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Research paper

Characterization of Intermediate Seed Storage Behavior in *Diospyros vaccinioides* Lindl.

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ABSTRACT

Diospyros vaccinioides Lindl. is a critically endangered species and a highly valued ornamental plant native to Taiwan. This study investigated the germination characteristics and seed storage behavior of *D. vaccinioides* to identify optimal seed storage conditions for its *ex situ* conservation. Two seedlots were examined, with initial germination percentages of 83.0 ± 9.9 and 92.5 ± 8.3%, and mean germination times of 30.1 and 30.0 days, respectively. Nearly all viable seeds germinated within 7 weeks, suggesting that *D. vaccinioides* seeds exhibit shallow dormancy. The seeds tolerated desiccation to approximately 13% moisture content (fresh-weight basis) and retained high viability after 2 years of storage at 4℃. However, complete loss of viability occurred when seeds were dried below 5% moisture content. Furthermore, seeds stored at -196 or -20℃ at moisture contents between 8-20% exhibited significant viability loss within 2 years. These findings indicate that *D. vaccinioides* seeds possess temperate intermediate storage behavior, characterized by moderate desiccation tolerance and sensitivity to freezing. For effective short- to medium-term *ex situ* conservation, best practices for maintaining seed viability and extending longevity involve drying freshly harvested mature seeds to a moisture content of 13-15%, followed by hermetic sealing and storage at 4℃. Due to the relatively short seed longevity of the species, seed stocks should be regenerated approximately every 6 to 10 years.

Keywords: *Diospyros vaccinioides* Lindl., *ex situ* conservation, germination, intermediate seed storage behavior

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INTRODUCTION

Seed storage behavior has traditionally been classified based on the degree of desiccation tolerance exhibited by mature seeds. Roberts (1973) initially proposed two primary categories: orthodox and recalcitrant. Orthodox seeds are capable of withstanding substantial dehydration, retaining viability even when their moisture content falls below 5%. In contrast, recalcitrant seeds are highly sensitive to desiccation, often experiencing a marked decline in viability when dried to moisture levels between approximately 12-31%, especially when the drying process is prolonged (Roberts 1973). In addition to their desiccation sensitivity, many recalcitrant seeds—particularly those from tropical species—also exhibit a pronounced intolerance to low temperatures. Storage below 10-15℃ commonly results in viability loss (Bonner 1990).

In addition to the orthodox and recalcitrant categories, Ellis et al. (1990a) identified a third class of seeds: termed intermediate, based on their study of *Coffea arabica*. These seeds tolerated desiccation to moisture contents of 5-10% but failed to retain viability when stored at temperatures ≤ 10℃. Intermediate seeds are thus characterized by moderate desiccation tolerance coupled with a sensitivity to low or freezing temperatures. Subsequent studies further supported this classification, reporting similar storage behavior for seeds of *Elaeis guineensis* (Ellis et al. 1991b) and various *Citrus* species (Hong and Ellis 1995). In general, most intermediate seeds can survive drying to 10-12% MC; however, further reduction in moisture often leads to viability loss. Optimal storage temperature tends to reflect the climatic conditions of the species' native habitats. For example, some intermediate seeds from temperate and subtropical regions, such as *Acer* species native to Taiwan, can survive sub-zero storage conditions (Yang and Lin 1999), whereas species from milder environments, such as *Zelkova serrata* (Yang et al. 2007) and *Litsea coreana* (Yang et al. 2008b), exhibit marked sensitivity to freezing temperatures.

Diospyros vaccinioides Lindl., commonly referred to as "small persimmon," is an evergreen shrub to small tree in the family Ebenaceae. This species is native to parts of East Asia, including Hainan Island, Hong Kong, Guangdong, and Taiwan. In Taiwan, its distribution is highly restricted and fragmented, occurring only in lowland tropical rainforests near Fenggang Village on the Hengchun Peninsula, located at the southernmost tip of the island (Liao et al. 1998). Due to its extremely limited geographic range and small population size—fewer than 50 mature individuals—*D. vaccinioides* was previously classified as a Critically Endangered species by Taiwan's Council of Agriculture (Lu and Lin 1996) and has been listed as Critically Endangered on the IUCN Red List since 1998. However, due to insufficient and outdated information on its distribution and population status, the species was subsequently reclassified as data deficient (DD) in The Red List of Vascular Plants of Taiwan 2017 (Editorial Committee of the Red List of Vascular Plants of Taiwan 2017). Today, *D. vaccinioides* is not only a threatened species but also regarded as a highly valued ornamental plant in Taiwan.

Diospyros vaccinioides typically flowers from April to May, with fruit maturation occurring between mid-November and mid-December in Taiwan. As the fruits ripen, the pericarp transitions in color from green to purplish-black (Figure 1). The fruits are oblong to ovoid berries, measuring

Figure 1. Fruits and extracted seeds of *Diospyros vaccinioides*

approximately 1.2 cm in length and 0.8 cm in diameter. Each berry usually contains two seeds, though one to three may occur. Fresh, mature seeds of *D. vaccinioides* are hemispherical in shape with a finely rugulose surface and a small apical beak. Seeds are approximately 9 mm long and 5 mm in diameter (Figure 1). Due to the species' rarity, dioecious reproductive system, and frequent fruit predation by wildlife, collecting large quantities of mature seeds from wild populations is extremely difficult.

Until recently, apart from a brief report on the germination and storage of *D. vaccinioides* seeds by Yang (2019), no studies published in peer-reviewed scientific journals have provided a detailed characterization of the seed storage behavior of this species. To fill this knowledge gap, the present study employed a factorial design combining different moisture contents and storage temperatures to accurately assess the species' seed storage behavior and identify optimal storage conditions. The findings aim to support nursery practices for species recovery and provide practical guidance for seed storage in *ex situ* conservation efforts targeting this endangered plant native to Taiwan.

MATERIALS AND METHODS

Seed collection and extraction

Detailed collection information for the two seedlots used in this study is presented in Table 1. The seeds were collected from several cultivated individuals in 2004 (seedlot 1) and 2015 (seedlot 2). Only fully mature fruits, identified by their purple to purplish-black coloration, were harvested. As the outer skins and mesocarps of most mature fleshy fruits were still firm at the time of collection, the fruits were placed in a greenhouse and kept moist for 3-5 days to promote post-harvest ripening and softening. Once the fruit flesh had decomposed sufficiently, seeds were extracted and thoroughly washed. The cleaned seeds were further manually sorted to remove undersized or damaged individuals. Approximately 8,450 high-quality seeds from seedlot 1 were extracted on December 3, 2004, and 21,380 from seedlot 2 on December 10, 2015. The seed characteristics of fresh mature seeds from both seedlots are also summarized in Table 1.

Table 1. Collection date, source information, seed characteristics, and germination performance of fresh mature seeds from 2 seedlots of *Diospyros vaccinioides* used in this study

Seedlot no.	Seedlot 1	Seedlot 2
Collection date	November 28, 2004	December 3, 2015
Collection location	Hengchun Peninsula, Pingtung County	Xizhou Township, Changhua County
Latitude, longitude	21°58'N, 120°48'E	23°52'N, 120°50'E
Elevation (m)	260	40
Moisture content (%, FW[1] basis)	44.6 ± 0.9	42.6 ± 0.3
Seed length (mm)	9.63 ± 0.69	9.38 ± 0.72
Seed width (mm)	5.67 ± 0.64	5.38 ± 0.44
Seed thickness (mm)	3.83 ± 0.63	3.64 ± 0.70
Number of seeds L^{-1}	6,250 ± 242	6,513 ± 222
TSW[2] (Thousand-seed-weight, g)	95.3 ± 1.7	93.7 ± 1.5
Germination percentage[3] (%)	83.0 ± 9.9	92.5 ± 8.3
Mean germination time[3] (d)	30.1 ± 1.0	30.0 ± 0.7

[1] FW, fresh-weight.
[2] Thousand-seed-weight was estimated at the moisture content shown.
[3] Seeds were incubated at alternating night/day temperatures of 20/30℃ and 8 hours of light for 12 weeks.

