Chapter 3.3
Analyses of Seed Germination of Littoral Forest Native Species in Southeastern Madagascar

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Abstract

Here we present data on the properties of seeds relevant to restoration activities. Seeds from pioneer species were most abundant from May to September. Most seeds from non-pioneer species ripened during the hot wet season. More than half of the species have germination rates below 50%, but once germinated, no species had mortality rates higher than 30%. It is important to intensify studies to understand the causes of dormancy as this might help improve storage conditions and increase germination rates for species with long dormancies.

Résumé

Analyse de la germination des semences des espèces autochtones de la forêt littorale du sud-est de Madagascar. Nous présentons ici les données sur les propriétés des semences qui sont adaptées à la restauration écologique. Les semences des espèces pionnières sont plus abondantes entre les mois de mai et de septembre. Les semences des espèces non pionnières arrivent généralement à maturité au cours de la saison chaude et humide. Plus de 50% des espèces ont des taux de germination inférieurs à 50%. Après germination, aucune espèce ne montre un taux de mortalité supérieur à 30%. Les graines restent dormantes à divers degrés. Il est important d'intensifier les études pour comprendre les causes de la dormance dans la mesure où cela permettrait d'améliorer les conditions de stockage et d'augmenter les taux de germination pour les espèces présentant des semences à dormance prolongée.

Introduction

Following the initial plant inventories of the littoral forests of the Tolagnaro region conducted by the Missouri Botanical Garden (Lowry and Faber-Langendoen 1991), a major gap still remained in the reproductive ecology and propagation of numerous members of the local flora. Studying germination is an essential part of planning species rehabilitation and conservation work because it enhances propagation techniques. With this in mind, a nursery system was established in 1999 to study the propagation of numerous native plant species. The results of this research are presented here.

Methodology

Seed collection

Seeds are defined as part of the organs that plants develop to ensure reproduction (Côme 1975). In the angiosperm spermatophyte, adult individuals often carry out this function. For propagation, seeds or fruits should generally be collected between ripeness and the commencement of natural dissemination (Morandini 1962). Phenological results were used for monitoring biodiversity and to assist in planning future ecological rehabilitation work.

The seeds were generally collected during the fruit maturation period, which was identified beforehand based on a detailed phenological dataset of the Tolagnaro region littoral forest plants (Bollen 2003). The collection methodology is based on norms and standards established by Kew Garden, Millennium Seed Bank (2001). The seeds were either gathered off the ground or collected directly from the plant. The following information was recorded for each collection: date, scientific name (genus and species), sampling method, plant description, characteristics (pioneering, intermediate, or climax species), habitat, and uses. A collection sheet was filled-out for

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each specimen and each seed lot was given an individual number, which was used for all nursery operations (from collection to stock to germination).

Seed treatment and conservation

According to Ewart (1908), seeds are classified into one of three different groups based on their viability or longevity: macrobiotic seeds that remain viable for more than 15 years, mesobiotic seeds that remain viable between 3 and 15 years, and microbiotic seeds that are only viable up to 3 years. The classification most often used to describe seed types was formulated by Roberts (1973) and includes orthodox seeds, which can withstand natural or artificial desiccation (water content of 4 - 6%) or consistently low temperatures over an extended period, and recalcitrant seeds that are difficult to keep over the long term, but which can be conserved if their specific characteristics are known.

In order to categorize littoral forest species behavior, we consulted the scientific literature including numerous works published by the Kew Garden. However, certain aspects of the germination ecology of several plant species occurring in the Tolagnaro littoral forests were still unknown. In order to advance in understanding the different seed types of the local flora, a series of tests were conducted. These employed a progressive desiccation method which placed the seeds in a hermetically sealed container with silica gel until the relative humidity (RH) was under 15%. The species that managed to germinate at this level of humidity were defined as being orthodox and those that did not as recalcitrant.

Treatment of seeds consisted of separating the seed from the fruit or from other parts, and cleaning the seed. The seeds were treated based on their type of fruit: fleshy stone or bay fruits were pulped and cleaned using different-sized screens, and the dried fruits were cleaned and sorted. The previously cleaned seeds were then spread out on a grass mat, sheltered from the sun, and divided into two lots: 1) planted directly at the Mandena nursery to analyze germination and produce plants, and 2) used for the behavior test (i.e. orthodox or recalcitrant character) and for long-term conservation in a seed bank. The orthodox seeds obtained from the analysis were sent to the KEW Millennium Seed Bank (MSB) and to the Antananarivo Silo National des Graines Forestières (SNGF) for long-term *ex-situ* conservation.

