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Germination studies on two tropical tree species, *Alnus acuminata* ssp. *arguta* (Schlechtendal) Furlow and *Pithecellobium saman* (Jacq.) Benth

by

Karen Lynne Castro

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

in

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Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **Germination studies on two tropical tree species, *Alnus acuminata* ssp. *arguta* (Schlechtendal) Furlow and *Pithecellobium saman* (Jacq.) Benth** submitted by **Karen Lynne Castro** in partial fulfillment of the requirements for the degree of **Master of Science** in **Conservation Biology.**

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Date: January 23, 1998

Abstract

Lack of knowledge of the germination behavior of tropical tree species is one factor hindering their use in reforestation programs. In this study germination protocols were developed for *Alnus acuminata* and *Pithecellobium saman*. Recommended germination conditions for *A. acuminata* are temperatures between 24 and 27°C, a photoperiod between 16 to 24 hours of light per day and a substrate of sand or paper. Germination increased linearly with increasing pH between pH 4 and 10. *P. saman* germinated equally well at temperatures between 24 and 35°C, under all photoperiods and throughout the range of pH tested. Germination was faster at the higher temperatures. Percent germination of this species was highest in a sand substrate. Additional trials with several pregermination treatments revealed that scarification with concentrated sulfuric acid for 75 minutes was best at breaking coat-imposed dormancy in *P. saman*. Finally, it was determined that seed size had no effect on germination of *P. saman*. Although seedlings from larger seeds were taller, it was concluded that seed sorting according to size was not recommended for this species.

Acknowledgement

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LIST OF ABBREVIATIONS

ANOVA = analysis of variance

BLSF = Banco Latinoamericano de Semillas Forestales (Latin American Seed Bank)

CATIE = Centro Agronómico Tropical de Investigación y Ensenañza (Tropical Agricultural Research and Education Centre

DGS = daily germination speed, calculated by dividing cumulative germination percentage by number of days since the beginning of the germination test

gv = germination value, a measure of both the speed and totality of germination as defined by Djavanshir and Pourbeik (1976)

ISTA = International Seed Testing Association

PROSEFOR = Proyecto de Semillas Forestales (Forest Seed Project)

pv = peak value, a measure of germination speed as defined by Czabator (1962)

TKW = thousand kernal weight, calculated based on the weight of eight repetitions of 100 seeds according to ISTA (1976)

1. INTRODUCTION

Tropical forests are home to a great diversity of tree species. The majority of these species have been excluded from local reforestation programs in favor of a few fast-growing, well-known species that are often not native to the areas in which they are planted. According to Evans (1987), pioneer tree species such as eucalyptus, pines and teak together account for 85% of tropical forest plantations worldwide. *Eucalyptus* spp. alone account for an astounding 37% of plantations with pines (*Pinus* spp.) a close second at 34% and teak (*Tectona* sp.) at 14%. The use of such a narrow range of species is unwise in such biologically diverse tropical countries where the potential of native species remains largely undiscovered and untapped. The exclusion of such species is in part due to a lack of knowledge about their propagation and management.

With the information that this type of research would provide, many could become excellent candidates for reforestation programs. Use of a variety of these species in sites where they are found naturally would be beneficial in providing people and wildlife with the habitat, food and wood resources to which they are already accustomed, thereby better guarding the natural integrity of the place where they are planted and also reducing pressure on primary forests. Their use could also protect those same species from genetic erosion or even possible extinction.

This study focused on determining germination protocols for two native Central American tree species. The species, *Alnus acuminata* and *Pithecellobium saman*, have good potential for use in local reforestation programs. Greater knowledge of their germination requirements is necessary for the culture and production of large quantities of tree seedlings.

The study took place at the Tropical Agricultural Research and Education Center (CATIE) in Turrialba, Costa Rica. The Latin American Seed Bank (BLSF) is located there, where a program called the Forest Seed Project (PROSEFOR) is currently running. The main objective of the program is to provide sound, high quality, well adapted seeds for tree planting programs. Additional goals include applied research and provision of information on tree species and their provenances as well as seed production, collection, processing and seed bank management (PROSEFOR pamphlet).

At the BLSF many native as well as a few exotic species are being investigated. One of the many goals of the Bank is to provide information on the best germination conditions for the species it collects and sells or distributes. This project, which deals with tree seeds, provides a good initiative in the process of using new species in reforestation programs.

The objectives of this study were:

1. To establish a germination protocol for two provenances of *A. acuminata* and one of *P. saman* by evaluating the germination response to treatments of temperature, substrate, photoperiod and pH. The aim was to determine the conditions under which consistent, high percent germination could be achieved in seed bank or tree nursery conditions in order to maximize seedling production and to prevent seed wastage.
2. To compare the effectiveness of several pregermination treatments for *P. saman*. The goal of this objective was to find an inexpensive, quick method of pretreating the seeds.
3. To investigate the effect (if any) of seed size on germination and early growth of *P. saman*. It would be advantageous to determine if seed sorting according to size would be worthwhile prior to planting to maximize percent germination and establish a uniform stand of robust seedlings.