Determination of moisture content

Seed moisture contents (MCs), expressed on a fresh-weight basis throughout this study, were determined gravimetrically for both seedlots using four replicates. In each replicate, five filled seeds were randomly selected and cut into fragments less than 4 mm in length. The minced seed tissues were then dehydrated using the low constant-temperature oven method at 103 ± 2℃ for 17 ± 1 hours (International Seed Testing Association 1999).

Germination assay

To prevent imbibitional injury resulting from rapid rehydration (Ellis et al. 1990b), seeds that had undergone various drying treatments were preconditioned before germination testing by placing them in sealed acrylic containers containing distilled water. A small fan was installed inside to increase airflow, and the seeds were suspended above the water surface without direct contact, allowing them to gradually absorb moisture from the humid atmosphere. After prehydration, seeds were thoroughly mixed with clean sphagnum moss and placed in sealable polyethylene (PE) bags (14 × 10 cm, 0.04 mm thick), with approximately two-thirds of the bag volume filled with air to ensure adequate oxygen availability for respiration. Excess water from the moss was removed by squeezing until a moisture content of approximately 450% (dry-weight basis) was achieved, following the method described by Lin and Chen (1993). Germination capacity was evaluated for both fresh mature seeds and those subjected to moist or dry storage. For each treatment, four replicates of 25 seeds (seedlot 1) or 30 seeds (seedlot 2) were randomly selected. Germination tests were conducted under alternating temperatures of 30/20℃ (day/

night) with an 8-hour photoperiod (light intensity ≈5000 lux). During the 12-week test period, germinated seeds—defined as those with a normal radicle extending at least 1 cm—were counted weekly. At each observation, approximately 3-5 mL of water was added to the moss, and fresh air was introduced into the PE bags to maintain moisture and aerobic conditions.

Germination speed

Germination speed was evaluated by calculating the mean germination time (MGT) using the formula:

$$MGT = \Sigma (n \times d) / N,$$

where n is the number of seeds germinated on day d, and N is the total number of seeds that germinated by the end of the test period (Hartmann et al. 1989).

Low-temperature moist and bare storage treatments

The durations of moist and bare storage at 4℃ for fresh seeds of the 2 seedlots are presented in Table 2. These treatments were designed to evaluate the effects of low-temperature storage conditions on seed viability, as well as to assess the influence of 4℃ stratification on the germination of fresh mature seeds of *D. vaccinioides*. For moist storage, a procedure analogous to cold stratification was employed. Fresh mature seeds from both seedlots were thoroughly mixed with moist sphagnum moss and sealed in polyethylene (PE) bags (14 × 10 cm, 0.04 mm thick). Approximately two-thirds of each bag's volume was left unfilled to allow for adequate respiration. During moist storage at 4℃, moisture was maintained and the internal atmosphere was refreshed monthly by adding water and exchanging air.

For bare storage, approximately 120 mL of fresh mature seeds from seedlot 2, with an initial seed moisture content of 42.6%, were evenly distributed into four 2-liter glass bottles without any substrate. The bottles were stored at 4℃, and the internal air was also renewed monthly.

Dry storage treatment and moisture content determination

Sub-seedlots exhibited varying MCs, ranging from approximately 5-15% for seedlot 1 and 2-20% for seedlot 2. Fresh mature seeds from both seedlots were placed in hermetically sealed acrylic chambers equipped with a small fan for air circulation,

Table 2. Duration of moist and bare storage at 4℃ and dry storage at 4 or 5 seed moisture content levels under 3 or 4 temperature conditions for seeds from 2 seedlots of *Diospyros vaccinioides* used in this study

Seedlot no.	Seedlot 1	Seedlot 2
4℃ moist storage duration (months)	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15, 18, 21, 24	0, 1, 3, 6, 9, 12, 18, 24
4℃ bare storage duration (months)[1]	–	0, 1, 3, 6, 9, 12, 18, 24
MCs of dry storage (FW[2] basis, %)	5.1 ± 0.2, 8.8 ± 0.3, 11.5 ± 0.5, 14.6 ± 0.6	2.5 ± 0.1, 4.4 ± 0.2, 9.0 ± 0.5, 13.8 ± 0.9, 19.9 ± 0.8
Dry storage temperature (℃)	-20, 4, 15	-196, -20, 4, 15
Dry storage duration (months)	0, 3, 6, 12, 18, 24	0, 1, 3, 6, 9, 12, 18, 24

[1] Fresh mature seeds of seedlot 2 were stored bare at a moisture content of approximately 42.6%.
[2] FW, fresh-weight.

and molecular sieves were employed to control drying at 15–20℃. Once each sub-seedlot reached the target MC, seeds were transferred into aluminum foil bags and stored temporarily at 4℃ for approximately 3 days to stabilize moisture levels prior to determination of the equilibrium MC.

Table 2 summarizes the storage temperatures and durations corresponding to the different MC levels for both seedlots. For seedlot 1, the initial MC of fresh mature seeds was 44.6 ± 0.9% (Table 1). Following dehydration, four MC levels were established: 5.1 ± 0.2% (after 23.2 days of drying), 8.8 ± 0.3% (19.3 days), 11.5 ± 0.5% (14.7 days), and 14.6 ± 0.6% (8.9 days) (Table 2). Seedlot 2 had an initial MC of 42.6 ± 0.3%, and 5 MC levels were controlled at 2.5 ± 0.1% (30.2 days of drying), 4.4 ± 0.2% (21.4 days), 9.0 ± 0.5% (18.7 days), 13.8 ± 0.9% (14.5 days), and 19.9 ± 0.8% (10.1 days) after dehydration. Upon reaching the target MC, seeds were sealed in double-layer aluminum foil bags and stored at designated temperatures.

Data analysis

Seed germination percentages were analyzed using analysis of variance (ANOVA) to assess the effects of moist, bare, and dry storage durations on germination. Furthermore, the interactive effects of storage temperature, MC, and storage period on germination were evaluated using the general linear model (GLM) procedure in R statistical software (The R Foundation).

RESULTS

Germination of fresh mature seeds

Under incubation at alternating temperatures of 30/20℃ (day/night) for 12 weeks, fresh mature seeds of *D. vaccinioides* from seedlot 1 exhibited a germination percentage of 83.0 ± 9.9%, with an MGT of 30.1 ± 1.0 days. Seeds from seedlot 2, tested under the same conditions, showed a germination percentage of 92.5 ± 8.3% and an MGT of 30.0 ± 0.7 days (Table 1). In both seedlots, germination was concentrated between weeks 3 and 5, during which approximately 88% (seedlot 1) and 86% (seedlot 2) of viable seeds germinated. Little to no germination was observed after week 7 (Figure 2). Upon dissection at the end of the 12-week test, all ungerminated seeds were found to have decayed. These findings suggest that *D. vaccinioides* seeds exhibit shallow dormancy and germinate at a relatively slower rate compared to most non-dormant woody species.

