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Lars Schmidt

Tropical Forest Seed

With 143 Figures and 19 Tables

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Lars Schmidt
Forest Genetic Resources
Forest & Landscape, Denmark
Hoersholm Kongevej 11
DK-2970 Hoersholm
Denmark

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Preface

The role and perception of forests in tropical areas has changed drastically during the last half century. Natural forests, as resources for forest products, are dwindling. Sustainable management of natural forests faces many difficulties in practice, although progress has been made. However, rural people in tropical countries often experience that the forests, which were previously the buffer for agriculture and an important resource, are becoming more and more inaccessible. Remaining forests are to a large extent protected, degraded or so far away from settlement that in practice they are beyond reach. The majority of the world's forest products in the future will come from man-made plantations and cultivated trees. The term 'plantation', usually referring to traditional block plantings of industrial species, is acquiring a wider meaning which includes, for example, smaller woodlots, shelterbelts and various types of agroforestry. Forest seeds are in this context of utmost importance. Not only are seeds the most commonly used propagation material, they are also the carriers of the genetic material from one generation to the next. Forest seed handling is thus an integrated part of selection, management, development and conservation of forest genetic resources in a larger context. With this in mind, and considering how self-evident the matter of seed quality is in agriculture, one can wonder how little attention has been and is given to forest germplasm in many afforestation and plantation programmes. The fact that seeds are small, seemingly ubiquitous and that the result of using good or poor seed will only become apparent far in the future tends to induce low priority or ignorance. The sad observation is that not only are forests degrading and dwindling at an alarming rate, but even the basis for reestablishment, good genetic material, is vanishing. For many species it is getting increasingly difficult to find 'good' seed.

Among potential afforestation or plantation species, relatively few exhibit major seed physiological problems. Yet many are not used because of alleged seed problems, problems that could easily be overcome by a little more careful handling during collection and subsequent procedures. Some tree seeds *are* difficult, or at least appear to be so, because they behave differently from what we expect. Systematic research has shown ways to overcome many practical problems. It has also shown that some features such as desiccation sensitivity and short viability are inert, and we must adapt our practices to these, e.g. using seed quickly if it cannot be stored.

The basic philosophy of this book is that good forestry practice should never be impeded by failure to get access to good-quality seed, and that the solution to possible seed problems is not to use poor seed or 'easy' species, but to improve and develop seed handling practices.

September 2006 Lars Schmidt

Foreword

Danish International Development Assistance (Danida) has a long experience of working with tropical forest seed. Danida Forest Seed Centre (DFSC), now merged with others into the Danish Centre for Forest, Landscape and Planning, has for more than 40 years been involved in research and development of all aspects of tropical forest seed, including tree improvement, seed technology, conservation and seed supply systems. The Centre continues to be a key centre for dissemination of information material via technical notes, lecture notes, seed leaflets, extension material and books. Among the most comprehensive material on seed technology was the book *Guide to Handling of Tropical and Subtropical Forest Tree Seed*, by Lars Schmidt, which was published in 2000. The book has been widely distributed to most tropical countries and has been translated into, for example, Bahasa Indonesia. In 2002 Springer addressed the former DFSC to write a volume on forest seed for the series of books on tropical forestry. The task was agreed after Lars Schmidt returned to the Centre from leave.

Although there are inevitably similarities and some sections have been reused with few changes from the previous publication, the present book is not a mere reissue or revision of the former DFSC publication but rather an independent contribution to the *Tropical Forestry* series of Springer. The book has a slightly different focus: in view of the generally improved access to technical facilities in tropical countries, there is more emphasis on these facilities. In addition, many pieces of new information have been included. The author has, during the years since he wrote the DFSC guide, been working on tree seed projects in Indochina and Indonesia. Experiences from these areas are included in this book.

In the past and present, seed problems have been and are a limiting factor for use of species. Forest seed handling is determined by a combination of knowledge of seed biology, of available technology and of seed demand. Knowledge of seed biology increases with experience and research. It is implicit that experience is primarily directed towards already used species – the more they have been used, the greater the experience. Many research efforts are designed to overcome crucial and limiting bottlenecks for particular problems of particular species. It can thereby make species choice less seed handling dependent. Tremendous progress has been made during the last decade on, for example, desiccation and storage conditions of recalcitrant seed (Sacande et al. 2004). The research has not eliminated the problems of these seeds, but we know far more about the interaction between water content and storage behaviour of desiccation-sensitive seed, in order to optimise seed handling practice. Available technology sets a limit to what can be done in practice. The advantages of cold storage are, for example, of little use in areas without cooling facilities. Fortunately, many tropical countries are also getting access to improved technical facilities.