Germination

The nursery was designed for seed germination analysis and, above all, to produce plants for ecological rehabilitation. The technique consists of sowing previously treated and sorted seeds directly in plastic pots filled with topsoil. Several parameters were considered and monitored during the experiments, the most important are: 1) Emergence (E), which is defined as the number of days between the seeding date and the initial germination emergence; 2) Germination rate (GR), using the formula GR = n/N x 100 (where n = number of germinated seeds and N = Number of seeds planted); and 3) Mortality rate (MR), using the formula MR = m/N x 100 (where m = number of dead seeds).

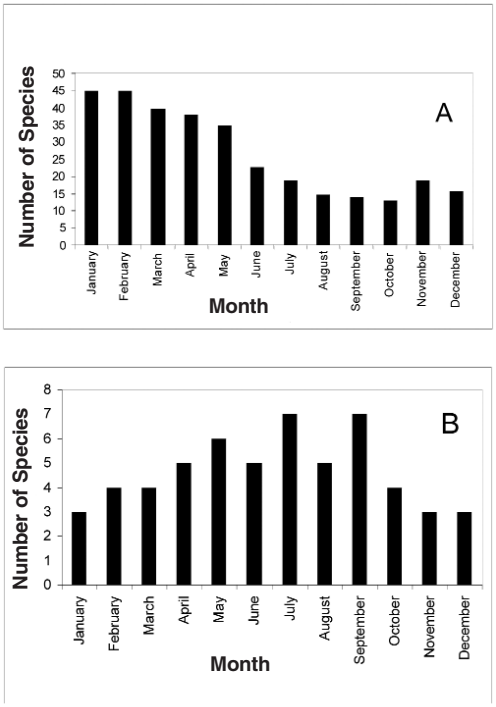

Figure 1. Monthly variation in seed collection of non-pioneering (A) and pioneering (B) species.

Results

Seed collection

Between 1998 and 2004, 119 species were studied (Table 1). Figure 1a illustrates the monthly variation in seed availability of non-pioneer species. It shows that

stocks of seeds are available year round in the forest. However, most seed-producing species are much more abundant in January and February, and then decrease until September when they flower. Moreover, Figure 1b shows the monthly variation in seed collection for pioneering species. The trend in the fructification periods of most pioneering species is inversely correlated to the general fructification trend of seeds from non-pioneering species.

The presence of seeds is positively correlated to monthly rainfall (Spearman correlation: $r_s = 0.88$, $p < 0.001$, $n = 12$). The presence of seeds from pioneering species is negatively correlated to the mean ambient temperatures ($r_s = 0.88$, $p < 0.001$, $n = 12$; Figs. 2a, b).

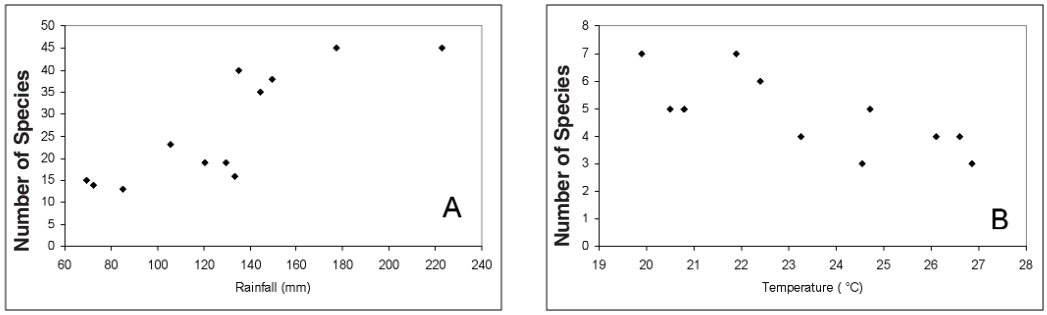

Figure 2. Correlation between non-pioneer species and monthly rainfall (A) and between pioneer species and mean, monthly temperatures (B).

