Guide to handling of tropical and subtropical forest seed

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PLANNING AND PREPARATION OF SEED COLLECTIONS

by

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Other Chapters of the book Guide to Handling of Tropical and Sub-Tropical Forest Seed by Lars Schmidt soon available on www.dfsc.dk

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3 PLANNING AND PREPARATION OF SEED COLLECTIONS

3.1 Introduction

It is important that careful planning precedes seed collection and all the processes that follow. Since planning relates to future activities, it not only requires knowledge of the biological basis, but also of succeeding activities like collection, processing, storage and germination (following chapters).

Planning of seed collection relates directly to the following questions:

1. Which species to collect (species selection)
2. How much seed to collect (quantity)
3. Where to collect (seed sources, seed trees)
4. When to collect (harvest time)
5. How to collect (collection method)

The plantation programme determines the first two questions, which is normally beyond the decision of the seed supplier. However, since customers often expect or require a speedy delivery of their seed orders, the planner must often be able to predict future demand before he/she receives the order. To compensate for annual fluctuations in seed production and seed demand it is usually sensible to establish a reserve stock of seed in a seed store. This implies obviously that the seeds can be stored for a prolonged period of time.

The last three questions relate to the immediate objective of seed collection viz. to provide the appropriate quantity of seed of a particular species and provenance with high physiological and genetic quality at the lowest possible cost. For the seed supplier the latter basically means with minimum of work investment.

Species bearing easily collectable, abundant and regular seed crops, which remain on the tree for a long time with little loss to predation and dispersal, impose little problem in collection but are unfortunately few. Several species produce small crops during a prolonged season but little can be harvested at any one time. Others have abundant seed crops only at long intervals and in some species the seeds are dispersed or destroyed by predators.

Planning of collection involves prediction of these 'where', 'when' and 'how', which are based on knowledge of the biology of the species and current observations.

Prediction of quantity and quality of a potential seed crop and the concurrent planning of appropriate harvest time and method are essential for efficient allocation of resources for seed collection, especially where seed sources are located far away from the organizing office. Collection expeditions to remote areas are costly and must be carefully planned in advance, both to make sure that mature seeds are available at the location, but also that the collection team is equipped with necessary permissions for collection and equipment to make the operation efficient. Further, the seed unit must be ready to receive the fruits or seeds so that processing and possible storage can proceed without delay. An efficient and successful collection can easily be ruined if delay or inappropriate handling causes the seeds to deteriorate before they are processed; and loss of viability cannot be regained.

Closely connected to crop assessment is the identification of potential seed sources. This book mainly deals with the physiological quality of seeds, but the planner should be aware of genetic factors influencing seed quality, e.g. inheritance of characters and inbreeding, and include these considerations in the choice of seed sources and seed trees (section 3.3).

For some seed sources, collection may be subject to special restrictions in relation to ownership, administration or conservational aspects. This may put limitations on both amount of seed to be collected and collection methods.

3.2 Prediction of Quantity, Quality and Harvest Time of Seed Crop

Prediction of quantity and quality of an expected seed crop and prediction of the correct harvest time is especially essential for species with variable seed crops from year to year, and with a short harvest season. Some years, fruit production may be so low that collection does not pay at all; other years a sudden mast production may justify a very large collection, where stores are filled up to serve as seed supply during interim low production years. In some cases an exceptionally large seed production may even influence the current nursery programme.

The best seeds are produced in mast years, or in stands with prolific flowering, efficient pollination and few predators. The best time to collect seeds is when they are mature but before they are lost to predators or dispersal. Forecasting quantity, quality and timing of a seed crop is subject to the following inevitable problem: the earlier the assessment, the better it can be incorporated into the work plan, but the more unreliable the prediction. In some cases where the potential seed sources are located far away, it may be impossible to make preliminary assessments on the actual stand, and one must rely on geographic correlations or other measures.

3.2.1 Climatic correlation and phenology tables

In most species, flowering and fruiting occur during definite times of the year according to climatic factors such as rainfall and temperature. This is particularly pronounced in seasonal climates, i.e. areas with distinct rainy/dry or hot/cold seasons (cf. chapter 2). Many species have similar phenology patterns. In dry climates most species flower during the dry season and fruits are mature and dispersed just before or during the early part of the rainy season. However, in some species, other factors than climate (e.g. availability of pollinators or dispersal agents) have a strong influence on the reproductive behaviour, and flowering and fruiting occur outside the main season for the area. For example, in Tanzania the main fruiting season is during the months of June-August, but some species (e.g. *Melicia excelsa* and *Syzygium cuminii*) fruit in January-February and others (e.g. *Pithecellobium dulce*) in September - November (table 3.1).

In the tropical region, the rainy season typically follows the shift in position of the intertropical convergence zone (ICZ) north and south of the equator during the year, and the phenology stages tend to follow that pattern. For example, in India and Pakistan the phenoperiods of neem (*Azadirachta indica*) usually occur 2-5 weeks earlier in the southern than in the northern part of the countries (Aziz 1985, Tewari 1992). Dwivedi (1993) states, as a rule of thumb, a delay of 4-5 days for each 1° increase in latitude between 20°N and 30°N in India. Seasonality in reproduction often follows seasonality in climate. For example, in the aseasonal climate of Colombia flowering and fruiting of *Cordia alliodora* may occur any time of the year, while in Central America reproduction is seasonal and synchronized (Stead 1971). In mountainous areas, stands growing at higher altitude normally flower and fruit later than stands of the same species growing at lower altitudes. In Guatemala a two-month delay of flowering at 950 m as compared to sea level was observed for *Gliricidia sepium* (Hughes 1987). The phenomenon of valley/hill variations can be evident within small areas. Floras and botanical guidebooks often indicate phenoperiods (although unfortunately often not specified to location) and together with local observations and recordings it is often possible to draw phenological tables of individual species (table 3.1). Such tables are useful tools for seed-source management as well as for seed collection. However, as mentioned in chapter 2, omission of reproduction by individuals or whole populations for one or more years is quite normal for forest trees. Hence, phenodiagrams have the restricted meaning that if the species reproduces in a particular year, it is likely to take place during the period indicated.

Climatic conditions vary from year to year and influence reproduction directly e.g. through its influence on total flower setting, or indirectly via its influence on pollination and predation (cf. section 2.10). Annual variation in e.g. duration of rainy/dry season, temperature or number of sunshine hours seems to have particular importance in species with pronounced periodicity (cf. chapter 2.8). Comparing climatic data with reproductive records of individual species over many years have resulted in good correlation for several species. For example, temperate *Fagus sylvatica* flowers prolifically if the time of floral differentiation (June-July the year before flowering) is dry and sunny (Holmsgaard 1972, Matthews 1963). In many dipterocarps flowering is triggered by a drought spell during floral differentiation (Whitmore 1984). Where such strong connection exists between specific climatic events and reproductive behaviour, good seed years can be predicted very early, i.e. before the flowers actually appear. In addition, flowering may be predicted even in areas where it is not possible to conduct flowering surveys.

SPECIES / MONTHS	J	F	M	A	M	J	J	A	S	O	N	D
Cedrela odorata						X	X	X	X			
Dalbergia melanoxylon					X	X						
Delonix regia					X	X	X	X	X	X		
Entandophragma bussei						X	X					
Eucalyptus tereticornis			X	X	X	X	X	X	X	X	X	
Eucalyptus saligna						X	X					
Faidherbia albida							X	X	X			
Gardenia ternifolia		X	X	X								
Grevillea robusta		X	X	X								
Gmelina arborea					X	X	X					
Julbernardia globiflora					X	X	X					
Khaya anthotheca				X	X	X						
Melicia excelsa	X	X										
Pithecellobium dulce								X	X	X		
Schinus molle					X	X	X					
Senna spectabilis					X	X	X					
Syzygium cuminii	X											
Terminalia catappa					X	X	X					
Vangueria infausta					X	X						

Table 3.1 Fruit collection calendar for some Tanzanian trees (see also table 3.7).

3.2.2 Flower and fruit assessment, methods and correlation

Sometimes a preliminary flowering assessment can be conducted in the bud stage (e.g. eucalypts); more often one has to await anthesis. Flowering often gives an indication of the future fruit crop but the correlation varies from species to species and from year to year (cf chapter 2.10). Flowering assessment has the following general and trivial justification and limitation: if none or only few flowers occur or if only few trees flower during the main flowering season, there will be no, or only a poor, seed crop (see remarks on inbreeding section 3.3.1); if many trees in the stand flower prolifically there is a potential for a good seed crop. In species with pronounced periodicity at long time intervals, e.g. the above mentioned dipterocarps and araucarias, the main point is to state whether the species is flowering or not. In these species there is often good correlation between a good flowering and fruiting, although a flower or early fruit crop may be destroyed by adverse environmental conditions (cf. section 2.10).