Seed demand is highly determined by political and economic considerations. Most seed users will select tree species which produce the desired result in the shortest possible time, i.e. good genetic quality, of the best provenance, of the best species. Since planting sites and product demands are diverse, this should imply a much diversified species demand. In reality, however, large afforestation programmes often tend to economise establishment cost by reducing species diversity and chose species which are cheap and easy to propagate and raise. The unfortunate consequence is that many species which could be grown and thereby enrich the environment and provide good return to tree planters in the long term are not used because of short-term economic rationales. Progress in seed technology does not alone overcome the diversity problems, but it helps. Fortunately, the political awareness of diversity and the importance of good seed quality for successful afforestation seem to be improving. With an optimistic view that the discrepancy between political will and practical field implementation will be overcome, there will inevitably be more pronounced focus on handling different tree seeds in the future.

Virtually all trees regenerate from seed and can thus be propagated from seed. Many species may be difficult to propagate at the first attempt. Persistent and systematic trials will usually help in identifying and overcoming the problems. Continuous research is necessary, as there are still many problems to be overcome and methods to be improved. Research and dissemination of research results are cornerstones in building up a better capacity in the supply of forest seeds. The Danish Centre for Forest, Landscape and Planning and the former DFSC have played an active role in research and development of tropical tree seed, with the overall objective of increasing species diversity, and improving seed quality of planted forests in the tropics. It is hoped that this book will be a contribution to this overall objective.

The present book attempts to cover all relevant aspects of practical seed handling, from collection to distribution with inclusion, when deemed necessary for understanding and further development, of relevant physiological or genetic background for the recommended practice. The book is thus primarily addressed to seed practitioners in seed centres or seed enterprises, but can be read by anyone with an interest in seed biology, technology and supply.

July 2006

Niels Elers Koch
Director General, Danish
Centre for Forest,
Landscape and Planning

Acknowledgements

The basis for my knowledge of tropical forest seed handling was set at the former Danida Forest Seed Centre (DFSC), i.e. during the compilation of the former seed handbook, *Guide to Handling of Tropical and Subtropical Forest Tree Seed*. The acknowledgements given there are still valid. My experiences in Indochina and Indonesia have added to my personal understanding about forest seeds, their biology, technology and constraints in seed supply. Some things I thought were complicated appeared to be less so in reality; some things I believed were easy turned out to be more diverse than anticipated. I have been unable to identify the sources of many pieces of practical information, but project colleagues and staff from research institutions helped 'thinking together' to overcome practical problems and willingly shared their knowledge and experience; I owe them thanks for their encouragements and contributions. For this book, Niels Arp Hansen from Levinsen Skovfrø, Denmark, helped me put some newer theories and technologies into a practical context of Danish seed handling. Finally, I am grateful to Melita Jørgensen for linguistic proofreading of the script.

The illustrations for this book are partly from my own archive, partly from external sources, which, as far as I have been able to trace them, are acknowledged with each picture. Markus Robbins deserves special mention for his excellent drawings, which have been used before in several DFSC publications. Some drawings by Poul Andersen made for the DFSC book have been reused in this publication. I am grateful to authors and publishers who have granted me permission to use their illustrations.

July 2006 — Lars Schmidt

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Introduction 1

Tropical tree seed handling continuously develops. Scientific research and less advanced, yet persistent practical progress bring about new knowledge and experience on tropical species. Development of new information technology, together with the more traditional writing of textbooks and technical material, bring the new information to a broader user group. Access to better technology and material has characterised many tropical countries over the past 10–15 years. Although many tropical countries are still lagging far behind in economic development, the former habit of making an uncritical parallel between tropical countries and developing/poor countries is not always valid. Progressive and resource-rich tropical countries have shown that it is possible to make well-functioning forest seed supply systems also under tropical climates. Seed research has species by species and topic by topic shown the way towards a more efficient seed handling procedure for individual species, for example in relation to storage behaviour and dormancy (Sacande et al. 2004). Technical facilities are becoming increasingly widely available, and quality is improving. Climbing equipment, storage containers, processing machines and refrigerators are examples of some equipment which can be found in most markets or specialised shops in larger towns throughout the world. Computerised seed documentation systems have revolutionised all documentation and data distribution systems. The technical facilities are thus to a large extent available to provide an efficient seed supply system.

