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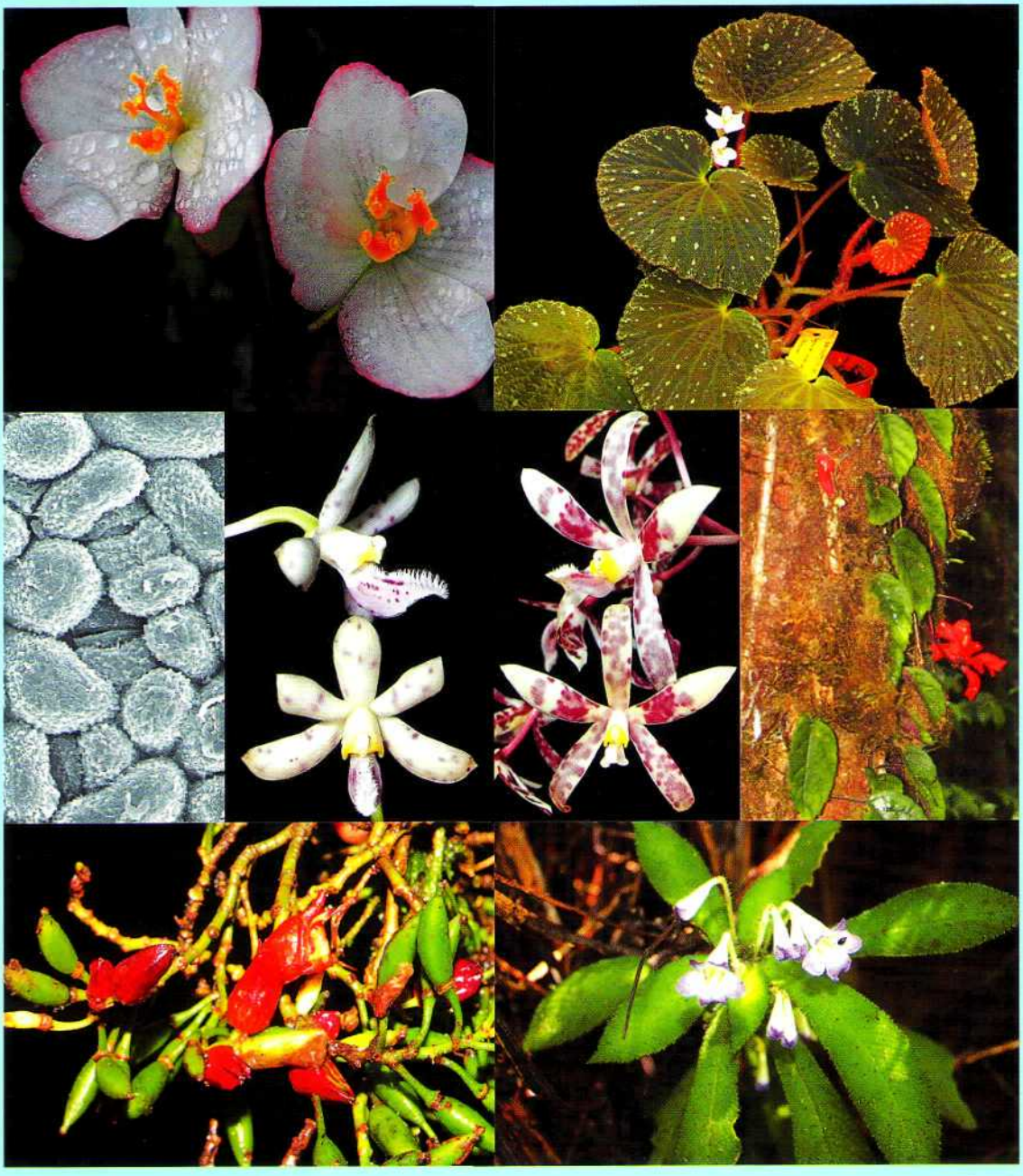

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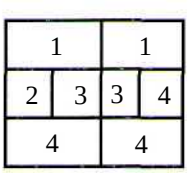

Cover images: 1. *Begonia holosericeoides* (female flower and habit) (Begoniaceae; Ardi *et al.); 2.* Abaxial cuticles of *Alseodaphne rhododendropsis* (Lauraceae; Nishida & van der Werff); *3. Dipodium puspitae, Dipodium purpureum* (Orchidaceae; O'Byrne); 4. *Agalmyla exannulata, Cyrtandra coccinea* var. *celebica, Codonoboea kjellbergii* (Gesneriaceae; Kartonegoro & Potter).

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A PHYSIOLOGICAL APPROACH TO CONSERVATION OF FOUR PALM SPECIES: ARENGA AUSTRALASICA, CALAMUS AUSTRALIS, HYDRIASTELE WENDLANDIANA AND LICUALA RAMSAYI

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ABSTRACT
LATIFAH, D., CONGDON, R. A. & HOLTUM, J. A. 2014. Physiological approach of four palm species conservation: *Arenga australasica*, *Calamus australis*, *Hydriastele wendlandiana* and *Licuala ramsayi*. *Reinwardtia* 14(1): 237 – 247. — Palms (Arecaceae) are an important component of many tropical rainforests. Many have also been cultivated widely for agricultural commodities with high economic value. They are also important components in rehabilitation of disturbed or marginal lands. Knowledge and application of germination strategies are essential in the cultivation of palms. Many species have seeds that do not germinate readily, even when light conditions are favourable. This research determined the effects of seed coats, light and temperature on germination of *Arenga australasica* (H. Wendl. & Drude) S. T. Blake *ex* H. E. Moore, *Calamus australis* Mart., *Hydriastele wendlandiana* (F. Muell.) H. Wendl. & Drude and *Licuala ramsayi* var. *tuckeri* Barford & Dowe. We examined physical treatments to promote germination or break dormancy, as well as different light and temperature conditions. The results showed that the hard seed coats of the four species slowed imbibition. Scarified seeds germinated best for *A. australasica*, *C. australis* and *L. ramsayi*. The germination of all seeds was inhibited by far red light. The red light requirement suggests that these species prefer to colonise open areas. This implies that dispersal agents, canopy gaps and forest margins may play important roles in promoting regeneration as well as conservation of these palm species.

Key words: *Arenga australasica*, *Calamus australis*, germination, *Hydriastele wendlandiana, Licuala ramsayi*, palms.