The thesis also contains an extensive appendix (appendix 1) on the habitat, morphology, phenology and propagation methods of 79 tree species found in the area of Monteverde, Costa Rica. The information was compiled in 1995 as part of a project at the Monteverde Conservation League Tree Nursery and may be considered as background material for this thesis.

2. LITERATURE REVIEW

2.1. Species

2.1.1. *Alnus acuminata*

2.1.1.1. Latin nomenclature

The scientific name of the species 'jaúl' is a matter of some confusion. An early thesis by Alvarez (1956) summarizes the names and descriptions of the various *Alnus* (family: Betulaceae) species found in Central and South America given by various authors. The names *Alnus acuminata* H.B.K. and *Alnus jorullensis* H.B.K. are considered synonymous by many, and separate species by others. (Jiménez *et al.*, 1985; Murillo and Vílchez, 1989; CATIE, 1986, NAS-CATIE, 1984; DGF-CATIE-ROCAP, 1986). Those of the latter mindset would argue that *A. acuminata* is a Central American species and *Alnus jorullensis*, with a slightly different leaf shape, is a South American species. The most recent literature from Costa Rica, where this study took place, claims that the jaúl of this same country is *Alnus acuminata* ssp. *arguta* (Schlechtendal) Furlow (CATIE, 1994; CATIE, 1995), a subspecies of a species native to both Central and South America.

The common name 'jaúl' is unique to Costa Rica. This species is also known by a variety of other names, differing from country to country. These names include: aliso (many parts of Central and South America), cerezo or chaquiro (Venezuela, Colombia), palo de lama (Guatemala), lambrán, ramrám, rambash, huayoo (Peru), aile, ilite, palo de águila, olmo del país, abedul, yaga-bizie (Mexico) (Vásquez, 1985; Pretell *et al.*, 1985; Niembro, 1986).

2.1.1.2. Distribution

A. acuminata is widely distributed, found in Mexico all the way south to Argentina. It is native to Mexico, Central America and northern Panama and has been introduced to other countries including Chile and New Zealand (CATIE, 1994; NAS-CATIE, 1984). Plantations of this species exist in Guatemala, Costa Rica, Colombia, Bolivia, Peru and Argentina (CATIE, 1994; NAS-CATIE, 1984). In Costa Rica its natural population is found in the Talamanca and Central Volcanic Mountain ranges (Murillo *et al.*, 1993).

2.1.1.3. Environmental requirements

Jaúl requires a cool, medium to high elevation environment in which to grow. It will develop in areas with temperatures ranging from 4 to 27°C, preferring between 16 and 18°C. Temperatures dropping to 0°C for short periods will not harm this tree (Bauer, 1982; CATIE, 1994; CATIE 1995; NAS-CATIE, 1984; Rojas, 1981; Pretell *et al.*, 1985 and Poschen, 1980a). It is usually found in mountainous regions at elevations between 1200 and 3200 meters above sea level (NAS-CATIE, 1984). An annual precipitation between 1000 and 3000 mm with a dry season of between two to five months is ideal, and it will grow in a wide variety of soil types (CATIE, 1994).

2.1.1.4. Morphology

A fast-growing pioneer tree species, jaúl typically reaches a height of 10 to 30 m (Appendix 1). Its bark is dark grey and smooth; its alternate leaves are dark green, doubly serrate along the edges and with pointed tips. The separate staminate and pistillate flowers are both yellow and found in inflorescences along the same branches (CATIE, 1994; CATIE, 1995). Small, round, scaled cone-like catkins are formed, each scale containing one or two winged samaras for a total of 80 to 100 seeds per cone (Alvarez, 1956; Murillo *et al.*, 1992). The brown seeds are up to 0.65 mm wide and 1.34 mm long (Arnáez and Moreira, 1992). The quantity of seeds per kilogram varies, with reports of 861,111 (BLSF, 1996), 1,000,000 (Lemckert, 1979) and 2,180,549 (Rojas *et al.*, 1991).

2.1.1.5. Phenology

In Costa Rica, seed catkins (closed strobili) usually appear from September to January and pollen catkins from January to February. Flowers are wind-pollinated. Mature jaúl seeds are available from September to January (Rojas *et al.*, 1991) These timings may vary somewhat with elevation.