Cheap and simple methods are still a reality in many countries and for particular user groups, and information on how to provide good quality by simple methods still has a place in the extension service. However, on central seed supply level, better equipment, better documentation systems and better distribution systems are often more subject to economic priorities rather than being beyond access, even in the so-called tropical developing countries.

The general advantage of using good quality seed has been well documented (Foster et al. 1995). Where there is a direct economic link between planting material and tree tenure, there should thus be a good incentive to use the best seed available. The incentive would normally justify a good investment in seed technology and improvement. When we can observe that the seed sector is often resource-poor and underdeveloped, and that quality of seed is far from optimal, the main reason should be sought in the lack of a link between planting material and tree harvest. Some frequently encountered constraints are:

1. The relative poverty of seed users. A large and increasing part of tree planting is done on farms and by smallholders (Simons 1997). Many smallholders are unable or hesitant to pay the extra cost for tree seed, which has been claimed, but not necessarily proved, to be of better quality.
2. Lack of a proper distribution system. For lesser-used species there may not be a source and supply at all. For more commonly planted species with improved seed supply, the bottleneck is to get seed distributed to remote areas and particularly to small end users in small quantities. In practice, most seed suppliers distribute seed within a radius of less than 50 km (Nathan 2001).
3. Poor-quality documentation. Seed quality contains a number of components and their relative importance is not always clear. Lack of research trials for most species makes documentation of genetic quality, for example for growth habit, unreliable. Documentation on origin, seed source and mother trees does contain indirect genetic information, but often a blurred concept of the 'best available', which is rather nontransparent for seed users. Since really good, documented quality is obviously expensive, the poor definition of quality obviously invites deceit. Documentation of physiological quality frequently suffers from lack of standards and outdated analyses.
4. Time span from planting to tree harvest. This is the general and ubiquitous problem of forest establishment. In terms of quality seed supply it has implications ranging from corruption and deception to insufficient means of investments in improvement means. Lack of confidence and trust in alleged improved material can almost always be referred back to the lengthy time span required from the purchase of seed or planting material until the trees have reached a reasonable size to be able to judge their growth potential. If there is no real legal procedure to get compensation if cheated, customers cannot be expected to pay for an alleged improved quality. And if customers are unwilling to pay, suppliers are unwilling to provide a better quality; this is the ubiquitous vicious cycle of tree seed supply.

The political-economic trend during the last 10–15 years in most tropical developing countries has been to reduce the public sector and strengthen market mechanisms. This has affected the forest seed sector, since this sector has traditionally been part of the public sector. Market economy necessarily implies generation of profit within a reasonable time span. Short-rotation industrial species in relatively large closed units suit market mechanisms. Long-rotation species, reforestation or supply for resource-poor people and environmental elements of forestry, such as biodiversity or watershed management, do not fit well into a purely private environment. Without an economic incentive or strong public control, the importance of species diversity and genetic quality tends to be neglected. The consequences of neglecting quality control tend to increase, as the quality of random supply gets poorer – the latter due to a general degrading of natural seed sources. The need for regulations and implementation of control systems has thus become increasingly important.

The last 10–15 years has seen a rapid development in the techniques of vegetative propagation. Although mass vegetative propagation requires a fairly high investment in propagation facilities, once it is there it has proved highly competitive with seed propagation for a number of species. Many improved varieties of trees are propagated almost exclusively by cuttings or tissue culture. Vegetative propagation does imply some risk factors compared with seed propagation in terms of genetic diversity. However, provided appropriate control can be maintained, vegetative propagated plants are a good alternative to seed, in particular for species with seed problems and where a uniform performance of a high-bred species is desired. However, although increasingly applied, vegetative propagation has not and will not replace seed propagation as the principal method of plant propagation. The genetic variation contained in seedling plants compared with vegetative propagules is a strong argument to maintain seed propagation in environmental plantings. Seed propagation will almost always be used by small and less equipped nurseries.

