Seeds
of the Economically Important Trees in Taiwan

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Contents

Preface

The idea of compiling this manual was originally conceived by Drs. Ching-Te Chien and Tsan-Piao Lin, Seed Physiologist at the Tree Seed Laboratory of the Taiwan Forestry Research Institute and Professor at the Institute of Plant Biology, National Taiwan University, respectively. For some time, we have thought that information on propagation of sub-tropical trees by seeds needed to be updated with the data accumulated from research and development on tree seed science and technology over the past 30 years in Taiwan. Some information on tree seed research of the most economically important trees of Taiwan has been published since the mid-1940's (Kuo 1989), but these papers are mostly in Chinese in local journals or magazines. Only recently have research results have been published in English in international journals. Thus, our goal is to make available in English the research on Taiwan trees published in Chinese, and at the same time update the information on each species using data generated from research done during the past 30 years.

This manual consists of three parts. The first part deals with the history of Taiwan forestry and seed dormancy in Taiwan trees. The second part contains information on 61 tree species growing in Taiwan, and the species are arranged in alphabetical order according to their botanical names following the "Flora of Taiwan, second edition" (six volumes, 1994-2003) with few exceptions. For each species, information is provided on seed biology (beginning with flower bud formation and ending with dispersal of the mature seed); seed physical characteristics; seed collecting, handing, processing, germination testing and storage; and seed dormancy and pretreatments to break dormancy, and factors affecting seed germination. In addition, the manual contains information about nursery production of plants for out-planting is provided. Part III consists of a glossary and literature cited.

Practically all information on seed characteristics and germination percentages/rates is based on filled, viable seeds; empty seeds in most of the studies were removed by the flotation technique. The warm and cold stratification procedures for dormancy-break and the temperature, light:dark, etc. conditions required for germination were developed by Drs. Chien and Lin at the Taiwan Forestry Research Institute.

Finally, we would like to thank Drs. Carol Baskin and Jerry Baskin, University of Kentucky, Lexington, USA, for their many comments and suggestions during the preparation of this manual.

Introduction

According to Heydecker (1972), "A seed is an end and a beginning; it is the bearer of the essentials of inheritance; it symbolizes multiplication and dispersal, continuation and innovation, survival, renewal and birth". As such, then, seeds of forest trees have been the focus of much applied and basic research in Taiwan, where forestry is of great economic and ecological importance. It is well known that natural regeneration of forests occurs gradually. Seeds land in favorable micro-environments, such as openings created by silvicultural cuttings, around dead or fallen trees with exposed mineral soil seedbeds and on rotting stumps and fallen boles. Temperature, soil moisture and light conditions in such sites are favorable for seed germination and early seedling growth. For example, natural regeneration of Taiwan hinoki falsecypress (*Chamaecyparis obtusa* var. *formosana*) occurs in open areas on Chilan Mountain in northern Taiwan, due to the high amount of rainfall, which keeps the soil wet for germination in winter and early spring after seeds are dispersed onto the wet soil in autumn.

Considering the importance of woody plants in the biodiversity of Taiwan, the quantity and quality of forest seeds for regeneration are critical for the conservation of forests for the future. Consequently, the traditional practices in seed collecting, handling, processing and nursery seedling production need to be updated. For example, cone or fruit collection from a population has to be made not only from a certain minimum number of trees, but also information on species identity and collection date and site needs to be kept with the material throughout handling, processing, storage and nursery seedling production. Furthermore, the best dormancy-breaking/germination treatments and procedures should be used to promote maximum seed germination percentages and rates (speed) in nursery seedling production. When seed storage is required, seed moisture content needs to be properly maintained to best ensure the maximum seed viability of each species.

As Taiwan advances to more intensive, sustainable forest management with an ever-increasing effort put into artificial regeneration by planting and seeding, large quantities of seeds of known origin and genetic quality are required annually. This means that seeds should be collected only in good seed years of sufficient quantity to bridge the intervals between the years with good seed crops, and they should be stored properly for use in regeneration. In many parts of the world, tree improvement programs have advanced to production of genetically improved seeds in seed orchards. The newly regenerated forests with genetically improved seeds will improve growth rates, form, wood quality and pest resistance of trees (Rudolf et al. 1974, Hollowell and Porterfield 1986, Bridgwater and Ledig 1986).

Seeds are still the conventional source of planting material for large-scale forest renewal programs despite the newly advanced *in vitro* cultural techniques. The advantages of using seeds to produce planting material are that they are easy to harvest and to store for years at low cost. In addition, many seedlings may be produced with mechanized

means at reasonable cost. However, high-quality seedling production is dependent on high genetic and physiological quality of the seeds. Therefore, it is essential to carefully plan for seed collection and documentation of characteristics of mother trees. The planning for seed collection should follow a simple rule of thumb known as '5 Ws': *why collect*, *what to collect*, *where to collect*, *which to collect* and *when to collect* (Wang 2002).

In Taiwan, most seed collections are relatively small scale, and the seed maturity index is fruit color change (Chien and Lin 1996). However, it is difficult to collect fruits with a uniform degree of maturity; thus, after collection it is always a good practice to include an artificial ripening treatment as standard procedure.

Seed maturity is the key to high-quality seeds, since immature seeds with high moisture content are susceptible to injury in subsequent handling, processing, storage and post-harvest ripening processes. It pays to collect mature and sound cones/fruits, especially in manual harvesting of seeds, since it takes the same amount of time and effort to pick good as it does to pick poor quality cones/fruits.

Another factor affecting seed quality is the method of cone/fruit collection. There are a number of techniques and kinds of equipment available for collecting cones/fruits and the one the collector chooses depends on the species, location and purpose of collection. For short trees and shrubs, collecting can be easily done using ladders, pruners or both. For collecting from tall trees, climbing by trained climbers with safety equipment is considered the most efficient way for harvesting good quality seeds. An excellent reference for safe tree climbing techniques and equipment is Yeatman and Nieman (1978). Collecting cones/fruits from felled trees following logging operation is efficient, although harvesting immature cones/fruits from trees felled too early should be avoided. Seed quality of cones/fruits harvested from the ground is usually poor, since they may have been there for some time or damaged by insects or diseases. Animal caches are a good source of easy collection, but collectors should consider sharing the crop by leaving one third of the seeds for the animals.

It is important that information on the species, stand and location should be noted and all the containers clearly and safely labeled. The collected cones/fruits, especially fleshy fruits, should be transported in ventilated containers to the seed processing facility as quickly as possible.

Seed Handling

If freshly collected cones/fruits are collected before full maturity, they must be handled very carefully to prevent them from being injured during processing. They should be spread on screened trays or kept in half-full burlap bags in a cool, well-ventilated place and turned over frequently. It is important that some of the cones/fruits cannot tolerate exposure to the sun and require air-drying or curing in shade, *e.g. Taiwania cryptomerioides*, *Chamaecyparis formosensis*, *Calocedrus formosana* and *Michelia compressa*. Many fruits of broad-

leaf tree are berries, drupes and pomes with high moisture content, and they require proper curing or processing depending on the degree of maturity. These fruits should be handled with care to avoid development of mold and fermentation.

Seed Processing

Seed processing is a major source of seed injury if it is not done properly. Seeds of broadleaved tree species are relatively simple to process, and there is little or no chance for seed injury unless they are carelessly handled. For example, sun-drying of cones/fruits is known to cause seed injury of some tree species, *e.g*. *Chamaecyparis obtusa* var. *formosana*, *Chamaecyparis formosensis* and *Calocedrus formosana* (Chen 1966). Another source of seed injury in commercial processing is mechanical de-winging. However, wet-dewinging seems to have solved that problem. In Taiwan, the majority of the processing involves artificial ripening of the fruits in greenhouse and manually rubbing and washing them with water. Such a manual practice is limited to small-scale operations. For more efficient operation, mechanical processing of fleshy fruits could be accomplished with a commercially available macerator.

Seed Storage

Seed storage is a necessity due to seed crop periodicity and requirement for continued seed supply for annual seedling production, reforestation and afforestation programs. As a sustainable forest management policy, seed inventory should maintain sufficient quantity of seeds for at least a 5-10 year supply. To maintain both genetic and physiological quality, the following key factors must be considered: (1) longevity of species and storage behavior (orthodox, intermediate or recalcitrant), (2) initial seed quality (seed moisture content, germinability and vigor), (3) seed moisture content (4-7% for orthodox seeds, 6-10% for intermediate seeds, and 30-45% for recalcitrant; fresh weight basis), (4) storage temperature (1 to -196℃) (True orthodox seeds can be stored for 100-200 years at -18 to -20℃), (5) storage container (aerated, airtight or sealed) and (6) frequency of seed withdrawal from the container. Nijënstein et al. (2007) have developed standards for the determination of seed moisture content.

Seed Dormancy Breaking

Seed dormancy breaking is an important aspect of the propagation of tropical trees via seeds, and this topic in relation to trees of Taiwan is reviewed in Part I, Chapter 2 “Seed dormancy in trees of Taiwan”.

Seed Germination and Testing

For effective and efficient seed utilization in stock production or direct seeding, seed quality must be tested before sowing. Although ISTA (2007) and AOSA (2014) have developed very comprehensive rules for testing seeds, they primarily cover the species that are recognized in international and national trade. However, their procedures are suitable for a wide range of species. Several comprehensive handbooks are available including the ISTA Forest and Shrub Seed Committee’s “Tropical and subtropical tree and shrub seed handbook” (Poulsen et al. 1998), DANIDA’s

"Guide to handling of tropical and subtropical forest seed" (Schmidt 2000) and the U.S. Forest Service's "Tropical tree seed manual" (Vozzo 2002). These handbooks provide users with general guidance in handling hardwood seeds of tropical and subtropical tree and shrub species.

Williams et al. (1992) suggested that the ISTA procedures for germination tests of small seedlots be reduced from four replicates of 100 seeds each to four replicates of 25 seeds each for small seedlots of *Acacia* species. One of the most important factors in seed testing is that we can only test what we have sampled. Thus, the truly random sampling principle must be followed in order to test the samples that are truly representative of the seedlot to be tested. This overlooked random sampling principle might be part of the problem contributing to differences in germination percentages between laboratory and nursery.

Moisture is a vital factor for seed germination, and it should be maintained constantly in the germination medium throughout the germination test. In Taiwan, we used moist sphagnum moss as the seed germination medium, and it prevents mold from attacking seeds because it contains the fungus *Trichoderma* and actinomycetes that are antagonistic to microorganisms (Wang et al. 1998). Commercial sphagnum moss should be cleaned before it is used. First, sphagnum moss is washed three times with water, and debris inside it is removed. Then, excess water is removed from the clean sphagnum moss by hand squeezing until no water drips (water content of the sphagnum was about 400% of its dry mass). Finally, the moss is cut into small pieces with scissors or a meat grinder. At the Taiwan Forestry Research Institute since 1985, thick (0.4 mm) sealable polyethylene bags are used as containers for seeds. In standard germination tests and for moist treatments, seeds are mixed with moist sphagnum moss. It is critical to check the moisture content of the medium (not too wet or too dry) and to open the bag for aeration once a week at least in germination test. Volume of seeds in moist sphagnum should be less than half of the volume of the plastic bag.

For our seed germination studies of Taiwan tree seeds, fresh seeds are mixed with moist sphagnum moss (as described above) in sealed polyethylene bags and incubated at daily alternating temperature regimes of 30/20, 30/15, 25/15, 20/10 and 15/5℃ and at constant temperatures of 25 and 30℃. At the alternating temperature regimes, the high and low temperatures are given for 12-hour each day. Seeds are exposed to light 12-hour each day, and for those incubated at the alternating temperature regimes the light period coincides with the high-temperature phase of the daily cycle. The light source is white fluorescent tubes, and photon irradiance (400-700 nm) is about 60-80 μmol $m^{-2}s^{-1}$. Due to the coarseness of the sphagnum moss, most seeds receive some light, but at any given point in time a few of them may have been in darkness. However, at weekly intervals the contents of each bag are poured onto a table to facilitate examination of seeds for germination. After germination is monitored, nongerminated seeds and sphagnum moss are returned to the bag, resulting in a re-shuf-

fling of seeds with regard to their position in/on the sphagnum moss and thus the light they received. Consequently, all seeds are in light part (or all) of the time during incubation.

Seeds of each tree species collected in Taiwan have optimal temperatures for obtaining maximum germination percentage and rate at an alternating temperature regime of 30/20℃ or 25/15℃ in light. However, seeds of some mountain species, such as those of *Phellodendron amurense* var. *wilsonii* require an alternating temperature regime of 35/10℃ with a 12-hour daily light period (Chen et al. 2010); seeds of *Cephalotaxus wilsoniana* germinated best at 15/6℃ with a 12-hour light period (Yang et al. 2011). Seeds of some tropical species, *e.g.* those of *Podocarpus costalis*, *Nageia nagi*, *Gomphandra luzoniensis*, *Nothapodytes nimmoniana* and *Goniothalamus amuyon*, germinated to higher percentages at 30/20℃and 25℃ than at 15/6℃ (Chen et al. 2013, 2015).

In the following pages, we describe 61 economically important tree species that grow in Taiwan and explore the details of seed collection, handling, processing, storing, breaking dormancy and germination testing for each of them with the goal of facilitating nursery production of plants for outplanting in the field.

Moist sphagnum moss has been used as a medium for seed germination tests, cold stratification and warm plus cold stratification in laboratory. [Germinating seeds of *Schima superba* (Theaceae) on small pieces of moist sphagnum moss]

PART I

Chapter 1

History of Forestry in Taiwan

Ching-Te Chien

Chapter 2

Seed Dormancy in Trees of Taiwan

Carol C. Baskin and Jerry M. Baskin

Chapter 1

History of Forestry in Taiwan

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Taiwan Island (21º45'-25º56'N, 119º18'-124º34'E) is located in eastern Asia and in the northwest of the Pacific Ocean. The area of Taiwan is about 36,000 km^2 and 60% of the country is in forests. Precipitation is abundant, and the annual mean is about 2,500 mm (1,600 mm/y-3,200 mm/y). The annual mean temperature is about 22℃, 28-29℃ in summer to 16-20℃ in winter. However, the human population of Taiwan is about 23,496,000, which results in a lack of a sufficient water supply in the winter dry season. Agricultural workers made up 44.69% of the total employment in 1966 but only 4.95% in 2014. The percentage of forestry workers is much lower. For example, forestry accounted for only 5.52% of the agricultural production in 1966 and 0.07% in 2014. Vegetation ranges from subtropical and tropical broad-leaved evergreen forests to cold temperate coniferous forests (Figures 1, 2, 3).

Before the 17th-century, natural forests covered all of the Island, and indigenous people lived in southern Taiwan. Most people agree that the origin of the indigenous people is the coastal areas of Indochina and Southeast Asia. These people (also called Austronesian) came to southern Taiwan 15,000 years ago, before the end of last ice age, and then they moved to the north and to the mountains. There are now 16 tribes of indigenous people in Taiwan with a population of about 530,000. The names of the 16 tribes are Amis, Atayal, Paiwan, Bunun, Tsou, Rukai, Puyuma, Saisiyat, Yami, Thao, Kavalan, Truku, Sakizaya, Sediq, Hla'alua and Kanakanavu. They used wood for building houses and boats and for fuel, carving and making various tools. These people are modernized now.

People from mainland China began to immigrate to Taiwan in the 1620s. The Portuguese first visited Taiwan in 1573, and they called it "Formosa", which means beautiful island with dense forests. In 1622, the Dutch came to Tainan (southern Taiwan) and started to cut trees and export wood. The Dutch occupied Taiwan for 38 years, and then soldiers from mainland China lead by Cheng-Gong Zheng (Koxinga) defeated the Dutch in 1661. Zheng started to develop Taiwan and made rules that everyone had to report on the land that they cleared for agriculture and wood. This is first time people understood the importance of the forest.

In the early 18th century, during the reign of the Qing dynasty, camphor oil production from camphor trees (*Cinnamomum camphora*) was

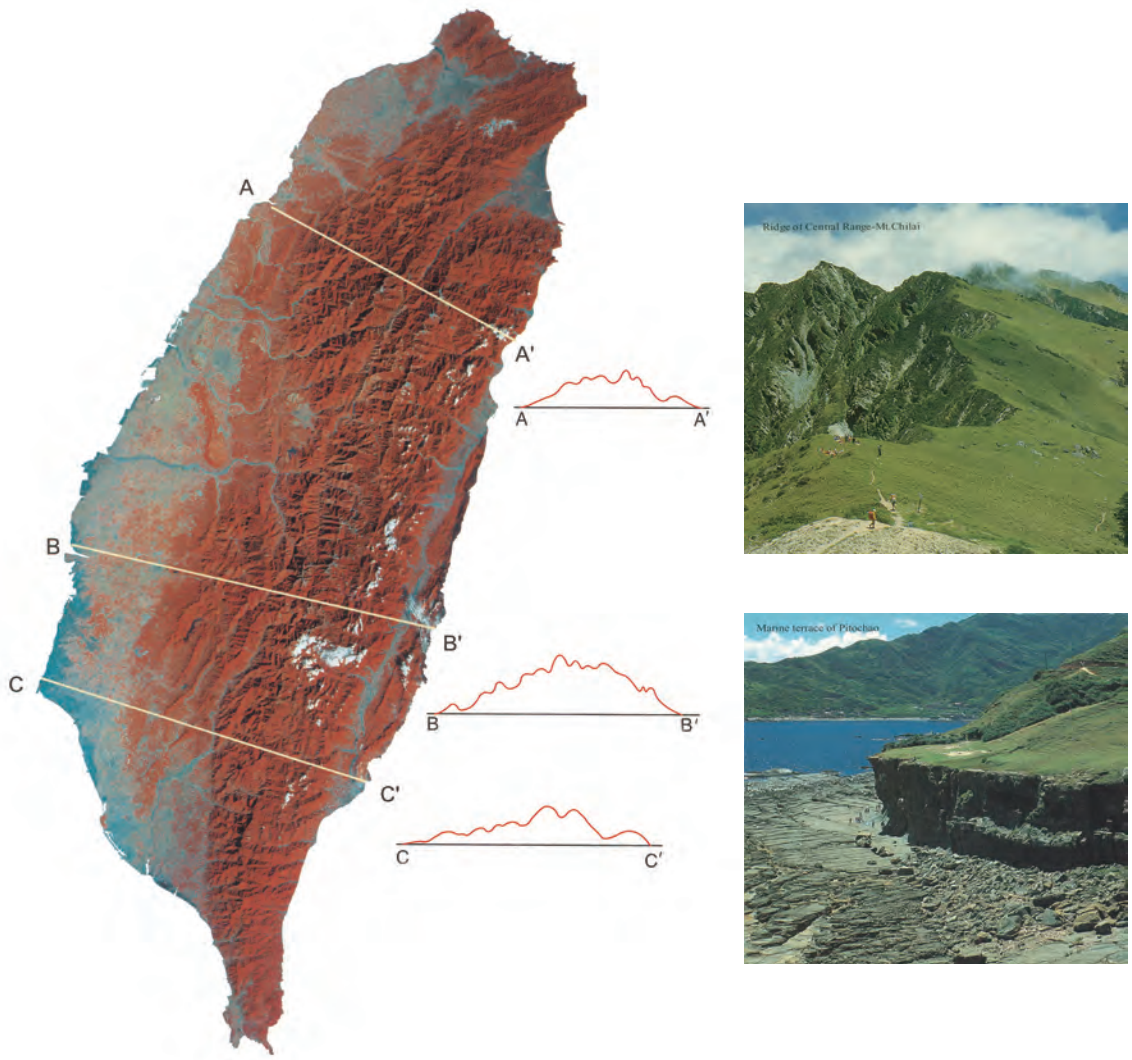

Figure 1. Geomorphology of Taiwan. The island of Taiwan is located approximately 150km off the coast of Fujian Province, South East China, between Japan and the Philippine islands. The island covers an area of about 36,000 square kilometers with north to south distance of 395 km and a maximum width of 144 km. The spindle-shaped island of Taiwan is an area of spectacular relief with more than 200 peaks that exceed 3,000 m above sea level and reflect the high tectonic activity. The highest peak, Yushan, is 3,952 m above sea level and is a varied landscape that includes volcanoes, basins, plateaus, uplifted terraces, etc. Photograph on upper right is of the ridge of Mt. Chilai, which is located at central Taiwan, and photograph on lower right is of the marine terrace of Pitochao, which is located at the northern tip of Taiwan.

A-A', highest peak, Mt. Nanhu, 3,742 m; B-B', highest peak, Yushan, 3,952 m; C-C', highest peak, Little Bald Mountain, 2,590 m. (From The Beautiful Island Nature Reserves of Taiwan 1997)

important in Taiwan. Meanwhile, shipyards were built, which required lots of wood. Natural forests were harvested, and the abandoned lands were replaced by secondary forests. Foreigners including Americans and Englishmen also operated camphor oil extraction facilities, and many hundreds of thousands of kilograms of camphor oil were exported. Camphor was regulated by the Qing dynasty, and British purchasers had to pay taxes before camphor oil could be exported. Thus, the camphor oil business was a flourishing industry during the Qing dynasty.

In 1854, R. Fortune of the Royal Horticultural Society arrived at Tamsui Port at the northern tip of Taiwan and collected herbarium specimens nearby. In 1858, Kew Botanic Gardens sent Charles Wilford to Taiwan, and he collected specimens along the sea shores of northern and southern Taiwan. In 1864, R. Oldham collected more than 700 specimens along the northern tip of Taiwan; he died in Taiwan. These collectors were followed by J.B. Steere (1865), T. Watters (1881-1883), W. Hancock (1881-1882), C. Ford (1884) and G.M. Playfair (1888-1889), who collected plant specimens and sent them to Kew for preservation. In 1892-1895, Augustin Henry collected specimens in southern Taiwan. He published the first plant book in English on Taiwan plants, "A List of Plants from Formosa", in which the morphology of 1,279 species of seed plants and 149 species of ferns was described.

The Japanese occupied Taiwan from 1895 to 1945. The Japanese government owned about 1.5 million ha of forests, with a timber volume about 183 million cubic meters. Major native species in these forests included the gymnosperms *Chamaecyparis formosensis*, *C. obtusa* var. *formosana*, *Cunninghamia konishii*, *Pinus armandii* var. *masteriana*, *Taiwania cryptomerioides* and *Tsuga chinensis* var. *formosana* and the angiosperms *Alnus formosana*, *Castanopsis* spp., *Cinnamomum camphora*, *C. kanehirae*, *Cyclobalanopsis* spp., *Lithocarpus* spp., *Machilus* spp., *Michelia compressa*, *Quercus* spp., *Sassafras randaiense*, *Zelkova serrata* and other broad-leaved species. For military uses and construction, about 3,600 ha (1,141,000 m^3 of wood) of forests were harvested between 1915 and 1945. However, reforestation also was undertaken from 1900 to 1942, and the total area of reforested land was about 102,971 ha: 52,361 ha of camphor trees; 26,546 ha of *Acacia confusa* and other economic species; 3,850 ha of afforestation on flood-prone areas; 11,844 ha of coastal afforestation; and 8,370 ha homeland security afforestation. Tropical trees such as *Cassia siamea*, *Cinchona ledgeriana*, *Dalbergia sissoo* and *Tectona grandis* were introduced for reforestation. It is worth mentioning that the yield of natural camphor oil in Taiwan was 3,000,000-7,000,000 kg per year from 1900 to 1941, and it dominated the world market.

In 1915, Ryôzô Kanehira (from Japan) came to Taiwan and collected many plant specimens, for example, the type specimens of *Elaeagnus formosana*, *Lindera communis* and *Yushania niitakayamensis* from Taipingshan, Ilan County, northern Taiwan. Kanehira returned to Japan in 1928, and he published the book "Formosan Trees", second edition, in 1936 (first edition was published in 1917 by the Formosan Government). Kanehira wrote in his book that there 3,658 species with 79 varieties of cryptograms and phanerogams, of which 1605 (42.9%) were endemic to Taiwan. In other words, > 92% of the species in Taiwan had been discovered by 1936. Syuniti Sasaki, Bunzō Hayata and the famous American botanist Ernest Henry Wilson visited Taiwan, and many species were named by them, *Prunus matuurai* Sasaki, *Stellaria reticulivena* Hayata, *Elaeagnus grandifo-*

lia Hayata, *Helwingia japonica* (Thunb.) Dietr. ssp. *formosana* (Kanehira & Sasaki) Hara & Kurosawa and *Rhododendron kanehirae* E.H. Wilson. Wilson was mostly interested in conifer species, and he sent three live seedlings of *Taiwania cryptomerioides* to the Arnold Arboretum (Harvard University, Massachusetts, USA) in 1918. In 1924, Kanehira sent seeds of *T. cryptomerioides* to the Arnold

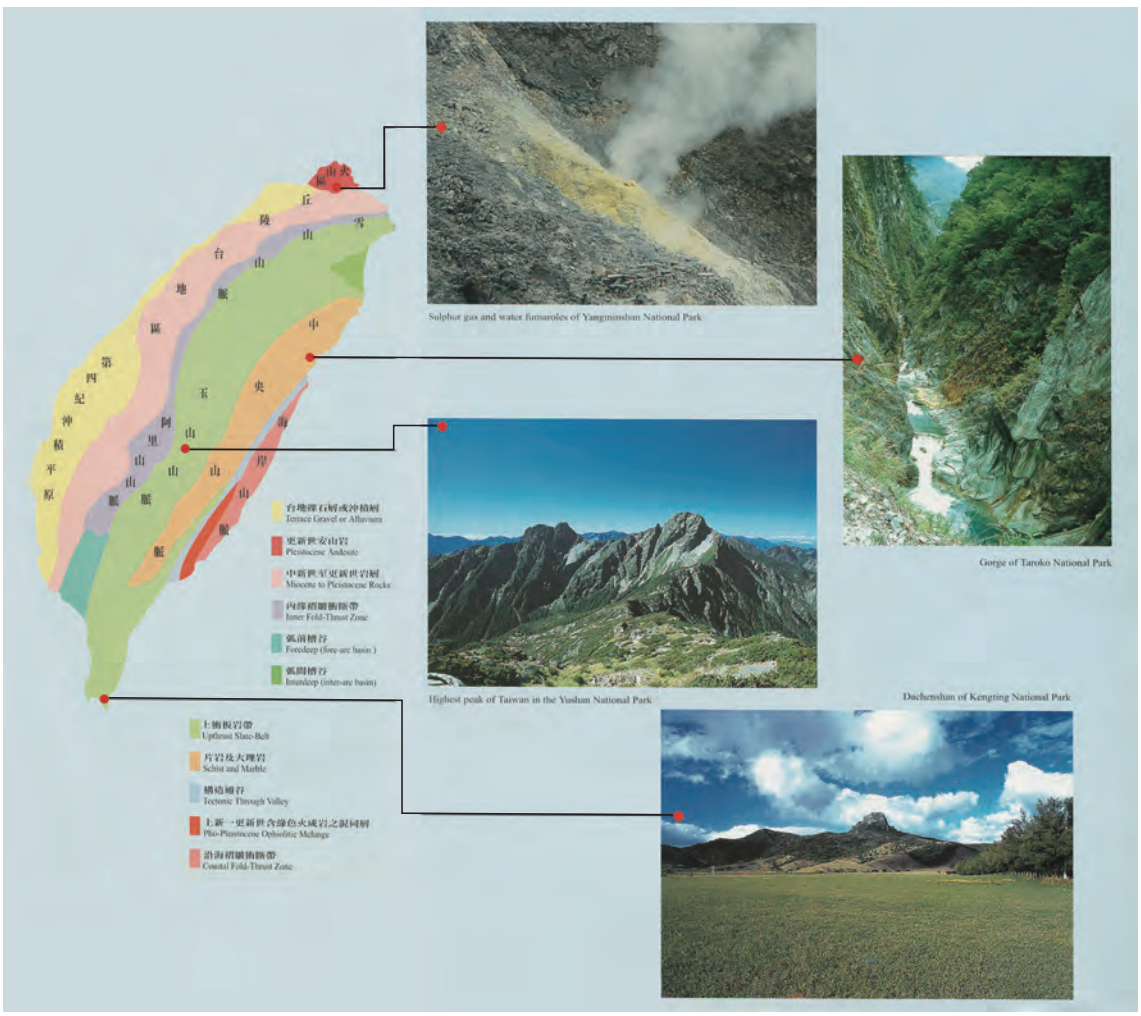

Figure 2. Geology of Taiwan. Taiwan lies at the boundary of the Philippine Sea Plate and the Eurasian Plate. The Taiwan orogenic belt links the Ryukyu island arc to the north and the Philippine arc to the south. The geological framework reveals a history of Neogene to Recent orogenic activity. There are Tertiary metamorphic rocks in the Central Range, Sheushan Range and Yushan Range. The rocks of the metamorphic complex, which are probably late Paleozoic to early Mesozoic, are predominantly metamorphosed clastic sedimentary rocks, limestones and volcanic rocks. The western foothills of Taiwan are underlain by late Oligocene or Miocene to early Pleistocene sedimentary rocks. The rocks are mainly sandstones, siltstones, shale, conglomerates, mudstones and intercalated limestone and tuff lenses. The andesitic volcanoes in northern Taiwan mainly erupted through the Miocene rocks. The basaltic lava from these fissure eruptions formed mesas in the Penghu Islands, 50 km west of Taiwan. (From The Beautiful Island Nature Reserves of Taiwan 1997)

Arboretum. These seeds were successfully germinated, and the seedlings grew well. Wilson published the book "Plants Hunting" in 1927, in which the Taiwan section was named "Formosa: Pearl of the Orient". Harley Harris Bartlett (Director of the Botanical Garden, University of Michigan, USA) arrived in Taiwan on 22 September 1926, and he went to the northern mountains to investigate the vegetation. Then, he traveled to Hualien County in eastern Taiwan, where he visited the Amis tribe; to Puli township, Nantou County in central Taiwan, where he investigated plants of the high mountains; and to Pingtung County in southern Taiwan, where he visited the Paiwan tribe. On 26 October 1926, he left for Japan to attend the "Third Pan-Pacific Science Conference," at which the Pacific Science Association was officially established. Bartlett collected 370 specimens in Taiwan among which were more than 250 species, and he compared his specimens to those in the Herbarium of Taiwan Forestry Research Institute. The type specimen of *Clematis parviloba* Gard. ex Champ. subsp. *bartlettii* (Yamamoto) Yang & Huang was named in his honor.

After Japan was defeated in World War II, the government of the Republic of China (ROC) led by Chiang Kai-Shek took control of Taiwan in 1945. However, the Chinese communists lead by Mao Zedong defeated the ROC government forces in China, and Chiang Kai-Shek and the ROC retreated to Taiwan in 1949, the same year Mao established the People's Republic of China in mainland China. Chiang Kai-Shek started to reconstruct Taiwan, and after his death in 1975 his son Chiang Ching-kuo continued to work hard to build Taiwan. Taiwan became a real democratic country in 1996, and that year the people elected their first president.

In 1945, the Taiwan Forestry Bureau (TFB) and the Taiwan Forestry Research Institute (TFRI) under the Agriculture and Forestry Department were formed. The TFB directly managed the about 2,051,443 ha of country-owned forests, which covered 57.5% of the total island area. It also supervised about 17,413 ha (0.5% of total area) of public forests and 216,260 ha of private forests (6.0% of total area). Sixty-four percent of Taiwan was forested in 1945. About one-third (33.14%) of the forested land was coniferous forests and about two-third (66.86%) broad-leaved forests. The TFRI consisted of ten Divisions: Forest Biology, Silviculture, Forest Management, Forestry Economics, Forest Protection, Watershed Management, Forest Chemistry, Wood Cellulose, Forest Utilization and Forestry Extension and five research centers (plus the Fushan Research Center in 1990) for a total of six research centers). However, forestry policy was changed once in a while according to society requirements. The major forestry policy is as follows: (1) homeland security forests need to be protected forever, (2) economic forests require sustainable management to generate maximum income and (3) forests need to be protected from fire, illegal logging, land reclamation and natural disasters. Other elements of the forestry policy include reforestation, improvement, forestry research, forestry education, wood utilization, multiple uses of forest land, forest recreation, etc. Logging operations and reforestation have been carried out continuously since 1949, and many good woods such as *Chamaecyparis formosensis* and *C. obtusa* var. *formosana* from natural forests were exported to other countries. In 1975, a big change was made in forestry policy to protect lands and strengthen soil and water conservation. Annual forest cutting area and volume were reduced from about 12,000 ha and 1,500,000 m^3, respectively, to about 7,000 ha and 800,000 m^3, respectively. Since 1992, cutting in natural forests has been prohibited, and only a small amount of cutting is allowed in man-made plantations. For example, in 2014, 155.45 ha were

clear-cut and 265.75 ha were selectively cut (total volume 62,271 m^3), a 92% decrease in volume.

Reforestation has been important in Taiwan, and the TFB mainly has followed the plantation plan. The plantation species (N, native; E, exotic) are the gymnosperms *Calocedrus formosana* (N), *Chamaecyparis formosensis* (N), *C. obtusa* var. *formosana* (N), *Cryptomeria japonica* (E), *Cunninghamia konishii* (N), *C. lanceolata* (E), *Pinus elliottii* (E), *P. luchuensis* (E), *P. massoniana* (N), *P. taiwanensis* (N), *Taiwania cryptomerioides* (N); the angiosperm trees *Acacia confusa* (N), *Albizzia falcataria* (E), *Aleurites fordii* (E), *Aleurites montana* (E), *Alnus formosana* (N), *Cassia siamea* (E), *Casuarina* spp. (E), *Cinnamomum camphora* (N), *Eucalyptus* spp. (E), *Fraxinus formosana* (N), *Leucaena leucocephala* (E), *Liquidambar formosana* (N), *Melia azedarach* (N), *Michelia compressa* (N), *Paulownia fortune* (E), *Sassafras randaiense* (N), *Swietenia macrophylla* (E), *Tectona grandis* (E) and *Zelkova serrata* (N); and the bamboo species *Dendrocalamus latiflorus* (N), *Phyllostachys edulis* (N) and *P. makinoi* (N). In northern and central Taiwan, *Pinus luchuensis* and some other pine species are killed by the pine wood nematode (*Bursaphelenchus xylophilus*), which was found in 1985. The fast-growing introduced *Eucalyptus* and some legume species often are damaged (top half of tree broken off) by typhoons. Introduced *Casuarina* species, especially *C. equisetifolia*, has become a very important first line species on the sea coast. Introduced *Swietenia macrophylla* grows well in southern Taiwan.

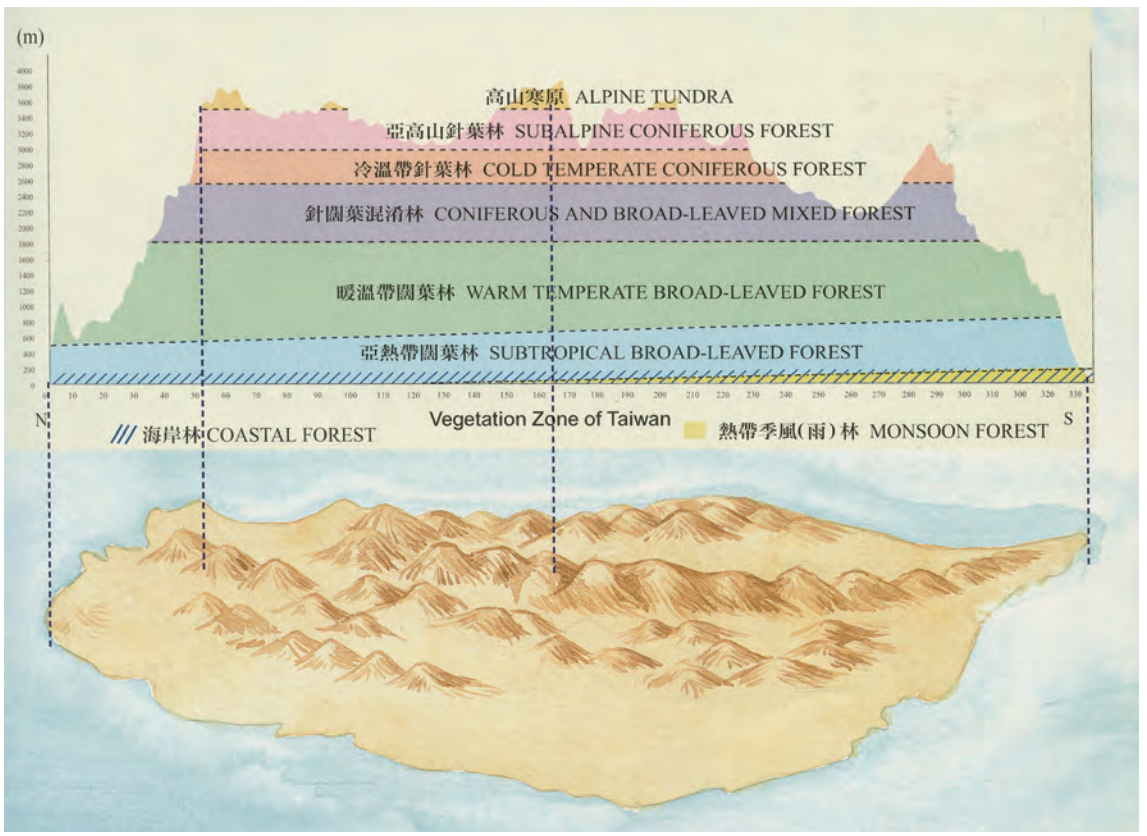

Figure 3. Vegetation zones of Taiwan. (From The Beautiful Island Nature Reserves of Taiwan 1997)

Figure 4. Nature reserves of Taiwan (From The Beautiful Island Nature Reserves of Taiwan 1997)

Forest recreation has been developed since 1958, and up to now a total of 22 recreation areas have been established. In 1972, in consideration of protecting mother trees in forests, 26 nature preserve areas totaling about 5,000 ha were established. Further, in accordance with the cultural heritage preservation law in 1986 the Council of Agriculture designated 18 nature reserves (63,243 ha, 1.8% of the total area in Taiwan) (Figure 4). In 1982, the first national park (Kenting National Park in southern tip of Taiwan) was established, and now there are nine national parks in Taiwan.

In conclusion, tree cutting and wood production have been reduced in Taiwan, and people have paid attention to protection of the environment and natural resource conservation. Of course, we preserve the natural forests, and no more trees are allowed to be cut in them. However, we need wood in our lives. To supply our need for domestic wood, we have focused on man-managed plantation forests. According to the Fourth National Forest Resource Investigation (2008-2011), the area of man-managed plantations in Taiwan was about 231,932 ha. Pruning and thinning of trees at certain ages for increasing volume and wood quality are in progress, and the wood from thinning is removed from the mountains for utilization. Our goal is to maintain sustainable forest management of the planted forests.

[The primary sources of information (all in Chinese) in this essay are from Guorui Wang, "History of Taiwan Forestry" (first edition published in 1980 and second edition in 1985), published by Guinness Book Co. Ltd., Taichung City; Henien Yao, "New Revision of Annals of Taiwan Province" (Forestry chapter in volume 4) in 1992, published by Taiwan Historical Committee, Nantou County; and Chao-Huan Wang, "Results analysis of the Fourth National Forest Resource Investigation", cited from Results Report of the National Forestry Board Green Gas Detailed List in 2015.]

Chapter 2

Seed Dormancy in Trees of Taiwan

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Abstract

The primary aim of this chapter is to give a brief overview of nondormancy (ND) and of the five *classes* of seed dormancy – morphological (MD), physiological (PD), morphophysiological (MPD), physical (PY) and combinational (PY+PD). In addition, the three *levels* (nondeep, intermediate and deep) of the class PD are described. ND and all five classes occur in seeds of angiosperms but only ND and the first three classes in seeds of gymnosperms, *i.e*. PY and (PY+PD) do not occur in gymnosperms. Several published studies on seeds of Taiwan trees with ND, PD, MD, MPD or PY are included in citations of examples of research on seeds of species in these categories. Nondeep PD is the most common kind of seed dormancy on earth, occurring in all the major vegetation zones; PY ranks second in importance, and (PY+PD) is rare (an example is the caesalpinioid legume *Cercis* of North America, Mediterranean Europe and eastern Asia but not Taiwan). Information is given on desiccation tolerant versus desiccation intolerant seeds, criteria to use in assigning seeds of a species to a dormancy class, and how to break the various kinds of dormancy, with emphasis on use of the "move-along experiment."

Introduction

In nature, environmental conditions at the time of, and immediately after, seed germination play a major role in determining successful establishment of seedlings. That is, if soil moisture and temperature are not within the range of tolerance of the newly-germinated seedlings, they will die (J. Baskin and Baskin 1971, 1980). One of the central questions in the field of seed germination biology is what controls the timing of germination in nature (C. Baskin and Baskin 2014); however, this is not necessarily an easy question to answer. Seeds can differ greatly in morphology/anatomy and physiology and thus in how they interact with environmental factors. Consequently, conditions, especially temperature, that promote breaking of dormancy and germination in seeds of one species might actually prevent these events from occurring in seeds of another species (J. Baskin and Baskin 1986, C. Baskin et al. 2000). Further, in seeds of some species one set of environmental conditions breaks dormancy, whereas another set is required to stimulate germination of the nondormant seeds (C. Baskin et al. 2003).

One of the accomplishments of seed biology

as a discipline has been the development of an ecologically meaningful way to organize information about dormancy (*e.g*. Crocker 1916, Harper 1957). Although several classification systems of seed dormancy have been proposed, the one by the Russian seed physiologist Marianna G. Nikolaeva (1969, 1977; see J. Baskin and Baskin 2008) is the most comprehensive and includes morphology/anatomy as well as responses of seeds to the plant growth regulator (hormone) gibberellic acid (GA_3) and environmental factors, especially temperature. Nikolaeva's system was modified into a hierarchical classification system that included *classes*, *levels* and *types* of dormancy (J. Baskin and Baskin 2004), but it now has been modified further to include *divisions*, *subdivisions*, *classes*, *subclasses*, *levels* and *types* (C. Baskin and Baskin 2014). Five classes of dormancy (morphological, physiological, morphophysiological, physical and combinational) are recognized in the hierarchical system. These classes are an effective way to organize information related to dormancy-breaking and germination requirements of seeds and thus to consider how germination is controlled in nature. The purpose of this chapter is to survey the five classes of dormancy (and of nondormancy) with regard to distinguishing characteristics and environmental conditions required to break dormancy and promote germination. Emphasis will be placed on woody plants, with examples from Taiwan when available.

Depending on their desiccation tolerance and storage behavior, seeds of most species can be placed into one of two categories: recalcitrant or orthodox. Recalcitrant seeds are desiccation-sensitive, and they lose viability when their moisture content falls below about 20% to 30% (or to less than about -1 to -3 MPa). Recalcitrant seeds cannot tolerate freezing, and those of some tropical species may be injured at temperatures as high as 10 to 15℃ (Farrant et al. 1988, Roberts and Ellis 1989, Pritchard et al. 1995). Orthodox seeds are desiccation-tolerant, and they do not lose viability when dried to a very low moisture content (around 2% to 5% or to as low as -350 MPa). Thus, orthodox seeds can be dried and stored at sub-zero temperatures (optimum is -18℃) and low relative humidity for long periods of time without loss of viability (Roberts 1973, Roberts and Ellis 1989). Seeds of a very high percentage of both angiosperm and gymnosperm taxa are orthodox, and their ability to tolerate drying is a major adaptation for dispersal and survival (Dickie and Pritchard 2002, Tweddle et al. 2003).

It should be noted that seeds of a few species do not fit into either the orthodox or recalcitrant category (Farrant et al. 1988), and these are placed into an "intermediate" category (Ellis et al. 1990, 1991). Intermediate seeds are less tolerant of drying (about 6% to 12% moisture content, or to as low as -250 MPa) than orthodox seeds, and their optimum storage temperature is > 0℃, with 15℃ being optimal for seeds of some species (Ellis et al. 1990, 1991, Pammenter and Berjak 1999, Dickie and Pritchard 2002). Further, it is becoming increasingly clear that the storage behavior of seeds varies along an orthodox → intermediate → recalcitrant continuum rather than fitting into one of the three discrete categories; this is particularly true for desiccation-sensitive seeds (Farrant et al. 1988, Pammenter and Berjak 1999). In working with seeds, it is necessary to give some attention to their response to drying; otherwise, seeds might be killed before their germination ecology can be investigated.

Overview of Seed Dormancy

As a first step in understanding the germination biology of a species, it is important to know whether the freshly-matured germination units

(hereafter seeds) are nondormant or dormant. The way to determine if seeds are dormant or nondormant is to test them over a range of conditions -- usually a range of temperatures in light (*i.e*. daily photoperiod such as 12 hr, not continuous light) and in constant darkness. Nondormant seeds germinate over the widest range of environmental factors (temperature, light/dark, etc.) possible for the genotype (and considering environmental parental effects), while dormant seeds do not germinate (or do so to only low percentages) under any combination of normal environmental conditions (J. Baskin and Baskin 2004). In determining if fresh seeds are dormant, there should be a time limit for the germination test, because seeds of some species begin to come out of dormancy shortly after maturation (*e.g*. J. Baskin and Baskin 1977, 1983). Thus, we recommend that the test to determine if fresh seeds are dormant be terminated after no more than about 30 days, *i.e*. before dormant seeds have time to become nondormant (C. Baskin and Baskin 2014). However, if seeds are to be incubated for an extended period of time (as in controls of an experiment) germination data could be collected at frequent, regular intervals. Some examples of Taiwan trees whose seeds appear to be nondormant at maturity are *Alnus formosana* (Chang 1996), *Cunninghamia lanceolata* (Joker 2000), *Machilus kusanoi* (Lin and Chien 1995) and *Schima superba* (Chien and Lin 1998, Chen et al. 2002). However, more research is needed on all of these species to fully document their germination requirements.

Assignment of Seeds to a Dormancy Class

Assigning seeds to a dormancy class requires answers to several questions. (1) Is the seed (fruit) coat permeable to water? (2) Does seed have a differentiated embryo, *i.e*. are an embryonic radicle and (a) cotyledon(s) present, or is the embryo undifferentiated (organless)? (3) If the embryo has organs, is it fully developed or underdeveloped, *i.e*. does the embryo have to grow inside the seed before the radicle emerges? (4) Do seeds require more than about 30 days to germinate to a high percentage? Combining information about the embryo, water-permeability of seed (fruit) coat and time required for a high percentage of the seeds to germinate will allow the investigator to distinguish nondormancy and dormancy and the various classes of dormancy (Table 1).

No matter how hard seeds feel to the touch, they may be water-permeable; the only way to be sure if they are permeable (or not) is to do imbibition studies. To determine if seeds have water-permeable or water-impermeable coats, seeds are weighed at the beginning and at the end of a period of incubation on a moist substrate, *e.g*. after 24 hours or longer (J. Baskin et al. 2004). If seeds are water-impermeable, there will be no increase in mass, whereas if they are permeable there will be a considerable increase in mass. However, in working with water-impermeable seeds it is not unusual for a few of them in the sample to imbibe, and imbibed seeds can be recognized by their increase in size. If seed coats are water-permeable, increase in mass typically is about 25-40%; however, when water-impermeable seeds are scarified the increase in mass may be > 100% (J. Baskin and Baskin 1997, 1998). Both water-permeable and water-impermeable seeds occur in angiosperms, but only water-permeable seeds occur in gymnosperms.

If a mature (ripe) seed does not have endosperm or perisperm (angiosperm) or female gametophyte tissue (gymnosperm), clearly the embryo must be fully developed because it has no source of nutrition for further growth, except that in the cotyledon(s). However, if seeds have endosperm, perisperm or female gametophyte tissue and if the embryo is ≤ 50% of the length of the food-storing tissues, the embryo may (or may not) be

Table 1. Criteria for assignment of seeds to nondormancy or to a seed dormancy class.
HGP = high germination percentage

Nondormant/Dormancy class	Embryo	Water-permeable coat	Time required for a HGP
Nondormancy (ND) Dormancy class	fully developed	yes	≤ 30 days[a]
Morphological (MD)	undifferentiated or underdeveloped[b]	yes	≤ 30 days[a]
Physiological (PD)[c]	fully developed	yes	> 30 days[a]
Morphophysiological (MPD)	undifferentiated or underdeveloped[b]	yes	> 30 days[a]
Physical (PY)	fully developed	no	< 30 days[d]
Combinational (PY + PD)	fully developed	no	> 30 days[d]

[a] Fresh seeds without a dormancy breaking treatment

[b] A few species have seeds with an undifferentiated embryo that differentiates into a radicle and cotyledon(s) and then grows within the seed before germination occurs (*i.e.* undifferentiated → underdeveloped → fully developed).