Plate 2-1. Leaves of *A. acuminata*

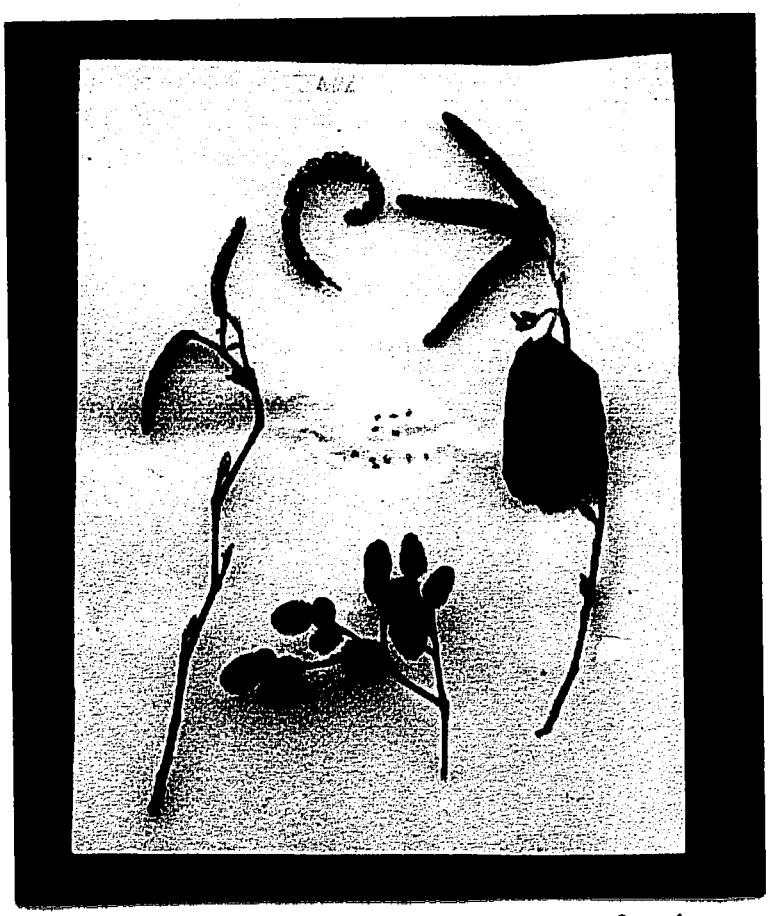

Plate 2-2. Male catkins (left and right), mature female cone-like catkins (bottom centre) and seeds (centre) of *A. acuminata*

2.1.1.6. Seed collection and management

The cones of this species should be harvested at the point when they change from green to dark yellow or brown. Past this point, as the cones become entirely dark brown, they will lose many of their seeds. The harvested cones are then transported in paper or cloth bags to the processing area where they are placed on a mat in full sun. The cones open to release the seeds. They may be sifted out from the larger debris using a screen (Rojas *et al.*, 1991; CATIE, 1995).

According to the literature, seeds do not require a pregermination treatment (DGF-CATIE-ROCAP, 1986; Jiménez *et al.*, 1985; Rojas *et al.*, 1991). Germination tests with this species performed under a variety of conditions have given a variety of results. A review of these results is presented in Table 2-1.

Table 2-1. Germination test results for *A. acuminata* from various literature sources

Source	Germ. (%)	Initial germ. (days)	Final germ. (days)	Optimal temp. (°C)	Substrate	Light (hours per day)
ISTA (1976)	?	7	21	20-30	top of paper	8+
Rojas *et al.* (1991)	70	6	?	?	no more than 1/3 sand (suggests sand:soil:organic mat. 1:1:2)	?
Lemckert (1979)	30	20-25	?	?	?	?
BLSF (1996)	varies	?	5	30	filter paper	constant
Galloway and Flores (1986)	80	?	?	?	?	?
CATIE (1995)	?	5-10	40	?	good proportion of both sand and organic material	?
Hernández (1990)	high	?	?	30-31	filter paper	?
Trujillo (1986)	29.1	6	9	?	?	?

Note: Question marks in the table indicate that the corresponding information was not provided by the source. Germination criteria not defined by most sources.

The reported germination data for jaúl is clearly a matter of controversy. Germination tests, including others not listed above, show values from 10 to 97.5% (Rojas *et al.*, 1991). Maturity of the cone may influence seed viability, or perhaps good seeds are shed first. A study of this nature revealed that 35% germination was achieved from seeds from green cones whereas only 15% was reported from dark brown cones (Vásquez, 1989; Rojas *et al.*, 1991).

Variability in germination tests indicates a need for collection and germination protocols for this species. With information on seed sources, optimal collection times and

optimal germination conditions of temperature, substrate, photoperiod and pH, germination would be consistently more favorable.

The storability of jaúl seeds is also subject to dispute. Several authors state that once collected, seeds lose their viability quickly. Rojas *et al.* (1991) report that germination of fresh seeds will drop from 80 to 20% in several months (likely at room temperature). Information from CATIE (1995) states that in common refrigerators the seeds will lose approximately 2% of their viability monthly. DGF-CATIE-ROCAP (1986) reports, however, that even at ambient temperature seeds maintain viability for three months. Trujillo (1993) writes that after four years of storage at 5°C and 60% relative humidity, 40% of jaúl seeds still germinated (initial percent germination was not given). Authors are in agreement that seeds of jaúl should be stored at low temperatures (3-5°C) in tightly sealed containers (Rojas *et al.*, 1991; Trujillo, 1993; CATIE, 1995). In the BLSF, these seeds are stored at 5°C in sealed black plastic containers.