Further improvement of seed technology and extension of skills and experiences of seed handling is thus still relevant. It is also necessary to avoid constraints in seed technology becoming a hindrance for diversity of plantations. Far too many planting programmes stick to the ‘easy ones’ when selecting species (Fig. 1.1). Developing good seed procurement and handling techniques is a method for making potential plantation species ‘available’ for planting. Experiences have shown that overcoming seed problems can sometimes boost the use of otherwise ‘impossible’ species.

The need for diversity in planting programmes is becoming more urgent as tree resources in most tropical countries are under pressure. Conservation of gene resources, both species and variation within species, is not done alone in protected areas. Conservation by use implies that conservation becomes integrated in the reforestation programme. Seed handling is one among several approaches to promote diversity.

Rehabilitation of vast areas of deforested land is one of the major challenges of environment rehabilitation and management now and for the many years in

Fig. 1.1. Hard native wood is popular for traditional furniture manufacturing. Natural resources are heavily exploited but the species are rarely planted because they are difficult to establish from seed and are slow-growing

the future. For far too long we have observed the destruction without creating efficient countermeasures. Hillsides turned into unproductive grassland and bushland, siltation of rivers and streams, destroyed coral reefs and thousands of endangered plants and animals not only on a local scale but also on a global scale is what deforestation in sensitive areas has brought. Repairing the damage is what faces our and future generations. Seed handling is one link in the chain to help restore the environment. Though seemingly small, the link is crucial. Seed is the genetic connection between the parent generation and the offspring, and the vehicle that brings progress or recession in terms of genetic quality (Fig. 1.2). The difference between good and poor is very large. For example a poorly managed and degraded shrub may yield less than 1 m^3 of fuelwood per hectare per year – about the consumption of a household. A well-managed forest in the same place may yield 20 m^3 – or from utilising 1 ha just for fuel, the family may, with better genetic material and management, utilise only 500 m^2 (Fig. 1.3).

The supply of quality forest seed has always been subject to a well-known demand–supply problem: customers who demand quality seed but allegedly cannot get it; and suppliers who produce quality seed but claim that there are no customers. Unfortunately both parties could be right. In practice it has appeared quite difficult to make good seed supply operational on a national level containing a broad range of species and containing the best documented genetic quality. Mostly it is a price problem. Genetically improved material is expensive; and any

Fig. 1.2. The seed is the apparatus of regeneration and the vehicle of genes. The physiological quality is influenced by maturity, age and deterioration, and it is manifested by the ability to germinate. The genetic quality is influenced by the parents and crossing, and it is manifested by the growth habit

Fig. 1.3. Fuelwood is one of the most important extracts from forests. Millions of rural people rely on fuelwood as their only or principal source of household energy. As the sources are being depleted, the pressure on the remaining forests is increasing and often results in poor productivity

reasonable selected and documented material is far more expensive than average, randomly collected seed.

This book focuses on seed handling rather than genetic quality. However, the implicit statement is that seed handling is handling of good (genetic) quality seed. The seed is the vehicle of genetic quality whose base camp is the seed source and whose destination is the planting site. Seed handling thus starts from collection from the selected trees in the selected seed source, and it continues to planting and germination in the nursery or the field. Each link in the chain contains risk factors and pitfalls, which can reduce seed quality and thus waste all previous work.

Seed Collection 2

2.1 Introduction

A good tree starts from a good seed. Whatever the succeeding procedures of seed handling, they can only maintain the quality, never improve it. It is thus well justified to pay attention to what is actually collected in the first place. Seed can sometimes be collected from the ground after natural fall. When this is possible without jeopardising quality it is always preferred, as it is by far the easiest and cheapest way. However, all seed collectors have come to realise that good seed must often be collected from the mother tree before it falls or is dispersed. Sometimes it is necessary to ensure that there are seeds (healthy seeds) to collect at all, i.e. before they are dispersed, or have been attacked by predators or even started to germinate – and sometimes to be sure of the identity of the mother tree. Collection from the crown by using long-handled tools and/or short ladders applies to many smaller intermediate-size trees. However, there are a number of species which grow very high and where seeds need to be taken from the crown. How to get up to the top and out to the very thin branches where seeds are usually borne, with minimum effort and risk, has given rise to much invention in tree climbing. Climbing has thus become an integrated part of seed procurement (Yeatman and Nieman 1978; Blair 1995; Barner and Olesen 1983a, b, 1984a, b). How to get to the top without climbing has appealed to even more inventiveness, e.g. balloons, raised platforms or even helicopters (Vozzo et al. 1988). The direct cost and the cost of operation of some of these inventions are so high that they are rarely used unless there are no other suitable alternatives, or where costs are not calculated, e.g. if they are hidden in an institution's core budget or are part of another exercise.