ABSTRAK
LATIFAH, D., CONGDON, R. A. & HOLTUM, J. A. 2014. Pendekatan fisiologi pada konservasi empat jenis palem: *Arenga australasica, Calamus australis, Hydriastele wendlandiana* dan *Licuala ramsayi*. *Reinwardtia* 14(1): 237 – 247. — Palem (Arecaceae) adalah komponen penting di hutan hujan tropis. Banyak jenis yang dibudidaya secara luas untuk komoditi pertanian dengan nilai ekonomi yang tinggi. Selain itu palem juga penting untuk merehabilitasi lahan-lahan marginal atau terganggu. Pengetahuan serta aplikasi strategi perkecambahan sangat penting dalam pembudidayaan palem. Banyak jenis yang mempunyai biji yang tidak langsung berkecambah walaupun dalam kondisi cahaya yang sesuai. Penelitian ini bertujuan untuk mengetahui pengaruh pelindung biji, cahaya dan suhu pada perkecambahan *Arenga australasica* (H. Wendl. & Drude) S. T. Blake *ex* H.E. Moore, *Calamus australis* Mart., *Hydriastele wendlandiana* (F. Muell.) H. Wendl. & Drude dan *Licuala ramsayi* var. *tuckeri* Barford & Dowe. Karakter fisik telah diamati untuk merangsang perkecambahan atau memecah dormansi demikian juga dengan perbedaan cahaya dan kondisi suhu. Hasil penelitian menunjukkan bahwa pelindung biji yang keras menunjukkan imbibisi. Perkecambahan biji terbaik pada *A. australasica*, *C. australis* dan *L. ramsayi*. Perkecambahan kesemua jenis palem tersebut banyak dipengaruhi oleh cahaya merah. Kebutuhan akan cahaya merah menunjukkan bahwa kesemua jenis tersebut lebih menyukai daerah terbuka. Hal ini berimplikasi pada agen penyebar, perbedaan kanopi serta perbatasan hutan yang kemungkinan mempengaruhi daya regenerasi dari jenis palem tersebut.

Kata kunci: *Arenga australasica*, *Calamus australis*, *Hydriastele wendlandiana*, *Licuala ramsayi*, palem, perkecambahan.

INTRODUCTION

Palms are an important component of many tropical rainforests. Approximately 75% of palm species grow in rainforests worldwide (Dransfield, 1978). In Australia, approximately 60% of palm species occur in rainforest habitats (Dowe, 2010). *Arenga australasica* (H. Wendl. & Drude) S. T. Blake *ex*

H. E. Moore, *Calamus australis* Mart., *Hydriastele wendlandiana* (F. Muell.) H. Wendl. & Drude and *Licuala ramsayi* var. *tuckeri* (F. Muell.) Domin have not been assessed for the IUCN Red List (IUCN, 2014). The conservation status of *A. australasica* is vulnerable (EPA, 2007), whereas, the other study species are not currently threatened (Dowe, 2010). Furthermore, *A. australasica* is endemic to north-eastern Queensland and the adjacent islands (Dowe, 2010); *C. australis* is endemic to Queensland (Hyland *et al*., 2003); *H. wendlandiana* is endemic to Queensland and the Northern Territory (Dowe, 2010; Hyland *et al*., 2003); and *Licuala ramsayi* var. *tuckeri* is restricted to north and north eastern Queensland (Barfod & Dowe, 2005; Dowe, 2010). Therefore, the conservation of these species is an important issue.

Studies have shown that canopy gaps play an important role in stimulating recruitment in most plant communities (Bullock, 2000; Fenner & Thompson, 2005; 1977). This may be caused by reduced competition for resources, such as light, nutrients and water. Bullock (2000) differentiated three stages of seedling development that may be influenced by canopy gaps: 'germination', 'emergence' and 'establishment'. Detecting early germination stages in the field can be difficult, but 'emergence' can be readily seen. Hence, most studies of germination responses to canopy gaps require the use of artificial shading in laboratories or glasshouses to compare to "full light" responses (Bullock, 2000). This study used laboratory trials on seed germination to determine the effects that changed light conditions are likely to have on palm regeneration following natural disturbance.

Many palms have seeds that do not germinate readily, even when light conditions are favourable. This seed dormancy is commonly caused by the hard seed coat that restricts the exchange of water and gases (Dessai & Salunkhe, 1997). It is also well known that palm seed dormancy is caused by a combination of immature embryos and the failure of developing embryos to rupture covering structures (Pérez, 2009; Pinheiro, 2001; Pritchard *et al.*, 2004). Dormancy is the suspension of growth by active endogenous inhibition (Jann & Amen, 1977), or "a state in which a viable seed will not germinate when placed in conditions normally considered to be adequate for germination, that is, when provided moisture and oxygen" (Tran & Cavanagh, 1984), and with suitable temperature. However, some conflicts in defining seed dormancy have arisen. Fenner & Thompson (2005) reviewed the conflicting views of ecologists and physiologists on seed dormancy. They suggested integrating the conflicting views by following Vleeshouwers *et al*. (1995) who have argued that "(1) dormancy should not be identified with the absence of germination, and (2) dormancy is a characteristic of the seed (and not the environment) and defines the conditions necessary for germination".

Three types of dormancy are recognised: (1) innate, (2) induced and (3) enforced (Harper, 1977). Other researchers, Adkins and Bellairs (2000) divide dormancy mechanisms into two types: (1) "coat-imposed dormancy", and (2) "embryo dormancy". The dormancy of some palm seeds may be classified as 'hard seed coat-imposed dormancy'. This type of dormancy presents in the seeds of *Cyrtostachys lakka* and *Roystonea elata* (Soedjono & Suskandari, 1996). Dormancy in these two palm species was broken by mechanically scarifying seeds by filing.

Embryo dormancy may also present in some palm seeds. Dormancy in *Butia* spp. appears to be caused by an immature embryo (Sento, 1986). The embryo immaturity, combined with the failure of developing embryos to release a covering structure, *i.e.* operculum, led to 'morpho-physiological' dormancy in *Pritchardia remota* seeds (Pérez, 2009; Pérez *et al.,* 2008). There are two methods of breaking dormancy: either through natural breakdown or artificial treatments (Koch & Dixon, 2000). Previous observations on the study species are presented in Table 1. The literature reveals few detailed studies of germination in these species. No information could be found on dormancy characteristics and the observations on germination of *H. wendlandiana* are inconsistent.

This research used laboratory trials to determine the effects that changed environmental conditions are likely to have on regeneration of palms following cyclonic disturbance. These experiments investigated the effects of seed coat, light and temperature on germination, with the following hypotheses:

(i) Germination will vary between species under three treatments: (1) no treatment; (2) moist heat at 50ºC; and (3) scarification. This will imply that seed germination is affected by hard seed coats that inhibit water absorption.

