dry weight remain the highest.

In this study, fruit color changes from green to orange indicated that terap fruits and seeds reached physiological maturity. It was because all characteristics (the size of compound fruit, single fruit, and seed) in the orange fruits were the highest, especially the seeds dry weight, which increased remarkably from green to orange fruits. Bareke (2018) stated that physiological maturity is optimum when the significant increase in seed dry weight stops. Maximum dry weight could become a reference point to characterize the end of seed development and the physiological independence of the seed from the parent plant (Bareke, 2018; Ellis, 2019). In general, fruit color changes from green (immature) to yellow/orange/red/brown (mature) when reaching physiological maturity (Suharsi *et al*., 2015).

Germination evaluation for maturity

The germination pattern of the terap seed appears in Figure 4. Terap seeds exhibited hypogeal germination, with the cotyledons remaining underground within the testa. Terap seeds germinated 28–30 days after sowing (DAS). The radicle then appears, accompanied by the plumule at 32–35 DAS (Figure 4A). Normal seedlings would surface at 40–42 DAS (Figure 4B). Germination evaluation revealed

Figure 4. A. germination pattern of terap seed and part of its seedling, B. normal and abnormal seedling, C. polyembryony of terap seed.

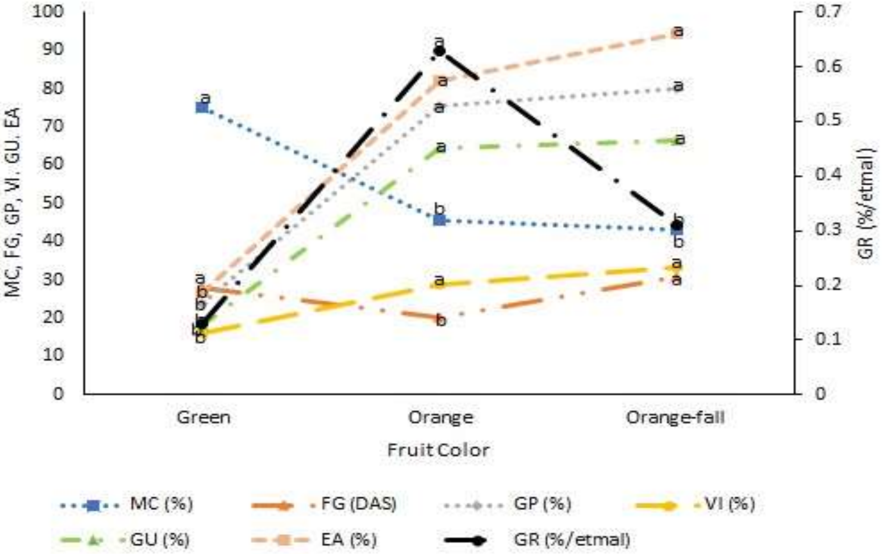

Figure 5. Germination evaluation of terap seeds based on fruit color (The different letter above markers indicates that fruit color gave significant effect at the DMRT test [ɑ 5%], MC = moisture content, FG = first day of germination, DAS = days after sowing, GP = germination percentage, VI = vigor index, GR = germination rate, GU = germination uniformity, EA = emergence ability).

that some seedlings with abnormal shapes are abnormal (Figure 4B). In general, abnormal seedlings in this study did not have a straight epicotyl (Figure 4B). Gagliardi and Marcos-Filho (2011) said that germination abnormality occurs because of morphological abnormalities in the seed. Germination evaluation also revealed that the terap seeds exhibited polyembryony (Figure 4C).

Figure 5 showed that the freshly harvested seed moisture content (MC) significantly decreased from 75.05% (green fruit) until it reached 43.02% (orange-fall fruit). The high MC indicated that green fruits were in the maturation period, while the nonsignificant MC marked that orange and orange-fall fruits had matured. MC decreases during maturation, although it remains relatively high throughout most of the period because water is the vehicle for transferring nutrients from the parent plant to the developing seed (Bareke, 2018). Terap had fleshy fruits, thus, a lower decrease in seed moisture content in the maturation period than dry fruits (Bareke, 2018).