Climbing remains the most suitable way of getting access to the crown, if necessary, but it is both risky and expensive. Genetic considerations suggest collecting from at least 25–50 unrelated good-looking mother trees (Sedgley and Griffin 1989). For large timber trees good-looking trees are large, straight individuals with no lower branches and a small crown with thin branches.

This type of tree is not 'climber friendly' and often has the additional drawback of producing few seeds. Five to six such trees in a day would be a very good achievement for a climber, i.e. a 'genetically safe' collection would take at least a week for a full collection team consisting of two climbers, ground staff and driver. No wonder that alternatives will be considered.

For the most commonly used species, seed collection can be rationalised in established seed sources, where trees are relatively small, managed for large seed production, and are accessible for the various technical accessories designed to ease a collection. In some cases yet another step is taken to reduce seed collection: plants are raised from vegetative material (cuttings or tissue culture) collected in low hedge gardens. In addition to reducing collection cost, established seed sources as well as hedged gardens are normally a part of a tree improvement programme, i.e. using genetically superior material. Labour cost, safety concern and rationalisation tend to reduce routine seed collection by climbing for commonly used forest species. However, species diversity and genetic diversity within species tend to become issues of increasing concern. Local seed collection will still to a large extent rely on seed. Therefore, seed collections that include climbing will remain a necessary element of a broad range of seed procurement programmes.

The choice of collection method thus depends on the biological basis, on the purpose and types of collection, which methods are applicable and available and the economic possibility.

The term 'seed collection' may be somewhat misleading, because in practice we are for the greater part collecting the whole fruit. However, it is the seed with its genetic trait and ability to germinate we want – therefore the term has become common use. Seeds are for most species extracted from the fruit during seed processing (Chap. 3).

2.2 Biological Factors Influencing Collection

Seed is biological material exhibiting a wide range of biological variation in morphology and physiology. Seed is the plant's reproductive material, containing the inherited trait of the parent, evolved and adapted to optimise regeneration in a multitude of niches appearing in forest ecosystems. Seeds are produced and dispersed in such a way as to optimise their survival from predators and in competition with other species. Some species produce a regular bulk crop of orthodox, wind-dispersed seed. Such species offer few problems. Others produce seed crops at long intervals or over long seasons. Animal-dispersed seeds impose particular problems, firstly because animals may eat them or carry them away and secondly because structures attracting animals, e.g. fleshy pulp, are likely to make both collection and extraction more difficult (Chap. 3).

2.2.1
Type of Fruit and Seed

Fruit type reflects an adaptation to dispersal. Most tree seeds are either dispersed by wind or by relatively large animals (birds or mammals). Some mangrove species and coastal palms, e.g. coconut and *Pandanus*, are principally dispersed by seawater. Species with specialised occurrence along rivers (riverine species such as *Acacia nilotica*) show morphological adaptation to water dispersal. However, as rivers necessarily float and thus deposit seed only downstream, water dispersal for such species is generally a secondary adaptation.

2.2.1.1
Wind-Dispersed (Anemochorous) Species

Small size and high air resistance help reduce falling speed and thus increase the time for horizontal displacement by wind. Very small and light seed may be more or less suspended in air (van der Pijl 1982). Tiny seeded species are, for example, *Anthocephalus chinenesis*, *Octomeles sumatrana* and most eucalypts and melaleuca species. Most winged diaspores[1] have wings designed for spiralling when falling, which reduces falling speed significantly. One-winged (mahogany, *Tarrietia*, *Pinus*), two-winged (*Acer*, dipterocarps) and three-, four- or five-winged (*Vatica*, *Shorea*) diaspores possess this feature (Fig. 2.1).

Although dry seeds are necessarily lighter than moist ones, wind dispersal is not entirely linked to orthodoxy, i.e. low moisture content at dispersal. The entire dipterocarp family is an example of a large group of species with mainly desiccation-sensitive seed but with apparent adaptation for wind dispersal. Recalcitrance[2] also occurs in wind-dispersed species in other families, e.g. Sterculiaceae, Meliaceae and Combretaceae. Very small wind dispersed seeds (e.g. Myrtaceae) are always orthodox.

