

ZAINAL ZAHARI ZAINUDDIN & JOHN PAYNE

HABITAT RESTORATION

for Fruit-eating Wildlife

AN ILLUSTRATED HANDBOOK

Seed and vegetative
propagation methods
for tropical rainforest
keystone plants



This handbook, illustrated with over 80 photos, provides a comprehensive guide to all aspects of propagating, planting and maintaining native trees, hemiepiphytes and lianas, with an emphasis on Ficus (wild figs) in the equatorial region of Borneo. Together with text that outlines the bigger picture, the emphasis is on details of nursery practice, vegetative propagation, seed preparation and storage, and dealing with common problems.

HABITAT RESTORATION FOR FRUIT-EATING WILDLIFE - AN ILLUSTRATED HANDBOOK

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for Fruit-eating Wildlife

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On the cover

Fruits of three common *Ficus* species, all ideal for habitat restoration. (Top two figs) *Ficus racemosa*, a beautiful riverside tree, readily grown from seed, whose fruits are eaten by fish, birds and mammals. (Bottom right cluster) *Ficus parietalis*, often found at forest edges and on old oil palm trunks, may grow as a climber, epiphyte or small tree, and can be propagated by marcots or seed. (Bottom left cluster) *Ficus benjamina*, a strangler with branches, twigs and leaves that point downwards, that provides numerous small fruits particularly attractive to birds, readily grown from cuttings and marcots.

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Habitat Restoration for fruit-eating wildlife — an illustrated handbook
by Zainal Zahari Zainuddin and John Payne

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Introduction

Restoration of habitats is already a recognised component of wildlife management globally, both conceptually and in terms of projects underway. Increasingly, however, active and targeted interventions in support of sustaining and recovering depleted wild populations in the equatorial tropical zone will need to be emphasised to an even greater extent than now. Why?

The era of establishing new large protected areas Southeast Asia is almost over. But many of the existing protected areas are too small to sustain viable populations of those large-bodied wild animal species which exist naturally at low population densities, and which require large areas of habitat for survival and reproduction. These species include not only elephants and tigers, but fruit-eating specialists such as orangutans, hornbills and pigeons. Set-aside lands in plantations (High Conservation Value areas, riparian zones, small forested hills and so on) are an important component of nature conservation, but—individually—are too small and too scattered to support viable populations of wildlife species that naturally exist at low population density.

Preventing hunting is important—but doing that alone is insufficient if food supplies are too small or seasonal to sustain the wild animals that are protected from hunters. Typically, the vegetation in set-aside lands has not been planted or enriched to cater for the production of foods for native wild animals. Apart from monitoring, there are rarely programmes in place to manage these areas in favour of sustaining endangered wild animal species. This is not to say that small remnant patches of forest (from less than one hectare to a few hundreds of hectares in extent) are not or cannot be of great value for endangered wildlife. Rather, the opposite is true. They are potentially very important, the key word here being ‘potentially’. Very few forest patches, if any, are managed collectively in ways that support the survival of scattered and fragmented populations of rare wildlife species.

Management of many small patches of residual forest helps to address the current conundrum of insufficient habitat for large-bodied wildlife species in governmental ‘protected areas’. To prevent extinctions, a better way is to think of the sum total of currently existing protected areas plus set-aside forest patches in plantations, which are currently not managed collectively as a single unit. If we assume that there will never be any new large protected areas, except perhaps in remote hill forests, the only remaining opportunity is to boost the productivity of the key food items

of those species, to above currently prevailing levels. That means a need to actively grow some of those foods on land outside the permanent forest estate, on corporate and other privately-owned lands. In any case, a long-term approach is needed. Corporate land-owners need to be convinced to join in and collaborate on this vision. Planting and maintaining wildlife food plants cannot be done quickly, especially if the plants involved are trees, which need years to grow large enough to supply fruits and young leaves as well as insects that feed on the trees’ leaves or nectar.

This thinking is already supported from several angles. One is that non-governmental organisations and their donors, as well as government departments, are already embarking on wildlife habitat restoration projects, albeit mainly within forest reserves and protected areas. Another is that palm oil certification schemes (both government-mandated and voluntary) require improved management of riparian zones and steep slopes in favour of environmental conservation, as well as evidence that land-owners and managers pay attention to rare, threatened and endangered wild species. There is also the move towards global recognition of ‘Other effective area-based conservation measures’ (OECMs).

But there are constraints to implementation, most notably in determining the locations of sites to be restored, and in the availability of appropriate planting materials.

Choice of sites for restoration

Usually, the choice of sites for restoration planting is determined by the land-owner. Small-holders are less likely to be involved, because they will tend to want to make all of their limited land area available for productive and income-generating crops. The land owner that is willing to allow restoration will most likely be an organisation, not an individual. It is most likely to be either the State Government, in which case the restoration site will be within a Forest Reserve or Wildlife Reserve or Wildlife Sanctuary; or a corporation that owns large areas of land (in the thousands of hectares), and is willing and able to allocate small parts of the land for restoration, either in order to support MSPO certification (which places emphasis on riparian management and threatened wildlife species), or RSPO certification (which also emphasises High Conservation Values, steep lands, and fulfilment of compensation liability in the case of corporations which cleared

forest after year 2007), or simply because some parts of their estates cannot support oil palms (usually permanent swamps and steep and rocky sites). Often, therefore, the precise sites chosen for restoration are not ideal for plant growth. Rather than fertile, well-drained, sunny, flood-free land, the sites allocated for restoration are more likely to be flood-prone or swampy (FIGURE 1) or steep or rocky or under existing tree canopy or with compacted soil.

Size of sites for restoration

Sites allocated for restoration planting on corporate or privately-owned land are usually small in size. There is a body of scientific literature which presents a rather negative view on forest fragments in agricultural landscapes. The findings are alarming in that very small patches do indeed support very few species, and with many taxonomic groups—including native plants—dying out entirely. Apart from this general picture, small patches of habitat suffer from an ‘edge effect’ (meaning ‘biological community structures that occurs at the boundary of two habitats’, typically forest and agriculture). Small set-aside lands inside plantations consist primarily of ‘edge’ rather than true forest. However, three points should be remembered. Firstly, restoration should be viewed, planned and implemented at a landscape scale, and not at an individual patch level. Secondly, the purpose of restoration in a particular landscape should never be directed at the impossible goal of increasing or even sustaining species diversity. In Malaysia, for example, the idea of bringing back a dipterocarp forest rich in insect diversity, within an oil palm landscape, is a non-starter. The restoration should instead be targeted at a very few species of plants or animals that could survive as reproducing populations in the landscape. Thirdly, people generally are unable to imagine something that they have never seen before, most especially in the landscape in which they live. Thus, there is little point in trying to present to the human residents or managers a vision of something that does not yet exist. In creation or restoration of multiple small habitat patches, the approach has to be by starting small, in a few patches, preparing for a future time when everyone can see that the method is feasible and useful, and ideally cheap and easy to manage.



FIGURE 1 · A swampy area in an oil palm plantation

Characteristics and treatment of allocated sites

Sites allocated for restoration treatment tend to be under one of three types of vegetation: either patches of secondary forest (that is, woody vegetation including trees that have grown naturally following partial or total removal of the original tree cover) (FIGURE 2), or old oil palms left in place when new palms are planted (FIGURE 3), or low woody or herbaceous vegetation (FIGURES 4 AND 5).

In general, the amount of sunlight penetrating to the ground under secondary forest is too limited for fast plant growth, and the existing trees tend to out-compete any new plantings. The only thing that can usefully be done is likely to be planting of a relatively small number of key wildlife food plants around the perimeter and in gaps within the forest (FIGURE 6). Silviculture (see 'Restoration silviculture' on page 90) may be helpful.

Patches of old oil palms, which are most usually retained in plantations along rivers, on steep slopes and as 'buffers' along the edge of Forest Reserves, allow partial light to reach the ground. The partial shade provided by the crowns of the old palms also suppresses the most invasive weed species, so seedlings and other plantings of wildlife food plants have a better chance of survival, and the burden of periodic cutting of weeds is low. Experience gained in 2018–2020 in planting strangling figs on to the trunks of these old palms showed that macaque monkeys tend to find and pull off most of the planted figs. In addition, growth rate of any surviving figs was low, in part due to the shade of the palm crowns, but mainly because the fig plant needs to extend its roots down to the ground before it can obtain sufficient water and minerals for faster growth. Old oil palms do indeed provide sites for restoration planting, but the restoration is usually best done by planting all wildlife food plants—including strangling figs—into the ground, rather than on to the palm trunks (FIGURE 7). Thus, the plants can obtain immediate access to minerals and water, and tend to be overlooked by macaques. However, grazing, nibbling and trampling animals (including grasshoppers, deer, rodents and pigs) may stunt or destroy any plantings on the ground under old palms.

Planting wildlife food plants in low herbaceous vegetation has the great advantage of ample light, which is a major factor promoting fast growth of most *Ficus* species. The two big problems are competition with weeds and the risk of desiccation during dry weather. The latter can usually be avoided by planting during wet periods and then fast growth rate,

facilitated by exposure to maximum available sunlight, adequate rooting and low evaporation from soil due to extensive weed cover, tends to protect the planting from drying out when the next dry period occurs. Weeds—whether grasses or herbaceous plants—can easily overgrow and outcompete seedlings and other plantings. The worst weed, typically, is *Merremia* (with three common species in Sabah) (FIGURE 8), which in unsubstantiated reports can grow in length as much as 10 cm per day, strangling even the largest planted seedlings. In sites with abundant *Merremia*, if weed removal cannot be done once or twice every month for at least a year after planting (FIGURE 9), it is best not to plant anything at that site. Other common weeds that can result in failure of restoration work include *Mikania micrantha* and legume cover crops (such as *Mucuna bracteata*) invading from oil palm plantations.

Choice and availability of planting materials

One major constraint in habitat restoration is that the supply of planting materials tends to be biased towards a traditional production forestry-based approach: dipterocarps, fast-growing native tree species and exotic species. It is true that the fruits, flowers and cambium of some dipterocarp and fast-growing native tree species are eaten in small quantities by wildlife. But scientific literature on orangutans and hornbills reveals that the percentage of the annual diet of these wildlife species that is contributed by these tree species is only a very tiny fraction of the total diet. There is not a single vertebrate animal species that can survive if their only foods are from dipterocarps and fast-growing native trees. If there is an intent to boost the supply of foods for wildlife species that feed on fruits and young leaves in a fragmented landscape, then it is necessary to produce, plant and maintain in large quantities the favourite food plants of these species, on a landscape scale.