[c] includes species in which the shoot emerges a few days after radicle emergence as well as those in which there is a delay of 2-3 or more weeks in shoot emergence after radicle emergence (*i.e.* epicotyl PD)

[d] for scarified seeds

underdeveloped (C. Baskin and Baskin 2005). To determine if seeds have an underdeveloped embryo, first embryos are excised from imbibed (for 24 h) fresh seeds and their lengths measured. Then, other seeds are incubated on a moist substrate and observed at regular intervals until the coat begins to split (but before the radicle emerges), at which time fully developed embryos are excised and measured (C. Baskin et al. 2005a). However, seeds of many species will have to be given dormancy-breaking treatments before the embryo will grow (see below) and length of the embryo prior to radicle emergence can be determined.

Seeds with undifferentiated embryos occur in eight angiosperm families with mycoheterotropic ("saprophytic") (Merckx 2013) and in nine families with holoparasitic (Kuijt 1969) species, and they have a special kind of morphological or morphophysiological dormancy (J. Baskin and Baskin 2004). However, no woody species and no gymnosperms are known to have undifferentiated embryos. Seeds with differentiated, underdeveloped (small) embryos occur in about 90 families of angiosperms and gymnosperms. Examples of woody angiosperms with underdeveloped embryos include Annonaceae, Aquifoliaceae, Araliaceae, Berberidaceae, Caprifoliaceae, Illiciaceae, Magnoliaceae, Santalaceae, Schisandraceae, Trochodendraceae and Winteraceae. Gymnosperm families with underdeveloped embryos include Cycadaceae, Ginkgoaceae, Podocarpaceae and Taxaceae (C. Baskin and Baskin 2014). The shape of the underdeveloped embryo varies with the species and may be rudimentary (as broad as long), linear (longer than broad) or spatulate (longer than broad, with

cotyledon(s) wider than radicle).

Classes of Dormancy Morphological Dormancy

Differentiated, underdeveloped (small) embryos must grow to a species-specific critical length before the radicle emerges from the seed. In some species with underdeveloped (small) embryos, growth of the embryo and germination can occur in ≤ 30 days. Thus, dormancy is due to the developmental state of the embryo at seed maturity and is the time taken for the embryo to elongate and the radicle to emerge under conditions suitable for germination. Growth of the embryo occurs after seeds are dispersed to (or are placed on) a moist substrate at suitable temperature and light/dark conditions. Experiments are needed to determine the optimum conditions for embryo growth and for seed germination. Some examples of Taiwan trees whose seeds have morphological dormancy are *Manglietia insignis* (Beniwal and Singh 1989), *Schefflera octophylla* (Chen et al. 2002), *Podocarpus costalis* (Chen et al. 2013) and T*rochodendron aralioides* (J. Baskin et al. 2006a).

Physiological Dormancy

In describing seeds with physiological dormancy (PD), Nikolaeva (1977) attributed lack of germination to a "physiological inhibiting mechanism". That is, the embryo does not have enough growth potential to overcome the mechanical restraint of the seed coat and/or other covering tissues (if present). After the embryo becomes fully nondormant (*i.e*. after the seed receives the appropriate dormancy-breaking treatment), it has sufficient growth potential to push through the seed coat and any other tissue(s) surrounding it. Based on ability of the excised embryos to grow, temperature requirements for dormancy break and response to GA_3, three levels of PD have been recognized (Nikolaeva 1969): nondeep, intermediate and deep. In terms of number of species in which it occurs, PD is the most important class of dormancy in all major vegetation zones on earth (sensu Walter 1979), and we estimate that > 90% of the species with PD have seeds with nondeep PD (C. Baskin and Baskin 2014).

Nondeep Physiological Dormancy

This level of PD occurs in numerous plant families (C. Baskin and Baskin 2014) and in seeds of trees, shrubs, vines and herbaceous species. Depending on the species, seeds with PD may or may not respond to GA_3, and they require either a cold (about 0 to 10 ℃) moist or a warm (≥ 15℃) moist stratification treatment for dormancy break, *i.e*. simulated winter and summer in the temperate region, respectively. Although seeds are water-permeable, scarification may promote germination (by lowering resistance of covering layer(s) to radicle penetration); excised embryos grow and produce normal seedlings (C. Baskin and Baskin 2014). Many seeds with nondeep PD will come out of dormancy during dry storage (afterripen); thus, it is important to begin germination studies with fresh seeds – not after they have had time to afterripen (C. Baskin et al. 2006). Seeds stored at 5℃ or even at subzero temperatures in freezers may afterripen slowly (*e.g*. Probert et al. 1985). Seeds of many species with nondeep PD can cycle between dormancy and nondormancy: dormant seed ↔ nondormant seed. There are numerous Taiwan trees whose seeds have nondeep PD, including *Camptotheca acuminata* (Chen et al. 2004), *Castanopsis indica* (Beniwal and Singh 1989), *Phellodendron amurense* (Chen et al. 2010), *Trema cannabina* (Chen et al. 2008b) and *Zelkova serrata* (Ishii 1979, Yang et al. 2007).

Intermediate Physiological Dormancy

Intermediate PD has been documented in seeds of several woody plant families, including the Ber-

beridaceae, Betulaceae, Ericaceae, Fagaceae, Oleaceae, Rosaceae and Sapindaceae (C. Baskin et al. 1993, 2002, Meyer et al. 1998). GA_3 may or may not promote germination, and excised embryos grow into normal plants (C. Baskin and Baskin 2014). Dormancy is broken by cold stratification. However, in many species length of the cold stratification period required to break dormancy decreases with an increase in length of a warm stratification pretreatment (J. Baskin et al. 1988, C. Baskin and Baskin 1995), or in some cases it decreases following a period of dry storage at room temperatures (*e.g.* Ransom 1935). Germination of nondormant seeds of many species is promoted by low temperatures, including those suitable for cold stratification (J. Baskin et al. 1988, C. Baskin and Baskin 1995), but in some species the optimum temperature for germination of nondormant seeds is higher, *e.g.* 25/15℃ (C. Baskin et al. 2002). Two examples of species from Taiwan that appear to have this level of PD are *Myrica rubra* (Chien et al. 2000, 2002a, Chen et al. 2008a) and *Prunus campanulata* (Chien et al. 2002b, Chen et al. 2007a).

Deep Physiological Dormancy

This level of PD has been reported in a few woody plant families, including the Celastraceae, Ericaceae, Rosaceae and Sapindaceae (C. Baskin and Baskin 2014). A species from Taiwan reported to have deep PD is *Sorbus randaiensis* (Rosaceae) (Chen 2011). GA_3 does not promote germination, and if excised embryos grow a dwarf plant is produced (nanism) (C. Baskin and Baskin 2014). Except for the one known example in the Ericaceae, several months of cold stratification are required to break deep PD. In seeds of the Hawaiian montane shrub *Leptecophylla tameiameiae* (Ericaceae), dormancy is broken only by 4-40 months of warm stratification (C. Baskin et al. 2005b). Perhaps, a warm stratification requirement to break deep PD is the reason why 30 species in 16 families (Burseraceae, Clusiaceae, Combretaceae, Euphorbiaceae, Fagaceae, Flacourtiaceae, Hernandiaceae, Lecythidaceae, Meliaceae, Menispermaceae, Myrtaceae, Rhizophoraceae, Rubiaceae, Rutaceae, Symplocaceae and Verbenaceae) in Ng's (1980, 1991, 1992) germination phenology studies in Malaysian forest trees did not begin to germinate until after 90 or more days. When deep PD is broken by cold or by warm stratification, the optimum germination temperatures are low and high, respectively. In fact, seeds with deep PD that become nondormant during winter can germinate in late winter to early spring; they may even germinate at the cold stratification temperature regime (*e.g.* 1 or 5℃).

Epicotyl Physiological Dormancy

A specialized kind of physiological dormancy has been found in seeds of *Quercus* (especially subgenus *Leucobalanus*) and a few other woody plant species, including the tropical rainforest understory tree *Humboldtia laurifolia* (Fabaceae, Caesalpinioideae) (Jayasuriya et al. 2010). In these species, emergence of the epicotyl/plumule is delayed for several weeks following radicle emergence. We have called this uncommon kind of dormancy epicotyl PD. A Taiwan example is *Chionanthus retusus* (Chien et al. 2004).

Morphophysiological Dormancy

In this class of dormancy, seeds have an underdeveloped embryo, and the embryo has PD. PD has to be broken, and the embryo must grow to some species-specific critical length before seeds can germinate. Depending on the species, PD is broken before (J. Baskin and Baskin 1990), during (J. Baskin and Baskin 1994), or after (J. Baskin and Baskin 1989, Phartyal et al. 2009) embryo growth. Nine levels of MPD have been distinguished based on the (1) temperature regime(s) that seeds must be subjected to before both the radicle

and cotyledon(s) emerge, (2) temperature requirement for embryo growth *per se* and (3) response of seeds to GA_3. Examples of woody plants whose seeds have MPD include *Cephalotaxus wilsoniana* (Yang et al. 2011), *Daphniphyllum glaucescens* (C. Baskin et al. 2009), *Ilex asprella* (Yang et al. 2014), *I. maximowicziana* (Chien et al. 2011b), *Nageia nagi* (Chen et al. 2013), *Schisandra arisanensis* (Chien et al. 2011a), *Taxus maireri* (Kuo-Huang et al., 1996, Chien et al., 1998b, Zhang et al. 2000), *Viburnum odoratissimum* (C. Baskin et al. 2008), *V. betulifolium* and *V. parvifolium* (Chien et al. 2011c). Seeds of these *V. odoratissimum* have nondeep simple epicotyl MPD (C. Baskin et al. 2008), and those of *V. betulifolium* and *V. parvifolium* have deep simple epicotyl MPD (Chien et al. 2011c).

Physical Dormancy

Seeds do not germinate under otherwise favorable conditions for germination because the seed (or fruit) coat is impermeable to water due to presence of one or more palisade layers of lignified macrosclereid cells in the seed (or fruit) coat. Dormancy is broken when a specialized anatomical area in the seed (or fruit) coat ("water gap") opens. Water gaps, which vary taxonomically in developmental origin and anatomy (Gama-Arachchige et al. 2013), open in response to various environmental "signals," thereby creating an entry point for water into the seed (J. Baskin et al. 2000, C. Baskin and Baskin 2014). Physical dormancy is known to occur in 18 angiosperm (no gymnosperm) plant families (sensu APG 2003): Anacardiaceae (*Rhus* complex), Biebersteiniaceae, Bixaceae, Cannaceae, Cistaceae, Convolvulaceae (including Cuscutaceae), Curcurbitaceae (*Sicyos*), Dipterocarpaceae (subfamilies Montoideae and Pakaraimoideae but not Dipterocarpoideae), Fabaceae (all three subfamilies: Caesalpinioideae, Mimosoideae and Papilionoideae), Geraniaceae, Lauraceae, Malvaceae (including Bombacaceae, Sterculiaceae and Tiliaceae), Nelumbonaceae, Rhamnaceae, Sapindaceae, Sarcolaenaceae, Sphaerosepalaceae and Surianaceae (J. Baskin et al. 2000, 2006b, Mahadevan and Jayasuriya 2013). Not all members of all these families have physical dormancy. In fact, seeds of some tropical members of these families (*e.g*. Anacardiaceae, Fabaceae, Malvaceae) may even be recalcitrant (see Introduction). No seeds with physical dormancy can be recalcitrant since they must dry to a moisture content below which recalcitrant seeds can remain viable in order for the seed/fruit coat to become water-impermeable (Qu et al. 2010, C. Baskin and Baskin 2014). The Anacardiaceae (*Rhus* complex only), Biebersteiniaceae, Lauraceae, Nelumbonaceae and Surianaceae have water-impermeable fruit coats, but members of the other 13 families with physical dormancy have water-impermeable seed coats. From a global perspective, physical dormancy is the second most important class of dormancy, and it is especially important in tropical deciduous forests, savannas and hot deserts of tropical/subtropical regions of the world and in steppes, matorral and cold deserts in temperate regions (J. Baskin and Baskin 2003, C. Baskin and Baskin 2014). Examples of woody species that occur in Taiwan that have been shown to have seeds with PY include *Acacia confusa* (Chen et al. 2002), *Dodonaea viscosa* (J. Baskin et al. 2004), *Hibiscus mutabilis* (Goo 1976), Rhus chinensis (Goo 1976, Chen et al. 2002, Hsu and Su 2013) and S*ophora tomentosa* (Offord et al. 2004).

In nature, seeds/fruits become permeable in response to changes in environmental conditions. Depending on the species, drying on the soil surface during summer (McKeon and Mott 1982) or an increase in the amplitude of the daily temperature fluctuations can cause seeds of some species to become water-permeable (Martínez and Moreno-Casasola 1998, Vázquez-Yanes and Orozco-

Segovia 1982). Sensitivity to high temperatures and/or amplitude of daily temperature fluctuations also can serve as a means of detecting depth in the soil or an opening (gap) in the forest canopy. Further, although seeds on the soil surface may be killed by fire (Hodgkinson and Oxley 1990), the heat from a fire may promote germination of seeds with physical dormancy that are buried 1-10 cm below the soil surface by causing the water gap to open (J. Baskin and Baskin 1997). Finally, depending on the species moist storage at 5ºC followed by alternating spring temperatures (Van Assche et al. 2003) or incubation on a wet substrate (over a range of temperatures) followed by wet-high summer temperature conditions (Jayasuriya et al. 2008) result in seeds becoming permeable. That is, dormancy-break is a two-step process. The first temperature regime (step) makes the water-impermeable seed sensitive, and the second one causes the water gap to open (Jayasuriya et al. 2008). If sensitive seeds are not exposed to the second temperature/step, they revert back to the insensitive state. Thus, a seed can cycle between the sensitive and insensitive states; however, it cannot cycle between dormancy and nondormancy. That is, once the sensitive seed becomes nondormant (water-permeable) it either germinates or dies. The model is as follows: nonsensitive seed (dormant) ↔ sensitive seed (dormant) → nondormant seed → seedling (or dead seed).

Combinational Dormancy

Germination is prevented both by a water-impermeable seed (or fruit) coat (an exogenous kind of dormancy) and nondeep PD (an endogenous kind of dormancy) of the embryo, and thus it is called combinational dormancy. Nikolaeva (see J. Baskin and Baskin 2008) included physical dormancy in her exogenous category of kinds of seed dormancy and PD in her endogenous kinds of dormancy. This class of dormancy is known to occur in a few woody plant families including the Anacardiaceae (*Rhus* complex), Fabaceae, Malvaceae, Rhamnaceae and Sapindaceae (J. Baskin and Baskin 1998). In winter annuals (nonwoody, of course, *e.g*. *Geranium* and *Trifolium*), PD is broken prior to the time the seed coat becomes permeable to water (*e.g*. J. Baskin and Baskin 1974, McKeon and Mott 1984). Nondeep PD in seeds of all temperate-zone woody species known to have combinational dormancy is broken by cold stratification, *e.g*. the *Ceanothus* species from the montane zone in California (Quick 1935), *Cercis* species (Afanasiev 1944, Geneve 1991, Gebre and Karam 2004) and *Rhus aromatica* (Li et al. 1999). The seed (or fruit) coat becomes permeable (PY broken) during summer, seeds imbibe water before the onset of winter, PD is broken during winter and seeds germinate in spring (*e.g*. Afanasiev 1944, Geneve 1991). Combinational dormancy has not yet been reported for a woody species native to Taiwan.

What Dormancy-breaking Treatments to Use?

If seeds are dormant and if it has been determined that they are water-permeable, what is the next step? First, we can look at the timing of seed dispersal in relation to seasonal changes in environmental factors in the habitat and perhaps hypothesize that they require either warm or cold stratification for dormancy break. However, seeds of some species require warm followed by cold stratification before they will germinate (C. Baskin and Baskin 1995). Second, since seeds may require warm and/or cold stratification treatments to germinate, why not do a simple experiment that requires relatively few seeds to determine the dormancy breaking-treatment(s) (or combination thereof) required for a species. This procedure is called a “move-along experiment” (C. Baskin and Baskin 2003, 2004).

In a move-along experiment, two germination phenology studies are conducted at the same time: one starts at simulated winter temperatures and the other at simulated summer temperatures for the region where the seeds were collected. From each starting point, seeds are moved through a simulated yearly sequence of temperatures. Control seeds are kept continuously at all the temperatures used in the study. Thus far, this experiment has been used only for seeds that are water-permeable, but there is no apparent reason why it could not be modified and used in studies of seeds with water-impermeable seed coats.

The move-along experiment can tell us several things. (1) If seeds are nondormant, they will germinate to high percentages shortly after being placed over the range of temperatures. (2) If dormancy is broken by cold stratification, seeds will germinate after they are moved from winter to spring. (3) If dormancy is broken by warm stratification, seeds will germinate after they are moved from summer to autumn. (4) If dormancy is broken by warm followed by cold stratification (*e.g.* nondeep complex MPD), seeds will not germinate until after they have been moved sequentially from summer to autumn to winter and then to spring, when germination occurs. For example, when embryo growth and germination were monitored for seeds of *Cephalotaxus wilsoniana* incubated at warm, cold and warm plus cold temperatures, and germination was monitored for seeds subjected to (1) cold → warm → cold → warm, and (2) warm → cold → warm → cold → warm temperature sequences, it was found that seeds had deep simple MPD. That is, seeds of *C. wilsoniana* required warm stratification followed by cold stratification and then warm-temperature incubation to break both the morphological and physiological dormancy of the embryo (Yang et al. 2011).

PART II

Individual Tree Species

(Alphabetical order of botanical names)

Abies kawakamii (Hayata) Ito

Pinaceae
Taiwan Fir

Growth Habit, Occurrence and Use

Taiwan fir is a large tree with grayish brown bark up to 35 m tall. Leaves are broadly linear, flat, 10-15 mm long, dark green and grooved above with two white stomatic bands beneath. This species is endemic to Taiwan, usually forming pure stands in the cool zone at elevations of 2,800-3,700 m along the Central Mountain Ranges. There is no distinction between sapwood and heartwood in this species. The wood has good elasticity, but it is more fragile and less-durable than Taiwan spruce.

Collection and Processing

Male and female cones appear in April-May, and seeds are mature in November-December. Mature cones are dark purple, upright cylindrical, fully covered with resin, and the scales fall off with the seeds, leaving a persistent spike-like cone axis. The collection window of Taiwan fir cones is short, and seeds will be lost if it is timed late. Many seed maturity indices have been developed for *Abies* of which cone moisture content (below 50%) and specific gravity (0.9) are the most objective and reliable (Rediske 1961). In British Columbia, Canada, fir seeds are considered mature if the embryo occupies 90% of the embryo cavity (Kolotelo et al. 2001). For large-scale collection, Edwards (2008) recommended that several criteria such as seedcoat and wing color, seed detachment from the cone scales and embryo color and extension should be used. Usually, timing cone collection earlier and artificially ripening the cones indoors results in more seeds than a late collection. According to Edwards (2008), fir seeds ripen in two stages: the first being the accumulation of organic materials and the second involves metabolic changes within the seeds that result in continuous germination capacity up to (or almost up to) seed dispersal. For this reason, it is a good practice that cones should be air-dried in a ventilated, cool place for a period of curing before seed extraction. Collection of Taiwan fir cones by climbing is the current practice, but it is risky because the branches are rather brittle. Handling the collected seeds requires gentle care since the seed has a thin coat with resin vesicles and is susceptible to injury in processing, especially in the de-winging process. Hand de-winging has been recommended to minimize potential injury to seeds (Roe 1948). Immediate processing without proper curing will result in decreased seed germinability. Air-drying cones in bottom-screened trays is advantageous, although they should be more than 6 cm deep (Edwards 2008).

Some physical seed characteristics are given below (Chung and Chang 1990):

Weight of seeds (g/L)	505
No. seeds/L	32,100
No. seeds/kg	63,600
Weight of 1,000 seeds (g)	15.7

Seed Dormancy and Germination

Taiwan fir seeds are non-dormant and fresh seeds incubated at alternating temperatures of 30/20, 25/15 and 20/10℃ germinated completely within 4 weeks (Ching-Te Chien and Shun-Ying Chen, unpublished data). Chung and Chang (1990) found that seeds cold-stratified at 4-6℃ for 2-4 weeks and incubated at a constant temperature of 20℃ for 21 days germinated to 20-30%. Ching-Te Chien and Shun-Ying Chen suggested that Taiwan fir seeds should be collected and air-dried in November and then stored at 4-6℃ for 3-4 months

until next spring for germination. For germination tests, seeds are placed in sealable transparent polyethylene bags (0.04mm in thickness) and mixed with moist sphagnum moss for 28 days at 30/20℃ alternating temperatures with 12-hour light. The moist sphagnum provides a good germination medium and prevents the spread of mould because it contains the fungi *Trichoderma* and actinomycetes that are antagonistic to microorganisms (Wang et al. 1998).

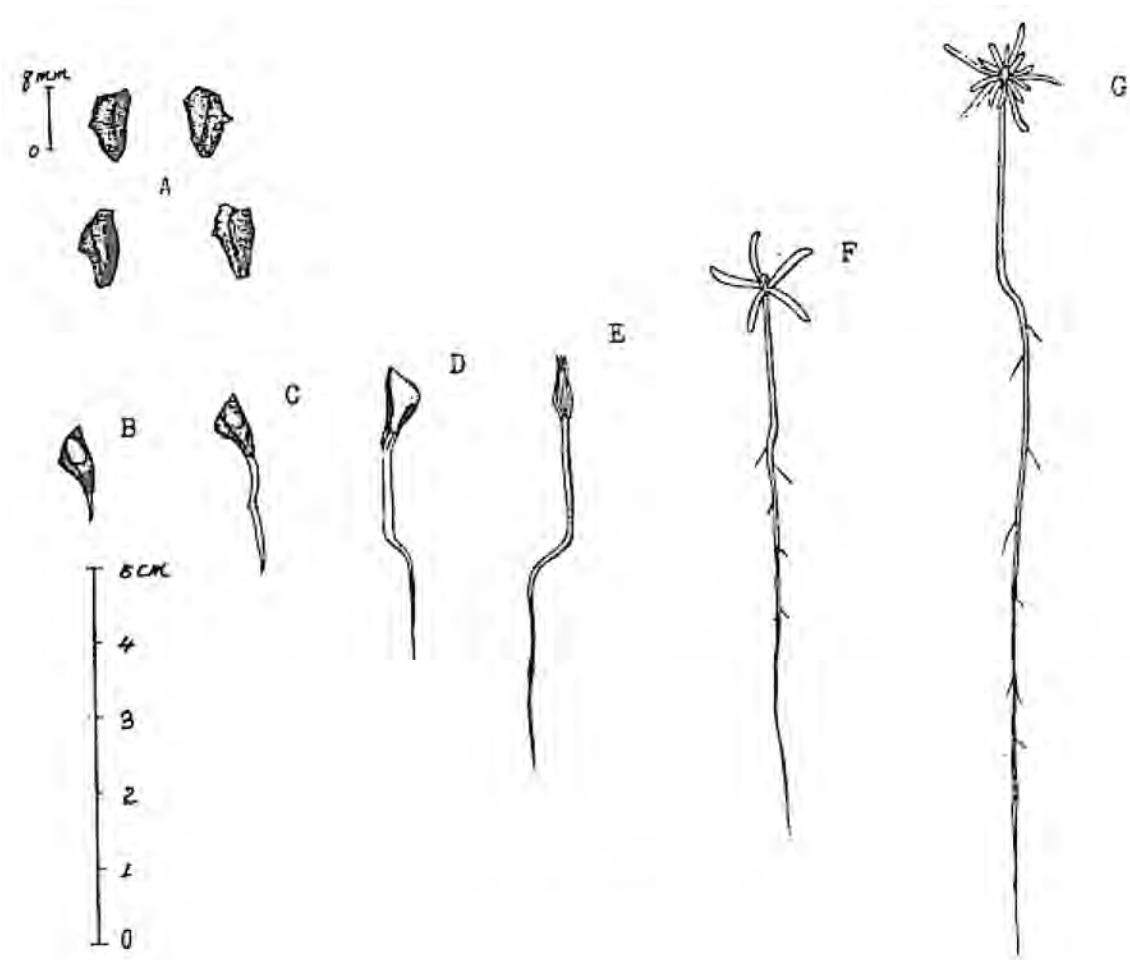
Seed Storage

Although no storage behavior information is available for this species, fir seeds in general have orthodox seed storage since they can tolerate desiccation and sub-freezing temperatures. Balsam fir (*Abies balsamea*) seeds with 4.1% moisture content had a germinability of 73% after 21 years storage in a sealed container at -20℃ (Simpson et al. 2004).

Nursery Practice

Taiwan fir seed quality is generally low (20-30% germinability), probably due to not separating filled and nonfilled seeds. It is assumed that nearly 100% of the filled seeds germinated. Treated seeds should be sown onto prepared moist seedbeds. As seeds germinate, germinants can be transplanted into plastic bags or other containers containing sandy loam soil mixed with manures.

While herbicides are not usually applied to seedlings in nurseries, bare-root seedling production requires a range of chemicals for pest control (*e.g.* damping-off). Irrigation control may be combined with wrenching, side pruning and undercutting to facilitate seedling dormancy (Edwards 2008). Shippable heights for fir seedlings in containers vary between 13 cm (one year on seed bed) and 15-26+ cm (2 years on seed bed) (Edwards 2008).



***Abies kawakamii* (Hay.) Ito**

A. Seed
B. Radicle-emerged seed, day 1
C. Radicle-emerged seed, day 3
D. Radicle-emerged seed, day 7
E. Seedling
F. Seedling
G. Young juvenile

From Yang 1984

Acacia confusa Marr.

Fabaceae
Taiwan Acacia

Growth Habit, Occurrence and Use

There are about 1200 species in this genus, which is distributed over the tropics and to a lesser extent into the temperate zones. There are 10 species native to Mainland China but only three in Taiwan. It is an evergreen tree and can grow up to 20 m tall and 1 m in diameter. The leaves are pinnately compound earlier and become false-leaf later when the petiole degenerates leaving a cladophyll. The cladophylls are sickle-shape, 8-10 cm long, oblanceolate and opposite, with both ends gradually pointed, deep green, shinny and leathery on both surfaces. This species is capable of fixing nitrogen. It was originally grown in the Hengchun Peninsula and now has been widely planted throughout Taiwan. Owing to its adaptability to a wide range of sites and strong wind-resistance, it is an excellent species for water and soil conservation, wind shelterbelts and greening roadside shade plantings. It also has been introduced to many tropical and subtropical regions of southern Mainland China for reforestation of denuded mountains. This species is often used to create protective shelterbelts for tea plantations. The lumber is used for ship-building and for making boat paddles, wheel axels, furniture, railroad ties and small farm tools. It is also excellent material for charcoal. The bark contains tannin, and the flowers are used for food seasoning.

Collection and Processing

Taiwan acacia has small, yellow, aromatic and perfect flowers that open in April-May. Seeds mature in July-September in the south and in September-November in the north of Taiwan. The mature thin and flat seed pod contains 4-10 seeds. The collected seed pods should be air-dried for a couple of days in a cool and shady place before they are dried in the sun. The pods should be turned over frequently and flung to open them for seed release. Mature seeds are shinny, dark brown and egg-shaped. Seed quality can be upgraded by water flotation with good results (up to 95% germination). Once the extracted seeds are cleaned and properly conditioned, they should be placed in cotton or jute bags for storage.

Basic physical seed characteristics are given below (Chung and Chang 1990):

Weight of seeds (g/L)	735
No. seeds/L	24,680
No. seeds/kg	33,580
Weight of 1,000 seeds (g)	30.3

Seed Dormancy and Germination

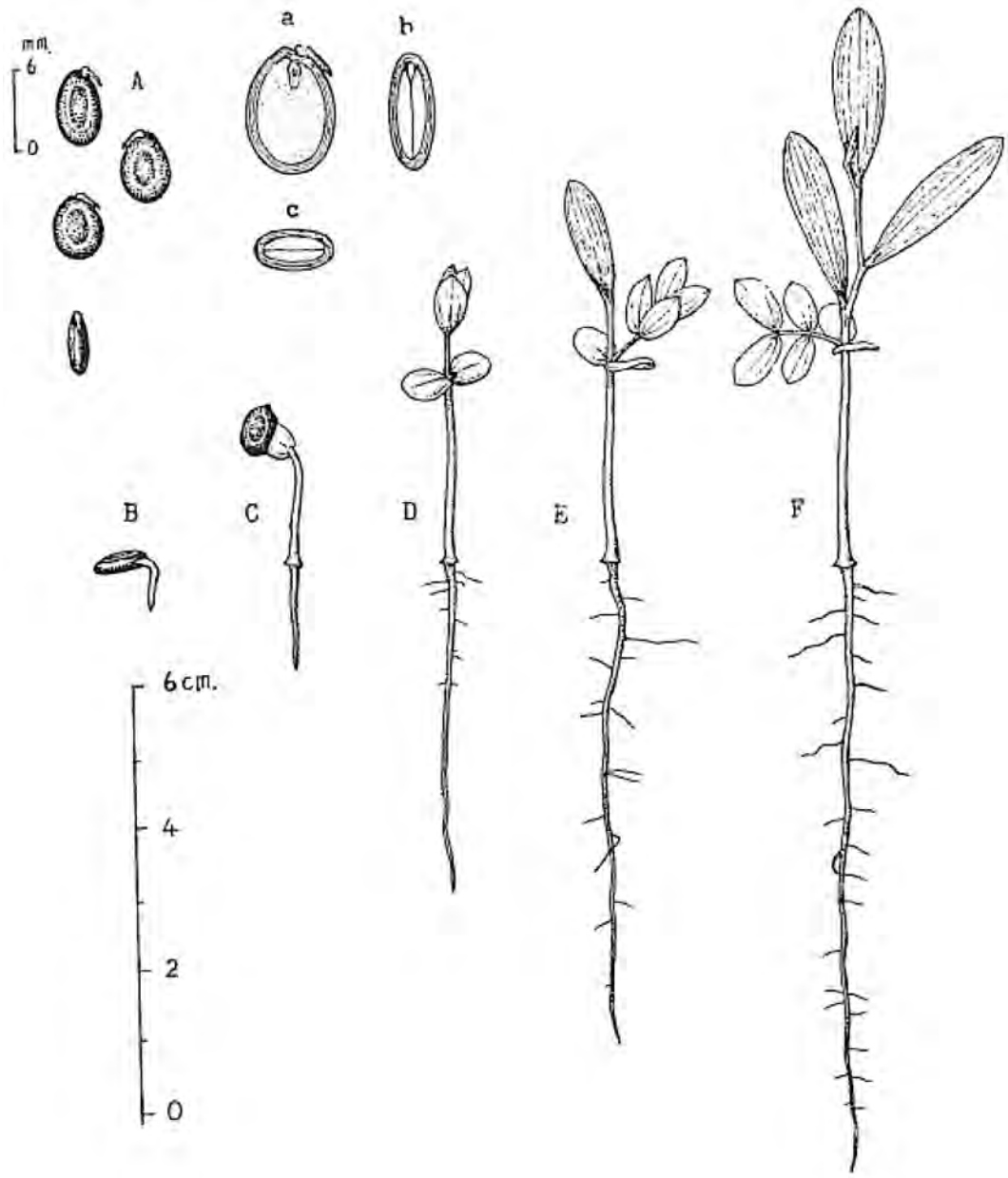
Seeds of Taiwan acacia have a water impermeable seed coat (physical dormancy) and require pretreatment for complete and fast germination. Thus, the seeds have physical dormancy. Methods have been reported to break dormancy of the seeds, including soaking seeds in boiling water until it cools (Li 1974); soaking seeds in boiling water for 4 seconds; soaking seeds in a seed:boiling water ratio of 1:1 volume and the water allowed to cool for 12 hours (Yang 1984). However, Chien and Yang (2007) found that the best treatment to break seed coat dormancy of this species was to soak seeds in 100℃ boiling water at a seed to water ratio of 1:2-3. Past records showed that Taiwan acacia seeds reached 94% germination at 28℃ in 3-15 days after pretreatment (Chung and Chang 1990).

Seed Storage

Seeds are susceptible to insect attack and should be stored with a small amount of lime or other insecticides. Seeds are orthodox and can be stored in sealed containers at 5℃ or -20℃ for >20 years (Chung and Chang 1990, Chien and Yang 2007).

Nursery Practice

For bare-root seedling production, pretreated seeds can be sown directly onto prepared seedbed by drilling or broadcasting. Following seed germination, attention must be given to weeding, irrigation and thinning as required. For container seedling production, pretreated seeds are sown mechanically or manually into the medium-filled containers. A mechanized watering system is the best for saving manual labor. In silvicultural practice, pretreated seeds can be directly sown by spot seeding in the rainy season or by using a water spraying system in early spring. Several pathogens have been found associated with the acacia stock production in the nursery, and therefore attention must be given to maintaining the container media at pH 5-6 and application of some protective insecticides such as benlate or mancozeb. The white-powder disease is caused by close seedling density and poor ventilation or by shading-over, and improvement must be made to correct such conditions (Sheu et al. 1999). Application of insecticides such as carbofuran or lannate is necessary to prevent insect attack of seedlings.



***Acacia confusa* Marr.**

A. Seed and sections (a, b, c) of seed
B. Radicle-emerged seed, day 1
C. Radicle-emerged seed, day 3
D. Seedling, day 15
E. Young juvenile, day 30
F. Young juvenile

From Yang 1984

Albizia lebbeck (Willd.) Benth.

Leguminosae
Siris Tree

Growth Habit, Occurrence and Use

Siris tree is a fast-growing, medium-sized deciduous tree with a natural range from eastern Pakistan through India and Sri Lanka to Myanmer (Burma). Trees can attain an average height of 18-25 m and a DBH of 50-80 cm, and they have a spreading umbrella-shaped crown of thin foliage. It is a valuable species for ornamental planting and is widely planted as a shade tree. The wood is coarse-grained, strong and relatively durable and is used for furniture, flooring, veneer, carving, fence posts and a variety of agricultural implements. The leaves, seeds, bark and roots are used in traditional medicine in India.

Collection and Processing

Flowering usually occurs with the appearance of new leaves in April-May. The fragrant, cream colored flowers are in rounded clusters 5 to 7.5 cm in diameter. The fruits are flattened pods that are 10-20 cm long and 2.5-3.8 cm wide, and they are produced in large numbers with each one containing several seeds. Seeds are mature when the pods turn from green to straw color. Mature pods open but remain attached to the tree until the following flowering season. The mature pods can be collected from the tree by climbing with ladders, use of pruning poles or manually from the ground. Caution must be exercised to avoid collecting pods late since they are susceptible to mold and insect attack. The collected pods can be dried in the sun and flung after they are sufficiently dried to break them for seed release. Siris tree seeds are oblong, about 9 mm long and 7 mm wide and light brown with a smooth, hard testa.

Physical seed characteristics are shown in the table below (Chung and Chang 1990):

Weight of seeds (g/L)	684
No. seeds/L	4,600
No. seeds/kg	6,725
Weight of 1,000 seeds (g)	143

Seed Dormancy and Germination

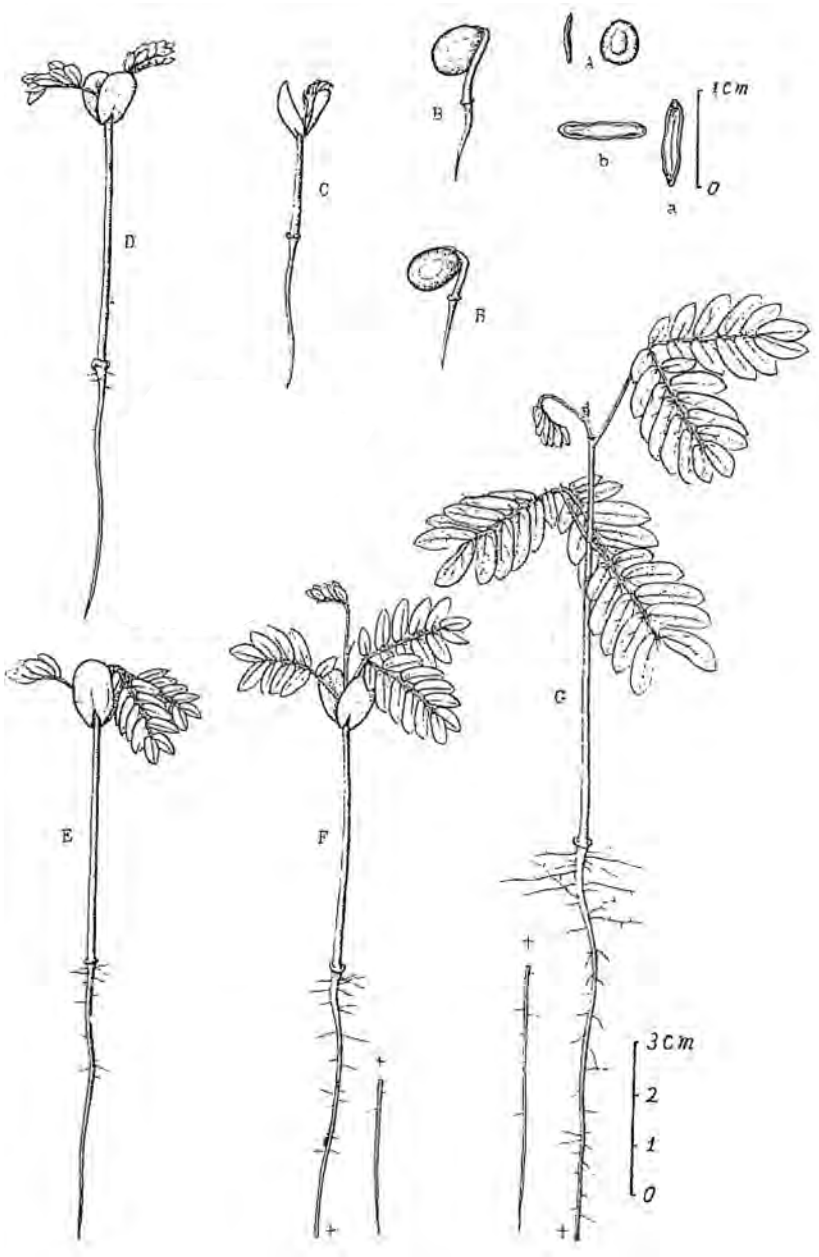
Germination of Siris tree is epigeal and usually takes 5 to 15 days at 25-30℃ Records from the Taiwan Forestry Research Institute show that germination of nontreated seeds is 50% (Chung and Chang 1990). Seeds have a water impermeable seed coat and exhibit physical dormancy. Thus, soaking seeds in boiling water for 1 minute and then in cool water for 24 hours improves the rate and uniformity of germination (Parrotta 2002).

Seed Storage

The seeds are orthodox and can be stored dry in sealed containers at 5℃ for a long period of time.

Nursery Practice

For speedy and uniform germination and early seedling development, seeds are sown just below the surface of moist soil under light shade or in full sun. If inoculated with *Rhizobium* or if sown in soils that contain nitrogen fixing bacteria, lateral roots will quickly develop large, branched nodules (Parrotta 2002). Seedlings raised in plastic sleeves under light shade attained plantable size of 20-30 cm in 3 months in Puerto Rico and had developed a long, stout taproot (Parrotta 1988).



***Albizia lebbeck* (Willd.) Benth.**

A. Seed and sections (a, b) of seed
B. Radicle-emerged seed, day 1
C. Seedling, day 3
D. Seedling, day 4
E. Young juvenile, day 6
F. Young juvenile, day 10
G. Young juvenile, day 15

From Yang 1984

Alnus formosana (Burkill *ex* Forbes & Hemsl.) Makino

Betulaceae
Formosan Alder

Growth Habit, Occurrence and Use

Formosan alder is a medium-sized, deciduous tree that can reach 20 m tall and 40 cm in diameter. Branchlets are glabrous or slightly pubescent when young. Leaves are alternate, elliptic and oblong to ovate-oblong, 6-12 cm long and 2-5 cm wide, acuminate at the apex and broadly cuneate at the base, smooth with serrulate margin and 6-7 pairs of lateral veins. This species is endemic to Taiwan, where it occurs from low elevations near the sea up to 2,500 m. It is a shade intolerant pioneer tree species that grows along river banks and in other open habitats. The species grows fast and often forms pure stands in eroded or denuded areas. Local afforestation records indicate that a 4-year-old plantation in Dajia Forest District reached 10 m in height and 6 cm in DBH; trees in a 13-14 year old plantation were 14 m tall and 14 cm DBH. Formosan alder is a nitrogen fixing species, and it is often the first species to become established in the natural revegetation of eroded or denuded areas. The wood is a superior raw material for paper making and for construction of buildings, shoes, boxes, matches and some tools. It is also an ideal tree species for afforestation of eroded areas and for soil and water conservation because it is very tolerant of drought and water-saturated soils.

Collection and Processing

Formosan alder is monoecious with male flowers in catkins and female flowers in spikes, usually on old branchlets. The flowering season is July-September. The woody, ellipsoid cones mature in September-October on the coastal plain and in November-December in the mountains. Cones are tolerant of drying and can be sun-dried with frequent turning over to open the cones for seed release. Clean seeds can be obtained through blowing.

Physical seed characteristics are as follows (Chung and Chang 1990):

Weight of seeds (g/L)	230
No. seeds/L	70,150
No. seeds/kg	305,000
Weight of 1,000 seeds (g)	3.28

Seed Dormancy and Germination

Seeds have no dormancy and can be germinated easily. The average germination capacity is 30-40% at 20-25℃ with fluorescent light for 21 days (Chung and Chang 1990, Sheu et al. 1999). ISTA (1999) recommends testing germination of *Alnus cordata*, *A. glutinosa*, *A. incana* and *A. rubra* seeds on top of germination paper at alternating 20-30℃ with 8-hour light for 21 days.

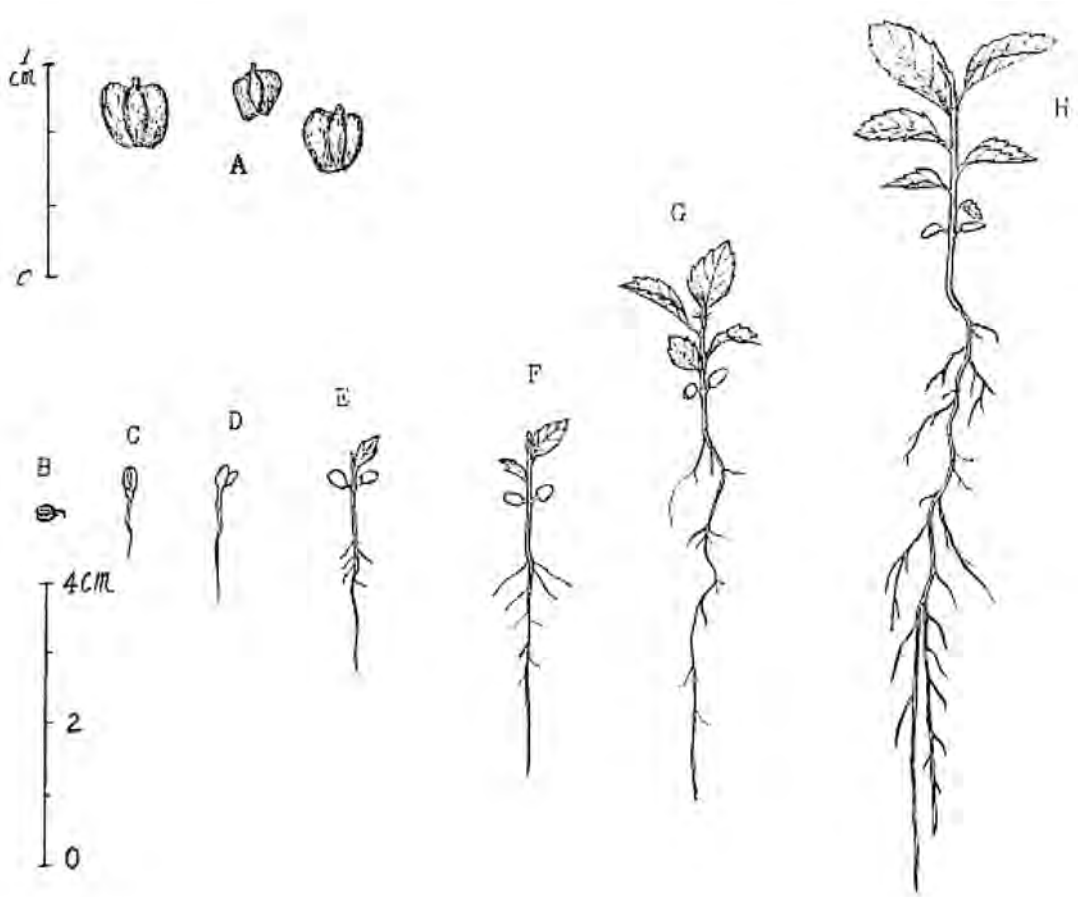
Seed Storage

Formosan alder seeds have orthodox storage behaviour and can be dried to very low moisture content and stored at a sub-freezing temperature of -20℃ for a long period of time.

Nursery Practice

Both bare-root and container seedling production methods are used. Seedbeds must be well prepared for sowing due to the small seed-size, and sowing rate is 0.05 liter seeds per square meter. After sowing seeds, seedbeds can be covered lightly with soil or not covered. There is no need for shade screens, but seedbeds should always be kept moist. It usually takes about 3 weeks for germination. Seedlings are transplanted when they reach > 5cm in height. For container seedling production, the

best medium is sandy loam soil mixed with manure at a ratio of 2:1. If an artificial medium is used, the ratio should be a 1:1:1:1 volume ratio for vermiculite, peat moss, perlite and manure. Application of fertilizers is important during the seedling development period. Prior to field planting, lower branches of the seedlings should be trimmed off to improve field survival.



***Alnus formosana* (Burkill *ex* Forbes & Hemsl.) Makino**

A. Seed
B. Radicle-emerged seed, day 1
C. Radicle-emerged seed, day 3
D. Seedling, day 5
E. Young juvenile, day 16
F. Young juvenile, day 29
G. Young juvenile, day 50
H. Young juvenile, day 69

From Yang 1984

Beilschmiedia erythrophloia Hayata

Lauraceae
Red Bark Slugwood

Growth Habit, Occurrence and Use

Red bark slugwood is a large evergreen tree with smooth grayish red bark. The stem is straight and grows up to 25 m tall, and DBH can reach 1 m. Leaves are nearly opposite, exstipulate, coriaceous, oblong, 7-15 cm long and 2.5-5.5 cm wide with an acuminate apex and an acute or obtuse base, and they have entire margins, a dark green upper surface and an olive green under surface. The species occurs in Taiwan and Hainan of Mainland China. It grows in broad-leaved evergreen forests all over Taiwan and is especially abundant at elevations of 300-800 m in central Taiwan. The wood is hard and heavy but slightly brittle and is commonly used for making charcoal. The species may be suitable for planting in parks for greening purposes.

Collection and Processing

The small flowers are bisexual and axilary in short panicles, and the flowering period is May-June. Fruits are elliptic drupes, and they ripen in November. Collected drupes, which may not be uniformly fully mature, should be post-harvest ripened. They need to be spread thinly on the ground or in trays and turned frequently and sprayed with water to hasten seed maturity. Drupes are processed by macerating them against a wire-mesh screen by hand with water. The clean seeds (i.e. seed enclosed by hard endocarp) are collected and slightly dried in shade before sowing or storage. There are 690-700 seeds in a liter that weigh 684 g. The weight of 1000 seeds is 975-1,100 g.

Seed Dormancy and Germination

Seeds have no dormancy. They germinate after 20 days, and germination is complete 40 days from sowing (Chien 1998). Fresh seeds can germinate to 85-94%.

Seed Storage

The seeds are recalcitrant and sensitive to drying and subfreezing temperatures. Freshly collected seeds have a moisture content of about 50% and can be dry-stored with a moisture content of 40% at 4℃ for 3 months or moist-stored at 4℃ for 2-6 months.

Nursery Practice

Seeding can be done in the spring using seeds moist-stored at 4℃. Seeds are sown in beds kept moist with an automatic watering system. The sown seeds must be covered with a thin layer of fine sand and always kept moist. Transplanting germinants into containers should be done as soon as radicles emerge. There should be an overhead shade-screen for the small seedlings. The best container medium is sandy loam soil mixed with manure. Slow-release fertilizers also must be applied to promote seedling growth.