Erythrinas, spathodeas and grevilleas often flower abundantly every year but great variation in fruit and seed crop is encountered, i.e. correlation between flowering and fruiting is poor. If flowering varies significantly from one year to another and there is normally a good correlation between flowering and fruit crop, some quantification or rating of flowering is feasible (see below).

In some species, floral assessments are subject to specific problems. *Pterocarpus indicus* flowers in several short cycles of 1-2 days' duration at intervals of 5-7 days during its main flowering season, which may last 1-2 months. Assessing flowering of one single flower burst would be of little value for crop prediction. In diffusely flowering species like dry-zone *Dobera glabra* and *Diospyros scabra* and many humid-zone species, flowering occurs over a prolonged season with seasonal variation. Flowering

assessment outside the main burst may suggest a very poor crop, while a large collectable crop may arise from a sudden burst in flowering. Both examples show that prolonged observation rather than a single assessment may be necessary.
Large-fruited species like *Swietenia* spp. and *Allanblackia* typically develop only one or two fruits per inflorescence and the number of inflorescences rather than the number of flowers are indicators of the future fruit crop.

Flowering and fruiting assessment in forest stands is constrained by the practical problem that the reproductive organs of trees are usually borne on the uppermost and most invisible parts of the canopy. Looking for flowers through dense foliage from under the trees can be very tedious. Even worse is early assessment of fruit crop as the trees enter the fruiting phase and lose the coloured floral appendices. It should at this point be emphasized that assessment should preferably be undertaken on several average trees in a stand rather than on single exposed or edge trees, as the latter may show a quite different reproductive behaviour than the stand. For example, successful reproduction of isolated trees may be due to their better exposure; crop failure of isolated trees may be due to inbreeding, both factors differing from individuals in closed stands.

Several methods can be applied to assess reproduction.

1. **Climbing trees**. The techniques of climbing are described in connection with seed collection (chapter 4). Although it is quite time consuming, it may be the only way to get a good survey of the crown. Climbing one tree may give a good view over the neighbouring trees (Stubsgaard and Baadsgaard 1989). Flower or early-crop assessment can be undertaken in connection with tree climbing exercises and training.
2. **Observation from natural or artificial high points**. In hilly terrain it is often possible to find natural observation points for particular parts of the forest. Roads, firebelts or other cleared areas are particularly useful since they form openings in the canopy. In flat terrain fire- or wildlife observation towers are often good viewpoints. Since good observation points may be scarce, strong binoculars or telescopes are often necessary. More sophisticated equipment like small planes or balloons may be used in large area surveys but are generally too expensive. They may, however, be applicable in some situations where they can be combined with some other purpose (For. Com. 1994).
3. **Inspecting fallen flowers or fruits**. Aborted flowers or dehisced corollas of particularly brightly coloured flowering species are often conspicuous on the forest floor for some days after flowering. For example, *Pterocarpus indicus* flowers in several prolific cycles during its main flowering season. The flowers appear 1-2 days after heavy rain (anthesis triggered by chilling (Whitmore 1984)), and are shed 1-2 days later. After each flowering cycle the bright yellow flowers or corollas cover the ground. In *Dipterocarps*, *Cordia* and *Swintonia* the petals remain attached to the developing fruits, but aborted or shed flowers

are often to be found during the flowering season and can be an indication that flowering has taken place (Ng and Loh 1974). Further, during heavy rainstorms flowering branches and branchlets often fall down and can be good indicators of both flowering and fruiting.

Figure 3.1.
Prolific flowering in a teak plantation, Tanzania.

Due to the relatively unreliable connection between flowering and fruiting, floral assessment is usually rated rather than quantified. Rating can, for instance, be done according to the following scale:

4. Very good	Most of the trees in the stand have abundant flowers
3. Good	Most of the trees have flowers, some abundant
2. Intermediate	Less than 40% of the trees bear flowers, few have many flowers
1. Poor	Most trees in the stand have few flowers, edge and exposed trees may flower prolifically
0. Very poor	Flowering poor and only on edge trees or isolated exposed trees

Floral assessment and rating require a high degree of knowledge of the species and experience in order to establish an arbitrary reference frame. The relative rating of flowering may be helpful in identifying potential seed sources. Stands with ratings 0 or 1 are excluded, those with score 2-4 are potential sources for further evaluation (Barner and Olesen 1984).

Fruiting assessment can be conducted only when the fruits have enlarged. Fruits of some species grow quickly into mature size, in others it may take several months. In teak (*Tectona grandis*) fruits enlarge to full size about 2 months after flowering but require another 5 months to mature (Hedegart 1975). Also fruits of eucalypts and cones of conifers are visible a long time before maturity. Unless the species is prone to heavy predation or late fruit abortion, a reliable quantitative crop assessment can usually be carried out on immature fruits. Normally a small part of the tree is surveyed carefully and the fruits counted. The figure is then multiplied for the visible part of the crown and again for the whole tree.

Example: in a fruiting survey of teak (*Tectona grandis*) in the Philippines the average number of fruits per inflorescence was 5 (range 2-11). On part of one main branch 35 fruit stands were counted. That was estimated to be 10% of the visible fruits on one side, which was again estimated 1/3 of the total tree. Hence, the total number of fruits on the tree was 5x35x10x3 = 5250 fruits. (See also example table 3.3). Conversion/multiplication factors of visible fruits to total fruit crop vary according to species. In species with a dense canopy leaves may hide many fruits especially in the upper part of the tree and there is a tendency to underestimate such seed crop. Conversion factors must be established for each species, based on experience of comparing estimated crop size with the actual crop, once the fruits have been harvested (Stubsgaard and Baadsgaard 1989). This implies that the fruit crop of individual trees is measured after harvest. It should in this connection be mentioned that often only a fraction of the total fruit crop is harvestable, and an additional conversion factor to 'harvestable seed crop' may be applicable.

Multiple seeded fruits like berries, cones and compound fruits vary in seed content. In order to establish the relation between fruit crop and seed crop the average number of seeds per fruit must be calculated. Calculation should be based on normally developed fruits of average size. In fruits with relatively few seeds like legumes, the fruits are split open and the number of sound seeds counted. In fruits with many seeds or in which seeds are difficult to extract before maturity (e.g. cones) a short cut can be established: the fruits are cleaved lengthwise with a sharp knife or a special cone cutter (fig. 3.3). All normally developed seeds on one surface are counted. The fruits are then split apart and all normally developed seeds counted. A conversion factor is calculated based on the two counts (cut and total) for 10-15 fruits depending on variation (Edwards 1981) see table 3.2.

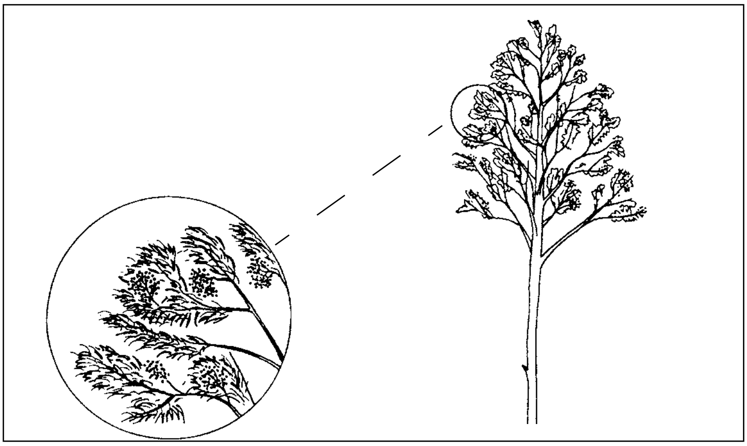

Figure 3.2.
Crop assessment. A small portion of the crown is surveyed, and the number of fruits counted is converted to an estimate of the total fruit production.

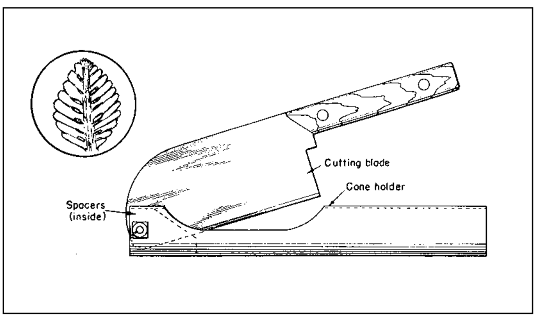

Figure 3.3.
Fruit/cone cutter. Cutting can be used to estimate number of seeds per fruit, and conditions of the seed e.g. insect attack and maturity.
Inserted figure: cut cone showing seeds.

3.2.3 Assessment of seed quality

Qualitative assessment was incorporated in the quantitative assessment of the cutting test above since it was implied that the seeds should be normally developed. Cutting test is also used for pure qualitative tests. Cut seeds may be examined for insect attack, normally developed endosperm and embryo. Insect attacks of seeds are sometimes visible on immature fruits. For example, holes of bruchid beetles in *Leguminosae* often appear on the surface of immature pods (chapter 7).