Effects of moist storage at 4℃ on germination of fresh mature seeds

To evaluate the impact of low-temperature moist storage on seed germination, germination percentage and MGT were assessed for the 2 seedlots of *D. vaccinioides*. In seedlot 1, seeds stored moist at 4℃ for 1 to 5 months exhibited germination percentages ranging from 71.0 to 84.0%, which were not significantly different from those of fresh mature seeds (83.0%; $p > 0.1$) (Figure 3). However, after 6 months of moist storage, germination percentage declined significantly to 54.0 ± 7.2% ($p = 0.006$). Seed viability continued to decrease with prolonged storage, and no germination was observed after 11 months. Changes in MGT were also observed over the course of storage. Seeds stored for 2 and 4 months at 4℃ exhibited significantly shorter MGT of 26.0 ± 1.0 and 25.0 ± 1.4 days, respectively, compared to fresh mature seeds (30.1 days; $p = 0.003$ and $p = 0.002$) (Figure 3). In contrast, seeds stored

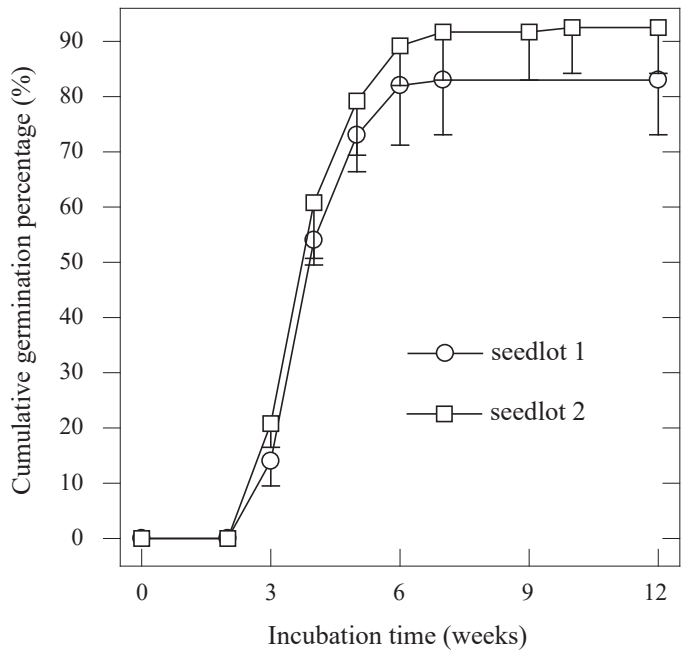

Figure 2. Cumulative germination percentages of fresh mature seeds from the 2 seedlots of *Diospyros vaccinioides*. Vertical bars indicate the standard error of the mean.

for longer durations displayed progressively slower germination rates. MGT increased to 34.6, 43.3, 54.7, and 64.2 days after 6, 7, 8, and 9 months of storage, respectively, all of which were significantly longer than the MGT of fresh mature seeds ($p < 0.03$). These results indicate that short-term moist storage at 4℃ can temporarily improve germination speed, while prolonged storage beyond 6 months leads to a decline in both germination percentage and germination rate (Figure 3).

For seedlot 2, seeds subjected to moist storage at 4℃ for 1 and 3 months showed germination percentages of 93.3 and 91.7%, respectively, which were not significantly different from that of fresh mature seeds (92.5%; $p = 0.89$ and $p = 0.88$) (Figure 4). However, extending the moist storage period to 6 months resulted in a significant decline in germination percentage to 56.7 ± 7.1% ($p = 0.001$). Further storage led to rapid loss of viability, and seeds completely lost germinability after 12 months of storage at 4℃. MGT after 1, 3, and 6 months of moist storage were 34.8, 27.6, and 32.7 days, respectively. These values did not differ significantly from the MGT of fresh mature seeds (30.3 days; $p = 0.05$, 0.06, and 0.12) (Figure 4). However, after 9 months of moist storage, MGT significantly increased to 57.6 days ($p = 0.004$), indicating a substantial delay in germination speed associated with prolonged storage.

Effects of bare storage at 4℃ on germination of fresh mature seeds

To examine the influence of low-temperature bare storage on seed germination, germination percentage and MGT were assessed in seedlot 2 of *D. vaccinioides*. Seeds stored bare at 4℃ for 1, 3, 6, and 9 months maintained high germination percentages of

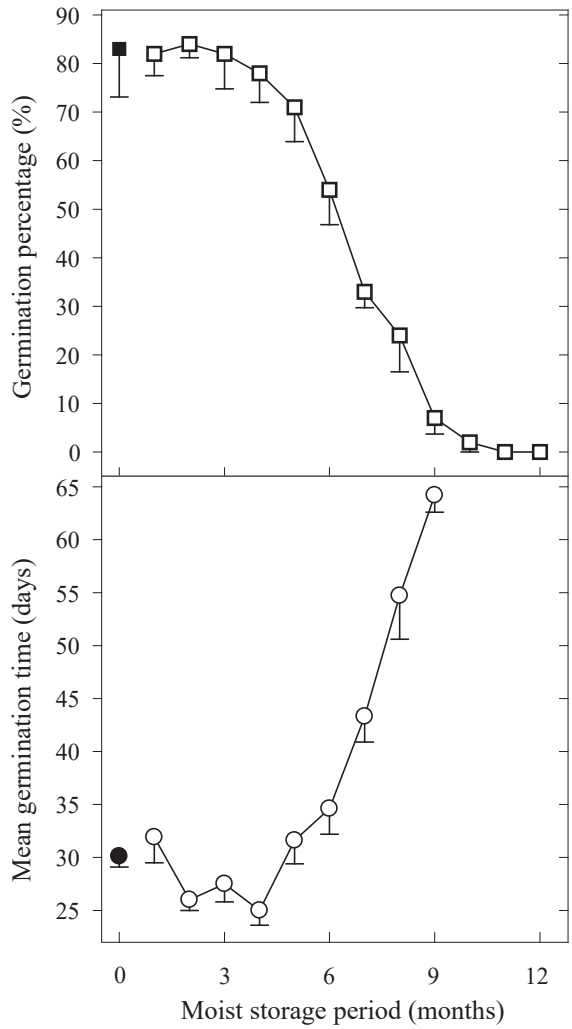

Figure 3. Effects of moist storage at 4℃ for 0 to 12 months on the germination percentage (□) and mean germination time (○) of *Diospyros vaccinioides* seeds from seedlot 1. Filled squares (■) and filled circles (●) indicate the germination percentage and mean germination time of fresh mature seeds, respectively. Vertical bars represent the standard error of the mean.

96.7, 90.0, 86.7, and 80.8%, respectively. These values did not differ significantly from those of fresh mature seeds (92.5%; $p > 0.09$) (Figure 4). However, after 12 months of storage, the germination percentage declined significantly to 74.2 ± 7.6% ($p = 0.03$). Prolonged storage beyond this point led to a rapid loss of viability, and seeds completely lost germinability after 18 months at 4℃.