Collection of wind-dispersed species is often easy since fruits and seed are often dry and easily break off the tree. The major observation to be made regarding wind-dispersed seed is time of collection – especially small seed: too

[1] Diaspore is the dispersed unit, which may be a seed, a fruit, part of a fruit with seed or an aggregate of several fruits.
[2] Recalcitrant seeds are seeds that do not tolerate drying to low moisture content (Chap. 4).

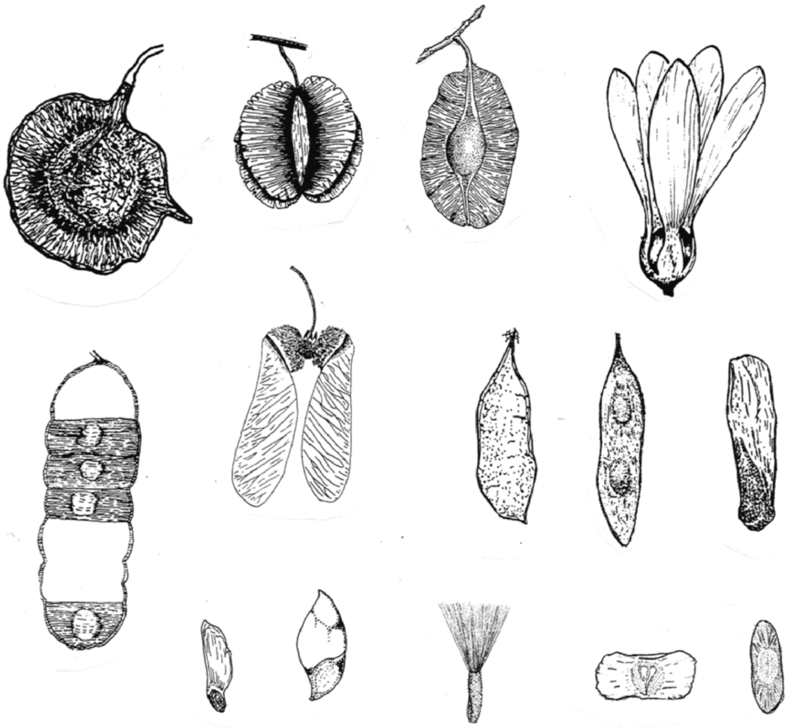


Fig. 2.1. Examples of wind-dispersed diaspores. Wings can be part of the fruits (samaras) or seeds. From *upper left*: *Pterocarpus*, *Combretum*, *Terminalia*, *Shorea*, *Entada*, *Triplochiton*, *Acacia*, *Dalbergia*, *Swietenia*, *Pinus*, *Chukrassia*, *Brachylaena*, *Spathodea*, *Dyera*

late and the seeds are gone! The period for seed dispersal is sometimes very short, in particular, in dry weather. Trying to shake down dehiscent fruits with light seeds may cause most of the crop to blow away.

2.2.1.2
Animal-Dispersed (Zoochorous) Seed

The majority of animal-dispersed seeds have fleshy fruit types, e.g. drupes, berries and various types of aggregate and multiple fruits. In dry areas some zoochorous diaspores, e.g. acacia and prosopis pods and ziziphus drupes, are rather dry. Nutritious appendices (arils) may be dry or moist, but they are usually very conspicuous. Animal dispersal occurs in both angiosperms and gymnosperms, but the morphological adaptations to animal dispersal are much wider in angiosperms. Animal-dispersed fruits and seeds are often quite large