(ii) Germination will vary between species under three treatments: (1) 20ºC and continuous white light; (2) 30ºC and continuous white light; and (3) alternating light at 30°C and dark at 20°C. Treatments were chosen to reflect the effect of conditions under a forest canopy and in canopy gaps or diurnal/diel changes of light and temperature on germination.

(iii) Germination will vary between species under five treatments: (1) continuous white light; (2) darkness; (3) continuous red light; (4) continuous far red light; and (5) a combination of red and far red light.

Table 1. Summary of previous observations on germination of the five palm species examined in this study. (n.a. denotes information is not available).

Species	Germination type	Information on germination
A. australasica (H. Wendl. & Drude) S. T. Blake ex H.E. Moore	Remote non ligular (Latifah, 2011)	90% of the seeds germinate within 19 days at 30°C; details of germination methods were not explained[1] (ISTA, 2006); dormancy occurred in the related species *A. microcarpa* (Latifah, 2004).
C. australis Mart.	adjacent ligular in *Calamus* genera (Dowe, 2010)	The germination capability of other *Calamus* spp varies: *C. peregrinus* showed 91% germination within 12-35 days with sarcotesta removed (Vangkualong, 1984); heat treatment at 40 ºC for 48 hours in *C. latifolius* increased germination (Mohd *et al*., 1994); *C. mannan* and *C. caesius* germinate within 2-3 weeks after sowing in nursery beds consisting of a sand:soil mix (1:4 or 1:3) and sown seeds were covered by 3 cm of sawdust (Ahmad & Hamzah, 1984); dormancy: n.a.
C. moti F.M. Bailey		
H. wendlandiana (F. Muell.) H. Wendl. & Drude	n.a	The seeds need scarification to germinate after 365 days (Lawie, 2007). Fresh seeds can also germinate within 3-6 months (Cronin, 1989); dormancy: n.a.
L. ramsayi var. *tuckeri* Barford & Dowe	remote-ligular in *Licuala* genera Uhl & Dransfield (1987)	The fresh seeds of *L. ramsayi* germinate after 6 months on various rich, well-drained soil types (Cronin, 1989); dormancy: n.a.

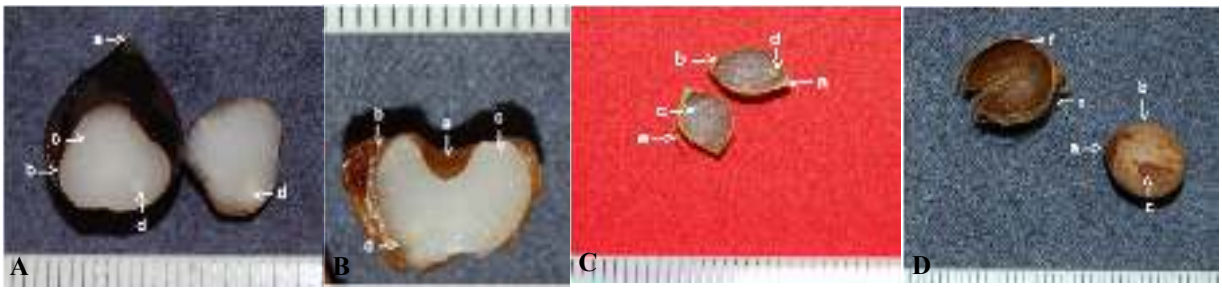

Fig. 1. Longitudinal sections of seeds of A. *A. australasica*, B. *C. australis*, C. *H. wendlandiana*, D. *L. ramsayi* showing a = apical end, b = testa/seed coat or sarcotesta in *C. australis* (Swartz, 1971; Uhl & Dransfield, 1987), c = endosperm, d = embryo, e = fibrous sheath (Essig & Hernandez, 2002), f = endocarp. Scale is in mm.

The results will indicate whether germination is affected by the quality of light passing through the canopy (far red/shorter red light, 730 nm spectrum, Atwell *et al*., 1999), in canopy gaps (red light, 660 nm spectrum, Atwell *et al.,* 1999), or the proportion of red to far red light.

MATERIAL & METHODS

Seeds of *A. australasica* and *H. wendlandiana* were obtained from mature specimens in the Townsville Palmetum, *C. australis* from Tam O'Shanter National Park at Mission Beach, *H. wendlandiana* from Kurrimine Beach National Park, and *L. ramsayi* from the Anderson Park Botanic Garden, Townsville. Longitudinal sections of the seeds demonstrate the nature of the seed coats (Fig. 1) and seed dimensions are given in Table 2. The seeds were fully imbibed to activate the seed metabolism for germination (ISTA, 1985). After the treatments, Thiram fungicide (active constituent: 800g/kg Thiram) was applied and all seeds were placed in a 20 or 30ºC controlled-temperature room under the relevant light conditions depending on theexperiment (Table 3). The source of continuous white light was a fluorescent lamp (36W/840 cool white Philips Lifemax). A few containers full of water were placed in various positions in the rooms to maintain humidity.

A completely randomized research design was applied to address the hypotheses (Gasperz, 1991). The dormancy breaking experiment used artificial techniques to simulate natural conditions that tend to take a long time. Therefore, for example, seeds were scarified by filing the seed coat deep enough

Table 2. Seed dimensions of study species. L = length (mm), W = width (mm) and D = diameter (mm), for seeds that are round in cross-section.

Species	N	Weight (g)		Dimension (mm)	
		Mean	Range	Mean	Range
A. australasica	127	0.75±0.02	0.20-1.15	L=12.92±0.31 W=10.33±0.21	L=8.73-17.31 W=7.79-12.79
C. australis	25	0.62±0.03	0.43-0.68	L= 10.05±0.22 D=10.33±0.17	L= 8.73-10.89 D= 9.31-10.86
H. wendlandiana	55	0.07±0.004	0.04-0.08	L=6.63±0.22 D=4.50±0.13	L=5.52-7.71 D=3.73-5.06
L. ramsayi var. *tuckeri*	50	0.27±0.02	0.13-0.34	D=7.04±0.17	D=5.66-7.58

Table 3. Overview of the germination experiments in four palm species including the details of each experiment and treatment. The table also presents the number of replicates and seeds used in each experimental unit; r= number of replicates; s= number of seeds in each replicate; n.a.=seeds were not available. There were insufficient seeds of *H. wendlandiana* which restricted the number of light treatments used. No seeds of *C. moti* were available for these experiments.