MGT remained statistically unchanged after 1 and 3 months of storage, at 31.9 and 29.8 days, respectively ($p > 0.05$ compared to 30.3 days in fresh seeds) (Figure 4). Interestingly, MGT were significantly shortened following 6 and 9 months of bare storage, decreasing to 24.0 and 24.7 days, respectively ($p = 0.0002$ and $p = 0.0001$). However, after 12 months of storage, MGT significantly increased to

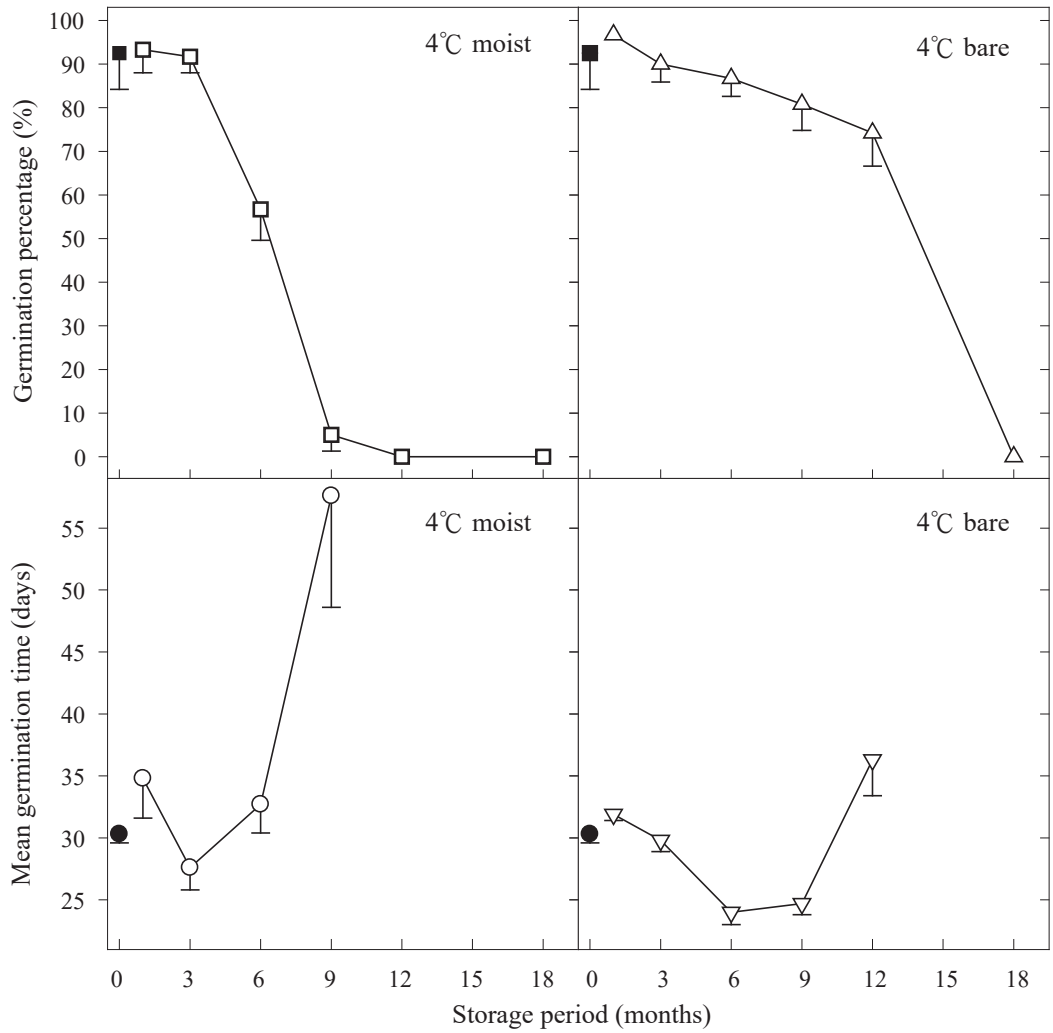

Figure 4. Effects of moist and bare storage at 4℃ for 0 to 18 months on the germination percentage (□, △) and mean germination time (○, ▽) of *Diospyros vaccinioides* seeds from seedlot 2. Filled squares (■) and filled circles (●) represent the germination percentage and mean germination time of fresh mature seeds, respectively. Vertical bars indicate the standard error of the mean.

36.3 days (p = 0.01), indicating a delay in germination associated with extended storage duration.

Effects of moisture content, storage temperature, and duration on seed viability

Figures 5 and 6 illustrate the effects of varying seed MCs and storage temperatures on the germination percentage of *D. vaccinioides* seeds from seedlots 1 and 2 under dry storage conditions for up to 24 months.

Seedlot 1

Immediately following dehydration, freshly dried seeds at 4 different MCs were incubated under alternating temperatures

of 30/20℃ for 12 weeks to assess initial viability. Seeds at an MC of 14.6% exhibited a germination percentage of 80.0 ± 6.3%, which was not significantly different from that of fresh mature seeds (83.0%; $p = 0.7$). However, germination significantly declined with decreasing MC. Seeds with MCs of 11.5% and 8.8% showed reduced germination percentages of 60.0 ± 9.4 and 46.0 ± 8.7%, respectively, with the latter being significantly lower than fresh mature seeds ($p = 0.3$ and $p = 0.003$, respectively). Complete loss of viability occurred when seeds were dried to an MC of 5.1%, as no germination was observed (Figure 5).

During storage at -20℃, seed viability of seedlot 1 varied depending on initial MC. Seeds stored at an MC of 14.6% exhibited a rapid decline in germination. Germination percentage significantly decreased to 61.0% after just 3 months ($p = 0.01$) and continued to decline, reaching 33.0% after 24 months (Figure 5). In contrast, seeds at an MC of 11.5% showed relatively stable germination percentages (46.0-51.0%) over the first 12 months of storage, with no significant differences from the freshly dried seeds (60.0%; $p > 0.05$). However, by 18 and 24 months, germination had significantly decreased to 40.0 and 37.0%, respectively ($p = 0.02$ and $p = 0.007$). Seeds with an initial MC of 8.8% maintained similar germinability throughout the 24-month storage period, with germination percentages ranging from 40.0% to 46.0%, not significantly different from freshly dried seeds (46.0%) (Figure 5).

When seeds from seedlot 1 were stored at 4℃, germination percentages after 24 months were 74.0, 61.0, and 41.0% for seeds with initial MCs of 14.6, 11.5, and 8.8%, respectively. These values were not significantly different from those of the corresponding freshly dried seeds (80.0, 60.0, and 46.0%; $p = 0.5$, 0.9, and 0.4, respectively) (Figure 5).

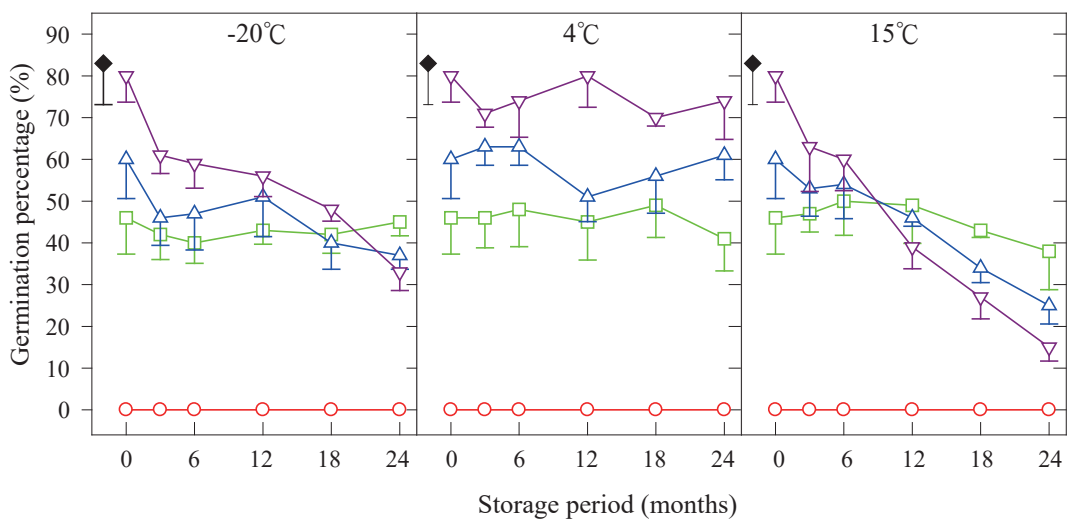

Figure 5. Effects of storage temperatures (-20, 4, and 15℃) and moisture contents (MCs; fresh-weight basis) on the germination percentage of *Diospyros vaccinioides* seeds from seedlot 1 over 24 months of storage. The initial germination percentage of fresh mature seeds was 83.0 ± 9.9% (◆). Seed MCs were as follows: ○, 5.1 ± 0.2%; □, 8.8 ± 0.3%; △, 11.5 ± 0.5%; ▽, 14.6 ± 0.6%. Vertical bars indicate standard errors of the mean.