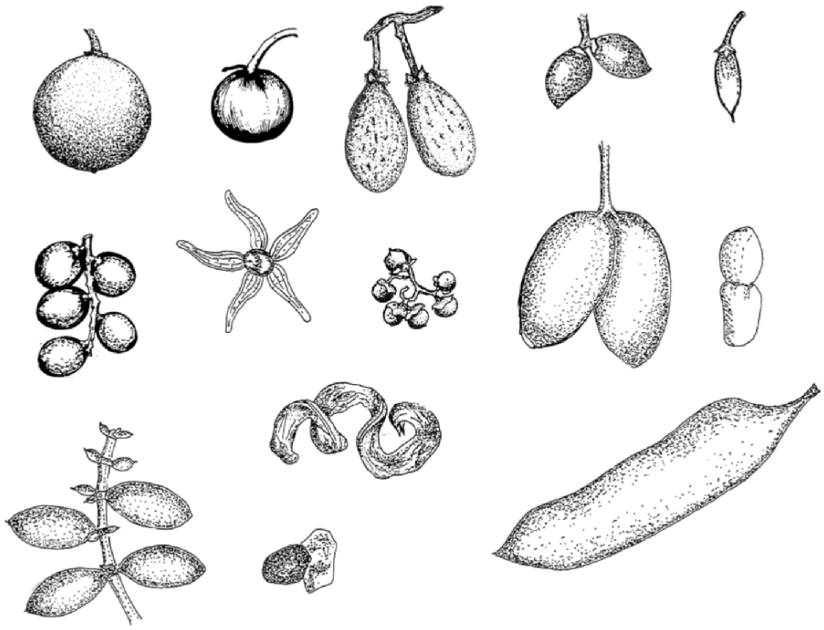


Fig. 2.2. Animal-dispersed seeds. Seeds may be ingested and pass the through the whole digestive track and be deposited with the faeces. In other cases seeds are regurgitated and sometimes they are just sucked free for pulp. From *upper left*: *Diospyros*, *Sandoricum*, *Maranthus*, *Olea*, *Peyena*, *Aglaia*, *Swintonia*, *Cordia*, *Syzygium*, *Dacrycarpus* (arillate seed), *Gnetum*, *Acacia*, *Sindora* (arillate seed), *Tamarindus*

and conspicuous (red or yellow fruits), and often contain protective structures around the seed, e.g. endocarp in drupes or seed coats in many other fruit types (Fig. 2.2).

Animal-dispersed seed may be orthodox, recalcitrant or intermediate. Dormancy is prevalent. Inhibitors in fleshy fruits have the role of impeding germination until after dispersal. Hard structures protect against damage by ingestion, which is the most common mode of animal dispersal.

Animal-dispersed species often have long fruiting seasons, especially those adapted to dispersal by few specialised dispersal agents (McKey 1975; van der Pijl 1981, Janzen 1972). This has two implications for collection: (1) that it is difficult to harvest enough seed in one or two collections; (2) that a fruit crop may be continuously removed by animals, which also has an enhancing effect on the first implication. Harvest of animal-dispersed fruits is often easy because of their large size. Processing, particularly extraction, can, on the other hand, be quite arduous.

2.2.2 Maturity and Seasonality

Physiological maturity of seed, for most species, coincides with readiness for dispersal. As seeds are normally germinable when they are about to be dispersed, natural dispersal time, or indication of dispersal, can be used as a physiological maturity criterion. There are situations where seeds must be collected prematurely and then after-ripened, e.g. if they are easily lost by early dispersal or predation, but even here dispersal maturity criteria are used to determine the best time of collection.

Maturity contains two practical aspects in relation to seed collection:

1. What are the visible or measurable maturity criteria for fruits and seed?
2. How long before potential natural dispersal can seed be collected and, by after-ripening, achieve the same quality in terms of germinability and storability as seed collected at full maturity?

2.2.2.1 Maturity Criteria

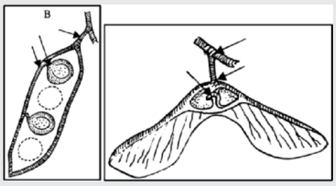
Seeds can be released from the tree in two ways:

1. Dehiscence, in which the fruit opens on the tree and the seeds fall out. The fruit here remains attached to the tree until after dispersal. Release of the seed happens via breaking of the seed connection to the fruit, the pedicel. This occurs in many dry fruits, e.g. dehiscent pods and capsules.
2. Indehiscence, in which the fruit is dispersed as a unit. The fruit is here released from the tree by softening or breaking of the fruit's connection to the branchlet, the peduncle. This occurs in both dry and fleshy fruits, e.g. nuts, pods and drupes.

The breaking off of seeds and fruits, and sometimes splitting up of the fruit occur in special layers of cells, the abscission zones, a phenomenon also known in leaf shedding and self-pruning of branches (Osborne 1989; Kitajima et al. 2003). Checking the strength of the abscission mechanism (e.g. breaking off fruits) is a practical way to check the maturity.