Experiments	*A. australasica*	*C. australis*	*H. wendlandiana*	*L. ramsayi*
Experiment 1: Effect of Dormancy Breaking Treatments on Imbibition				
(1) No treatment	n = 4r x 10s	n = 4r x 10s	n = 3r x 7s	n = 5r x 13s
(2) Scarification	n = 4r x 10s	n = 4r x 10s	n = 3r x 7s	n = 5r x 13s
(3) Moist heat 50°C	n = 4r x 10s	n = 4r x 10s	n = 3r x 7s	n = 5r x 13s
Experiment 2: Effect of Dormancy Breaking Techniques on Germination				
(1) No treatment	n = 4r x 10s	n = 4r x 10s	n = 3r x 7s	n = 5r x 13s
(2) Scarification	n = 4r x 10s	n = 4r x 10s	n = 3r x 7s	n = 5r x 13s
(3) Moist heat 50°C	n = 4r x 10s	n = 4r x 10s	n = 3r x 7s	n = 5r x 13s
Experiment 3: Diel Fluctuation of Light and Temperature				
(1) Continuous white light and 20°C	n = 5r x 13s	n = 4r x 9s	n.a.	n = 4r x 9s
(2) Continuous white light and 30ºC	n = 5r x 13s	n = 4r x 9s	n.a.	n = 4r x 9s
(3) Alternating between light and temperature	n = 5r x 13s	n = 4r x 9s	n = 3r x 7s	n = 4r x 9s
Experiment 4: Light Treatments				
(1) Continuous white light	n = 4r x 13s	n = 4r x 8	n = 3r x 7s	n = 4r x 13s
(2) Darkness	n = 4r x 13s	n = 4r x 8	n = 3r x 7s	n = 4r x 13s
(3) Continuous Red light	n = 4r x 13s	n = 4r x 8	n = 3r x 7s	n = 4r x 13s
(4) Continuous Far Red light	n = 4r x 13s	n = 4r x 8	n = 3r x 7s	n = 4r x 13s
(5) Combination of Red and Far Red light	n = 4r x 13s	n = 4r x 8	n.a.	n = 4r x 13s

to allow water absorption, because in nature the germination of seeds with a hard seed coat that is impermeable to water is stimulated when the seed coats are cracked or softened gradually by abrasion against soil and rocks (Bewley & Black, 1994).

The general design of the experiments is presented in Table 3, including the number of replicates and seeds used in each experimental unit, which varied according to the number of seeds available. Species were not analysed as treatments as the experiments on each species were not conducted at the same time due to differences in seed availability; however, general comparisons between species were possible.

The fully-imbibed seeds were sown between two water-saturated 9 cm-filter papers in petri dishes (ISTA, 1985). All treated seeds were then placed in the temperature-controlled room. As scarification could help water intrusion, based on previous work on palm seed imbibition (Latifah, 2004), all seeds were scarified in experiments 3 and 4, and germination was monitored. Variables observed were:

Water mass and time to full imbibition

The amount (g) of water imbibed was determined per 10 seeds, because the mass of one seed was too small (Table 2). Water mass is the quantitative variable in the imbibition process and is described as the amount of water imbibed across the dormancy breaking treatments during the imbibition period. The imbibition period was determined as the time when there was no further change in the amount of water absorbed.

Germination

The quantitative variable in the seed germination experiments is 'germination' expressed as a percentage. The formula is as follows:

$$\text{Germination} = n/N \times 100\%$$

(n = number of seeds that germinated, N = total seeds per experimental unit)

Germination was defined by the appearance and elongation of the cotyledonary tubule in *A. australasica* and *L. ramsayi* var. *tuckeri*. In *C. australis* and *H. wendlandiana*, germination was defined as the appearance and elongation of the plumule. The number of seeds germinated was recorded regularly and then they were removed. After seeds ceased germinating, the viability of ungerminated seeds was tested using tetrazolium. The presence of viable ungerminated seeds indicated seed dormancy. Viability was calculated as:

$$\text{Viability} = (n1+n2)/N \times 100\%$$

(n1= number of seeds that germinated, n2= number of seeds that were viable according to the tetrazolium test, N = total seeds per experimental unit).

Viability was used to help interpret the germination results.

The viability of the seeds was based on the staining pattern in embryos and endosperms (Bhodthipuks *et al.*, 1996; ISTA, 1985). Since no information is available on palm seeds, this determination was based on viability tests done on *Oraniopsis appendiculata* and *Arenga microcarpa* (Latifah, 2004). As palm seeds have a hard endosperm and seed coat, the palm seed is determined as viable when the embryo is red and endosperm is red or more than 50% red.

Time to first germination and final germination

The rate of germination can be determined by several measures such as time to first germination, time to final germination, T_{50}, coefficient rate of germination or coefficient rate of germination simultaneity (Bewley & Black, 1994; ISTA, 1985). However, as the palm seeds germinated slowly, time to first germination and time to final germination were used to assess the germination rate. Time to first germination was the time (days after sowing) when the first seed germinated in each replicate. Time to final germination was time to the last signs of seed germination.

The differences in the amount of water imbibed across the treatments over time and the differences of the time effect were analysed by repeated measures ANOVA. Germination and time to final germination were analyzed by one-way analysis of variance (ANOVA) to determine if there were significant treatment effects. When the data were not normally distributed, the Kruskal Wallis Non Parametric Test was applied using SPSS version 17.0 package was used for all the analyses.

RESULTS & DISCUSSION

Arenga australasica belongs to the sub family Arecoideae, and all members of this group have a very thick seed coat (Uhl & Dransfield, 1987) (Fig. 1). The seed coats of *A. australasica* seeds slowed their imbibition (Fig. 2A; Table 4). The fully-imbibed scarified or heated seeds tended to have higher germination (82-88%) within 185-200 days (began to germinate after 40-42 days) than untreated seeds (68%) within 167 days (began to germinate after 39 days). Hence fewer untreated seeds germinated, but they germinated faster. This