Seeds that develop full size seeds without fertilization and consequent embryo development like many conifers (parthenocarpy, cf. section 2.4) impose a special problem. A cutting-test that may reveal these empty seeds is rather time-consuming. Alternatively the seeds can be exposed to a flotation test: extracted seeds are dried and put into a liquid with a density of less than 1 (e.g. kerosene, SAE motor oil); filled seeds will sink in the liquid, empty seeds float. X-ray examination is another way of examining seed quality but requires special equipment and facilities. These methods are described in details in chapter 10.

Table 3.2. Example of calculation of conversion factor for a cutting test in cones.

Fruit No.	Cut seeds visible on one surface	Total number of seeds
1	10	50
2	8	55
3	12	63
4	9	28
5	6	18
6	8	48
7	8	38
8	10	52
9	11	66
10	11	59
Total	93	477
Average	9.3	47.7

Conversion factor: 47.7 : 9.3 = 5.1

Table 3.3. Example of crop assessment of *Swietenia macrophylla*.

Fruit count, 20% of the visible side of the crown	12 fruits
Fruit crop on the total visible side of the crown, x 5	60 fruits
Fruit crop total, x 3	180 fruits
Estimated harvestable, 40%	70 fruits
Average number of seeds per fruit	60 seeds
Harvestable seed crop, number of seeds	4,200 seeds
Seed weight	2,000 seeds per kg
Harvestable seed crop	2.1 kg

3.2.4 Correlation over geographical areas

If seed collections are to take place in remote or seasonally inaccessible areas, it may be impossible or too costly to conduct preliminary surveys in the particular stand. If flowering and fruiting are synchronized and correlated with e.g. climatic factors, reproduction in one area may reflect the trend of a larger geographical area. Flowering of several species of dipterocarps near the forest research station in Kepong, Malaysia appeared to reflect the flowering trend over a large area of Peninsula Malaysia (Yap and Chang 1990). Also flowering of semelparous bamboo species is known to occur simultaneously over large regions. However, sometimes flowering is only local. Possible seasonal displacements such as delayed fruiting seasons with increasing latitude or altitude (cf. example of neem and *Gliricidia* section 3.2.1) should also be taken into account.

3.2.5 Determining optimal harvest time; maturity indices

The optimal time to harvest is when a large amount of viable, germinable seeds can be collected. This is when most fruits and seeds are mature but only few have been lost to predation, dispersal and (for ground collection) germination or deterioration. Species can be grouped into 3 categories:

1. Trees with more or less continuous reproduction throughout the year but often with one or two peaks.
2. Trees with definite, sometimes short, seed maturation season and early dispersal, predation and/or short physiological viability.
3. Trees with a definite maturation season but with prolonged persistence on the tree before dispersal.

Re. 1. These are the diffuse flowering or fruiting species typical of aseasonal climates. Fruit and seed at any stage of maturity may be present on the tree any time of the year. Often there are one or two peak seasons in which both quantity and quality are at optimum. In terms of seed collection they have the advantage that some seed is normally available at any time of the year but the disadvantage that only a small amount of seeds can be picked during each collection. They may stay viable on the tree for some time but are often continuously removed by dispersal. *Agathis* spp. is an example of this group in which considerable variation exists between individual seeds, individual cones and individual trees in respect of maturity (Whitmore 1980). Other examples of prolonged flowering are *Dobera glabra* and several *Acacia* spp.

Re. 2. These are frequent in seasonal climates. For seed collection they have the advantage that a large amount of seeds can be collected at one time but the disadvantage that seeds are easily lost, hence making timing very crucial, sometimes a matter of days (Fung and Hamel 1993). *Pinus strobus* var. *chiapensis* is an example of a tropical highland species with extremely short collection season. The cones open to disperse their seeds within 24-48 hours after full cone maturity. Premature collection of this species yields seed of low quality while delayed collection yields little seed. In *Taxus brevifolia* the embryo continues to develop up to the time of full maturity, and early collection results in poor viability and storability (Vertucci *et al.* 1996). Maturation period and dehiscence or abscission are all influenced by local weather conditions during the maturation period (Gordon *et al.* 1972). Relatively cold and moist weather may delay maturation and dispersal for several weeks. Conversely, a sudden dry and warm spell may speed up dehiscence and abscission. Such events can be extremely crucial in species in which dispersal follows rapidly upon seed maturation, e.g. grevilleas, many acacias and cassias, and some conifers (Stein *et al.* 1974, Gray 1990, Barnett 1979).

Also aseasonal equatorial climates contain species with short maturation and concurrent harvest season. Timing here is especially crucial because many of the species have recalcitrant seeds a characteristic of which is that they continue to accumulate dry matter up to full maturity; seeds collected early are therefore likely to be small and underdeveloped. Since the seeds have short viability and no dormancy, late collection is equally unsuitable since seeds are easily lost to germination or deterioration (Berjak and Pammenter 1996). The fruiting seasons in equatorial climates may vary according to variation in flowering season. Yet, fruit development may be relatively constant, so that harvest can be predicted roughly based on flowering season (Ng and Loh 1974).

Re. 3. In some species, fruits persist for a long time on the tree after maturity, sometimes several months. Such species are convenient in seed handling because collection time is not critical and collection can take place during seasons of relative low activity at the seed centre. In West Africa, *Terminalia ivorensis* is such a species whose seeds stay viable on the tree for a long time after maturity although they often suffer from predation and damage by weevils (Evans 1992). In species with dehiscent fruits, long persistence on the tree is often related to extraction problems (cf. chapter 6). Several eucalypts (e.g. *E. cloeziana*, and *E. pilularis*) and pines (e.g. *P. banksiana* and *P. contorta*) belong to this group.

The quality of a seed crop sometimes varies during the fruiting season. Exceptionally early or exceptionally late fruiting may be preceded by an exceptionally early or late flowering in which case the risk of self-pollination and concurrent inbreeding is high. Further, fruits with small or underdeveloped seeds are likely to mature or dehisce more quickly than those with normally developed seeds. This also holds for insect-infested seeds which often undergo false ripeness, in which the fruits take the colour and consistency of ripe fruits, but contain damaged seeds and fall early (Ng and Loh 1974). Consequently, especially the early part of a seed crop is often of poor physiological and genetic quality and should be avoided (Hedegart 1975, Morandini 1962, Seeber and Agpaoa 1976). Hence, it is generally advisable to collect seeds only during the peak fruiting season.

Maturity indices

Determination of the best collection time pre-supposes knowledge of structural changes in fruits and seeds during the later part of the maturation period as discussed in section 2.4. The seed collector must be able to judge, preferably on fruit appearance, when the largest quantity of good seeds can be collected. Normally, the earliest possible collection is when seeds are germinable; the latest possible collection is before abscission (dispersal). The interval between, which for some species is very short, is the potential harvest period. In some cases it is necessary, or practical, to collect fruits before full maturity; these aspects are discussed in section 3.2.6.

Maturity indices vary according to fruit type and species and should be learned for the particular species to be collected. Change of colour, moisture content and development of abscission zones occur in most types. Dehiscent fruits often develop visible aperture structures prior to dispersal, i.e. lines where the fruit will eventually split open. Dehiscence lines of the operculum of eucalypt capsules are an example of a good maturity index for that genus (For. Com. 1994). A summary of some practical maturity indices is given in table 3.4.

For species where harvesting can be done without significant loss of seeds and where the trees can be kept under observation, collection may be postponed until natural dispersal has commenced, hence dispersal in itself is an indication of seed maturity. This can be observed either directly, on opening of dehiscent fruits or falling seeds, or indirectly on e.g. frugivores visiting trees with animal dispersal. The majority of seeds of species with a relatively short maturation season are normally mature when the first ones are released. Typically, however, seeds of poor quality (e.g. underdeveloped or infected) are shed before the main crop (Owen 1995).

In species with a very short dispersal period and small seeds that are easily lost, e.g. some eucalyptus, the commencement of dispersal may be too late for collection. Artificial drying of early picked fruits may speed up dehiscence with the practical interpretation: 'if the fruits will open upon desiccation, they are mature and ready to be collected, if not, harvest should be postponed' (For. Com. 1994). This check is especially practical if cold or moist weather delays natural dehiscence although the seeds are physiologically mature, e.g. *Gliricidia, Sesbania*, and some *Eucalyptus* and *Acacia* spp.

Direct examination of the seeds is applicable for species with relatively large seeds. Cutting tests reveal the development of the embryo and the firmness of seedcoat and endosperm. The endosperm, where present, should be firm and not milky (except coconut). The size of the embryo varies with species (chapter 2). In some species e.g. several conifers and Taxus spp. the embryo continues to enlarge up to the time of full maturity and its development can be used as a reliable maturity index (fig. 3.4) (Dobbs *et al.* 1976). Cutting tests should be conducted on average seeds and not on early fallen ones, which may have inferior quality.