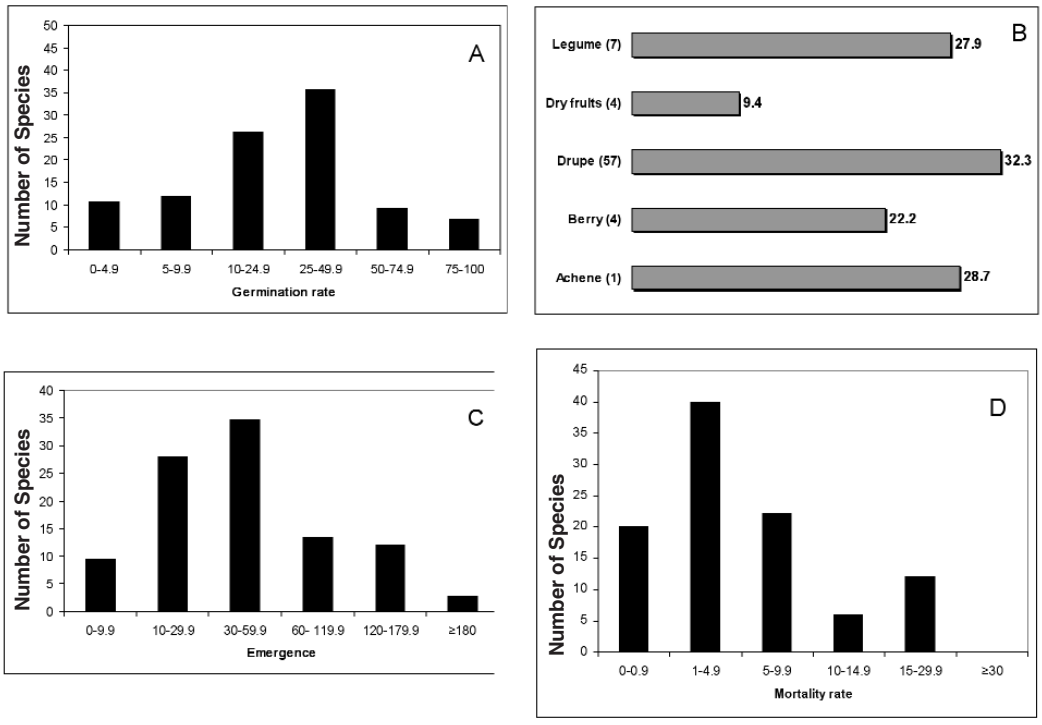

Figure 3. Germination tests showing (A) species distribution by germination rate, (B) relation between germination rate and type of fruit, (C) species distribution by emergence in days, and (D) percent of species distribution by mortality rate.

Conservation test

Among the 114 plants tested and documented, 50 species are presumed orthodox, 19 recalcitrant, and 45 intermediate.

Germination

For all plants treated at the nursery, we were able to distinguish between the easily germinating species and those requiring special treatment. These analyses are presented separately for germination rate and types of fruits (Figs. 3a, b), germination emergence (Fig. 3c), and mortality rate (Fig. 3d). Over 50% of species have an average germination rate below 50%. Stone fruits have a higher germination rate (Fig. 3b). Delayed germination may be due to seed dormancy and inhibition phenomena. Nevertheless, over 72% of seeds were able to germinate in less than two months. Over 60% of species have mortality rates below 5%, and no species mortality exceeds 30% (Fig. 3d).

Fruit type did not have any effect on the time to emergence but germination rate was negatively correlated with the time required to emergence (r_s = 0.28, p = 0.017, n = 75; Fig. 4).

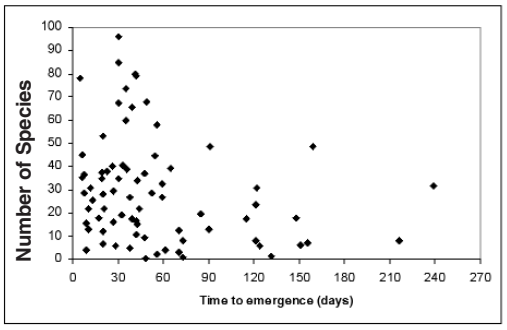

Figure 4. Correlation between germination rate and time to emergence.