2.1.1.7. Uses

Jaúl is a multiple-use species (Appendix 1). Its wood, fine textured and straight grained, is used for pulp and paper production, firewood, carpentry and construction (NAS-CATIE, 1984; Jiménez *et al.* 1985; DGF-ROCAP-CATIE, 1986). Some jaúl wood products include: pencils, matches, musical instruments, fence posts, coffins, broomsticks and orthopedic shoes (Poschen, 1980a; NAS-CATIE, 1984; DGF-CATIE-ROCAP, 1986; Rojas *et al.*, 1991; CATIE, 1994; CATIE, 1995). The bark contains tannins used to cure leather. Moreover, the leaves are used in several medicinal roles; people claim they help heal wounds and fight against rheumatism and colds (Rojas *et al.*, 1991). Jaúl is often found as a source of additional income in agroforestry systems, grown in association with pasture, coffee, corn and beans (Poschen, 1980a; Poschen, 1980b; Alvarez, 1956; CATIE, 1995). The trees not only shade the companion crops but enrich the soil with nitrogen. Jaúl forms a symbiosis with the actinomycete *Frankia*, causing nodule formation and allowing the fixation of nitrogen (between 40 and 320 kg nitrogen/ha/year), making it an ideal species to aid in the reclamation of degraded soils (NAS-CATIE, 1984; Rojas *et al.*, 1991; CATIE, 1994).

2.1.1.8. Status in Costa Rica

In Costa Rica, jaúl is planted intensively in reforestation programs (Camacho and Murillo, 1987). Due to its rapid growth and multiple uses, it is considered a species of great potential for the wet, high elevation zones of Central America (CATIE, 1995). In 1988 it was one of the top species produced in tree nurseries in Costa Rica (CATIE-DGF, 1985-91). An estimated 100,000 (of a total of 12,229,895 trees of 11 species) seedlings of jaúl were produced in private and state-run tree nurseries in 1989 (Ochoa, 1989). By 1995 a total of 2894 ha of jaúl were planted, the majority at elevations above 1500 m above sea level in volcanic soils (CATIE, 1995). Despite its great potential, there is a lack of specific information on the production and management of this species (CATIE, 1995).

2.1.2 *Pithecellobium saman*

2.1.2.1. Latin nomenclature

Pithecellobium saman (Jacq.) Benth is a huge, spreading mimosaceous tree found throughout the tropics (Janzen, 1983; IRENA, 1992). It is synonymous with *Samanea saman* and *Albizia saman* (Martínez and Enriquez, 1984; Nichols and González, 1992; Raintree, 1987).

Like jaúl, common names for *Pithecellobium saman* are varied. Names include genízaro (Nicaragua), carreto (Honduras), algarrobo, guanja (Jamaica), samán (Colombia, Ecuador, Venezuela), urero, cenicero, lara (Venezuela), raintree, samanea, monkey pod, cow tamarind (Hawaii) (Martínez and Enríquez, 1984; Cristino, 1992; SEFORVEN, 1992; IRENA, 1992, Janzen, 1983; Raintree, 1987). In Costa Rica, the species is known as árbol de lluvia or more commonly, cenízaro (Martínez and Enríquez, 1984; Nichols and González, 1992).

2.1.2.2. Distribution

The native territorial expanse of cenízaro ranges from Mexico to northern South America, including Bolivia, Paraguay and parts of Brazil (Holdridge and Poveda, 1978; Janzen, 1983; IRENA, 1992). It is typically found in hot, dry lowlands and grass savannas where it behaves as a deciduous tree, but where planted in rainforest will

remain evergreen (Janzen, 1983). Cenízaro has been widely introduced throughout the tropics, including such countries as Malaysia, Indonesia, the Philippines and the United States (Hawaii) (Raintree, 1987), where it is popular as a shade and garden tree. In Costa Rica, this species is found mainly in the province of Guanacaste and elsewhere where planted.

2.1.2.3. Environmental requirements

Cenízaro, unlike jaúl, is suited to grow in low elevation areas and will tolerate a wide range of precipitation. It grows best in warmer climates (mean annual temperature 22-28°C) of the humid and sub-humid tropics, thriving within an annual precipitation range of 600 to 3000 mm (Raintree, 1987). It is fairly drought resistant (Allen and Allen, 1981). This tree will usually be encountered at elevations from sea level to 500 m above sea level (IRENA, 1992). Found in a variety of soil types, cenízaro grows best in fertile, well-drained, medium-textured soils, neutral to acidic in pH (Raintree, 1987; IRENA, 1992; SEFORVEN, 1992).