Development of dispersal devices as summarised in Figs. 2.1 and 2.2 and Table 2.1 is a reliable maturity criterion. If seed trees are nearby and can be followed currently, seed collection may be arranged when the first seeds can be found under the tree or animal-dispersal agents start to feed on the fruits. If seed trees are remote, waiting until the 'last minute' is risky. In particular, change of weather from moist, cool and cloudy to hot and dry may cause an amazingly

Table 2.1. Practical maturity indices for forest tree fruits

Maturity event	Method of examination
Colour change: dry fruits, green to yellow, brown or black; fleshy fruits, green to conspicuous red, yellow, blue, etc.	Visual 
Dehydration (dry fruits)	Visual, touching or 'weighing' in the hand Measurement of specific gravity
Dehiscence and abscission 	Observation of fruit fall or opening of dehiscent fruits Shaking or beating fruit-bearing branches Beating or manual splitting of dehiscent fruits Examination of opening structures in dehiscent fruits, e.g. valves, scales and margin Breaking off fruit stalks
Hardening of fruit/seed coat	Cutting, pricking, breaking of seed or fruit coat
Hydration (fleshy fruits). Softening of fruit flesh	Squeezing
Loosening of fruit pulp (fleshy fruits)	Squeezing, rubbing or other separation of fleshy part from seed or endocarp
Accumulation of sugar substances (fleshy)	Taste (careful as some fleshy fruits are poisonous to humans) Observation of visiting frugivores
Endosperm and embryo development of seed	Cutting of seed. Squeezing the embryo – the embryo should be firm and hard (Boshier and Lamb 1997)

rapid drying and dehiscence of dry fruit types. Trees which tend to synchronise their crop production may disperse it all in 1 day. At the other extreme are some eucalypt and pine species which retain their seeds in the fruit for a very long time after maturation, sometimes 1 year or even more (Gray 2004).

2.2.2.2 Premature Collection

The latter part of fruit and seed maturation consists of an internal restructuring and denaturation of components, e.g. proteins and hormones, and loss of water (Bewley and Black 1994). The flow of water and nutrients from the branchlet through the peduncle and pedicel to the seed gradually ceases.

The sequence and duration of events leading up to full maturity differ between species and premature collection is always a matter of experience. However, for most orthodox seeds, fruits can be picked and after-ripened when the fruit or seed changes from green to a mature colour (i.e. loses the ability to photosynthesise), which is usually 2–3 weeks before natural dispersal (Boshier and Lamb 1997). Recalcitrant seeds are also in this connection a problem because they continue to accumulate dry matter (i.e. increase in size and weight) up to full maturity (Berjak and Pammenter 1996; Phartayal et al. 2002). These types of seeds must be collected practically at the time of their normal fall or dispersal, as there is only a limited option for after-ripening of nearly mature fruits.

2.2.2.3 Seasonality

Most species have distinct fruiting seasons and seed collection is usually aimed at seasons where most fruits and seeds are available. However, in practice, collection teams often arrive too early or too late, i.e. the crop was either not mature or very little was left. Often collection teams will take whatever little is available. This is not always advisable. Very early, very late or out-of-phase fruiting may be preceded by concurrent early, late or out-of-phase flowering, i.e. isolated in time and thus implying a relatively high risk of inbreeding (Boshier and Lamb 1997). Inbred seeds are often morphologically or physiologically abnormal. Sometimes they are aborted early, sometimes they remain on the tree for a long time after other seeds have been dispersed. The phenomenon of inbreeding differs between species, from species with strong inert inbreeding barriers to species with full compatibility. Most forest tree species are facultatively outcrossing, meaning that foreign pollen has an advantage over their own pollen (Griffin 1990; Sedgley and Griffin 1989). Where inbreeding occurs it is found mainly where flowers are isolated in time and space. The proportion of inbred seed is smaller during the peak season, because peak flowering is the time with the highest chances of outcrossing (Griffin 1990; Sedgley and Griffin 1989). There are other aspects of seed quality affecting especially early and late crops, e.g. maturation (early crops) and insect infestation (mainly late crops). Whatever the cause it is thus generally recommended to collect seeds during the peak season and to avoid very early and very late crops.

2.2.3 Damage to Trees and Future Seed Crop

The method of collection may in some cases directly or indirectly affect the future seed crop. The impact is usually negative, e.g. damage to fruit-bearing