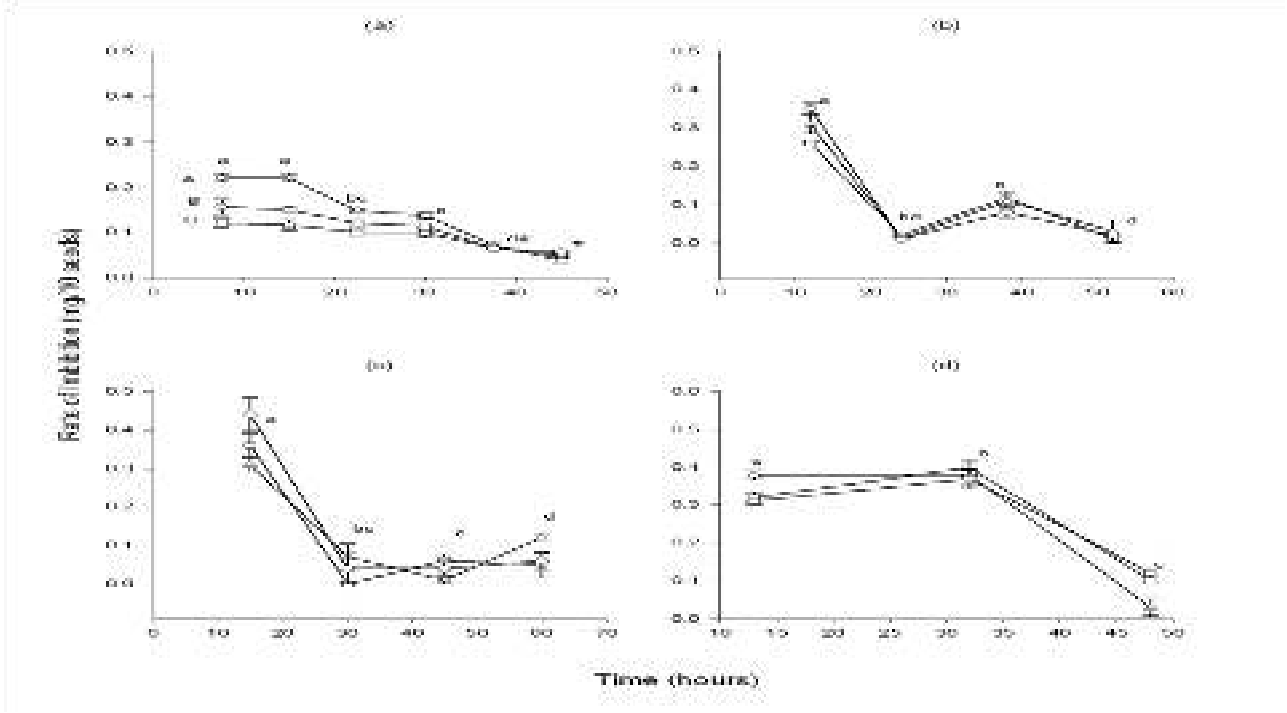

Fig.2. Amount of water absorbed per 10 seeds (mean ± SEM) and time for imbibition of A). *A. australasica,* B). *C. australis*, C). *H. wendlandiana* and D). *L. ramsayi* in response to different dormancy breaking techniques: no treatment (□), scarification (Δ), moist heat 50°C (○). Samples with the same upper (treatment effect) or lower case letters (time) are not significantly different ($p > 0.05$); Rate*Time=interaction.

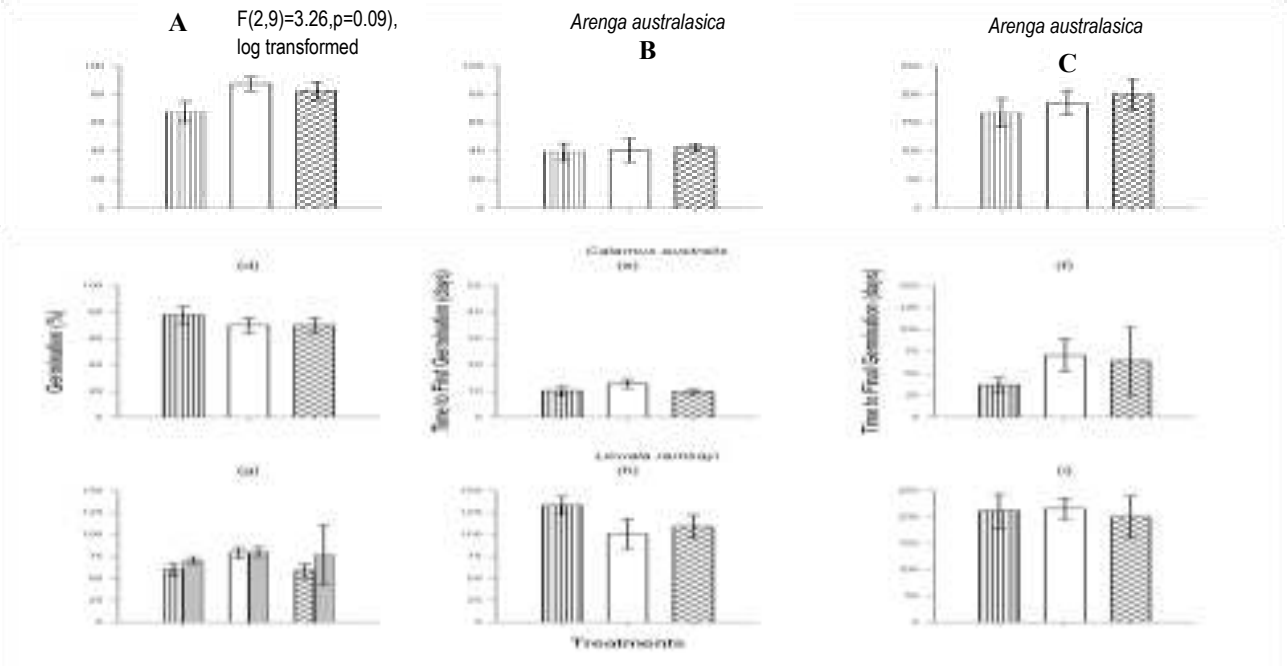

Fig. 3. Germination and times to first and final germination (mean ± SEM) of (A-C) *A. australasica*, (D-F) *C. australis* and (G-I) *L. ramsayi* in response to different dormancy breaking techniques: no treatment (■), scarification (▢) and moist heat 50 ºC (▢). Secondary histograms (▣) for *L. ramsayi* show seed viability (%) after adding the viable ungerminated seeds to the number of germinated seeds.