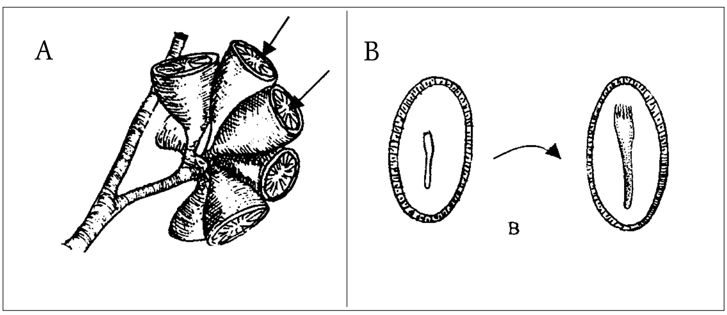

Figure 3.4. Maturity indices. A) dehiscence lines of maturing eucalypt capsules. B) embryo development in *Taxus* spp.; the embryo continues to develop up to full maturity.

3.2.6 Collection of immature fruits and seeds

During the later part of fruit and seed maturation the stream of nutrients and water from the mother tree ceases and the late maturation events involve physiological processes only within the fruit and seed (cf. chapter 2). These processes do not always require the fruit being attached to the tree, in which case fruits may be harvested immature and then after-ripened under controlled conditions. It should be

Maturity event	Method of examination
Colour change: Dry fruits: green to yellow, brown, black etc. Fleshy fruits: green to conspicuous	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

Table 3.4. Practical maturity indices for forest tree fruits

noted that this only holds for orthodox seeds; recalcitrant seeds tend to continue to accumulate dry matter up to full maturity and can generally not be collected immature and after-ripened.

Collection of immature fruits may have the following rationale:

1. Minimize loss of seeds to dispersal and/or predation
2. Avoid development of dormancy
3. Extend collection season
4. Reduce pre-processing damage

Re. 1. Some fruits are prone to serious predation and/or dispersal at the early fruit stage. In Africa many acacias and other legumes suffer from serious attack by bruchid beetles. Bruchid larvae develop within the seeds (fig. 7.1 plus text chapter 7). Sometimes more than 50% of the seeds are infected with bruchids when seeds are mature (Doran *et al.* 1983). Drupes of *Maesopsis eminii* are removed by hornbills, which may raid a tree in a few days, especially if the fruit crop is small. Flocks of weavers, fruit bats or migratory birds may completely empty a tree for fruits in a matter of hours. Premature collection also applies to many small-seeded, wind-dispersed species with a short maturation season, in which seeds are widely scattered once mature (Stein *et al.* 1974, Gray 1990). For example, seeds of *Ailanthus excelsa* are usually picked before maturity since fully mature fruits are liable to lose most of their seeds as soon as attempts are made to collect them (Khullar *et al.* 1991).

Re. 2. Some types of dormancy develop only during the late maturity processes (Mayer and Poljahoff-Mayber 1982). If seeds are to be sown immediately after collection, pretreatment can sometimes be avoided if the seeds are collected early. An example is physical dormancy in Leguminosae, which develops as a result of dehydration of the seed-coat. Seeds are germinable before the seed-coat becomes impermeable and early collected seeds thus need no or only a very weak pretreatment (cf. chapter 9).

Re. 3. Some species have a very long fruiting season and only a few fruits are mature at any one time. In such cases the amount of harvested fruits may be increased if immature fruits are harvested along with mature ones. The fruits must then be sorted so that only the immature fruits are after-ripened. Collection of immature fruits may also be feasible if collection happens to be scheduled too early and the collection team arrives at a remote site before the seeds are mature.

Re. 4. Fermentation of fleshy fruit pulp may damage the seeds. If depulping is not possible in the field or immediately after collection, fermentation risk may be delayed by collecting fruits early.

The crucial point of collecting immature fruits and seeds is to determine the critical point after which seeds can be collected without hampering the physiological quality. This requires both experience and experiments in which the physiological development of the seeds is related to fruit appearance.

Collection of immature fruits and seeds implies some potential problems and additional costs:

1. Additional resources for after ripening
2. More laborious seed collection
3. More laborious seed extraction
4. Reduced viability and vigour of collected seeds

Re. 1. After-ripening is an extra link in the chain of seed-handling processes, which requires space, manpower and other resources (process of after ripening described in chapter 6). Premature collection implies that extraction must be postponed until the seeds are fully mature, which excludes e.g. field extraction for reduction of bulk (chapter 5).

Re. 2. Collection of immature or early mature fruits inevitably implies collection from the trees. Since abscission zones have not yet developed, shaking of branches will rarely be sufficient for releasing fruits, and the more laborious cutting of fruits or fruit-bearing branches will be necessary (cf. chapter 4).

Re. 3. Extraction of seeds from artificially ripened fruits is often more difficult than from naturally matured ones. Problems of opening dehiscent fruits and loosening of fruit pulp are frequent problems, especially in fruits collected very early (Gordon *et al.* 1972).

Re. 4. Even if germination capacity has been achieved some maturity processes may have been hampered. Inappropriate ripening often causes reduced storability and seedling vigour (cf. chapter 9 and 10).

3.3 Seed Sources

The term 'seed source' applies to the stand of trees where seed is collected. A seed source can be a number of single trees, a natural stand, a plantation, and a seed-production area or seed orchard. Seed trees are the individual trees from which the seeds are collected. Potential seed sources are identified in the planning phase; actual seed trees are often only selected during the seed collection.

A seed source should yield an appropriate quantity of seed with a high physiological and genetic quality which matches the plantation site and purpose. Hence, in general the seed trees should be of good phenotype, neither juvenile nor over-mature and good seed producers (Morandini 1962). For special planting purposes, for example conservation or provenance seed stands, special consideration on sampling for the capture of genetic diversity may be included. For plantations not intended for future seed production, genetic diversity is usually of less importance, but collection should avoid inbred seed and inferior parent trees, which may affect the performance of the plantation. If, however, the plantation is envisaged to become a seed source itself some time in the future, appropriate measures should be taken to assure reasonable genetic diversity.

Information on seed source is very important for seed documentation (see chapter 14). For each species in a seed-procurement programme a list of potential seed sources should be identified, mapped and regularly surveyed. The purpose of such listing is partly to be able to deliver seed of a particular species from a desired provenance, partly to assure that several alternative sources are available in case of crop failure in part of the population. In addition to biologically determined crop failures mentioned above, it often happens that seed sources simply disappear due to cutting.

3.3.1 Genetic quality of seeds

The genetic constitution or inheritance carried by the seeds makes up the potential performance of the progeny: if the genetic potential is poor, the performance will remain poor regardless of environment and silvicultural efforts; if the genetic potential is good, this potential may be expressed by appropriate silvicultural measures. Genetic quality can only be proven by genetic tests (e.g. progeny tests) which are outside the scope of this book. Yet, in the selection of seed sources and seed trees of unknown genetic constitution a few measures and precautions can and should be taken in order to avoid genetic inferiority, viz.

1. Avoid seeds from related individuals or inbred populations
2. Avoid phenotypically inferior trees.

Re. 1. A narrow genetic base implies a risk of inbreeding. In a population of few flowering individuals the risk of self-pollination is high, and unless the species has a strong inbreeding barrier, many seeds of a small breeding population may be inbred. Isolated trees or trees flowering out of phase with the majority of the population are more likely to self pollinate and consequently produce inbred seed. Therefore, such trees should be rejected as seed trees.

Neighbouring trees in natural stands are often half sibs or full sibs (Griffin 1990). Species with short-range pollination and dispersal are more likely to create groups of related individuals in the stand than species with long distance pollination and dispersal (fig. 3.5). This is especially to be considered in natural stands of a single dominant species, e.g. *Tectona grandis*, *Acacia senegal*, *Brachystegia* spp. and many pines and eucalypts. A distance of 100 meters between seed trees is usually considered a minimum in natural stands, but it depends on collection purpose (Gray 1990, Palmberg 1985). Genetic diversity is also assured by collecting from a large number of seed trees. Special sampling techniques are applied for special collections like trials or ex situ conservation, which is outside the scope of this book; reference is made to e.g. Eldridge *et al.* 1992, and Palmberg 1985.

First generation of progeny from a tree that is mainly outcrossing is not inbred. Inbreeding may occur if these progenies are used as mother trees in plantations. Therefore the genetic history (e.g. number of mother trees) of seed sources of planted material is important. Plantations raised from a narrow genetic base (i.e. few mother trees) should be rejected as seed sources. Obviously this is even worse in clonal plantations, unless specifically designed for seed production.

Many exotic plantations are known to have originated from few mother trees during the first introduction. For example, mahoganies (*Swietenia* spp.) cultivated in many parts of Asia are believed to originate from a small number of seed trees in Honduras and Belize. Unless new material from a broader genetic base has been introduced later, plantations raised from seeds of such trees are likely to suffer from inbreeding depression. Other examples of exotic plantations based on a few mother trees are *Cupressus* in Kenya and *Gliricidia* in Sri Lanka.