Ficus is the most significant plant genus for frugivores—that is, wildlife species that feed on fruits. This genus provides regular food to orangutans, other primates, binturong, hornbills, pigeons and many other vertebrate animal species, including those that feed on fallen fruits on the ground, and to fish in streams and rivers. The many *Ficus* species (about 150 native species in Sabah) include tall trees, small trees, shrubs, climbers, epiphytes and (most famously) hemiepiphytes, the latter commonly known as strangling



FIGURE 2 · An example of secondary forest

FIGURE 3 · Old oil palms left in place on a steep hillside when new palms are planted on the flatter lands



FIGURE 4 · Low vegetation on an unplanted hill top in an oil palm plantation

FIGURE 5 · A biologically moribund riparian zone in an oil palm plantation covered in ferns and creeping plants





FIGURE 6 · Planting seedlings of lianas at the base of small trees on the edge of a forested set-aside zone



FIGURE 7 · An array of two-year-old strangling *Ficus marcots* planted under old oil palms
FIGURE 8 · *Merremia peltata*, the most aggressive weed affecting habitat restoration work





FIGURE 9 · A one-year old *Ficus racemosa* seedling, thriving with frequent weed removal (the kink in the trunk is a result of earlier *Merremia* presence)

figs. The genus is collectively known in English as fig, and in Malay and Indonesian as ara. The term fig and ara refer to the genus *Ficus* and to its fruit. The 'fruit' is actually an inflorescence in an enclosed receptacle, known technically as a syconium. In this guide, the word 'fruit' is used to refer to the *Ficus* syconium (FIGURE 10). Significantly, also, all *Ficus* species can grow in 'forest edge' conditions and even as stand-alone plants in an agricultural landscape.

A basic need for growing plants for frugivores, at a scale needed for the restoration or creation of habitat, is to establish a nursery that can produce *Ficus* planting materials. Other genera of plants can be added, according to available resources and interest.

Sabah Ficus Germplasm Centre (SFGC) (FIGURE 11) in Tabin Wildlife Reserve has been developed over several years as a centre to grow and maintain living *Ficus* plants of multiple species, and to supply planting materials and provide training in production methods. This guide outlines the methods used at the SFGC to propagate, plant and maintain *Ficus* and other plant types, with the intent to have these plants provide food for wild orangutans and other wildlife species, both outside and inside protected areas, in the long term.

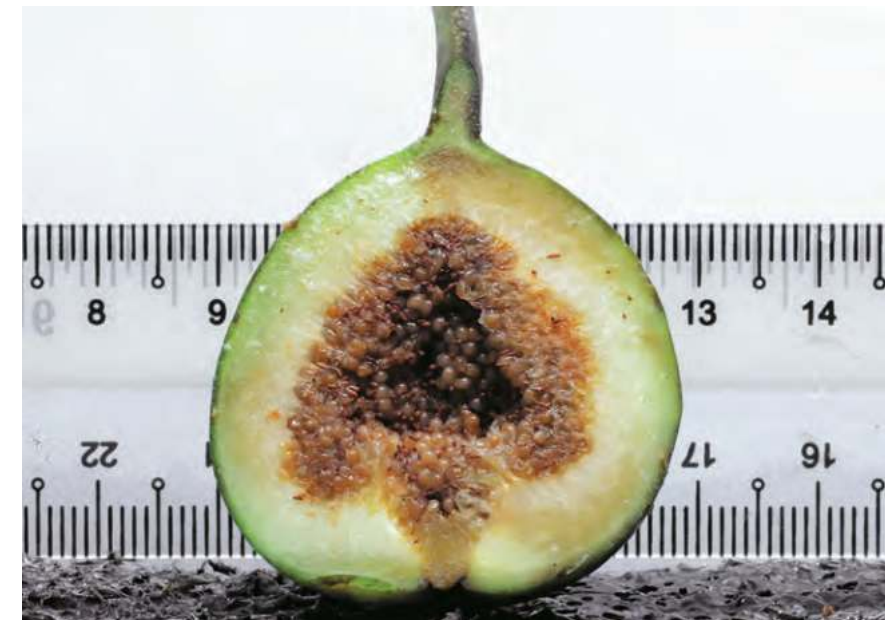


FIGURE 10. Cross section of *Ficus variegata* showing the ovaries and ostiole (single opening that forms in every fig syconium)



FIGURE 11 · Sabah Ficus Germplasm Centre (SFGC) in Tabin Wildlife Reserve

Explanation of terms

The terms ‘plant’ and ‘planting’ are rather confusing and cumbersome. Apart from silviculture (see ‘Restoration silviculture’ on page 90), the main initial activity in habitat restoration is ‘planting plants’. Plants can be produced for planting as a restoration activity in at least five different ways. Those five ways can be divided into two: sexual (involving seeds that derive from both female and male flowers) and asexual (that derive from the stems or roots of a mother plant). The latter is known as vegetative propagation. (A few plant species can produce seeds without the need for fertilization by a male flower, but this is not relevant in this guide).

♦ Potting and poly bags

Before the advent of plastics, planting materials were usually planted into soil contained in hard clay pots. The term ‘potting’ is still used to refer to planting materials into soil or mixtures in black, cylindrical-shaped poly (poly = low-density polyethylene) bags (FIGURE 12), the poly bags being the modern and much cheaper and more flexible equivalent of a pot. Some people in Sabah use the word ‘bayong’ to refer to these poly bags used for seedlings. As the texture and quality of the soil used in the poly bags needs to be made optimum (and therefore standardised) for small, young plants, usually the contents of the poly bag will be a mix of soil with other ingredients. Together this mix is known as potting medium or potting mix.

♦ Planting material

The term ‘seedling’ is often used to describe the very young plants that are purposefully taken and planted on set-aside sites on corporate-owned lands, forest reserves and protected areas. But not all planting materials are seedlings.

♦ Seedling

For the purpose of this guide, this means a plant that is grown from a seed, in managed conditions, usually in a dedicated, custom-built nursery. There are variations in the details, but in many cases, seeds are put into a soil-based mixture in a poly bag, and raised to a height and size that is considered sufficient to plant into soil at the site where it will grow to maturity. If the seeds of the species to be grown are very small (less than 2 mm diameter) and numerous, a feature which applies to almost all Ficus

species, then the seeds are usually first germinated in a 'bed' of fine soil (FIGURE 13). 'Germinate' means the process of the very first tiny stem and leaves sprouting from the seed.

♦ Wilding

This refers to a seedling which has grown naturally in the wild from a seed dropped or dispersed from the parent plant by an animal or the wind or flood waters. Small, wild seedlings (= wildings) (FIGURE 14) can be collected (carefully, to minimise damage to the roots) and brought into a nursery, planted into soil in a container, and grown to a height and size that is considered sufficient to plant into soil at the site where it will grow to maturity.

♦ Cuttings

This refers to vegetative propagation, whereby lengths of large, leafy twigs are cut from living mother plants of the desired species and treated in a nursery to create materials that look like seedlings (FIGURE 15). A big disadvantage is that only a few native plant species are amenable to this method. For some species, the treatment needed is rather complex but the rate of survival of the resulting 'seedlings' is unpredictable and often low. This method represents a form of cloning, as the 'seedling' is genetically identical to the mother plant and to all other cuttings taken from that mother plant. With robust species that are amenable to vegetative propagation, however, use of cuttings represents a possible alternative to waiting for fruiting or time-consuming seeking, collecting and handling of wildings.

♦ Stakes

These are very large cuttings, whereby instead of twigs, sections of the branches of strangling figs, some 5–8 cm in diameter and 2–3 metres long (FIGURE 16), are cut from the parent tree. This method works for only a very few species. Even amongst the various strangling fig species, this method appears to work for only some. The stakes need to be cared for over several months in the nursery, to allow robust growth of adventitious roots (= roots that grow from a plant above ground level) before being planted into soil at the target site. This method is used only for two reasons in combination. Firstly, noting that aggressive weed growth kills almost all plantings at some sites (especially on moist, fertile alluvial sites with no tree cover, where weedy stems and tendrils grow too rapidly for



FIGURE 12 · Ficus seedlings 'potted' into soil in black, cylindrical-shaped poly bags
FIGURE 13 · Tiny seedlings germinating in a soil bed





FIGURE 14 · Wild seedlings (wildings) may be found growing in the forest, and transplanted individually to a nursery for potting



FIGURE 15 · Cuttings—vegetative propagation using lengths of large, leafy twigs cut from a mature mother plant



FIGURE 16 · Stakes—very large cuttings taken from a parent plant, and kept in the nursery until copious roots have grown

adequate manual removal to cope) it is best to make the planting material as tall as possible. Secondly, it is fortuitous that this method works for a few *Ficus* species which produce fruits favoured by wildlife. The term ‘stake’ is used here, but there is no commonly-accepted term for this type of vegetative propagation. The term ‘stake’ is often also used to refer to locally-cut stems of any woody plant, or bamboo, that are planted next to seedlings to help keep the seedling growing vertically. ‘Post’ and ‘pole’ are also used, but these words normally refer to dead wood.

♦ Marcot

This is a third vegetative method for propagation of planting materials, and derives from the term ‘marcottage’ or air-layering in English. Unlike cuttings and stakes, this method involves getting healthy growing twigs of the mother plant to produce roots while the twig is still on the mother plant (FIGURE 17). Once the roots are visible, the stem with these roots are cut from the mother plant and put into soil in poly bags, to be grown to large size before planting out in the target planting site. A big potential advantage of this method is that the marcotted twig is from an adult plant, and it can potentially start producing fruits within a year or two. The advantage of marcots over cuttings is that survival rate in the nursery, and after planting out, is usually much higher (often 100%) with marcots.

In summary, the cumbersome term ‘planting material’ is used in this guide, because not all things that are to be produced and out-planted for habitat restoration are derived from seeds.

♦ Hardening

The process of introducing planting materials that have been nurtured under the optimum conditions of moisture, light and nutrients in a nursery to the harsher conditions that they will experience in the real world of the out-planting site. Hardening is an interim phase between the nursery and the planting out site, with the planting out site typically subjecting the seedling to sudden water stress and greater intensity of light. Without the hardening phase, seedlings usually exhibit signs of shock soon after they have been planted out, with leaves curling or falling off, cessation of growth and sometimes death. In the case of restoration planting in Sabah, the hardening process typically means putting the seedlings in a site near the nursery where exposure to light is greater and there is less consistent provision of moisture (FIGURE 18).



FIGURE 17 · Typical marcot on the mother plant

FIGURE 18 · Hardening *Ficus racemosa* seedlings outside the nursery

The nursery, light, shade and water

To be able to produce planting materials on the scale needed for a habitat restoration or creation programme, a nursery is needed. The nursery for production of planting materials is likely to be developed from small scale, increasing in size and production capacity according to funding availability and demand for planting materials. This was the trajectory of the development of SFGC. Key features of a nursery can be found in other texts and by visiting existing nurseries.

In SFGC, seedlings of *Ficus* go through a 'Double Stage' process, whereby small seeds are initially planted *en masse* into 'beds' of soil (FIGURE 13), and after germination, removed individually into individual poly bags for further growth up to the size needed to plant them out. Plant species with large seeds, wildings and vegetative planting materials normally go through a 'Single Stage' process, of planting directly into individual poly bags (FIGURES 15).

All *Ficus* species appear to grow fastest under maximum sunlight. However, at the very earliest stages (small seedlings and young marcots), strong sunlight can stress the plants, especially in terms of dehydration. So, the nursery in which they are grown needs partial shade, which is usually provided by extensive 50% black-shade netting (FIGURE 19). The nursery will likely contain plant species in addition to *Ficus*, where partial shade is optimum for smaller seedlings.