Bischofia javanica Blume

Euphorbiaceae
Autumn Maple Tree

Growth Habit, Occurrence and Use

Autumn maple tree is semi-deciduous and 20 m tall, with a rather short leaf-fall period. Leaves are alternate, long-petiolate (8-15 cm) and 3-foliolate. Leaflets are ovate to ovate-oblong, 6-12 cm long and 3-7 cm wide with a cuspidate-caudate apex and an acute or obtuse base, and they have crenate-serrate margins and midribs elevated on both surfaces. The species is distributed in southern China, India, Malaysia, the Philippines, Taiwan and the Pacific Islands. It is one of the most common long-lived trees in the plains and foothills in Taiwan. This species has strong adaptability, a deep root system and is well known as an indigenous greening species. In Hengchun roots of autumn maple grow in the shallow soil on the uplifted coral reef. The wood is hard and can be used as a substitute for sandal-wood padauk for furniture and art-crafts, and it is used for ship-building, bridge materials, vehicles and railroad ties. The growth rate of this species is medium. Trees in a 5-year-old plantation of this species in central Taiwan had an average height of 6.2 m and a DBH of 10.5 cm. Fruits are edible but do not taste good. Fruit flesh is used for wine making, and the cooked young leaves are a tasty vegetable. Oil extracted from the seed can be used for industrial purposes. The roots, bark and leaves are used as medicine.

Collection and Processing

Autumn maple is dioecious and flowers in February-March. The flowers are minute, yellowish green, apetalous, unisexual in axillary panicles and pendulous. Fruits are rounded berries that mature in August-October, when they turn from yellowish green to reddish brown. The berry is about 1 cm in diameter and contains 3-4 dark purple, lustrous seeds. Berry collection can be made by hand with the aid of bamboo poles, pruning shears and ladders or from the ground. Collected berries are spread thinly in a cool and shady place with good ventilation and sprayed with water for 5-7 days until the berries become soft for processing. Seeds are extracted by manually macerating the fruits and washing with water. Empty and undeveloped seeds can be removed by flotation. Clean seeds are air-dried in the shade for 1 day before sowing or storage.

Physical seed characteristics are shown below (Chung and Chang 1990, Yang et al. 2006b):

Weight of seeds (g/L)	502-591
No. seeds/L	35,400-40,500
No. seeds/kg	70,500-72,400
Weight of 1,000 seeds (g)	13.8-14.2 (16.3)

Seed Dormancy and Germination

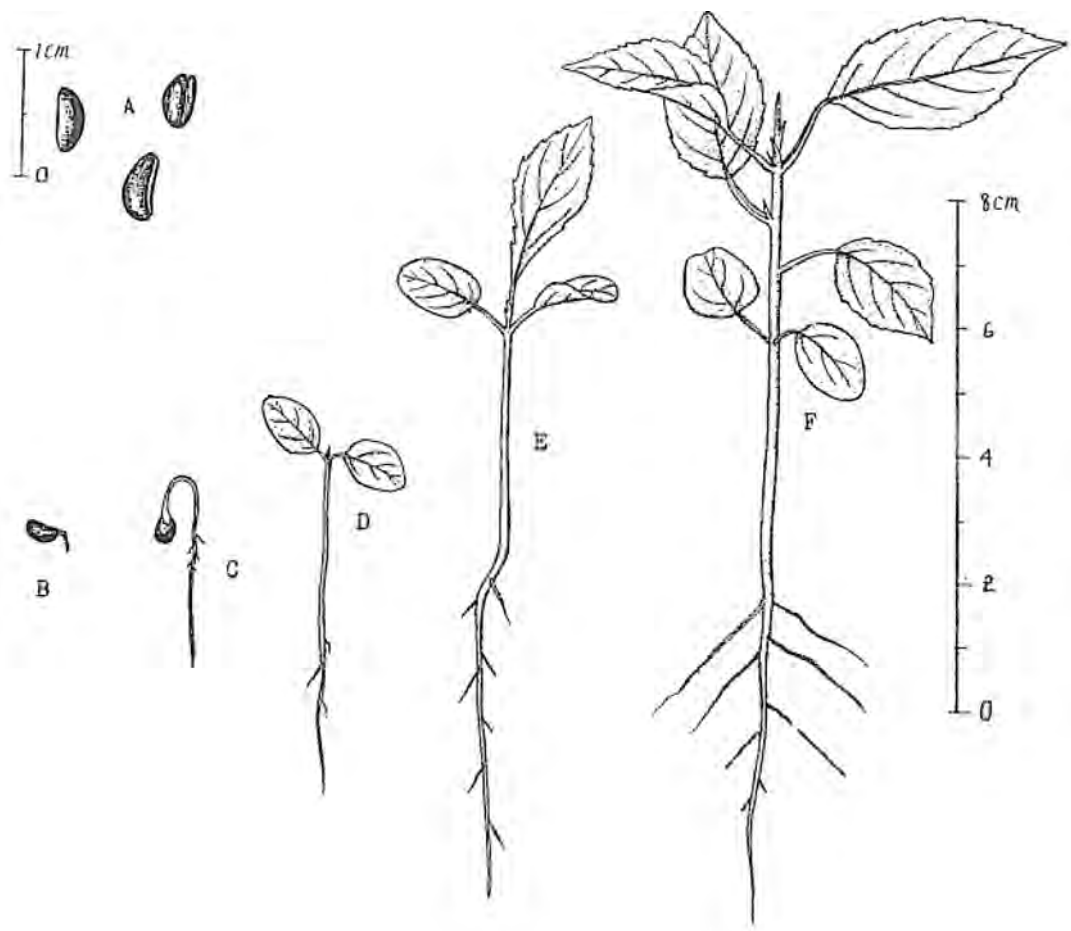
Fresh seeds have no dormancy, and most of them germinated in the first 2 weeks with a total germination of 78% at alternating temperatures of 30/20℃ with 12-hour light (Yang et al. 2006b). Seeds stored moist at 4℃ for 11 months germinated to 77 and 89% at 30/20℃ (Yang et al. 2006b).

Seed Storage

The seeds have been classified as having orthodox storage behavior based on their tolerance to desiccation and low temperature (Chien 1998). However, Yang et al. (2006b) found that seeds of this species are best stored with 8% moisture content at 4℃ and have intermediate storage behavior.

Nursery Practice

Seeds can be sown on moist sandy beds with overhead shade screens or in a greenhouse and covered with a thin layer of fine sand. To facilitate seed germination, seedbeds should always be kept moist. Transplanting of germinants into plastic bags or other containers should begin as soon as they emerge above the soil surface. Initially, there should be a 60% sun-screen overhead. If high germinability seed lots are used, seeds can be sown directly into containers to save transplanting cost. Autumn maple seeds are commonly sown in the spring, and seedlings are 50-60 cm tall and ready for field planting the next rain season. Young seedlings grow fast, and growth is favored by high temperature and high humidity. Occasional insect problems will occur, and relevant pest control manuals should be consulted for information.



***Bischofia javanica* Blume**

A. Seed
B. Radicle-emerged seed, day 1
C. Radicle-emerged seed, day 4
D. Seedling, day 11
E. Young juvenile, day 27
F. Young juvenile, day 58

From Yang 1984

Calocedrus formosana (Florin) Florin

Cupressaceae
Taiwan Incense-cedar

Growth Habit, Occurrence and Use

Taiwan incense-cedar is an evergreen tree 30 m tall with a straight trunk and a conical crown. The bark is smooth and reddish brown. It is native to Taiwan and is distributed at elevations between 300 and 1,900 m in the mountain. Taiwan incense-cedar is one of the major temperate conifers used for restoration in Taiwan, and its growth rate is not as fast as that of China fir or peacock pine but is faster than that of Taiwan red cypress. The wood quality is equal to that of Taiwan hiroki falsecypress for house construction, furniture, carving and decorative material. Buddhist religious altars sometimes are made of the wood due to its fragrance. Ground wood also is used for making Buddhist religious incense. Because of its beautiful form and appearance, Taiwan incense-cedar is widely used for ornamental and landscaping purposes (Chien1998).

Collection and Processing

Taiwan incense-cedar is one of the most desirable reforestation species, but seeds cannot be collected in sufficient quantity to meet the demand, due to small natural populations, long seed crop periodicity and low yields of filled seeds. Taiwan incense-cedar produces male and female cones in February, and mature seeds are released at the end of August at low elevations and the end of September at high elevations. Therefore, the best cone collection time is between late August and mid-September (Chung and Kuo 2005). It takes 6-7 months from pollination at the end of February to seed maturation at the end of August of the same year. When seeds mature, the cones become deep to light green, and seed wings are brown (Chung and Kuo 2005). Two field seed-maturity indices are (1) opening of the cones on the sunny side of cone-bearing branches, and (2) opening of cones when lightly squeezed between two fingers. It is important to schedule cone collection carefully since there is only a 3-week window between seed maturity and natural seed dispersal. During cone collection, care must be taken to avoid cutting large branches to ensure continuous development of future cone crops. The cones are about 1.0 to 1.5 cm long with four cross-opposite scales. Only the two side scales bear seeds, and each scale has 1-2 seeds with two wings, one large and the other small. Collected mature cones are air-dried in a shady place for cone opening. Unopened cones can be moistened, and further air-dried indoors. Cones should never be air-dried in direct sunlight. Otherwise, seeds will lose their germinability if oil is exuded. Cones that remain closed are usually immature and should not be opened manually. Each cone usually contains 4 seeds of which only 1 is germinable. Even in seed orchards in Taiwan, filled seed yields vary greatly among seed orchards, genetic systems and individual trees. According to Chung and Kuo (2005), the average filled-seed ratio per cone is 1.1 in the seed orchard of Liukuei Research Center compared to 1.7 in the Lienhwachih Research Center, Taiwan Forestry Research Institute.

Physical seed characteristics are summarized as follows (Sheu 2007, Chung and Chang 1990):

Weight of seeds (g/L)	216.5
No. seeds/L	29,764
No. seeds/kg	136,500
Weight of 1,000 seeds (g)	7.33

Seed Dormancy and Germination

Seeds require some post-harvest maturation and have epigeal germination. Seeds germinated to 16-40% during 5-25 days of incubation at a constant temperature of 20℃ (Chung and Chang 1990).

Seed Storage

Seeds have orthodox storage behavior. Air-dried clean seeds usually have moisture contents of 11-14% (fresh weight). Seeds with these moisture contents can be stored at 5℃ for sowing the next spring but require further reduction in moisture content to 5-6% for long-term storage at -20℃When seed moisture content is reduced to 5-6%, it was thought that these high-lipid seeds could be stored safely for 4-5 years. More research is needed to find improved methods for extending their current storability. Based on their current storage behavior, it seems that the seeds of this species can be classified as the 'sub-orthodox' (Wang et al. 1995).

Nursery Practice

For seedling propagation, seeds should be sown immediately after they are collected. The best time to sow is in late September. The nursery should be located in an areas where the soil is a well drained, humus loam or mixed with the manure. Seeding can be done by drilling or by broadcasting. Seed quality should be tested, and samples should be taken to determine the filled-seed percentage to ensure accurate calculation of sowing rates. Sown seeds should be covered lightly with soil and overhead shelter and an irrigation system must be provided. When the soil is kept moist, germination should occur 1 week after sowing. Young seedlings are susceptible to insect attack and proper insecticides should be applied to the seedbed when it is prepared for sowing. If seeds are sown in fall, transplanting at a density of 100 seedlings per square meter is carried out the next spring when seedlings are 5-7 cm tall. Transplants require overhead shading. When the 3-year-old seedlings are 25-35 cm tall, they are ready for outplanting. For container seedling production, young seedlings can be transplanted from the seedling beds to containers, but at low elevations overhead shelter is required for container seedlings to develop properly. To ensure production of high quality shippable planting stock, care must be taken for proper scheduling of irrigation, weeding and application of insecticides.

Calophyllum inophyllum Linn.

Guttiferae
Indiapoon Beautyleaf

Growth Habit, Occurrence and Use

Indiapoon beautyleaf is a large evergreen tree up to 20 m tall with thick, irregular deep-furrowed bark. Leaves are opposite, thick, coriaceous, elliptical and 10-18 cm long with a rounded, retuse apex with petioles 1-2.5 cm long. Lateral veins are numerous, slender and at right angles to the midrib. This species occurs in tropical Asia; in Taiwan, it is found in Heng-Chun Peninsula, eastern Taiwan and Lanyu Island. It is deep-rooted, has vigorous growth and is resistant to salt, shade, wind and drought. This is a very desirable shelterbelt species for coastal planting. The wood is strong, and it is used for construction, shipbuilding and production of furniture and farm tools. This species also can be planted as a street tree and in parks and as firebreaks.

Collection and Processing

This species flowers twice a year: April-May and July-August. The fragrant white flowers are 25 mm across and occur in panicles or racemes with 4-15 flowers. Fruits are yellowish purple, and the globose drupes are 3-4 cm in diameter and mature in October-November and February-March. The drupe consists of a fibrous exocarp, a woody mesocarp, a fleshy, corky endocarp and a single pale yellow seed. Fruits should be collected when they become yellowish brown and spread in a cool, ventilated place until the flesh is soft for cleaning with water. The clean seeds should be air dried in the shade for 10 days before sealed storage at 5℃. There are 81 seeds per liter, and they weigh 450 g.

Seed Dormancy and Germination

Seeds of this species are water-permeable and have fully developed embryos, but they require a long period of incubation for germination to occur (Ng 1992, Baskin and Baskin 2014). Thus, it can be concluded that seeds have physiological dormancy. It takes 2 months for the seeds to germinate, but pretreatments such as excising embryos, removing a piece of the hard pericarp or soaking in water that at 50-60℃ will promote germination.

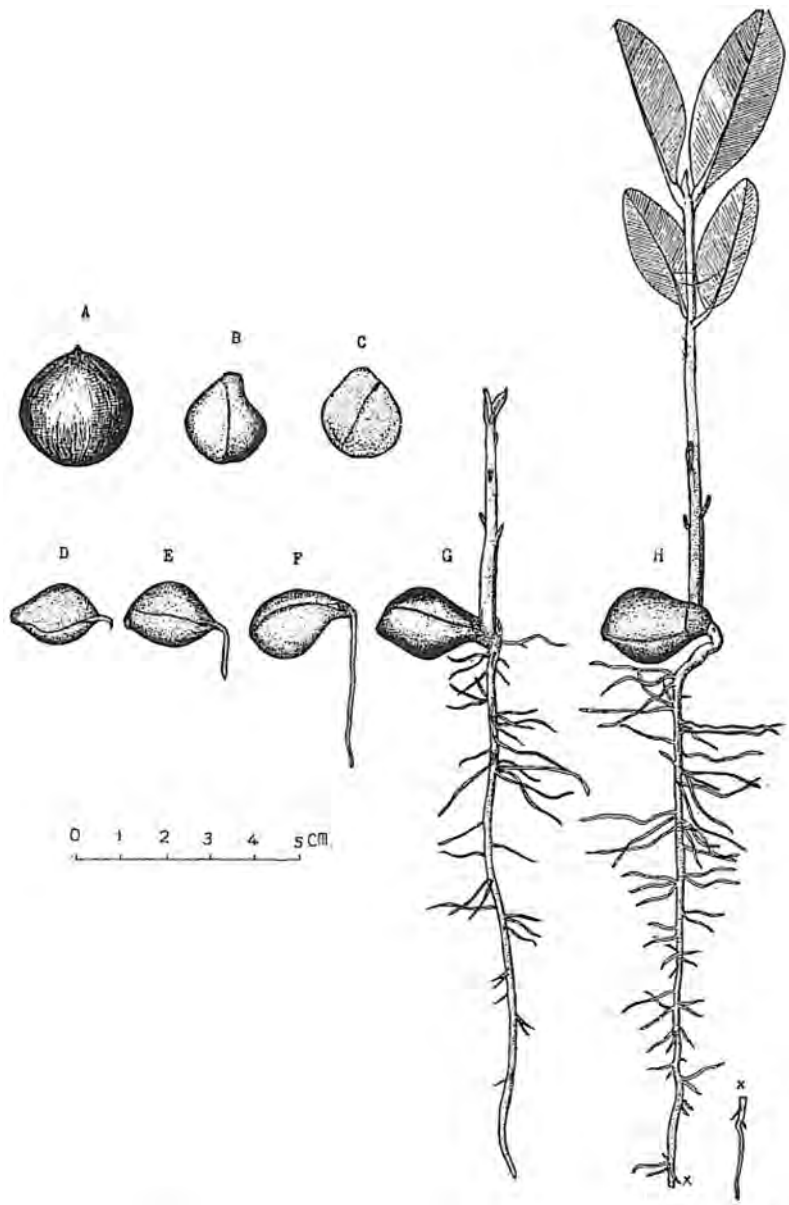
Seed Storage

The seeds probably have recalcitrant storage behavior. They are usually air-dried in shade for 10 days and placed in plastic bags at 5℃ for 1 year. However, Hathurusingha and Ashwath (2012) found that when seeds of *C. inophyllum* collected from Yeppoon, Australia, were subjected to chilling injury and they maintained their viability for > 8 months if stored in a warm environment.

Nursery Practice

Treated seeds can be sown on moist sandy beds and covered with 1-2 cm of fine sand. As soon as the radicle emerges from the seed coat, germinants can be transplanted into plastic bags or other containers. Container medium should be sandy loam or lime loam soil mixed with manure or a 1:1:1 mixture of soil, sand and manure. If the medium is artificially made, it should consist of vermiculate, peat moss, perlite and manure at a ratio of 1:1:1:1. This species has a tap-root system with few secondary roots; therefore, it is best to move the containers a few inches and trim the roots on the outside of the containers when seedling height reaches 25 cm. The same operation should be repeated 1 month before field planting. It is important to fertilize with extra nitrogen during the seedling development period since it has been reported that nitrogen fertilizer affects height growth,

root-collar diameter and dry-weight of this species. It is also important to watch for common pest infestations such as aphids and scales, especially in March to May; symptoms are the curling up of the infested new leaves.



***Calophyllum inophyllum* Linn.**

A. Seed
B. Embryo
C. Embryo
D. Radicle-emerged seed, day 2
E. Radicle-emerged seed, day 3
F. Radicle-emerged seed, day 6
G. Seedling, day 11
H. Young juvenile, day 30

From Yang 1984

Camptotheca acuminata Decne.

Nyssaceae
Camptotheca

Growth Habit, Occurrence and Use

Camptotheca is a large deciduous tree endemic to Mainland China and introduced to Taiwan from Hangzhou and Guangdong in 1948 and 1952, respectively (Chen and Hu 1976). It has been planted sporadically all over the Island. Leaves are alternate, entire margined and pinnately veined. The stem, leaf, root, bark and seed of camptotheca are rich in camptothecin (CPT), an ingredient for anticancer medicine (Chen et al. 2004). Camptothecin was found to have serious side effects when it was used to cure a digestive tumour in 1971-1972. CPT-11, brand name 'irinotecan' with a modified structure, was developed and widely used for curing cancer of the intestines. The wood of this species is light and soft with fine structure but slightly brittle. The tree is used primarily for making paper and match sticks.

Collection and Processing

Camptotheca is monoecious or dioecious and flowers in June-July. The flowers are sessile in heads, solitary or in panicles with 5 valvate petals and 10 stamens. The cup-shaped disks are epigynous, and the oblong ovary has one ovule and develops into a drupe. Camptotheca fruits are linear, cuneate at apex, about 2.32 cm long, 0.67 cm wide, 0.36 cm thick and stalkless. The seeds ripen in October-November when the fruits change from green to yellowish brown. Ripe drupes are collected from the ground after knocking them from fruit-bearing branches. After slightly air-drying, clean drupes (seeds) are obtained after removing the fruit axis and debris. There are 1,629 seeds per liter, and 25,000 seeds per kg; and a thousand seeds weigh 40 g (Chung and Chang 1990, Chen et al. 2004). Current biotechnology research is focused on producing 'Camptothecin' via cell culture (Chang et al. 2006).

Seed Dormancy and Germination

Past local experience indicated that camptotheca seeds pre-soaked at 45℃ for 1-2 days would germinate at 25℃ after 20-40 days. The average germinability is 50%. However, after removal of the pericarp seeds germinated to 95% after 2 weeks, and after 3-5 months of cold stratification at 4℃ drupes germinated to 80% and also increased germination speed (Chen et al. 2004). The optimum germination conditions were 30/20℃ with 12-hour light for 3 weeks. For seeds from China, Wang (2001a) reported slightly higher germinability. After 4 weeks of cold stratification at 0-5℃ or removal of the pericarp and incubated at 30℃, seeds germinated to 84% and 82% after 8 and 17 days, respectively. Light was very important not only for promoting the rate of germination but also for increasing germination percentage (Wang 2001a). The difference in germinability could be due to seed source or crop year. The seeds of this species are water-permeable, and they require at least 3 months cold stratification for maximum germination; thus, seeds of camptotheca exhibit physiological dormancy.

Seed Storage

Local experience suggests that the seeds can be stored dry or moist cold stored at 5℃ for > 3 years (Chung and Chang 1990). However, Chen et al. (2004) reported that whereas 90% of fresh seeds germinated, seed whose moisture content was reduced to 8% and then stored at 15, 4 and -20℃ for 4 months germinated to only 14, 18 and 12%, respectively. Furthermore, seeds cold-stratified at

4℃ for 9 months retained the original germination percentages of non-stored seeds. Thus, we suggest here that seeds are best stored moist cold at 4℃ for 9 months.

Nursery Practice

Spring sowing is the standard practice when seeds have been moist cold stored over winter. Drilling in rows is preferable to broadcasting. The distance between rows should be around 25-30 cm and the sowing depth 2-3 cm. The sown seeds should be covered with 1 cm soil and grass. For container seedling production, seeds can be sown directly into the container medium. If sowing is done in March, germination can be expected in 20-30 days and average seedling emergence is about 75-80%. After growth for 1 year, the seedlings reach 60-80 cm in height and are ready for field planting (Wang 2001a).

Castanopsis indica A. DC.

Fagaceae
Acuminate-leaved Chinkapin

Growth Habit, Occurrence and Use

Acuminate-leaved chinkapin also called Hengchun chinkapin is a large evergreen tree with grayish brown bark that has longitudinal shallow fissures. Branchlets are pubescent. Leaves are simple, alternate, with fugacious stipules, ovate or oblong-ovate, 9-18 cm long, and 4.5-9 cm wide with acuminate apex and acute or cuneate base with serrate margin. Freshly cut sapwood is pale reddish white with prominent wood rays and vessel lines. This species occurs in Taitung, Kaohsung, and Hengchun Peninsula at elevations of 300-1,620 m. The tree is used for ornamental planting due to its beautiful form and lush leaves. The wood is hard and suitable for production of glued laminated boards and for making wheelbarrows and tools. The nuts are edible, especially for Formosan rock-monkey. Stem sections are used for culturing mushrooms.

Collection and Processing

The species flowers in February-May, and the flowers are small, yellow, apetalous and in aments. Nuts mature in January-April, when they change from green to brown. Collections are made when the involucres (cupules) open and expose the nuts. Collection schedules have to be well planned to out smart the pilferers, such as Formosan rock-monkey. Cupules are globose, about 4 cm across and densely covered with spines. One must be careful in handling the fruits; wear gloves. Coleoptera larvae often are found in the mature fruits.

Seed Dormancy and Germination

Seeds have no dormancy and can be germinated easily without pre-treatment. It usually takes 20 days from sowing for the seeds to begin to germinate.

Seed Storage

The seeds are recalcitrant. The nuts are sown immediately after processing, or they can be stored in moist sphagnum moss at 5℃ over winter for germination and seedling production the next year.

Nursery Practice

Nut quality can be upgraded by the water flotation technique. Clean and sound nuts are sown onto moist sandy beds and covered with a thin layer of fine sand. The seedbeds should have a 40% overhead shade screen for four months. Seed germination usually begins 20 days after sowing and is completed in 90 days. The newly emerged germinants can be transplanted into plastic bags or other containers for further growth and development. The container medium is usually a mixture of sandy loam and manures. Slow-release compound fertilizers should be used in the containers to enhance seedling growth.

Chamaecyparis formosensis Matsum.

Cupressaceae
Taiwan Red Cypress

Growth Habit, Occurrence and Use

This evergreen tree can reach 65 m tall and has thin, smooth grayish red to brownish red bark that falls off in strips or scales. The branches are horizontal although the thin branch tips tend to be slightly weeping. It is a very valuable reforestation species in Taiwan and occurs at elevations of 2,200-2,500 m in the South and 900-2,500 m in the North. It is a valuable timber species for the high-elevation temperate zone in Taiwan. Unfortunately, over-logging of this species and subsequent reforestation with *Cryptomeria japonica* has made this species rare (Chen 1966). The wood is dense and somewhat soft with a light reddish color, and it is fragrant. It is resistant to high humidity and termites but susceptible to lotus-root rot fungus. The wood is used for construction, bridges, furniture, plywood and carving. People are mystified by the size of the big trees of this species growing in Alishan, Shitou and Lalashan, and "Holy Trees" have been preserved by the public (Chien 1998).

Collection and Processing

This species is monoecious, and it produces male and female cones in February and March. The seeds mature in November, when the oblong cones turn from green to brown. Each cone consists of 10-11 scales, and each scale has two winged seeds (Chien 1998). According to Chen (1966), the best time to collect the red cypress cones from the Alishan Work Station area is early- to mid-November for high-quality seeds. It is of utmost importance that the collected cones are air-dried at the collecting sites for 4-7 days, i.e. before they are shipped to a processing facility. Since curing has a great influence on seed quality and storage, it is critical that the cones are air-dried in a shaded and well-ventilated place and never under the sun or with artificial heat (Chen 1966). During the 7 day air-drying period, cones must be turned over often to facilitate seed release and to avoid molding or heating. The filled-seed percentage of a seedlot from Heping Township, Taichung City, was only 30% as compared to of 21 to 55% for *Chamaecyparis obtusa* var. *formosana* (Li 1977).

Physical seed characteristics are as follows (Chung and Chang 1990):

Weight of seeds (g/L)	275-300
No. seeds/L	220,000-260,500
No. seeds/kg	1,293,500
Weight of 1,000 seeds (g)	0.77

Seed Dormancy and Germination

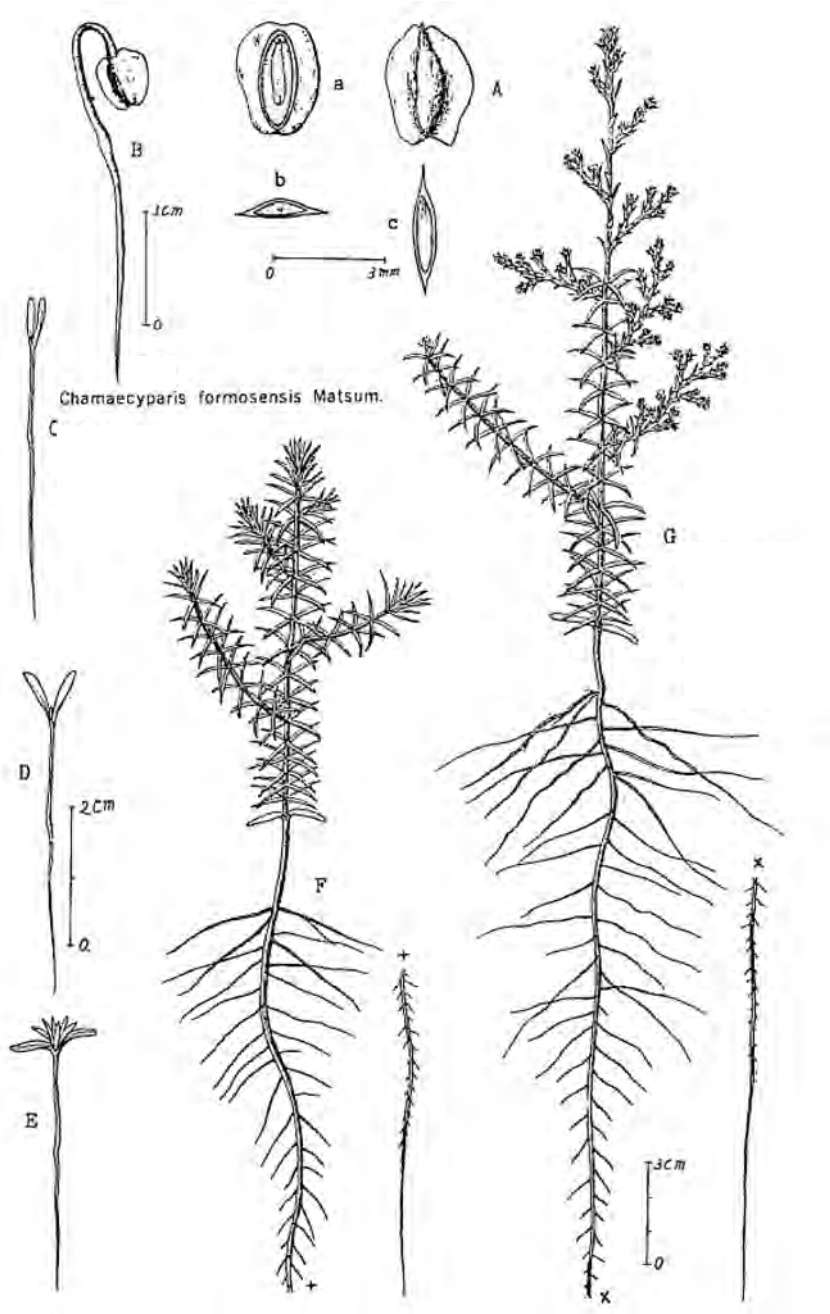
Germinability varies greatly with seed-crop years and seed sources (Chien 1998). Chung and Chang (1990) obtained 12-30% germination in 1-4 weeks at 15ºC to 25℃, but Hu et al. (1978) found that 15℃ and a 16-hour photoperiod were the best conditions for germination of this species. The conditions and requirements for laboratory germination testing for *Chamaecyparis obtusa* seeds prescribed by ISTA (2005) are incubating 4 replications of 100 seeds on top of moist paper at 20-30℃ with 8 hour light for 21 days with the first count of germination progress after 7 days from sowing. Li (1977) reported that the best germination for a seedlot from 2,000 m elevation in Taipingshan, Taiwan, was obtained under either 30/20℃ with a 16-hour daily light period or 20/10℃ with a 14-hour daily light period.

Seed Storage

The seeds of the Taiwan red cypress are orthodox and can be stored at 0-5℃ for a few months, but they must be stored at temperatures < -5℃ to remain viable for 2 years (Chung and Chang 1990). When moisture content of seeds is reduced to 5-6% (fresh weight), they can be stored at -20℃ for a long period of time (Chien 1998).

Nursery Practice

Red cypress seeds germinate best in fertile, sandy soil beds with sufficient moisture supply. The sown seeds should be slightly covered with soil, and the beds protected by a shade and provided with an automatic watering system. Transplanting can proceed when seedling height has reached 10-12 cm. To obtain the maximum number of plants, watering and weeding must be done timely after transplanting. The medium of the containers in which the seedlings are to be transplanted is preferably a sandy loam soil with organic fertilizers. During the seedling development period, attention must be given to shading, irrigation, weeding and preventing insect and disease attacks. Slow release fertilizers such as ‘nutricoat’ are best since they allow for gradual absorption by the seedlings.



***Chamaecyparis formosensis* Matsum.**

A. Seed and sections (a,b,c) of seed
B. Radicle-emerged seed, day 1
C. Seedling, day 2
D. Seedling, day 5
E. Seedling, day 10
F. Young juvenile, day 90
G. Young juvenile, day 180

From Yang 1984

Chamecyparis obtusa (Sieb. et Zucc.) Endl. var. *formosana* (Hay.) Rehder

Cupressaceae
Taiwan Hinoki Falsecypress

Growth Habit, Occurrence and Use

Taiwan hinoki falsecypress is an evergreen timber tree with a height up to 45 m and a DBH of 3 m. The morphology of this species is very similar to that of Taiwan red cypress. It occurs in the Central Mountain Range at elevations of 1,300-2,900 m. There are not many plantations of this species because of its slow growth. The wood is fragrant, resistant to long-horn beetles and termites and excellent for construction, carving and making furniture, wheel-barrows, coffins and tools.

Collection and Processing

This species produces male and female cones in February and March, and seeds mature in mid-November to early December (Chen 1966). Cones are round with diameters of 9-10 mm and have 8-10 scales. Each scale contains 2-3 short-winged seeds about 3mm long. Freshly collected cones are best air-dried under artificial heat (35℃) or in the shade but never directly in the sun (Chen 1966). The important rule is to open the cones with moderate heat for seed release as quickly as possible. Seed crop periodicity is about 2-3 years (Chung and Hu 1986), and like Taiwan red cypress more than 20% of Taiwan hinoki falsecypress seeds are lost due to insect attack with larvae developing inside the seeds. The affected seeds can be identified clearly by x-radiography; they also can sometimes be distinguished by the naked-eye (Chung and Chang 1990). Damage can be eliminated or reduced by soaking the freshly collected cones in water, while the pupae are attached to the cone scales (Chung and Chang 1990?). The filled-seed percentage of this species varies with seed source but ranges from 21% to 55% with an average of 37% (Li 1977).

Some physical seed characteristics are summarized below (Chung and Chang 1990, Sheu 2007):

Weight of seeds (g/L)	230-294
No. seeds/L	105,000-140,000
No. seeds/kg	612,000
Weight of 1,000 seeds (g)	1.63

Seed Dormancy and Germination

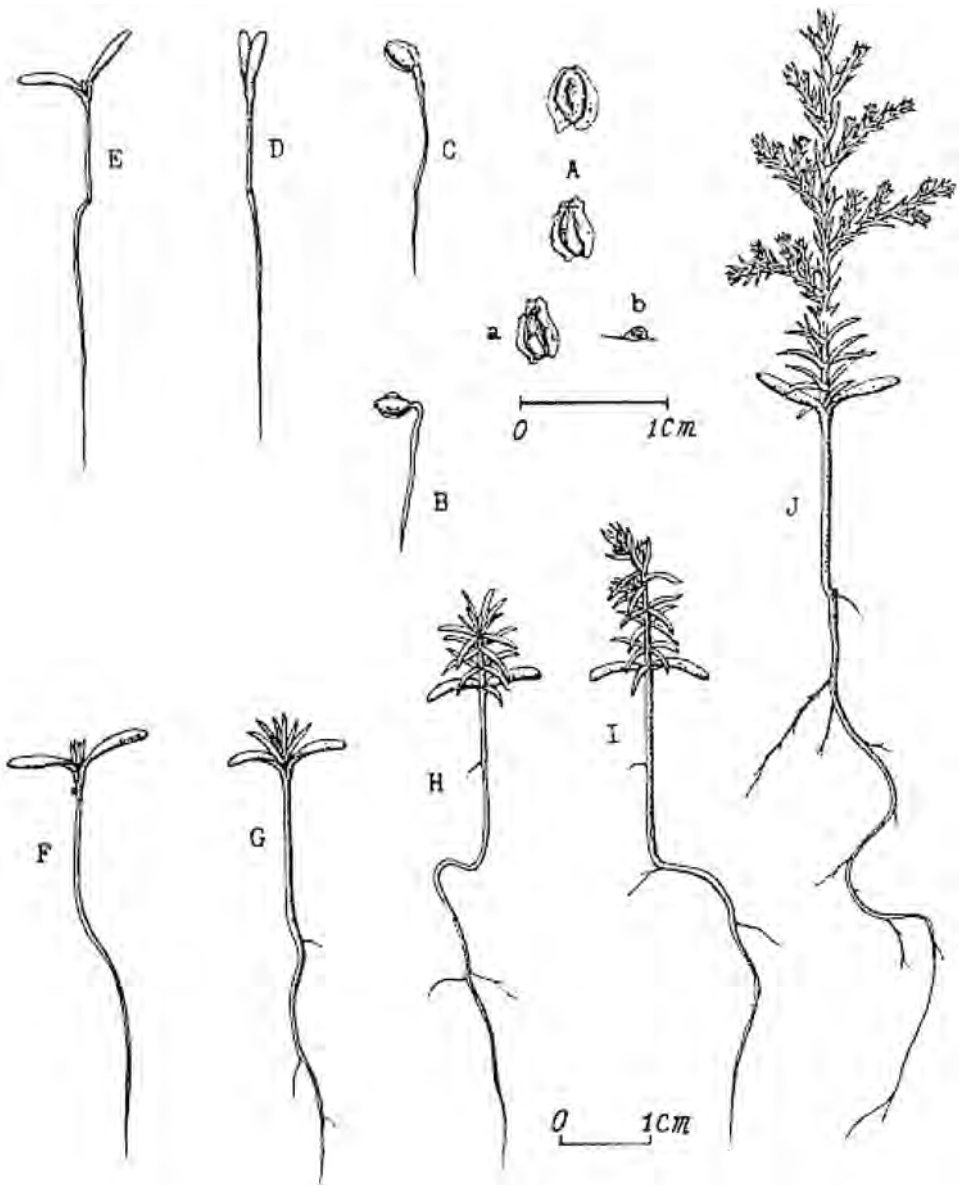
Seeds of this species germinate best at cool temperatures. Li (1977) studied the effects of illuminance, photoperiod and temperature on the germination of *Chamaecyparis obtusa* var. *formosana* seeds from five sites ranging in elevation from 1,200 to 1,900 m in Taiwan and found that a low illuminance of 430 lux was better than a high illuminance of 5400 lux regardless of temperatures and that an alternating temperature of 14 hours at 30℃ and 10 hours at 20℃ in darkness gave the best germination (57%). Chiang (1981) tested seeds from various sources at alternating temperature regimes of 20/10, 25/15 and 30/20℃ in 16-hour light at high temperature each day for 25-30 days and obtained 45, 43 and 39% germination, respectively. These results appear to be different from the conditions prescribed by ISTA (2005) for *Chamaecyparis obtusa* seeds: on top of paper medium at alternating temperatures 30/20℃ with 8-hour light at high temperature for 21 days. This germination condition seems to be closer to that of Li's findings than those reported by Chiang (1981).

Seed Storage

Chung and Hu (1986) found that -5℃ was the best storage temperature for 3 years and -20ºC was good for 7 years with slightly reduced germinability when seed moisture content was reduced to 9%. In another study, -10ºC was the best for seed storage of Taiwan hinoke falsecypress (Chen 1966). Data from these two studies seem to indicate that the seeds of this species have a sub-orthodox storage behavior. More research is required to confirm its real long-term storage behavior.

Nursery Practice

Several weeks of cold stratification in moist sphagnum at 4℃ enhance the rate and uniformity of germination. During seed germination and early seedling development, overhead shade and moist seedbeds must be maintained. Once the radicle emerges, seeds can be transplanted into containers. For more information, see Taiwan red cypress.



***Chamecyparis obtusa* (Sieb. et Zucc.) Endl. var. *formosana* (Hay.) Rehder**

A. Seed and sections (a, b, c) of seed
B. Radicle-emerged seed, day 1
C. Seedling, day 2
D. Seedling, day 4
E. Seedling, day 6
F. Seedling, day 10
G. Young juvenile, day 20
H. Young juvenile, day 45
I. Young juvenile, day 60
J. Young juvenile, day 180

From Yang 1984

Chionanthus retusus Lindl. & Paxt.

Oleaceae
Chinese Fringetree

Growth Habit, Occurrence and Use

Chinese fringetree is a large deciduous tree occurring in the southwestern provinces of Mainland China and in Japan, Korea and Taiwan. The branchlets are nearly glabrous. Theleaves have entire or sometimes serrulate margins and are chartaceous or sub-coriaceous, elliptic or obovate, 3.5-6 cm long, 1.7-4.2 cm wide, green above and pale green and pubescence below, with brownish trichomes along the lower part of the midrib. The petioles are 0.7-1.5 cm long and pubescent.

In Taiwan, the species grows on windward ridges or side slopes in Taiwan acacia stands at 200 m elevations in Linkou. It is widely planted as an ornamental tree. The summer wood is grayish white and heartwood yellowish brown with apparent annual rings. The wood is hard and can be used for making abacuses.

Collection and Processing

The inflorescence is a loose thyrsus, and the white dioecious flowers bloom in March-April. The flower has 4 long triangular calyx-lobes and 4 linear spathulate corolla lobes rounded at apex. The ellipsoid fruit (drupe) is about 8 mm long and 6 mm wide. Drupes mature in August-October at which time the color changes from green to dark purple. Collected fruits are spread on screened trays or on the ground in the greenhouse and sprayed with water and turned frequently until they become soft. Seeds (enclosed by endocarp) are extracted by macerating with water by hand rubbing and cleaned by flotation. There are very few empty seeds.

Physical seed characteristics are as follows (Yang and Lin 2004, Sheu 2007):

No. fruits/L	1,165
No. seeds/L	3,000-3,570
Weight of seeds (g/L)	460

Seed Dormancy and Germination

Chinese fringetree seeds have epicotyl physiological dormancy (Baskin and Baskin 2014) and require warm and cold stratification for complete germination. Germination is hypogeal. According to Chien et al. (2004), seeds need 4 weeks of warm stratification for radicle protrusion and then 3-month cold stratification at 5℃ for releasing epicotyl dormancy. However, the cold stratification treatment can be replaced by removing the endocarp and endosperm. Further, seeds will germinate without cold stratification if they are given an extended period (3-3.5 months) of warm stratification. The epicotyl shoot apex was not quiescent but continued to grow slowly as the radicle protruded rapidly. It took 10-12 weeks of incubation at 30/20℃ with 12 hours light for the epicotyl to begin emergence. Chien et al. (2004) concluded that epicotyl dormancy probably is caused by inhibitors, glucoside phenolics, GL-3, Nuzhenide, ligustroside and oleoside dimethyl ester.

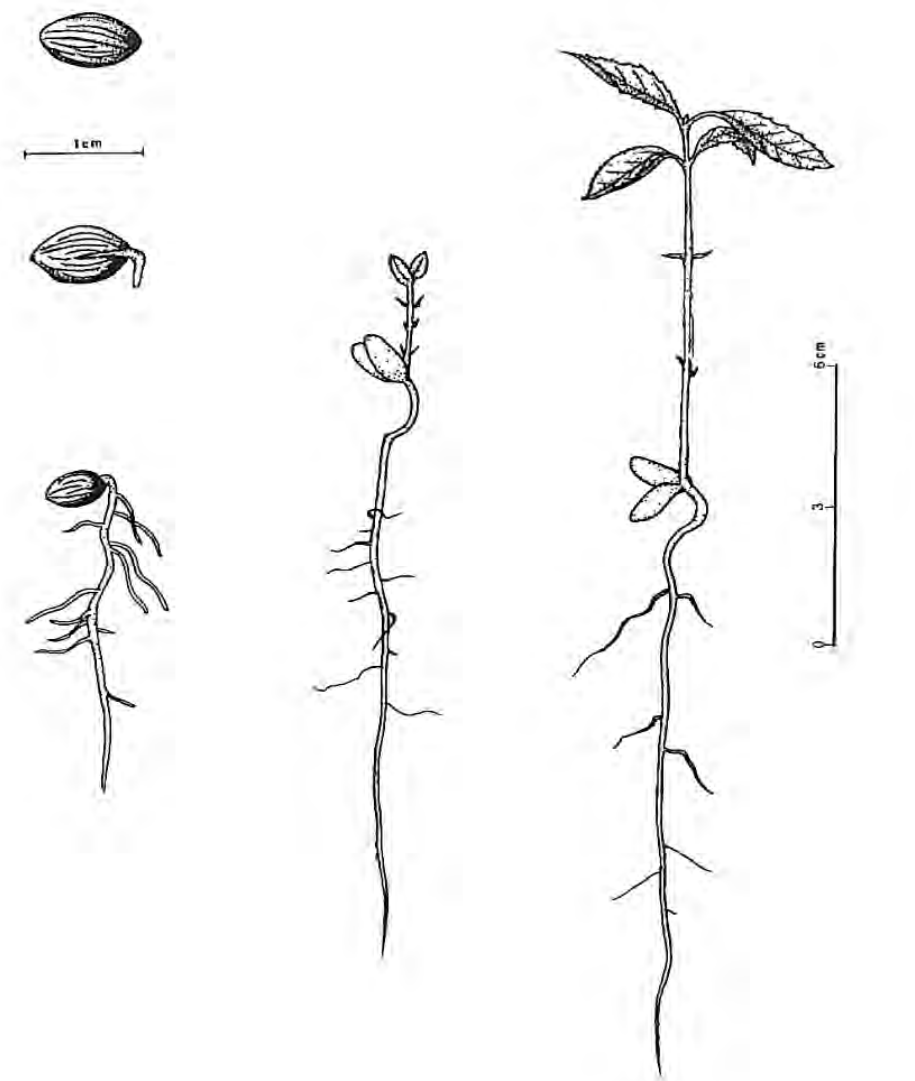
Seed Storage

Seeds are considered to have orthodox storage behaviour, but they can not be stored safely at -20℃ when their moisture content is 8% or higher (Yang and Lin 2004). Thus, it is questionable whether seeds of this species should be classified as orthodox. Obviously, more research is required to confirm these findings. The current recommendation for storage of seeds of this species is to re-

duce the moisture content to 5 ± 2% and store them in sealed containers at -20℃ for long-term storage, or the moisture content can be lowered to ≤ 15% and seeds stored at 4℃ for 2 years (Yang and Lin 2004).

Nursery Practice

Propagation is primarily from seeds. There are two techniques to overcome dormancy of the epicotyl for seedling development. (1) as soon as the radicles protrudes from the seed coats (about a month after sowing), the germinants are transplanted to containers for continuous growth, with frequent watering for 5 weeks after which the cotyledons emerge above the soil surface. (2) Remove the endocarp and endosperm to expose the cotyledons, and transplant seedlings into containers after they begin to grow. Overhead shade screen is needed during the early transplanting period until seedlings reach 10 cm in height. Frequent weeding, watering and pest control are important for good seedling growth.



***Chionanthus retusus* Lindl. & Paxt.** (From Chung and Chang 1990)

Cinnamomum camphora (L.) J. Presl.

Lauraceae
Camphor Tree

Growth Habit, Occurrence and Use

Camphor tree is an evergreen that can grow up to 40 m tall, but there is a giant tree 50 m tall and 4.2 m diameter at breast height in central Taiwan. All parts of the camphor tree are fragrant. It is widely distributed all over the Island from low elevations near sea level up to 1,200 m in the north and to 1,800 m in the south. This species was divided into three local ecotypes with one variety based on camphor and linalool contents. Trees of the major ecotype was a tree contain high camphor content (> 50%), and 70-80% of all camphor tree plantations belong to this ecotype (Liu et al. 1988). These ecotypes and variety can be identified based on wood-chips or leaves by local camphor experts, and alternatively they can be identified by a chemical test (Liu et al.1988). At present, there are still about 1,833, 000 m^3 standing volume in Taiwan, which is the largest in the world (Chien 1998). In addition to making camphor oil, camphor trees are used for furniture and carvings, and it is a major species planted in parks, along streets and for city green-belts.

Collection and Processing

Camphor trees flower in February-April, producing yellow-green panicles. The 6-10 mm berry turns dark purple at maturity in October-December. Attention must be directed towards the collection window as berries will fall after they ripen. Collected mature berries should be air-dried in a shady and well-ventilated place for 2-3 days. The berries should be moistened and turned over frequently to avoid heating and fermentation (Chien 1998, Chung and Chang 1990). Seeds are removed by rubbing the soft berries in nylon net with water, after which seeds are air-dried in a shady place but never exposed to the sun.

Physical seed characteristics are summarized below (Chung and Chang 1990, Sheu 2007).

Weight of seeds (g/L)	501-552
No. seeds/L	5,500-10,000
No. seeds/kg	9,350
Weight of 1,000 seeds (g)	107

Seed Dormancy and Germination

Dormancy of camphor seeds can be broken by soaking in 15% H_2O_2 for 25-30 minutes followed by a thorough washing until there are no more air bubbles (Chien and Lin 1994). Seeds germinated to 58% after this treatment when incubated at a constant temperature of 22℃ and 12-hour light. However, an improved treatment combination of 4-month cold stratification at 5℃ followed by a 25-minute soak in 15% H_2O_2 increased the maximum percentage (77%) and uniformity of germination (Chien and Lin 1999). It should be pointed out that the chemical treatment process requires that the operator wears rubber gloves to protect the skin from direct contact with the chemical. During the treatment process, a lot of air bubbles (oxygen) will appear, and the noise from seed coat cracking can be heard.