When seeds from seedlot 1 were stored at 15℃, those with initial MCs of 14.6 and 11.5% experienced a more rapid decline in viability compared to seeds stored at -20 or 4℃. After 24 months of storage, germination percentages dropped significantly to 15.0 and 25.0%, respectively, relative to their freshly dried counterparts (p = 0.000004 and p = 0.001) (Figure 5). In contrast, seeds with an MC of 8.8% maintained relatively stable germination percentages ranging from 38.0 to 50.0% throughout the 24-month storage period. These values were not significantly different from the germination percentage of freshly dried seeds (46.0%; $p > 0.3$).

Seedlot 2

Following dehydration, freshly dried seeds from seedlot 2 at 5 different MCs were immediately incubated under alternating temperatures of 30/20℃ for 12 weeks to assess initial germinability. Seeds with MCs of 19.9 and 13.8% exhibited germination percentages of 86.1 ± 2.3 and 78.8 ± 10.6%, respectively. These values were not significantly different from those of fresh mature seeds (92.5%; p = 0.2 and p = 0.1). In contrast, seeds dried to an MC of 9.0% showed a significant reduction in germination (55.6 ± 4.5%; p = 0.005). No germination was observed in seeds dried to MCs of 4.4 or 2.5%, indicating complete loss of viability at these 2 lower moisture levels (Figure 6).

During cryogenic storage at -196℃, seed viability of seedlot 2 was highly dependent on initial MC. Seeds with an MC of 19.9% exhibited a complete loss of viability after just 1 month of storage, with no germination observed. Similarly, seeds at an MC of 13.8% showed a sharp decline in germination, dropping to 20.0% after 1 month. Germination remained low during extended storage, ranging from 6.7% to 22.7% between 3 and 24 months, all significantly lower than the freshly dried seeds (78.8%; $p < 0.00001$). In contrast, seeds stored at an MC of 9.0% maintained relatively stable germination percentages between 42.9 and 66.7% throughout the 24-month storage period. These values were not significantly different from

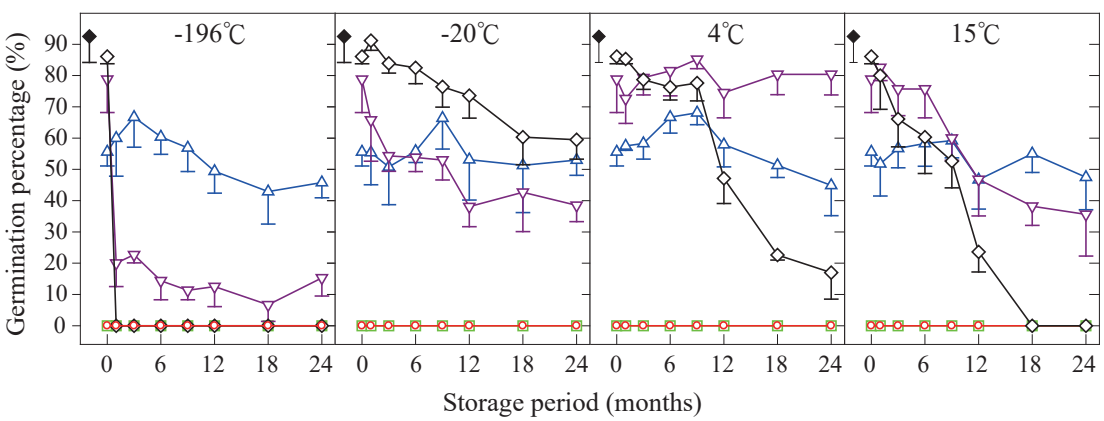

Figure 6. Effects of storage temperatures (-196, -20, 4, and 15℃) and seed moisture contents (MCs; fresh-weight basis) on the germination percentage of *Diospyros vaccinioides* seeds from seedlot 2 over 24 months of storage. The initial germination percentage of fresh mature seeds was 92.5 ± 8.3% (◆). Seed MCs were as follows: ○, 2.5 ± 0.1%; □, 4.4 ± 0.2%; △, 9.0 ± 0.5%; ▽, 13.8 ± 0.9%; ◇, 19.9 ± 0.8%. Vertical bars indicate standard errors of the mean.

the freshly dried seeds (55.6%; $p > 0.09$), indicating that lower MC at 9.0% improved tolerance to cryogenic storage (Figure 6).

When seeds from seedlot 2 were stored at -20℃, germination percentages declined over time, particularly in seeds with higher initial MCs at 19.9 and 13.8%. Seeds at an MC of 19.9% maintained high viability for the first 6 months, with germination percentages ranging from 82.5 to 91.2%, which were not significantly different from fresh mature seeds (92.5%; $p > 0.1$). However, a significant reduction to 74.6% was observed after 9 months ($p = 0.04$), followed by a continued decline to 59.5% at 24 months. Similarly, seeds at an MC of 13.8% exhibited a progressive loss of viability throughout the storage period, with germination decreasing to 38.5% after 24 months—a significant reduction compared to fresh mature seeds ($p = 0.00007$). In contrast, seeds stored at an MC of 9.0% maintained germination percentages between 50.8 and 66.4% over the 24-month period. While these values were significantly lower than those of fresh mature seeds (92.5%; $p < 0.003$), they were not significantly different from the freshly dried seeds (55.6%; $p > 0.1$) (Figure 6).

During storage at 4℃, seed viability of seedlot 2 varied notably with initial MC. Seeds with an MC of 19.9% exhibited a rapid decline in germination percentage, decreasing significantly to 76.3% after 6 months ($p = 0.02$), and continuing to decline sharply to 17.0% after 24 months of storage. In contrast, seeds at an MC of 13.8% maintained relatively high germination percentages, from 72.6 to 85.2% throughout the 24-month period. Although germination declined to 80.4% at 24 months, this reduction was not statistically significant when compared to fresh mature seeds (92.5%; $p = 0.1$). Furthermore, seeds stored at an MC of 9.0% showed germination percentages between 44.9 and 68.1% over the 24 months. While these values were significantly lower than those of fresh mature seeds (92.5%; $p < 0.005$), they did not differ significantly from freshly dried seeds (55.6%; $p > 0.1$) (Figure 6).

At 15℃, seed viability in seedlot 2 declined more rapidly than at -20 or 4℃, particularly at higher moisture contents. Seeds with an initial MC of 19.9% exhibited accelerated deterioration and were completely non-viable after 18 months of storage. Similarly, seeds at an MC of 13.8% experienced a faster decline in germination compared to those stored at lower temperatures. After 24 months, germination had significantly decreased to 35.6%, compared to 92.5% in fresh mature seeds ($p = 0.0008$). In contrast, seeds stored at an MC of 9.0% maintained germination percentages between 46.7 and 59.2% throughout the 24-month period. Although these values were significantly lower than those observed in fresh mature seeds (92.5%; $p < 0.001$), they did not differ significantly from those of freshly dried seeds (55.6%; $p > 0.2$) (Figure 6).