Discussion

In this study, certain aspects of the relationship between seeds and their environment have been elucidated, and progress has been made on the selection of appropriate plants, which is based on seed characteristics, for the rehabilitation project:

- A positive correlation exists between general seed production and rainfall, and a negative between the seed production of non-pioneering species and monthly temperature.
- Dormant or inhibited species require more in-depth research to determine the type of dormancy or inhibition (embryonic dormancy or tegument inhibition).
- There may be many causes for the low germination rates. These include external factors such as high relative humidity and temperatures in the study area. These factors may influence seed quality and viability.

In our collection of seeds from the littoral forests of southeastern Madagascar and studies of their development, we found considerable variation in their life-history traits with regard to germination ecology. There is a need to identify other aspects of the germination of these plants, for example dormancy phenomena, to help further advance ecological restoration and plantations. These studies are also an effective means for advancing *ex-situ* conservation of biodiversity.

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Table 1. Collection period for seeds of native plant species in the littoral forests of Tolagnaro.

	Scientific Name	Common Name	Family	January	February	March	April	May	June	July	August	September	October	November	December
1	*Albizia* sp.	*sambalahy*	Fabaceae							x	x	x	x		
2	*Ambavia gerrardii*	*roadria*	Annonaceae	x	x										
3	*Anthocleista longifolia*	*lendemilahy*	Gentianaceae	x	x	x									
4	*Aphloia theiformis*	*fandramanana*	Aphloiaceae	x	x	x	x	x	x	x					x
5	*Apodytes bebile*	*bibilahy*	Icacinaceae								x				
6	*Apodytes bebile*	*hazomamy*	Icacinaceae		x										
7	*Asteropeia micraster*	*fanolamena*	Asteropeiaceae		x	x	x	x							
8	*Asteropeia multiflora*	*fanolafotsy*	Asteropeiaceae			x									
9	*Astrotrichilia elliotii*	*sagnira*	Meliaceae	x	x								x	x	x
10	*Beccariophoenix madagascariensis*	*boakabe*	Arecaceae								x				
11	*Beilschmiedia madagascariensis*	*kangy*	Lauraceae		x	x									
12	*Brexia madagascariensis*	*voakarepoka*	Celastraceae	x	x	x									x
13	*Brochoneura acuminata*	*mafotra*	Myristicaceae	x											
14	*Brochoneura* sp.	*mafotra rano*	Myristicaceae	x	x										
15	*Burasaia madagascariensis*	*farisaty*	Menispermaceae												x
16	*Buxus madagascarica*	*haramboanjo*	Buxaceae	x	x										
17	*Cadia commersoniana*	*kelimaneza*	Fabaceae									x	x		
18	*Campylospermum obtusifolium*	*hazombato*	Ochnacaea					x	x	x	x	x			
19	*Canarium boivinii*	*ramy*	Burseraceae	x	x	x	x	x	x	x	x	x			
20	*Canthium* sp.	*fantsikahitra*	Rubiaceae			x	x	x							
21	*Canthium* sp.	*hazongalala*	Rubiaceae	x	x	x	x	x	x	x	x	x			
22	*Cassia* sp.	*sarongaza*	Fabaceae					x	x						
23	*Cassia tora*	*korondolo*	Fabaceae					x	x						
24	*Cerbera manghas*	*kabokala*	Apocynaceae	x	x	x	x	x	x						
25	*Chrysophyllum delphinense*	*nantohetika*	Sapotaceae	x	x										
26	*Coffea commersoniana*	*kotofotsy*	Rubiaceae	x	x										
27	*Colea obtusifolia.*	*tsikondrokondro*	Bignoniaceae												x
28	*Crataeva obovata*	*belataky*	Capparaceae	x											
29	*Cryptocarya* sp.	*varongy*	Lauraceae												x
30	*Cuphocarpus aculeatus*	*voantsilana*	Araliaceae							x	x	x			
31	*Cynometra cloiselii*	*mampay*	Fabaceae	x	x							x	x	x	x
32	*Dalbergia maritima*	*manary toloho*	Fabaceae											x	
33	*Diospyros myriophylla*	*forofoky madiniky*	Ebenaceae	x	x	x	x	x							
34	*Diospyros* sp.	*forofoky*	Ebenaceae	x	x	x	x	x							
35	*Dodonaea viscosa*	*tsiokanomby*	Sapindaceae									x	x	x	
36	*Dombeya australis*	*berehoka*	Malvaceae							x	x				
37	*Dracaena bakeri*	*falinandro kely*	Convallariaceae			x	x	x							
38	*Dracaena reflexa*	*falinandro be*	Convallariaceae					x	x	x					
39	*Drypetes madagascariensis*	*kambatrikambatry*	Euphorbiaceae	x										x	x
40	*Dypsis saintelucei*	*boaka*	Arecaceae				x								
41	*Dypsis lutescens*	*jambo coco*	Arecaceae			x									
42	*Dypsis scottiana*	*amboza*	Arecaceae				x	x	x	x		x			
43	*Eligmocarpus cynometroides*	*hazomainty*	Fabaceae			x	x	x	x	x	x	x	x	x	
44	*Embelia procumbens*	*vahy taratasy*	Myrsinaceae		x	x	x	x							
45	*Eremolaena rotundifolia*	*fontombavy be*	Sarcolaenaceae				x								
46	*Erythroxylum corymbosum*	*menavoa*	Erythroxylaceae	x	x									x	x
47	*Eugenia cloiselii*	*ropasy*	Myrtaceae	x	x							x	x	x	x
48	*Eugenia* sp. 1	*ropoaky*	Myrtaceae		x	x									
49	*Eugenia* sp. 2	*rotry*	Myrtaceae	x	x		x	x						x	x
50	*Faucheria hexandra*	*nanto*	Sapotaceae											x	