All the seeds from all maturity phases germinated, but the orange fruits germinated earliest (20 DAS) compared with others (Figure 5). It indicated that the orange fruits had reached physiological maturity and that the seed could respond to environmental conditions better than less mature seeds. Seed germination is the first step in plant growth, beginning with imbibition and ending with radicle emergence (Han and Yang, 2015). Imbibition made the testa and endosperm rupture, making the radicle tips visible (Bareke, 2018).

Figure 6 shows that the seed germination period for orange-fall fruits was more extensive than the rest. It happened because the orange-fall fruits were at an over-physiological maturity stage. Over-physiological maturity decreased seed viability because of weather conditions in the field, which could cause deterioration processes to begin and a decrease in viability (Widjaya *et al*., 2021). The germination period measures the germination rate and time spread, an essential parameter in seedling establishment in the field (Soltani *et al*., 2015).

The NS I and NS II for green, orange, and orange-fall fruits were 46 and 70 DAS, 32 and 50 DAS, and 90 and 197 HSS, respectively (Figure 6). The germination period of orange fruits was the shortest among others. The reason might be due to the seeds having reached physiological maturity. Jackfruit also had the same germination period as terap (50–53 DAS) (Gawankar *et al*., 2021). Terap started germinating at 28–30 DAS, while jackfruit began germinating at 11–14 DAS. The final count of seeds from orange fruits was not significantly different from the final count of jackfruit (53 DAS) (Barbosa *et al*., 2019).

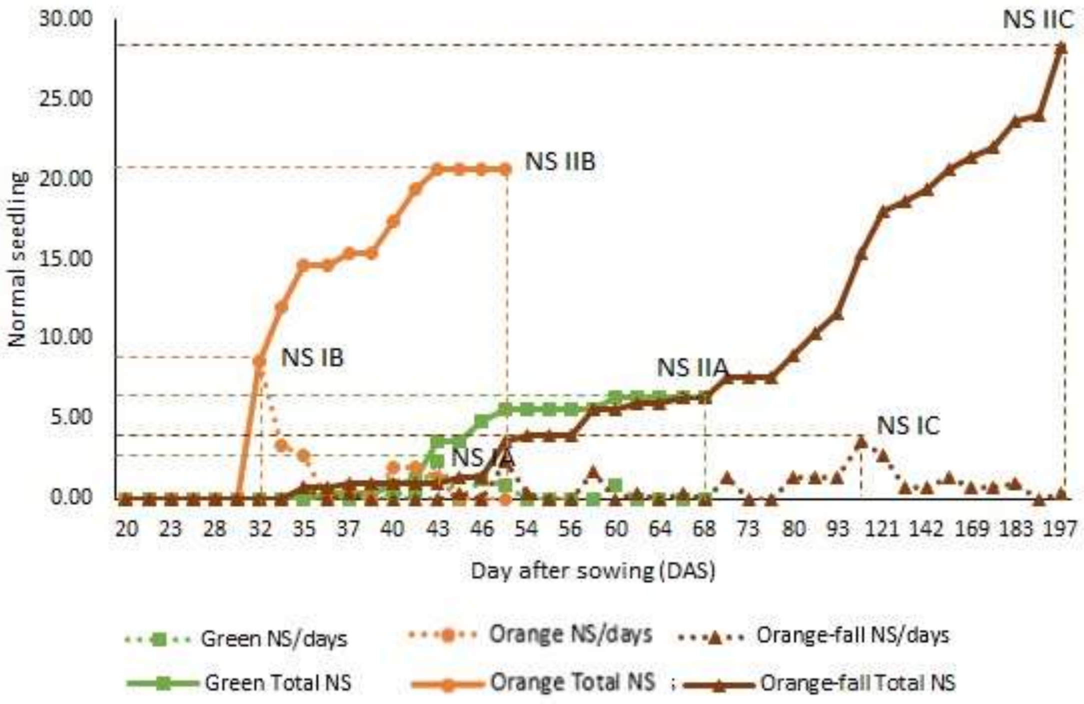

Figure 6. Curve determination of first count (NS I) and last count (NS II) of terap seeds from green fruits (A), orange fruits (B), and orange-fall fruits (C).