Compared to natural stands, neighbouring trees in plantations are less likely to be related, provided the total genetic base is broad. This is because both seeds and plants are usually mixed during the establishment. Consequently, distance requirement for seed trees is less strict in plantations than in natural stands. However, as neighbouring trees are likely to be pollinated by the same pollen cloud, seeds collected from two adjacent trees may have a higher probability of being related on the paternal side than two distant trees.

Plantations raised from a broad genetic base and superior phenotypes are good seed sources. Since both seeds and plants have been mixed during establishment, the risk of neighbouring trees being related is not higher than for distant trees. Therefore distance requirement during sampling is less important.

Re. 2. The phenotype (the tree as we see it) is a product of both genotype and environment. A poor phenotype can be caused by detrimental environment and the progeny may perform excellently when grown under favourable conditions in plantations.

For example, Lake Albucutya provenance of *Eucalyptus camaldulensis* grows, in their natural environment in Australia, heavily exposed to wind and sand flow, and the trees are bent and crooked. Grown in plantations in e.g. Israel the progeny grows fast and straight.

Yet, phenotypic selection does have a justification: if the phenotypic quality is good, then we know that the tree has the genetic potential for good performance; if the phenotype is poor, then we do not know the cause. Hence, in environments with moderate environmental stress a certain selection of seed trees is appropriate. Trees with exceptionally poor phenotypes (multiple stems, forking, attack by diseases etc.) should be avoided.

To avoid detrimental genetic effects in seed collection the following practical measures are recommended (For. Com. 1994):

1. Avoid seed collection from sites where seed crops are sparse or heavy crops restricted to isolated trees, i.e. prefer stands with heavily fruiting trees in close proximity to each other.
2. Within the preferred stand, spread each collection over the largest possibly number of widely dispersed trees; collect from at least 15 trees which are preferably at least 100 m apart.
3. Collect from vigorous trees of good form; some defects due to physical damage (e.g. from fire or falling trees) can be ignored.

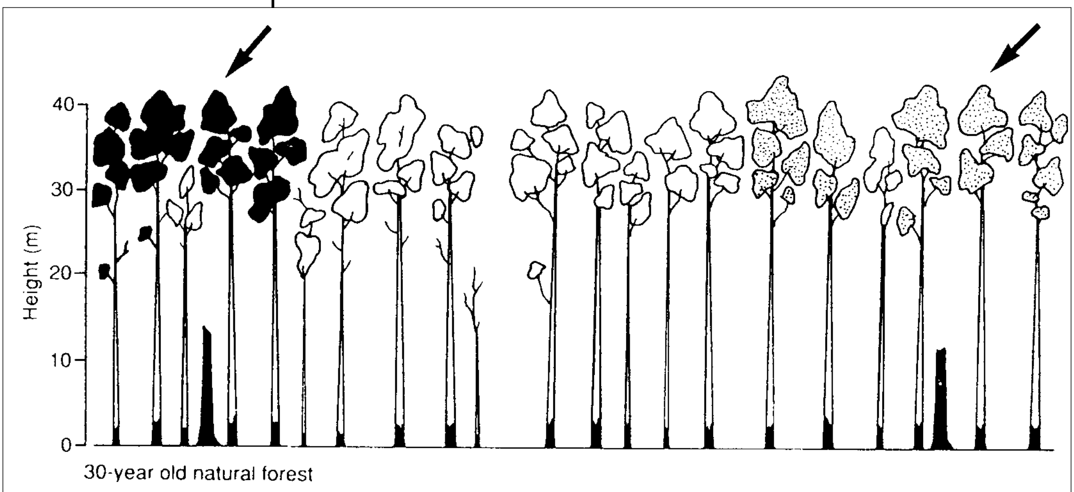

Figure 3.5. Regeneration of eucalyptus after fire tends to create groups of half sibs (From Eldridge *et al.* 1992).

3.3.2 Species and provenance

The species concept, based on morphological characters, is relatively well established. If significant morphological variation occurs within a species, it may be further divided into subspecies, varieties (lat. *varietas*) and forms (lat. *forma*). Characteristic of the taxonomic divisions is that they can be recognized morphologically. However, within a species (or other taxonomic sub-unit) a large variation exists in terms of ecological adaptation and growth forms. In botanical ecology the term **ecotype** designates a special growth site (habitat), e.g. dry zone, humid zone or high altitude. In forestry the term **provenance** has come into common use as the place of origin of the planting material because it designates both the ecotype and the growth habit (e.g. fast growth, straightness of stem or other desired traits). For example, *Eucalyptus camaldulensis* grows over most of the Australian continent. Despite its morphological similarity, various ecotypes occur according to different ecological conditions. Variations of growth habits have been revealed through provenance trials, i.e. trials of comparative performance of different seed sources grown under similar conditions. Provenance names such as Petford and Lake Albucutya are known sources of seeds of the species whose progeny has proven superior growth habit in many areas of the world with climate and soil similar to the original site.

The provenance name normally designates the distinct location of origin of the seed source, for example named from the nearest town, lake, river or hill. An ideal provenance is, according to Barner (1975) characterized by:

1. It is composed of a community of potentially interbreeding trees of similar genetic constitution (and significantly different from the genetic constitution of other provenances).
2. It is sufficiently large for the collection of reproductive material in quantities significant for forest practice.
3. It can be defined by means of boundaries which can be identified in the field.

Although boundaries of gene flow (interbreeding) may be difficult to define in areas with more or less continuous population, the provenance concept is practical in forestry and should be included in seed documentation (chapter 14).

Trees of a particular provenance may be grown in a different area and become seed sources themselves. In these cases the original seed source should be indicated in the seed documentation, e.g. Homa Bay, Kenya (immediate parent) ex Petford, Australia (original source). A more common way for exotics is, however, to distinguish between provenance and origin: the provenance name applies to the location of the seed source and origin applies to the original source. In the above example provenance name is Homa Bay and origin is Petford.

3.3.3 Managed seed sources

Improved seed sources are established in connection with tree improvement. In tree improvement programmes, Seed Production Areas (SPA) or Seed Stands are interim sources of seed of non-proven genetic superiority, but phenotypically upgraded by removal of undesired phenotypes. Progeny of trees that have proven superior performance in trials are established in seed orchards (SO), either raised from seeds (seedling seed orchards, SSO) or vegetative material (clonal seed orchards, CSO). As the tree improvement programme proceeds, 2nd, 3rd or more advanced generations of seed orchards are established. The term 'seed orchard' is occasionally used for any planted seed source. However, where no prior progeny trials have been carried out, such sources are more correctly referred to as 'provenance seed stands'. In both seed production areas and seed orchards, trees are managed especially for seed production, for example by spacing, thinning and pruning. Both SPAs and SOs are convenient seed sources because of their superior genetic quality and because it is often much easier to collect seeds: seed production per tree is normally high, they are usually easily accessible and the spacing often allows use of equipment and efficient collection methods not possible in natural stands and plantations (see chapter 4).

3.4 Management, Administrative Aspects and Work Plans

Planning of activities based on biological systems must necessarily be flexible and adjustable since these systems are often unpredictable or things can change rapidly, which makes current adjustment essential. A crop failure of one species or seed source may be compensated for by a larger collection of another species or in another seed source. A sudden masting of a rarely fruiting species should be taken advantage of by a large collection of that species. In both cases the succeeding operations will be affected, and must be geared to adjustment. In some species, processing can be delayed without detrimental consequences, e.g. dry orthodox seeds; in other species lack of preparation or shortage of capacity of the processing unit may ruin an otherwise successful seed collection. In some cases seed availability may influence the planting programme, especially for those species where a storage buffer is lacking, e.g. recalcitrant seeds (cf. chapter 8). Hence, planning and management of seed collection involves the whole seed-handling process.

3.4.1 Factors affecting size of seed collection

Only rarely is the person that plans a plantation programme the same as the one planning seed collection. In most cases a seed centre or seed-procurement unit receives an order of a certain amount of seed of a particular species and provenance. Seed orders are usually given with very little notice and customers expect to get their seeds so speedily that current seed orders are of little value for the planning of seed collection. Determination of species and quantities of seeds may be based on previous years' records of demand. However, often the demand changes and it is economically desirable to know the trend and plan accordingly. Expenditure on seed procurement of species for which there is no demand is wasted; inadequacy in meeting seed demand of other species is lost profit and failed service. The shift in demand of seed from one year to another may be caused by normal fluctuations in the plantation programme or by the sudden appearance (or closure of) afforestation projects. Shift in species priority may be caused by pest problems, purpose of planting and/or political decisions.