is a high total germination compared to that found in previous studies of *Arenga* species. In one study, seeds of *A. pinnata* and *A. wightii* yielded only 27% and 4% germination and germinated after 27 and 3 days respectively, without any treatments (Rees in Koebernik, 1971). Dormancy of *A. pinnata* seeds was broken by acid or mechanical scarification (using a file) treatments after 30-365 days; a few samples germinated after 730 days (Mujahidin *et al.*, 2003). *A. microcarpa* seeds gave 74-86% germination after warm stratification for 2-6 weeks at 27-40°C (Odetola, 1987). *A. engleri, A. microcarpa, A. obtusifolia, A. pinnata, A. tremula, A. undulatifolia* and *A. wightii* broke dormancy after 83-626 days without any treatments (Koebernik, 1971). In another study, scarified seeds of *A. microcarpa* had 70% germination after 63-308 days (Latifah, 2004). On the other hand, the seeds of *A. australasica* had 90% germination within 19 days (ISTA, 2006); there is no information about the treatment, the source and the age of the seeds used in this study. The varying results above suggests that *Arenga* spp., including *A. australasica,* may have secondary dormancy (Baskin & Baskin, 2001; Fenner & Thompson, 2005; Vleeshouwers *et al.*, 1995), which refers to seeds that are able to germinate after shedding from their parent trees when conditions are suitable for germination and seedling establishment; but the seeds can also lie dormant during seasons that are unfavourable for germination and establishment.

Imbibition of *C. australis* seeds was also slowed by the seed coat (Fig. 2B; Table 4). The properties of the sarcotesta may cause water impermeability according to Bass (1979). No previous research on *C. australis* could be found; however, the literature contains some information for other *Calamus* species. In the current study, 78% of untreated seeds (sarcotesta removed (Fig. 1) germinated after 10 days (but within 37 days) (Fig. 3.D-F). In comparison, *C. peregrinus* showed 91% germination within 12-35 days with the sarcotesta removed (Vangkualong, 1984). In the current study, 70% of *C. australis* seeds, which had been scarified or heated, germinated after 10-13 days (within 64-71 days); but, this was not significantly different to untreated seeds. Mohd *et al.* (1994) found increased germination of *C. latifolius* after heating at 40°C for 48 hours. The current study and the previous research by the other authors did not examine germination without removal of the sarcotesta.

Similarly, the seed coat of *H. wendlandiana* slowed imbibition (Fig. 2C; Table 4). As in *A. australasica, H. wendlandiana* also belongs to sub family Arecoideae whose members have a very thick seed coat (Uhl & Dransfield, 1987) covered by a fibrous sheath (Essig & Hernandez, 2002) (Fig. 1). Untreated seeds (the fibrous sheath was not removed) of *H. wendlandiana* gave 43% germination after 102 days. The scarified and heated seeds did not germinate. Lawie (2007) found that scarified seeds of *H. wendlandiana* took 365 days for the first germination, but does not describe the percentage that germinated. Another worker found that fresh seeds without any treatment germinated within 90-180 days (Cronin, 1989). In the present study, scarification and moist heat did not promote germination. The seeds may require certain light conditions for germination (Fig. 6; Table 4).

Imbibition was slowed by the seed coat of *L. ramsayi* (Fig. 2D; Table 4), as in the other three species. *L. ramsayi* belongs to sub family Coryphoideae in which many members have very thick seed coats (Uhl & Dransfield, 1987). The seeds of this species also absorbed more water (0.08 mg/ seed) when fully imbibed after 48 hours than the other study species despite the seed weight being lighter than *A. australasica* and *C. australis*. In the current study, scarification gave 78% germination after 101 days (within 216 days), which was higher than untreated (60%, after 133 days, within 211 days) and heated seeds (58%, after 109 days, within 199 days). Moreover, some of the ungerminated seeds were still viable, resulting in 71% (no treatment), 80% (scarification) and 77% (moist heat) viability. A previous study found that *L. ramsayi* var. *ramsayi* germinated slowly and erratically in the nursery as well as in rainforests. In the nursery, the germination of *L. ramsayi* var. *tuckeri* seeds took a year (Diy pers. comm., January 7th 2009). Previous research on other species of *Licuala* found *L. elegans*, *L. gracilis*, *L. lauterbachii*, *L. muelleri*, *L. peltata* and *L. spinosa* took 53-475 days to germinate without any treatments (Koebernik, 1971). These results suggest that seed coat-imposed dormancy is present and the endocarp that covers the seed coat may inhibit imbibition and germinationin *L. ramsayi* seeds.

A. australasica seed germination was inhibited by far red light (Fig. 5A; Table 4). This suggests that canopy gaps created by cyclonic disturbances may induce seed germination in this species since: (1) this result was not significantly different from that in white light and (2) the far red and red-far red combination resulted in lower germination, 14% (72 days first germination) and 38% (130 days first germination).