2.1.2.4. Morphology

An impressive tree, cenízaro is normally found free-standing in savanna areas where its "massive, dome shaped crowns and rich green foliage sprinkled with conspicuous pink powderpuff flowers" extend from a short, thick trunk (Raintree, 1987). It grows rapidly. In a plantation in Pejibaye, Costa Rica, it attained an average diameter of 17.8 cm and height of 13.4 m in ten years (Nichols and González, 1992). Full height is approximately 30 m (IRENA, 1992, Appendix 1). The bark is dark grey to black and fissured (Holdridge and Poveda, 1978; IRENA, 1992). Leaves are compound, bipinnate and alternate with well-developed petiolar nectaries (Janzen, 1983; IRENA, 1992). Leaflets close at night. The showy flowers of cenízaro appear in dense umbels. Each flower has many pink stamens (Holdridge and Poveda, 1978). Brown, curved, indehiscent glabrous fruits are formed, ranging in length from 10 to 20 cm and in width from 1 to 2 cm (Holdridge and Poveda, 1978). The hard brown seeds contained within are surrounded by a sugary pulp. Seeds measure approximately 5 to 13 mm in length.

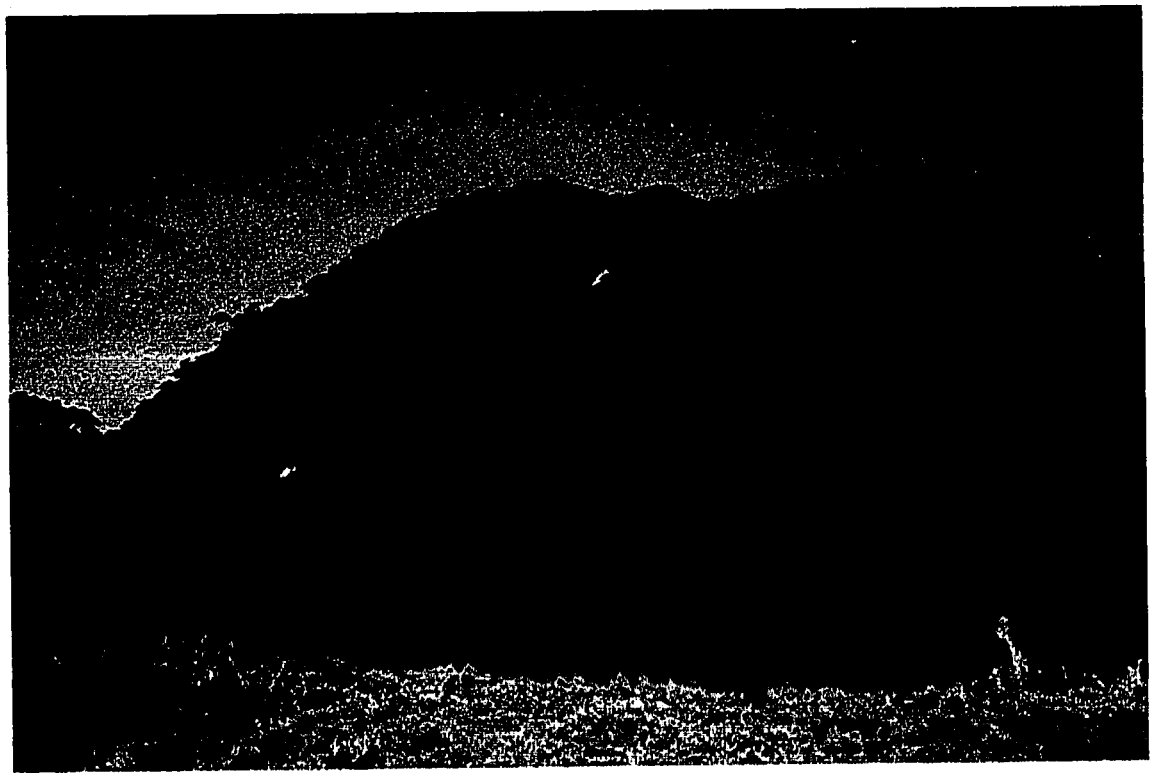

Plate 2-3. *P. saman*

Plate 2-4. Leaves and flowers of *P. saman*

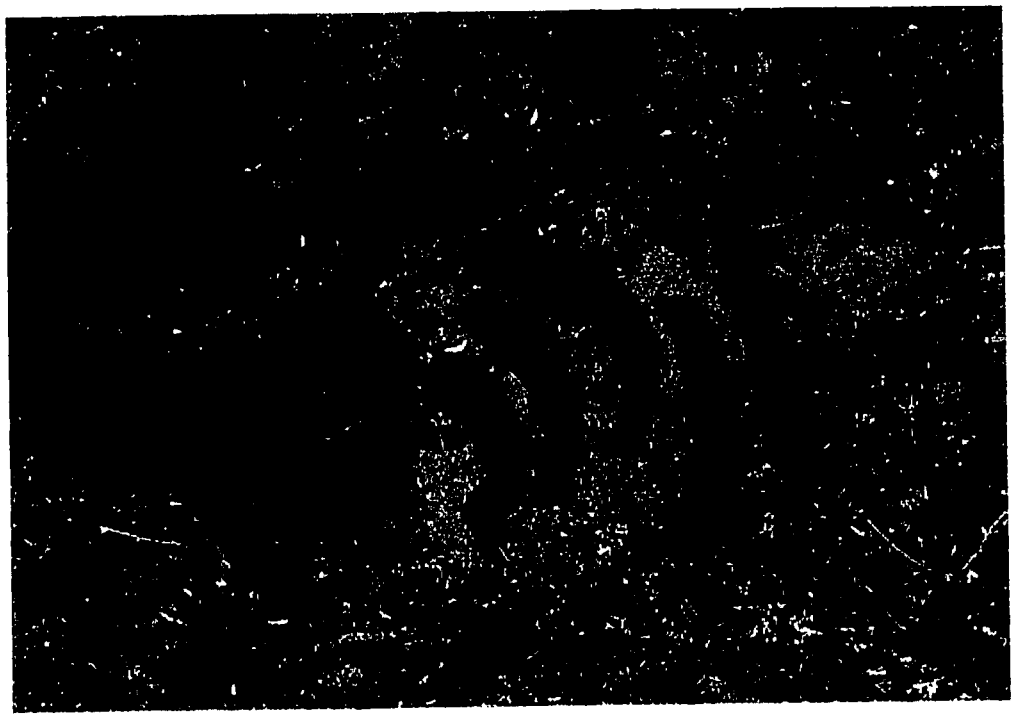

Plate 2-5. Pods of *P. saman*

Typical pods contain 9 to 13 seeds (SEFORVEN, 1992). Number of seeds per kilogram range from 4400 to 7000 (IRENA, 1992).

2.1.2.5. Phenology

In Cost Rica, cenízaro trees flower in the last two months of the dry season (March-April). Fruits remain small (3 to 5 cm long) through the rainy season and rapidly enlarge and mature in the dry season (March), shortly before the flowering begins again (Janzen, 1978; Janzen, 1982).

2.1.2.6. Seed collection and management

Upon maturing, cenízaro pods turn from green to dark brown and fall from the tree (Appendix 1). The pods are then collected from the ground and must be broken open to release the hard seeds inside.

A variety of pregermination treatments are recommended for cenízaro seeds by several authors. Due to a hard seed coat, seeds must be scarified before they will germinate. At CATIE, standard procedure is to make a small cut in the testa opposite the side where the embryo is located (González, 1996). Trujillo (1986), however, states the best treatment for the seeds is a soak in sulfuric acid (95%) for 75 minutes. Raintree (1987) suggests a hot water treatment for three minutes followed by soaking in cool water overnight. For Fonseca *et al.