Of even greater concern than light intensity is moisture. Being adapted to the equatorial tropics, young native plants cannot tolerate drying out. They can wilt within a few hours if they lack adequate moisture, and die within a day or two if not provided with enough water. Thus, nurseries must be equipped with a system of small pipes that sprinkle or drip water on to the plants at frequent intervals (FIGURE 20). Alternatively, there must be workers who reliably water all the plants two or three times per day, at least on days with no rain (FIGURE 21). It is possible 'over-water' plants in a nursery, however, leading to poor health and death of the plants. This occurs largely if the amount of water in the soil is so great that there is no space left for oxygen in the soil. An indicator of chronic over-watering is moss growing on the surface of the soil. But a good potting mix (see page 26) allows adequate drainage of excess water. On balance, lack of water on dry days is likely to be a higher risk to the survival of planting materials than too much watering. The water should be as pure and clean as possible. Treated tap water can be used in a nursery, if that is the most convenient option.



FIGURE 19 · A 50% black shade netting covering the nursery at the Sabah Ficus Germplasm Centre

FIGURE 20 · The overhead water pipes inside the nursery



FIGURE 21 · Manual watering of Ficus marcots in the nursery

Planting medium

After light and water, soil represents the third key ingredient to produce large quantities of healthy planting materials. Apart from topsoil on flood-free alluvium, and at the sites of forest tree falls years ago where there is ample moist organic matter, however, soils in Sabah tend to be deficient in some minerals, with little organic matter, and somewhat acidic (typically pH varies from 4.5–6.0). In eastern Sabah, they tend also to be rich in clay, a mineral which tends to inhibit drainage, and in which it is difficult for small seeds to develop their root system. In any wet soil conditions, seeds may rot due to fungal infection. Thus, additional ingredients ideally need to be added to dug-up soil for use in the nursery, in order to provide optimum conditions for growth of seeds and vegetative plant parts.

An underlying need is to boost not only the quality of soils used in the nursery, but to minimise the costs of production. High-quality, soil-free potting medium can be made using compost, coconut fibre or coco peat and perlite (a natural volcanic glass), but these ingredients are costly and sometimes impossible to obtain locally. Instead, local ingredients are used at SFGC.

In SFGC, two kinds of mixture are prepared as planting medium, one (known as 'starting mix') is prepared for small *Ficus* seeds that will be grown in soil beds. The other (known as 'potting mix' or 'potting medium') is prepared for seedlings, wildings, cuttings, marcots and large seeds. The main ingredient at SFGC for both starting and potting mix is non-alluvial topsoil, removed from a maximum depth of 30cm from the ground surface. For the starting mix, river sand and compost are added to this topsoil. The sand serves to help provide a loamy texture with improved drainage and better ability of the seeds to develop a root system. Apart from retaining moisture, the compost also improves texture and introduces beneficial microbes and nutrients that are deficient in clay and sand.

The soil: sand: compost mixture (FIGURE 22) used at SFGC for starting mix is in the ratio 2:1:1. Other ratios of the three ingredients have been tried at SFGC, but the results are inferior. With a ratio of 1:1:1, for example, with regular watering there is a tendency for sand to remain on the top of the mixture, while the compost and soil is flushed downwards, some being washed out through the drainage holes at the bottom of the tray (FIGURE 23). Compost alone or a mix with majority compost is not suitable for germination of seeds or growth of marcots, in large part because it tends to promote fungus growth and death, a syndrome known



FIGURE 22 · The mixture for seed germination consisting of (left to right) top soil, compost and sand

FIGURE 23 · Compost and soil, flushed out through the drainage holes at the bottom and side of the tray, in a potting mix with too much sand



as 'damping off'. Larger cuttings and seedlings can tolerate this, but for tiny *Ficus* seeds, this process can cause mortality.

In potting mix at SGFC, therefore, the bulk component is a good topsoil. Ideally, this is thoroughly mixed with rock phosphate (RP) in a ratio of 20 kg topsoil to 1 kg RP (FIGURE 24). Extra compost can be added to enrich potting mix, especially if the topsoil is of poor quality, but compost should never be the major component.

What is the best form of compost? Trials were conducted at SFGC to obtain compost using a variety of locally-obtainable sources: empty fruit bunches from oil palms (EFB), rotted leaf mould (forest leaf fall decomposed naturally by fungi), rotted tree trunks, swiftlet's droppings, elephant dung, Bornean banteng dung and over-ripe and rotting male fig fruits (FIGURES 25–31).

None of the compost types were ideal. Rotted EFB, also rotted leaf mould and wood, often has chunks of dense organic matter that weigh down on very small *Ficus* seeds and prevent them from sprouting normally. This problem is overcome by sieving the final mixture prior to placing



FIGURE 24. One part rock phosphate (whitish powder) is mixed with 20 parts top soil



FIGURE 25 · Compost made of decomposed empty oil palm fruit bunches

FIGURE 26 · Rotted leaf mould can be used as compost





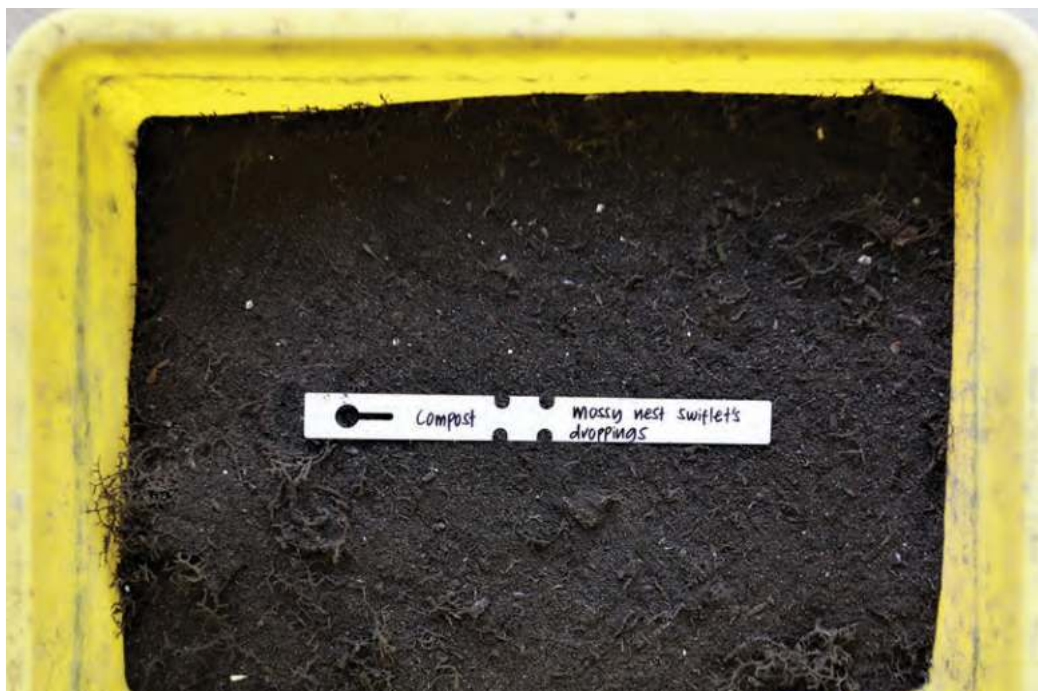


FIGURE 28 · Swiftlet droppings should be used with care as compost due to their high urea content

FIGURE 29 · Elephant dung compost is an option, but too fibrous to be used in seeder trays



FIGURE 30 · Old Bornean banteng (Tembadau) dung compost is excellent for seed germination but occurs mainly in Forest Reserves and is difficult to obtain in large quantities

FIGURE 31 · Compost of rotting fig fruits (*Ficus nota*) is an alternative where this locally-abundant streamside fig species occurs



it into seed trays. The wild animal dung and natural fig compost are good but typically too localised and infrequently found in sufficient quantity to become the standard compost type. Essentially, the solution is to use whatever compost can be found or made most easily and cheaply with local ingredients. In SFGC, natural compost consisting of male *Ficus nota* fruits (FIGURE 32) proved to be a good choice as male *F. nota* plants have been grown in large numbers nearby for this purpose. The proximate analysis of *F. nota* compost showed a moisture content of 80%. The remaining 20% dry matter included 0.34% phosphorus and 2.7% nitrogen (analysis done at KDC Laboratory, KL-Kepong (Sabah) Sdn Bhd).

Mixing of topsoil, sand and compost can be done in a pail (if only small quantities are needed) (FIGURE 33), a barrow (in order to be able to move the mix to another site) (FIGURE 34) or with a shovel on a cement floor (if large quantities are needed) (FIGURE 35). Clumps of soil and thick fibres in the compost are broken up using hands or shovel. All hard objects such as small stones and woody chunks need to be removed (FIGURE 36). Starting mix needs to be sterilized before the seeds are planted, in order to kill pathogens, nematodes and any competing grass seeds that may be present, while potting mix does not.

In order to avoid purchase of a costly autoclave, sterilization can be done in a lengthwise-cut half of a metal drum. A little water is sprinkled on to the mix in the drum (FIGURE 37), stirring thoroughly, but not so much water that the mix becomes runny or overly saturated. The water is needed to create steam that will kill pathogens (bacteria, viruses, fungal spores) and seeds of plants that are in the soil, other than those to be grown subsequently. The drum is closed tightly with a thick rubber mat that is secured using plywood to make it almost air tight (FIGURE 38), and heated from underneath using a flame, that may derive from gas or kerosene.

The amount of heat and length of exposure time will determine level of sterilization. In SFGC, starting mix is steamed for 40–60 minutes at a temperature of 70–90°C, in order to kill most potential pathogens and competing seeds of weeds that might be present. Temperature can be checked by using a meat thermometer (FIGURE 39).

After the heating process is done, the mix is allowed to cool to ambient temperature. Re-mixing is then done to break up any clumps that may remain. The mix is sieved and stored in either lidded containers or in sacks or strong plastic bags, with the top rolled down tightly and secured (FIGURE 40). The storage space must be dry and as cool as possible.