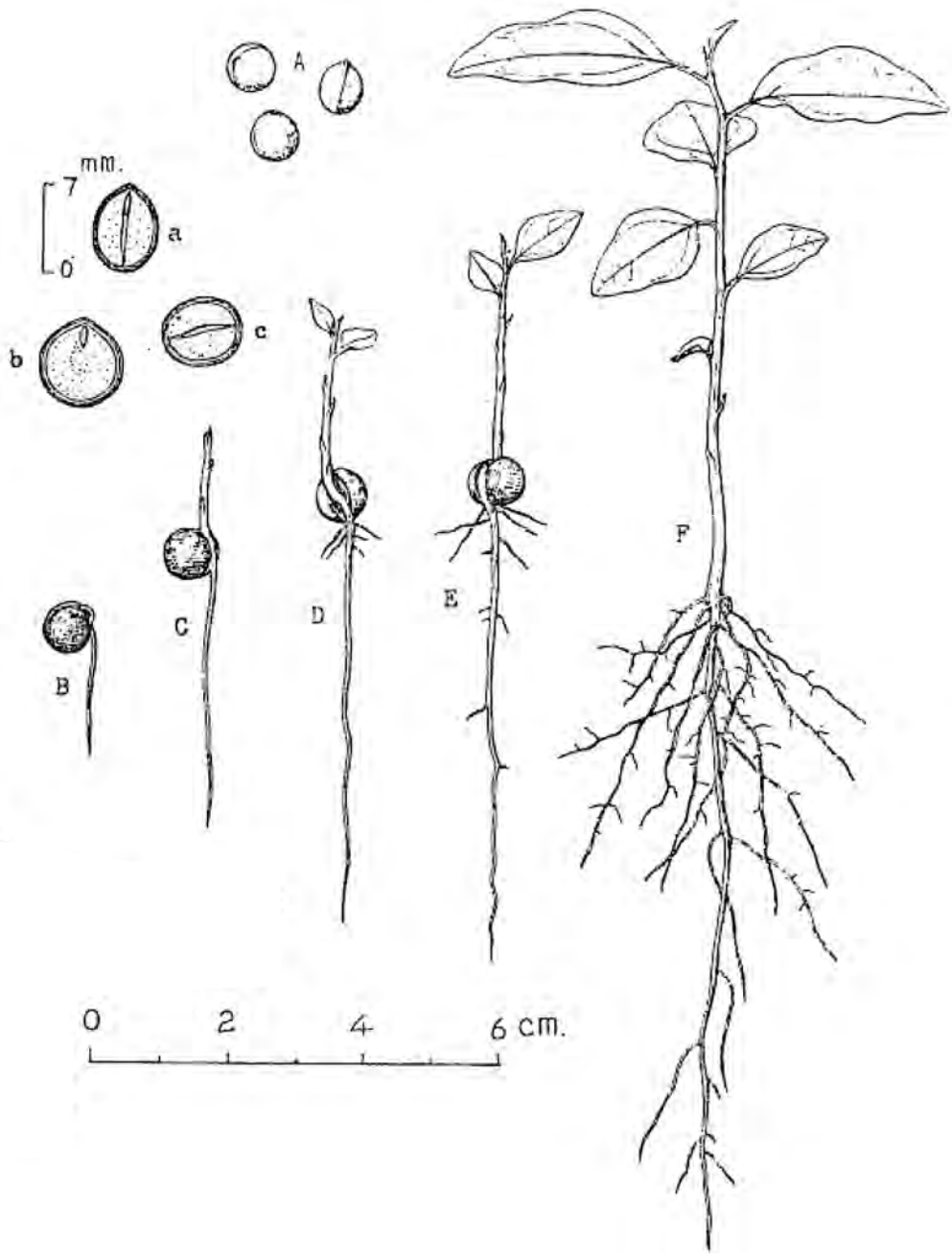
Seed Storage

Camphor seeds can tolerate drying to less than 10% moisture content (fresh weight). However, they are sensitive to a sub-freezing temperature of -20ºC and are considered as probably having intermediate storage behavior. The best storability of camphor seeds was 4 months at 5℃ at a moisture content of less than 10%. However, only 60%

of the originally viable seeds were alive after 12 months (Chien and Lin 1999).

Nursery Practice

After processing, camphor seeds should be stored wet with moist sphagnum at 5℃ for 3-4 months and then treated with 15% H_2O_2 for 25 minutes before spring sowing on sandy seedbeds. The seeds usually germinate to 60% or higher. Seeds start to germinate at > 15℃ after 10 days, and germinants should be transplanted when they grow to 10 cm tall. This applies to both bare-root and container seedling production. For container seedlings, the germinants are transplanted to containers. During the first stage of transplanting, small seedlings should be covered with 40% overhead shade screen to reduce the direct sun light. A twice-daily irrigation schedule should be maintained with additional watering if necessary. Under normal growing conditions, the light screens can be removed in 20-30 days, after the transplants have resumed their normal growth and development. Care must be taken to apply proper fertilizers and insecticides to protect and maintain seedling quality (Chien 1998).



***Cinnamomum camphora* (L.) J. Presl.**

A. Seed and sections (a, b, c) of seed
B. Radicle-emerged seed, day 1
C. Seedling, day 10
D. Young juvenile, day 15
E. Young juvenile, day 20
F. Young juvenile, day 50

From Yang 1984

Cinnamomum kanehirae Hayata

Lauraceae
Stout Camphor Tree

Growth Habit, Occurrence and Use

Stout camphor tree is a valuable timber species that is endemic to Taiwan, but it has become a rare and endangered species due to over-logging in the past several decades (Huang et al. 1996). It occurs on middle to lower mountain slopes at elevations from 300 to 2,000 m. Because of its importance, a series of domestic promotional campaigns for restoration of stout camphor trees have been launched since1991, and much progress has been made in understanding various aspects of the species' natural forest distribution, reproductive biology and seed characteristics. In 1990, stout camphor tree was one of the major tree species included in the "All citizens' tree planting movement" (Sheu et al. 1999). Wood of stout camphor tree can be used for construction, furniture, carving and veneers, and the oil is widely used for making soaps and aromatic materials.

Collection and Processing

Stout camphor tree flowers in October-November. The flowers are in panicles and are light yellow with a sweet fragrance; fruits mature in October-November the next year. Each berry contains a single seed with a hard water-permeable coat. This species usually produces only a small amount of seeds. This could be due to destruction of the sweet fragrant flowers by ants or bees, pilferage of the fruits by birds and rodents and/or the old age of the trees. However, some seeds are still being collected from natural stands. Collected mature berries should be placed in a moist environment for 2-3 days to allow the outer fruit skin to become soft for easy removal of seeds by rubbing and cleaning with water. The cleaned seeds should be air-dried in the shade for a day before being stored with moist sphagnum at 5℃ for 3-4 months.

Physical seed characteristics are given below (Chung and Chang 1990, Sheu 2007).

Weight of seeds (g/L)	435
No. seeds/L	2,980
No. seeds/kg	6,850
Weight of 1,000 seeds (g)	146

It should be noted that the fruits of this species and *Cinnamomum micranthum* are quite different that the former are round and short with a long receptacle, while those of the latter are long and pear-shaped with a short receptacle (Lin 1993). Note that one species, *C. micranthum* (Hayata) Hayata has similar tree morphology as *C. kanehirae*, but the morphology of fruits and seeds, constituents of essential oil from thewood and allozyme analyses are different (Lin 1993).

Orchards consisting of 254 clones selected from 25 natural stands across Taiwan were established at the Lioukuei and Lienhuachih Research Centres (Huang et al. 1996). According to a study on allozyme variation in four geographic areas in Taiwan (Cheng et al. 1997), estimated within-area variation was 88% of the total variation, which is much higher than the expected heterozygosity, and the number of alleles/loci was higher than that found in other local woody species. These results seem to support the hypothesis that Taiwan was a distributional centre of *Cinnamomum*. In 1975, the Taiwan Forestry Bureau established 107 seed tree stands of 31 species and 16,507 seed trees in 2249 ha. Eight-wo of these seed trees were stout camphor trees, and the number was increased to 142 by 1996. In the Hualien District, the Forestry

Bureau established a scion garden of this species as a source for cutting production (Lin 1997). Extensive research has been conducted on vegetative propagation of this species with good results (Kao and Huang 1997).

Seed Dormancy and Germination

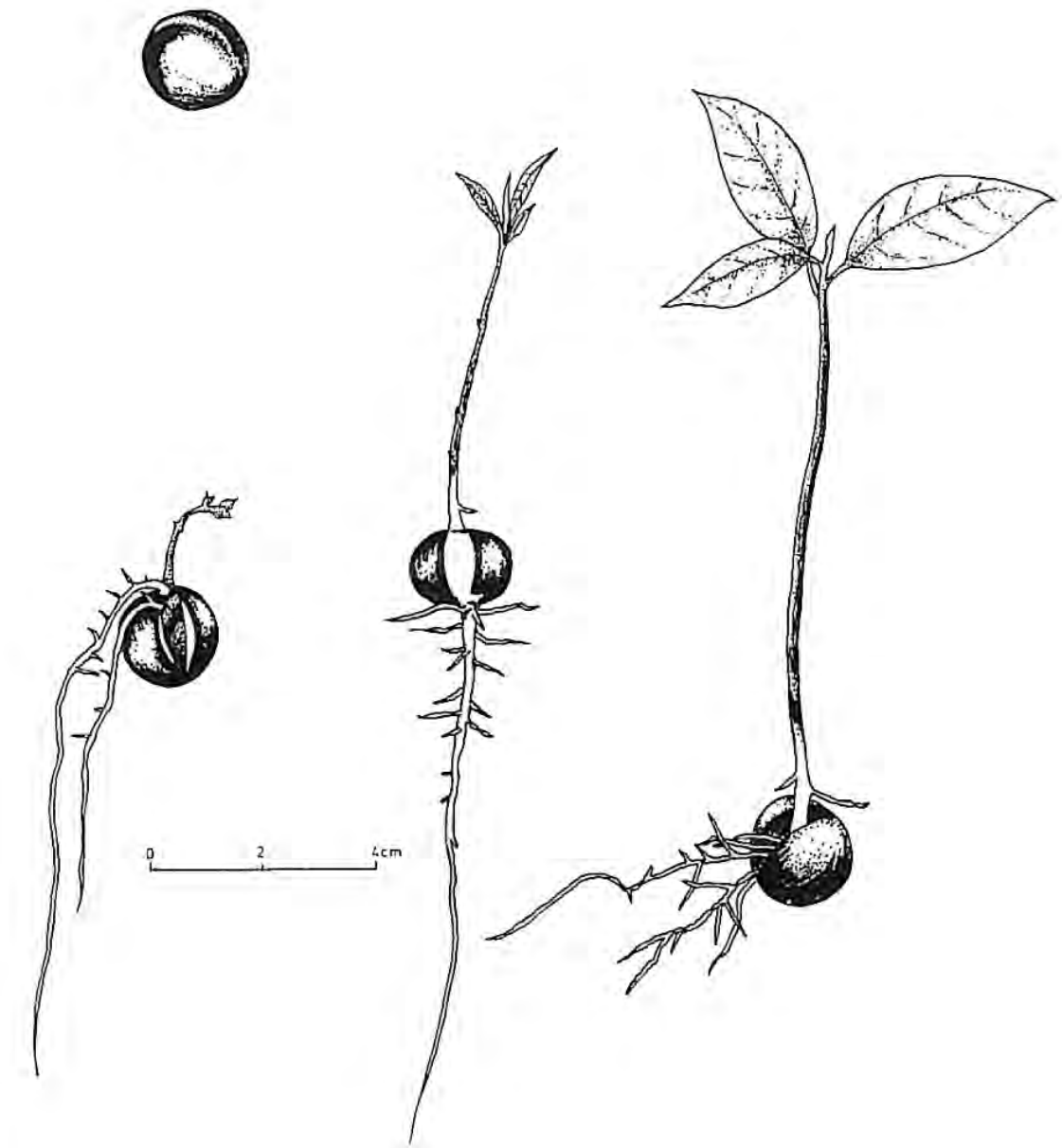
Stout camphor tree seeds have physiological dormancy and germinate slowly due to their hard (water-permeable) and thick coat, and germination is hypogeal (Chien and Lin 1997). Chung and Chang (1990) reported 40% germination at 25℃ after 2 weeks following a 3-month cold stratification in sphagnum at 4℃. For fast, uniform and complete germination of this species, it is recommended that the seeds should be cold stratified with sphagnum at 4℃ for 3-4 months, and then treated with 15% hydrogen peroxide for 25 minutes. The treated seeds should be thoroughly washed before they are incubated at an alternating temperature regime of 20-30℃ with 12-hour light (Chien and Lin 1997).

Seed Storage

Seeds of this species do not tolerate drying and have recalcitrant storage behavior.

Nursery Practice

Propagation can be from seeds or by cuttings. For production from seeds, freshly collected seeds cold stratified for 4 months should be treated with 15% hydrogen peroxide for 25 minutes and thoroughly washed before sowing. Seeding beds should be shaded with overhead nets until seedling reach a height of 10-15 cm. For transplanting the developing seedlings to containers, the best medium to use is sandy loam soil with manure. Because of the scarcity of stout camphor trees, techniques for propagation from cuttings have been well developed and widely practiced. One of the best known techniques involves first treating the cuttings with a 4,000 ppm IBA solution and then planting them in a mixture of peat moss, perlite and sandy loam soil. This procedure will result in rooting of over 80% of the cuttings. Rooted cuttings can then be planted in containers with overhead net covering. This species has a main tap-root system; thus, side roots growing out of the containers should be trimmed before field planting. Cuttings propagated in containers for 1-2 years have been reported to have 58-70% survival in field plantings (Kao and Huang 1997, Yu and Horng 1997).



***Cinnamomum kanehirae* Hayata** (From Chung and Chang 1990)

Cinnamomum osmophloeum Kanehira

Lauraceae
Indigenous Cinnamon Tree

Growth Habit, Occurrence and Use

Indigenous cinnamon tree is a medium sized evergreen occurring in natural broadleaf forests at elevations of 400-1,200 m. It can grow to 12 m tall and 40 cm DBH. Unfortunately, this species has become rare due to overexploitation. Early forest surveys indicated that the majority of individuals occurred in Taichung County, although the species also grew in Kaoshung, Pingtung and Hualien Counties (Hu 1992). It is often found growing on the sunny side of steep slopes. The bark and root of indigenous cinnamon tree contain cinnamaldehyde, which has food and medicinal values. The whole tree has a sweet-hot taste, and the bark is used for medicine and spices. Sticky exudates are produced when the wood is soaked in water. The wood can be used for paper making. See Pan (1992) for a detailed description of the classification of the indigenous cinnamon tree and some other species in the genus.

Collection and Processing

Indigenous cinnamon tree flowers in June-August, depending on elevation. The oval berries turn purple black at maturity in December-January. Collected berries need be placed in a warm, humid greenhouse for 2-3 days, *i.e.* they become soft for seed extraction and cleaning with water. If some berries are still green, the period of artificial ripening should be extended, with mist spraying. Cleaned seeds should be air-dried in shade before storage.

Physical characteristics of the seeds are summarized below (Chung and Chang 1990)

Weight of seeds (g/L)	530
No. seeds/L	5,480
No. seeds/kg	10,340
Weight of 1,000 seeds (g)	97

Seed Dormancy and Germination

Seeds have no dormancy and can attain > 95% germination at 25℃ in 10 days (Chung and Chang 1990). Lin and Wu (1992) reported that fresh seeds can germinate to 98% with 50% of the seeds germinating in 30 days. However, when seeds were cold stratified at 4℃ for 4.5 months, the time to 50% germination decreased from 30 days to zero when they were incubated at 25℃. On the other hand, 50% seeds germinated while they were at 4℃ for 4.5 months. These data indicate that the seeds may have had a little physiological dormancy. In contrast, germination of seeds stored dry at 4℃ decreased from 100 to 80% and time to 50% germination decreased from 30 to 15 days (Lin and Wu 1992).These authors also found that fresh seeds germinated to 98% in 18 days after seeds were treated with 1,000 ppm GA_3 for 18 hours.

Seed Storage

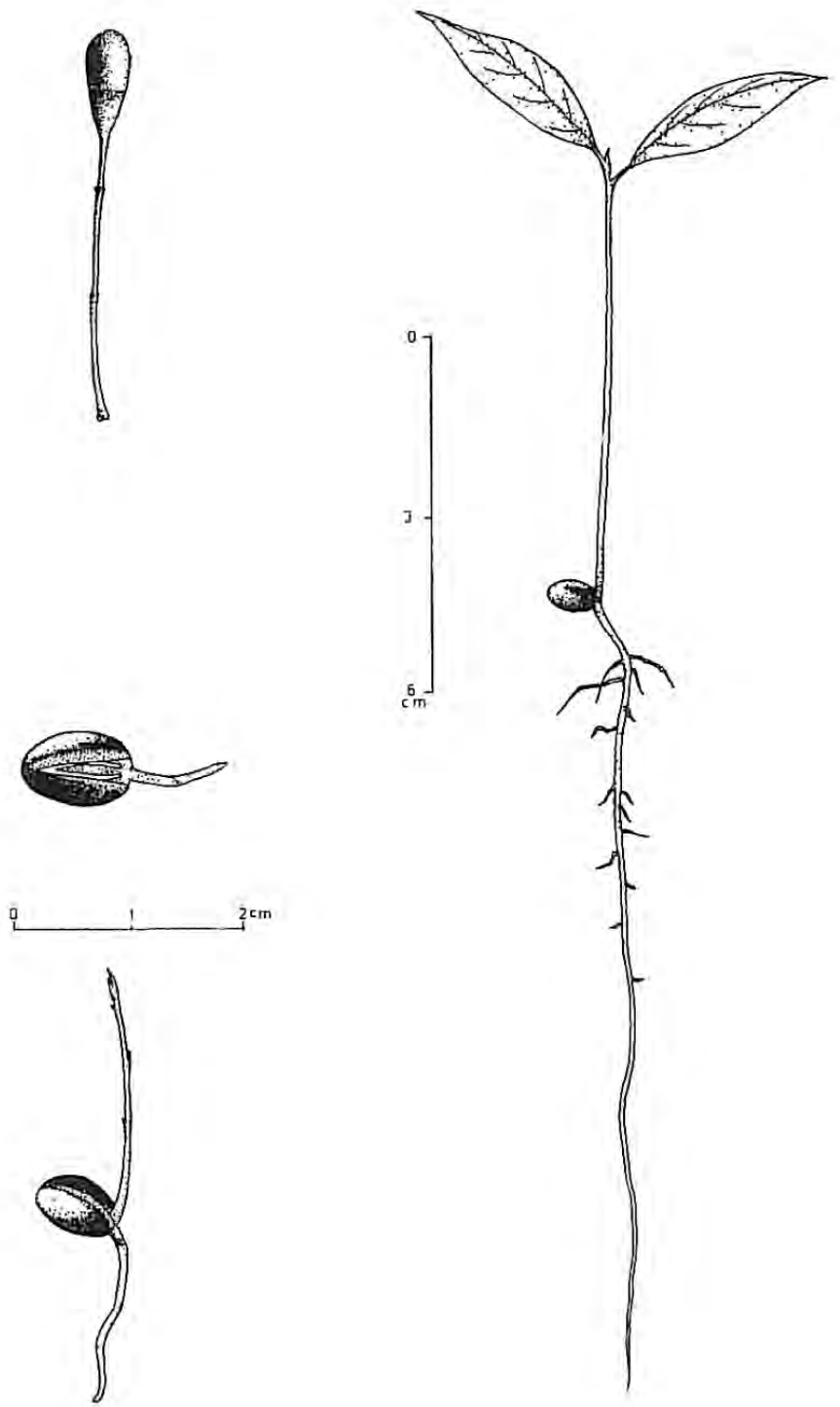
Seeds have intermediate storage behavior and cannot tolerate sub-freezing temperatures. Seeds with moisture content reduced from 26 to 21% (fresh weight basis) stored in a sealed bag inside a can at 4℃ for 9 months showed a decrease in germination from 98% to 78%, and time to 50% germination was 15 days. When dry storage was extended to 10-11 months, 15% of seeds germinated (Lin and Wu 1992). The best storage condition for

longevity for 1 year is moist sphagnum at 4℃ (Lin and Wu 1992).

Nursery Practice

Considering the problem that seeds of this species germinate prematurely during cold stratification at 4℃, it may be best to change the stratification temperature to 1-2℃. Stratified seeds are sown on sandy nursery beds with overhead shading and a mechanized watering system and are covered with fine sand. Seeds are expected to be germinating after 10 days, and as they germinate seedlings are transplanted into prepared containers for further seedling culture. The container medium is peat moss, calcium superphosphate and cow manure. The early stage of seedling development is slow and requires weekly application of liquid fertilizers and protection of seedlings from attack by rodents. First-year seedlings will grow to about 20 cm tall (Lin and Wu 1992).

Although much research has been done on vegetative propagation for cutting production, the resulting plants do not compare favorably with those produced by seeds in terms of economy and physiology (Lin and Wu 1992). Results from field trials suggest that while vegetatively propagated cuttings will maintain heritability, production cost (66%) and plant survival (53%) are higher and lower, respectively, than for plant production from seeds. However, there is much variation between plants produced from seeds (Cheng 1992).



***Cinnamomum osmophloeum* Kanehira** (From Chung and Chang 1990)

Cunninghamia lanceolata (Lamb.) Hook var. *konishii* (Hay.) Fujita

Taxodiaceae
Luanta Fir

Growth Habit, Occurrence and Use

Luanta fir is an evergreen tree that can reach a height of 50 m and a DBH of 2.5 m. It is a variety of China fir and can be distinguished from China fir by its short, narrow, linear needles many of which have strips of stomata on the surface. The taxon was first discovered by Konishi in 1908 on Randa Mountain, and therefore it also is called Randashan fir. Luanta fir is native to Taiwan and occurs primarily in the central and northern parts of the Island at elevations of 1,600-2,300 m in pure stands or in mixed forest with pines, red cypress, Formosan Douglas-fir (*Pseudotsuga wilsoniana* Hay.) and other conifers (Chien 1998). The wood has a distinctive fragrance, can tolerate decay and is classified as grade 1 construction material.

Collection and Processing

Luanta fir is monoecious, and occasionally there are individuals with more male than female cones. This taxon produces cones in March and seeds mature in November-December, depending on the location. For example, cones from Alishan and the Research Forest of National Taiwan University are collected in mid- and late-October, respectively; while cones from Taipingshan and Zhudong mature in mid- and early-November, respectively. For a range-wide cone collection, the collecting schedule should be made in the order from north to south. Cones are 2.81cm long and 2.09cm diameter, and there are 79 mature cones in a liter (Liu et al. 1988). Collected cones should be spread thinly on the ground in a shady place for air drying at the collection sites. Cones should be turned over frequently and sprayed with water 3-4 times daily for 2-3 days before they are bagged and shipped to the processing facility. There is a problem with filled seed yields, and a high percentage of seeds is empty and underdeveloped due to problems of poor pollination and selfing (Seeds of woody plants in China 2001). At the processing facility, cones should be dried further on the ground for 2 weeks until they open and seeds are released. Released seeds should be dried in a well-ventilated shady place before cleaning.

Physical characteristics of the seeds are summarized below (Chung and Chang 1990):

Weight of seeds (g/L)	300
No. seeds/L	102,000
No. seeds/kg	340,000
Weight of 1,000 seeds (g)	2.94

Seed Dormancy and Germination

Germination of Luanta fir seeds is epigeal and does not require any pretreatment. Chung et al. (1980) reported that seeds germinated to 16-36% at a constant temperature of 20℃ with 24 hour light after 7-38 days. In contrast, seeds cold stratified at 6℃ for 10 weeks germinated to only 21% after 2-6 weeks (Kung 1976). Apparently, seed germination percentage varies greatly with time and location of collection (Chien 1998).

Seed Storage

Luanta fir seeds are orthodox. Seeds with a moisture content of 5-6% (fresh weight) have been stored in sealed containers at -20℃ for 10 years (Chien 1998).

Nursery Practice

Seeds are usually sown in March, after they are kept in cold storage during winter. Seeds can be sown directly onto the soil beds and covered by 40% shading screen, which protects them from

stronglight and drying and wind (Chien 1998). It is important that seed germination be tested in order to calculate seed sowing rates. Seed beds should be equipped with overhead covering shelter and an automatic watering system. Some germination occurs 7 days after sowing and reaches its peak after 10 days. Germination becomes sporadic 2 weeks after sowing. Early seedling growth is slow, with first year seedlings reaching 6 cm tall. Seedlings are transplanted in February-March in the next spring. During transplanting, weakly developed, abnormal and insect and disease damaged seedlings should be removed, and plants benefit from overhead shelter and an automatic irrigation system. For container seedling production, transplanting to containers should be carried out in February-March. Sandy loam with a manure mixture is considered the best container medium. Care must be taken for properly scheduled fertilization, weeding and protection from insect and disease attack. It is recommended that slow-release fertilizers be used to facilitate uptake by small seedlings.

Cunninghamia lanceolata (Lamb.) Hook. var. *lanceolata*

Taxodiaceae
China Fir

Growth Habit, Occurrence and Use

China fir is an evergreen tree that can grow to a height of 30 m tall and a diameter at breast height of 3 m. This taxon is native to Mainland China and Vietnam, and it has been grown in Taiwan since 1840. It is mainly planted in elevations around 500-1,500 m in northern, 700-1,600 m in central and 800-1,800 m in southern Taiwan (Chien 1998). It grows fast especially in warm, moist shady sites. The wood is aromatic and resistant to insect attack and decay and is used as a superior house construction material, bridge building and furniture making (Chien 1998).

Collection and Processing

China fir is monoecious and may produce cones when plants are only 3-5 years old, although generally cone production begins when plants are around 6-10 years old. However, high yields and quality of seeds are produced by older trees in 15-year-old plantations. Bumper seed crops occur every 1-4 years. According to research results from the Forest Soils Research Institute of the Chinese Academy of Sciences (1973), high quality seeds of China fir cannot be produced until the mother trees are 25 yeas old or older. Female cones are borne in the upper part of the crown, while male cones are borne in the middle to lower parts of the crown. China fir cones are somewhat round with short stalks drooping when mature. In Taiwan, cones are produced in February-March, and seeds mature in October. Cones are 4.5-5 cm long and 3 cm in diameter. Each scale contains 2-3 winged seeds. Collected cones must be spread thinly on the ground in a shady place for air-drying and turned over frequently until the cones open and seeds are released (Chung and Chang 1990).

Physical characteristics of seeds are given in the table below (Chung and Chang 1990):

Weight of seeds (g/L)	320
No. seeds/L	475,000
No. seeds/kg	148,000
Weight of 1,000 seeds (g)	6.74

Seed Dormancy and Germination

Germination of China fir seeds is epigeal. Seeds have no dormancy and are easy to germinate, although the percentage is generally low (20-30%) (Chien 1998). Kung (1976) attained 20-25% germination of the seeds incubated at 20-25℃ for 2-4 weeks following 6-week stratification at 2℃.

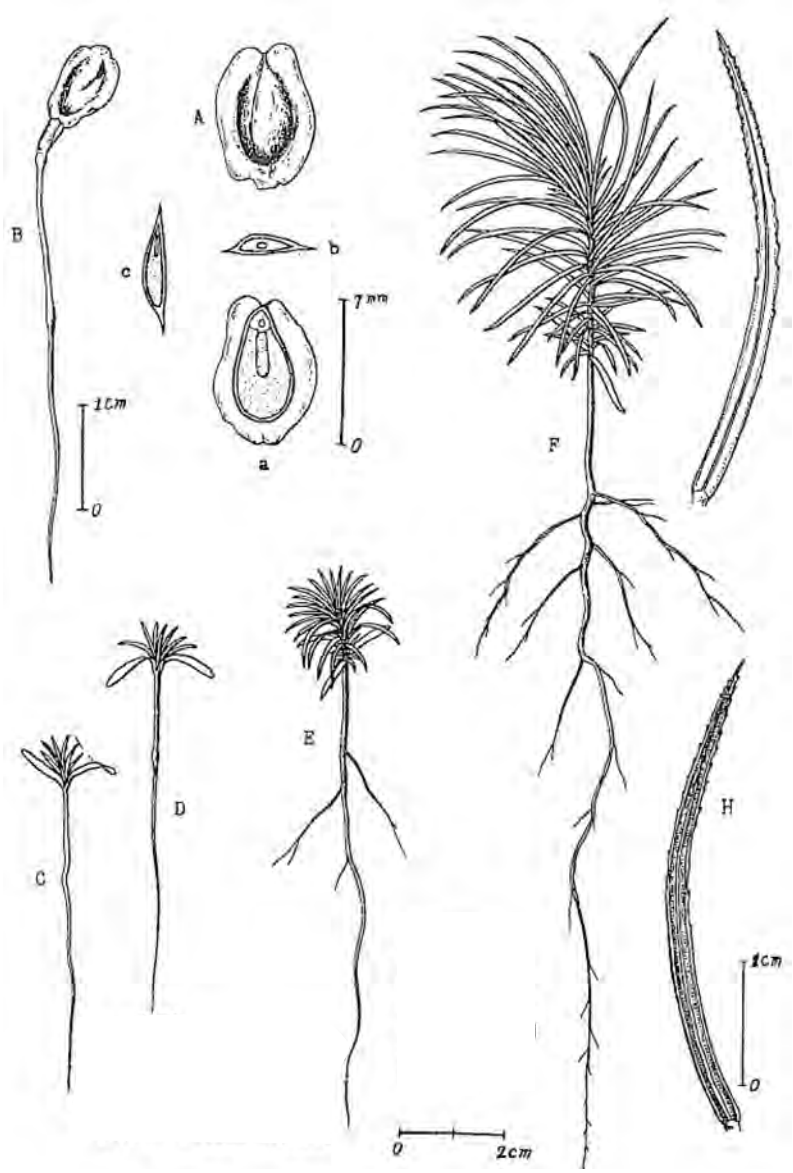
Seed Storage

Seeds are orthodox and thus they can tolerate drying. Seeds can be dry stored for long periods of time at 5℃ or -20℃ when their moisture content is 5-6% (fresh weight) (Chien and Yang 2007).

Nursery Practice

Germination tests must be conducted before sowing the seeds in order to calculate sowing rates. Seeds germinate best in seedbeds of well-drained sandy loam soil or fine sand mixed with organic matter that are shaded. Seeds can be covered loosely with sandy soil, and germinants should be protected from birds. Young seedlings grow fast and should be transplanted when they reach 10-15 cm in height, and the shade cover should be removed 2 months after transplanting. Germinants usually are transplanted into containers filled with a mixture of sandy loam soil and manure. It is critical that application of chemical fertilizers and weeding be done diligently to promote seedling growth during

the early seedling development stage. One-year-old seedlings can reach a height of 25-40 cm. Care should be taken to avoid overirrigation, since the seedlings cannot tolerate a water-saturated substrate (Chien 1998).



Cunninghamia lanceolata* (Lamb.) Hook. var. *lanceolata

A. Seed and sections (a, b, c) of seed
B. Radicle-emerged seed, day 1
C. Seedling, day 5
D. Seedling, day 7
E. Young juvenile, day 20
F. Young juvenile, day 180
G. Dorsal side of leaf
H. Ventral side of leaf

From Yang 1984

Cyclobalanopsis gilva (Bl.) Oerst.

Fagaceae
Red-bark Oak

Growth Habit, Occurrence and Use

Red-bark oak is a large evergreen tree. Leaves are alternate, simple, oblong-lanceolate to oblong-ovate, 9-15 cm long and 3-5 cm wide. The leaf surface is smooth above and yellowish brown beneath. Catkins are about 6 cm long and pendulous. Cupules are shallow, 0.9 cm across and 0.6 cm high with conical acorns about 0.7 cm across and 1 cm high. This species is distributed in Zhejiang and Fujian provinces of mainland China and in Japan and Taiwan. In the northern and central regions of Taiwan, red-bark oak occurs in hardwood forests at elevations of 180-1800 m (Shen 1984). The species is used for scull, gun-stocks and mechanical tools.

Collection and Processing

Red-bark oak flowers in March-May, and acorns mature in September-November. Seeds collection should occur when the cupules turn deep brown and the cups are easy to remove. Collection can be made either by beating the acorn-bearing branches or shaking the trees, after which acorns are picked up from the ground. The viable acorns should be separated from the dead ones by floating in water. The sunken viable acorns should be air dried in shade and stored with sphagnum, fine sand or vermiculite in plastic bags at 5℃. A liter of acorns weighs 590 g, and there are 590 acorns per 1 kg (Daping Nursery, Hsinchu, 1992).

Seed Dormancy and Germination

The seeds are dormant and require 5-6 months moist chilling at 5℃ for maximum, uniform germination at alternating temperatures of 30/15℃ with 12 hour light. It takes 2 months for a complete germination test. Acorns collected from central Taiwan in 1992 required 2-month moist chilling to overcome seed dormancy, and they germinated to 50-75%.

Seed Storage

Red-bark oak acorns exhibit temperate recalcitrant storage behaviour. Acorns with a moisture content of 49% (fresh seeds) stored better than those with a moisture content of < 34% at 4℃, and those stored at -20℃ quickly lost viability. It was noted that acorns did not germinate at 4℃ during the 1 year storage with moist sphagnum moss (Lin 1995).

Nursery Practice

Red-bark oak acorns should be sown in spring after over-wintering in moist storage. Acorns can be sown directly in moist seedbeds or containers. Seedbeds should always be kept moist and covered with shade screens. It is always important to maintain regular watering, weeding, applying fertilizers, herbicides and insecticide. For container seedlings, the medium should be sandy loam soil mixed with manure.

Cyclobalanopsis glauca (Thunb.) Oerst.

Fagaceae
Blue Japanese Oak

Growth Habit, Occurrence and Use

This species is a large evergreen tree up to 30 m tall and has grayish brown bark. Leaves are simple, alternate, coriaceous and oblong-ovate or lanceolate-oblong, 8-14 cm long and 2.5-6.0 cm wide; margin serrated at the upper part and white on dorsal side; young leaves are whitish wooly. The species is widely distributed in southern and northern China, and in Japan, Korea, India and Taiwan. Natural populations of blue Japanese oak can be found in broad-leaved forests from the 100 m to 2,000 m elevation in Taiwan, and it is an important component of these forests. The blue Japanese oak has a strong adaptability to a wide range of climates and soils. It can even grow on limestone mountain sites. The wood is used for construction, vehicles, boats, farm tools, tool handles, floors and sporting goods. The acorn starch can be used for animal food and for making wines, desserts and tofu. It is widely planted as a wind breaker and for greening and landscaping purposes.

Collection and Processing

This species flowers in April-May and has pendulous staminate catkins. Fruits mature in October-December when they turn to brown. The cup-like cupules are 1.2 cm in diameter and 1 cm in height. Acorns are ellipsoid, 1.5-2.0 cm long and 1.2-1.5 cm across. When acorns become fully mature, the nuts are easy to separate from the cupules. Collections are usually made by shaking the trees or beating the branches and then gathering the acorns from the ground. However, the early naturally-dropped acorns should not be collected because they usually are insect-damaged or diseased. Freshly collected acorns should go through water flotation in order to remove the empty or bad ones. Cleaned acorns should be maintained at moisture contents of 30-50% (fresh weight). There are 640 acorns in a liter, and they weigh 470 g. A thousand seeds weigh 735g (Sheu 2007).

Seed Dormancy and Germination

Blue Japanese oak acorns are dormant, and a period of cold stratification (4 months) in mixture with moist sphagnum moss or fine sand in plastic bags at 5℃ results in maximum, uniform germination. After cold stratification, acorns germinated to 85% at 20-25℃ after 5-28 days (Chung and Chang 1990). ISTA (1999) recommends soaking the acorns of all *Quercus* spp. for up to 48 hours, cutting off at the scar end of the seed and removing the pericarp and placing the prepared acorns on top of moist sand for germination at 20℃ for 28 days with the first count after 7 days.

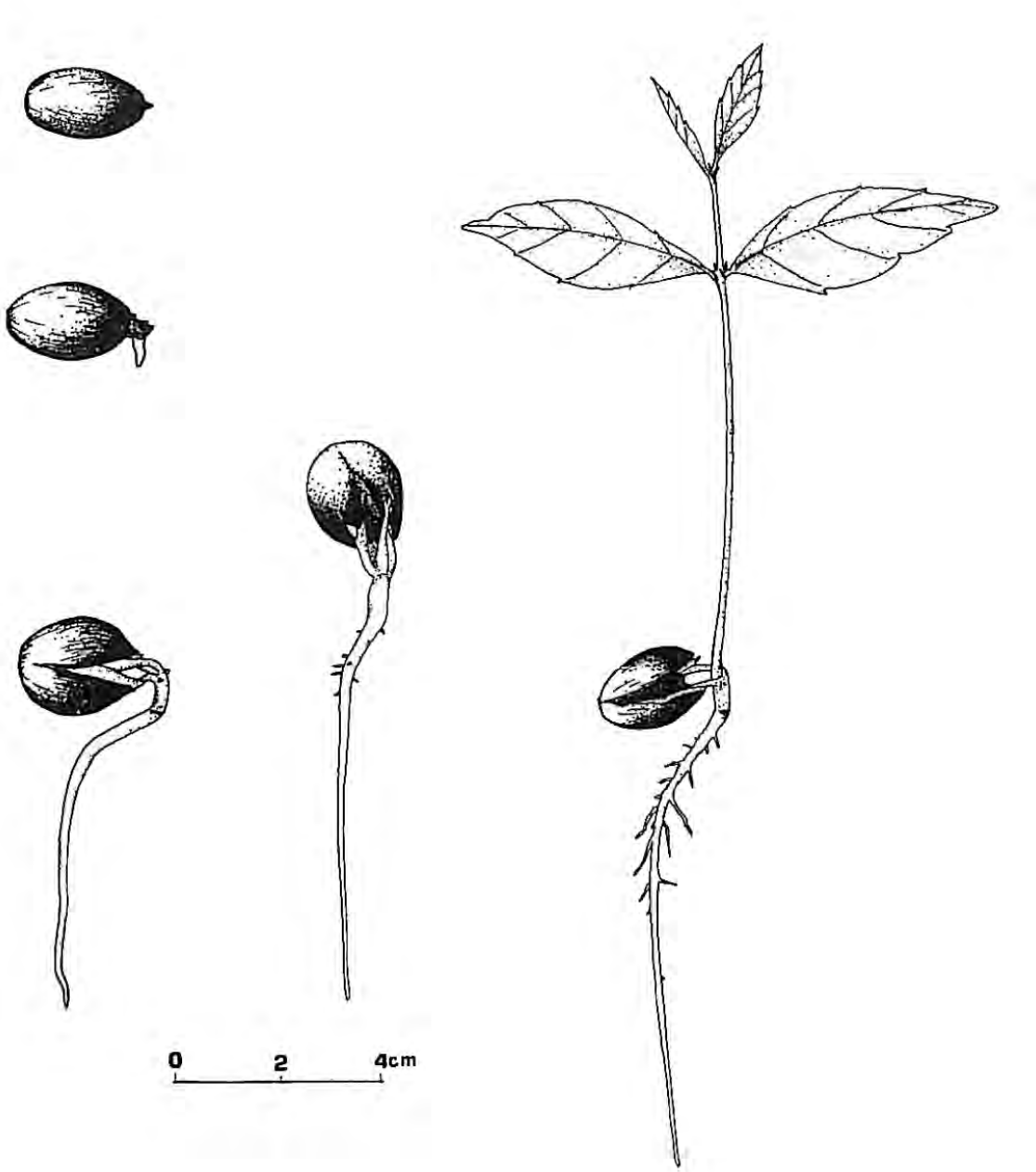
Seed Storage

The seeds have temperate recalcitrant storage behaviour; they should always be maintained at a moisture content of 40-50%. The best condition for 3-4 years storage is in moist sphagnum or fine sand in plastic bags at 5℃. It is important that the medium is moist but not wet. The best way to test a suitable moisture content in the sphagnum medium is that when squeezed by hand no water comes through the fingers.

Nursery Practice

Propagation of this species is not difficult either from seeds or cuttings. Since the germination capacity of this species is high, acorns can be sown directly onto the bare-root seedbeds or in containers. Medium for containers can be sandy loam soil well mixed with manure. If tube-type containers

are used, the recommended medium is peat moss, vermiculite and perlite mixed with manure at a ratio of 1:1:1:1. At the early stage of seedling development, seedbeds should be covered with proper shading nets for 60 days. Attention must be given to regular watering, weeding and insecticide and herbicide applications.



***Cyclobalanopsis glauca* (Thunb.) Oerst.** (From Chung and Chang 1990)

Diospyros philippensis (Desr.) Gurke [*Diospyros discolor* Willd.]

Ebenaceae
Taiwan Ebony

Growth Habit, Occurrence and Use

Taiwan ebony is a valuable tropical tree species growing in Hengchung Peninsula, Taitung, Green Island and Lanyu areas of Taiwan (Chien 1998). The DBH of original old trees can reach 120 cm, and an old specimen in Hengchun Botanical Garden has a DBH of 50 cm. The bark is black and leaves are lanceolate, leathery, 15-30 cm long and 6-10 cm wide with yellow-brown trichomes on the back. The heart wood is black and is commonly known as Taiwan ebony. Trees grow slowly. The wood is hard and heavy with a beautiful, smooth, shiny wood grain and sinks immediately in water. It is usually found growing with other tree species such as *Palaquium formosanum*, *Ficus retusa*, *Heritiera littoralis*, *Terminalia catappa*, *Cerbera manghas*, *Hernandia sonora*, *Calophyllum inophyllum* and *Aglaia formosana*. Taiwan ebony is suitable for parks and large gardens and is also considered as an indigenous fruit tree species.

Collection and Processing

Taiwan ebony is dioecious and flowers from April to a full bloom in June-July. The berries turn dark purple when mature in August-October. Collected fresh berries should be cured in a cool, shady place until they become soft enoughfor seed removal and cleaning with water, after which the cleaned seeds are ready for sowing. Seeds should be handled with care since they cannot tolerate drying. Each berry contains 3-8 half-moon shaped seeds. Nearly 90% of the berries have 6-8 seeds each (Lin 1968). Taiwan ebony fruits are edible.

Physical characteristics of seeds are given in the table below (Sheu 2007):

Weight of seeds (g/L)	647
No. seeds/L	199
No. seeds/kg	307
Weight of 1,000 seeds (g)	3,200

Seed Dormancy and Germination

Taiwan ebony seeds have no dormancy and germinate well. Lin (1968) reported that seeds in a nursery germinated to 90% after 26 days with 78% seedling survival 3 months after germination (Lin 1968). In another nursery report, seeds germinated to 97% after 25-29 days from sowing (Chang 1976). Young and Young (1992) suggested that laboratory germination tests of seeds of common North American persimmon (*Diospyros virginiana*) be conducted using sand or peat substrates and an incubation temperature of 20-30℃.

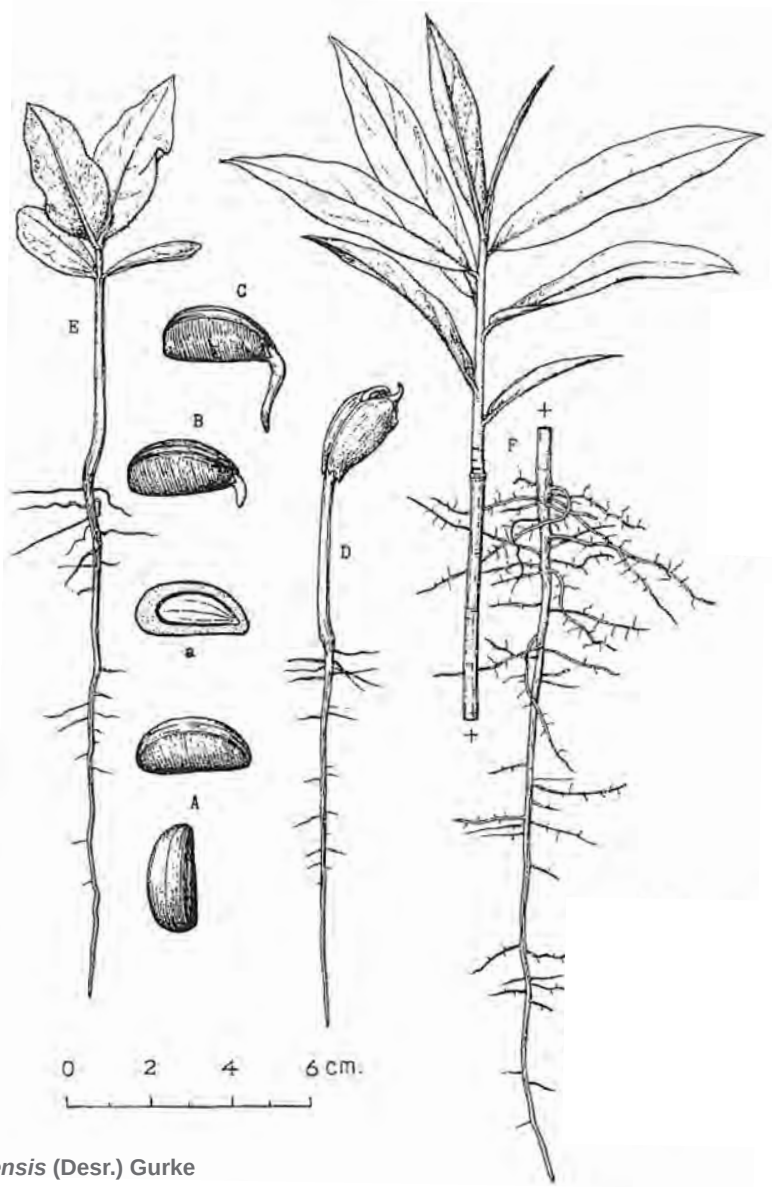
Seed Storage

Taiwan ebony seeds have recalcitrant storage behavior and cannot tolerate drying. Viability of the seeds is greatly reduced if they are stored dry for 1 month after processing. Note that seeds cannot be stored at 5℃, and they should be sown as soon as they are collected (Chien and Yang 2007).

Nursery Practice

Firstly, when seeds are sown on moist sandy nursery beds germination will begin in 2 weeks and reach 90%. Seedbeds should be maintained moist but not too wet in order to prevent seedling root-rot (Lin 1968) Seeds can be sown directly into containers. Otherwise, the radicle-emerged germinants from seedbeds can be transplanted into containers. The medium can be sand, manure and loamy soil at a ratio of 1:1:1 or a mixture of sandy loam soil and

manure. This species is shade-tolerant, and seedlings require 60% overhead shade covering (Chien 1998). Taiwan ebony has a low transplant survival rate because it is a deep-root species with long tap-root and few side-roots. Container seedlings should be moved 2-3 times prior to field planting to prune the tap-root and promote side-root development. Bare-root seedlings of Taiwan ebony are not suitable for planting (Chien 1998). The plant regulators IAA and IBA can improve survival and height growth of transplanted seedlings (Chang 1976).



***Diospyros philippensis* (Desr.) Gurke**

A. Seed and section (a) of seed
B. Radicle-emerged seed, day 2
C. Radicle-emerged seed, day 5
D. Seedling, day 20
E. Young juvenile, day 30
F. Young juvenile, 1-year-old

From Yang 1984

Elaeocarpus sylvestris (Lour.) Poir. — Elaeocarpaceae

Growth Habit, Occurrence and Use

This species is a large evergreen tree that grows to 20 m tall. Leaves are simple, alternate and crowded at the apex of branches, thin-coriaceous, elliptic, 7-19 cm long, 2-2.5 cm wide, apex acute, base obtuse or acute. The species is distributed in Taiwan, Mainland China, Viet Nam and Japan. In Taiwan, the species occurs in mixed hardwood forests of Fagaceae, Lauraceae and *Schima superba* at or below 1700 m elevation. The wood is used for making various small tools and for cultivating mushrooms, and owing to the golden red color of its leaves in autumn, is widely used for landscaping, greening and park and roadside tree planting.

Collection and Processing

The flowering period is May to July. Racemes are axillary, and petals are white, inverted-ovate and laciniate at the apex. Fruits (drupes) mature in October-November, when they turn dark purple. Collected fruits are placed in a warm, moist place with frequent spraying with water and turning for 3-5 days. When the fruits become soft, seeds (enclosed by endocarp) can be extracted by maceration and cleaned with water.

Physical seed characteristics are given below (Sheu 2007):

Weight of seeds (g/L)	585
No. seeds/L	1,250-2,000

Seed Dormancy and Germination

Seeds are dormant and germinate sporadically during a year. The effective dormancy- breaking treatment is to first warm-stratify the seeds in moist sphagnum at 25/15 or 30/15℃ for 6 months and then cold stratify them at 5℃ for 3 months (Chien 1998). After this treatment, seeds can reach 60% germination in the nursery. For laboratory germination, warm stratification at 35/10℃ (90%) or 30/20℃ (87%) was more effective than at 25℃ (52%) (Chien et al. 1998a). According to Chien et al. (1998a), the degree of seed dormancy varies with seed source. Seeds from central Taiwan required a longer period of warm stratification (6 months) than those from southern Taiwan (4 months). Further, seeds from central Taiwan had a maximum germination capacity of 66% compared to 90% for seeds from southern Taiwan.

Seed storage

Seeds of this species can be stored moist at 5℃ for > 1 year (Chien 1998).