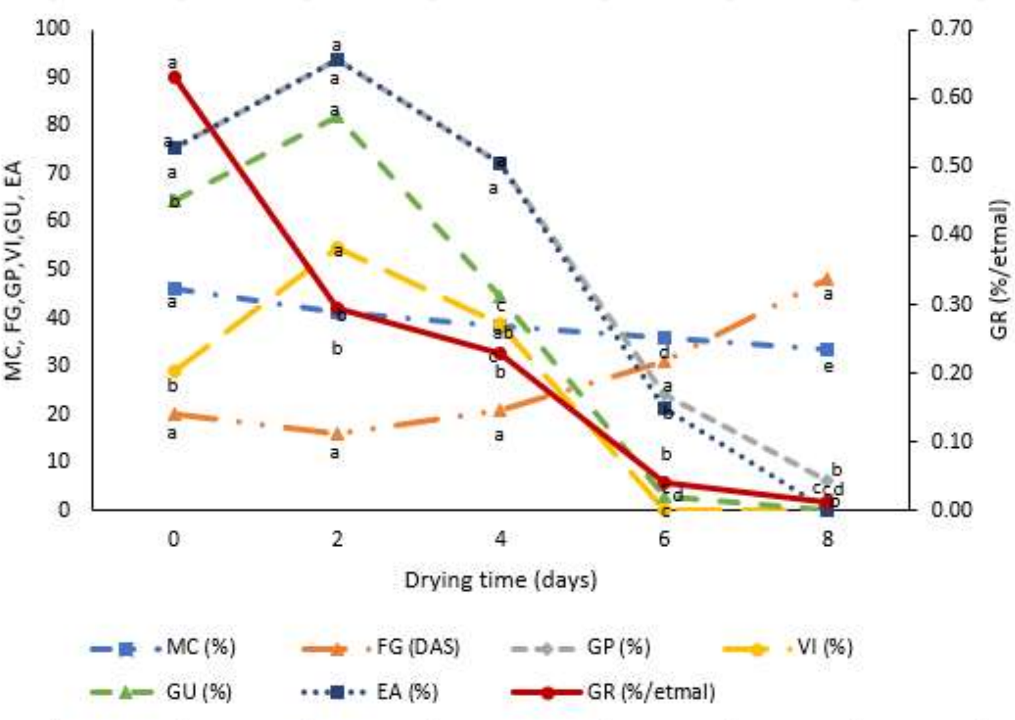

Figure 7. Germination evaluation of terap seeds from orange-mature fruit after drying for 0, 2, 4, 6, and 8 days to determine their critical moisture content. (The different letter above markers indicates that drying time gave significant effect at the DMRT test [ɑ 5%]; MC = moisture content, FG = first day of germination, DAS = days after sowing, GP = germination percentage, VI = vigor index, GR = germination rate, GU = germination uniformity, and EA = emergence ability).

Figure 5 also revealed that orange and orange-fall fruits GP, VI, GU, and EA were not significantly different. The GP, VI, GU, and EA of green fruits were smaller (24%, 16%, 18%, and 26.67%, respectively) and substantially varied from the orange fruit (75.56%, 28.89%, 64.44%, and 82.22%, respectively) and orange-fall fruit (80%, 33.33%, 66.67%, and 94.44%) ($P < 0.05$). These results showed that the seed from orange-fall fruits has a higher GP, VI, GU, and EA than orange fruits (not significantly differ) because seeds ably germinated with a high moisture content soon after harvest; they are still not capable of expressing their total germination potential (Ramos *et al*., 2021).