DISCUSSION

The results of this study suggest that a portion of fresh mature seeds of *D. vaccinioides* exhibit shallow dormancy, as evidenced by their delayed germination. Although these seeds were viable, none germinated within the first 30 days, and it took approximately 9 weeks to achieve full germination, with an MGT of around 30 days (Figure 2). The delayed germination indicates that some seeds likely possess mechanical dormancy due to their hard and thick seed coat (Baskin and Baskin 2014). Nevertheless, moist storage at 4℃—essentially simulating cold stratification—was insufficient to fully

overcome this dormancy. Moreover, chilling injury was observed when the duration of cold storage exceeded 6 months (Figure 3, 4). Based on these findings, and in the absence of a more effective dormancy-breaking treatment, we recommend incubating *D. vaccinioides* seeds at alternating temperatures of 30/20℃ for up to 2 months to achieve optimal germination. Although this approach may extend the germination period, it does not result in significant seed mortality (Figure 2).

The results of this study demonstrate that seeds from both seedlots of *D. vaccinioides* were able to tolerate desiccation to approximately 13% MC without a significant loss in viability, and retained nearly their original viability after 2 years of storage at 4℃. In contrast, seeds dried to below 5% MC exhibited complete loss of viability. Furthermore, seeds stored at MCs ranging from 8 to 20% experienced marked viability loss when stored at -196 and -20℃ for up to 2 years (Figures 5, 6). These patterns—specifically, the rapid decline in viability at very low MC and the intolerance to prolonged exposure to sub-zero temperatures—differ markedly from the behavior of orthodox seeds. Based on these findings, seeds of *Diospyros vaccinioides* are best classified as exhibiting temperate intermediate seed storage behavior—characterized by moderate tolerance to desiccation and sensitivity to freezing temperatures—while still maintaining high viability when stored at 4℃. Therefore, we recommend adjusting the MC of fresh mature seeds to 13-15%, followed by immediate hermetic sealing and storage at 4℃. Due to the relatively short lifespan of intermediate seeds and the challenges associated with their long-term storage, we suggest that stored seeds of *D. vaccinioides* be regenerated or replaced approximately every 6 to 10 years to ensure viability in *ex situ* conservation programs.

The genus *Diospyros* comprises over 700 species worldwide; however, only limited studies have investigated the seed storage behavior of ebony and persimmon species. Interestingly, seeds of *Diospyros* exhibit a wide range of storage behaviors across the genus. For instance, seeds of *D. mollis* and *D. mun* display orthodox storage behavior (Ellis et al. 2007), while those of *D. malabarica* (Ellis et al. 2007) and *D. philippensis* (Yang et al. 2008a) have been classified as recalcitrant. Additionally, intermediate storage behavior has been reported in *D. melanoxylon* (Malik et al. 2011) and *D. glandulosa* (Waiboonya et al. 2019). Yang (2019) provided a brief overview of the seed storage behavior of six native *Diospyros* species in Taiwan, suggesting that the seeds of *D. ferrea* (Willd.) Bakhuizen, *D. kotoensis* Yamazaki, and *D. philippensis* (Desr.) Gürke exhibit tropical recalcitrant behavior, those of *D. morrisiana* Hance may be temperate recalcitrant, *D. japonica* Sieb. & Zucc. may tend toward orthodox behavior, and *D. vaccinioides* may possess intermediate storage behavior. However, these classifications were presented as preliminary assessments and were not supported by experimental data. Consequently, empirical evidence remains necessary to substantiate these proposed storage behavior classifications.

Most intermediate seeds are capable of surviving desiccation when their MC is maintained within the range of 10-12%; however, their germinability generally declines as MC decreases (Hong and Ellis 1996). Notably, some intermediate seeds exhibit greater desiccation tolerance, with optimal storage MCs falling below this typical range (<10%). Examples of such species include *Khaya senegalensis* and

Swietenia macrophylla (Hong and Ellis 1998), *Coffea canephora*, *C. congensis*, and *C. racemosa* (Dussert et al. 1999, Eira et al. 1999), *Acer morrisonense* (Yang and Lin 1999), *Citrus limon* (Hong et al. 2001), *Fagus crenata* (Pedro and Ellis 2002), *Bischofia javanica* (Yang et al. 2006), *Zelkova serrata* (Yang et al. 2007), and *Litsea coreana* (Yang et al. 2008b). In contrast, the estimated optimal MC for storing *D. vaccinioides* seeds is approximately 13-15%, which is slightly higher than the typical range observed in most intermediate seeds. This suggests that while *D. vaccinioides* seeds exhibit comparatively lower desiccation tolerance than many other intermediate species, they are nonetheless not as highly desiccation-sensitive as recalcitrant seeds.

Seeds exhibit remarkable flexibility in adapting to their native ecological environments. Tropical intermediate seeds, in particular, frequently lose viability rapidly when exposed to sub-zero temperatures—much more so than their temperate counterparts (Hong and Ellis 1996). According to Hong and Ellis (1996), optimal storage temperatures for tropical intermediate seeds are generally ≥ 10℃. Representative species exhibiting this tropical intermediate behavior include *Elaeis guineensis* (Ellis et al. 1991b), various *Coffea* species (Ellis et al. 1990a, 1991a; Hong and Ellis 1992, 1995; Dussert et al. 1999, Eira et al. 1999), *Azadirachta indica* (Gamene et al. 1996, Hong and Ellis 1998, Nayal et al. 2000), *Khaya senegalensis* and *Swietenia macrophylla* (Hong and Ellis 1998), and *Phoenix reclinata* (von Fintel et al. 2004). In contrast, temperate intermediate seeds better tolerate low or sub-zero conditions, making ≤ 5℃ more suitable for their optimal storage (Hong and Ellis 1996). Examples of such seeds that withstand freezing include *Araucaria columnaris* (Tompsett 1984), *Citrus limon* (Hong et al. 2001), *Fagus sylvatica*, *F. crenata* (Pedro and Ellis 2002), and *Zizania palustris* (Berjak et al. 1994, Vertucci et al. 1994, 1995; Hong and Ellis 1996, White and Jayas 1996, Ntuli et al. 1997). Notably, temperate-origin intermediate seeds from *Calocedrus macrolepis* var. *formosana* (Yang 2021) and the Aceraceae (Yang and Lin 1999) in Taiwan also exhibit strong cold tolerance and long potential storage lifespans—estimated at 10-20 years under appropriate conditions.

Nevertheless, seeds of certain Taiwanese tree species exhibiting temperate intermediate storage behavior remain highly sensitive to freezing temperatures, likely due to their long-term adaptation to the island's subtropical climate, which is characterized by relatively high temperatures and humidity. For these, the most effective preservation method is moist storage at approximately 4℃. Examples include species in the Lauraceae such as *Cinnamomum camphora* (Chien and Lin 1999), *C. subavenium* (Lin 1996), *Neolitsea parvigemma* (Lin 1996), *Lindera communis* (Chien et al. 2004), *L. megaphylla* (Lin 1996, Chien et al. 2004), and L. coreana (Yang et al. 2008b). These species typically produce relatively large seeds (length > 5 mm) with high initial moisture content (ca. 25-38%) within fleshy fruits.

Interestingly, mature seeds of *Diospyros vaccinioides*—which exhibit relatively high MC (> 40%) and are comparable in size to intermediate seeds of Lauraceae species—were able to retain approximately 50% germinability after 2 years of storage at -20℃ (Figure 5, 6). This suggests that *D. vaccinioides* seeds possess greater freezing tolerance than the intermediate seeds of Taiwanese Lauraceae (Lin 1996, Yang et al. 2008b), which are generally highly sensitive to sub-zero temperatures. However, their

freezing tolerance remains lower than that observed in intermediate seeds of *Acer* spp. (Yang and Lin 1999), which originate from dry fruits and exhibit superior cold resilience under similar storage conditions.