* (1990), the best results (93% germination) were achieved by placing the seeds in water at 100°C, allowing it to cool, then soaking them in water at room temperature for 24 hours. This procedure would then be repeated two more times with non-imbibed seeds. Quirós and Chavarría (1990) placed seeds in water at room temperature for 48 hours, changing the water every 12 hours, and found that germination initiated in two days. IRENA (1992), using a very similar method, found that the period of germination oscillated between 14 and 20 days. Lastly, SEFORVEN (1992) recommends a 24-hour submersion in water at room temperature or 30 seconds in boiling water.

There are many pregermination treatments available for *P. saman*. These treatments should be compared to determine which is the most effective and efficient for

this species. The best method could then become the standard used in seed laboratories and tree nurseries.

Once seeds are properly scarified, they germinate readily, usually initiating at the second to fourth day and terminating after approximately two weeks (Trujillo, 1986). Trujillo (1986), after repeating germination tests many times, found that with different lots of cenízaro seeds, percent germination ranged from 51 to 100%, with a high average of 94.5%.

P. saman seeds are durable and store well. Even at ambient temperature, seeds may be stored for a year in sealed glass jars without loss in viability (Brenes, 1995). This is due to a hard seed coat and low moisture content (14% on average), making cenízaro seeds true orthodox seeds (Trujillo, 1986). At low temperatures seeds will store for much longer periods. Storage in hermetically sealed containers at 4°C is recommended by Becerra (1977). At CATIE, seeds are stored in tightly sealed dark plastic containers at 5°C.

2.1.2.7. Uses

Cenízaro, a multi-use tree, is highly prized for its "beautifully but subtly grained" heartwood used for furniture and wood paneling (Janzen, 1983). The wood is also used for cabinets, carvings, posts and general construction (Appendix 1; Raintree, 1987; SEFORVEN, 1992; IRENA, 1992). It may also be used for firewood, although in many areas the wood is considered too valuable for this use. In pastures, its spreading, mushroom-shaped crown provides shade for cattle which avidly consume the fruits. It is also grown as a shade tree for crops such as cacao, coffee, vanilla and nutmeg (Raintree, 1987). As well, its beautiful form makes this species "one of the most commonly planted avenue and park trees in the tropics" (Raintree, 1987). Lastly, this legume is a nitrogen-fixing tree and will improve soil conditions (Raintree, 1987).