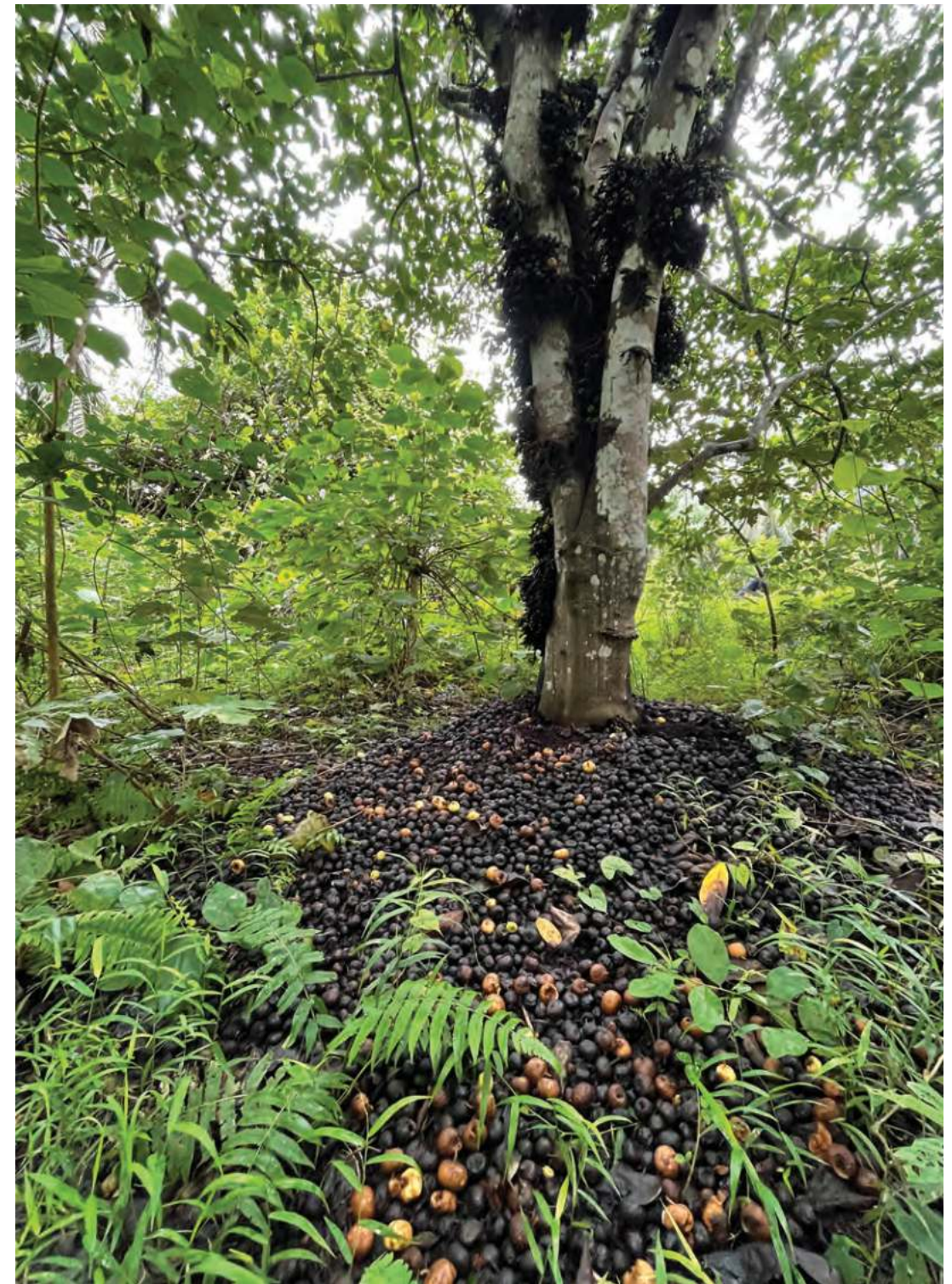


FIGURE 32 · Male *Ficus nota* fruits suitable for harvesting as compost



FIGURE 33 · Mixing of top soil, sand and compost in a pail
FIGURE 34 · Mixing of top soil, sand and compost in a barrow



FIGURE 35 · Mixing of topsoil, compost and sand on the cement floor
FIGURE 36 · Clumps of soil, thick fibres, woody chunks and stones from soil mix





FIGURE 37 · Soil mixture in a metal drum sprinkled with a little water before sterilization



FIGURE 38 · The drum is closed tightly using a clip lock

FIGURE 39 · The starting mix is sterilized by steaming for at least 40 minutes at 70–90°C





FIGURE 40 · Sterilized starting mix stored in a sack

Acquisition, treatment and storage of seeds

Introduction

Growing planting materials from seed is potentially the best choice if the aim is to produce large quantities. Also, whereas wildings and all forms of vegetative reproduction have to be planted out at the optimum time, wherever and whenever that may be, seeds can potentially be stored for long periods. It should be noted that the seeds of many equatorial forest plant species are 'recalcitrant', meaning that they do not survive drying or freezing—or even temperatures of less than 10°C. But not all tropical plant species have recalcitrant seeds, and none of the *Ficus* species tested to date are recalcitrant. Another fundamental advantage of non-recalcitrant seeds, therefore, is that they provide the materials for a 'seed bank', the concept of storing the living genomes of species and genetic diversity for long periods, irrespective of current needs, fruiting seasons and other circumstances.

Seeds for 'banking' need to be treated to maximise their longevity, otherwise they will either rot and die, or germinate prematurely. Prior to storing seeds, it is necessary to remove impurities including galls, fruit remnants and mucus (the latter being present in several *Ficus* species, such as *F. stupenda* and *F. annulata*). The two elements of extending the viability of *Ficus* seeds for long periods are drying (to reduce water content) and freezing (to prevent any biological processes). The intent is to prevent both the natural germination process and the process of rotting, whereby organisms, usually bacteria or fungi, feed on the seeds or surrounding tissues, and cause their death. In general, plant species of the equatorial tropics have evolved seeds that must survive in moist conditions, and so excessive drying of these seeds tends to kill them. Thus, freezing is the more promising method for successfully preserving viable tropical rainforest seeds.

The number of seeds in one fig fruit varies according to species from 1 to more than 100,000, with a few hundreds to over one thousand per fruit being common in most species. *Ficus* seeds vary in colour, shape and size according to species, with a range of about 0.5 x 0.65mm per seed to 3.0 x 4.5mm (FIGURE 41).

In SFGC, initial trials focused on *Ficus racemosa*, in part because trials with vegetative production of this species were not very successful, and

because it is locally common with frequent fruiting (FIGURE 42), so that sourcing plentiful seeds is easy. Later, other species were trialled for seed-banking, from the species with the smallest fruits (*F. cumingii*) to the largest (*F. punctata*). Over time, improvements have been made in all aspects of preparing seeds, both for immediate planting and for preservation. Aspects that require attention include choice, collection and handling of ripe fruits, species identification, seed separation techniques, quality control and monitoring of growth rates after planting. Although fig plants may potentially produce fruits with seeds at any time of the year, varying with species, location and individual plant, there is a tendency in Tabin Wildlife Reserve for a peak in *Ficus* fruiting between November and February.

Selection of fruits

In addition to identification of the species (which is not always possible at time of collection), there are two main aspects of selection of fig fruits for the preparation of seeds: ensuring that the fruits do contain seeds, and taking only ripe fruits. Thus, it is first necessary to ensure that any fruits collected are female; two thirds of all *Ficus* species are dioecious, having female and male plants, with the male fig fruits unable to produce seeds. With experience, the sex of fig fruits on the plant, and the species identity can be ascertained in the field. But it may be necessary to use a magnifying glass to determine the sex, and to bring twigs, leaves and photos for further examination at home. Each fig fruit takes months to ripen, and many fruits are quickly found and eaten by birds and mammals as soon as they are ripe. Thus, most fig fruits that we see are unripe. Although viable seeds can be found in some unripe fruits, it is nevertheless advisable to seek and collect only ripe fruits (which will be the softest and darkest in colour of those visible on the plant or on the ground, if they are not already rotting) for maximising the yield of viable seeds. Fallen fruits tend to be ripe or nearly ripe (FIGURE 42). Most fig fruits found on the ground will be damaged or rotten, however, and those should not be selected. Larger fig plants, such as *F. racemosa*, *F. drupacea*, *F. annulata* and *F. callosa*, tend to produce large numbers of fruits, and many fall to the ground, allowing for selection of the best. But for some species, finding good quality, ripe fruits can be challenging. It is wise to label every package of fruits as they are collected, with one package per fig plant, to avoid the risk of confusion or inadvertent mixing later.



FIGURE 41 · Ficus seeds (scale in mm) from left to right, *F. scaberrima*, *F. sagittata*, *F. fistulosa*, *F. francisci* and *F. racemosa*

FIGURE 42 · The many fallen ripe Tangkol (*Ficus racemosa*) fruits



Fruit processing and seed separation

After collection, fruits need to be brought to the site where processing is to be done, and where the best ones are selected and washed to remove debris and soil. The selected fruits are examined to determine their sex. Any male fruits can be discarded. Fully ripe fruits can be mashed easily for seed extraction (FIGURE 43), but harder ones can be soaked overnight in clean water to soften the pulp. A plastic or metal (ideally stainless steel) sieve is used to separate most of the seeds from the pulp, into a basin (FIGURE 44).

This is done by continuously mashing and pressing the figs inside and against the sieve. Once the seeds have been separated from the pulp, they should be further thoroughly washed, two or three times. During each wash, the seeds (and inevitably some small amounts of fine debris) and supernatant (the water containing the seeds) are swirled, causing the seeds to spin to the centre of the container by centrifugal action. The supernatant is then slowly drained out (FIGURE 45). The process is repeated until only the seeds remain with a small amount of water. These are poured onto a piece of white filter paper, or ordinary A4 if filter paper is not available (FIGURE 46), and spread out to dry at room temperature for one or two days. This should not be exposed to direct sunlight. The filter paper absorbs the excess water rapidly, but it takes a longer time to dry all the seeds at room temperature. Seeds with a layer of mucous will stick to the paper. The processing and drying should be done away from possible sources of ants.

The dry seeds are labelled (common name and/or scientific name, date and location of collection), and sealed in tubes (FIGURE 47), before chilling them in a refrigerator (4–5°C).

Freezing seeds

If it is intended to preserve some or all of the seeds for future use, and not to plant them immediately, it is wise to first check their viability by taking one or more samples, and planting them in beds of planting mix. There is no point in freezing seeds if it is found that few or none of the seeds germinate.

The next optional but useful step prior to freezing seeds is to estimate the number of seeds per 0.5 or 1 millilitre (ml) batch. A microscope will be needed to perform the counting. The concentration of seeds per ml varies with species. *F. racemosa*, for example, has about 8,000 per ml. Each batch can be put into small capped tubes.



FIGURE 43 · Mashing the ripe figs in a strainer

FIGURE 44 · Sieving the mashed figs in a strainer





FIGURE 45 · Draining the supernatant from the container

FIGURE 46 · The wet seeds are air dried on a piece of paper



FIGURE 47 · Drying seeds in a cryovial, with silica gel (at bottom)

FIGURE 48 · Fully dried seeds sealed with parafilm before storing them in freezer



The seeds can and ideally should be dried more completely by uncapping the tubes and placing them inside an air-tight wide-mouth container with activated silica gel for 24 hours. It is important to ensure that the silica gel is not saturated. After 24 hours of drying, the tubes are capped immediately whilst inside the wide-mouth container prior to removing them. They are then labelled and sealed with para-film (FIGURE 48), ideally in 1.8 ml cryotubes. Seeds may be stored in an ordinary freezer (-18 to -20°C), or in an ultracold freezer (-82°C) if available.

Planting seeds in starting mix

Ficus seeds or seeds of other plants that are very small can be planted on to starting mix in one of two approaches. One is to retrieve and use seeds that have already been cleaned, dried and stored. The other is to plant seeds as soon as possible after the ripe fruits have been obtained. In the latter case, it is necessary to minimise clumping of seeds in uneven, wet clusters. This can be done by mixing the seeds, along with any remaining pulp from the fruits, together with sterilized fine sand, in a ratio of 1:20 parts, and then spread evenly on top of the soil in the boxes.