Nursery Practice

Apparently, seeds that have been moist stored at 5℃ still require warm and then cold stratification to break dormancy and promote maximum germination (Chien 1998). Seeds are sown on moist sand seedbeds with an automatic watering system and covered lightly with fine sand. It will take about 2 weeks for the seeds to start germinating. Stock production can be made through container seedlings or bare-root seedlings. For container seedling production, the medium should be sandy loam soil with manure and slow-release fertilizers (Nutricoat). For bare-root seedling production, seedbeds must have manure to improve the soil, and germinants should be given slow-release fertilizer. The seedbeds must be covered with shade screens, which should be removed when seedlings reach 10 cm tall. It is important that attention be directed to necessary weeding,

watering and insecticide spraying. If large seedlings are desired, thinning or transplanting is necessary to avoid crowding and shading.

Euscaphis japonica (Thunb.) Kanitz

Staphyleaceae
Japanese Euscaphis

Growth Habit, Occurrence and Use

Japanese euscaphis is a small deciduous tree less than 5 m tall. Leaves are opposite, with reddish petioles, odd-pinnately compound and the 5-9 leaflets are oval, opposite with acute apex and base orbicular or sometimes heart shaped; margins serrate. This genus is monotypic (Yang et al. 2005). It is distributed in southeastern China, Hainan Island, Ryukyu (Okinawa), Japan, Korea and at lower elevations of northern Taiwan. Japanese euscaphis is primarily planted as an ornamental species for its production (from June to September) of showy red fruits. It is very desirable for scenic beauty planting in gardens, city streets and parks.

Collection and Processing

This species flowers in March-April. The small, yellowish white flowers are produced in a terminal panicle. Fruits are coriaceous folicles each of which contains 1-3 dark seeds covered by a red fleshy aril. Fruit collection should be made when the arils turn black, and the collected fruits should be placed in the greenhouse and sprayed with water until the arils become soft enough for removal (7 days). Seeds of harvested from Yangmingshan in 1999 germinated to 96% (Yang et al. 2005).

Physical characteristics of seeds are as follows (Yang et al. 2005):

No. seeds/L	15,270
Weight of 1,000 seeds (g)	46

Seed Dormancy and Germination

Seeds are dormant and warm stratification at 30/20℃ for 3 months followed by cold stratification at 4℃ for 2 months was effective in breaking dormancy, resulting in > 90% germination (Yang et al. 2005). For germination, seeds were mixed with moist ground sphagnum in sealable plastic bags at 30/20℃ with 12-hour of light.

Seed Storage

Seeds have orthodox storage behavior and can be stored at 4℃ and 15℃ for short periods of time and at -20℃ for at least 2 years if moisture content is 3-7% (Yang et al. 2005).

Nursery Practice

Seeds should be warm stratified at 30/20℃ for 3 months and then cold stratified at 4℃ for 2 months to break the dormancy before direct sowing into containers. Germination can be expected to begin within a week. The best container medium is a mixture of sandy loam soil and manure. All the usual precautions such as scheduled irrigation, weeding, application of proper fertilizers and pest control measures should be taken.

Fraxinus formosana Hayata

Oleaceae
Formosan Ash

Growth Habit, Occurrence and Use

Formosan ash is a large semi-deciduous tree that can grow to 70 cm DBH, The grayish red brown or grayish green bark is irregularly thin-flaky, and spline-shaped flake-scars occur on the surface of the trunk. Branchlets are terete and slightly pubescent. Leaves have glabrous petioles 1.5-5.5 cm long and are opposite. Leaves have 5-7 (-9) pairs of leaflets that are sub-coriaceous, elliptic, obliquely ovate or lanceolate, 3-6 cm long and 1-1.25 cm wide, entire, acute or acuminate with an obtuse tip and a cuneate or acute base. They are glabrous above and pubescent along lower part of midrib beneath or rarely glabrous with 7-9 pairs of lateral veins. This species is distributed in India, Indonesia, the Philippines, Mainland China, the Ryukus (Okinawa, Japan) and Taiwan. In Taiwan, Formosan ash occurs in hardwood forests of low-middle elevations throughout the Island and is one of the important reforestation species. It is a shade intolerant hardwood species that grows fast and has strong tolerance of dry sites. Growth data from a 9-year-old mixed wood stand of Formosan ash, *Michelia compressa* and *Cinnamomum camphora* in Taimalee Research Center revealed that the Formosan ash grew to an average height of 7.2 m with a DBH of 9.1 cm. The wood of this species is used for construction, furniture, plywood, musical instruments, sculpture and sports equipment. It is also planted as ornamental and as greening trees in gardens and along streets. However, careful consideration should be given to selecting this species for planting in the future because the emerald beetle has destroyed millions of trees of all ash species in North America.

Collection and Processing

Formosan ash flowers in April-June with yellowish white blossoms arranged in apical panicles. Fruits, (samaras) are mature when they turn yellowish brown in September-October, but they stay on the tree for a long period of time, which facilitates seed collection. Mature samaras can be picked by hand with the aid of pruners and ladders; shaken or beaten off the branches onto a tarpaulin sheet on the ground. Naturally-dispersed samareas also can be swept up from the ground. Seed maturity can be checked by cutting open the samara and examining the seed to determine if it is fully developed. Collected samaras are usually sun-dried for 2-3 days to reduce the seed moisture content to 5-6% for safe storage.

The key physical seed characteristics are below (Sheu 2007):

Weight of seeds (g/L)	120
No. seeds/L	13,300
No. seeds/kg	110,800
Weight of 1,000 seeds (g)	9.02

Seed Dormancy and Germination

Formosan ash seeds have no dormancy and germinate easily up to > 90%; however, germinability varies greatly among seed crop years. ISTA (1999) procedures for breaking dormancy and germinating seeds of *Fraxinus* species from Europe and North America are: warm stratification at

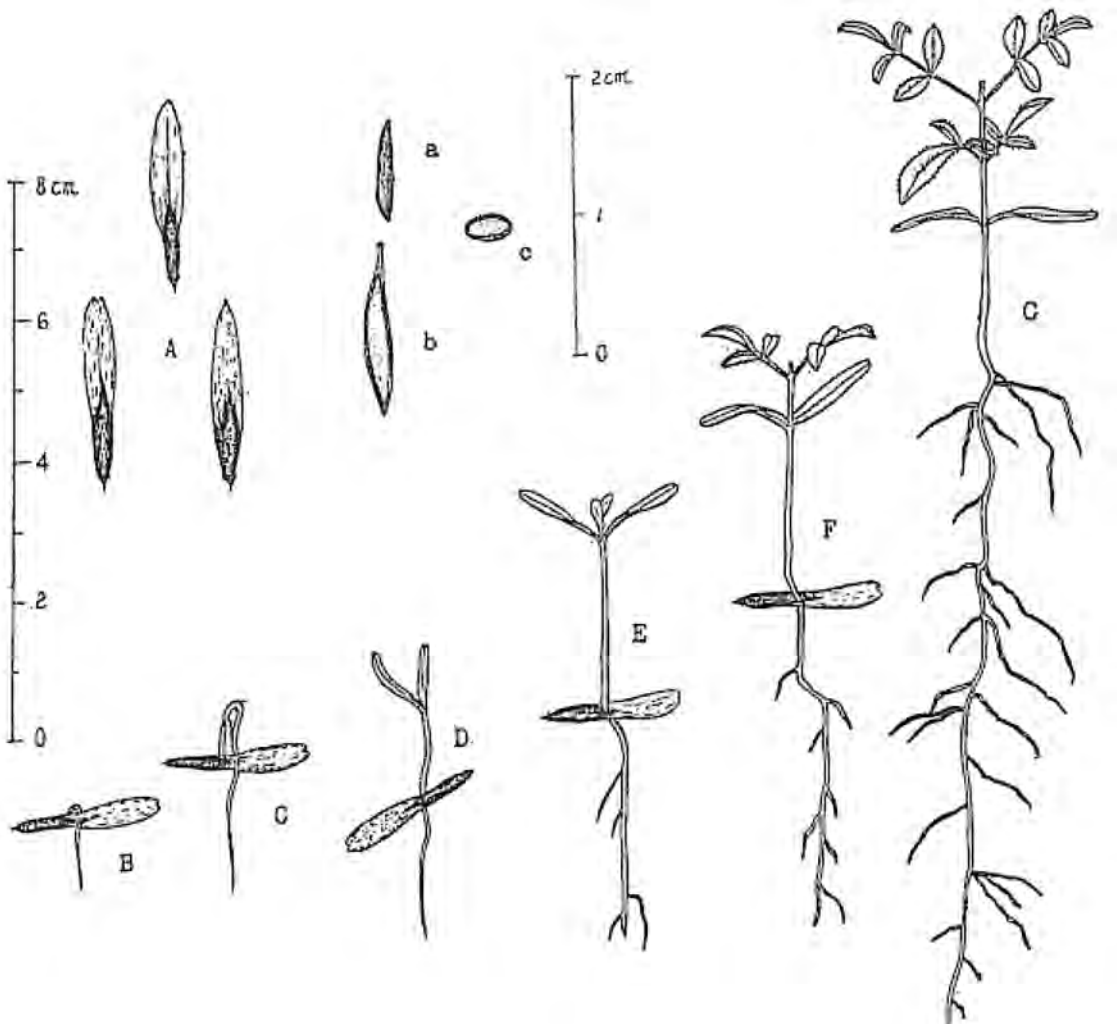
20℃ for 2 months followed by cold stratification at 3-5℃ for 7 months. Seeds are then incubated at an alternating temperature regime of 20-30℃ with 8-hour light for 56 days with first count on day 14. For the difficult-to-germinate seed lots of *F. formosana*, the ISTA prodedures are useful.

Seed Storage

Formosan ash seeds are orthodox and tolerate drying and sub-freezing temperatures. According to Chien (1998), they can be stored in sealed containers at 5℃ for a few years or at -20℃ for a long period of time. Wings are left on the samaras when the seeds are stored in sealed containers at -20℃.

Nursery Practice

Local practice suggests that prior to sowing a large quantity seeds can be soaked in warm water (30-40℃) for 24 hours, while small amounts of seeds can be warm stratified at room temperature for 2-4 weeks or moist chilled at 5℃ for 1-3 months (Chung and Chang 1990). Considering the benefit of genetic diversity and thus the need for high germination percentages, a few months of cold stratification will promote fast, maximum and uniform germination and early seedling growth. Newly planted seedlings should be pruned within 5 years after planting since they are susceptible to forking (Chien 1998).



***Fraxinus formosana* Hayata**

A. Seed, wing removed seed (a) and sections (b, c) of seed
B. Radicle-emerged seed, day 3
C. Radicle-emerged seed, day 5
D. Seedling, day 8
E. Young juvenile, day 25
F. Young juvenile, day 40
G. Young juvenile, day 60

From Yang 1984

Garcinia subelliptica Merr.

Guttiferae
Common Garcinia

Growth Habit, Occurrence and Use

Common garcinia is a medium-sized evergreen tree up to 10 m tall. The leaves are opposite, coriaceous, oval, 10-15 cm long, entire margined, with a dark green, glabrous and lustrous upper surface and a glabrous yellowish-green lower surface. The species is native to the Philippines and Ryukyu (Okinawa, Japan), and it was introduced to Taiwan from Ryukus in 1898 and grown in Lanyu and on Green Island. The species recently has been widely planted in areas below 400 m elevation. Common garcinia is a superior coastal shelterbelt species due to its strong resistance to wind and salty fogs. However, it grows slowly. The conical form of the tree is beautiful in ornamental plantings. The wood is hard and can be used for tools and posts, and yellow dyes can be extracted from the bark.

Collection and Processing

Common garcinia flowers in April-May, and the dioecious flowers are yellowish-white; male flowers are arranged in a pseudospike. Fruits are globosely baccate, about 2 cm across, and they turn orange when mature in August-September and have a foul smell. Each fruit contains 1-4 brown, smooth seeds. Fruit collection can be made by shaking or knocking the fruits from the branches and collecting the fallen fruits from the ground. Fruits on an individual tree will ripen gradually. Freshly harvested mature fruits are spread in a cool, ventilated place and kept moist but not hot to avoid development of mold. Processing can begin after 10-15 days when the fruits become soft. Fruits are macerated by rubbing with hands and washing with water to remove the pulp and debris, and floating is used to remove bad seeds. The cleaned seeds can be dried lightly in shade and then stored in moist sphagnum at 5℃.

Physical characteristics of the seeds are given below (Chung and Chang 1990):

Weight of seeds (g/L)	650
No. seeds/L	90
No. seeds/kg	138
Weight of 1,000 seeds (g)	7, 220

Seed Dormancy and Germination

Although common garcinia seeds are not very dormant, 3-6 months of cold stratification at 5℃ will reduce the time required for germination and increase uniformity of germination. The average germination percentage can be expected to be 80-90% (Chung and Chang 1990, Chien 1998).

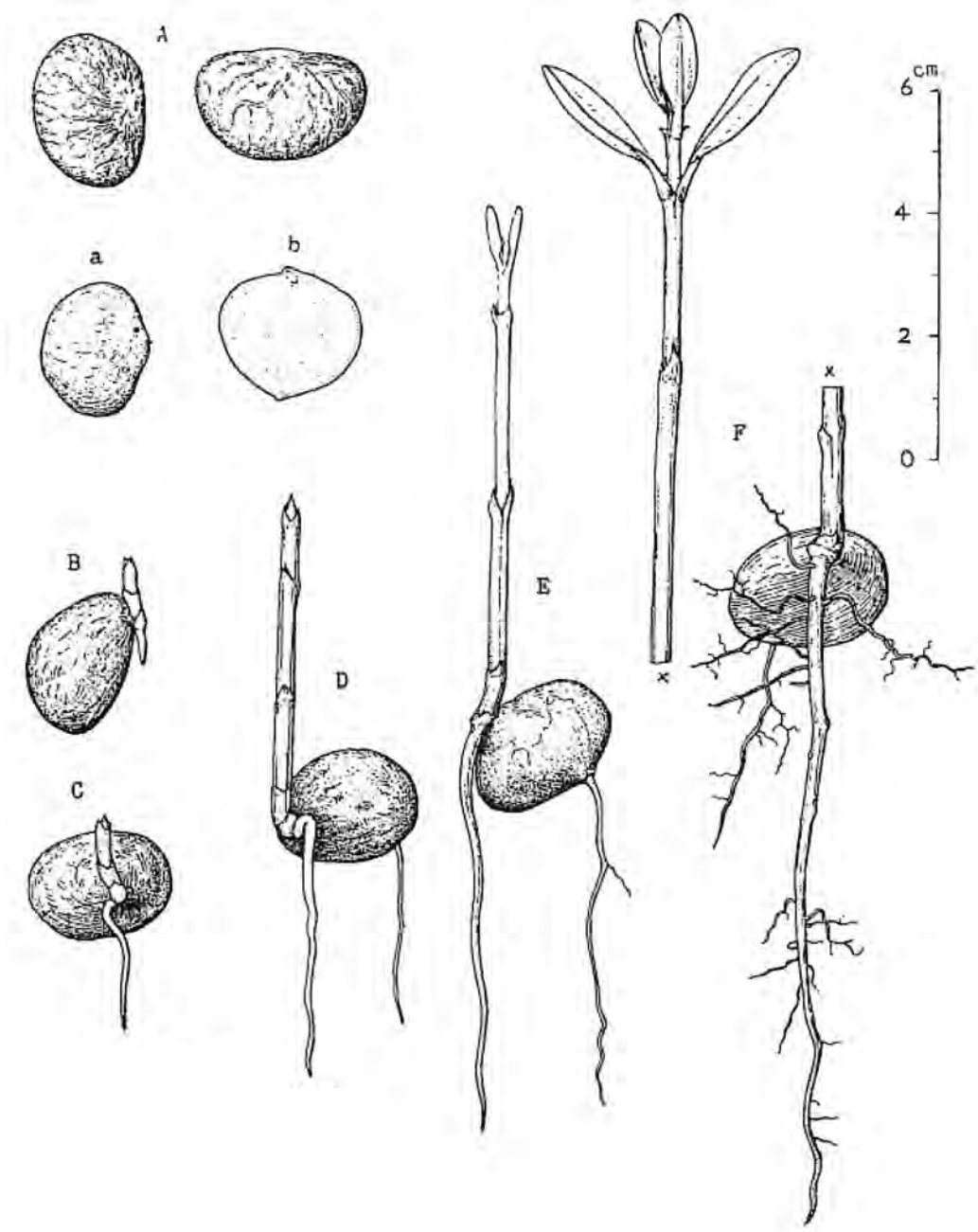
Seed Storage

Common garcinia seeds have recalcitrant storage behavior, and thus they cannot tolerate drying or subfreezing temperatures. Longevity is about 6 months when seeds are stored in sphagnum at 5℃ (Chien 1998)

Nursery Practice

Seeds can be sown on prepared moist sandy seedbeds by point (or spot) seeding at a spacing of 15 cm andcovered by 4-5 cm of soil. It is essential that seedbeds always be kept moist but not wet. Uniform seed germination will be completed within 4-6 weeks. Usually, 90% germination can be expected. Transplanting with soil attached should be done when seedlings reach 15-20 cm tall. In the transplanting beds, seeds should be sown at 30 x 20 cm spacing to promote side-roots growth. The transplanting beds should have overhead shade screens to avoid full sun-light, and they should be irrigated frequently. For container seedling pro-

duction, seeds germinated on sandy beds can be transplanted into containers and placed under 60% overhead sun screens. The container medium is usually a mixture of sandy loam soil and manure. Owing to high germinability, seeds can be sown directly into the containers to avoid transplanting cost. Plastic-bag container seedlings are suitable for field planting when they are 1- year-old with a height of about 30 cm. If larger seedlings are required, they should be transplanted into larger containers or transplant beds. Common gardenia seedlings have a tap-root system; thus, their roots should be trimmed 2 months before field planting. Also, seedlings should have some soil attached (for bare-root seedlings) to the roots to facilitate survival. Common garcinia seedlings are susceptible to insect attack, and therefore proper pest control measures for aphid and scale insects are needed during the whole propagation period.



***Garcinia subelliptica* Merr.**

A. Seed, embryo (a) and section of embryo (b)
B. Radicle-emerged seed, day 1
C. Radicle-emerged seed, day 3
D. Seedling, day 7
E. Seedling day 10
F. Young juvenile, day 20

From Yang 1984

Gordonia axillaris (Roxb. *ex* Ker.) Dietr.

Theaceae
Taiwan Gordonia

Growth Habit, Occurrence and Use

Taiwan gordonia is a medium-sized evergreen tree with smooth branchlets and vestured terminal buds. Leaves are alternate, coriaceous, oblong or oblanceolate, obtuse or rounded at the apex, acute or cuneate at the base, 6.5-13.5 cm long and 2-4 cm wide. They are dark green, glabrous and lustrous above and pale yellowish green, glabrous or puberulous beneath when young. The margin is remotely crenulate at the upper part, entire at the lower pant and slightly revolute toward the base. This species is distributed in Indonesia, Philippines, Sri Lanka and Ryukyu Islands (Japan). In Taiwan, the species is found in the broadleaved forests at elevations of 400-1,200 m. It regenerates well by natural means by colonizing sunny slopes and open denuded areas. The species is an important component of the secondary forests at lower and middle elevations in Taiwan. The wood is used for construction, charcoal making and mine posts. The bark contains tannin that is used for dyestuffs. It is also a desirable species for ornamental planting due to its large white flowers, vigorous growth and wind and air pollution resistance.

Collection and Processing

Taiwan gordonia flowers in December-February and produces prominent yellowish white, choripetalous flowers that are axillary or sub-terminal and solitary or in pairs. The fruits (capsules) turn yellowish brown when they mature. Maturation begins in June in the south and in October in central Taiwan. Collections are usually made by shaking the capsule-bearing branches and gathering them from the ground. The collected mature capsules are dried in a ventilated, shady place to promote their dehiscence and release of the seeds. The oblong capsules are woody, 2-3 cm long and open loculicidally, leaving a free central axis. The seeds are flat and obliquely winged. Seed wings are usually moist dewinged to facilitate cleaning and save space during storage. Clean seed yield of this species from China is 20-25% (Wang 2001b). The seeds should never be dried in direct sunlight.

Physical seed characteristics of this species are given below (Wang 2001b, Sheu 2007):

Weight of seeds (g/L)	840
No. seeds/L	31,100
No. seeds/kg	40,000-48,000
Weight of 1,000 seeds (g)	21-25

Seed Dormancy and Germination

Taiwan gordonia seeds can be germinated easily. For seeds of Taiwan gordonia collected in China, the tetrazolium test showed that viability averaged 85%. A seed lot collected in Guizhou, China in 1990 and incubated at 28℃ germinated to 50% in 100 days. It took 30 days for germination of this seed lot to begin (Wang 2001b). Obviously, the seed germination behaviour of this species varies greatly with seed source.

Seed Storage

Taiwan gordonia seeds have orthodox storage behavior and can be dried to 5-6% moisture content for long term dry storage at 5 or -20℃. For short term storage, seeds can be mixed with moist sphagnum at 5℃.

Nursery Practice

Propagation is primarily from seeds, although it can also be done by cuttings. Cleaned seeds can

be sown directly on moist seedbeds and covered with a thin layer of soil. If seedbeds are kept moist, germination begins 15-25 days after sowing (Chien 1998). Transplanting into plastic bags or other containers is done when seedlings reach 4-5 cm tall. Container medium should be sandy loam soil mixed with manure. After seedlings are transplanted, they need an overhead sun screen for the first 20-30 days, until the seedling height reaches 6-7 cm. Seedlings are exposed to full sun for vigorous growth after removal of the shade screen. Regular irrigation, weeding and application of additional manure are essential for good growth. However, to avoid fertilizer toxicity additional manure should not be applied until seedling height reaches more than 10 cm.

Keteleeria davidiana (Franchet) Beissner var. *formosana* Hayata

Pinaceae
Taiwan Cow-tail Fir

Growth Habit, Occurrence and Use

Taiwan cow-tail fir is a very large tree and grows up to 35 m in height and 2-2.5 m in diameter. The bark is dark gray and irregularly furrowed. Young branchlets are short-pilose or glabrous. Leaves are flat, linear, 2-4 cm long and 3-4 mm broad and keeled on both surfaces.The apex is acute to obtuse or emarginate and margins more or less revolute. The species occurs in central and western China. Variety *formosana* is found in Taiwan at elevation of 300-600 m in the extreme northern sections of the island and at 500-900 m in the southern sections. It used to be found in association with broad-leaved forests in open areas, but now it has become scarce. The wood of this taxon is hard and used for construction, and the tree is planted for landscaping purposes.

Collection and Processing

Taiwan cow-tail fir produces male and female cones in March-April, and seeds mature in October. Mature cones are solitary, erect, cylindrical-oblong, 5-15 cm long, 4-4.5 cm in diameter and pale chestnut in color. Seeds ripen in their first year, and are about 1 cm long with a wing as long as the seed or longer. The interval between good seed crops is about 10 years (Yang et al. 2006a), and the low seed fill seems to result from embryo degeneration (Ho et al. 2000). This taxon has a chromosome number of n=12. In collecting cones, it is important to avoid damaging young branches since this may affect next year's seed crop. Freshly collected cones can be sun-dried for 1-2 days and should be thinly spread and turned over from time to time to facilitate cone opening and prevent molding. De-winging is usually done by placing seeds in a cotton bag and gently rubbing with the hands, after which wings can be separated from seeds with a fan. For a small amount of seeds, de-winging can be done by moistening the seeds in a container for 15 min, stirring them with a stick and fanning out the wings. The seed has a high oil content, and the embryo has two cotyledons. There are 3,800 clean seeds in a liter, and they weigh 82 g. There are 46,300 seeds in a kg, and a thousand seeds weigh 21.6 g.

Seed Dormancy and Germination

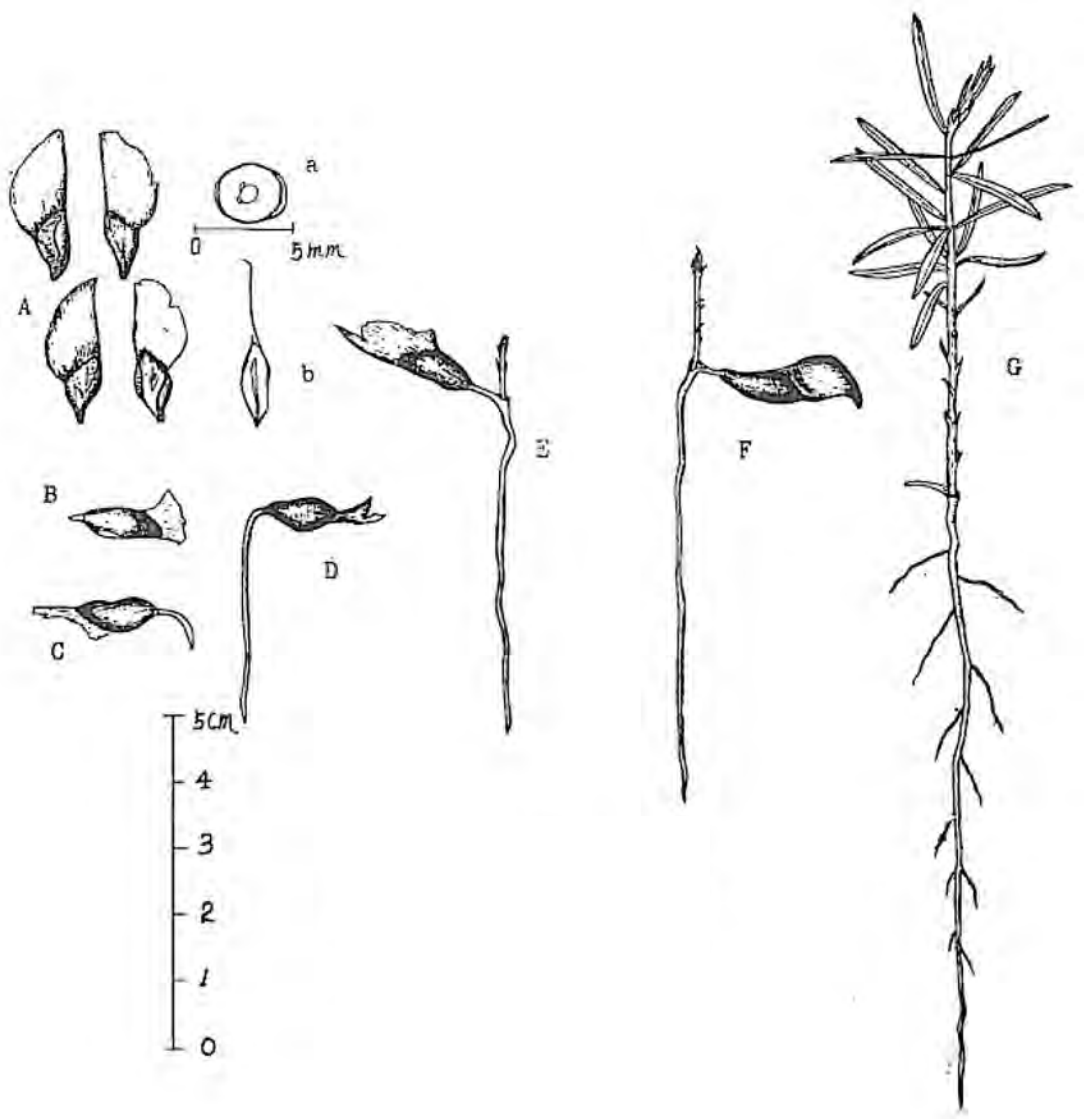
The seeds are known to have a low germination capacity due to the low percentage of filled seeds (20%) (Yang et al. 2006a). When two seed lots were cleaned by blowing, germination percentage was 70% and 82% at 30/20℃ with 8 hour light for 16 weeks (Yang et al. 2006a). Yang et al (2006a) found that 10% of the seeds were dormant, and 2-3 months moist chilling at 4℃ improved germination.

Seed Storage

Taiwan cow-tail fir seeds have recalcitrant storage behavior and cannot tolerate drying (Yang et al. 2006a). Partial loss of germinability occurred when seed moisture content is reduced to 23% (fresh weight), and most seeds lost germinability when moisture content is reduced to 10-12%. The seeds are extremely sensitive to sub-freezing temperature (-20℃), but they can be stored moist at 4℃ for 4 months, it is interesting that seeds of this coniferous species are recalcitrant, which means long-term storage of the seeds for *ex situ* conservation currently is not possible.

Nursery Practice

Since seeds are short-lived, they should be sown immediately following collection and processing. All efforts should be made to maintain the seed moisture content around 30%. Alternatively, the seeds could be stored in moist sphagnum at 4℃ for 5 months and sown the next spring. Complete germination can be expected within 4 weeks (Yang et al. 2006a).



***Keteleeria davidiana* (Franchet) Beissner var. *formosana* Hay.**

A. Seed and sections (a, b) of seed
B. Radicle-emerged seed, day 1
C. Radicle-emerged seed, day 3
D. Seedling, day 7
E. Seedling, day 12
F. Seedling, day 15
G. Young juvenile

From Yang 1984

Koelreuteria henryi Dummer

Sapindaceae
Flame Goldrain Tree

Growth Habit, Occurrence and Use

Flame goldrain tree is a large deciduous tree with a straight trunk and umbrella-shaped crown. Leaves are doubly pinnate, alternate, and estipulate with a glabrous rachis. Leaflets are alternate, oblong, 6-8 cm long and 2.5-3.0 cm wide, have an acuminate apex, oblique base, and serrate margins, and they are olive green above and dull yellowish green beneath. The species is endemic to Taiwan and mainly occurs in the broadleaf evergreen forests at low elevations. Because of its beautiful color change from flowering to fruit ripening, it has been recognized as one of the famous flowers in the sub-tropics. The species is widely planted as an ornamental tree in parks, along streets and in gardens. The wood is used as board material.

Collection and Processing

Flame goldrain tree flowers in August-October and forms white terminal panicles. Fruiting immediately follows flowering. Capsules are pink to reddish brown, 3-valved, bladder-like, about 4 cm long and ripen in November-December. The collected mature capsules are sun-dried for 1-2 days before processing by turning over the capsules frequently to promote seed release. Water flotation can be used to separate filled and empty seeds. Clean seeds are air-dried to reduce seed moisture content and then stored in cloth bags.

Physical seed characteristics are given below (Chung and Chang 1990):

Weight of seeds (g/L)	460
No. seeds/L	11,500
No. seeds/kg	25,000
Weight of 1,000 seeds (g)	40

Seed Dormancy and Germination

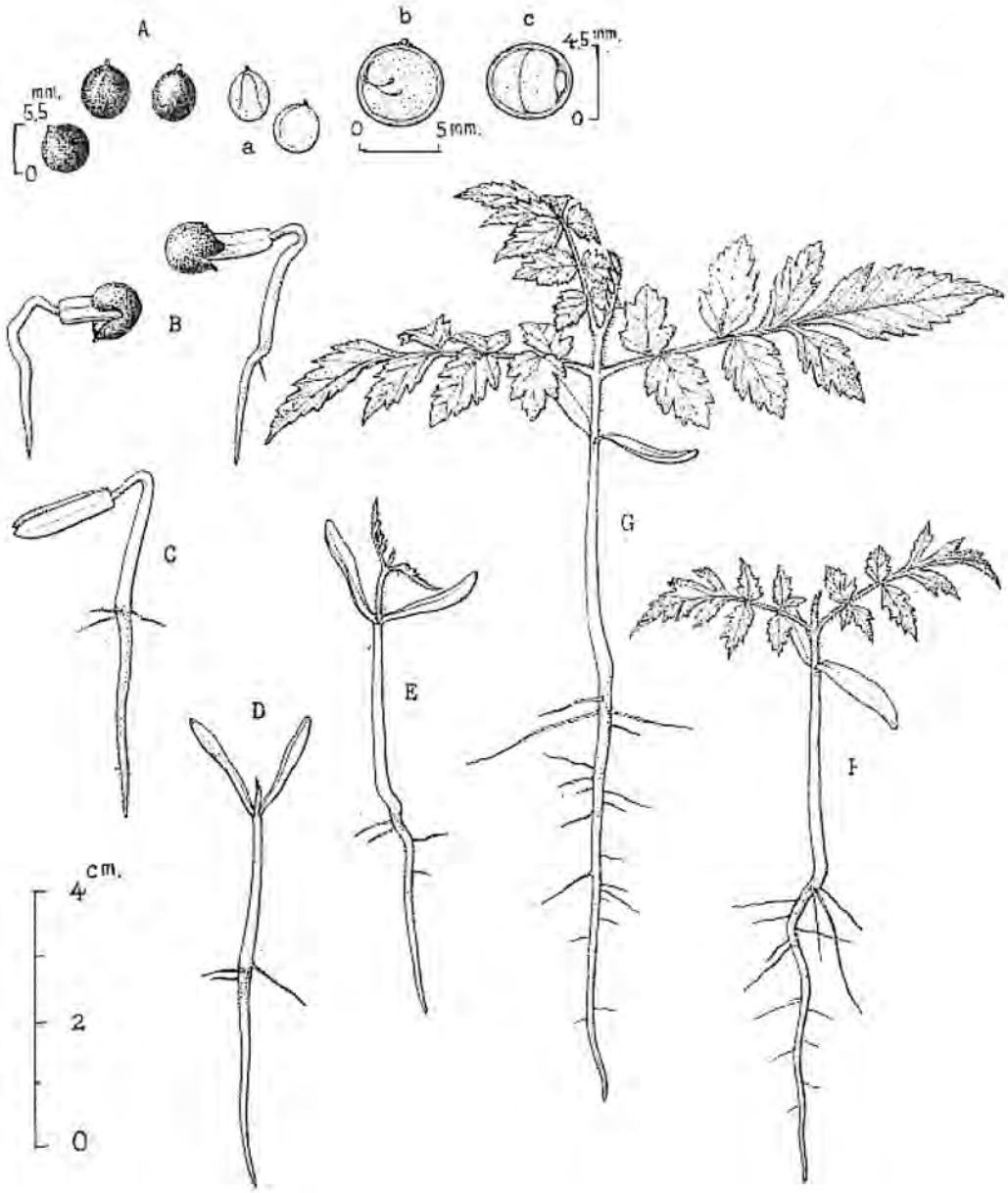
Seeds of this species will germinate to 70% within 2 weeks after sowing. The best seed treatment for promoting germination is a 30 min-period of soaking in water or 30 min of soaking in 60% sulphuric acid (Yang 1984). Average germination is 95%.

Seed Storage

The seeds can tolerate drying and sub-freezing temperatures and thus have orthodox storage behaviour. If the seed moisture content is reduced to less than 6%, seeds remain viable during long term storage. However, it is best to mix the seeds with insecticide or use vacuum seal.

Nursery Practice

Seeds cleaned by water flotation will usually germinate to > 90%, and therefore can be sown directly into containers. The preferred container medium is sandy loam soil mixed with manure. In addition, other proper fertilizers also are needed during the seedling growing period, and usual scheduled irrigation and weeding are important. Preventive measures must be taken to control brown root rot, rust and powdery mildew.



***Koelreuteria henryi* Dummer**

A. Seed and internal morphology (a, b, c) of seed
B. Radicle-emerged seed, day 1
C. Radicle-emerged seed, day 2
D. Seedling, day 3
E. Young juvenile, day 5
F. Young juvenile, day 8
G. Young juvenile, day 20

From Yang 1984

Limlia uraiana (Hayata) Masam. & Tomiya

Fagaceae
Urai Tanoak

Growth Habit, Occurrence and Use

Urai tanoak is a large evergreen tree with a straight trunk and deeply furrowed bark. The species can grow up to 20 m tall and 80 cm DBH. Leaves are simple, alternate, oblong, 6-8 cm long, 2 cm broad and have an entire margin or 3-7 serrate at the upper part of the margin. They are pale green to bluish green above, pale yellowish green beneath and glabrous on both surfaces. Petioles are about 1 cm long. The species is known to have abundant sap. It is endemic to Taiwan, occurring in broadleaf forests at 300-1,500 m elevations in central and northern parts of the Island. The growth rate of this species is considered medium. For example, 10-year-old trees in northern Taiwan had an average height of 4.5 m and a DBH of 6.54 cm, and 20-year-old trees had a height of 8.8 m and a DBH of 19.7 cm (Sheu et al. 1999). The wood is used for construction, barrels, vehicles, farm tools, railroad ties and mining timber.

Collection and Processing

Urai tanoak flowers in March-May with many male flowers in pendulous catkins. Fruits are saucer-shaped involucres and half-covered by cupules that mature in November-December. The acorns are elliptical or oval, about 1 cm long and 0.8 cm diameter with acute tips and truncate bases. Collection should be made when acorn color changes from green to yellowish brown. When acorns are ripe, they are easily separated from their cups. Collection can be made by picking up acorns from the ground or shaking or flailing them off the branches onto plastic sheets. It is important to know that the early naturally-dispersed acorns on the ground may be wormy or diseased. The processing for acorns involves removing the cups, leaves, twigs and other debris and using flotation in water to remove empty, wormy and diseased acorns. The acorns cannot tolerate drying; therefore, they should be kept at high moisture content (30-35%).

Physical seed characteristics are shown below (Sheu 2007):

No. acorns/L	1,700
Weight of acorns (g/L)	578

Seed Dormancy and Germination

Seeds have no dormancy and hypogeal germination. However, acorns must be kept moist, otherwise they will lose germinability. Therefore, it is best to sow them immediately after processing or store them in moist sphagnum at 5℃ for spring sowing.

Seed Storage

Urai tanoak seeds have recalcitrant seed storage behavior. However, acorns can be stored in moist sphagnum at 5℃ for 2 years (Chien and Yang 2007).

Nursery Practice

Seedling production is primarily from seeds that are sown onto moist seedbeds, and germinants are transplanted into containers. High quality acorns can be sown directly into containers. The best container medium is sandy loam mixed with manure at a 2:1 ratio. It is important that scheduled irrigation, application of fertilizers and weeding be carried out during seedling development. Seedlings can reach 40 cm tall in a year, at which time they are ready for field planting (Chien 1998).

Liquidambar formosana Hance

Hamamelidaceae
Formosan Sweet Gum

Growth Habit, Occurrence and Use

Formosan sweet gum is a large deciduous tree up to 40 m tall and 1 m in diameter. The tree is straight with grayish brown bark that is longitudinally deeply fissured and furrowed. Leaves are simple, alternate, stipulate, thin-coriaceous, cordate to truncate, 8-15 cm broad, 10-14 cm long and 3-lobed. Leaves on young trees are often 5-lobed, serrulate and glabrous on both surfaces, and they turn yellow in the autumn and fall from the trees in January-March. The species is widely distributed in southern China and in most secondary forests or along streams below 1,500 m throughout Taiwan. The species is most commonly found in the central Taiwan at elevations of 900-2,000 m. It is a valuable reforestation species in Taiwan, and its wood is used for construction, cabinet making, ship building and for culturing mushrooms and edible fungi. The tree is desirable for garden and street planting, and its leaves are used for feeding silkworms.

Collection and Processing

Formosan sweet gum flowers in March-April and is dioecious. The pale yellowish green flowers are axillary with male flowers in racemes or panicles and female flowers in a solitary globose head. The fruit is a spiny globose head, about 3 cm in diameter, composed of capsules. Each capsule contains a single seed that is about 3 mm long, and seeds mature in October-November. A good seed crop year occurs every 3-5 years (Chung and Chang 1990). Although large quantities of seeds have been collected by the Forestry Bureau, natural regeneration has been the official forest management policy. The collected capsules can be dried in the sun and should be turned over frequently to facilitate capsule opening and release of seeds. Empty seeds can be removed by blowing. There are 118,000 cleaned seeds in a liter, and they weigh 220.2 g (Sheu 2007). There are 536,000 seeds in a kg, and a thousand seeds weigh 1.86g.

Seed Dormancy and Germination

Seeds can be germinated easily without pretreatment. Local experience has found that seeds of *L. formosana* incubated at 25/20℃ alternating temperatures for 5-20 days have an average germination of 70% (Chung and Chang 1990). The seeds of the American species (*Liquidambar straciflua*) have shallow dormancy and require 30-day moist chilling to enhance germination (Bonner 1974).

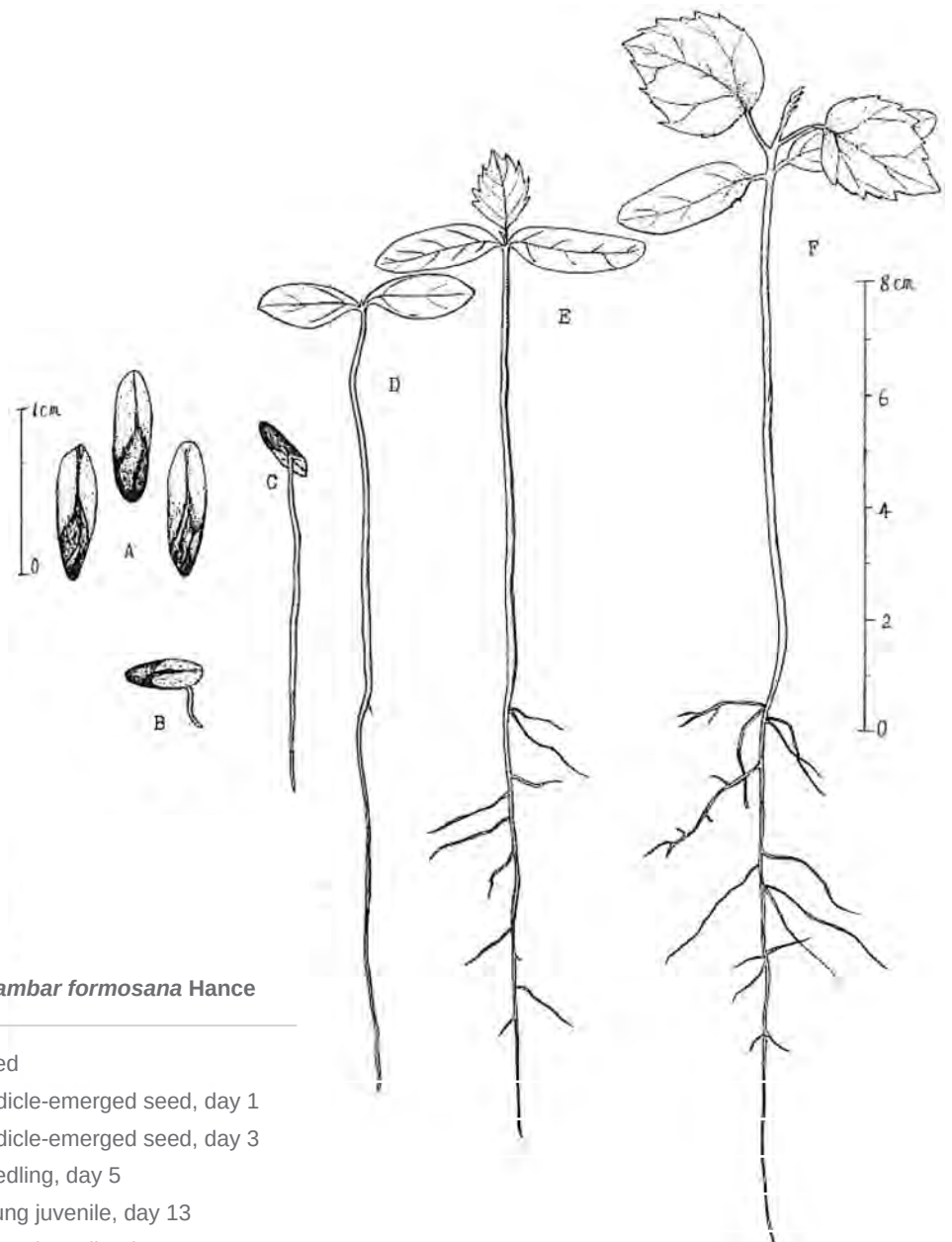
Seed Storage

Formosan sweet gum seeds are tolerant to desiccation and have orthodox storage behaviour. When seed moisture content is reduced to 5-6%, they can be stored in sealed containers at 5℃ for 5 years or longer, and long-term storage can be achieved at -20℃ (Chien 1998).

Nursery Practice

Seeds can be sown on sandy seedbeds immediately after processing, or they can be stored until next spring, which is more desirable. Germination begins 15-20 days after sowing. A short period of moist chilling will speed up germination. Generally, plastic bags or dibbling tube containers are used for seedling production. The container medium should be filled with sandy loam soil mixed with manure since the seedling has a tap-root and requires moist, rich fertile soil for seedling growth. Although young seedlings require 60% shade, seedling growth is best in full sun light. Seedlings

require a great amount of water and automatic watering facility is essential for the operation. In general, seed germination percentage is less than 50%; thus, it is best to determine seed quality before sowing in order to accurately calculate the sowing rate for the number of seedlings to be raised. Application of complete fertilizer, NPK and other appropriate chemical fertilizers are vital to seedling development. Preventive measures should be taken against diseases such as damping-off.



***Liquidambar formosana* Hance**

A. Seed
B. Radicle-emerged seed, day 1
C. Radicle-emerged seed, day 3
D. Seedling, day 5
E. Young juvenile, day 13
F. Young juvenile, day 37

From Yang 1984

Litsea accuminata (Blume) Kurata

Lauraceae
Nanto Actinodaphne

Growth Habit, Occurrence and Use

Nanto actinodaphne is a medium-sized evergreen tree growing in the hardwood forests at middle to lower elevations (400-2,000 m) in Taiwan. Although most species in the Lauraceae are fragrant, this species has a foul odor (Chien 1998). The wood is used for small tools and farm hand-tools.

Collection and Processing

This species flowers in July-September and the fruits mature the following April. The berries are oblong, about 1.25 cm long and turn dark purple at maturity. Collected berries should be handled with care since the seeds are recalcitrant and cannot tolerate drying. After collection, seeds must be processed quickly with water in a warm, humid place, and only the seeds that sink in water should be used. Cleaned seeds can be stored moist at 5℃ for 1 year.

Some of the physical seed characteristics are listed below (Lin and Wu 1991):

No. seeds/L	1,767
Seed size (cm)	1.25 × 0.79
Weight of 1,000 seeds (g)	379

Seed Dormancy and Germination

Seeds of this species have no dormancy and germinated to 98% in 19 days at 22℃ with 12 hours light, and they reached 50% germination in 13 days. Fresh seeds treated with 1,000 ppm GA_3 for 12 hours reached 50% germination in 12 days (Lin and Wu 1991).

Seed Storage

Seeds have recalcitrant storage behavior. Freshly collected seeds have 41% (fresh weight) moisture content after cleaning. When seeds were stored in moist sphagnum at 4℃, the decline in germinability was gradual for the first 4 months, and after 6 months seeds began to germinate at 4℃. All seeds stored in moist sphagnum at 4℃ lost viability completely after 10 months, whereas all those with their moisture content reduced to 19% lost viability immediately (Lin and Wu 1991).

Nursery Practice

Because recalcitrant seeds lose viability quickly, they should be sown on moist sandy seedbeds and covered with fine sand immediately after processing. It is important to keep the seedbeds moist. Germination can be expected to occur about in 10 days after sowing. As seeds germinate, the germinants should be transplanted into containers filled with sandy loam soil mixed with manure. An automated watering system is preferred for seedling culture, along with application of fertilizers. Seedlings usually grow fast and should be ready for field planting in the next rainy season (Chien 1998).

Maba buxifolia (Rottb.) Pers.

Ebenaceae
Philippine Ebony Persimmon

Growth Habit, Occurrence and Use

Philippine ebony persimmon is a small evergreen tree. Leaves are simple, entire, slightly revolute alternate, slightly emarginated, thick coriaceous and espitulate, obovate, 2-3 cm long and 1.5-2 cm wide, with a rounded apex and attenuate base, and they are dark green above and dull yellowish green beneath and glabrous on both surfaces. This species is distributed in India, Malaysia and Australia, and in Taiwan it is found on Lamay island, Hengchun peninsula and Lanyu coastal areas. The heartwood is dark, lustrous and hard and is a superior material for art-craft. It is also widely planted in parks and gardens and used for pot culture due to the beautiful form of the tree and its leaves and colorful fruits.

Collection and Processing

Philippine ebony persimmon has small axillary, yellowish white choripetalous flowers that open in April-May. Fruits are elliptical berries that ripen in July-August, when the pericarp turns from green to deep red. The berries are 0.6-1 cm long. Collected fruits can be placed in a greenhouse and sprayed with water for 2-3 days until the fruit flesh is soft for processing. Seeds can be extracted by rubbing the berries against a wire screen and washing the pulp away. It is important to keep the fruits moist.

Seed Dormancy and Germination

Seeds of this species have no dormancy and can germinate easily to 50% in 2 weeks.