The highest GR resulted in the seed of orange fruits (0.63%/etmal) and significantly higher than those of green or orange-fall fruits (0.13%–0.31%/etmal) ($P \geq 0.05$). Previous studies have demonstrated that another reliable metric when studying seed germination is the germination index, the same term as GR in these studies (Sadeghi *et al*., 2011). The GR estimated the time (in days) to reach a specific germination percentage (Lotfi *et al*., 2019). Yang *et al*. (2016) observed that seeds germinating faster are likely to have a higher GR.

All of the variables in the germination evaluation showed that the seeds from orange fruits had high vigor and germination. The seeds germinated earlier than others, had a short germination period to reach normal seedlings, and had high GP, GR, VI, GU, and EA. Therefore, no differences in results occurred between the characteristics of fruit and seed and germination evaluation to determine the physiological maturity of terap seeds. Orange fruits had the highest seeds dry weight, followed by high vigor and germination. Bareke (2018) and Ramos *et al*.

(2021) also said that seed physiological maturity is utmost when seeds show high vigor and germination, coinciding with maximum seed dry weight accumulation. Thus, using seeds from the orange fruit ensued in the succeeding experiment.

Seed critical moisture content

The effect of drying time for terap seeds is available in Figure 7. Moisture content (MC) decreased significantly from 46.28% at harvest time (zero days) to 33.32% at eight days of drying. The decrease of MC caused nonsignificant differences in the first germination (FG) but led to a sharp decline in the germination percentage (GP), from 93.94% at two days to 6.06% at eight days. These results indicated that terap seeds were desiccation-sensitive. Berjak and Pammenter (2013) suggested that the more desiccation-sensitive the seed, the greater the degree of vacuolation. Mechanical damage associated with volume reduction when water is lost suggests vacuolar collapse occurring in cells of tissues not primed by reducing/filling these compartments is the damage accrued by desiccation-sensitive seeds (Berjak and Pammenter, 2013).

The outcomes revealed that the GP at zero days drying time was smaller than the GP at two days drying time (Figure 7). In contrast to Pammenter and Berjak's (2014) statement, sensitive seeds did not have a readily identifiable switch from developmental metabolism to germinate metabolism, with development grading almost imperceptible into germination. However, the GR at zero days drying time was the highest among other drying times (0.63%/etmal). In contrast to the previous study at germination evaluation, drying time causes the GR not to align with GP. According to Pammenter and Berjak (2014), partial drying was necessary to enhance the optimal germination for some desiccation-sensitive species, and terap is one of them.

Other variables, such as VI, GU, and EA, yielded high results at two days of drying time, i.e., 54.54%, 81.82%, and 93.94%, respectively, and decreased sharply at the final drying time (8 days). In these studies, the drying rate was slow. One method to maintain the viability of desiccation-sensitive seeds is to enhance the drying rate (Berjak and Pammenter, 2013). Desiccation-sensitive seed is metabolically active; thus, under conditions of rapid drying, curtailing the time during which metabolism-linked damage occurs considerably lower water content commensurate with achieving viability retention (Berjak and Pammenter, 2013).

The research obtained an equation that GP = 6579 - 557.5 MC +1 5.42 MC^2 - 0.1384 MC^3 with R^2 = 97% based on polynomial regression (Figure 8). The prediction revealed that a slight decrease in MC caused a rapid decline in GP. Robert (1972) stated that critical moisture content (CMC) was moisture content, which resulted in 50% germination (P50); hence, the critical moisture content of terap seeds was 36.93% (Table 1), with a 46.28% initial moisture content. The critical moisture content is attainable by drying the seed for 4–5 days at room temperature. Therefore, the terap seeds belonged to exceptional species (recalcitrant seeds). An outstanding seed is a plant species that is difficult to conserve efficiently and effectively for long-term *ex-situ* under the conditions of conventional seed banking, requiring modified approaches (Pence *et al*., 2022).