2.1.2.8. Status in Costa Rica

There is little information available regarding the number of seedlings produced and planted in Costa Rica. In 1991 it was calculated that 8,500 seedlings of cenízaro had been seeded in tree nurseries associated with the *'programa de desarrollo forestal*

campesino' (DGF) in southern Costa Rica (Retana and Stanley, 1991). Beyond this figure, it is clear that cenízaro is a species of interest as it has been included in numerous scientific studies. For example, in Liberia, Costa Rica, an experiment in which native tree species were planted in mixed plantations in blocks included cenízaro as a species of good potential (Brenes, 1996). Cenízaro is also identified as a promising species for plantations by Rodríguez (1996), who mentions that studies done to date are valuable but scarce and that there is a need for more studies and the continuation of current studies. Butterfield (1995) investigated the development of numerous tree species, including *P. saman*, in sun and shade plots in La Selva, Costa Rica. Seedling survival and height measurements over time were reported in a study by Knudson and Prosnier (1985). Little by little, knowledge of this species increases. It is clearly a very useful species that requires more study in numerous aspects such as methods of storage and germination of seeds, seedling production and growth and behavior at a plantation level (Quirós and Chavarría, 1990).

2.2. Seed Germination And The Importance Of Seeds

Seeds play a fundamental role in our existence. Seeds of many plants provide us with things we need and enjoy from day to day. Consider waking up to a typical breakfast. The coffee bean enlivens us to face the day. The wheat or rice in our cereal or toast nourishes our bodies. The table we sit at may well have originated as a seed, such as pine or maple, not to mention the roof over our heads. And the morning newspaper, too, would not have appeared without the miracle of seeds, nor the beautiful and brightly-colored flower garden seen just outside the window.

The importance of seeds should not be underestimated. Their viability and germination are key components to the cycles we depend on. Seeds are the remarkable product of sexual reproduction in plants. These units are dispersed in a variety of ways, via wind, insect or mammal, and under suitable conditions will germinate and produce a new plant.

Germination of orthodox seeds will, according to Bewley and Black (1994) "transform a dehydrated, resting embryo with a barely detectable metabolism into one that has a vigorous metabolism culminating in growth." This process typically starts with

imbibition, or water uptake by the seed, and terminates as the embryonic axis (the radicle) begins elongation (Bewley and Black, 1994). Many events are happening concurrently at this time, including protein hydration, enzymatic activation, subcellular structural changes, increasing respiration, assimilation and translocation of food reserves and cell elongation leading to the emergence of the radicle and plumule (Bewley and Black, 1994; Samaniego, 1995).

For germination to take place, three conditions must be met. These conditions are: 1.) The seed must be viable, with a live embryo capable of germination; 2.) internal conditions of the seeds must be favorable for germination; that is, any physical or chemical barrier to germination must have disappeared and; 3.) environmental conditions must be favorable, such as appropriate temperature and the availability of water, oxygen and in some cases, light (Garza L. de Lara and Ortega, 1980, as cited in Samaniego, 1995).

Given the first condition (that the seeds are viable), artificial manipulation of internal and external conditions can greatly influence the success of germination. Knowing how these factors influence germination is valuable, for when appropriate measures are taken germination can be maximized. The importance and influence of temperature, light, substrate and pH on germination are discussed in the following section.

2.3. Factors Influencing Germination

2.3.1. Temperature

Temperature affects both total percent germination and the rate of germination (Bewley and Black, 1994). Optimal temperature for germination is that temperature at which the highest percentage of germination is attained in the shortest time (Mayer and Poljakoff-Mayber, 1963, as cited in Roberts, 1972). Both optimal temperature and temperature range over which germination will occur are unique to each species. Above a certain minimal temperature required for germination, percent germination and rate of germination increase as temperature increases to a maximum and then declines. The increase relates to the rate of biochemical reactions within the seed (Garza L. de Lara and Ortega, 1980) and the subsequent decline to the possible induction of thermodormancy

and, at very high temperatures, deleterious protein denaturation (Bewley and Black, 1994).

The literature contains numerous examples of the effects of temperature on germination. In many of these studies, the seeds of one or more species are tested over a range of temperatures to determine their optimal temperature. For example, Villagra (1995) studied germination of two pioneer species, *Prosopis argentina* Burk. and *P. alpataco* Phil., at temperatures of 10, 15, 20, 25, 30, 35, 40 and 45°C. He determined that optimal germination temperature for both species was 35°C, with a minimum germination temperature of 15°C and maximum of 40°C. Similar studies include those by Teketay (1996), Bell *et al.* (1995), Cavero *et al.* (1995), González and Haddad (1995), Samaniego (1995), Jara and López (1996), Torres and Mello (1994), Torres *et al.* (1994) and Herrera and Alziga (1992).

Seeds of both *A. acuminata* and *P. saman* were sown at 30°C for typical germination tests in the seed laboratory at CATIE. The two species come from different habitats, however, and likely germinate better at temperatures lower or higher than 30°C.