Seed Storage

Seeds have recalcitrant storage behavior, and all seeds lost germinability in moist storage at 5℃ after 2 months (Chien 1998)

Nursery Practice

Seeds can be sown directly into containers if they have high germinability. Otherwise, they can be sown onto moist sandy seedbeds and covered with fine sand. Seedbeds should always be kept moist. As soon as the seeds germinate, germinants can be transplanted to containers. Container medium should be well-drained sandy loam soil. Shade is required for the early stage of seedling culture, but sun screens should be removed when seedlings are about 10 cm in height. Because seedling growth is usually slow, liquid fertilizers or slow-release chemical fertilizers should be applied to promote seedling growth and development. This species grows best at high temperatures and high humidity, and the most suitable temperature is 23-30℃.

Machilus kusanoi Hayata
M. thunbergii Sieb. et Zucc.
M. zuihoensis Hayata

Lauraceae
Large-leaved Nanmu
Red Nanmu
Incense Nanmu

Growth Habit, Occurrence and Use

Large-leaved nanmu is an evergreen tree about 35 m tall, and it grows in hardwood forests and secondary forests all over Taiwan at elevations below 1,800 m; it commonly occurs in river valley sites. It is a deep-rooted species, and its roots can penetrate into cracks in rocks. It is one of the fast growing and high wood-quality species in the Lauraceae. Its wood is a light-reddish brown color and is used for construction, furniture, farm tools, wheelbarrows and musical instruments.

Red nanmu is an evergreen tree about 25 m tall primarily distributed in Taiwan, Mainland China, Japan and Korea. It occurs widely in Taiwan from the sea shore flats to hardwood forests at 2,000 m elevation. It is used for scenic planting in greenbelts and parks, or for windbreaks, and it is an important timber species.

Incense nanmu is a large evergreen tree with straight trunk about 30 m tall. It is native to Taiwan and grows in hardwood forests at elevations below 1,800 m. The wood is aromatic (or fragrant) and is used as construction timber, furniture and bridge-building. The bark contains a sticky material that can be ground into powder and used in the preparation of incense-sticks. It is a favored native tree species for greening, street and park plantings.

Collection and Processing

Large-leaved nanmu and incense nanmu flower in February-March, and fruits mature in June-July and May-June, respectively, when the round berries turn from green to dark purple. Red nanmu flowers in February to April, and fruits (berries) mature in May-July. Freshly collected mature berries are hard and need to be softened in a warm, moist greenhouse for a couple of days before seed removal by rubbing and washing. Berries should never be dried directly under the sun. Cleaned seeds require careful handling since they can not tolerate drying. Seed size varies greatly with seed source.

Some physical characteristics of the seeds are summarized below (Chung and Chang 1990, Sheu et al. 1999, Ching-Te Chien unpublished data):

Species	*M. kusanoi*	*M. thunbergii*	*M. zuihoensis*
Weight of seeds (g/L)	490-550	543	720
No. seeds/L	900-1,200	540-680	5,850
No. seeds/kg	900-1,200	950-1,100	8,130
Weight of 1,000 seeds (g)	833-900	800-1,000	123

Seed Dormancy and Germination

Seeds have no dormancy and can germinate to high percentages.

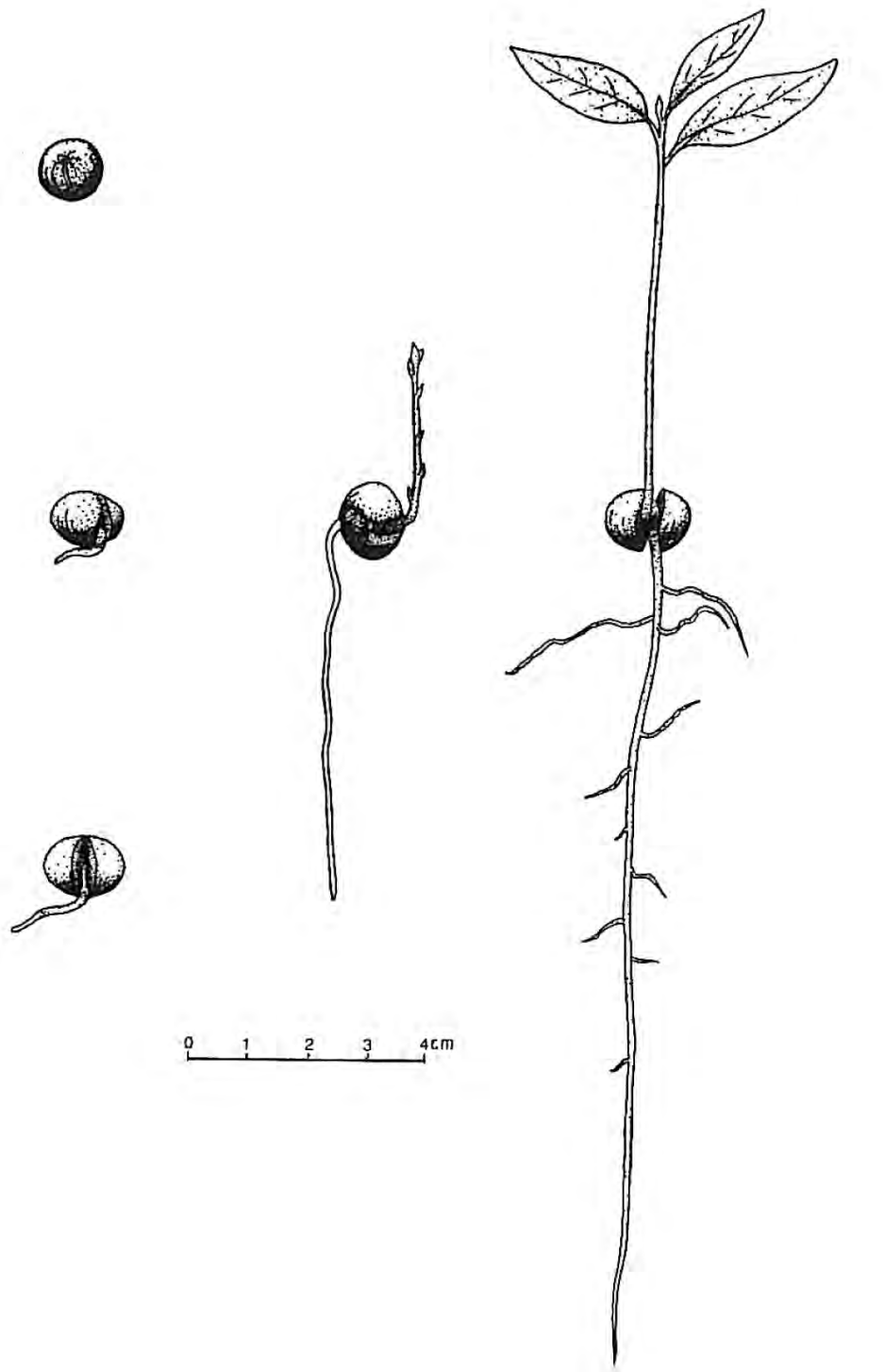
Seed Storage

Seeds of all three species have typical recalcitrant storage behavior. Seeds of large-leaved

and red nanmu can be stored moist at 5℃ for 2-4 months depending on seed quality, while those of incense nanmu can be stored moist at 5℃ for longer than 2-4 months but less than 12 months. It is thus recommended that seeds of these three species should be sown as soon as they are collected or stored with moist sphagnum in plastic bags at 5℃ over winter (Chien and Lin 1996, Lin and Chen 1993, Chien et al. 1994)

Nursery Practice

The freshly collected mature berries are often still hard and require spraying with water in a greenhouse for few days until they become soft enough for processing. The seeds will germinate on the moist sandy beds in 1-2 weeks. The germinated seeds can be transplanted into containers filled with a mixture of sandy loam and manure. The medium should be a mixture of peat moss, vermiculite, perlite and manure should be at a ratio of 1:1:1:1. If seeds have high germinability and vigor, they can be sown directly into containers. This is especially true with large-leaved nanmu which has a deep taproot. Young seedlings require full light to promote their growth except during the seed germination and transplanting period when they need 50% shade cover for 2 months. For seedling development, attention must be given to watering, weeding, application of fertilizers and protection from insects and diseases. Care must be taken for transplanting and trimming of side roots growing outside the containers.



***Machilus kusanoi* Hayata** (From Chung and Chang 1990)

Michelia compressa (Maxim.) Sargent

Magnoliaceae
Formosa Michelia

Growth Habit, Occurrence and Use

Formosa michelia is a medium sized evergreen broadleaf tree about 20-30 m tall with a grayish-brown, spotty bark. Leaf buds are covered with reddish brown fine hair. Leaves are lanceolate or elliptical, opposite and about 6-11 cm long and 2-4 cm wide. It is a valuable broad-leaved forest species and grows all over the island at elevations of 200-2,200 m. Its wood is hard and strong with beautiful structure and is a grade 1 hardwood suitable for construction, carving, musical instruments, high-class furniture and other arts and hand-craft products. The species also is used for ornamental and street tree plantings. It is well-known in Taiwan as one of the five major hardwoods, along with *Cinnamomum kanehirae*, *Sassafras randaiense*, *Zelkova serrata* and *Diospyros discolor*.

Collection and Processing

Formosa michelia flowers in January-March, and the white flowers are fragrant. Fruits ripen in September-October, at which time the arils turn red. Each follicle contains 2-4 flat, oval seeds. Fruits can be collected in September-October. Only small fruit-bearing branches should be pruned for seed collection in order to maintain continuous future fruit production capability. Collected fruits should be spread thinly on the ground or in aerated nylon bags for drying. Fruits should never be dried directly in the sun. It is a good practice to turn over the fruits frequently to avoid heating or molding. It usually takes about 3-5 days of air drying for the fruits to open and release the seeds. Cleaning of the seeds is done by washing and rubbing to remove the arils and floating to remove the empty, undeveloped seeds.

Physical seed characteristics are summarized below (Sheu 2007, Chung and Chang 1990):

Weight of seeds (g/L)	599.4
No. seeds/L	7,860
No. seeds/kg	9,300
Weight of 1,000 seeds (g)	108

Seed Dormancy and Germination

Formosa michelia seeds are dormant and require 4-month cold stratification in moist sphagnum medium at 5℃ for vigorous, uniform and maximum germination percentage.

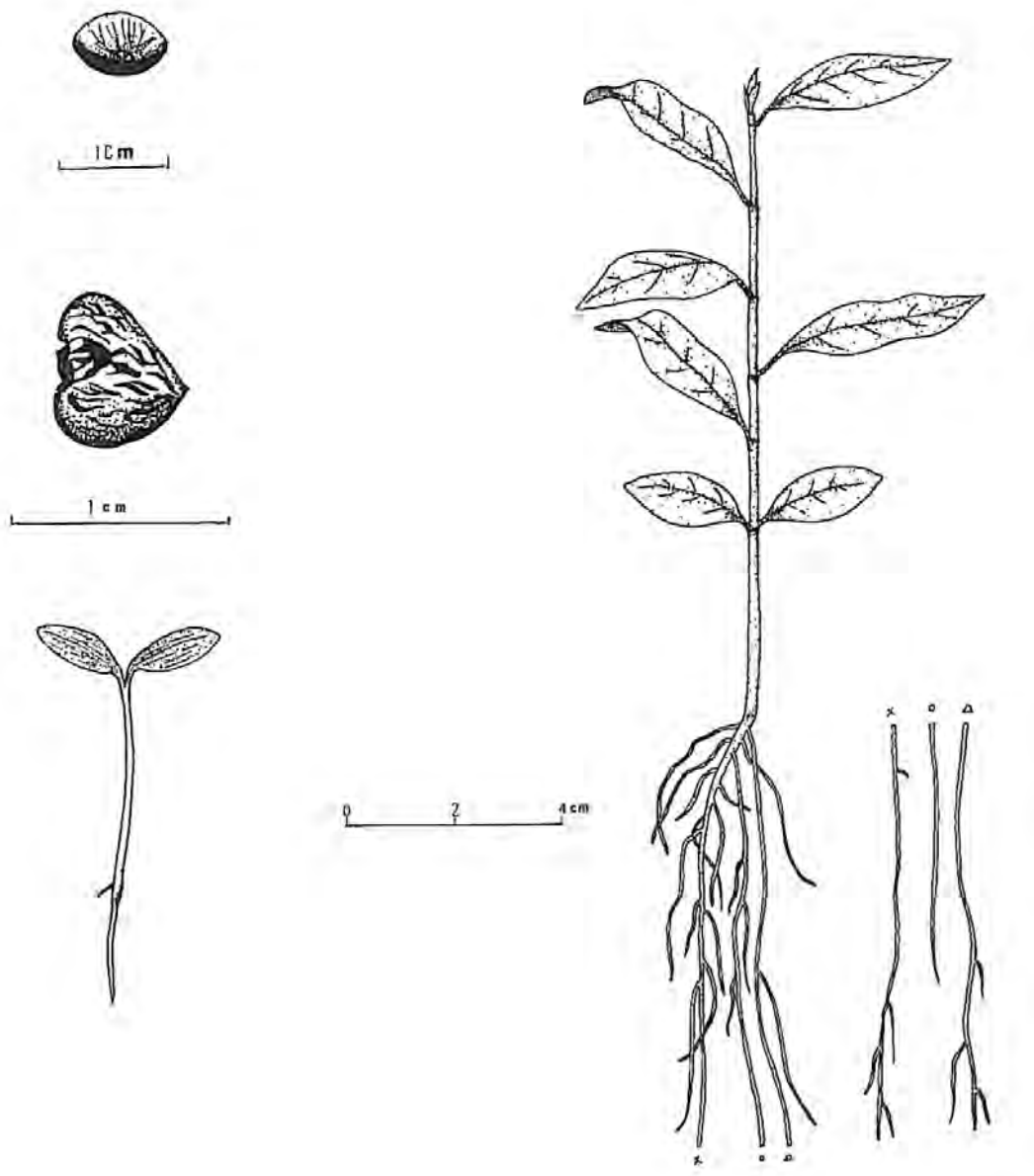
Seed Storage

Seeds have orthodox storage behavior although they have been considered as recalcitrant. For seed sowing the next spring, it is best to store seeds moist at 5℃. For long-term storage, moisture content must be reduced to 5-6% (fresh weight) and seeds placed at -20℃ (Lin and Wu 1995).

Nursery Practice

Mature fruits are collected by clipping small fruit-bearing branches. To allow for future continuous fruit production, pruning of large branches should be avoided. Collected mature fruits should be air-dried in shady places and with frequent turning-over and wetting. Further cleaning can be done by washing the seeds with clean water to remove the arils, debris and empty and undeveloped seeds. For spring sowing, the seeds can be cold stratified at 5℃ for 4-5 months before sowing. Good quality seeds should have 80% germinability. For container seedling production, germinants should be transplanted to containers for continued

culture. During the initial seedling development stage, seedlings should be covered with 40-50% shade screen. Since seedlings have a tap root, they need to be moved every other month. Application of NPK complete fertilizer will promote root-hair growth and increase seedling quality. The seedlings can be out planted when they reach over 30cm tall.



***Michelia compressa* (Maxim.) Sargent** (From Chung and Chang 1990)

Myrica adenophora Hance

Myricaceae
Hengchun Bayberry

Growth Habit, Occurrence and Use

Hengchun bayberry is a small evergreen tree or shrub with grayish bark and pubescent branchlets. Leaves are subsessile or short-petiolate, coriaceous, obovate-oblong, 2-5 cm long, 1-2 cm broad and have slightly revolute margins. The species occurs in Mainland China's Guangdong and Fijian provinces and Taiwan's Hengchun Peninsula, as well-as in the eastern and sourthern parts of Taiwan, where it grows in thickets at low elevation. Although Hengchun bayberry and the Mainland Chinese bayberry are considered to be the same species (Yang and Lu 1996), starch gel electrophoretic analysis showed that they may be two species (Cheng et al. 2000). Fruit size of Hengchun bayberry is smaller than that of Chinese bay-berry. Even within Hengchun bayberry, the flowering time of trees growing in Hengchun Peninsula differs from that of trees growing in Taitung, although their morphological characteristics are similar. Hengchun bayberry is classified as a rare species in Taiwan, and there is a need for improving propagation and increasing planting of this species. This shrub is mainly planted for landscaping and greening purposes.

Collection and Processing

Hengchun bayberry is mostly dioecious. The staminate catkins are about 1.5 cm long, solitary or in short panicles of 3-6 staminate flowers, and each flower has 2-4 stamens. Pistillate catkins are about 1.2 cm long and pubescent. The fruit is a small ovoid or globose drupe that is resinous with a hard endocarp. Seeds have a membranous testa, no endosperm and a straight embryo with plano-convex cotyledons and a short radicle. Seeds mature in January-March in Hengchun district and in August-October in Taitung. Fruits are collected when they turn reddish purple, and they vary from 0.6 to1.3 cm in diameter. The fleshy fruits are placed in nylon nets, and seeds are extracted by rubbing them against each other followed by washing and floating in water to remove fruit material, debris and empty seeds. The cleaned seeds are air-dried in shade for 24 hours before storage.

Seed Dormancy and Germination

Hengchun bayberry seeds have physiological dormancy from which they can be released by a combination of 2-month warm (30/20℃ with 12-hour light) and followed by 2-month cold (5℃) stratification. Germinability reached 70% when the treated seeds were incubated at 30/20℃ with 12-hour light for 8 weeks (Chien et al. 2000). Seed lots from Hengchun Botanic Garden germinated to 89% following 2-month warm stratification at 30/15℃ and 3-month cold stratification at 5℃ or after 2-month warm at 25℃ constant and 3-month cold stratification. In contrast, seeds from Chiupeng and Hsuhai reached a maximum germinability of 50% after 2-month warm stratification at 30/20℃ and 3-month cold stratification (Chien et al. 2000). To save time, 1000-2000 p.p.m. GA_3 can be used as a substitude for both the warm and cold stratification treatments.

Seed Storage

There is no information on seed storability of this species. However, based on storability information of *Myrica gale* seeds (Schwintzer and Ostrofsky 1989), it is suggested the seeds of Hengchun bayberry have orthodox storage behavior. Thus, if the moisture content is reduced seeds can be stored dry at 5℃ or -20℃.

Nursery Practice

Prior to sowing, seed dormancy must be broken by 2-month warm stratification followed by 3-month cold stratification. To save time, however, seeds can be planted after soaking in 1000-2000 p.p.m. GA_3 for > 12 hours (Chien et al. 2000). For other procedures, consult the information for *Myrica rubra*.

Myrica rubra (Lour.) Sieb. et Zucc.

Myricaceae
Chinese Bayberry

Growth Habit, Occurrence and Use

Chinese bayberry is a medium-sized evergreen tree up to 20 m tall and 1 m in diameter. Its bark is gray with shallow longitudinal furrows, and its branchlets are glabrous. Leaves are obovate-elliptic or oblanceolate, 5-10 cm long, 2-2.5 cm wide, entire or serrate above the middle, glabrous on both sides, have an obtuse or rounded apex and a narrowly-cuneate base, and petioles are 0.2-1 cm long. The species is distributed in southern China, Japan, Korea, Taiwan and the Philippines. Chinese bayberry occurs in thickets and forests at low elevations (300-1,500 m) throughout Taiwan. The tree is beautiful for planting on urban streets, in parks or as hedges. It also has been suggested that the wood could be used for the middle layer of sound barriers. Roots have nitrogen fixing nodules. The bark contains tannin that can be extracted for dyestuffs. The species can be cultivated as a fruit tree, and the fruits are edible and can be preserved.

Collection and Processing

The yellowish green dioecious flowers of Chinese bayberry open in March-April. Staminate inflorescences are solitary or several tuffed together in axils of leaves and 1-3 cm long, and staminate flowers have 4-6 stamens. Pistillate inflorescens are solitary, axillary and 0.5-1.5 cm long. The fruits (drupes) mature in June-July when they turn purple red. Freshly harvested mature drupes should be placed in a cool well-ventilated place until they become soft for processing and cleaning with water, but caution must be exercised to prevent them from fermenting. Cleaned seeds (enclosed by endocarp) must be air dried in shade for 1-2 days before storage or pre-sowing treatments.

Physical seed characteristics are given below (Chung and Chang 1990, Sheu 2007):

Weight of seeds (g/L)	513
No. seeds/L	3,040
No. seeds/kg	5,920
Weight of 1,000 seeds (g)	170

Seed Dormancy and Germination

Chinese bayberry seeds have physiological dormancy and require a combination of warm and cold stratification to release dormancy before maximum germination can be obtained (Chien 1998). According to Chien et al. (2000), the seeds must be mixed with moist sphagnum in plastic bags (0.04 mm thickness) at 25/15℃ with 12-hour light for 6 months followed by 3-month cold stratification at 5℃ to break their dormancy for maximum and uniform germination. The seeds so treated began to germinate in 2 weeks at 25/15℃ with 12-hour light, and germination reached 64-68% (Chien et al. 2000). Because of the prolonged treatment period, it is important to check the color of the sphagnum medium and replace it if it turns black (Chien et al. 2000). To promote seed germination, seeds first are soaked in 1000 p.p.m. GA_3 for 24 hours and then germinated at 30/20℃ (Chen et al. 2008a).

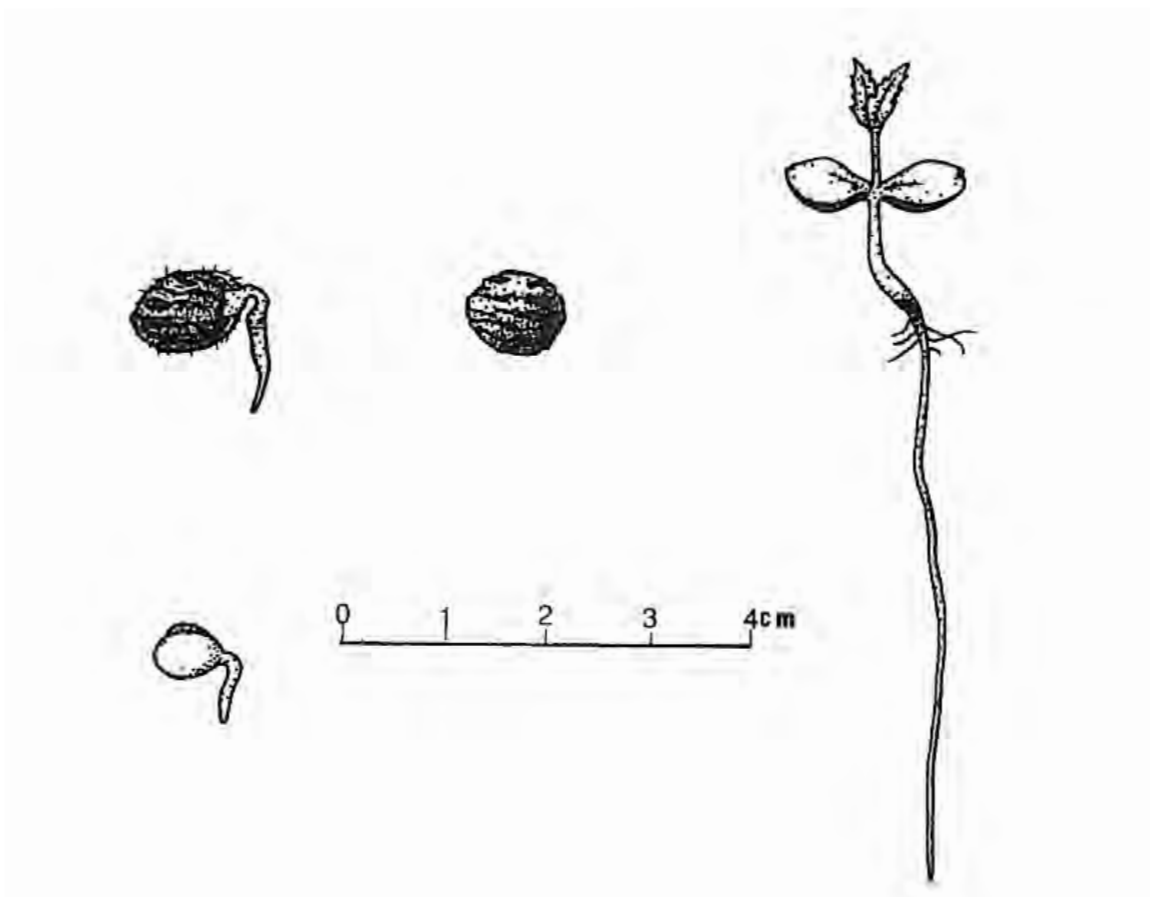
Seed Storage

Chinese bayberry seeds are orthodox, and after a reduction in moisture content they can be stored dry. Seeds can be stored moist at 5℃ for a year or longer or dry stored at 5℃ for 2 or more years (C.T. Chien, unpublished data). Also, the report by Schwintzer and Ostrofsky (1989) that seeds of

Myrica gale remained viable after 6 years of storage at 5℃ seems to infer that the Chinese bayberry have orthodox storage behavior.

Nursery Practice

The freshly harvested drupes should be placed in a cool, shady place with good ventilation. When drupes become soft, they should be macerated and cleaned with water. Cleaned seeds must be air dried in shade for 1-2 days before giving them warm followed by cold stratification. In the absence of alternating temperature germination facilities, fresh seeds should be sown outdoors in moist sand; it is important to keep the sand moist. As seeds germinate, germinants should be transplanted into containers such as plastic bags or dibbling tubes. Container medium should be sandy loam soil with manure. In the early stages of development, transplants must be covered with a shade screen that can be removed when plants reach a height of 10-15 cm. Exposure to full sun will promote continued growth of seedlings. Chinese bayberry seedlings have strong resistance to damage from insects and diseases. Application of combined NPK fertilizers will promote seedling growth and quality (Chien 1998).



***Myrica rubra* (Lour.) Sieb. et Zucc.** (From Chung and Chang 1990)

Nageia nagi (Thunb.) O. Kuntze

Podocarpaceae
Japanese Podocarp

Growth Habit, Occurrence and Use

Japanese podocarp is a large evergreen tree. Leaves are opposite or sub-opposite, coriacious, ovate, ovate-lanceolate or elliptic, 6 cm long and 2 cm wide, bright green on both surfaces and subsessile. The bark is dark brown, irregularly flakey and spline-shaped or with somewhat rectangular flake-scars on the tree. This species is distributed in southern China, Japan, Ryukyu (Okinawa) islands and in Taiwan. The bamboo-like leaves favor the species for landscape plantings. The wood is used for construction, furniture, sculptures and making match stickes and paper.

Collection and Processing

Japanese podocarp flowers in April-May, and seeds mature in August-October. Mature seeds with green fleshy sarcotesta are collected and placed in a cool and moist place for several days until sarcotesta becomes soft, and then they are washed and cleaned with water to remove the sarcotesta. All cleaned seeds are air-dried at room temperature overnight and then stored at 5℃. According to local records from Nan-Zuang (1992, 1994), yield of cleaned seed was 472 g per kg of fruits (based on 3.6 kg of fruits); there are 931-1,180 seeds in a liter and they weigh 586-667 g.

Seed Dormancy and Germination

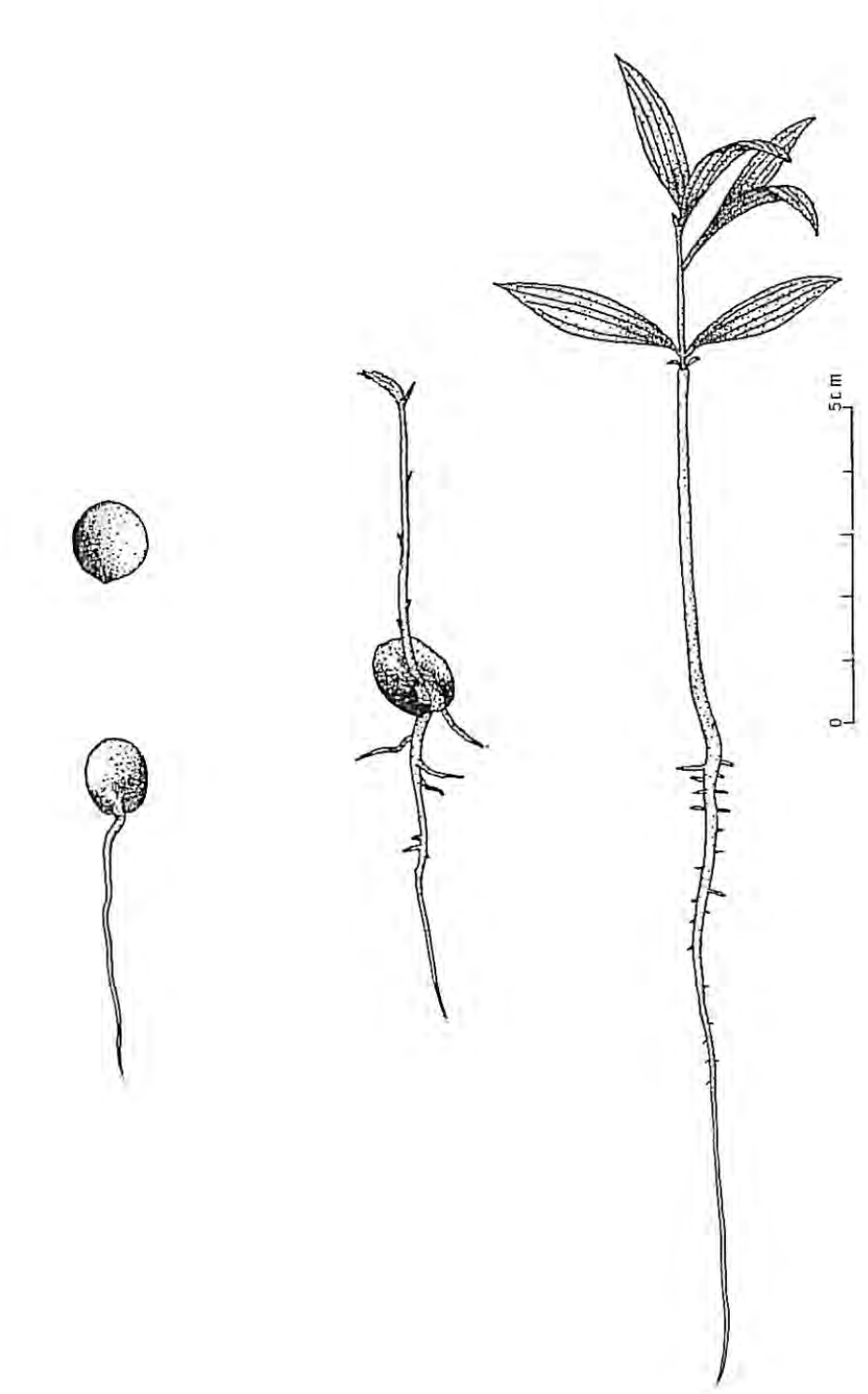
The embryo in fresh seeds of *N. nagi* is small, and it increased in length by about 39% inside the seeds before radicle emergence occurred; thus, the embryo is underdeveloped. Germination of *N. nagi* seeds reached the maximum 99% after 14 weeks at 25℃ and 16 weeks at 30/20℃, thus, most seeds have morphophysiological dormancy (Chen et al. 2013).

Seed Storage

Seeds have tropical recalcitrant storage behavior, and moisture content of freshly harvested seeds is 32%. Seeds should be sown immediately after collection or stored in moist sphagnum at 4-5℃ for sowing the next spring. Storage studies (1992-1995) indicated that retention of seed viability was not directly related to moisture content, but rather it was related to how and under what conditions the moisture content is reduced. More in-depth research is required.

Nursery Practice

Because they are recalcitrant, seeds should be sown immediately following processing or stored in moist sphagnum or fine sand in plastic bags at 4-5℃ for sowing the next spring. The maximum lifespan for seeds in moist, cool storage is 1 year. Seeds can be sown directly on seedbeds or in containers because of their usual high germinability. As in standard nursery practice, it is important that seedbeds or containers be kept moist with proper shading, weeding, watering and application of proper fertilizers, insecticides and herbicides during the early stages of seed germination and seedling development. The medium for containers should be a mixture of sandy loam soil and manure.



***Nageia nagi* (Thunb.) O. Kuntze** (From Chung and Chang 1990)

Neolitsea konishii (Hayata) Kanehira & Sasaki

Lauraceae
Konishi Neolitsea

Growth Habit, Occurrence and Use

Konishi neolitsea is a medium-sized evergreen tree with an umbrella-shaped crown. Leaves are alternate, coriaceous, crowded at the branch tip, lanceolate or oblong, 10-15 cm long and 3.5-4.5 cm wide, abruptly acuminate at the apex and cuneate at the base. Leaf marins are entire, and leaves are distinctly 3-nerved with 3 pairs of lateral veins, glabrous above and glaucous and appressed pubescent beneath when young but becoming glabrate; petioles are 1-1.5 cm. This species is endemic to Taiwan where it occurs in broadleaf forests up to 1,500 m elevation; it is especially abundant in the central and northern parts of the Island. The wood is used for construction and furniture. The beautiful form of the tree makes it a desirable ornamental and greening species.

Collection and Processing

Konishi neolitsea is dioecious and flowers in June-July. Male flowers are axilary or terminal in a head inflorescence, and the rounded involucral bracts are fugacious. The oblong drupes are about 15 mm long and 12 mm wide and become purple black at maturity in November-December. Seeds (enclosed by endocarp) are removed by rubbing, and sound seeds are separated from fruit debris and unfilled seeds by floatation in water. Clean seeds are stored in moist sphagnum in plastic bags at 5℃.

Physical seed characteristics are given below:

Weight of seeds (g/L)	586
No. seeds/L	1,980
No. seeds/kg	3,370
Weight of 1,000 seeds (g)	296

Seed Dormancy and Germination

Seeds have physiological dormancy and require 3-4 months of cold stratification in moist sphagnum at 5℃ for maximum percentage, speed and uniformity of germination. However, fresh seeds collected from Nanheng highway in 1995 reached 68% germination without any pre-treatment (TFRI, unpublished data).

Seed Storage

Konishi neolitsea seeds have recalcitrant storage hehavior and can be stored for only a very short period of time in moist sphagnum at 5℃. Seeds dried to moisture contents of 22.5, 17, 15.2, and 10.9% and stored at 4, 15 and -20℃ were all dead after 2 months (TFRI, unpublished data).

Nursery Practice

Pre-chilled seeds can be sown directly onto prepared seedbeds with overhead shade-screens in the spring. Seeds should be covered thinly with fine sand and kept moist. When germination begins, the germinants can be transplanted into containers. The preferred medium is sandy loam soil mixed with manure. Regular irrigation, weeding and preventive pest control should be maintained during the seedling development period. When seedlings reach 20 cm tall, liquid fertilizers should be applied.

Palaquium formosanum Hayata

Sapotaceae
Formosan Nato Tree

Growth Habit, Occurrence and Use

Formosan nato tree is an evergreen 15-20 m tall with grayish brown bark that contains rich white milky juice. Leaves are simple, alternate, thick coriaceous with fugacious stipules, obovate-oblong, 10-15 cm long and 5-7 cm wide, rounded at the apex, emarginate, obtuse at the base and have entire margins. They are olive green, glabrous, lustrous on the upper surface and a yellowish green on the lower surface. The midrib and lateral veins are not very distinctive above, but they are prominent beneath. This species occurs in coastal areas of the Philippines and Taiwan. Many individuals of this species can be found growing in Hengchun Peninsula and Lanyu of southern Taiwan. It grows best in a high temperature and high humidity environment with well-drained, fertile, sandy loam soil rich in organic matter (Lai 1987). The fruits are edible, and the bark can be used for dyestuffs and the wood for construction. The species is very resistant to sea wind and pollutants and grows well in dry and wet sites. Thus, it is a superior coastal shelterbelt species. It is also suitable for ornamental planting in gardens and parks.

Collection and Processing

The flowers of Formosan nato tree are axillary and long-pedunculate, have a yellowish green corolla. They open in October-November and have a rank odor. Fruits are dark purple, elliptic, fleshy drupes that ripened in July-August of the next year. Each drupe usually contains a single flattened-elliptic seed but occasionally 2-4 seeds. Seeds (enclosed by an endocarp) are extracted by removing the outer fruit coat and washing with water. Cleaned seeds should be lightly dried in shade before sowing.

Physical seed characteristics are as follows (Sheu 2007):

Weight of seeds (g/L)	500
No. seeds/L	127

Seed Dormancy and Germination

Seeds have no dormancy, and complete germination requires 3-5 weeks.

Seed Storage

Seeds have recalcitrant storage behavior; thus, it is best to sow them as soon as they are collected.

Nursery Practice

Cleaned seeds can be sown onto moist seedbeds and covered with a thin layer of fine sand, and it usually takes 20-30 days for most of the seeds to germinate. Since this species has a tap-root system, germinants should be transplanted into containers for continuous development. Transplants should be covered with a 60% sun screen that is removed after 2 months. Container medium should be well-drained sandy-loam soil mixed with manure. During the seedling development period, attention should be given to scheduling irrigation, weeding, application of fertilizers and pest control. Sunny locations are best for seedling propagation.

Phellodendron amurense Rupr. var. *wilsonii* (Hayata and Kanehira) Chang

Rutaceae
Taiwan Cork-tree

Growth Habit, Occurrence and Use

Taiwan cork-tree is deciduous and occurs in China, Korea, Japan and Taiwan. It is sparsely distributed in natural mixed evergreen coniferous and broadleaf forests in central and northern Taiwan at elevations of 1,600-2,400 m. The taxon is considered to be endangered and requires urgent conservation measures. The branchlets are slightly hairy. Leaves are ovate-oblong, chartaceous, about 27 cm long (including petioles) and 15 cm wide, compound with 9 opposite or alternate leaflets that are acuminate at the apex and oblique at the base. They are glabrous above and pubescent along the veins beneath and have subentire margins. Leaffall occurs in October-November. This species is a valuable source of medicinal compounds. The inner-bark contains 5 major alkaloids (berberine, obacunone, phellodenrine, magnoflorine and palmatine) that are the principal ingredients for stomach medicines. Taiwan cork-tree is sought after for its high yield and superior quality of these alkaloids.

Collection and Processing

Flowering occurs in March-April, and flowers are in axillary or terminal racemes. The fruits are globose berries that mature in August-September and are ripe when they turn black. Each berry contains 3-5 black or reddish brown seeds, although 4 seeds are common (Chien 1998). Freshly collected mature berries are artificially ripened in the greenhouse with frequently spraying with water. The berries should be turned over frequently to prevent them from heating, fermenting and developing mold. As the berries become soft, they should be macerated by rubbing over wire-screen and the pulp, debris and empty seeds separated from good seeds with water. The seeds that sink in water are slightly surface-dried in the shade and then stored in moist sphagnum at 4-5℃. The number of cleaned seeds per liter varies from 70,000 to 100,000.

Seed Dormancy and Germination

Seeds have physiological dormancy and require at least 12 weeks of cold stratification, followed by incubation at 35/10℃ with 12-hour light to germinate (Chien et al. 2006). The seed coat may mechanically restrict embryo growth, thus soaking scarified seeds in 500 ppm GA_3 or GA_4 will significantly enhance seed germination (Chien et al. 2006, Chen et al. 2010)

Seed Storage

Taiwan cork-tree seeds can be dried to < 10% moisture content and stored at sub-freezing temperatures; thus, they are classified as having orthodox seed storage behaviour (Chien et al. 2006; Lin et al. 1994). Lin et al. (1994) found that seeds dried to 6.6% moisture content could be stored at -20℃ for at least 16 months, and Chien et al. (2006) reported the seeds dried to 8.8% moisture content survived storage at -80℃ and -196℃ for 7 months. They recommend that the seeds should be dried to a moisture content of < 10% and stored in liquid nitrogen for long-term conservation purposes. Seeds of this species from Mainland China with a moisture content of 8-10% survived for 4-5 years at 0-5℃ (Zhou and Zou 2001).

Nursery Practice

After sound seeds are separated via flotation in water, they are cold stratified at 5℃ for 3-5 months before sowing. Sowing could be done indoors at

35/10℃ with 12-hour light because seeds receive some cold stratification at 10℃ each day. However, seeds can be cold stratified at 4-5℃ for 12 weeks and then sown at warm temperature, *e.g.* 30/20℃ for fast germination (Chen et al. 2010). The germinating seeds can be transplanted into containers as soon as the radicle emerges. Sandy loam soil mixed with manure is the preferred container medium. For bare-root seedling production, cold-stratified seeds are drill-sown in four rows per m^2, and seeds are covered with soil 2-3 times deeper than the thickness of the seed. Overhead shade screen and regular watering are needed. The density of the developing seedlings should be checked 2 months after seed germination and thinned if necessary to a density of 100-140 seedlings/m^2. The 1-year-old seedlings can be field-planted when their height has reached 35-45 cm.

Pinus morrisonicola Hayata

Pinaceae
Taiwan Short-leaf Pine

Growth Habit, Occurrence and Use

Taiwan short-leaf pine is a large tree belonging to the soft-pine group. Young bark is gray and smooth, but mature bark has irregular, shallow fissures or shallow crackes and scaly and tiered layers of scales. Leaves are 5-fascicled, dark green, about 8 cm long, triangular in cross section and have 1 vascular bundle and 2 marginal resin ducts. This species is endemic to Taiwan and often is found growing in broadleaf forests at elevations of 300-2,300 m throughout the island. It often forms pure stands on top of cliffs and on mountain ridges. Many trees of this species are found growing in the mountainous areas of Puli and Guguan of the central part of Taiwan. It is a pioneer in open, denuded areas and can be used for afforestation purposes because of its fast growth rate. The wood is an important material for construction, paper making and extraction of resin. It is also used as an ornamental tree for landscaping and greening purposes due to its beautiful form.

Collection and Processing

Taiwan short-leaf pine produces male and female cones in February-March, at which time pollination occurs. Seeds ripen in October of the next year. Female cones are ovoid to ellipsoid, about 10 cm long, 4-5 cm in diameter and with have oblong scales that are slightly reflexed at the apex; they change from green to brown when mature. Seeds have a long wing. Cone collection should be made when the cone scales turn brown but before they open. Freshly collected mature cones should be spread out thinly for air-drying in a well-ventilated place or in screen-bottom trays and turned over frequently. There are several techniques to measure seed maturity, including cone moisture content, specific gravity, cone and seed wing color and seed cutting test. Of these, a combination of cone color change and results of the cutting test give practical and accurate information for judging seed maturity. The cutting test shows that the embryo of a mature seed occupies 90% or more of the embryo-corrosion cavity (Kolotelo et al. 2001). Cones are usually collected just before they start to open and then are artificially ripened in a cool well-ventilated place and sun-dried. As cone opens, they can be tumbled in a rotating drum or in a cone shaker to extract the seeds, after which they are de-winged by hand or in a big container by the moist method (see Kolotelo et al. 2001). De-winged seeds are subjected to a blower or air aspirator treatment to remove the detached wings, underdeveloped or empty seeds and debris. The cleaned seeds need to be air-dried to reduce seed moisture content to 4-7% for storage.

Physical seed characteristics are as follows (Chung and Chang 1990, Sheu 2007):

Weight of seeds (g/L)	438.5 (467.8)
No. seeds/L	5,370 (5,194)
No. seeds/kg	12,250
Weight of 1,000 seeds (g)	81.5

Seed Dormancy and Germination

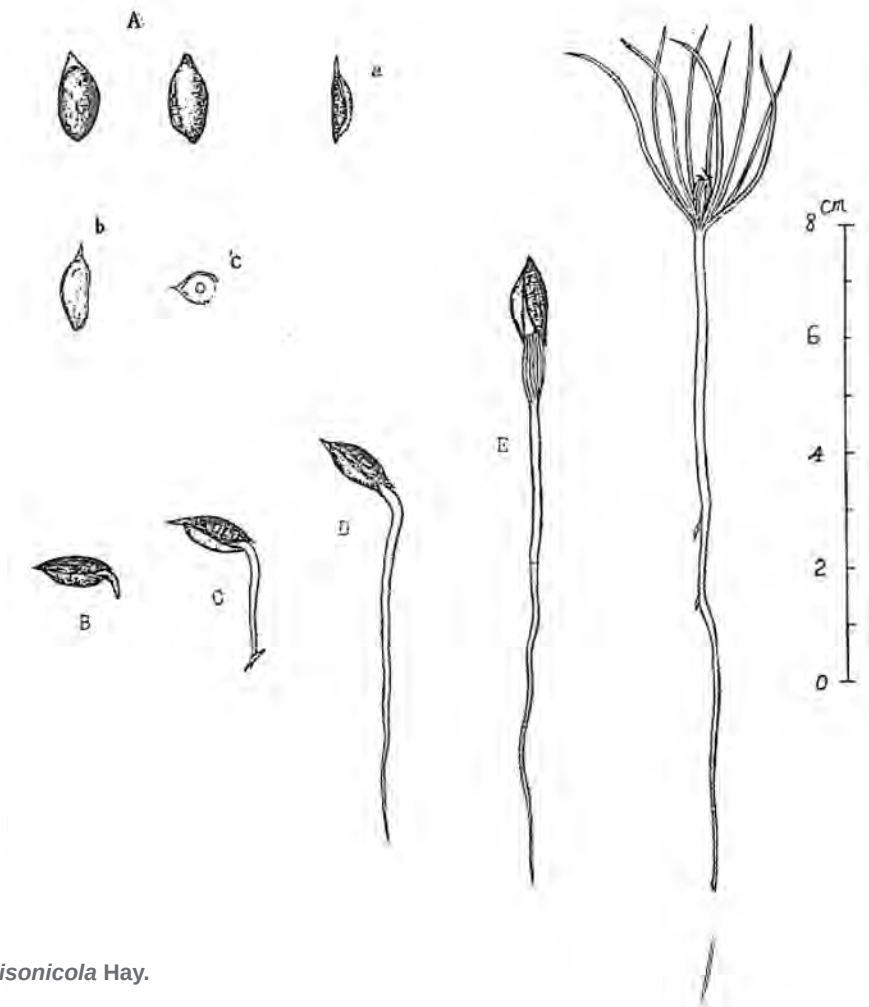
Seeds have physiological dormancy and require 8-week cold stratification at 7℃ to become nondormant; after this treatment they are incubated at 30℃ for 21 days (Kao 1969a, 1969b). Seeds were used successfully for studying seed viability using x-radiography and x-ray contrast technique (Yang 1966).

Seed Storage

Seeds can tolerate drying and sub-freezing temperature and thus have orthodox storage behavior. They can be stored dry in sealed containers at -20℃ for a long period of time.

Nursery Practice

The dormant seeds can be sown in late fall or cold stratified and sown in the spring. For bare-root stock production, cold stratified seeds can be drill-sown or broadcast by hand onto moist sandy loam soil seedbeds or directly into containers filled with sandy loam soil mixed with manure. Germination takes about 28 days with an average of 70% (Chung and Chang 1990). High sowing densities are used when plants are to be grown in transplant beds for 1 or 2 extra years. To prevent damping-off, fungicides are required during and after seedling emergence, and both fungicide and insecticide treatments are needed during the growing season to control insects and foliar diseases (Krugman and Jenkinson 2007).



***Pinus morrisonicola* Hay.**

A. Seed and sections (b, c) of seed
B. Radicle-emerged seed, day 1
C. Radicle-emerged seed, day 3
D. Radicle-emerged seed, day 5
E. Radicle-emerged seed, day 9
F. Seedling, day 14

From Yang 1984

Pinus taiwanensis Hayata

Pinaceae
Taiwan Red Pine

Growth Habit, Occurrence and Use

Taiwan red pine is a two-needle evergreen tree that occurs at elevations of 650-2,800 m in the mountains of Taiwan. The wood is used for construction, bridge-building and paper making. Young trees under 30 years old are used for paper making.

Collection and Processing

Taiwan red pine produces male and female cones in February-March, and seeds mature in November-December of the next year. Cones are 6-7 cm long and turn brown when the seeds are mature. Collected cones can be air-dried in the sun. Mature unopened cones can be moistened with water and turned over, but after they have been dried they can be flung to promote seed release. The seed is oval and about 5 mm long and has a knife-like wing 10–13 mm long.

Physical characteristics of the seeds are summarized below (Chung and Chang 1990, Sheu 2007):

Weight of seeds (g/L)	488-509
No. seeds/L	35,000-40,000
No. seeds/kg	80,740
Weight of 1,000 seeds (g)	12.4

The physical characteristics of Taiwan red pine seeds are difficult to distinguish from those of *Pinus massoniana* Lamb., *P. thunbergii* Parl. and *P. luchuensis* Mayr (Chung and Chang 1990).