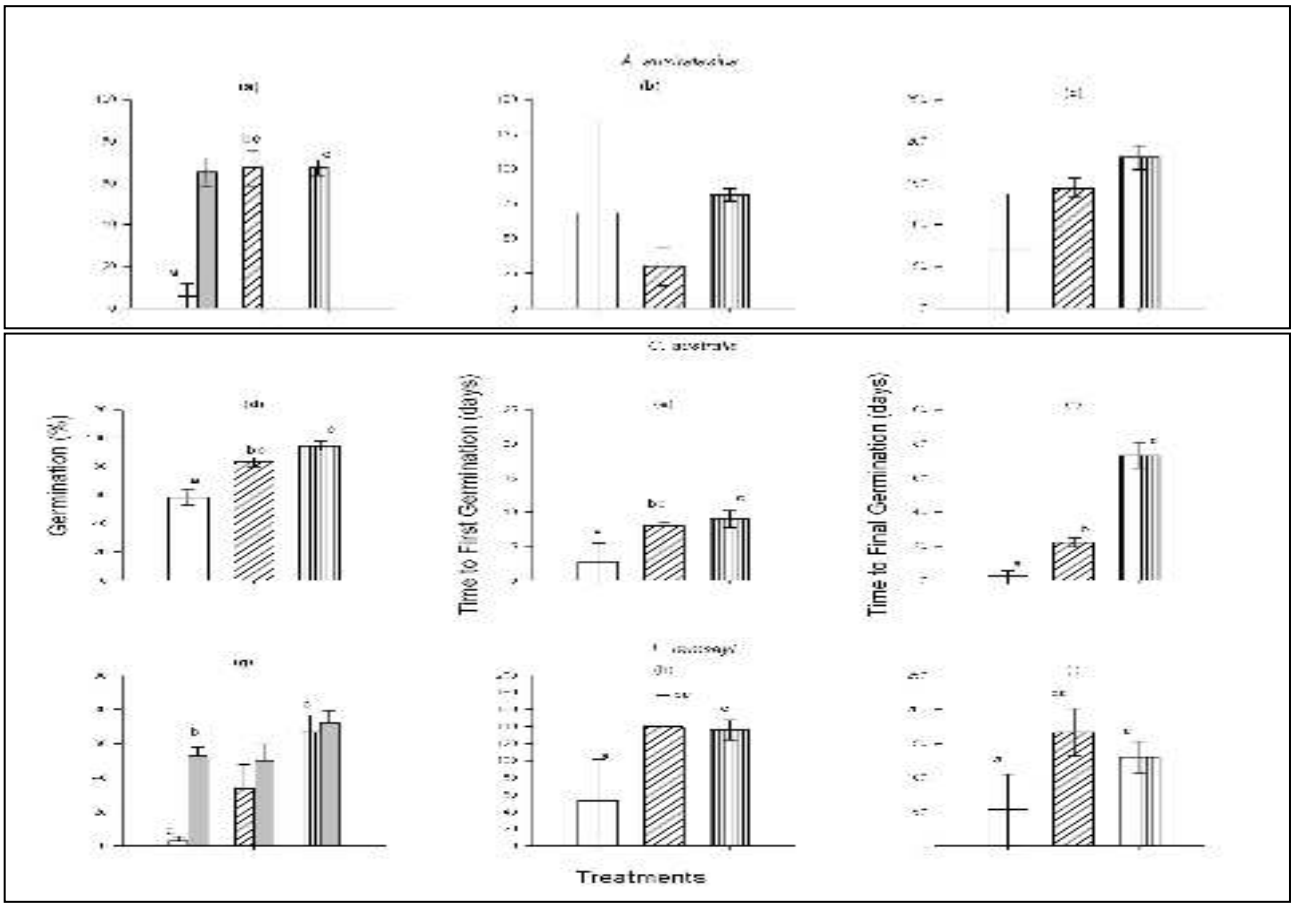

Fig. 4. Germination and times to first and final germination (mean ± SEM) of (A-C) *A. australasica*, (D-F) *C. australis* and (G-I) *L. ramsayi* in response to different temperature treatments and diel fluctuation of light and temperature: 20 ºC full light ( ), 30 ºC full light ( ) and 20/30 ºC dark/light ( ). Samples with the same lower case letters are not significantly different (p=0.05). Secondary histograms ( ) for *L. ramsayi* show seed viability (%) after adding the viable ungerminated seeds to the number of germinated seeds.

All of the *C. australis* seeds germinated under all light treatments (Table 4). This indicates that canopy gaps were also favourable for germination of *C. australis*. The germination of this species was not affected significantly by light condition. No previous research of this nature has been done on *C. australis*.

No *Hydriastele wendlandiana* seeds germinated under far red light, while most germinated under darkness or red light (Fig. 6A; Table 4). Under white light only 43% untreated seeds germinated after 102 days (Experiment 2: Dormancy Breaking Treatments). The seed germination was inhibited by far red light. No previous research on effects of light on germination of this species could be found in the literature. However, these results suggest that untreated seeds germinated slowly under continuous white light and scarified seeds under white light did not germinate; although the scarified seeds germinated under darkness or red light.

Similarly, most seeds of *L. ramsayi* germinated under red and white light and were inhibited by far red light (Fig. 5F; Table 4). This suggests that germination of *L. ramsayi* seeds may be favoured by canopy gaps. No similar studies could be found for *L. ramsayi* in the literature.

Seed germination of the four palm species also occurred in darkness (Fig. 5-6; Table 4). The phytochrome system is involved in seed germination in darkness, the seeds may have sufficient Pfr which is an active form that can promote germination in darkness (Bewley & Black, 1994b). No research in this area has been done in *A. australasica*. However, in another *Arenga* species, *A. microcarpa*, darkness resulted in low germination when the seeds were placed inside 500 gauge polyethylene bags and exposed to continuous