The presented study also indicated that desiccation below 36.93% leads to seeds becoming nonviable and losing their germination ability. It was due to the loss of free-bound water, slowing cell metabolism, which resulted in controlling seed deterioration and viability rate (Gawankar *et al*., 2020a). The critical moisture content of jackfruit seeds was also high, at 37.71% (18.51% water loss) (Gawankar *et al*., 2020a). The high CMC means that terap seeds require additional treatment before storage.

Gawankar *et al*. (2020b) explored innovative seed storage techniques for jackfruit seeds, favoring screw-cap bottles and earthen pots buried in the soil to prevent desiccation, maintaining seed viability for up to 150 days. Moreover, tissue culture and cryopreservation techniques are appropriate for storing recalcitrant seeds, especially from the genus *Artocarpus*. Ganeshan *et al*. (2012) also used a

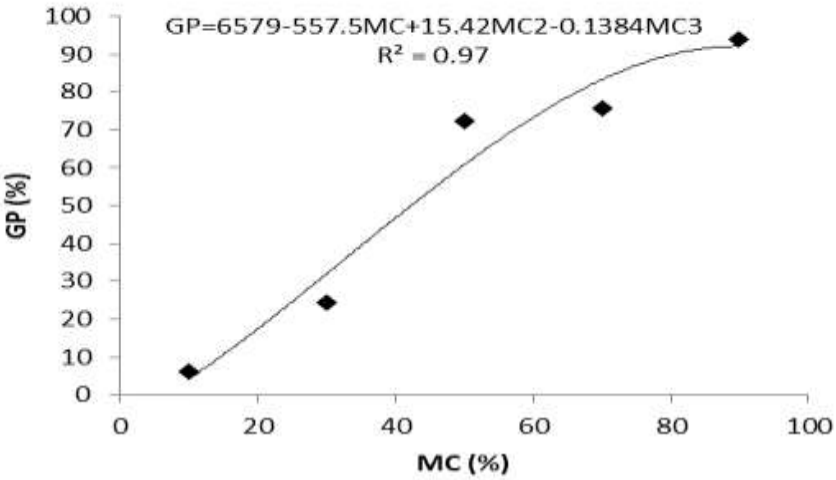

Figure 8. Regression analysis of moisture content (MC) and germination percentage (GP) to predict the critical moisture content of terap seeds.

Table 1. The value of seed moisture content in each prediction germination is based on the regression analysis.

Prediction Value	Prediction MC (%)
P0 (GP 100%)	40.60
P20 (GP 80%)	39.00
P40 (GP 60%)	37.59
P50 (GP 50%)	36.93
P100 (GP 0 %)	33.00

Note: GP = germination percentage, MC = moisture content

slow-growth storage method to store jackfruit. The jackfruit explant bore subculturing for four years by planting on media MS + 8.87 µM BA, with a reduced temperature and light intensity until 10 °C and 2.97 $\mu m^{-2}s^{-1}$, respectively (Ganeshan *et al*., 2012). Okunade (2018) stored jackfruit using cryopreservation and the vitrification method with PVS4 as a cryoprotectant and shoot tips as an explant. The results showed that 37.9% of shoot tips could regrow as a plantlet.

CONCLUSIONS

For efficient seed banking, terap fruits must be orange-colored when harvested (100–120 DAA) to get physiologically mature seeds. The physiological mature seeds at the first and final counts for germination were 35 and 50 DAS, respectively. Those seeds had the highest 100-seed dry weight, i.e., 35.31 g. Germination evaluation showed that physiologically mature seeds had more than 75% GP, 0.63%/etmal GR, 64% GU, and more than 82% EA. The initial and critical moisture content of terap seeds was 46.28% and 36.93%, respectively, making terap seeds recalcitrant. Recalcitrant seeds are sensitive to desiccation; hence, seed conservation needs moist storage conditions. In addition, storing seeds for conservation can also proceed by in vitro conservation using tissue culture and cryopreservation techniques.

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