Seed Dormancy and Germination

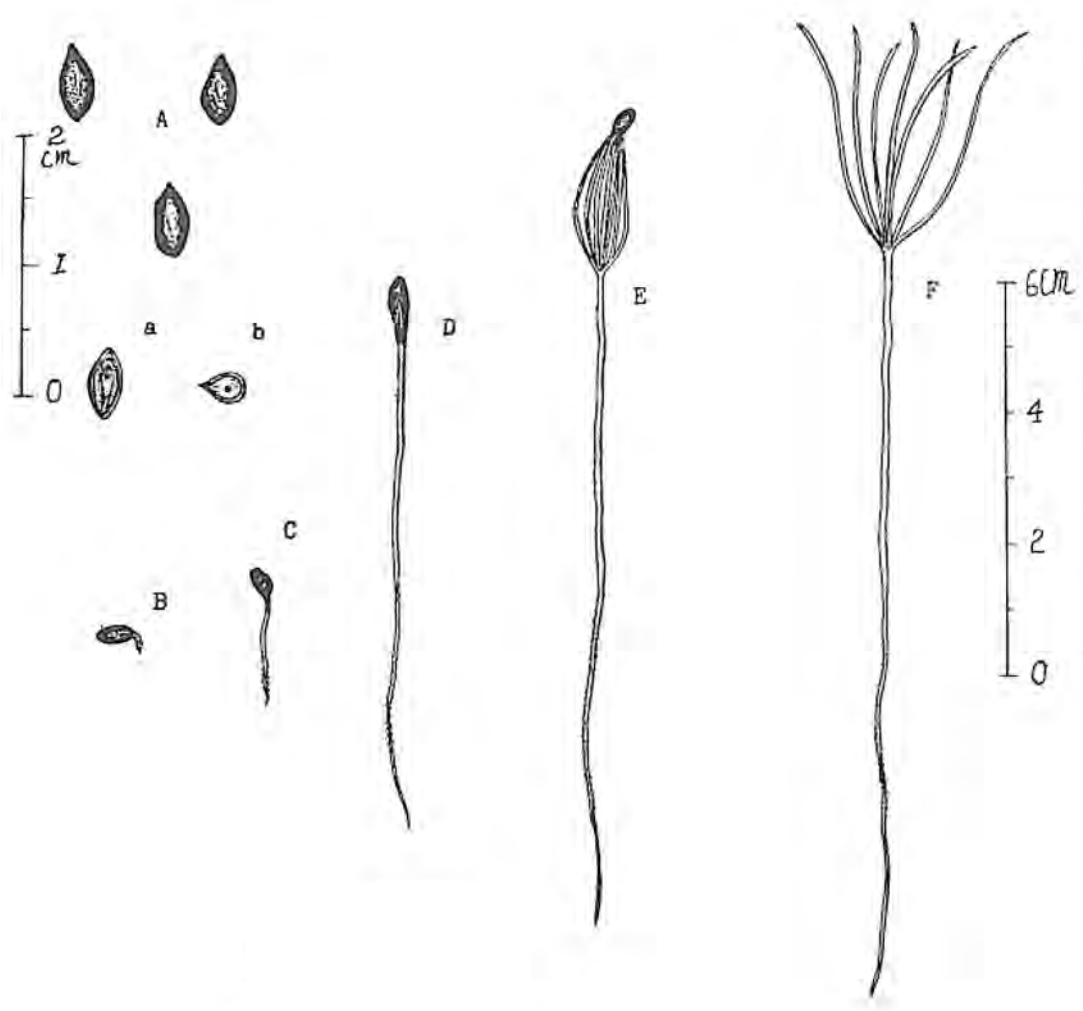
Seeds have physiological dormancy. Kung (1976) compared the effects of cold stratification and duration on the germination of coniferous seeds in Taiwan and found that red pine seeds are dormant and require 6 weeks cold stratification in moist sand at 5℃ for best results (78% germination in 8 days at 23℃ compared with 57% in 20 days of the nonstratified).

Seed Storage

Seeds are orthodox, and when seed moisture content is reduced to 6-10% (fresh weight) they can be stored for a short period of time at 5℃ or for a long time at -20℃ (Chien and Yang 2007, Yang 1984).

Nursery Practice

Seeds should be tested for quality evaluation before sowing. For maximum, fast and uniform germination, seeds should be cold stratified for at least 6 weeks at 5℃.



***Pinus taiwanensis* Hayata**

A. Seed and sections (a, b) of seed
B. Radicle-emerged seed, day 1
C. Radicle-emerged seed, day 3
D. Radicle-emerged seed, day 5
E. Seedling, day 10
F. Seedling, day 16

From Yang 1984

Pistacia chinensis Bunge

Anacardiaceae
Chinese Pistache

Growth Habit, Occurrence and Use

Chinese pistache is a large semi-deciduous tree that occurs in Mainland China, Taiwan and the Philippines. It can grow to 30 m tall and 2 m DBH. The stem is usually crooked, and the bark is grayish red-brown with irregular, longitudinal shallow furrows. Leaves are alternate and odd-pinnate with 6-10 of pairs leaflets, and new leaves are deep red. In Taiwan, the species grows from Miaoli County to Hengchun Penisula at elevations below 900 m. Its hard and dense wood makes is a first-class lumber. The wood is used for construction, furniture and sculpture, and the seeds contain 42% oil that can be extracted and used for lamp oil. Chinese pistache used to be a protected species and was promoted for use in reforestation. Because of its broad crown with lush, colorful autumn leaves, the species should be considered for ornamental planting. The weakness of this species is the tendency for old trees to have heart-rot. It is an ideal species for planting in barren, eroded or denuded land.

Collection and Processing

Chinese pistache dioecious and flowers in June-August (or April-May), and fruits (drupes) mature in October-December, when they turn from green to red and to dark red or purple. Although fruits mature in September-November, drupe collections are usually made in October-November. Collected mature drupes have waxy outer layers of the fruit coats and should be kept moist for 3-5 days and then soaked in warm water or diluted lime for 2-3 days to facilitate removal of the wax. Cleaned seeds (enclosed by endocarp) are extracted by hand maceration and washing with water. There are a high percentage of empty seeds that usually can be removed by water flotation. The cause of the high percentage of empty seeds may be due to a lack of a sufficient number of male trees within the effective pollination distance of female trees, unsynchronized male and female flowering times or the seasonal northeastern wind during the pollination period.

The physical seed characteristics are as follows (Chung and Chang 1990):

Weight of seeds (g/L)	457
No. seeds/L	17,350
No. seeds/kg	37,960
Weight of 1,000 seeds (g)	26

Seed Dormancy and Germination

Chinese pistache seeds have physiological dormancy and they are usually soaked in warm water for 24 hours or warm stratified in moist sand at room temperature for 2-3 months. Germination conditions are 20-25℃ with light for 30 days with average germinability of 20% (Chung and Chang 1990).

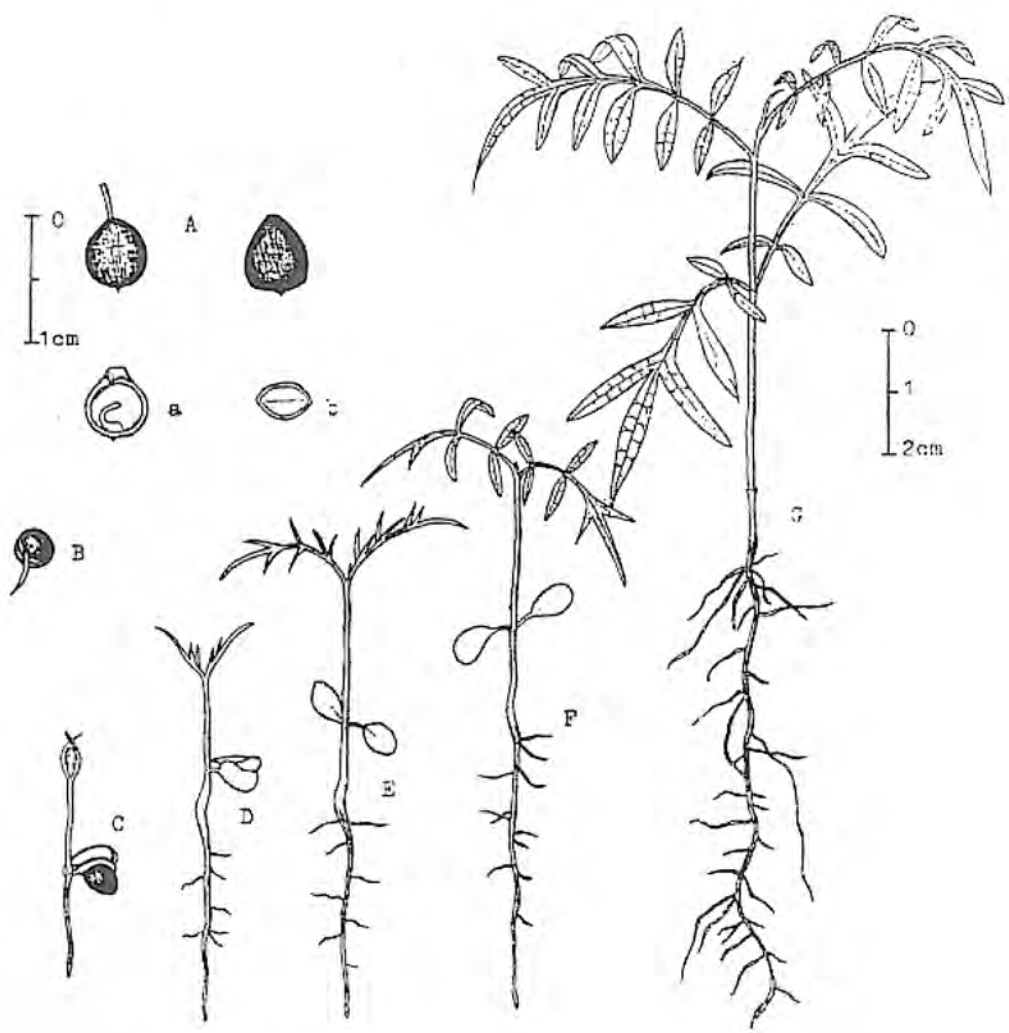
Seed Storage

The seeds have orthodox storage behavior. When their moisture content is reduced to about 6%, seeds can be stored in sealed containers at 5℃ for a short term and at -20℃ for a long term (Chien et al. 1997).

Nursery Practice

Planting stock is primarily propagated from seeds. Seeds should be soaked in warm water for 24 hours before spring sowing on seedbeds. Seedbeds should have an overhead shade screen of 50-60%. The suggested seed sowing rate is 0.03-

0.05 liter seeds per square meter. The sown seeds should be covered with 1.0-1.5 cm of soil. The overhead shade screen can be removed as soon as seeds begin to emerge through the soil surface. It usually takes 10 days from sowing seeds to begin germinating and 30 days to complete the germination. As seeds germinate, the germinants can be transplanted into containers. When seedlings reach 15-20 cm in hight, they should be moved and the tap root trimmed off to promote growth of the side-roots. They can be planted out in the next rainy season. The best container medium is sandy loam soil mixed with manure or a mixture of soil, sand and manure at the ratio of 1:1:1 (Chien 1998).



***Pistacia chinensis* Bunge**

A. Seed and sections (a, b) of seed
B. Radicle-emerged seed, day 2
C. Seedling, day 5
D. Young juvenile, day 7
E. Young juvenile, day 10
F. Young juvenile, day 20
G. Young juvenile

From Yang 1984

Prunus campanulata Maxim.

Rosaceae
Taiwan Cherry

Growth Habit, Occurrence and Use

Taiwan cherry is a medium-sized deciduous tree 8-15 m tall. It is native to southern Mainland China and Taiwan. The species is distributed all over Taiwan, but it is mainly found in hardwood forests in the northern and central parts of the Island at elevations of 300-2,000 m. It also can grow on the plains and at lower elevations. The prolific flowering and natural beauty of Taiwan cherry trees make it desirable for group plantings in parks, green belts, scenic areas and along highways and as shade trees for urban areas. The spring-blooming flowers attract tens of thousands of visitors to Alishan and Yang-Ming Shan every year. The pink-red colored wood with a yellow-stripped grain makes it a highly demanded material for sculptures.

Collection and Processing

Taiwan cherry flowers in December to February or March, depending on the locality. The red, bell-shaped flowers are pendulous, and the new leaves expand after the flowers are gone. The fruits (drupes) mature from April through June, when they turn red to reddish purple. Taiwan cherry is insect pollinated. Each drupe consists of a single seed, which is covered by the endocarp (stone). The embryo consists of two cotyledons, an epicotyl, a hypocotyl and a radicle. The drupes are edible and have a sweet and sour, slightly astringent taste. Seeds (covered by the stone) are extracted by mechanical or manual maceration of the outer layers of the fruit and empty seeds removed by floatation in water. Fleshy layers of the fruit contain high levels of the seed germination inhibitor abscisic acid (ABA). Therefore, they must be completely removed from the seeds for germination. Cleaned seeds are usually air-dried in the shade for a couple days before dry storage at 5℃.

The physical seed characteristics are shown below (Sheu 2007):

Weight of seeds (g/L)	564
No. seeds/L	4,285
No. seeds/kg	7,600
Weight of 1,000 seeds (g)	130

Seed Dormancy and Germination

Taiwan cherry seeds have an intermediate physiological dormancy and require a combination of warm and cold stratification for maximum germination percentage. Stratification at alternating temperatures of 35/10℃ or 25/15℃ for 1 month followed by 2 months of cold stratification at 5℃ will successfully break seed dormancy and promote 90-100% germination (Chien et al. 1996, Shu et al. 2000). Apparently, warm stratification lowers the concentration of the germination inhibitor ABA, while cold stratification at 5℃ increases the concentration of the germination promoter gibberellins (such as GA_4) in the embryo, which allows it to overcome the mechanical restriction of the endocarp (Chen et al. 2007a). By following the above treatment procedure, Taiwan cherry seeds can attain complete germination at alternating temperatures of 25/15℃ or 30/20℃ with 12 hour light in 2 weeks (Chien et al. 1996). For seeds of *Prunus avium, P. padu* and *P. serotina*, ISTA (2005) recommends viability testing first by tetrazoleum staining or excision of the embryo, or germination testing on sand at 30/20℃ or 20℃ with 8 hour light for 28 days following 3-4 month prechill at 3-5℃. To facilitate nursery sowing operations, Chien et al. (2002b) evaluated the effectiveness

of dormancy-breaking treatments prior to storage. They found that most pretreated seeds retained the treatment effects during storage at 5℃ or -20℃ for one year, with a loss of 20% germinability. They recommended the stored seeds be cold stratified for 2 weeks to restore treatment effectiveness.

Seed Storage

Seeds have orthodox storage behavior since they can tolerate drying to a moisture content of 5.8% fresh weight and a temperature of -20℃ (Shu et al. 2000). Seeds with a moisture content of 13.4, 10.1 and 5.8% retained their germinability for 1 year at -20℃, while 41, 32 and 88% of seeds with a moisture content of 17.2% lost germinability at 12, 5 and -20℃, respectively (Shu et al. 2000). According to Grisez (1974), high viability of *Prunus serotina* (black cherry) seeds with moisture content of 12-15% could be maintained for at least 3 years by storage at 0.5-5℃ or by drying the seeds to a moisture content of 4-6% and storage in a freezer (below 0℃). Both freezer storage at high moisture content and storage at room temperature resulted in loss of viability.

Nursery Practice

Seeds must be pretreated according to the above recommended procedures to break the seed dormancy. Then, seeds are sown directly on prepared sandy seedbeds and kept moist and shaded. Seed germination begins about 1 week after sowing. As seeds germinate, the germinants should be transplanted to suitable containers filled with a mixture of sandy loam soil and manure. If the seeds have high germination percentage and vigor, they can be sown directly into the containers. To facilitate seedling growth, attention should be given to scheduled irrigation, fertilization and weeding. With proper tending, seedlings grow fast and will reach 40-50 cm tall for field planting after 6 months.

Pseudotsuga wilsoniana Hayata

Pinaceae
Formosan Douglas-fir

Growth Habit, Occurrence and Use

Formosan Douglas-fir is a large tree with dark brown bark that has irregular deep longitudinal fissures. Leaves are flat, spirally arranged and spread in 2 rows, linear, 15-25 cm long and 1-1.5 mm wide, shiny green and grooved above, keeled with 2 whitish bands beneath and have an emarginated apex. This species is endemic to Taiwan and mainly occurs at elevations of 1,000-2,700 m in the upper stream of Dahsi River in Taoyuan County and the upper stream of Dajia River in Taichung County. The wood is second-grade coniferous lumber and is used for construction, ship-building and tools.

Collection and Processing

Formosan Douglas-fir produces male and female cones in March-April, and seeds mature in October of the same year. Mature cones are ovoid, 6 cm long and pendulous, and cone scales are concave, thin and rhomboidal with bracts that are linear, exerted reflexed and 3-lobed at the apex. Seeds are winged and about 1.8 cm long. In North America, Douglas-fir seed maturity is judged by the general appearance of the cones and embryo in relation to the embryo cavity. The seed is considered to be fully mature if the embryo occupies 90% of the cavity (Kolotelo et al. 2001). Cone collections in North America are carried out by climbing and taking cones from standing trees following logging operations and/or from squirrel caches. Collected cones are air-dried in half-filled burlap bags for 3-5 days in a cool, ventilated place to facilitate cone opening and seed release. Seed wings are removed by moistening the winged seeds in a large container and stirring the moistened seeds for 15-20 minutes. The detached wings can be blown off using an electric fan or a blower. Following the dewinging process, the cleaned seeds require air drying or conditioning to reduce the moisture content to 4-7% for storage. In North America, all the processing is done by machinery.

The physical seed characteristics are given below (Chung and Chang 1990):

Weight of seeds (g/L)	225
No. seeds/L	7,740
No. seeds/kg	34,400
Weight of 1,000 seeds (g)	29

Seed Dormancy and Germination

Formosan Douglas-fir seeds have shallow physiological dormancy and can be germinated at 25℃ within 21 days. Light is essential for germination of this species (Chung and Chang 1990). Local germination data of Formosan Douglas-fir indicate an average germinability of 20-60%; these low percentages could be due to problems in seed processing efficiency or seeds were collected from poor harvest year (C.-T. Chien, unpublished data).

Seed Storage

The seeds of Formosan Douglas-fir tolerate desiccation and sub-freezing temperatures and therefore have orthodox storage behavior. Seeds can be dried to a moisture content of 4-7% and stored in sealed containers at -20℃ for a long period of time.

Nursery Practice

Although seeds of this species have shallow dormancy, it is best to moist chill them for 2-3 weeks before sowing for fast, uniform germination.

Reevesia formosana Hayata

Sterculiaceae
Formosan Reevesia

Growth Habit, Occurrence and Use

Formosan reevesia is a medium-sized deciduous tree. Leaves have caduceus stipules and are simple, alternate, usually crowded at the apex of branches, elliptic, oblong or oblong-ovate, 3-10 cm long and 1.5-3.0 cm wide, coriaceous, acute or acuminate at the apex and cuneate or rounded at the base, olive green above and grayish yellow green beneath. Midribs are slightly elevated above and prominent beneath the blade, and petioles are 2-3 cm long and thickened at the top. This species is endemic to Taiwan and occurs at elevations of 100-700 m in Taichung, Puli, Pingdong and Hengchun.

Collection and Processing

Formosan reevesia flowers are produced in terminal paniculate cymes, and the pubescent, yellowish green flowers are about 1.5 cm in diameter. Fruits are ovoid capsules that are about 3 cm long and 5-valved. Seeds are flat, 6 mm across and have narrow wings. Ripe capsules are yellowish brown- and can be collected manually by climbing up ladders and cutting branches with pruning shears. Also, the branches can be shaken with a long pole that has a hook and capsules collected from a plastic sheet spread on the ground. Collected mature capsules should be dried in the shade for few days and then broken by flailing or occasionally by cutting them open with secateurs. Wet or dry seeds can be de-winged by hand-rubbing them in a cotton bag.

Seed Dormancy and Germination

Seeds do not have dormancy and can be germinated easily.

Seed Storage

Seeds of this species are suspected to have intermediate seed storage behavior. Following processing, seeds are usually air-dried to a moisture content of 10% and stored at 5℃.

Nursery Practice

Seeds can be sown into containers with sandy loam and manure. Germination usually will be completed within a month. Properly scheduled irrigation, weeding and application of fertilizers should be carried out.

Sapindus mukorossii Gaertn.

Sapindaceae
Soap Nut Tree

Growth Habit, Occurrence and Use

Soap nut tree is a large deciduous tree up to 25 m tall that has yellowish green branchlets. The leaves are alternate, evenly-pinnate with 4-8 pairs of leaflets crowded at the ends of branchlets, and petioles are usually angular. Leaves are chartaceous, oblong-lanceolate, 6-10 cm long, 3-4 cm wide with an acuminate apex and an oblique, cuneate base, glabrous and green or olive-green on both surfaces and have an entire margin. The 11-13 pairs of secondary veins are slender and elevated on both surfaces with veinlets very conspicuous and reticulate. It is distributed in India, China, Japan and Taiwan, where it occurs in the broadleaf forests at elevations lower than 1,000 m. The species grows fast especially in a warm, humid environment. The wood is used for boxes and tools, and the fruit coat contains saponin used for soap making. Seeds can be used as medicine or for extraction of oil used for making soap or as lubricants. Trees of this species are also used for ornamental planting in gardens, parks or along streets due to their beautiful shape form and yellow leaf-color in autumn.

Collection and Processing

Soap nut trees are monoecious, and the small white or pale green flowers which are produced in axillary or terminal panicles open in May-July. Drupes are globose and turn from green to yellowish brown when they ripen in September-November. Mature drupes can be collected from the ground after shaking the trees and cutting off drupe-bearing branches. Collected drupes are post-harvest ripened in a cool and ventilated place by spraying with water and turning over frequently to promote seed maturity. Each drupe contains one seed surrounded by a black lustrous endocarp. Seeds are extracted from the drupes when the outer fruit walls become soft by rubbing against a wire screen with water. The clean, sound seeds are separated from the fruit coat material and empty seeds by floatation in water and air-dried in the shade for a few days before sowing or storage. Seed yield from Mainland China is 50-60% (Huang 2001).

Physical seed characteristics are below:

Weight of seeds (g/L)	683-696 (690)[1]
No. seeds/L	532-544 (539)
No. seeds/kg	770-790 (783)
Weight of 1,000 seeds (g)	1,251-1,283 (1,272)

[1] Number in parenthesis is a mean value.

Seed Dormancy and Germination

Seeds germinate very slowly due to physical dormancy. According to Chien and Yang (2007), an effective pre-treatment to break the seed coat dormancy is to soak the seeds in 48% H_2SO_4 for 4 hours and then wash them with water several times to remove the acid residue. Use of this method made the endocarp water permeable and resulted in a germinability of > 80%. Another practical but tedious method is to pre-soak the seeds in running water for 5-6 weeks which results in a germinability of > 50%. It was found from local experience that the more mature the seeds are the more difficult they are to germinate. Thus, it may be better to harvest the seeds prior to full maturity but after they have a fully developed embryo (C.T. Chien, personal communication, 2007). Huang (2001) found no clear evidence of dormancy in the seeds from China. However, the seeds were usually stored in moist sand or dry over winter and then soaked before spring sowing. Thus, seed dormancy

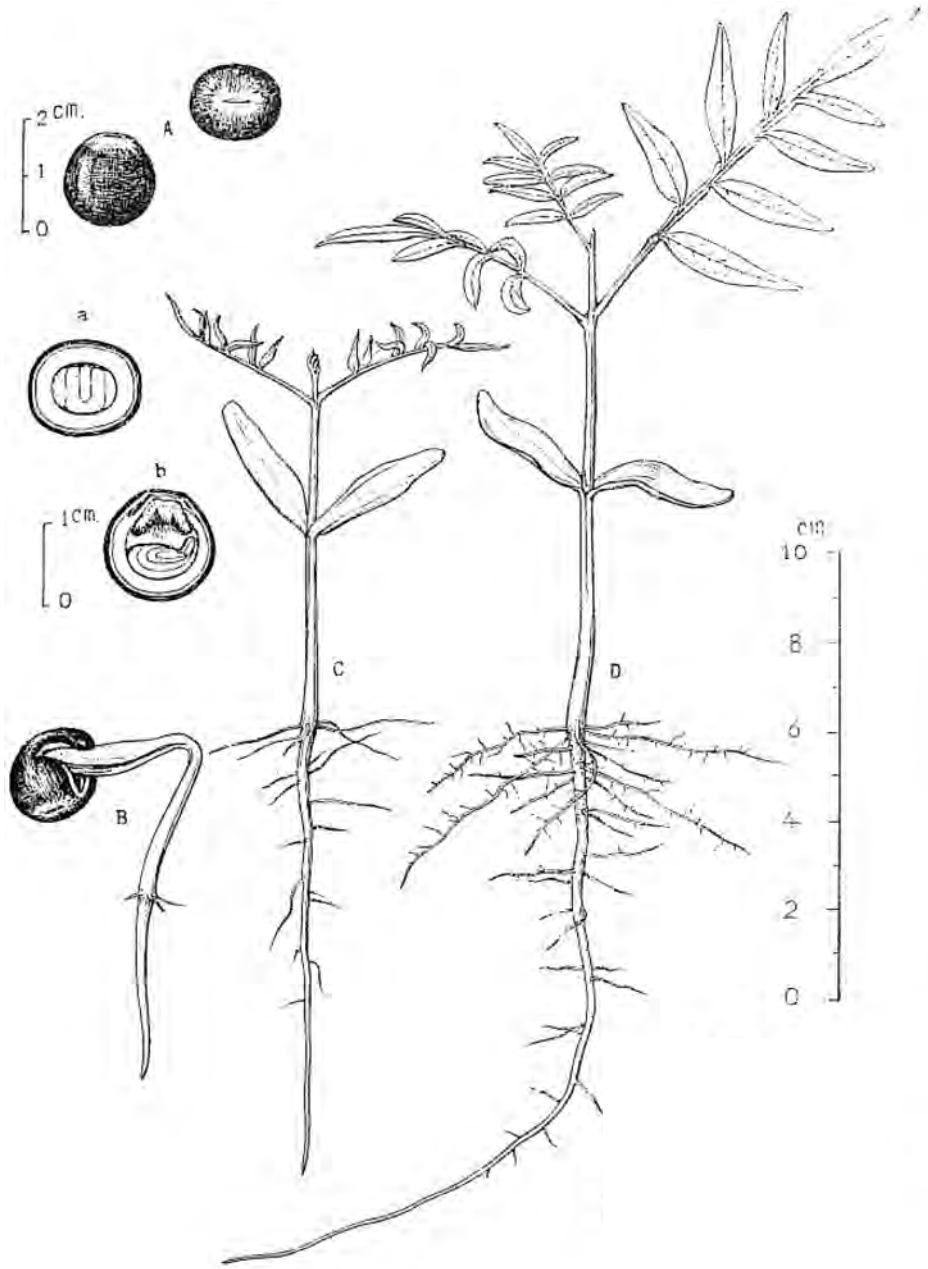
may have been broken prior to sowing.

Seed Storage

The seeds seem to have orthodox storage behaviour and can be stored dry at 5℃ or -20℃ for years. They also can be stored in moist sphagnum at 5℃ for a year or longer, which increases seed germination percentage.

Nursery Practice

Seeds can be sown directly onto moist prepared seedbeds and covered with a thin layer of soil. Germinants will emerge above the soil surface 30-40 days after sowing, and then they are transplanted immediately into plastic bags or other containers for cultivation. The best container medium is sandy loam soil mixed with manure or ordinary soil mixed with sand and manure. If an artificial medium is used, the suggested ratio of vermiculite, peat moss and perlite is 1:1:1, with the same ratio of manure to promote early seedling growth, i.e. 1:1:1. Under sound nursery management with scheduled weeding, irrigation and fertilization, 1-year seedlings should reach 30-40 cm in height and 2-year seedlings 60-100 cm in height, which are suitable for field planting.



***Sapindus mukorossii* Gaertn.**

A. Seed and sections (a, b) of seed B. Radicle-emerged seed, day 3 C. Young juvenile, day 10
D. Young juvenile, day 16

From Yang 1984

Sassafras randaiense (Hay.) Rehder

Lauraceae
Taiwan Sassafras

Growth Habit, Occurrence and Use

Taiwan sassafras is a deciduous broadleaf tree up to 25 m tall that has become rare in Taiwan. It occurs in hardwood or mixed forests with conifers at elevations of 1,000 to 2,500 m in Taipingshan and Chilanshan in Yilan County and in the Kwanwu area of Shinchu County. It is considered to be a world-class superior timber species trees because it grows fast and has a clear wood grain. The dense and durable wood is used for ship building and construction of high-class furniture. The tree has a beautiful shape and light orange-red young leaves, making it a desirable species for ornamental planting at elevations above 1,000 m.

Collection and Processing

The dioecious flowers appear in February-March, and the round fruits (drupes), which are 0.6 cm in diameter, mature in July-August. As drupes mature, they turn from green to black. Since animals and birds like the drupe, they should be protected by bagging or collected with branches when slightly immature and artificially ripened in a greenhouse by frequently spraying them with water until they become soft. Seeds (enclosed by endocarp) are removed by rubbing the fruit, and sound seeds are sparated from fruit material and empty seeds by floatation. Mature drupes collected from the ground should be cleaned immediately. Drupes should never be dried directly in the sun. To remove the waxy exocarp, drupes can be rubbed in sand containing grass ashes or soaked in alkaline water. Cleaned seeds should be stored in sphagnum at 4℃ over winter or longer.

Some of the physical seed characteristics are given below (Chung and Chang 1990, Sheu 2007):

Weight of seeds (g/L)	521
No. seeds/L	10,523
No. seeds/kg	26,450
Weight of 1,000 seeds (g)	37.8

Seed Dormancy and Germination

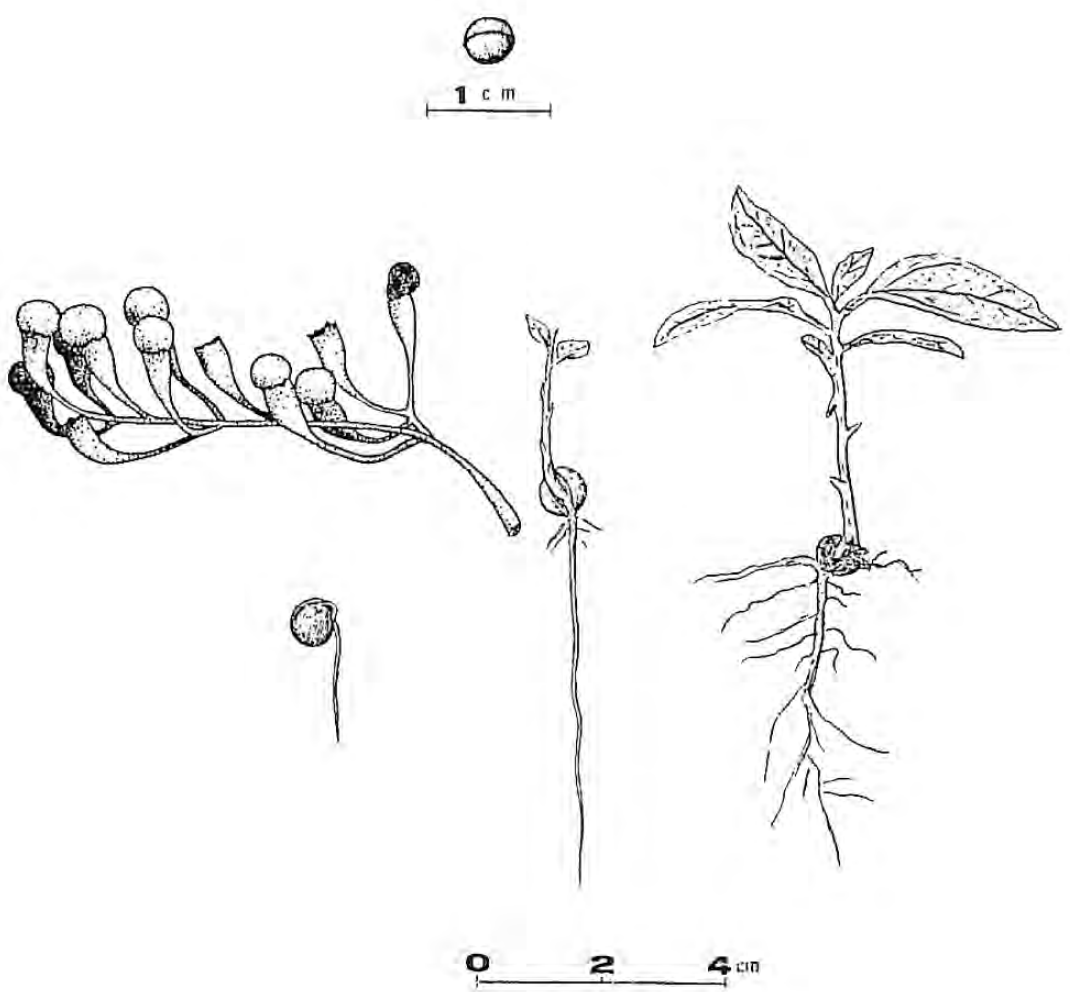
Taiwan sassafras seeds have physiological dormancy. For maximum and complete germination, seeds require a 3-minute period of scarification in concentrated sulphuric acid followed by a treatment with GA_3 (200 p.p.m.) and BA (10 p.p.m.) (Wang et al. 1986). In general, the average germination is low (20%), which may be partly due to poor seed development. The maximum germination obtained following the acid scarification and treatment with a combination of GA and BA was 22% (Wang et al. 1986). However, further improvement in germination (up to 32%) was obtained through seedbed sterilization with 40 g/m^2 Basamid (Wang et al. 1986). Apparently, soil sterilization was necessary because the acid treatment weakens the seed coat and renders the treated seeds susceptible to fungal attack. An improved treatment has been developed in which seeds germinated to 40% after they were cold stratified at 5℃ for 7 months followed by 25 minutes of soaking in 15% hydrogen peroxide and incubation at 35/10℃ with 12 hour light (Chien and Yang 2007). With this treatment procedure, the seeds will begin germinating 10 days after sowing and complete germination within a month.

Seed Storage

The seeds of Taiwan sassafras can be stored in moist sphagnum at 5℃ for a year or longer.

Nursery Practice

For protecting germinants from attack by insects and diseases, seedbeds should be properly sterilized prior to sowing. Following seed treatment procedures described above in the germination behavior section, seeds can be sown directly on sandy seedbeds and covered with fine sand. Once germination begins, the germinants can be transplanted into containers. The nursery for seedling production should be located above 1000 m elevation with an abundant water supply. During the period of young seedling development, there is no need for shading. Owing to the scarcity of seeds, it was reported that *in vitro* somatic embryogenesis could be used as an alternative method propagation of this species (Chen and Wang 1985).



***Sassafras randaiense* (Hay.) Rehder** (From Chung and Chang 1990)

Schefflera octophylla (Lour.) Harms

Araliaceae
Common Schefflera

Growth Habit, Occurrence and Use

The common schefflera is a semi-deciduous tree up to 25 m tall that has solid pith and occurs in southern China, Taiwan, Okinawa, and southern Japan. It is found in broadleaf forests all over Taiwan. Leaves are digitately compound, long-petiolate and crowded at the apex of branches, and stipules are connate within the petioles. The 6-11 pairs of leaflets have petiolelets and are coriaceous, elliptic or ovate-elliptic, 7-11 cm long and 3-6 cm wide, acute or shortly caudate at the apex and cuneate to rounded at the base; the margin is entire. This species occurs on shady, moist sites along river valleys with deep soil that is rich in organic matter and can regenerate by seeds or by sprouting. Seedlings and saplings in the secondary forests require full sunlight for best growth and have a high demand for phosphate in the soil. For artificial planting, thorough site preparation and frequent weeding and tending can minimize seedling forking. An extra quantity of phosphate fertilizer should be added to the regular application of fertilizers. The species has a medium growth rate. In silvicultural trials at the Taimalee Research Centre, 9-year-old trees had an average height of 6.1 m and a DBH of 9.6 cm (Chen et al. 2007b). The wood is used to make furniture, wooden boxes and wooden shoes (Japanese geta, clogs), waterwheel pedals, rough sculptures and matchsticks.

Collection and Processing

Common schefflera flowers in October-December, and the flowers are borne in terminal umbel-panicules that are up to 25 cm long. The fruits (drupes) are rounded and dark purple when mature in March-April in the north and February-March in the east of Taiwan. Drupes are readily eaten by birds; therefore, collections have to be carefully scheduled to occur before they are taken by birds. Collected drupes are spread thinly in trays or on the ground in a cool and well-ventilated place with frequent turning and spraying with water to hasten their maturation and post-harvest ripening. Seed extraction is done by macerating the drupes in water. The cleaned seeds (enclosed by endocarp) are dried in the shade and should never be sun dried. Based on data from Wang (2001c), cleaned seed yield of this species from China is 17-20% with purity of 85-95%. The seed is half-moon shaped with abundant endosperm.

Physical seed characteristics are given below (Chung and Chang 1990):

Weight of seeds (g/L)	367
No. seeds/L	84,500
No. seeds/kg	230,000
Weight of 1,000 seeds (g)	4.34

Seed Dormancy and Germination

Common schefflera seeds have morphological dormancy and can be germinated without any pretreatment. Seeds incubated at 20-25℃ for 7-25 days germinated to 50% (Chung and Chang 1990).

Seed Storage

Seeds cannot tolerate drying and have recalcitrant storage behavior. They should be stored at 5℃ for less than 1 year (Chung and Chang 1990). Storage in moist sphagnum at 5℃ can maintain original germinability for 2 months (Chen et al. 2007b). However, Wang (2001c) suggested that the critical moisture content for maintaining seed germinability of common scheffleria seeds from southern China is about 20%, and longevity is gen-

erally about 6 months.

Nursery Practice

Cold-stored or presoaked seeds are directly broadcast onto moist seedbeds and covered with a thin layer of fine sand. It takes about 6-8 days for radicles to emerge and another 20-30 days for the true leaves to develop. Germinants can be transplanted into plastic bags or other containers 15 days after the true leaves are developed. While container seedlings can be field planted when seedling height reaches 60-90 cm, transplanted bare root seedlings require 1 year of growth prior to field planting (Wang 2001c).

Schima superba Gard. et Champ.

Theaceae
Chinese Guger-tree

Growth Habit, Occurrence and Use

The Chinese guger-tree is a large evergreen up to 30 m tall. It is an important pioneer successional species. The bark contains white alkaloid crystals that cause itching of the skin on contact. Leaves are simple, oblong, acute at the apex, alternate and crowded at the tips of branches. Flowers are pale yellowish white and are produced in racemes crowded on the tips of branchlets. Capsules are depressed globose, 1.2 cm across, and contain 5 seeds. Seeds are flat, 7-8 cm long and 4.5 cm wide and narrowly winged. This species occurs in southern China, Taiwan and Ryukyu Islands. In Taiwan, it generally grows in temperate hardwood forests at elevations below 2,300 m in the Central Mountain Range. The species is somewhat shade intolerant and grows best in warm and sunny sites with well-drained, moist, deep loam, sandy loam or clay-loam soil. Although this species is known to be strongly resistant to attack from pests, it is susceptible to wind damage and wind-throws. Chinese guger-tree grows fast; for example, 3-year-old container seedlings planted at an elevation of 300m in the Wulai District of northern Taiwan reached a height of 3.3 m and a DBH of 4.5 cm; trees in a 9-year-old plantation at 850 m in Taimalee, in eastern Taiwan, had an average height of 6.7 m and a DBH of 8.7 cm (Yu et al. 2008); and at an elevation of 1,600 m, trees in a 25-year-old plantation had a DBH of 18.4 cm with the maximum of 40 cm.

This species is strongly resistant to air pollutants such as sulphur dioxide. Its flowers and the whole tree are aesthetic. The trunk is straight and the board wood grain is beautiful and pale red to pale yellowish brown. The wood is durable and resistant to insect attack, and it is used for construction, furniture, vehicles and boats.

Collection and Processing

The Chinese-guger-tree flowers in May-June, and the yellowish white flowers are fragrant. Fruits (capsules) mature in November-December and turn from green to brown. Since seeds disperse when the capsules dehisce, capsules should be harvested as soon as they start to turn brown. Collected capsules should be air dried in shade to facilitate seed maturity and dehiscence. The percentage of filled seeds is usually low but can be improved by flotation (good seeds sink) in pentane (200%) (Chien and Lin 1998). There are 19,500 seeds in a liter, and they weigh 120 g (Sheu 2007).

Seed Dormancy and Germination

The seeds of this species have no dormancy and germinate well without any pre-treatment. However germinability is low due to the high percentage of empty seeds. Floating seeds in pentane will greatly improve germination percentage by removing many of the empty seeds, and there are no ill-effects of the chemical on germination. However, the disadvantage of this process is that it also removes some of the filled seeds.

Seed Storage

The seeds have orthodox storage behaviour and can be stored for a long time when their moisture content is reduced to < 10%.

Nursery Practice

Owing to the generally low germinability of this species, seeds should be germinated indoors and then the germinants transplanted to seedbeds or

containers for further seedling culture. It is important that the seedbeds should always be kept moist and covered with shade screens during the early stages of seedling development. As soon as the germinants are transplanted to containers, they should be covered with 60% shade screen and watered regularly. Shade screen should be removed when seedlings reach 15 cm tall. For container seedlings, the medium could be sandy loam soil mixed with manure. When artificial container medium, such as a mixture of vermiculite, peat moss and perlite, is used, appropriate fertilizers should be applied during seedling development to promote growth. However, fertilizers and watering frequency should be reduced during the seedling hardening stage to improve seedling quality.

Swietenia macrophylla King

Meliaceae
Honduras Mahogany

Growth Habit, Occurrence and Use

Honduras mahogany is a large deciduous tree > 30 m tall and is an important economic tree species for planting. It has a straight trunk, few branches and grows fast. Leaves are 9-15 cm long and 3.5-5.0 cm wide, alternate, glabrous on both surfaces and evenly-pinnate with 4-7 pairs of leaflets that are opposite, petiolulate, obliquely lanceolate or oblong with an acuminate apex and obtuse or rounded oblique base. The 7-10 pairs of lateral veins are nearly opposite, and they are elevated on both surfaces. Honduras mahogany is native to Honduras and South America, and it was introduced to Taiwan in 1901 and planted in the southern part of the Island with good results (Chien et al. 2009). The wood is hard with a fine texture and is used for high-class furniture, ship-building, construction and wheelbarrows. It is also desirable for ornamental planting due to its magnificent form and green-shade effect.

Collection and Processing

Honduras mahogany flowers in April-May and has small, white blossoms in axillarly cymose-panicles. The fruits are ovoid capsules that turn deep brown when mature in March-April of the next year. Fruits have an acuminate apex and minute warty projections, and they are ligneous and about 16 cm long and 8 cm across. Each capsule contains 50-60 long-winged seeds. Capsules should be collected after the old leaves fall and before the new leaves emerge and air-dried in the shade until they open. Information from Central America suggests that the capsules can be sun-dried for 4 days until they open (Poulsen et al. 1998). Seeds can be de-winged in a cotton bag by hand to save storage space. If moisture content is reduced to 3%, seeds can be stored dry for at least 4 years (Chien et al. 2009).

Physical seed characteristics are shown below (Sheu 2007):

Weight of seeds (g/L)	150
No. seeds/L	250-290
No. seeds/kg	1,800
Weight of 1,000 seeds (g)	555

Seed Dormancy and Germination

Honduras mahogany seeds have no dormancy and will germinate to over 80% (Chien et al. 2009). However, in laboratory germination tests fungi can be a big problem, but severe fungal development can be alleviated by incubating seeds in the dark (B.S.P. Wang, personal observation). According to Hung (1961), it is important that seeds be planted with the prominent face of the radicle facing up and careful attention given to moisture conditions. Germination is inhibited if the substrate is too wet. The current recommendation for germination tests is to draw from a seed sample of 1,200 g of seeds and incubate them on moist sand at 30℃ with 8-hour light and 16-hour darkness or at 30/25℃ with 8-hour light (Poulsen et al. 1998).

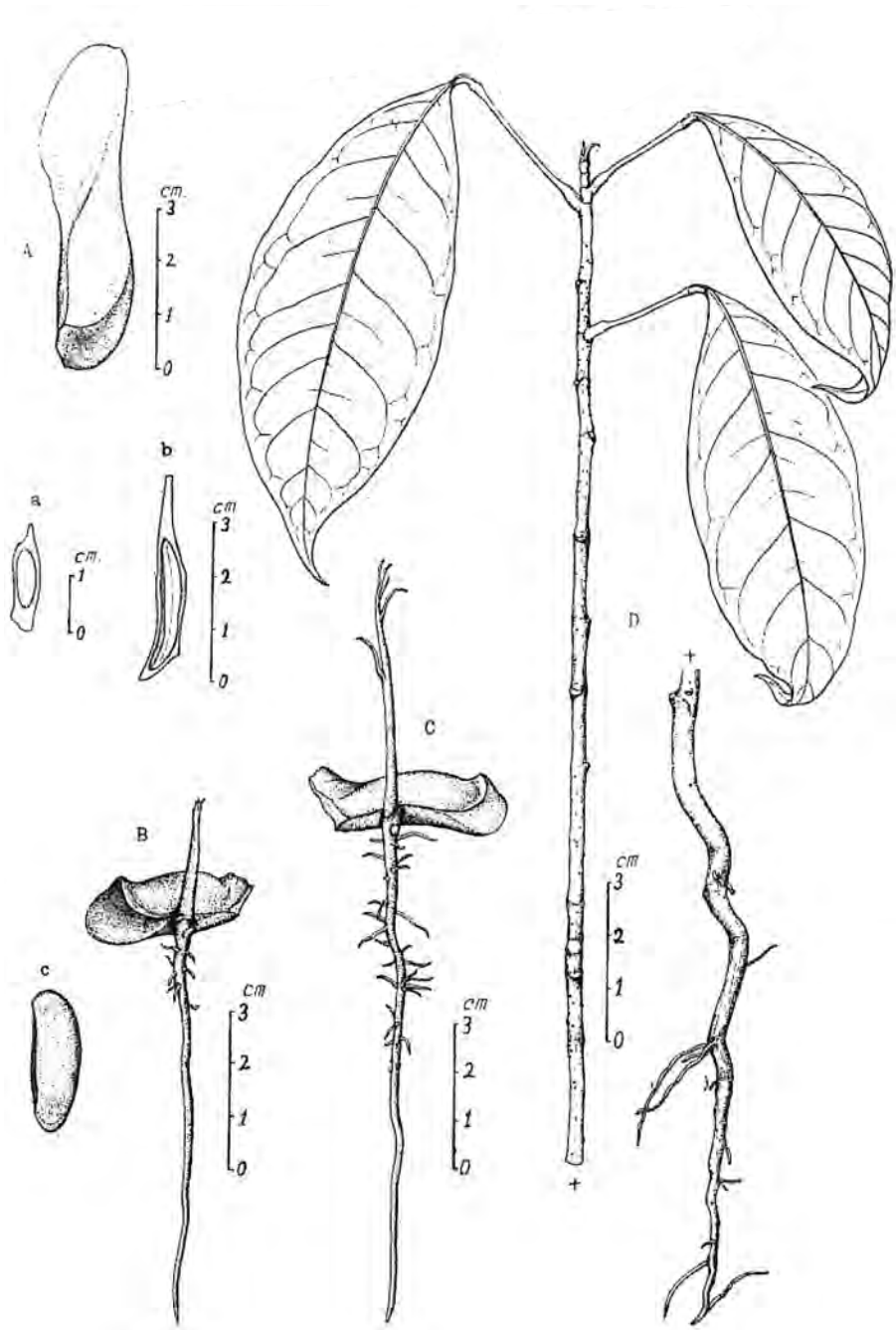
Seed Storage

Honduras mahogany seeds produced in Thailand were stored in polyethylene bags for more than 2 years at 10℃ when seed moisture was reduced to 7% and were classified as having intermediate storage behavior (Pukittayacamee et al. 1995). However, recent information from the Taiwan Forest Research Institute suggests that the seeds can tolerate drying to 3% and be stored at 3℃ for 2 years and at -20 and -196℃ for 24 and 12 months, respectively,

without any loss of germinability. These results suggest that seeds from Taiwan have orthodox storage behavior (Chien et al. 2009).

Nursery Practice

Although plants can be produced from either seeds or cuttings, propagation from seeds is still the primary method of propagation. Currently, fresh seeds are preferred for seedling propagation. If the seeds are to be stored, the moisture content must be reduced. Seeds are commonly sown on sandy seedbeds with automatic irrigation, and germinants transplanted into containers when radicles break through the soil surface; this prevents abnormal seedling development. It is very important that the seeds are sown with the radicle surface pointed up and that they are covered with soil to a depth of 0.5 cm and the beds covered with a shade screen. The best container medium is sandy loam soil mixed with manure. Application of appropriate fertilizers and weeding are essential for seedling growth. If plastic bags or other plastic containers are used, they should be moved around when seedlings reach a height of 20-25 cm and 40-50 cm, and then leave them in nursery for 1-2 month prior to field planting. To increase the rate of seedling survival, all roots outside the containers should be trimmed.