CONCLUSIONS

Seeds of *D. vaccinioides* exhibit shallow dormancy. Under alternating temperatures of 30/20°C, germination occurred sporadically between weeks 3 and 7, with approximately seven weeks required to complete germination. Cold moist storage and bare storage were unsuitable for seed preservation; when seeds were subjected to moist storage or direct bare storage at 4℃, viability declined sharply and was nearly lost after approximately 9 and 18 months, respectively. The seeds of *D. vaccinioides* can be classified as having a temperate intermediate storage behavior. Optimal storage is achieved by immediately drying freshly harvested seeds to a moisture content of 13–15%, followed by sealed storage at 4℃, under which original viability can be maintained for up to two years. Given the relatively short storage longevity of *D. vaccinioides* seeds, long-term *ex situ* conservation through seed banking alone is challenging. Therefore, it is recommended that stored seed stocks be regenerated approximately every 6–10 years to support short- to medium-term germplasm conservation of this critically endangered species.

LITERATURE CITED

Baskin CC, Baskin JM. 2014. Seeds: Ecology, biogeography, and evolution of dormancy and germination. San Diego: Academic Press. 1600 p.

Berjak P, Bradford KJ, Kovach DA, Pammenter NW. 1994. Differential effects of temperature on ultrastructural responses to dehydration in seeds of *Zizania palustris*. Seed Sci Res 4(2):111-21.

Bonner FT. 1990. Storage of seeds: potential and limitations for germplasm conservation. For Ecol Manag 35(1-2):35-43.

Chien CT, Lin TP. 1999. Effects of moisture content and temperature on the storage and germination of *Cinnamomum camphora* seeds. Seed Sci Technol 27:315-20.

Chien CT, Yang JC, Lin TP. 2004. Seed storage behavior of *Lindera communis, Lindera megaphylla*, *Phoebe formosana*, *Helicia cochinchinensis*, and *Helicia formosana* in Taiwan. Taiwan J For Sci 19(2):119-31. [in Chinese with English abstract].

Dussert S, Chabrillange N, Engelmann F, Hamon S. 1999. Quantitative estimation of seed desiccation sensitivity using a quantal response model: application to nine species of the genus *Coffea* L. Seed Sci Res 9:135-44.

Editorial Committee of the Red List of Taiwan Plants. 2017. The red list of vascular plants of Taiwan, 2017. Chichi, Taiwan: Endemic Species Research Institute, Forestry Bureau, Council of Agriculture, Executive Yuan, and Taiwan Society of Plant Systematics. 187 p.

Eira MTS, Walters C, Caldas LS, Fazuoli LC, Sampaio JB, Dias MCLL. 1999. Tolerance of *Coffea* spp. seeds to desiccation and low temperature. Rev Bras Fisiol Veg 11:97-105.

Ellis RH, Hong TD, Roberts EH. 1990a. An intermediate category of seed storage behaviour? J Exp Bot 41(230):1167-74. http://www.jstor.org/stable/23695125

Ellis RH, Hong TD, Roberts EH. 1990b. Effect of moisture content and method of rehydration on the susceptibility of pea seeds to imbibition damage. Seed Sci Technol 18:131-7.

Ellis RH, Hong TD, Roberts EH. 1991a.

An intermediate category of seed storage behavior? Effects of provenance, immaturity, and imbibition on desiccation-tolerance in coffee. J Exp Bot 42:653-7.

Ellis RH, Hong TD, Roberts EH, Soetisna U. 1991b. Seed storage behavior in *Elaeis guineensis*. Seed Sci Res 1(2):99-104.

Ellis RH, Hong TM, Hong TD, et al. 2007. Comparative analysis by protocol and key of seed storage behaviour of sixty Vietnamese tree species. Seed Sci Technol 35(2):460-76.

Gamene CS, Kraak HL, VanPijlen JG, De Vos CHR. 1996. Storage behaviour of neem (*Azadirachta indica*) seeds from Burkina Faso. Seed Sci Technol 24:441-8.

Hartmann HT, Kester DE, Davies FT. 1989. Plant propagation: principles and practices. 5th ed. Englewood Cliffs, NJ: Prentice-Hall. 647 p.

Hong TD, Ahmad NB, Murdoch AJ. 2001. Optimum air-dry storage conditions for sweet orange (*Citrus sinensis* (L.) Osbeck) and lemon (*Citrus limon* (L.) Burm. f.) seeds. Seed Sci Technol 29(1):183-92.

Hong TD, Ellis RH. 1992. Optimum air-dry seed storage environments for Arabica coffee. Seed Sci Technol 20:547-60.

Hong TD, Ellis RH. 1995. Interspecific variation in seed storage behaviour within two genera – *Coffea* and *Citrus*. Seed Sci Technol 23:165-81.

Hong TD, Ellis RH. 1996. A protocol to determine seed storage behavior. IPGRI Technical Bulletin no. 1. Rome: International Plant Genetic Resources Institute (IPGRI). 62 p.

Hong TD, Ellis RH. 1998. Contrasting seed storage behaviour among different species of Meliaceae. Seed Sci Technol 26:77-95.

International Seed Testing Association. 1999. International rules for seed testing. Rules 1999. Seed Sci Technol 27(Suppl). 333 p.

Liao LH, Lu SU, Yang YP. 1998. Ebenaceae. In: Editorial Committee of the Flora of Taiwan. Flora of Taiwan. 2nd ed., Vol. 4, Taipei, Taiwan: Department of Botany, National Taiwan University. p 88-94.

Lin TP. 1996. Seed storage behaviour deviating from the orthodox and recalcitrant type. Seed Sci Technol 24:523-32.

Lin TP, Chen MC. 1993. Desiccation intolerance in seeds of *Machilus kusanoi* Hay. Taiwan For Res Inst New Series 8(2):143-7. [in Chinese with English abstract].

Lu SU, Lin MJ. 1996. Rare and endangered plants in Taiwan (I). Taipei, Taiwan: Council of Agriculture. 163 p. [in Chinese].

Malik SK, Chaudhury R, Kalia RK, Dulloo E. 2011. Seed storage characteristics and cryopreservation of genetic resources of tropical underutilized fruits in India. Acta Hortic 918:189-98.

Nayal JS, Thapliyal RC, Rawat MMS, Phartyal SS. 2000. Desiccation tolerance and storage behaviour of neem (*Azadirachta indica* A. Juss.) seeds. Seed Sci Technol 28(3):761-7.

Ntuli TM, Berjak P, Pammenter NW, Smith MT. 1997. Effects of temperature on the desiccation responses of seeds of *Zizania palustris*. Seed Sci Res 7(2):145-60.

Pedro LL, Ellis RH. 2002. Seed storage behaviour of *Fagus sylvatica* and *Fagus crenata*. Seed Sci Res 12:31-7.

Roberts EH. 1973. Predicting the storage life of seeds. Seed Sci Technol 1:499-514.

Tompsett PB. 1984. The effect of moisture content and temperature on the seed storage life of *Araucaria columnaris*. Seed Sci Technol 12:801-16.

Vertucci CW, Crane J, Porter RA, Oelke EA. 1994. Physical properties of water in *Zizania* embryos in relation to maturity status, water content and temperature. Seed Sci Res 4:211-24.

Vertucci CW, Crane J, Porter RA, Oelke EA. 1995. Survival of *Zizania* embryos in

relation to water content, temperature and maturity status. Seed Sci Res 5(1):31-40.

von Fintel GT, Berjak P, Pammenter NW. 2004. Seed behaviour in *Phoenix reclinata* Jacquin, the wild date palm. Seed Sci Res 14:197-204.