Table 1. Continued.

	Scientific Name	Common Name	Family	January	February	March	April	May	June	July	August	September	October	November	December
51	*Ficus* sp.	*fihamy*	Moraceae						x	x	x	x	x	x	x
52	*Ficus* sp.	*nonoky*	Moraceae					x						x	
53	*Ficus* sp.	*sarinonoka*	Moraceae			x									
54	*Flagellaria indica*	*vahipika*	Flagellariaceae	x	x	x	x	x							
55	*Gaertnera arenaria*	*tanatananala*	Rubiaceae	x	x	x	x	x							
56	*Garcinia* sp.	*disaky*	Clusiaceae	x	x	x									
57	*Garcinia* sp.	*sivory*	Clusiaceae	x									x		
58	*Homalium planiflorum*	*zoramena*	Salicaceae					x							
59	*Homalium* sp.	*ambiripiso*	Salicaceae			x	x								
60	*Homalium* sp.	*maranitratoraky*	Salicaceae					x							
61	*Homalium* sp.	*zoralahy*	Salicaceae							x					
62	*Hyperacanthus mandenensis*	*taholagna*	Rubiaceae	x			x	x							
63	*Intsia bijuga*	*harandrato*	Fabaceae	x	x	x	x	x	x	x					
64	*Leptolaena delphinensis*	*fontombavy*	Sarcolaenaceae		x	x	x	x	x						
65	*Leptolaena pauciflora*	*fonto*	Sarcolaenaceae									x	x	x	
66	*Ludia* sp.	*zora*	Salicaceae				x								
67	*Macaranga obovata*	*mokarana*	Euphorbiaceae											x	
68	*Macphersonia radlkoferi*	*sanira fotsy*	Sapindaceae	x	x										
69	*Magnistipula tamenaka*	*tamenaka*	Chrysobalanaceae	x											
70	*Malleastrum mandenense*	*sarigoavy*	Meliaceae	x	x	x	x	x	x						
71	*Mammea sessiliflora*	*zambo*	Clusiaceae	x	x	x			x						
72	*Mapouria aegialodes*	*mangavoa*	Rubiaceae	x	x	x	x	x							
73	*Memecylon sabulosum*	*tomizo*	Melastomaceae									x			
74	*Mimosa latispinosa*	*rakaraka*	Fabaceae						x	x	x				
75	*Mimusops commersonii*	*nanto*	Sapotaceae	x											
76	*Morella spatulata*	*voalaka*	Myricaceae			x	x	x	x	x	x				
77	*Nepenthes madagascariensis*	*takotry*	Nepenthaceae		x										
78	*Olax imernensis*	*hazomiteraky*	Olacaceae	x										x	x
79	*Oncostemum* sp.	*lona mena*	Myrsinaceae					x							
80	*Ophiocolea delphinensis*	*akondronala*	Bignoniaceae	x	x	x	x	x	x						
81	*Petchia madagascariensis*	*tandrokosy*	Apocynaceae		x	x	x								
82	*Phyllarthron ilicifolium*	*zahambe*	Bignoniaceae				x								
83	*Phylloxylon xylophylloides*	*sotro*	Fabaceae			x	x	x	x	x	x				
84	*Pittosporum* sp.	*membovitsika*	Pittosporaceae					x	x	x					
85	*Plagioscyphus* sp.	*voambirimbarika*	Sapindaceae			x	x								
86	*Potamea madagascariensis*	*resonjo*	Lauraceae	x											
87	*Poupartia chapelieri*	*sisikandrongo*	Anacardiaceae	x	x										
88	*Psiadia angustifolia*	*volovohitry*	Asteraceae				x	x							
89	*Psorospermum lanceolatum*	*harongampanihy madinika*	Clusiaceae		x										
90	*Psorospermum revolutum*	*harongampanihy*	Clusiaceae		x	x	x	x							
91	*Rapanea* sp.	*lona*	Myrsinaceae		x	x	x	x	x				x	x	
92	*Ravenala madagascariensis*	*ravinala*	Strelitziaceae										x	x	
93	*Reference specimen not available*	*hazondambo*		x											
94	*Rhopalocarpus coreaceus*	*tsilavimbinanto*	Sphaerosepalacea	x											
95	*Rhus tarantana*	*taranta*	Anacardiaceae												x
96	*Salacia madagscariensis*	*voatsimatra*	Hypocrateaceae			x	x	x	x	x					
97	*Sarcolaena eriophora*	*meramavo*	Sarcolaenaceae		x	x	x								
98	*Sarcolaena multiflora*	*meramaitso*	Sarcolaenaceae		x	x	x								
99	*Schizolaena elongata*	*fontondahy*	Sarcolaenaceae	x	x										x
100	*Sideroxylon beguei*	*nantobonaky*	Sapotaceae		x										
101	*Stephanodaphne cremostachya*	*havoa*	Thymelaceae									x	x	x	