In Malawi a large plantation programme was launched for *Pinus radiata* up to 1965. Attack by needle blight disease (*Dothistroma pini*) caused the plantation programme to shift to resistant *Pinus patula* and *Cupressus lusitanica* (Willan 1985). In India a large social-forestry programme suddenly expanded the market tremendously, especially for *Eucalyptus* spp. Debate on the ecological role of eucalypts in exotic plantations made several countries shift to local species in their planting programmes, and new approaches to tree-planting practices, e.g. agroforestry, shelterbelt, roadside planting, fuelwood plantations and urban forestry, shifted the demand from relatively few plantation species of often exotic origin to a large number of native species, for example legumes. Similarly, the identification of 'new' species e.g. *Leucaena, Gliricidia, Tephrosia* and *Azadirachta indica* or new promising provenances may cause sudden demand for hitherto relatively unknown species.

As early as possible, seed-procurement units and seed customers must make preliminary estimates on seed demand for the coming season(s). Calculating seed demand is based on field requirement for appropriate species in various plantation programmes (see table 3.5).

In addition to the actual expected seed demand for the current plantation programme, seed may be collected to satisfy a possible or expected market from private owners, projects or organizations raising their own seedlings, plus possible export (to other districts, regions, or countries). Because of unreliable and fluctuating markets it is advisable, wherever possible, to build up storage buffers. The size of such reserve stock depends on the annual fluctuation of the market, seed availability, potential longevity etc. If seeds are normally only produced over long intervals of say 5-8 years (e.g. *Araucaria cunninghamii*), a store of seed to meet consumption during the interim years should be established (Huth and Haines 1996). Although, for such species, the consumer should be geared to change his/her species selection to take advantage of a sudden burst in seed availability, there will normally be a demand for seed of popular species every year. Even where trees fruit regularly every year it may be feasible to collect a seed crop for several years' consumption, especially if the seed collection site is in a remote location. Once the seed collection expedition has been launched, the cost of surplus collection is relatively small compared to making a new collection trip (section 3.4.2).

Collecting seed two or more years in advance obviously requires that seed can be processed fast enough to avoid deterioration, and that it can be safely stored for the period in question. Potential storage costs should be weighed against cost of collection. Small-seeded species where large quantities of seeds can be stored in a small space, e.g. a refrigerator, may justify a large collection, while store-room facilities required for large-seeded species may make large collections uneconomical, especially if low temperature is necessary for maintaining viability (see chapter 8).

Where seeds cannot be stored beyond the first coming sowing season because of physiological limitations, i.e. recalcitrant seeds, customers must be able to change their planting programme to take advantage of a sudden seed year. As soon as a good seed crop can be predicted for these species, the seed supplier should quickly communicate the seed availability to the nurseries and make a plan for the amount of seed needed. Very sensitive seeds must be sown without delay, and in such cases timely co-ordination between seed collector and nursery is of paramount importance.

Table 3.5.
Example of calculation of seed demand based on seedling requirement for a plantation programme with 3 species.
Notes:
* Germination percentage and mortality is calculated based on the number of germinated seeds and planted seedlings respectively, i.e. the lower figure is the one to be computed in the calculation.
** *Pterocarpus indicus* seeds not extracted from the samara.

	Plantation type	Casuarina equisetifolia		Pterocarpus indicus		Swietenia macrophylla	
Spacing	Plantation	2x2 m		2x3 m		3x3 m	
	Shelterbelt	1½ x 2 m					
		Area	No of plants	Area	No of plants	Area	No of plants
Seedling demand (programmes)	Plantation	75 ha	187,500	100 ha	167,000	125 ha	138,750
	Shelter belts/border planting	25 km	20,000				
	Farmers		5,000		7,500		2,000
	Others		2,000		4,000		1,000
	Total		214,500		178,500		141,750
Field demand (seedlings)	Total plantation target		214,500		178,500		141,750
	Expected field mortality		10%		15%		20%
	Total field demand *		238,300		210,000		177,200
Nursery demand (seedlings)	Total field demand		238,300		210,000		177,200
	Expected nursery + transport mortality and culling, %		10%		10%		12%
	Total germinated seeds, number*		264,800		233,300		201,400
Nursery demand (number of seed)	Total germinated seeds		264,800		233,300		201,400
	Germination percentage		90%		75%		80%
	Total seed demand, number*		294,200		311,100		251,800
Seed demand (weight)	Total seed demand, number		294,200		311,100		251,800
	Seed weight, no. of seed per kg		750,000		865**		2,000
	Total seed demand, pure seed, kg		0.390		360		126
Fruit demand, number	Total seed demand, number		294,200		311,100		251,800
	Average number of seeds per fruit		70		2		70
	Total fruit demand, number		4,200		155,550		3,600
Fruit demand, weight	Total fruit demand, number		4,200		155,550		3,600
	No. of fruits per kg		230		865		45
	Total fruit demand, kg		18.2		180		80

3.4.2. Budgeting seed collections

Larger seed collecting expeditions, taking several days and going to remote areas, should be budgeted and later accounted for individually. This assists the economic planning of collection i.e. determining appropriate amount of seed to be harvested and duration of collection tours. The procurement costs ultimately influence pricing of the seeds (see chapter 15).

A seed-collection tour has typically certain basic expenditures which are independent of the duration of the trip and the amount of seeds collected (e.g. transport to collection site and equipment), and some variable expenditures according to duration and amount of seed collected (e.g. local transport, salary and daily subsistence allowance (DSA)). Collection in remote areas typically has large basic costs both because of the direct transport cost and because people must be paid while unproductively sitting in the vehicle to and from the collection site. In some cases hiring of local casual labourers near the seed source may be an economical alternative to bringing many people from the central seed unit. Hiring local staff may also have other positive effects, e.g. facilitating access to seed sources. On the other hand, much time may be used looking for labourers, and operations that require technical skills, such as climbing, can only be done by trained personnel (cf. chapter 4).

Because of the basic expenditures, the cost per unit weight of seed will decrease for large collections (table 3.6). Consequently, remote collections should gather large amounts of seeds which (provided the seeds can be appropriately processed and stored) can serve as a market buffer (see chapter 8).

	Unit price	3 day field collection	10 day field collection
Transport to and from seed source - 500 km	$0.2 per km	100	100
Basic salary for 3 officers during transport to site and local arrangement, 2 days	$6 per day/per person	36	36
DSA for 3 officers during transport and local arrangement, 2 days	$4 per day/per person	24	24
Transport within site, 30 km per day	$0.2 per km	18	60
Basic salary for 3 officers during collection	$6 per day/per person	54	180
DSA for 3 officers during collection	$4 per day/per person	36	120
4 casual labourers, salary	$4 per day/per person	48	160
Total cost	—-	316	680
Collection cost per kg seed collected (8 kg/day)	—-	13.2	8.5

Table 3.6.
Example of budget of seed collection involving 2 days' transport to site including local arrangement (permits, survey, hiring casual labourers etc.). It was envisaged that there are 3 officers and 4 casual labourers and that 8 kilos of seed could be collected per day. All figures are arbitrary.

3.4.3 Permits and restrictions for seed collection

If the seed collection unit and the owner or administrator of the seed source are under the same administration, e.g. forestry department, permission for seed collection may be irrelevant or a minor formality. This is often the case in collections from seed orchards, seed-production areas or plantations. In the cases where several governmental offices are involved, or the responsibilities and authorities are not clearly defined, seed collection can be seriously delayed due to bureaucratic procedures. On private land, permits and restrictions are often up to the individual owner and often more easily negotiated. In either case payment for the collection may be involved, either as a fixed fee or dependent on quantity collected.

Collection in natural stands may imply specific problems since they may be conservation areas and subject to various restrictions. Seed collection in national parks, game parks, sanctuaries or forest reserves is normally limited by protective legislation, which differs from one country to another. Special restrictions on seed collections are often put on the following activities:

- Movement. Vehicles are often restricted to official roads or their immediate vicinity. Movement on foot may be feasible but time consuming and often prone to some risk. In some countries armed guards are compulsory in parks (cf. next paragraph).
- Use and possession of firearms. Rifle shooting of branches (see chapter 4) is nearly always prohibited in national parks and reserves and near populated areas. Weapons for self-protection against dangerous wildlife, which are necessary in many African and Asian national parks and re-serves, are often restricted to official guards; hence arrangement with the park authorities must be made for escort by guards.
- Damage to trees. Any form of collection from the tree will almost inevitably cause some damage. Tree owners or administrators may restrict the use of saws (or rifles) for cutting seed bearing limbs of trees, or the use of climbing spurs. When cutting is permitted, there is often some limitation on the amount of seeds collected from individual trees. Collection methods must be agreed with owner, park or reserve authorities.
- Camping. In most conservation areas camping is subject to restrictions, and usually camping is not allowed outside official campsites. This is partly in order to protect visitors from dangers, partly to minimize poaching, pollution and accidental fires. Such restrictions should obviously be respected.