In either case, the starting mix needs to be placed into shallow, large boxes that have drainage holes (to prevent water-logging and aid in aeration of the mix), known as 'seeder boxes' or 'seed trays' (FIGURE 49), and sprayed with a little water. The seeds, with or without sand, are then scattered on to the starting mix, as evenly as possible. The soil mixture inside the seed tray should be at least 3 inches deep to provide enough depth for the roots of the seedlings. Inadequate depth will expose the tap root and may cause the seedlings to collapse. A thin layer of additional starting mix can be scattered on top, and a small mister-type spray used to apply more water.

The seeds should start to germinate in 6 to 9 days, but some species may take longer. It is normal practice to allow up to 3 weeks before deciding that the seeds were not viable and to discard the soil mixture. In theory, the sterilization process should have killed the seeds of any plants other than the seeds applied deliberately for germination. Daily observation should be accompanied, however, by removal of any germinating weeds that may have crept in. Daily checking is also needed to ensure that the drainage holes of the box remain not blocked. Once the seedlings have developed at least four true leaves, they may be removed for planting into potting mix in poly bags (FIGURE 50). They are still very small and need to



FIGURE 49 · Seed trays used for seed germination

FIGURE 50 · Pricking out a seedling from the seed tray



be carefully removed (a process known as ‘pricking out’) and transplanted, one by one, into poly bags of potting mix, so that there is ample space and nutrients for each tiny seedling to grow bigger.

Planting seedlings (and wildings, cuttings, marcots and large seeds) into potting mix

Potting mix can be put into a variety of containers, with one seedling or wilding or cutting or marcot per container. Black poly bags are the most cost-effective container, being cheap and usually available in small towns.

Potting mix is put manually into the poly bags, filling the bag to the brim (FIGURE 51). There should be holes already in the poly bag for drainage. Typically, 5x7 inch or 6x9 inch poly bags are used. One filled 6x9 inch bag will weigh about 1 kg. Ideally, about 10 to 50 grams of rock phosphate is added into the mix for each poly bag. This is equivalent to 10 to 50 kg of rock phosphate per 1,000 poly bags. In SFGC, 5x7 inch bags are used for *Ficus* seedlings grown from seed. Once seedlings have four leaves, they may be transplanted to 6x9 inch bags of potting mix. 6x9 inch bags are used for wildings, cuttings and marcots.

So that bags filled with the mix do not tend to topple over, two methods can be employed. Either the bottom corners of the bag can be pushed into the mix, or batches of poly bags filled with mix can be placed into simple wooden frames.

It is good to prepare the filled poly bags about one week before anything is planted into them, to allow settling. Extra mix and water can be added to maintain the mix to the brim of the bag. The seedling (or seed, if the plant is not *Ficus*, and with a seed more than a few mm wide) is placed into a hole in the centre of the surface of the mix, which can be made by hand or with aid of a knife or bamboo stick. The mix should be watered soon before or soon after planting is done.

The plantings should be labelled in a way that is clear and long-lasting, either one label for every bag (FIGURE 52), or one label for a batch of several or many, which are collectively demarcated by the wooden frames.

These young plantings need to be protected from direct sunlight, kept in a shaded part of the nursery, and watered at least twice daily, unless they receive water naturally by rainfall. After 3–4 months, the plantings can be moved to a site that is under 50% black shade netting. Shading is critical at this stage.



FIGURE 51 · Potting mix filled to the brim in a polybag

FIGURE 52 · Recently planted seedling showing a clear label



Collection and treatment of wildings

There are several reasons why wildings may be preferred over seedlings. The major one is that trees and lianas whose seeds are sought for habitat restoration will typically bear fruit only during one short season in the year and, for most tropical trees, fruiting occurs not annually but only once in every 2 to 12 years. As seedlings in the tropical rainforest typically grow very slowly under prevailing conditions of low light, however, wildings of suitable size can be found at any time.

For *Ficus*, there are two other potential sources of wildings: old buildings (FIGURE 53) and old oil palms (FIGURE 54) just before they are scheduled to be felled and chipped.

General procedure for collection of wildings

- 1 Do it in conditions of cooler temperature, dampness and low light conditions.
- 2 Depending on whether the target is forest wildings or from an oil palm or urban landscape, prepare digging tools (e.g. shovel, cangkul), cutting tools (eg. axe, secateurs, parang) and containers (e.g. gunny-sacs, plastic bags, chiller boxes).
- 3 Choose plants that are about 30–60 cm tall and 5–10 mm in stem diameter for ease of collection and transportation and high survival rate, although SFGC has achieved success with wildings 2–3 meters tall and 5 cm diameter.
- 4 Record the location where the wilding is obtained.
- 5 If the wilding is in soil, ensure that it is wet during collection, pouring water around it if necessary, and removing it carefully; the amount of topsoil attached to the root is not crucial.
- 6 If the wilding is on an old palm or attached to a building, it is carefully removed with as many roots as possible.
- 7 Soak the wilding in water and wrap in wet cloth or newspaper, and place in the transport container.

At the nursery

- 1 Prune some of the leaves and longer fine lateral roots, but do not prune the tap root; soak the roots again in water mixed with rooting hormone, which can be obtained from gardening and agricultural retail stores.
- 2 Plant the wilding into a hole made in moistened potting mix in individual poly bags, allowing some space for the root to grow further downwards to the bottom of the poly bag.
- 3 The potting mix should be pressed against the roots of the wildings to ensure efficient water and nutrient transport into the wilding.
- 4 Water the wilding thoroughly and keeping it in a shaded part of the nursery.
- 5 The wilding should be ready for transplanting within two months.

The leaves and leaf-arrangements of seedlings may differ greatly from the leaves of the mature plant of the same species. Especially for non-*Ficus* genera and species, personnel tasked to harvest wildings need to be sufficiently experienced, to minimise the risk of taking plants that are not the target species.

Production and treatment of cuttings and stakes

A cutting is a section of the stem of a mature plant. Most plant species cannot easily be propagated by this method and, through trial and error, SFGC found that only a few *Ficus* species are amenable. The *Ficus* species for which cuttings can produce useful planting material are: *F. microcarpa* (nunuk), *F. crassiramea* (ara manggis), *F. caulocarpa*, *F. pisocarpa* and *F. benjamina* (beringin). The first four are often found in floodplain and riverine habitats. To date, *F. microcarpa* and *F. caulocarpa* appear to be the species most amenable for production of stakes.

The original 'stock plants' from which cuttings and stakes are to be taken must be large, vigorous and disease-free (FIGURE 55). At SFGC, some of the initial cuttings were planted into the ground and are growing well

under managed conditions, with frequent pruning to sustain them at small size and as a source for more cuttings (FIGURE 56).

For cuttings and stakes, it is important to plan collection and treatment according to available manpower and time of day, and to ensure in advance that the necessary materials are available.

Conventional cuttings are 30–45 cm long, with a diameter of 1–1.5 cm (FIGURE 57). Stakes are very much larger.



FIGURE 53 · *Ficus benjamina* wilding on a building

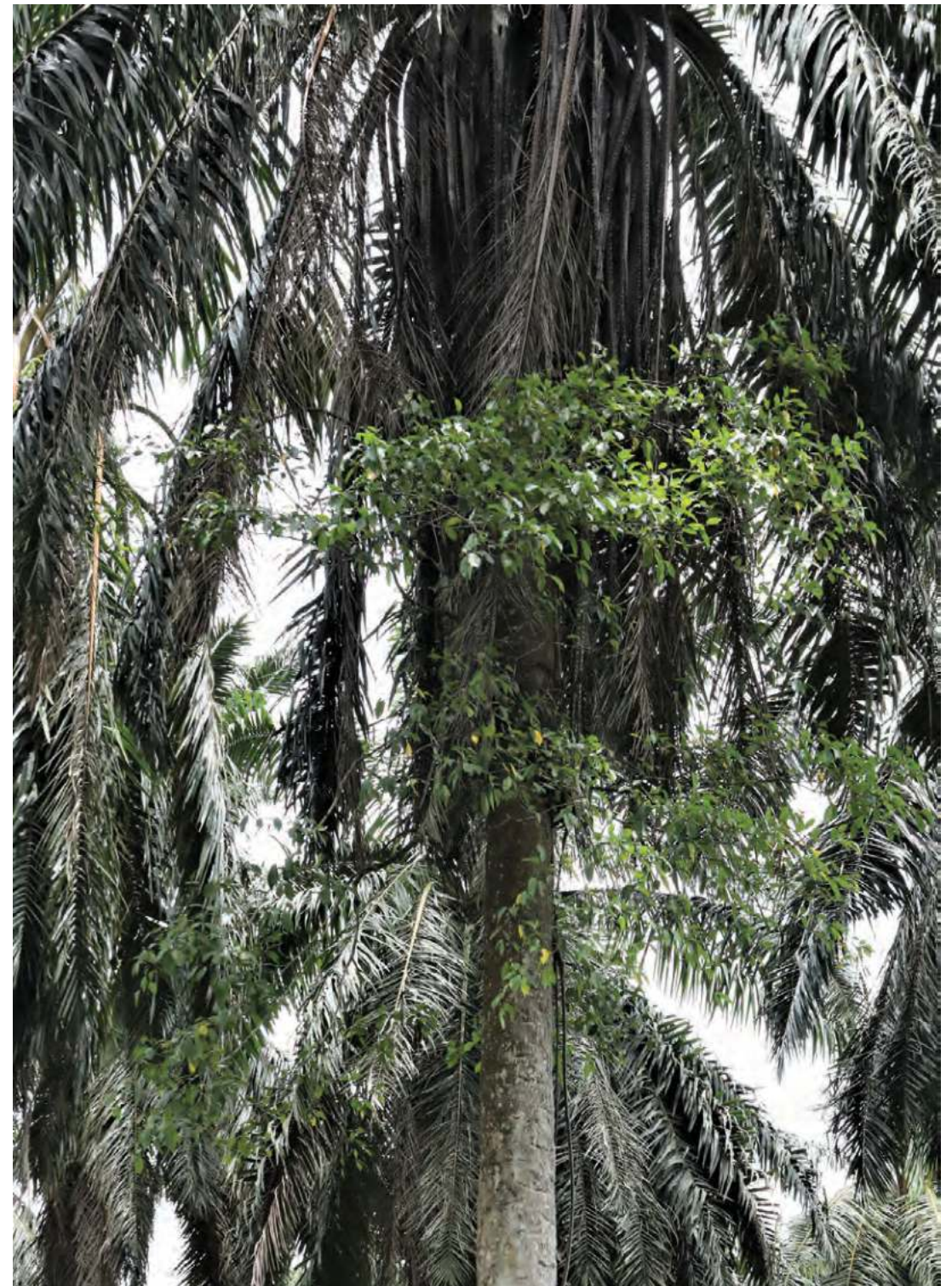


FIGURE 54 · Ficus wilding on a mature oil palm tree

FIGURE 55
BORA staff cutting
stakes from
abandoned Lahad
Datu cinema





FIGURE 56 · Example of a Ficus plant about 18 months after the initial cutting and still growing well