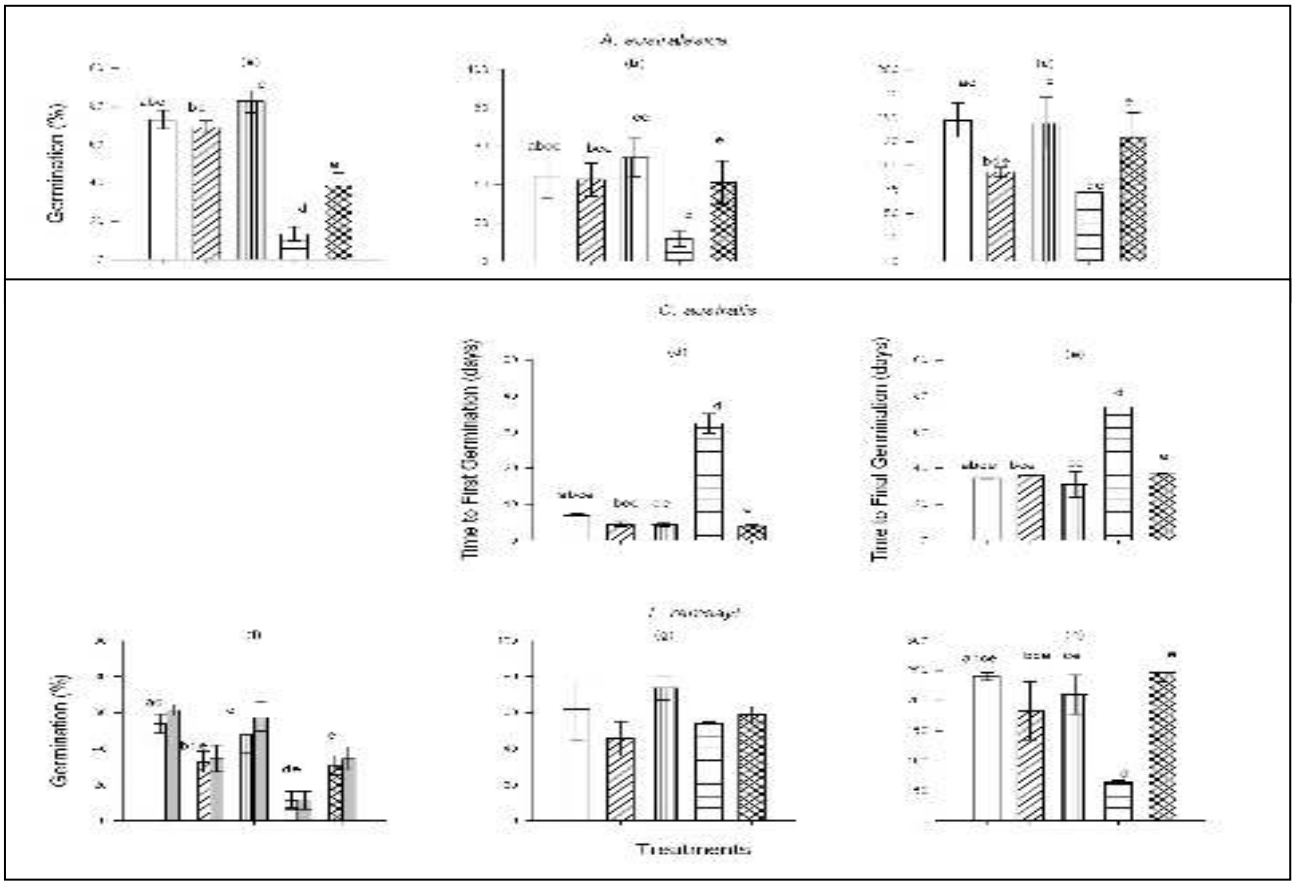

Fig. 5. Germination and times to first and final germination (mean ± SEM) of (A-C) *A. australasica*, (D-E) *C. australis* and (F-H) *L. ramsayi* in response to different light treatments: continuous white light ( ), darkness ( ), continuous red light ( ), continuous far red light ( ). Samples with the same lower case letters are not significantly different (p=0.05). Secondary histograms ( ) for *L. ramsayi* show seed viability (%) after adding the viable ungerminated seeds to the number of germinated seeds.

white light or continuous darkness (Odetola, 1987).

The germination of the palms studied varied in response to different temperatures (20 and 30°C) and diel light and temperature fluctuations. The germination of *A. australasica*, *C. australis* and *L. ramsayi* was lower at 20°C, compared to 30°C. The effects of diel fluctuations were not significant in *A. australasica* and *C. australis* compared to *L. ramsayi,* which germinated best under the fluctuating treatment. In contrast, diel fluctuations inhibited the germination of *H. wendlandiana* seeds. A review of the literature found no similar research on palms. A non-palm and invasive tropical plant, *Mikania micrantha*, germinated rapidly in 25, 30 15/30 °C (night/day) and an ambient temperature (24-32°C) suggesting it is widely adapted to a range of natural conditions (Yang *et al.*, 2005). Temperature and light fluctuations did not significantly increase the R:FR (Red:Far Red light) ratios and the transformation of Prto Pfr is influenced by temperature (Pr is a physiologically inactive form of phytochrome activated by Red light and transformed into Pfr, an active form, that canbreak seed dormancy (Atwell *et al*., 1999)).

CONCLUSION

The hard seed coats of *A. australasica*, *C. australis*, *H. wendlandiana* and *L. ramsayi* slowed imbibition. Scarified seeds germinated best in *A. australasica*, *C. australis* and *L. ramsayi*. The germination of all seeds was inhibited by far red light. The red light requirement suggests that canopy gaps created by cyclonic disturbances could promote their germination. This implies that in disturbed rainforests, the dispersal agents may play important roles in promoting germination of some palms by scarifying through the frugivore gut passage and specific placement in canopy gaps.

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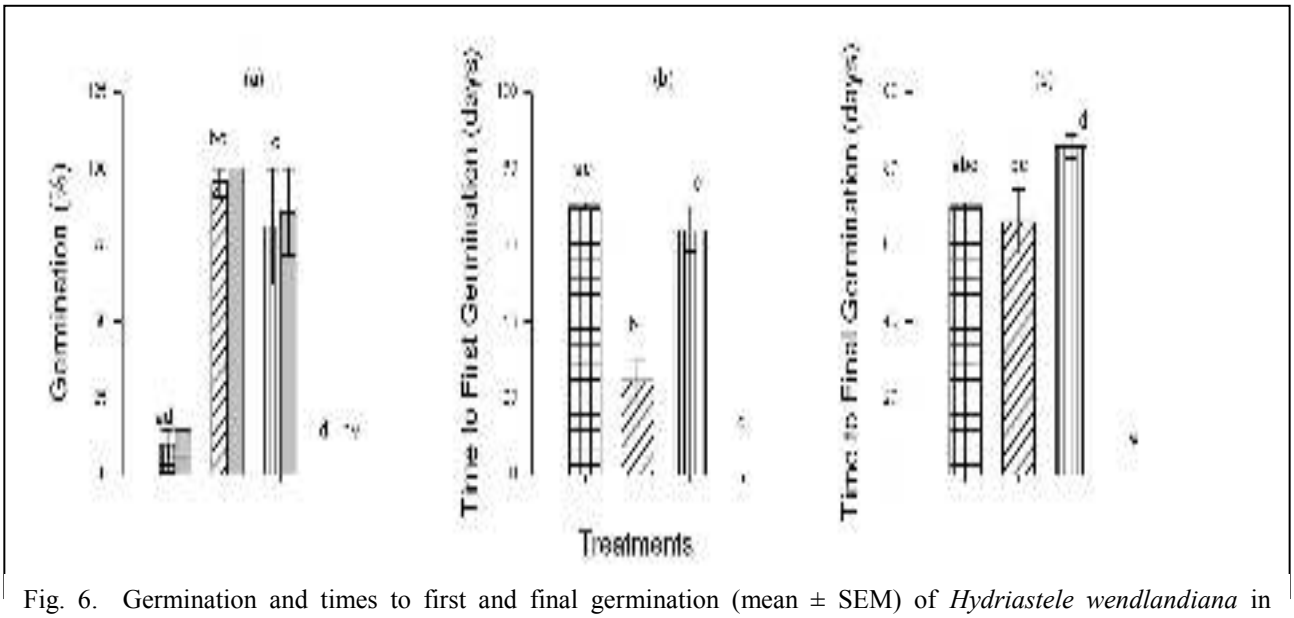

Fig. 6. Germination and times to first and final germination (mean ± SEM) of *Hydriastele wendlandiana* in response to light and temperature treatments. Due to the low seed viability, the experiment consisted of four treatments – the diel fluctuation of light-temperature and the light treatments consisting of: 20/30 ºC day/light (■), darkness (❑), continuous red light (■), continuous far red light (no germination). Samples with the same lower case letters are not significantly different (p=0.05). Secondary histograms (❑) for *L. ramsayi* show seed viability (%) after adding the viable ungerminated seeds to the number of germinated seeds; nv = the remaining ungerminated seeds were not viable.

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