Waiboonya P, Elliott S, Tiansawat P. 2019. Seed Storage Behaviour of Native Forest Tree Species of Northern Thailand. Environment Asia 12(3):104-11.

White NDG, Jayas DS. 1996. Deterioration during storage in wild rice, *Zizania palustris*, and polished basmati rice, *Oryza sativa*, and potential for insect infestation. Seed Sci Technol 24:261-71.

Yang JC. 2019. Harvesting, germination, and storage of seeds of six native Taiwanese *Diospyros* species. For Res Newsl 26(5):40-4. [in Chinese].

Yang JC, Kuo SR, Lin CL. 2021. Seed germination and storage behavior of Taiwan incense-cedar (*Calocedrus macrolepis* Kurz var. *formosana* (Florin) Cheng & L. K. Fu). Taiwan J For Sci 36(3):171-88.

Yang JC, Kuo SR, Lin TP. 2007. Intermediate storage behavior and the effect of prechilling on germination of Japanese zelkova (*Zelkova serrata*) seeds. Seed Sci Technol 35:99-110.

Yang JC, Kuo SR, Lee CM. 2008a. Germination and storage behavior of seeds of *Litsea garciae*, *Diospyros philippensis*, and *Myristica ceylanica* var. *cagayanensis*. Q J Chin For 41(3):309-21. [in Chinese with English abstract].

Yang JC, Kuo SR, Lee CM. 2008b. Germination and storage behavior of seeds of *Litsea coreana* Levl. Taiwan J For Sci 23(4):309-21.

Yang JC, Lin TP. 1999. The seed storage behavior of five species of *Acer*. Taiwan J For Sci 14(4):479-92. [in Chinese with English abstract].

Yang JC, Lin TP, Kuo SR. 2006. Seed storage behavior of *Sapium discolor* Muell.-Arg. and *Bischofia javanica* Blume. Taiwan J For Sci 21(4):433-45. [in Chinese with English abstract].

研究報告

楓港柿(*Diospyros vaccinioides* Lindl.)種子的中間型儲藏特性

楊正釧[1]

摘　要

背景

楓港柿(*Diospyros vaccinioides* Lindl.)是柿樹科(Ebenaceae)的常綠灌木或小喬木，僅原生於海南島、香港、廣東及臺灣等地。本種在臺灣的天然族群僅出現於恆春半島的楓港村附近，因其地理分布範圍極小，且野生族群數量稀少，故被IUCN列為極危(Critically Endangered, 1998)等級，且在臺灣維管束植物紅皮書(2017)被列為資料缺乏(Data Deficient, DD)，足見其在野外已經是非常稀有。又因其樹型優美且枝葉濃密，故目前它在臺灣不僅是稀有瀕危植物，也是極具觀賞價值的園藝樹種。本研究以細緻的試驗設計探討楓港柿種子的發芽及儲藏特性，來明確判斷其儲藏性質並界定其最佳的儲藏條件，進而評估以儲藏種子方式作為本種種原長期保存利用之可行性，以建立復育本重要原生瀕危及景觀樹種之基本參考資料。

材料與方法

供試的2批楓港柿種子分別為2004與2015年採於屏東縣恆春鎮及彰化縣溪湖鄉的多株栽植母樹，將洗淨種子以水選及人工篩選剔除輕粒及劣粒後，以獲得試驗用精選種子，此時2批新鮮種子的含水率分別為44.6及42.6%。本研究各種處理之發芽率檢測均是以30/20℃變溫發芽(每日8小時的30℃；約5,000 Lux光照，及16小時的20℃；黑暗)，胚根突出1 cm且無任何不良性狀則視為正常發芽，發芽期為12週，每週記錄1次發芽數。以濕藏(本研究低溫濕藏方法與層積處理相同)與裸藏(Bare Storage，將未經乾燥的新鮮種子在不添加任何介質的狀態下進行低溫乾藏) 於4℃環境，經0-24個月等多個時間點的發芽率檢測數據，來探討不

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同低溫濕藏與裸藏時間對其種子活力之影響。此外，在種子儲藏性質的探討上，將第1批種子乾燥控制成5.1、8.8、11.5與14.6%；第2批種子控制成2.5、4.4、9.0、13.8與19.9%等4或5級含水率，並立即以雙層鋁箔袋密封儲藏於-196、-20、4或15℃等3或4種不同溫度，於0、1、3、6、9、12、18及24個月等6或8個儲藏時間點，檢驗各不同處理的種子發芽率，以探討不同含水率與溫度於儲藏期間對種子活力的影響。本研究各不同處理的發芽試驗：均是4重複，第1批每重複25粒；第2批每重複30粒。

結果與討論

本研究的2批楓港柿新鮮種子以30/20℃變溫發芽時，其起始發芽率分別為 83.0 ± 9.9和92.5 ± 8.3%，平均發芽時間為30.1天與30.0天，具活力的種子在7週後幾乎能發芽完畢，且在第3-7週分散發芽，但因約有35%種子無法在1個月內發芽，此顯示本種種子部分具有淺度休眠特性。以4℃層積(與濕藏方法相同)或4℃裸藏並無法解除其種子休眠，反而在4℃濕藏3個月後及4℃裸藏12個月後活力開始急遽下降，並分別約在9及18個月後完全喪失發芽能力，此結果有別於一般具休眠性種子能經由冷激(Chilling)程序來解除其休眠，因此，4℃濕藏及裸藏均沒有解除其種子休眠的效果，也均非其種子儲藏之良方。在尚未獲得有效解除其種子休眠的方法之前，建議以直播在溫室來育苗即可，即使如此，也只會花約2個月的稍長時間來完成發芽。

本研究乾藏之結果顯示楓港柿種子能耐乾燥至約含水率13%(鮮重)，並在4℃ 保存2年後仍能維持原有活力，其發芽率並無顯著下降趨勢。但當種子含水率被降低至< 5% 時，則活力立刻完全喪失。此外，將含水率8-20%的種子儲存在-196與-20℃時，各處理之發芽率在2年內均呈顯著衰敗趨勢。上述結果顯示楓港柿種子不符合正儲型種子能耐旱及耐零下低溫的特性。再者，本研究發現儲存楓港柿種子的溫度以4℃為最佳，-20℃次之，15℃又次之，而以-196℃最劣，且保存其種子的最佳水分狀態為含水率13-15%。綜上，楓港柿種子以優於異儲型種子的中等耐旱性，及對零下低溫敏感但能耐4℃低溫的特性，判斷其屬「溫帶中間型」。建議應將鮮採的成熟種子儘快且小心乾燥調控到含水率13-15%，並立刻密封儲藏在4℃的環境中。因楓港柿種子屬壽命不長的中間型，故難以用儲存種子方式來達到其長期的區外保育工作，並建議庫存種子應約每6-8年更新一次，以對此國家極危等級植物進行中短期的種原保存。

結論

楓港柿種子部分具休眠性，種子以30/20℃變溫發芽時，於第3-7週陸續零散發芽，且需約7週才能發芽完畢。低溫濕藏及裸藏並非保存楓港柿種子的良好方法，當其種子濕藏及直接裸藏在4℃時，分別約在9及18個月後就幾乎死亡殆盡。楓港柿種子屬「溫帶的中間型」，其最佳儲藏方法為將熟採種子立即乾燥到含水率13-15%，並密封儲藏在4℃的環境

中，於2年內仍能維持原有活力。因楓港柿種子的儲藏壽命不長，故難以用儲存種子方式來達到其長期的區外保育工作，建議庫存種子應約每6-8年更新一次，以對此極危等級植物進行中短期的種原保存。

關鍵詞：楓港柿、區外保育、發芽、中間型種子儲藏行為

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