FIGURE 57 · Typical cuttings

Standard operating procedure for cuttings

- 1 Collect them early in the morning, when they are still turgid. All cuttings must have leaves and shoots (leaf buds), which are important in stimulation of rooting.
- 2 Retain all the leaves on the cutting.
- 3 Include a minimum of two nodes in the cutting. The basal (lower) cut is usually best made just below a node.
- 4 Removal of the selected stem should be done cleanly with sharp knife or secateurs; the cut can be horizontal or at a slant.
- 5 Cover the cuttings in a damp cloth to prevent or compensate for transpiration, and keep them in a chiller box or sack. Process the cuttings as soon as possible, ideally within six hours. Alternatively, they may be kept overnight in a refrigerator (4–8°C).
- 6 Once at the nursery, the cuttings can be soaked in a solution of rock phosphate (half table spoon to a litre of water), while processing the others.
- 7 Shoots are now removed, along with excessive leaves, leaving 3 or 4 leaves intact (FIGURE 15).
- 8 Dab the base of the cutting into rooting hormone powder (obtainable at gardening and agricultural stores) for 5 seconds.
- 9 Wrap the base of the cutting tightly in a handful of coconut husk to form a clump, about 5 cm in diameter and height, and fit it into a plastic rooting tray (FIGURES 58 AND 59) containing wedged compartments (obtainable at gardening and agricultural stores). Additional husk can be packed into the tray as needed, to ensure all the cuttings are firmly in place. Do not use decomposed, crumbly husk.
- 10 The top end of each cutting is painted with an oil-based paint to minimise risk of desiccation and infection.

- 11 The species, date and origin are written on a tag and attached to the tray.
- 12 The tray is placed in a shaded part of the nursery. Ensure there is adequate aeration at the base of the tray to allow penetration of oxygen to the roots.

Management of cuttings in the tray

- 1 Initiate and maintain a record book, noting the appearance of new shoots and any deaths of cuttings.
- 2 The cuttings are watered twice daily using a spray or watering can. This is done in the morning (8am) and early evening (4pm).
- 3 Every two weeks all cuttings are gently scratched on the bark. Green indicates that the cutting is alive; brown, dead. Do not pull out the plant and coconut husk from the tray.
- 4 Dead cuttings are recorded and may be replaced.
- 5 Depending on species, roots should appear between 1–8 weeks.
- 6 Once the volume of roots has occupied most of the bottom compartment, the cutting is ready to be transplanted into a 5x7 or 6x9 inch poly bag containing potting mix or good topsoil.
- 7 Several granules of controlled release fertilizer are placed into a small hole made in the potting mix or soil in the poly bag. The rooted base of the cutting together with the coconut husk is carefully placed in the hole, covered with extra potting mix or soil, and watered.
- 8 Each poly bag with cutting is moved to a shaded area in the nursery and kept there for another 1–2 months, with regular watering.



FIGURE 58 · Ficus cuttings planted into coconut husk clumps in plastic rooting trays



FIGURE 59 · Close-up view of a coconut husk clump

Standard operating procedure for stakes

- 1 Having identified the mother strangling fig, select healthy, relatively straight branches measuring 5–8 cm diameter (FIGURE 55). The stake is cut off, using a hand saw or a parang, into a length of 2–3 metres. This should be done during relatively wet periods.
- 2 Prune off all the lateral branches, leaving about 10 cm of each branch from the main stake. All cut surfaces, including the apex, are immediately painted with an oil-based paint to limit desiccation and rot.
- 3 Transport the stakes to the nursery or directly to the planting site, cushioning them to prevent damage.
- 4 If the stakes are to be tended in the nursery, to allow growth of adventitious roots under managed conditions, they should be planted into large poly bags with potting mix or coconut husk (FIGURE 16).
- 5 If the stakes are to be planted out without nursery treatment, at least the bottom end and ideally the entire stake should be wrapped with thin plastic up to time of planting (FIGURE 60).
- 6 Prior to planting out, the stake is girdled (entire bark removed) up to about 30 cm above the base, to promote rooting. Alternatively, the stake may be completely debarked, starting 10 cm from the last node to the end of the stake.
- 7 Stakes should be planted into holes 50 cm deep (FIGURE 61) ensuring that they remain vertical, and compacting the soil adequately for stability (FIGURE 62).
- 8 During the regeneration process after planting out, stakes are susceptible to attacks by borers. Thus, the whole stake is painted with an anti-borer agent, ideally cypermethrin ('Cyperguard' is used at SFGC).
- 9 Steps must be taken to ensure that, in the absence of rain, stakes are frequently watered. If that is done, the stake will have the appearance of a small tree within one year or so (FIGURE 63).



FIGURE 60 · Bringing stakes into the planting site

FIGURE 61 · Digging a planting hole for a stake





FIGURE 62 · A recently-planted stake

FIGURE 63 · A stake (*Ficus microcarpa*) 15 months after planting

Production and treatment of marcots

Marcotting is a technique to produce cuttings that already have adventitious roots when they are removed from the mother plant. At SFGC, specific fig plants have been identified and these are pollarded so that they do not grow too tall for easy marcotting. The technique can be used successfully on most *Ficus* species. Various media can be used to promote growth of adventitious roots on the stem of a mother plant, but plain top soil is the most convenient medium, ideally with added rock phosphate. If done well, most marcots are successful, although some fail due to imperfect techniques, or to being molested by pig-tailed macaques or adverse weather or because some plant species are not amendable to the technique.

Materials needed for marcotting
1 secateurs (FIGURE 64) or sharp scissors
2 sharp knife (FIGURE 65)
3 pieces of clear or translucent plastic sheet (7x10 cm per piece) (FIGURE 66) that allows visibility of roots
4 top soil with rock phosphate, or similar rooting medium
5 Raffia string or parafilm tape or twist ties to secure the rooting medium inside the plastic wrap (FIGURE 67)
6 a black permanent marker fine-tip pen



FIGURE 64




FIGURE 65




FIGURE 66




FIGURE 67

The marcotting process

- 1 Select a healthy slender branch with numerous leaves on the chosen mother plant. The section to be marcotted should be 45–60 cm from the base, with a diameter of 1–1.5 cm.
- 2 Using the sharp knife, make a circular slit just under a node, and girdle (cut off the entire circumference of) the bark, up to the cambium layer.
- 3 The second girdling is done 5–6 cm underneath the first cut.
- 4 Cut off the bark between the two girdles with a straight cut penetrating into the cambium.
- 5 Continue cutting off the bark between the two girdles by peeling lengthwise in straight slices, until there is no more bark between the two girdles.
- 6 The bare area should continue to be scraped slowly in order to remove any remaining moisture and 'slime' (FIGURE 68).
- 7 A small amount of moist soil is placed on to a piece of transparent plastic (FIGURE 69).
- 8 The plastic with soil is wrapped around the girdled area, ensuring that there is a 2.5 cm overlap with the stem that still retains its bark, above the girdle.
- 9 The entire plastic and soil is wrapped around the stem and tied neatly at both the upper and lower ends; the soil should be no more than 2.5 cm in thickness around the stem.
- 10 Write with a marker pen on the plastic the date and name of the person making the marcot (FIGURE 70).
- 11 Remove many, but not all, of the leaves from the stem above the marcot, in order to reduce desiccation and risk of the stem bending over or even snapping.
- 12 Check the marcot frequently and replace the plastic and soil if the plastic is torn or if the soil is dry.

- 13 When adventitious roots have grown to fill $\frac{1}{2}$ – $\frac{3}{4}$ of the soil inside the plastic (FIGURE 71), which usually occurs after 3 to 4 weeks, the marcot needs to be cut off and transferred to the nursery; the cut-off point is immediately below the place where the lower girdle was made; sharp scissors can be used.
- 14 Remove some of the leaves from the stem in order to reduce desiccation.
- 15 The cut end of the branch from which the marcot has been removed should be painted with an oil-based paint, using brush or spray paint, to prevent rotting or insect attack on the mother plant.

Common mistakes made in producing marcots

- 1 The branch selected was too big.
- 2 The site chosen for marcotting was too close to the main trunk or to a large branch.
- 3 The branch had dense leaves and twigs above the marcot site, causing the branch to break off above the marcot.
- 4 Too many marcots were made on one plant or branch, sometimes leading to the death of the plant or the branch.
- 5 The plastic was not tied strongly to the branch, and the gap resulted in the soil drying out.
- 6 Use of poor-quality material to tie the plastic and soil in hot humid conditions, resulting in leakage or falling off.
- 7 Insufficient soil was placed inside the plastic.
- 8 The original soil put inside the plastic was too dry.
- 9 The marcot was removed too early with insufficient roots.
- 10 The marcot was left for too long, roots filled the plastics, and the branch above the marcot site withers and dies.



FIGURE 68 · A fully girdled stem

FIGURE 69 · A clump of soil on plastic sheet applied on a girdled stem



FIGURE 70 · Freshly applied soil, wrapped in clear plastic and labeled

FIGURE 71 · Close-up of the marcot showing numerous adventitious roots



Treatment of marcots in the nursery

- 1 The plastic and soil are opened carefully, so that the new roots retain most of the soil.
- 2 The marcot is planted into a 6x9 inch or 7x12 inch poly bag with potting mix, watered and kept in a shady area. Prior to planting, a pinch of controlled released fertilizer is added inside the planting hole.
- 3 A small stake of split bamboo or similar material can be added into the poly bag to help keep the marcot upright. The marcot should be watered frequently, 3 or 4 times daily. Plastic materials used for marcotting should be disposed of properly and recycled if possible.

Translocation of planting materials to the permanent planting site and planting out

This is the process of moving planting materials from the nursery to the designated sites for planting out. Before moving the planting materials, they must be 'hardened' for about one month (FIGURE 18). Planting materials selected for translocation need to be at least 45 cm tall. For open sites with plentiful weeds, they should be at least 1 metre tall.

Three main factors are involved in deciding the suitable size of planting materials for planting out into the allocated site where it will grow to maturity. Firstly, as the biggest threat to the survival of the seedling after planting is, in many circumstances, competition with weeds. Planting sites that are rich in aggressive weeds (FIGURE 72) require taller seedlings as well as frequent weeding after planting. Secondly, the bigger the seedling, the larger and heavier the soil-filled bag in which it is growing. And the larger and heavier the bag, the more time-consuming (and costly) it is to carry the seedling to the planting site. Thus, it is usually found to be practical that planting sites far from a road will be enriched with smaller seedlings. Thirdly, as seedlings grow, it is common in nurseries for the tap root (the main central root) to grow out from the bottom of the bag.