Table 1. Continued.

	Scientific Name	Common Name	Family	January	February	March	April	May	June	July	August	September	October	November	December
102	*Suregada baronii*	*kalavelo*	Euphorbiaceae	x											
103	*Tacca leontopetaloides*	*tavolo*	Tacceceae									x			
104	*Tambourissa castri-delphinii*	*ambora*	Monimiaceae	x	x	x	x	x	x						
105	*Tambourissa purpurea*	*ambora*	Monimiaceae			x	x				x				
106	*Tarenna* sp.	*tanatananala fotsy*	Rubiaceae		x	x									
107	*Terminalia fatraea*	*katrafa*	Combretaceae				x								
108	*Tina thouarsiana*	*sagnira*	Sapindaceae											x	x
109	*Trachylobium verrucosum*	*manjorofo*	Fabaceae							x	x				
110	*Trema orientalis*	*andrarezo*	Ulmaceae	x	x	x	x	x	x	x					
111	*Tricalysia cryptocalyx*	*hazongalalalahy*	Rubiaceae			x	x	x	x	x	x	x			
112	*Turraea lanceolata*	*sakaimboalavo*	Meliaceae		x	x									
113	*Uapaca densifolia*	*voapaka madinika*	Euphorbiaceae										x	x	
114	*Vaccinium imernense*	*tsilanitria*	Vaccinaceae	x	x										x
115	*Vepris elliotii*	*ampoly*	Rutaceae	x	x									x	x
116	*Vernoniopsis caudata*	*fitobohantsiny*	Asteraceae							x	x	x	x		
117	*Vitex bracteata*	*nofotrakoho*	Lamiaceae	x			x	x	x	x	x	x	x		
118	*Vitex tristis*	*nofotrakoho marec*	Lamiaceae							x					
119	*Ximenia caffra*	*fantsinakoholahy*	Celastraceae	x											