Permits including specification of limitations or restrictions plus possible fee should generally be negotiated well in advance of the actual collections. On public or governmental administrated land (parks or reserves) the permit is often obtained from the head office of the administrative department, and confirmation obtained from the local administrative unit (forest office, park office etc.) just before the collection takes place. In most cases the particular permit is based on a general agreement between the unit in charge of seed collecting and the administration of the seed sources. An example of a collection permit is given in appendix A3.3. In some countries there are restrictions on the transfer of plant material between regions; local legislation should be consulted.

3.4.4 Determination of collection methods

Collection methods are described in chapter 4. Sometimes several alternative methods of collection may be considered. More often, however, seed/fruit morphology, availability and transport of equipment, potential damage to trees and other issues restrict methods of collection. Seed collection of some plantation species may be linked with a cutting operation in which case special arrangements must be made with the responsible authority.

3.4.5 Work plans

Reproductive phenology and quantity of seeds of the species to be collected are the main determining factors in the elaboration of annual work plans. Since seed collection is typically seasonal work, it is important that as many workers as possible can be allocated for collection and processing during the peak season. This also implies that preparation and other work with no critical seasonality should, as far as possible, take place outside the collection season. Tasks that could mainly be undertaken outside the collection season include:

1. Calculation of seed quantity and labour demand
2. Analysis of potential seed markets and advertising
3. Identification of seed sources
4. Maintenance of seed sources
5. Updating of seed-source documentation
6. Settlement of permissions and agreements with seed-source owners and administrators
7. Preliminary assessment of flower and seed crop
8. Training of staff, e.g. for tree climbing or other collection methods and processing
9. Preparation and printing of forms for seed documentation and instructions for collections
10. Maintenance of equipment including repair and possible replacement
11. Purchase of new equipment and possible spare parts
12. Preparation of seed-processing and storage units

A precondition for the efficient use of the work force during the year is that permanent staff can be shifted between various seasonal work tasks. For example, the main duty of tree climbers is collection of seed, which, however, has a relatively short duration. Outside the main season climbers may be used in flower and crop assessment, seed processing or any other related tasks. Even with efficient organization of permanent staff and workload throughout the year it may be necessary to hire casual workers during the main season. Preferably casual workers should be semi-permanent in the sense that the same workers are used every year.

Annual work plans (and budgets) may follow the calendar year or another interval, but are typically of 12 months' duration. Work plans may be elaborated in several ways. They are typically elaborated as two dimensional tables or matrices with time (weeks or months) on one axis and activities on the other (appendix 3.4). Often a further breakdown of activities on e.g. species is necessary before the annual work plan can be elaborated. The following four steps are included in the elaboration:

1. Species-wise determination of seed demand. An appropriate calculation procedure is presented in table 3.5.

2. Species-wise determination of activities on seed handling and calculation of number of man-days required for each activity. The time of fruit maturity typically determines the time of seed collection (table 3.1 and 3.7). Processing like pre-curing, extraction, and cleaning typically follows immediately after collection, especially for species where fruits are susceptible to fast deterioration.
3. Determination of total activities of seed handling throughout the year and calculation of total number of man-days for each activity. The total work requirement of individual activities are summed up for each species over the year and put into a new matrix.
4. Calculation of overall activity plan for each staff member or staff group. Calculations of man-days for individual activities may reveal critical points of shortage during peak periods. This is in planning terminology called critical path analysis. Critical paths may appear both in the breakdown of activities and the workload of particular persons. The problem may be solved by rearrangement of activities or persons (possibly with inclusion of training) or employment of extra staff during peak periods. Other critical paths may be allocation of equipment, vehicles and processing activities. Purchase or hiring of equipment, alternative collection methods and extension of processing facilities may be solutions to these problems.

Usually a country's seed-procurement programme consists of several subunits covering smaller areas of the country. Species and fruiting seasons often vary from one end of the country to another, and each sub-unit must therefore have its own work plan and budget. However, co-ordination with neighbouring districts, regions or national centres can be very economical when, for example, collections are made from the same seed sources. Such co-ordination should be undertaken already during the elaboration of work plans to make efficient use of all resources.

Shortage of funds, even for essential seed collection for forest departments' planting programmes, is often the reality in many tropical countries. Therefore work plans must be adjusted to available budgets. This may affect species priorities (e.g. excluding species with relatively expensive procurement costs), provenances (e.g. excluding distant sources) as well as collection methods (e.g. excluding methods (and species!) where special equipment like climbing gear is necessary) and target amount (e.g. excluding any surplus seed collection for storage even if it might have been economical in the long run). Budgets are usually allocated on an annual basis, and annual work plans must reflect the budgetary limitations throughout the year. No species should be given low priority just because they happen to fruit during the end of the financial year.

Work plans are intentional plans and always subject to changes. They must obviously be flexible enough to adjust to current changes of e.g. seasonality, seed demand or other unpredictable factors. During the planning period it is important to keep a current record of each species collection, and to currently update the demand for further collections of each species (see also chapter 14).

Minor changes in activities may not need incorporation into the work plan. For larger changes adjustment is feasible, especially if they tend to influence several succeeding work procedures. Degree of detail, use and current adjustment of work plans typically varies according to personality and taste. Some managers tend to keep track on targets, seasons, processes and persons in their head, while others prefer detailed work plans. However, it should be stressed that annual work plans are both helpful and necessary tools for the whole planning process. Recorded adjustments of current year's work plan are often important for elaborating future ones.

Workplans as the ones described above may be elaborated manually. However, for large projects or seed collection units with many species and workers involved, available computer programmes can be helpful. Some special programmes are designed to make Gannt charts, critical path analysis and adjust for current changes in work programmes.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Acacia angustissima	●							●	●	●	●	●
Acacia auriculiformis								●	●	●		
Acacia mangium					●				●		●	
Agathis alba	●	●								●	●	●
Albizia falcataria ssp. falcataria	●	●				●						●
Albizia falcataria ssp. fulva	●	●										
Anthocephalus			●	●								
Araucaria cunninghamii									●	●	●	
Araucaria hunsteinii								●	●	●	●	
Calliandra calothyrsus	●	●	●					●	●	●		
Calliandra houstoniana	●	●	●					●	●			
Eucalyptus deglupta	●	●	●	●	●	●	●	●	●	●	●	●
Eucalyptus tereticornis					●	●						
Eucalyptus torelliana					●	●	●	●		●		●
Eucalyptus urophylla				●			●	●	●	●	●	
Gmelina arborea	●						●	●	●	●	●	●
Leucaena (all species)	●	●	●	●	●	●	●	●	●		●	
Octomeles		●										
Pinus caribaea var caribaea	●	●	●									
Pinus caribaea var. hondurensis	●	●	●	●	●							
Pinus merkusii		●	●	●	●	●	●				●	
Pinus oocarpa			●			●			●	●	●	
Pinus strobus var. chiapensis				●	●							

Table 3.7. Example of seed collection plan from Papua New Guinea. (From Howcroft 1990).

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Appendix A3.1 Checklist on planning

1. Seed demand

Seed demand is calculated based on planned consumption with break-down of each species and each mode of disposal plus, where applicable, building up storage reserves.

Species / provenance					
Plantation					
Store					
Sale					
Other					
Total demand					
Estimated loss					
Collection target, kg seeds					
Collection target, kg fruits					

2. Seed production and seed sources

Based on seed demand of each species (and provenance) potential seed sources are listed. Dependent on records on potential production in good, medium or poor seed years plus, if possible, pre-harvest crop (flower or fruit) assessment, the number of seed sources to be collected from is determined.

	Seed source name	Seed source category A: Identified stand B: Selected stand C: Prov. seed stand D: SPA E: SO	Annual potential seed production (harvestable), kg			Crop assessment H: High M: Medium L: Low			
Species			High	Medium	Low	Date	Assess	Date	Assess

As to detailed information on individual seed sources, reference is given to appendix A14.1A.

Extract from 'Guide to Handling of Tropical and Subtropical Forest Seed'
by Lars Schmidt, Danida Forest Seed Centre. 2000.

3. Individual seed collections

Prior to each seed collection, formalities pertaining to legal issues must be settled. The collection team must be provided with essential documents, equipment and finances to make their expedition efficient. Details vary from one country to another and between species, type of collection, duration of collection expedition and many other conditions. The following lists are not full checklists fitting any type of collection, but suggestions from which to make one's own relevant lists.

a. Administrative issues and documents

The type and number of necessary arrangements and documents to be prepared before a collection vary with the overall administrative set-up of the seed-procurement unit, local legislation etc. Formal issues must be settled before the collection team departs. The head of the team should be provided with copies of all necessary documents, with forms to be filled in during collection (see appendices to chapter 14), and carry enough cash to cope with planned or unforeseen expenses. It must be arranged for each member of the team, including possible casual or local labourers, to be provided with food and accommodation during the expedition, either in the form of advance payment or through a team leader meeting these expenses. Administrative arrangements and travel documents pertain to the following issues:

- Seed collection permit / licence
- Itinerary of expedition
- Vehicle papers: Insurance documents
  - Log book
  - Driver's authorization
  - Road map
- Map of collection area
- Firearm licence (where applicable)
- List of contacts (addresses, phone numbers etc.)
- Copies of seed source information forms
- Seed collection and handling record form
- Financial pre-arrangement for staff, vehicle, casual labourers etc.

b. Collection equipment

The list depends on species and mode of collection. Distance from roads and/or vehicle capacity may limit certain equipment types. The number of individual items depends on number of members of the team. It is advisable to bring spare pieces of items like hand pruners, which tend to get lost during field operations. A repair kit should include appropriate spares (bolts, blades etc.) as well as all-round repair material (strings, rivets etc).