If the substrate is soil, then the root will grow downwards into the soil. If the substrate is cement or gravel, it will start to coil between the bottom of the poly bag and the cement or gravel. Neither situation is good for the future development of the plant. Thus, there should always be some impetus to get the planting materials out of the nursery and into the intended planting site, as soon as reasonably possible, before the tap root starts growing out from the bottom of the bag. In addition, there is usually a project-specific and site-specific mix of subjective prevailing circumstances. Some project managers will prefer to plant small numbers of large seedlings, rather than many smaller seedlings, in the belief that survival rate of larger seedlings is almost always higher in equatorial regions where weed growth can be fast and unmanageable. If there is a dry period, it is usually better to await a rainy period before for planting out, because plant species in the equatorial tropics cannot withstand many days without rain when they are still small. If there is a delay in planting due to dry weather, the seedlings in the nursery still need daily watering in order to survive but the tap roots will continue to grow. When planting time comes, the seedlings may be larger than originally planned.

Often, moving the planting materials from the nursery / hardening site to the planting out site represents a significantly risky time in the entire process that starts with preparing seeds or marcots, and ends with successful growth in the targeted restoration area. The first risk is that the planting materials may be carelessly loaded on to the vehicle that is used between the nursery and the restoration site. The people doing the loading must use as much care and thought as has been employed in the seedling and marcot production process. Apart from tight packing to prevent leaning or snapping of stems, most importantly the leaves must be protected from the strong airflow and desiccation that comes with a vehicle moving at high speed over several hours. In 'pickup' vehicles, it is best to surround the entire batch of seedlings / marcots with a wall and even a roof of plywood or similar protection. A common-sense approach to tying the entire batch is also needed—not too loose, not too tight.

On arrival at the targeted restoration area, further risks may occur. Careful liaison with the personnel who manage the land, in advance, should minimise the risks but miscommunication can still occur.



FIGURE 72 · Restoration site in low vegetation in the riparian zone in an oil palm plantation

Possible scenarios on arrival at a restoration area

- the security gate personnel have not been informed in advance of the arrival of the transport vehicle
- planting holes should have been dug in advance, but were not, or they are too small, or not in agreed places
- a temporary holding area for the planting materials should have been prepared, but has not been made ready in advance
- the manager of the land has not briefed in advance his people on the ground

For some planting sites, a regular and pre-determined array of points for planting is not practical. This will be the case in swampy, flood-prone sites (where planting should be done only on the highest points) (FIGURE 73), irregular rocky sites, and under secondary forest (where gaps in the tree canopy are the only points suitable for planting). For sites which are more homogeneous, it is best to mark out planting points along lines, and mark them with bamboo stakes. This facilitates not only the initial planting, but also finding the planting sites in the future, and maintenance.

At each planting point, a hole is dug, about twice the size of the poly bag containing the planting material (FIGURE 74). A small amount of rock phosphate and / or compost is placed in each hole. The planting material is removed from the poly bag, placed into the hole and the remaining space filled with soil. The soil should be firmly compacted by repeatedly treading around the planting material, to ensure good contact between roots and soil. A bamboo stake is used to secure the plant in a vertical position, using 25 mm parafilm tape. Each planting point is assigned a number and a GPS record taken of each location (FIGURE 75). A random 10% of the plants are tagged for future health and growth evaluation, which should ideally be done at three months intervals.

The act of planting out the seedlings or marcots represents yet another risky time, especially if many planting materials are planted at one time and the labour force are regular estate workers. Immediately after the seedling or marcot is in the planting hole, there may be a temptation to be hasty, and quickly fill the space with clayey lumps and topsoil mixed with

weedy plant debris, rather than fill the space with crumbly soil, which is then gently compacted by the planter's feet. It is good to then immediately place a small pile of mulch around the base of the planting, which may be a mix of recently cut weeds surrounding the planting and dead vegetation. In any case, planting out should be done during or just before rainy periods. It is usually best to delay planting out during any ongoing or anticipated dry periods. The only exception would be if planting is done along a road-side, and the land manager can arrange for a bowser (water tank drawn by a motor vehicle) to be used.

Maintenance of plantings

If the leaves of planted seedlings turn yellowish (a symptom termed 'chlorosis') the cause might be poor soil drainage, or damaged roots or acidic soil or disease or nutrient deficiencies, with nitrogen deficiency being most common. NPK fertilizer could be applied, to observe if there is an improvement in leaf colour. However, application of fertilizer to plantings after the date of planting out is rarely needed or practical.

Usually, the biggest need after planting out is regular and frequent removal of weeds, which not only compete for space, light and nutrients, but also may physically damage and disable the plantings. The most common weeds that can strangle and kill plantings are either legume cover crops (e.g. *Mucuna bracteata* and *Calopogonium mucunoides*) that grow into the planting site from nearby oil palm plantations (FIGURE 76), or other invasive strangling plants, both native and exotic. *Merremia* (FIGURE 8) is a common native strangling vine that rapidly dominate other plants, often smothering them. In addition, *Mikania micrantha*, an introduced South American vine is also extremely fast growing, and can cause serious damage to plants.

Use of herbicides is normally not recommended, as the habitat enrichment or restoration work is expected to be as 'environmentally friendly' as possible, and because the scale of the planting is usually localised, so manual removal of weeds is practical.

Weeding needs to be carried out as frequently as necessary and practical. In sites with abundant *Merremia* or *Mikania*, twice-monthly weeding may be necessary for at least the first year after planting.



FIGURE 73 · Choosing restoration planting sites in a swamp set-aside land with secondary forest

FIGURE 74 · The planting hole should be at least, twice the size of the polybag





FIGURE 75 · Newly planted seedling and taking GPS coordinates

FIGURE 76 · A set-aside site in a plantation, planted with *Ficus* marcots, that has been over-run by *Mucuna bracteata* and requires massive efforts for removal

Threats to success (other than weeds) and mitigation measures

Macaques

In many localities in eastern Sabah, the greatest threat to restoration success is that of macaque monkeys. Wherever they occur, pig-tailed macaques (*Macacca nemestrina*) (FIGURE 77) and long-tailed macaques (*M. fascicularis*) are the major cause of damage to restoration planting. They detect any new item within their home range, and investigate it. 'Investigation' includes pulling, snapping, ripping, biting and uprooting. Damage by macaques can be expected at the very early marcotting stage (at SFGC, up to 50% of marcots are destroyed on the branch of the mother plant before they can be harvested). Preliminary trials adding chilly powder to the marcotting medium saw some reduction in such damage. When seedlings or marcots are planted out on to set-aside areas in oil palm plantations where macaques occur, it can be expected that about 20% (range 0–100%) will be significantly damaged by macaques. This damage leads to the death of many plantings, while the growth rate of some is slowed, or tree figs grow misshapen (FIGURE 78). Damage by other mammal species is rare and localised.



FIGURE 77 · Pig-tailed macaque troop foraging near the BORA nursery



FIGURE 78 · This seedling has suffered repeated damage by pig-tailed macaques, and the last viable branch needs to be supported

Both macaque species are categorised by IUCN as Vulnerable and declining in numbers. This is not the case in eastern Sabah, where numbers of pig-tailed macaques are higher than in the past in the mixed oil palm forest landscape, and their reproduction rate is maximal. Both are 'protected animals' under the Wildlife Conservation Enactment 1997, so culling is not permitted. The only possible mitigation measures appear to be avoidance of restoration where macaques occur, and making plantings as inconspicuous as possible.

Insect pests

Insect damage in restoration planting tends to be slight. The most serious insect damage appears to be by larvae of a moth (*Phauda flammans*) which can defoliate entire *Ficus* plantings, and some stem borers (larvae of various insects, usually longhorn beetles or moths) that can significantly damage the stems of plantings (FIGURE 79). Leaf galls (growths that develop in reaction to the feeding stimulus of insects and mites) are swellings that are unsightly but do not kill the plant (FIGURE 80). They are common on *Ficus caulocarpa* and *F. racemosa*. Crickets and grasshoppers feed on shoots and young leaves, but to date this has been very localised. *Crematogaster* species ants (known as semut tongek) may construct nests that encircle the stems of plantings, causing significant damage to the bark (FIGURE 81), which then opens the stem to pathogens. It seems that this risk can be minimised by ensuring that all traces of weeds, including dried remnants of cut weeds, are removed from the plantings.

Dry weather

Dry weather can potentially cause the death of young plantings. It is best to plant during rainy periods. This is especially so for stake planting.

Shade

All *Ficus* require ample sunlight for growth, although some species are more tolerant than others of shady conditions. Even with frequent weeding, partial shade from nearby trees can stunt *Ficus* growth very significantly.

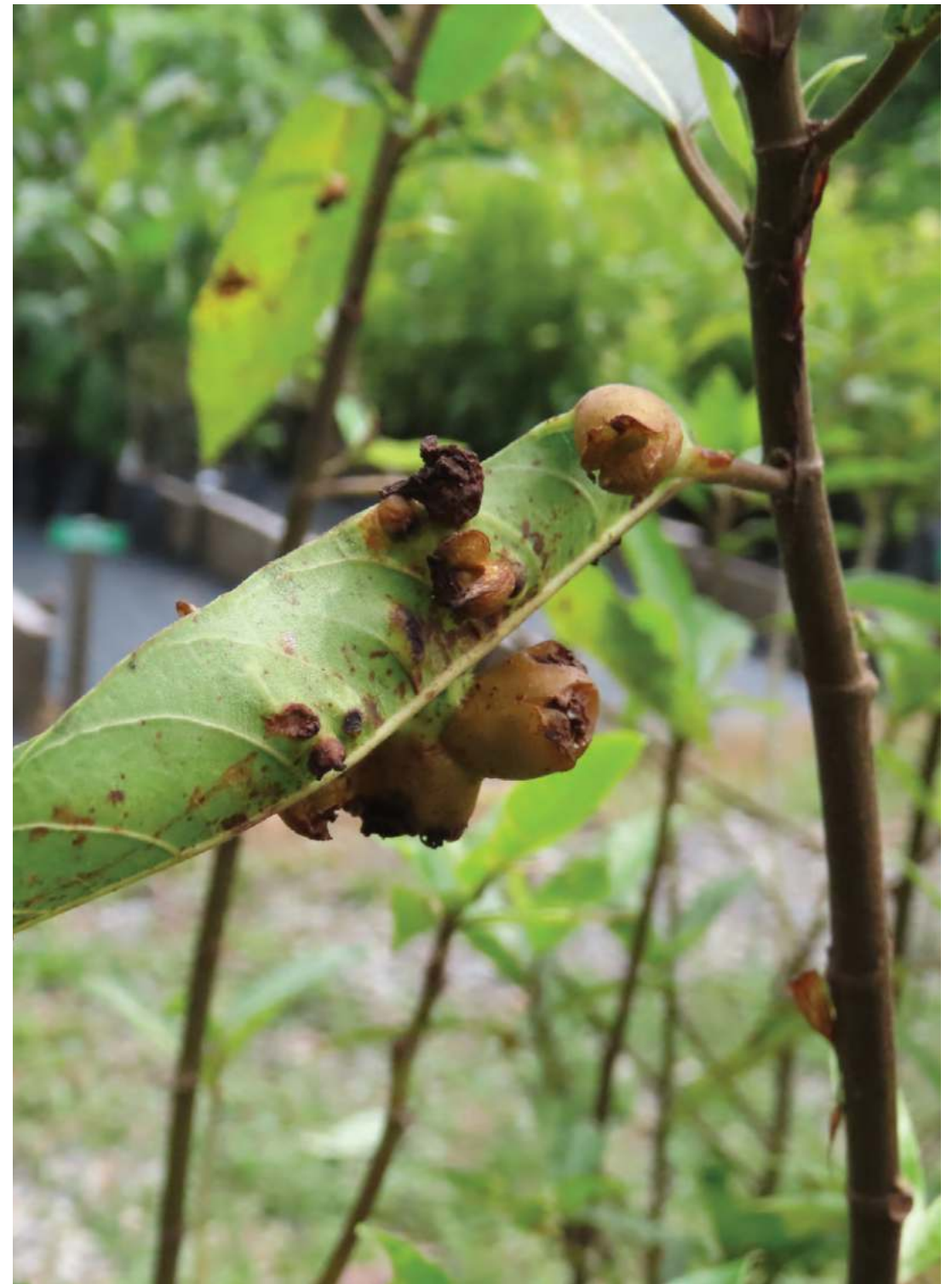
FIGURE 79 · The split trunk of a young *Ficus* tree showing the stem borer caterpillarFIGURE 80 · Leaf gall on a *Ficus racemosa* sapling