***Swietenia macrophylla* King**

A. Seed and sections (a, b) of seed and embryo (c) B. Radicle-emerged seed, day 5 C. Seedling, day 10 D. Young juvenile, day 50

From Yang 1984

Syzygium formosanum (Hay.) Mori

Myrtaceae
Taiwan Eugenia

Growth Habit, Occurrence and Use

Taiwan eugenia is an evergreen tree that occurs in broadleaf forests at middle to lower elevations in central and southern Taiwan. Leaves are simple, opposite, estipulate, coriaceous, oblong or obovate, obtuse at both ends (but the apex is sometimes cuspidate), 5 cm long and 2.5-3.0 cm wide, and they have conspicuous lateral veins on both surfaces with a minute punctuate lower surface, entire margins and petioles that are 0.8-1.2 cm long. The bark is grayish red brown and exfoliates in longitudinal strips. The tree has a beautiful form, and thus the species has potential to become a valuable ornamental. The wood is resistant to decay and can be used for construction and tool-making.

Collection and Processing

Taiwan eugenia flowers in May-July and produces white blossoms in terminal or axillary cymose panicles. The fruit is an oblique-globose berry about 1.0 cm in diameter, and it is deep-red to dark purple at maturity in December-January. Each fruit contains a single seed. Freshly harvested berries are placed in a greenhouse and sprayed with water for 3-5 days till the flesh berry becomes soft for processing. Berries are macerated by rubbing them over screen wire and washing with water. The clean and sunken seeds are collected and shade-dried and then stored in moist sphagnum at 5℃ until sown in spring.

Seed Dormancy and Germination

Taiwan Eugenia seeds have no dormancy and can be easily germinated to 90%.

Seed Storage

Seeds can not be stored for more than 1 year, and they are usually stored in cold stratification at 5℃. Seeds probably have recalcitrant storage behavior.

Nursery Practice

Cleaned seeds are dried in the shade for 1 day and immediately sown in prepared sand beds with an overhead shade-screen. The sown seeds are covered with a thin layer of fine sand. Germination will take place in 2-3 weeks with an average of 80-85%. The true leaves appear about 2 weeks after the radicles emerge. In general, the survival percentage is higher if transplanting is done before the true leaves appear. Usually, transplants in containers are covered by a shade screen for about 30 days. Regular watering is important during the seedling growth period. One-year-old seedlings can reach 40-50 cm tall.

Taiwania cryptomerioides Hayata

Taxodiaceae
Taiwania

Growth Habit, Occurrence and Use

Taiwania is a large evergreen timber tree that can be up to 75 m tall and have a DBH of 3 m. Large branches extend laterally, and twigs are drooping. This species has two types of leaves: needles about 2 cm long with 4-5 lines of stomata on young trees and diamond-shaped scales about 0.4-0.5 cm long on older trees. Taiwania, along with red cypress, Taiwan hinoki falsecypress, Taiwan incense-cedar and lutana fir, are the five most valuable timber species in Taiwan. Trees grow at elevations of 1,500-2,600 m. The wood is straight, soft and fine, and it is strongly resistant to termites and harbors wood-eating beetles. The lumber is excellent for construction of furniture, piers, buildings, and the species is used for ornamental planting.

Collection and Processing

Taiwania is dioecious or monoecious and produces male and female cones in March. Male cones are about 0.5 cm long and occur in clusters of 5-7 on the bottom of branches, whereas female cones are at the top of trunk above the male cones. Seeds mature in November-December. Cones are ovoid with 12-20 scales. Seeds have a smooth surface with wide, nicked wings around them, and the embryo has two cotyledons. Seed production periodicity is distinctive with intervals of 3-11 years (Chung and Hu 1986). Collected mature cones should be spread thinly on the ground in a well ventilated shady place and turned over frequently to facilitate air-drying and cone opening. Released seeds should be collected and cleaned for testing and storage. Filled-seed percentage of this species is low, and winnowing can improve seed quality, *e.g.* from 12% germination before to 60% germination after winnowing (Chung and Hu 1986).

Physical seed characteristics are summarized below (Chung and Chang 1990, Sheu 2007):

Weight of seeds (g/L)	94.8-97.4
No. seeds/L	127,880-157,620
No. seeds/kg	114,800
Weight of 1,000 seeds (g)	1.01

Seed Dormancy and Germination

Taiwania seeds have physiological dormancy and require post-harvest ripening for maximum and complete germination, and 3-4 months of dry storage at 5℃ fulfills the post-harvest ripening requirement (Hu and Chung 1982). Germination can be completed within 1 month after seeds are placed on a moist substrate (Chien 1998). Germination is usually low, ranging from 16 to 35% in 16-28 days at constant 20℃. When the seeds were cold stratified at 5℃ for 6 weeks, only 29% germination was obtained at 23℃ in 4-8 weeks (Kung 1976). However, Chung and Hu (1986) were able to improve the germination from 60 to 71% when the seeds were cleaned by winnowing and stored dry at 5℃ for 3 months. Obviously, the problem with the low germination for this species is due to a high percentage of empty seeds and a requirement for post-harvest ripening.

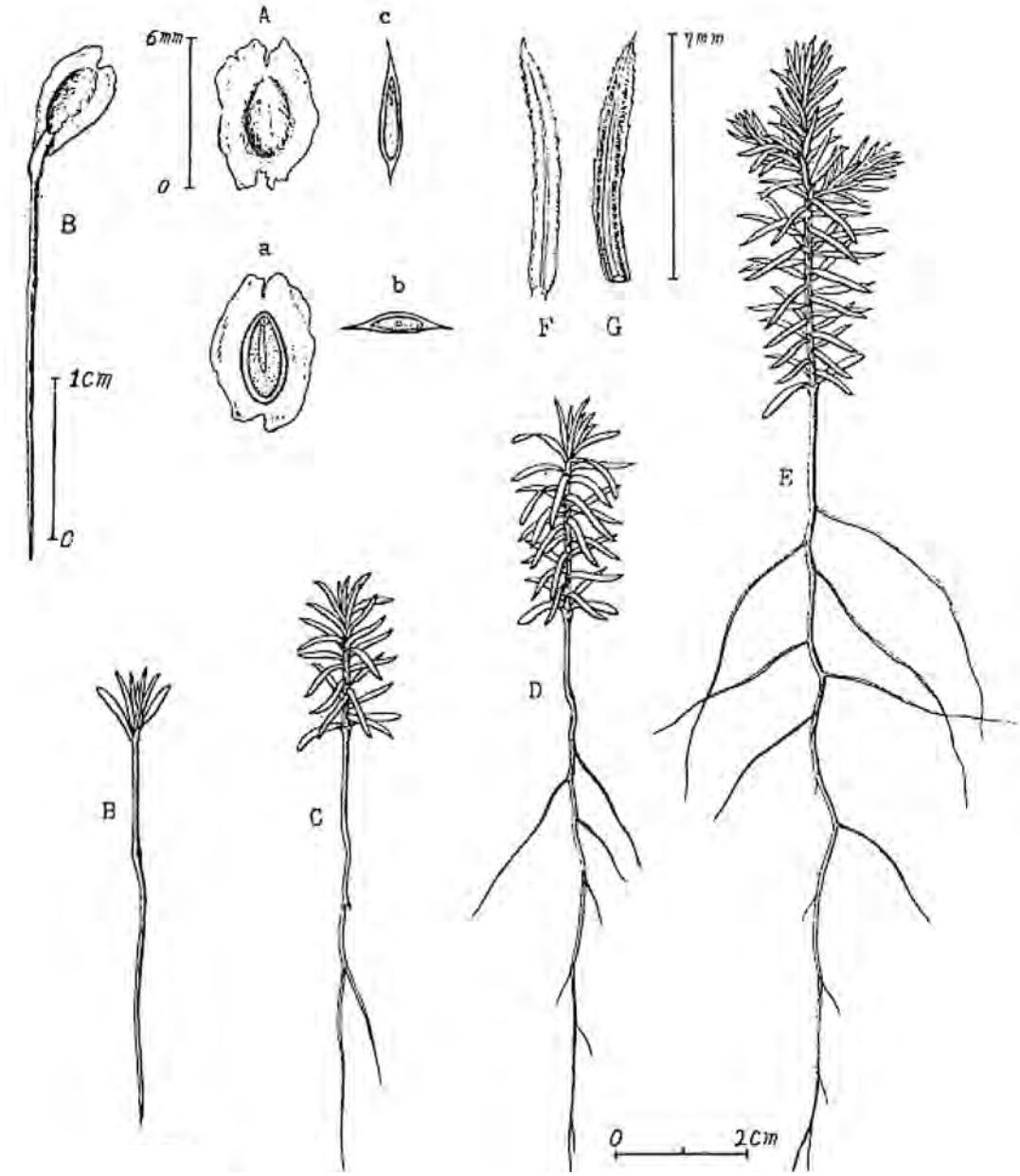
Seed Storage

The storage behavior of Taiwania seeds is orthodox, and they can be stored for > 8 years at -20℃ when moisture content is reduced to 5-6% (fresh weight) (Chien 1998). Chung and Hu (1986) found that when moisture content was reduced to

8% (fresh weight), seeds retained their germinability for 3 months at room temperature, 5 years at -10℃ and 8 years at -20℃.

Nursery Practice

A nursery for Taiwania seedling production is best situated at an elevation of 600-1,000 m at a site with an abundant water supply. Seedbeds should be mixtures of sandy loam soil, humus soil or manure. Based on the general seed germinability of 20%, the sowing rate is between 0.03 and 0.05 liter per square m. The seeds are customarily sown in drills of 10-12.5 cm strips for 8-10 rows per square meter. Prior to sowing, seedbeds must be sterilized, and overhead shelter needs to be installed after seeds have germinated. One-year-old seedlings are transplanted in the spring, grown for another 1 year in the transplanting bed and field-planted as 3-year-old stock. For container seedling production, seedlings are transplanted to containers when they reach 10 cm tall. It is best to use sandy loam soil or manure mixtures as the medium. During the period of seedling development, attention must be given to proper irrigation, weeding and application of fertilizers. Taiwania seedlings should be kept moist but not too wet as they are susceptible to damping-off fungi. Fertilizers, especially the slow-release ones such as Nitricoat, can help promote root collar growth of seedlings (Chien 1998).



***Taiwania cryptomerioides* Hayata**

A. Seed and sections (a, b, c) of seed
B. Seedling, day 10
C. Young juvenile, day 20
D. Young juvenile, day 30
E. Young juvenile, day 150
F. Dorsal side of leaf
G. Ventral side of leaf

From Yang 1984

Taxus mairei (Lemée & Lévl.) S.Y. Hu *ex* T.S. Liu [*Taxus sumatrana* (Miq.) de Laub.]

Taxaceae
Taiwan Yew

Growth Habit, Occurrence, and Use

There are eight species in this genus of which five are native to middle, southern and western Mainland China, but only Taiwan yew grows in Taiwan. Taiwan yew is a large, slow-growing tree that can be up to 40 m tall and 300 cm in diameter. The species is sparsely distributed in natural forests of Taiwan between 1,000 and 2,700 m above sea level. The wood is hard and fine-textured, and its attractive reddish brown and yellow color is especially favored for furniture or carving. Since the discovery of taxol in the Pacific yew (*Taxus brevifolia*) in North America (Wani et al. 1971), Taiwan yew has received considerable research attention as a source of anticancer drugs. When a high concentration of taxol was found in Taiwan yew, research was conducted to find ways to increase *T. marei* populations within a framework of forest management and genetic resource conservation. At the same time, however, protection measures for Taiwan yew were initiated. At the Taiwan Forestry Research Institute, intensive research on *T. mairei* has resulted in improved knowledge of seed dormancy and germination, vegetative propagation and tissue culture of this species, thereby facilitating mass seedling production (Chang et al. 1996, Chang and Yang 1996, Ho et al. 1997, Chien 1997, Chien et al. 1998b). The chemical constituents of leaves and twigs of 7-year-old *T. mairei* trees have been extensively investigated resulting in the discovery of new natural taxoid compounds that have cytotoxic activity (Shen et al. 2002, Shen et al. 2005a, Shen et al. 2005b).

Collection and Processing

Taiwan yew is dioecious and produces male and female cones in March-April, and its seeds mature in November-December when their cuplike arils turn red. Like some fruits of the tropical tree species, Taiwan yew trees will have seeds with various degrees of maturity, and thus green to red arils are seen. Following collection, seed with green arils are artificially ripened in a greenhouse. The red arils are removed via maceration, and seeds are washed with water; empty seeds and debris are removed by floation in water. Cleaned seeds are compressed-ovoid, about 6-7 mm long, 3-4 mm wide, slightly 2-angled and sometimes 3-angled. Cleaned seeds are mixed with moist sphagnum, sealed in a polyethylene bags (0.04 mm thick) and stored at 5℃.

Seed Dormancy and Germination

Taiwan yew seeds have a small underdeveloped embryo (i.e. morphological dormancy) that also have physiological dormancy; thus, seeds have morphophysiological dormancy. Chien et al. (1998b) recommended that the best technique for germinating Taiwan yew seeds was to warm-stratify them at 23/11℃ (8-hour day high and 16-hour low temperature) for 6 months, followed by 3-month of cold, moist stratification at 5℃, and then incubation at 25/15℃ with a 12-hour photoperiod. Apparently, the 6-month warm stratification allows the immature embryo to grow 1.5-1.7 times its original size, and the cotyledons and shoot apical meristem also enlarged. Cold stratification is necessary to induce cell division in the shoot apical meristem. Seed germination starts gradually about a week after sowing and reaches a peak in 3 weeks, and the entire process is completed in 6 weeks with fast and uniform germination of 88%. ISTA (2005) prescribes the laboratory germination tests for seeds of *Taxus* as: prechill seeds for 9 months at 3-5℃ and germinate them on moist sand medium

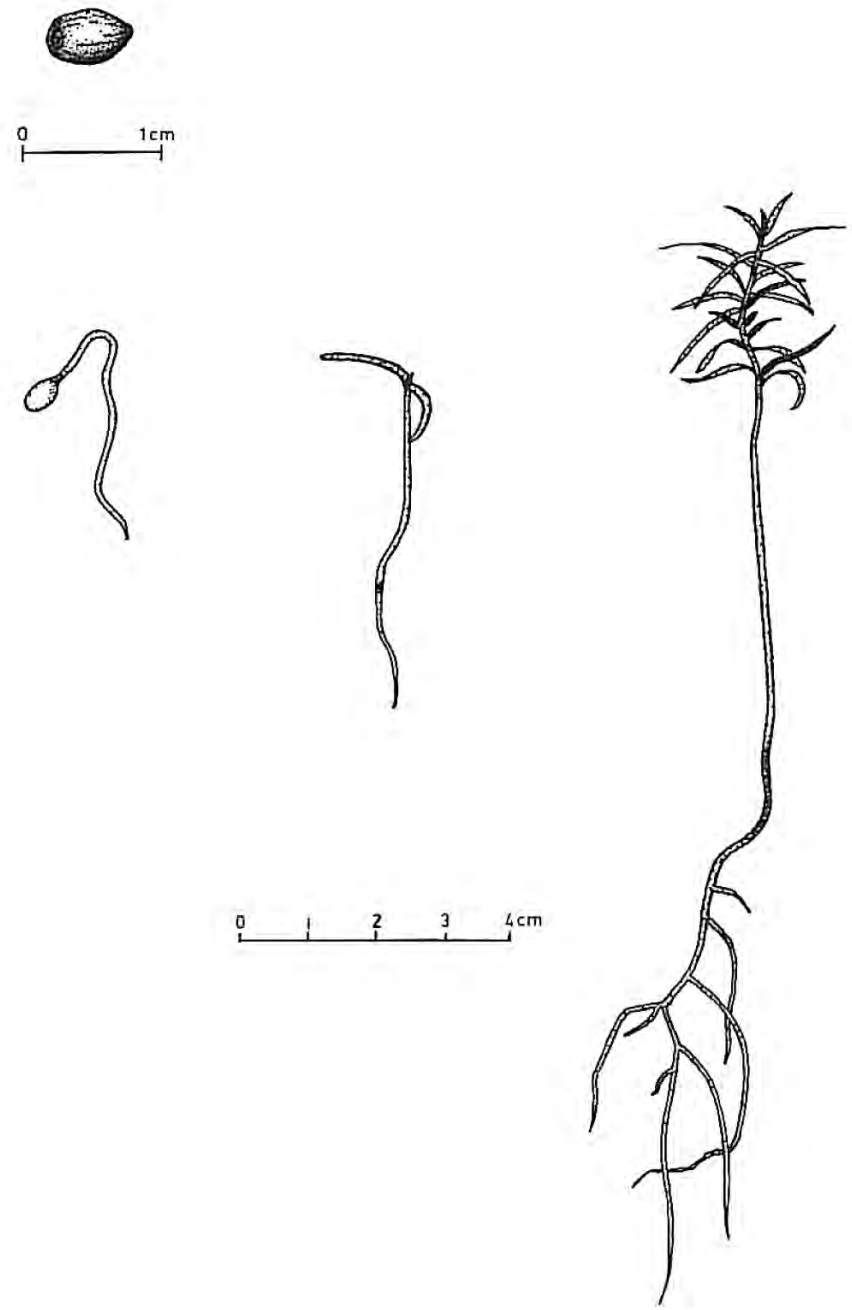
at alternating temperatures of 30/20℃ with 8 hour light for 28 days. Obviously, the ISTA prescription is not as precise as that recommended by Chien et al. (1995).

Seed Storage

Taiwan yew seeds are considered to be temperate recalcitrant, since they can be stored in moist sphagnum in polyethylene bags (0.04 mm thickness) at 5℃ for 3 years (Chien and Lin 1996). Seeds stored for 4 years in moist sphagnum at 5℃ germinated to only 8% following a retreatment with warm and cold stratification.

Nursery Practice

Taiwan yew seeds are expensive because they are scarce and difficult to collect. To insure maximum germination, seeds should be germinated in a controlled environment of 25/15℃ and 12-hour light following a combination of 6-month warm stratification at 11/23℃ and cold stratification for 3-month at 5℃. After the seeds have germinated, the germinants can be transferred into containers for continued growth and seedling development. According to Chien (1997), seedlings of Taiwan yew can grow 15 cm or more in 1 year, and they can be planted out in 3 years. Planting stock also can be propagated by cuttings, although there is a problem with plagiotrophism (Sheu 1985). It is also possible to produce plants using tissue culture, but the process is more expensive than traditional stock production. With the advancement in biotechnology, emblings (plants produced from tissue culture) can reach 90% survival (Chien and Lin 1996). Chien (1997) also suggested that the nursery for producing Taiwan yew seedlings be located at an elevation above 1,000 m because young seedlings suffer heavy mortality from high summer heat at lower elevation sites.



***Taxus mairei* (Lemée & Lévl.) S.Y. Hu *ex* T.S. Liu** (From Chung and Chang 1990)

Terminalia catappa Linn.

Combretaceae
Indian Almond

Growth Habit, Occurrence and Use

Indian almond is a deciduous tree that grows to a height of 15-25 m. The branches are verticillate. Leaves are simple, thick-coriaceous, crowded at the ends of the branchlets, obovate, 20-25 cm long, 8-12 cm wide, rounded at the apex and cuneate at the base with two glands at the base, glabrous on both surfaces except the pubescent midribs. Leaves change from green to dark red in the autumn-winter. Leaf-fall occurs in January-February, and new leaves emerge in March. The bark is grayish brown and longitudinally furrowed. The roots often have swollen butts.

The native range of this species is uncertain because it has long been widely distributed by humans. In Taiwan it occurs in Kaohsiung, Hengchun Peninsula and Lanyu (Orchid Island). Trees of this species are widely planted in parks and along urban streets especially in the coastal cities because of their beautiful shape and clear stratification of branches and leaves. The wood is used for construction and tool making. The fruit skin can be used for dyes, and the aromatic seed-kernel is edible.

Collection and Processing

Indian almond is monoecious, and the unisexual flowers occur in axillary spikes. Flowering occurs in April-May. The fruit (drupe) is flat, compressed-ovoid, about 5-6 cm long and 4 cm wide with two longitudinal ridges. Drupes are mature in September-October, at which time they turn yellow. Fruit collection can be made by shaking the branches to cause the mature fruits to fall onto a sheet underneath the tree. The fruits do not require cleaning if they are sown immediately. However, the fleshy pulp needs to be removed and seeds (enclosed by endocarp) washed with water if dry storage is desired.

Physical characteristics of seeds are as follows (Chung and Chang 1990):

Weight of seeds (g/L)	455
No. seeds/L	35
No. seeds/kg	77
Weight of 1,000 seeds (g)	13,000

Seed Dormancy and Germination

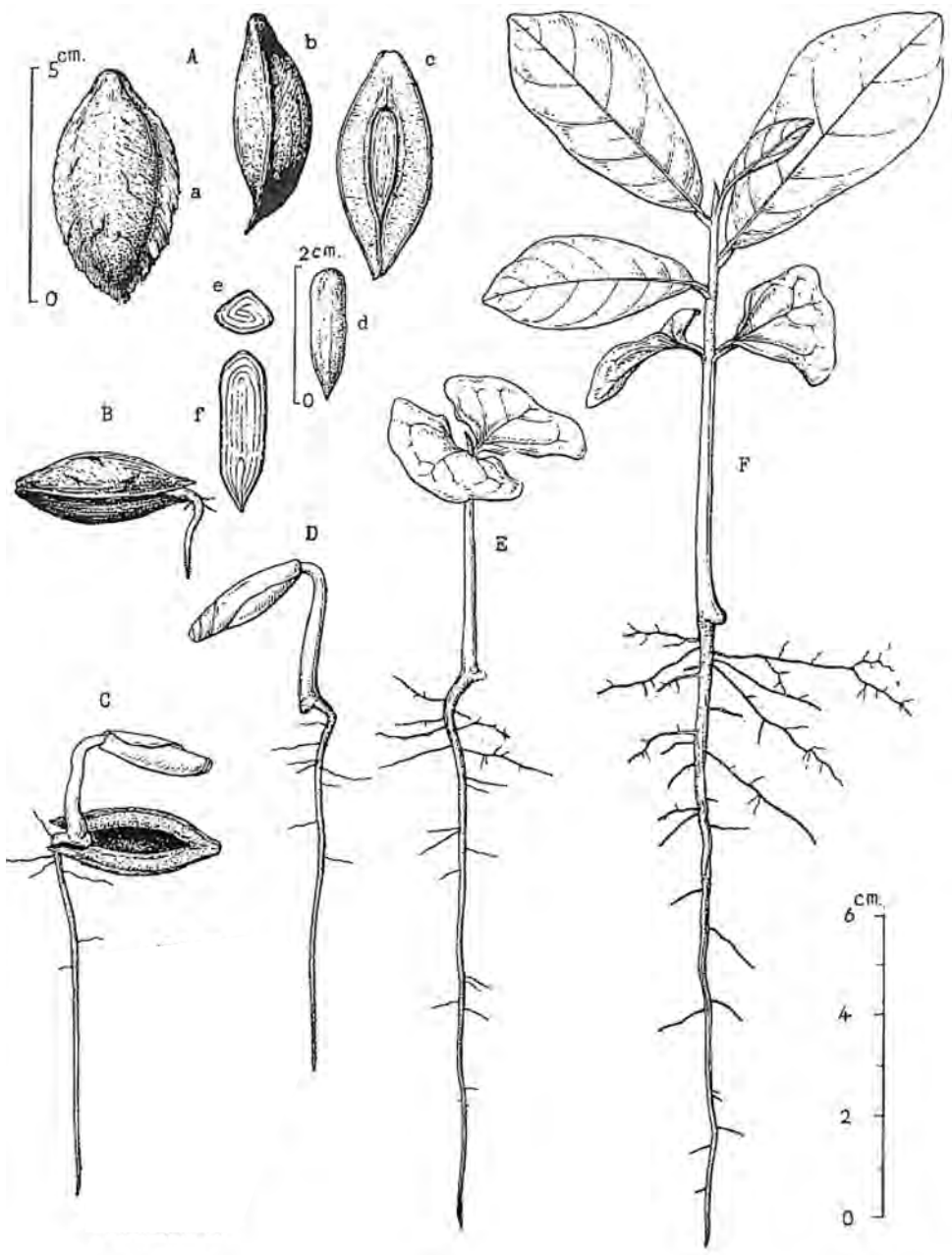
Indian almond seeds have physiological dormancy and take a long time to begin to germinate (1 month), but when the endocarp is removed germination begins in 1-2 days. Local practice for breaking dormancy is warm stratification for 3 weeks or cold stratification for 2-3 months; average germination is 70% (Chung and Chang 1990).

Seed Storage

The seeds have recalcitrant storage behavior and can be stored in moist sphagnum at 5℃ for less than one year (Chien 1998).

Nursery Practice

Unprocessed fruits or clean seeds can be sown directly onto prepared seed beds and covered with a thin layer of fine sand. The seed beds should always be kept moist. Germination usually occurs 1 month after sowing, and germinants can be transplanted into containers for continued growth. The container medium is usually sandy loam soil mixed with manure. Developing seedlings grow fast, but plants require regular watering. Also, attention should be given to pest control since young leaves are very susceptible to insect attack.



***Terminalia catappa* Linn.**

A. Drupe (a, b), section (c) of seed and embryo (d, e, f)
B. Radicle-emerged seed, day 1
C. Seedling, day 3
D. Seedling, day 5
E. Seedling, day 7
F. Young juvenile, day 37

From Yang 1984

Trema cannabina Lour.

Ulmaceae
Lesser Trema

Growth Habit, Occurrence and Use

Lesser trema is a small deciduous tree up to 4 m tall with spreading slender branchlets that are sparsely appressed-hirsute when young. Leaves are membranous, ovate-oblong to ovate-lanceolate, 7-8 cm long, 2.5-3.5 cm broad, and nearly glabrous on both surfaces, except for being slightly hairy along midrib and lateral veins. Leaf margins are crenate-serrulate, apex is long acuminate and base is cordate or rounded to truncate. Petioles are pubescent and 5-10 mm long. The species occurs widely in Myanmar, Thailand, Indonesia, Hainan Island (China), Malaysia, Australia, Melanesia to Micronesia and Taiwan. It grows in open areas and secondary thickets at low elevations in the northern and central parts of Taiwan. Trema is an important component of secondary succession following natural and man-made disturbances, and it may be used as a nurse-plant because of its capability to fix nitrogen.

Collection and Processing

Flowers are produced in axillary cymes and have 4-5 membranous calyx lobes. Fruits mature in September-October, when the drupes turn reddish orange. The harvested drupes are sorted by color to remove the immature ones, and they are hand macerated in water. The cleaned, sunken filled seeds (enclosed by the endocarp) are allowed to dry for 8 hours at room temperature before storage. Fruits should never be dried in direct sunlight.

Seed Dormancy and Germination

Lesser trema seeds have physiological dormancy. When seeds were cold stratified at 4℃ for 5 weeks, total germination was 73% (Chen et al. 2008b). There was no significant beneficial effect of extending the cold stratification period beyond 5 weeks. Soaking seeds in concentrated sulphuric acid for 90 minutes was effective in improving germination but not as effective as 5-week of cold stratification (Chen et al. 2008b).

Seed Storage

Based on results from Chen et al. (2008b), lesser trema seeds have intermediate storage behaviour. Seeds can be stored for 8 months in moist sphagnum moss at 4℃, or they can be dry stored for at least 24 months if moisture content is reduced to 5-10%.

Nursery Practice

Seedlings of this species are propagated from seeds. Container seedling production should use a medium of sandy loam soil mixed with manure. Diligent watering and weeding are required to facilitate seedling growth. Field planting should be done in the spring or fall just before rainfalls.

Trema orientalis (L.) Blume

Ulmaceae
India-charcoal Trema

Growth Habit, Occurrence and Use

India charcoal trema is a medium-sized deciduous tree up to 8-15 m tall. It grows fast but has a short life span. The bark is pale grayish red-brown or greenish-gray and smooth. Trees have both appressed and erect branchlets that have velutinous and glandular hairs. Leaves are simple, alternate, chartaceous, ovate-oblong to oblong-lanceolate, 6-15 cm long, 2-6 cm broad, acute to acuminate at the apex, obliquely obtuse to cordate at the base and densely to sparsely scabrid on the upper surface and completely velutinous and woolly on lower surface, and they have crenate-serrulate margins. The species is distributed in southeastern and eastern Asia, Polynesia and New Guinea. In Taiwan, the species occurs on plains, river sides and hills throughout the Island. India-charcoal trema is a shade intolerant pioneer species and usually forms large, pure stands on denuded land. It can grow in a wide range of infertile sites and has strong resistance to drought, insects and diseases. It can become established in denuded land very effectively and grow quickly. The wood is light and soft and is used for hand tools, Japanese wooden shoes (geta) and paper making, and the young, tender leaves are used as feed for cattle, sheep and deer.

Collection and Processing

The yellowish green bisexual or dioecious flowers of India-charcoal trema open in mid-to late-April in the northern and April-June in the southern part of Taiwan. Fruits are drupes, and they mature in July in the north and in July-August in the south. However, Sheu and Chang (1981a) found that September was the best time for collecting seeds of this species in central Taiwan. Collected fruits should never be dried in the sun and should be artificially ripened in a greenhouse. Fruit are macerated by hand with water, and filled seeds are separated from debris and empty or damaged seeds by water floatation. The cleaned seeds are air dried or wind dried at room temperature. Clean dried seeds are dark gray and have a seed moisture content of 12.8% (fresh weight).

Physical characteristics of seeds are as follows (Ching-Te Chien, unpublished):

Weight of seeds (g/L)	500-550
No. seeds/L	140,000-180,000
No. seeds/kg	254,000-363,000
Weight of 1,000 seeds (g)	2.8-3.9

Seed Dormancy and Germination

India-charcoal trema seeds have physiological dormancy and germinate well but slowly at alternating temperatures of 30/20℃ with 12-hour light in 49 days (Sheu and Chang 1981a). Neither cold stratification, soaking in sulphuric acid nor exposure to red light significantly increased germination percentages, but the rate of germination was greatly increased by 75-90 days moist chilling (moist cold stratification), 15 minutes soaking in 25% of concentrated H_2SO_4 or a 24-hour exposure to red light (Sheu and Chang 1981b).

Seed Storage

Sheu and Chang (1981b) found that seeds of India-charcoal trema can be dried to 8% moisture content and stored in sealed plastic bags at 5℃ for 14 months with a loss of only 16% germinability. This method is better than storing seeds at room temperature or at -5℃.

Nursery Practice

Seeds should be kept moist in cold stratification until spring sowing. Seedbeds must be carefully prepared and maintained moist. After seeds are sown, they should be thinly covered and kept moist. It takes 27 days for the radicle to emerge, another 3 days for cotyledons to emerge and another 4 days for the cotyledons to be fully expanded. For container seedling production, number of seeds to be sown per container should be calculated according to the seed quality. Container seedlings can be ready for field planting after 3-4 months.

Viburnum odoratissimum Ker

Caprifoliaceae
Sweet Viburnum

Growth Habit, Occurrence and Use

Sweet viburnum is an evergreen shrub or small tree up to 10 m tall. Branchlets are puberulous or glabrous. Leaves are coriaceous, glabrous, obovate to elliptic, 7-14 cm long, obtuse to rounded at the apex, cuneate at the base and have entire margins. This species occurs in Indochina, southern China, the Philippines and Taiwan. In Taiwan, it grows at elevations of 300-1,500 m in the Hengchun Peninsula area. Due to its beautiful color and strong resistance to wind, pollutants, insects and diseases, this species has great potential to become desirable for ornamental landscaping and greening in parks and planting in gardens and along streets (Chien 1998).

Collection and Processing

Sweet viburnum flowers in February-April and has white, bell-shaped blossoms arranged in an umbel. Its fruits, a single seeded drupe 1 cm long and 0.5 cm wide, mature in July-August, when the drupe changes from green to red and then gradually to purplish brown. The maturation period is long and varies among and within trees (Chen et al. 1999). When the drupes are collected, about half of them are dark purple and the others are red. Fruits require a few days of artificial ripening in a cool, shady place with frequent spraying with water. Seeds are extracted by macerating by hand in water. The cleaned seeds are then air dried in the shade and mixed with moist (about 75% moisture content) sphagnum in plastic bags for pre-sowing treatments. There are 9,500 clean seeds in a liter, and 1,000 seeds weigh 43 g.

Seed Dormancy and Germination

Sweet viburnum seeds have morphophysiological dormancy and require a combination of warm-cold stratification for maximum germination (C. Baskin et al. 2008). The best germination (88%) was obtained by 2 months of warm stratification at 30/20℃ followed by 3-month cold stratification at 4-5℃ in moist sphagnum in plastic bags, and then incubation at 30/20℃ with 12-hour light (Chen et al. 1999). Seeds began germinating after 1 week of incubation, and germination was completed in 3 weeks.

Seed Storage

Sweet viburnum seeds have intermediate storage behaviour. When seed moisture content is reduced to 8-12%, they can be stored dry at 5℃. They can also be stored in moist sphagnum at 5℃ for 6-12 months but not longer (Chien 1998).

Nursery Practice

The best practice is to sow seeds of known germinability after seed dormancy has been broken. Seeds are sown directly in seedbeds or containers. Container medium should be sandy loam soil mixed with manure. If vermiculite, peat moss and perlite are used, their ratio should be 1:1:1 with a mixture of the same ratio of manure, i.e. 1:1:1. Shade screens are required during the germination and early seedling development, but they should be removed after seedlings are well established. In the past, cuttings were the standard method of stock production due to the difficulty of propagation from seeds, but now that seedling production from seeds is the standard practice as the seed dormancy problem has been resolved.

Zelkova serrata (Thunb.) Markino

Ulmaceae
Taiwan Zelkova

Growth Habit, Occurrence and Use

Taiwan zelkova is a large deciduous tree with a straight trunk and can grow up to 30 m tall. Leaves are ovate, 2-3 cm long and 1.3-3.0 cm wide with leaf abscission between December and February. New leaves are fresh green, but they turn yellowish red before falling. Natural distribution of this species includes south-central China, Korea, Japan and Taiwan. In Taiwan, the species occurs over the whole island in hardwood forests at elevations of 300-1,400 m. The wood is hard and maintains its original shape after drying, and it has a beautiful shine after being planed and sanded. The wood is one of the most superior hardwoods and is used for ship-building, construction, bridge-building, furniture, farm tools and domestic fixtures. Standing volume in the natural forests has been drastically decreased due to over-logging in the past. This species is a drought and pest resistant and shade intolerant hardwood, and it should be considered a desirable species for soil and water conservation. In Japan, it is widely planted in gardens, for landscaping and street greening.

Collection and Processing

Taiwan zelkova flowers in February-March, at which time the new leaves are flushing. Flowers are small, yellow-green and dioecious; male flowers are shortly pedicellate and female flowers subsessile. Drupes are brown, sub-globose and oblique and mature in October-November. Since mature drupes will fall with the deciduous leaves, they should be collected in late October by cutting the fruit-bearing branches. The fruit-bearing branches require air-drying in the shade for 3-5 days to allow the seeds to fully mature. Seeds (with dried fruit material around them) are easily released by lightly threshing and winnowing. Clean seeds should be air dried in shade for 2 days before they are stored in containers at 5℃. It should be noted that seeds are very susceptible to molding. There are 43,900 seeds in a liter, and a liter of seeds weighs 359 g (Sheu 2007).

Seed Dormancy and Germination

Seeds of Taiwan zelkova have physiological dormancy and the freshly harvested seeds can reach 65% germination when they are incubated at 30/20℃ for 9 weeks (Yang et al. 2007). Cold stratification for 2 months increases both the rate and uniformity of germination, and increasing the cold stratification time increases the germination capacity and energy (Ishii 1979, Young and Young 1992, Yang et al. 2007).

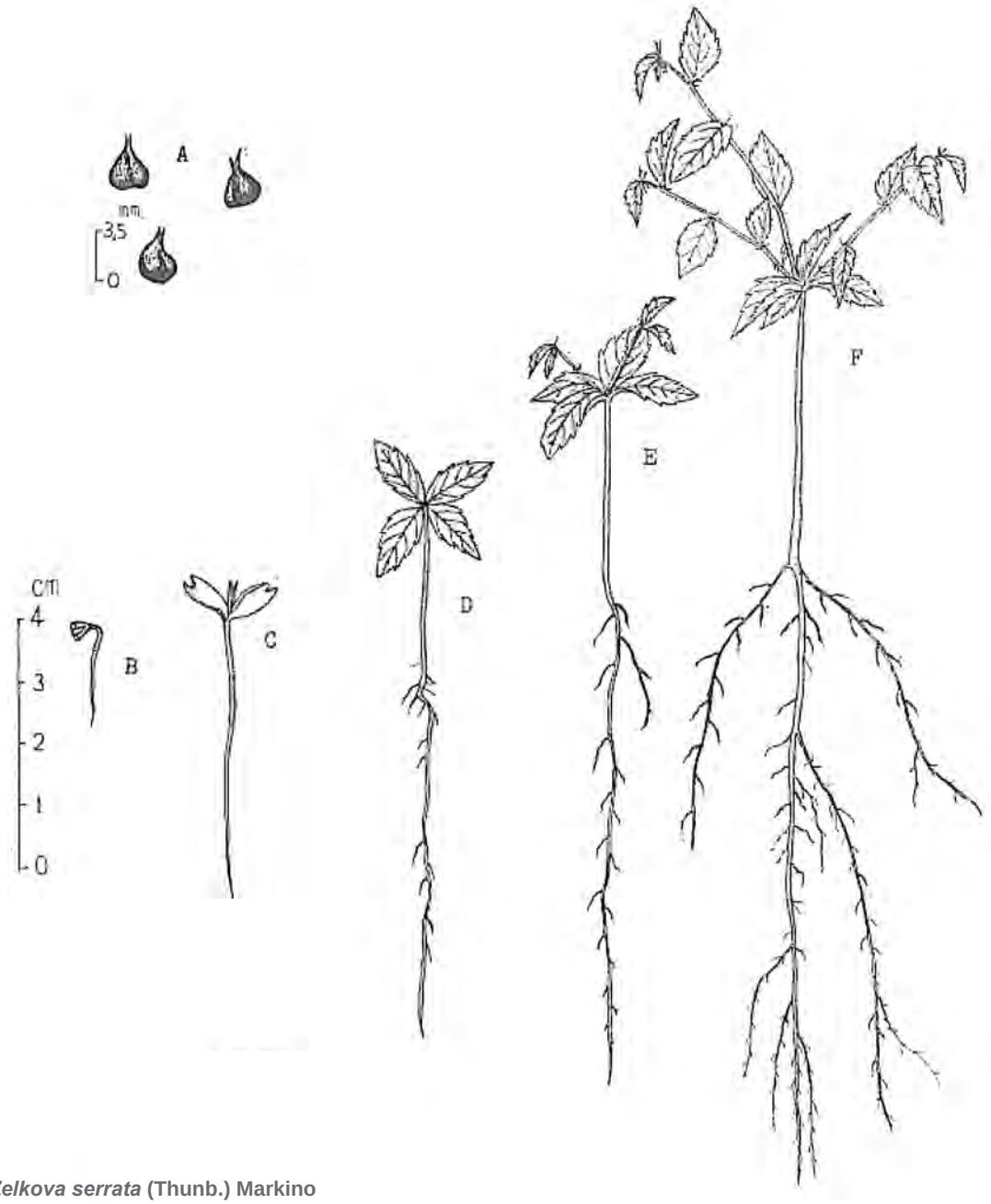
Seed Storage

The seeds have intermediate storage behavior. When the seeds are dried to a moisture content of 6-10%, they can be stored in sealed containers at 15℃ and 5℃ for 24 months, but germination is reduced quickly at -20℃ (Yang et al. 2007).

Nursery Practice

Seeds should be soaked in cold water for 24 hours before sowing, although 2 months moist chilling will improve both the capacity and rate of germination. Although bare-root stock is usually used for field planting, 80-100 cm tall plants grown in plastic bags have been planted with good results. During the early stages of growth of the newly planted stock, attention must be given to forking of the planted trees in addition to the usual weeding and other necessary conditions for culturing the plants. A pruning operation is required within

5 years of planting in order to facilitate the young tree's continued stem growth.



***Zelkova serrata* (Thunb.) Markino**

A. Seed
B. Radicle-emerged seed, day 2
C. Seedling, day 8
D. Young juvenile, day 16
E. Young juvenile, day 30
F. Young juvenile, day 60

From Yang 1984

PART III

Glossary

Afterripening (also known as post-harvest maturation) Cones or fruits maturation process required by some tree species in which organic matter is translocated from cones or fruits to seeds during the post-harvest curing period in order for the seeds to reach maximum germinability and vigour. The term afterripening means the breaking of physiological dormancy during dry storage of seeds, usually at or near room temperature.

Aril An accessory seed covering, often formed by an outgrowth at the base of the ovary, *e.g. Taxus mairei*.

Cold stratification This is a pre-treatment for breaking physiological seed dormancy. The traditional process involves mixing seeds with moist media such as peat moss, vermiculite or sand and placing them at a low temperature (0-10℃) for a period of time, the length of which depends on species and degree of dormancy. For many species, 5℃ is optimal for dormancy break. In some species with morphophysiological dormancy (MPD), cold stratification is not very effective in breaking the physiological dormancy part of MPD unless it is preceded by several weeks of warm (≥ 15℃) moist stratification, *e.g. Taxus*, *Cephalotaxus*, and some *Fraxinus* and *Viburnum* species. In Taiwan, fresh seeds are mixed with moist sphagnum moss (cut into small pieces and water content about 400% of dry mass), sealed inside polyethylene bags (0.04 mm thick), and placed at 5℃ in darkness for several weeks, depending on species.

Combinational dormancy This refers to seeds with both physical and physiological dormancy. The seed (or fruit) coat is water impermeable, and the embryo is physiologically dormant. In some seeds, physiological dormancy is broken via afterripening, after which the coat becomes permeable while in other seeds the coat becomes permeable first, after which physiological dormancy is broken by cold stratification, *e.g. Cercis* species, *Rhus aromatica*.

Damping-off Death of seed, germinants or young seedlings caused by a certain soil-living fungi in the nursery.

Dormancy A dormant seed (or other germination unit) is one that does not have the capacity to germinate in a specified period of time under any combination of normal physical environmental factors (temperature, light/dark, etc.) that otherwise is favourable for its germination after it becomes nondormant.

Drupe A fruit with a soft, thin outer layer (exocarp); soft fleshy middle layer (mesocarp); and a hard, stoney, water-permeable or water-impermeable, inner layer (endocarp or pit) that encloses the seed, *e.g.* peach, *Rhus* species.

Endocarp The inner layer of the pericarp (fruit wall) that in some species is hard and stony, *e.g. Prunus* species. In some species with physical dormancy, *e.g. Rhus* species, it is the water-impermeable layer of the diaspore.

Exocarp The outermost layer of the pericarp, *i.e.* the skin on the fresh fruit, such as in *Prunus* species.

Flailing Stricking dry cones or fruit with a wooden implement to release the seeds.

Germinability The germinating capacity of a seed lot.

Germination Emergence of radicle or some other part of the embryo from the seed.

Germination capacity The total germination of a seed lot under standard germination conditions without a time limit and expressed as a percentage.

Germination percentage The total germination of a seed lot under standard germination conditions within a given time limit. The percentage may be based on number of seeds sown or on number of viable seeds.

Germination rate This refers to the speed of germination. A common measure of germination speed is time to germination to 50% germination of the viable seeds (t_{50}).

Gibberellins This is a group of plant growth regulators. GA_3 is the most commonly used gibberellin to break seed dormancy.

Intermediate seed storage behavior Seeds tolerate drying to a moisture content below 10% (fresh weight), but they are sensitive to subfreezing temperatures; optimum storage temperature is 4-10℃ for up to 3 years, This storage behavior is "intermediate" between orthodox and recalcitrant and was discovered by Ellis et al in 1990.

Juvenile As used for figures in this publication, a stage in the plant life cycle between appearance of first true leaves and sexual maturity.

Medium This is the substrate such as sphagnum (used in Taiwan), blotting papers, filter paper, rolling towel, vermiculite, sand or Kimpak (cellulose cotton), on which seed are placed for dormancy-break and germination. The sphagnum moss used by the Taiwan Forestry Research Institute has proven especially beneficial for warm or cold stratification since it contains actinomycetes that prevent mould development, especially for pronged cold stratification (Wang et al. 1998). The word "medium" also refers to the soil manure mixture or the mixture of vermiculite, peat moss and perlite placed in containers to which seedlings are transplanted for growth.

Moisture content This is the amount of water in the seed or fruit measured by oven-drying, and expressed as a percentage of water either on fresh or dry weight basis. The International Seed Testing Association prescribes specific weight of seed sample to be tested by oven-dry method at 103℃ for 17 hours and expressed as a percentage of fresh weight.

Morphological dormancy This is a *class* of dormancy found in seeds with a small (underdeveloped), differentiated embryo, *i.e.* cotyledon(s) and hypocotyl-radicle can be distinguished, that must grow inside seed before germination occurs. However, dormancy-breaking treatments *per se* are not required. The dormancy period is the time required for embryo growth.

Morphophysiological dormancy Seeds with this *class* of dormancy have an underdeveloped embryo that has physiological dormancy. This *class* of dormancy is broken by warm and/or cold stratification, and the embryos grow during warm or cold stratification, depending on species. There are 9 levels of morphophysiological dormancy based on responses to warm and cold stratification, temperature requirement for embryo growth, effectiveness of GA_3 in promoting germination and amount of time between root and shoot emergence.

Normal seedling The newly germinated seedling has the essential structures, such as root system, shoot axis and cotyledon(s) that are healthy and show the potential for continued development into a vigorous plant under favourable conditions of soil, moisture, temperature and light.

Orthodox seed storage behavior Seeds have high tolerance to desiccation to extremely low moisture content (0.5-2% fresh weight) and can be stored in sealed containers at low and ultra-low temperatures (-18º to -196℃). There is a modified classification of orthodox seed: 'true' and 'suborthodox' with the suborthodox seeds being less tolerant to desiccation and ultra-low temperatures and having shorter longevity than true orthodox seed.

Physical dormancy Seeds with this *class* of dormancy have one more water-impermeable layers of palisade cells in the seed or fruit coat, and they have a specialized anatomical structure on the seed (or fruit) coat that serves as the water gap. In response to natural environmental signals, such as high or alternating temperatues, the water gap opens, allowing water to enter. Artifically, Mechanical or chemical scarification (*e.g.* concentrated H_2SO_4) will also promote germination.

Physiological dormancy Seeds in this dormancy *class* have a physiological inhibiting mechanism of germination that results in low growth potential of the embryo. There are three levels of physiological dormancy (PD): deep, intermediate and nondeep. Seeds with deep PD require 3-4 months of cold stratification for dormancy-break to occur, GA_3 does not promote germination and excised embryos do not grow or do not produce normal seedlings. Seeds with intermediate PD require 3-4 months of cold stratification for dormancy-break to occur, but warm stratification or afterripening can decrease the length of the cold stratification period required to break dormancy; GA_3 promotes germination in some but not all species; and excised embryos produce normal plants. Seed with nondeep PD require cold or warm stratification to break dormancy depending on the species, GA_3 promotes germination and excised embryos produce a normal plant.

Recalcitrant seed storage behavior Seeds germinate without maturation drying, and they are sensitive to desiccation, sealing in containers without a moist medium and low temperatures (< 0℃) and have short longevity (few weeks to less than a year). For tree seeds, Bonner (1990) created two categories: 'temperate' and 'tropical' recalcitrant seeds, with the former group being more tolerant to low storage temperatures (up to 4℃) and having longer storage longevity (1-2 years) than the latter group.

Seedling As used for figures in this publication, a stage in the growth of a plant between germination (radicle-emerged seed) and the time when it becomes independent of stored reserves for growth and thus before formation of first true leaves.

Vigor This refers to the relative robustness of a seed lot. Vigorous seed lots have the capacity to germinate rapidly and uniformly and produce healthy, normal seedlings under a wide range of conditions. A vigor classification system has been developed for laboratory use to help identify high-vigor seeds that are germinable and capable of developing into normal, healthy seedlings (Wang 1973, 1976).

Warm stratification This is a dormancy-breaking treatment in which seeds are imbibed and subjected to temperatures of ≥ 15℃ for 1-3 months.

Viability This means percentage of the seeds that is alive. Rapid, indirect tests to determine the percentage of living seeds include the cut test, color and firmness of excised embryo, x-ray, hydrogen peroxide and tetrazolium staining.

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