- Ladders
- Spurs (pairs)
- Rope of different types (for safety lines, tool line etc.)
- Safety harness / belt
- Extended pruners
- Hand pruners (secateurs)

- Saw pruners
- Shaking devices
- Tarpaulins
- Flexible saw
- Tree bicycle
- Advanced line equipment (catapult or bow with fishing reel, arrows/lead weights etc., throwing rope)
- Shooting equipment (gun, bolt, ammunition, cleaning equipment, rifle case, ear muff)
- Repair kit (special spares, plus rivets, straps, strings, screws etc. and tools)

c. Field processing equipment

Dependent on species, duration of collection tour and quantity of fruits collected, the following field processing equipment is recommended:

- Drums
- Mortars
- Sieves
- Winnowing baskets
- Tarpaulins
- Portable threshers
- Portable depulpers
- Brooms/brushes
- Drying trays
- Electric fans
- Water hose and buckets

d. Field testing equipment

- Field moisture meter with calibration curves
- Magnifying glass
- Sharp knife for cutting test

e. Field storage equipment

- Canvas or cotton sheets
- Gunny bags
- Wooden boxes
- Polythene bags
- Small polythene bags for soil samples, microsymbionts etc.
- Tent or construction material for temporary shelter
- Cool-boxes
- Tags or identification labels

f. Special field equipment

- Tape measuring - 30 m
- Soil pH-meter or pH kit
- Flora
- Compass
- Binoculars

- Tree-height measurement instrument
- Camera
- Films
- Diameter tape
- Global Position System (GPS) equipment
- Plant press
- Notebooks, pencils etc.

g. Personal protection

Depending on location, type of fruits collected and mode of collection, the following equipment is recommended:

- Protective boots
- Gloves
- Protective clothes
- Safety helmet
- Safety glasses
- Mosquito hats
- Mosquito or insect repellant
- Wet/cold weather gear
- First aid kit
- Mobile phone or other communication system

h. Camping equipment

If the collection involves overnight stay in the field, the following equipment is recommended:

- Tents
- Mosquito nets
- Sleeping bags
- Portable mattresses
- Portable gas or kerosene cooker
- Extra gas or kerosene bottles
- Matches
- Cooking pots and pan
- Knives, can opener and other cooking facilities
- Plates, cups and cutlery for each member of the team
- Cool boxes
- Water containers with excess water
- Food containers with excess food
- Soap or detergents
- Tea towels

i. Vehicle emergency repair kit

Before any longer trip, vehicles should be thoroughly checked and any damage repaired or worn out parts replaced. In addition it is advisable to bring basic spares and repair material which, depending on vehicle type, may include the following items:

- Extra fuel

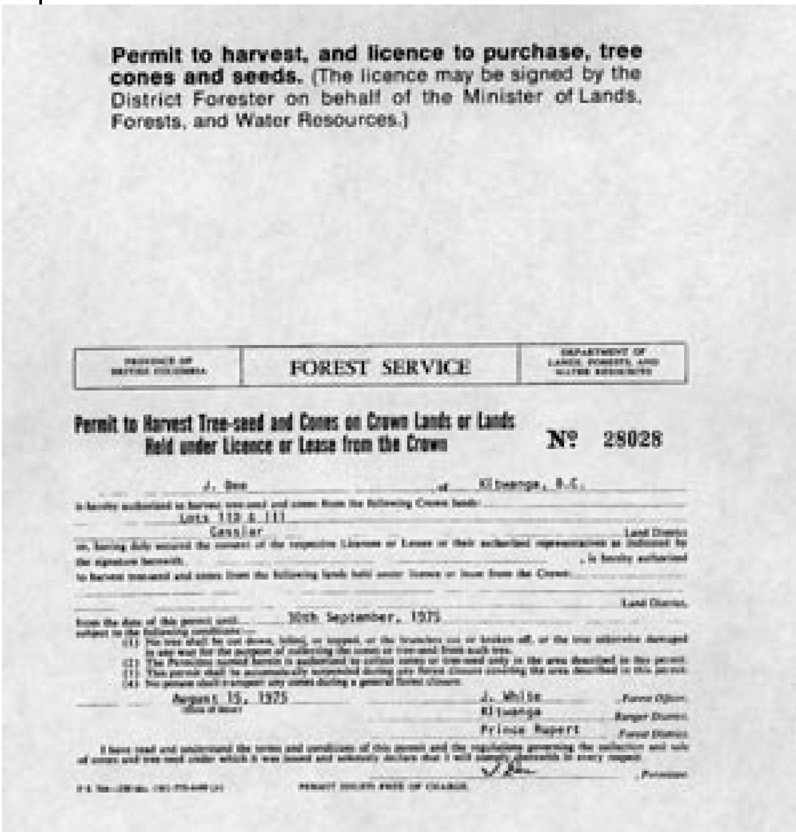
- Spare wheel
- Hydraulic jack with levers plus brick-stone-size wood block
- Tyre levers
- Puncture repair kit
- Air pump
- Engine oil
- Brake fluid
- Tool kit incl. screw drivers, spanners, hammer
- Tow rope or wire
- Electric wire and insulation tape
- Spare parts incl. bolts, bulbs, fuses, fan belts, filters, radiator hoses
- Fire extinguisher

Appendix A3.2 Number of plants per area unit at different spacing

Spacing	Plants per hectare	Plants per acre
1½ x 1½ m	4,445	1,800
2 x 2 m	2,500	1,015
2 x 2½ m	2,000	810
2 x 3 m	1,650	675
2½ x 2½ m	1,600	650
2½ x 3 m	1,335	540
3 x 3 m	1,110	450
3 x 3½ m	950	385
3 x 4 m	835	340
3½ x 3½ m	816	330
4 x 4 m	625	255

Appendix A3.3 Example of a collection permit

PERMIT TO COLLECT SEED IN AS PUBLIC FOREST IN



Permit to harvest, and licence to purchase, tree cones and seeds. (The licence may be signed by the District Forester on behalf of the Minister of Lands, Forests, and Water Resources.)

FOREST SERVICE

Permit to Harvest Tree-seed and Cones on Crown Lands or Lands Held under Licence or Lease from the Crown № 28028

J. Doe of Kitwanga, B.C.

Lots 110 & 111

Cassiar

30th September, 1975

August 15, 1975

J. White

Kitwanga

Prince Rupert

Appendix A3.4 Example of an annual work plan

ANNUAL COLLECTION PLAN

Collection Period	Species	Seed source location	Alternative source	Fruit/ 100 lt	Trans-port	Manpower liaison	Equipment	Permits	Budget
FEBRUARY									
weeks 3-4	Climbing instruction for 3 new climbers					1c+1s	5 climbing sets		600
MARCH									
weeks 3-4	Pinus patula	Seed orchard A, Monreale	None	100	2x4WD	6c+6a+1s	6 climbing sets 120 sacks 2 tarpaulins	None	2300
weeks 3-4	Pinus patula	Seed Production Area No 3, Kilima	None	100	2x4WD	6c+6a+1s	6c set 120sacks 2 tarp		2550
APRIL									
weeks 1-3	Pinus patula	Compartments 21, 22, Msitu	Cmpts. 6, 7 & 8, Kitivo	300	4x4WD	12c+12a+ 2s	12c set, 200 sacks,4 tarp	None	7200
week 4	Pinus patula	ditto	ditto	50	2X4WD	6c+6a+1s	6c set, 50 sacks 1 tarp	None	1200
week 4	Cupressus lusitanica	Cmpts. 1-3 Boi Tak	Cmpt. 10 Boi Tak	80	2x4WD 1 tarp	6c+6a+1s	6c set, 50 sacks	Check final thinning completed	1350
MAY									
week 1-2	Cupressus lusitanica	Cmpts. 1-3 Boi Tak	Cmpt. 10 Boi Tak	320	4x4WD	12c+12a+ 2s	12c set, 200 sacks,4 tarp	Ditto	5400
etc.									

Notes: c = climbers, a = assistants/anchormen, s = supervisors, 4wD = 4 wheel drive pickup. Budget includes working costs (vehicles, lodging etc), and therefore varies in accordance with accessibility, as well as size of team and period of collections.
Budget figures for illustration only, currency not specified