FIGURE 81 · Nest of *Crematogaster* ants on the trunk of a planted *Ficus racemosa*, causing significant damage to the bark

Floods and waterlogged soils

Few plant species are tolerant of frequent flooding or of waterlogged soil. This is because soil saturated with water deprives plant roots of oxygen and prevents carbon dioxide from diffusing out, thus limiting plant growth and eventually killing the plants—unless the plants are of the very few species evolutionarily adapted to these conditions. Almost all of those that are adapted are not important sources of foods for wildlife, with the possible exception of the proboscis monkey.

Many set-aside lands in plantations in eastern Sabah, which are potentially ideal for restoration in favour of wildlife, are either flood-prone or permanently waterlogged or both. But there is no point to plant species which will eventually die years later, when they are mature, because of inability to tolerate chronic waterlogged soil. The main impediment to enriching designated 'set-aside' lands which are swampy or flood-prone, therefore, is that there are very few plant species which can survive in these soils. *Ficus microcarpa* and *F. crassiramea* are amongst those few that can thrive in swamp lands. But there is also the problem that periodic flood waters that are incurred at least once annually will kill the great majority of small plantings. This is because flood waters will over-top small plantings in the ground before they have grown tall enough for the crown (leafy twigs) to escape being under water. For most seedlings of any species, more than two or three days under water will result in death. The only possible ways to mitigate these risks are to strictly choose plant species that are adapted to freshwater wetlands and to plant on only the highest points in the restoration area, or to plant strangling figs on to posts that are taller than usual maximum flood level (FIGURE 82), or onto forks in the trunks of flood-resistant trees that are already present (FIGURE 83). Planting strangling figs onto hardwood posts or frames is expensive. Experiments conducted by BORA comparing planting on to portions of dead oil palm trunks embedded into the soil and large bamboo posts (FIGURE 82) indicate that the latter is preferable, being much lighter in weight and longer-lasting.



FIGURE 82 · *Ficus crassiramea* planted in swamp land, held in a large bamboo post with holes to allow drainage and downward growth of roots



FIGURE 83 · A *Ficus marcot* planted into a fork in a remnant tree in a swamp

Restoration silviculture

Silviculture is ‘the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet diverse needs and values such as wildlife habitat, timber, water resources, restoration, and recreation on a sustainable basis.’

In tropical forestry, popular literature often reveals lack of clarity on what is needed to re-grow damaged forests. The biggest misunderstanding concerns the purpose of growing trees: is it to grow wood for future harvesting, or to restore the structure and diversity of a damaged habitat, or is it to enrich an area with wildlife food plants? The answer is that this depends on the particular programme, but often that is not made clear. In the case of habitat restoration, the next biggest misunderstanding concerns the role of planting seedlings. The system of tropical forest management developed more than a century ago was to remove the big trees for sale of the trunks, leaving existing small trees and seedlings to grow naturally to maturity over a period of 30–80 years. Thus, in the original idea of sustainable management of tropical forests, there was rarely a need to actively plant seedlings. But global and national institutions, aided by non-governmental organisations and numerous digital platforms, have focused almost exclusively on planting as a means to restore damaged forests.

This focus has shifted attention away from two important elements of wildlife habitat restoration. One is that, in many circumstances, the best types of seedlings to be planted will be fast-growing pioneer species that do not necessarily provide much food or habitat for vertebrate animals, but instead serve to assist recovery of slower-growing native plant species by mimicking the shady conditions of tropical rainforest. The other element is that for the purpose of recovery of damaged forest, it may be cheaper and quicker to identify and remove weeds (that is, plants that are invasive or exotic or too abundant or simply not wanted) in order to allow more space and light for desired plants to flourish. A careful investigation of any site where restoration is planned will usually find desirable woody plants being smothered by weeds. It is often easier, cheaper and quicker to embark on a weed removal programme than a seedling production, planting and maintenance programme. Any restoration programme can (and often should) opt to prioritise weed removal over planting seedlings, but there are then two problems to be addressed. Firstly, the entire implementation team needs to be able to recognise both the weeds and the desirable plant species, including the seedlings of the desirable species. Secondly, there is

a bigger element of subjectivity in work on the ground than when seedlings are planted. There are no ideal standard operating procedures to tackle any particular site. It is up to the people doing the job to decide exactly what to cut. For example, *Merremia* and *Dinorchloa* are two native creeping plant genera which smother residual natural plants and planted seedlings alike. Both are eaten in small quantities by orangutans, especially when other foods are not available. But as both are invasive, it is usually best to cut and kill most of the *Merremia* and *Dinorchloa* plants in any one locality. On the other hand, the leaves of the seedlings and saplings of many desirable woody plant species appear different from the leaves of the mature plant. It will be largely up to the team on the ground to guess (rather than know) which wild seedlings and saplings to retain. As a rule of thumb, it is best to not cut any woody stem that is greater than about 1 cm in diameter, unless the species is known to be exotic or is very abundant.

This guide does not advise in any more detail on techniques for restoration silviculture for endangered wildlife, but there is a need to emphasise its significance, as a necessary twin to planting of seedlings and other nursery-cultivated planting materials.

A plea to cultivate lianas

Native lianas, meaning woody climbing plants, do not feature in texts and projects relating to habitat restoration for wildlife, except in relation to removing them if they are considered to be weeds. One reason for the lack of lianas in nurseries is that they tend to be viewed as weeds that compete with trees. Another is that there are no field experts in the taxonomy of liana species, and so identifying them is, at best, difficult and sometimes almost impossible. Collectively, however, lianas can provide numerous small sources of young leaves and fruits for wild orangutans, and do indeed form an important part of this species’ diet in the rainforests.

Lianas that can be identified to genus level and which are known to provide food for orangutans can be cultivated in a nursery, in the ways described in this book. Best results are seen using seeds and with wildings, rather than with vegetative propagation. The seedlings can be planted at the base of small trees in set-aside areas (FIGURES 6 AND 84), and the seedlings will grow in height and size with the host trees. Liana seedlings are less suitable for planting at the base of old oil palms, because the growing tip of the liana is usually unable to attach to the wide diameter of the palm—but almost anything is possible in nature (FIGURE 85).



FIGURE 84 · Seedling of *Spatholobus* (the second-most important orangutan food plant genus after *Ficus*) planted at the base of a small tree in a riparian zone



FIGURE 85 · A *Spatholobus* liana growing naturally on an abandoned old oil palm

Glossary

Adventitious root	Roots that are above ground level, usually growing from a stem
Borer	Any of many species of beetles, where eggs are laid into a woody stem, the larvae hatch and feed for weeks or months inside the stem, on the wood, until they are mature and fly out
Controlled release fertilizer	A NPK (nitrogen-phosphorus-potassium) fertilizer with additional minerals, encapsulated into polymer coated granules, that continuously release the minerals into soil independently of moisture, thereby ensuring constant availability of all minerals for growth and preventing wastage during watering
Cutting	A portion of a large, leafy twig, cut from a living mother plant, treated in a nursery to create materials that look like seedlings
Epiphyte	A plant that lives on another plant
Germinate	The process of the very first tiny stem and leaves sprouting from a seed
Habitat restoration	Any targeted work to restore, improve or create new terrestrial vegetation using only or predominantly native plant species
Hardening	The process of introducing planting materials that have been nurtured under the optimum conditions in a nursery to the harsher conditions that they will experience in the real world of the out-planting site
Hemi-epiphyte	A plant that starts life as an epiphyte, but grow downwards into soil, often known as a 'strangler'
Marcot	Vegetative propagation by cutting the bark from a section of a living leafy slender branch, covering the wound with a small handful of soil, and wrapping and tying the soil in place with a piece of transparent plastic sheet; adventitious roots form and grow over a period of a few weeks into the soil; the slender branch is then cut off, just below the adventitious roots, and planted into soil in the nursery
Node	A swollen point on a stem or branch where a leaf or a branch emerges
Planting material	A term used in this book to refer to any plant that has been prepared to be used in habitat restoration, because not all things that are to be produced and out-planted for habitat restoration are derived from seeds

Planting out (or 'out-planting')	The process of putting the planting materials into the ground, or sometimes on to other substrate in the case of strangling figs, where they will be nurtured to grow to maturity
Pollard	Removal of the upper branches of a small tree to promote the growth of a dense head of foliage and branches
Poly bag	A black, cylindrical-shaped poly (poly = low-density polyethylene) bag (the modern and much cheaper and more flexible equivalent of a pot), that will be filled with soil or potting mix, to grow seedlings and marcots in a nursery. They can be purchased in various sizes, with 5 x 7 inches and 6 x 9 inches being the common sizes for habitat restoration nursery use
Potting	To put plants along with soil into a container, usually a black, cylindrical poly bag (formerly, before plastics were available, into clay pots)
Potting mix (or medium)	A specific mix of topsoil, sand and compost put into pots for planting of seedlings or marcots
Rock phosphate	Any commercially available mineral that is rich in phosphorus—an essential element in plant cells—that promotes root and shoot growth, but often in very low concentrations in humid tropical soils
Seedling	A small plant that is grown from a seed, in managed conditions, usually in a dedicated, custom-built nursery
Stake	In this book, a very large cutting, whereby instead of twigs, sections of the branches of strangling figs, some 5–8 cm in diameter and 2–3 metres long are cut from the parent tree for later planting out
Vegetative propagation	Growing new plants from cuttings, marcots or stakes taken from old plants, and not from seed
Weed	A plant growing where it is not wanted and in competition with target plants
Weeding	Active removal of weeds to provide space, light and nutrients for target plants
Wilding	A wild seedling that is removed from the wild, instead of from germination of seeds in a nursery



Inside the Sabah Ficus Germplasm Centre
 (left to right, standing) Hassan Sani, James Sandiang, Maslin Mohiddin
 (squatting) Mohamad Soprih Bin Amdan, Ronald Jummy @ Kuramat, Mellinda Jenuit

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