In light of this possibility, the first of seven tests for this study was to determine the optimal temperature for germination of *A. acuminata* and *P. saman*. The seven tests given in Sections 2.3 through 2.5 were used as the means of achieving the three general objectives listed in Section 1.

2.3.2. Light

Intensity of light, quality of light and daylength influence germination of seeds in a variety of ways. Many small seeds require exposure to light for germination. These seeds are referred to as photoblastic seeds. A light requirement by small seeds may be an adaptation to prevent them from germinating when buried too deep in the soil (Fenner, 1985). Light may also be a cue for pioneer species to germinate when gaps are created in forests and conditions are opportune for colonization.

On the contrary, there are many species with negatively photoblastic seeds. These seeds are inhibited by continuous white light (Bewley and Black, 1994). Germination of seeds of this type would more likely occur when buried and in better contact with soil moisture. Roth *et al.* (1996) found that germination of barley (*Hordeum*

vulgare L.) cv. Triumph was inhibited by prolonged (16 h/day) to continuous illumination, especially when environmental conditions (for instance, temperature and water availability) were less than optimal for germination. Choudhury and Gupta (1995) also found greatly reduced germination of *Catharanthus roseus* (L.) G. Don cv. alba seeds in continuous light versus dark. A steady decrease in germination with increased light duration from 0.5 h to continuous illumination was observed by Gutterman (1996) while studying the seeds of *Schismus arabicus* Nees. An adaptation of this nature may be linked to avoidance of very hot, dry conditions that may be associated with long day-lengths.

There are yet other seeds which are completely insensitive to light during germination. Samaniego (1995) claims that most tropical tree species germinate without the stimulation of light as they are often covered by leaf litter on the forest floor. Bell *et al.* (1995) found that of 43 native Australian species, large-seeded species were less sensitive to light exposure than smaller-seeded species, likely because depth of burial would not be as critical for seedling survival with the larger-seeded species that have more food reserves available. Seeds of various species were deemed insensitive to light quantity in recent studies by Teketay (1996) and González and Haddad (1995).

The influence of light on germination is complex. Seeds contain phytochrome, a light-sensitive pigment involved in breaking dormancy. Photoblastic seeds require exposure to red light to convert phytochrome to its active form and allow germination (Bewley and Black, 1994). Seeds differ in the length of exposure time required to break dormancy, from seconds to minutes to hours to long days (Bewley and Black, 1994). The activation of phytochrome is reversed by exposure to far-red light. High temperatures can also interfere with the phytochrome complex by hastening deterioration of its active form to inactive form, thereby inducing thermodormancy, a type of secondary dormancy.

The influence of light on germination of a species is clearly important knowledge for the person interested in achieving a consistent, high percent germination. Although daylength is fairly consistent in regions near the equator, a light requirement for seeds may be important in preventing or promoting germination under different forest conditions, such as burial vs. exposure. Daylength, like temperature, is a variable used in germination protocol studies at the BLSF. For example, Samaniego (1995) determined

that germination of caoba (*Swietenia macrophylla* Jaq.) was significantly higher with a 16 h photoperiod compared to a 24 h photoperiod. A second study by Jara and López (1996) showed that germination of six forest species, including several leguminous trees, was not significantly affected by photoperiods of 0, 8, 16 and 24 h of light although there was a tendency for two of the species to germinate better under 0 or 8 h of light.

In this study, the second test was to determine if there would be any differences in the germination of seeds of *A. acuminata* and *P. saman* under four daylength conditions (photoperiods).

2.3.3. Substrate

Choice of substrate for a germination test is another factor influencing germination. According to Roberts (1972), "the principal function of the substrate is to supply moisture." As a result of moisture conditions in the substrate, availability of oxygen is also determined. Water and oxygen are critical in the process of germination. If water supply is insufficient, seeds will not germinate (Chowings, 1970). Too much water, however, impedes oxygen uptake and promotes the growth of fungi and bacteria which may harm the seedling as well as compete for available oxygen (Orphanos and Heydecker, 1967; Gaber and Roberts, 1969).

A good substrate will maintain an adequate balance of hydration and aeration. As well, it should be free of fungi and other microorganisms and be non-toxic to plants (Samaniego, 1995).

There are many types of substrates available, such as paper, sand, soil, vermiculite, cotton, bark and peat. They may be used alone or in various mixtures. Choice of substrate will depend on such factors as seed size, requirement of light by seeds, availability and ease of use (Samaniego, 1995). For instance, sterile paper is often used for small, photoblastic seeds (Roberts, 1972). Sand would be more appropriate for larger, non-photoblastic seeds. In general, seedbed coarseness should increase with increasing seed size. Germination studies comparing several different substrates have been carried out using various species by Torres *et al.* (1994), Torres and Mello (1994) and Otsamo *et al.* (1996).

At the BLSF, Jara and López (1996) recently found that filter paper was not a suitable substrate for five tropical leguminous tree species as it did not allow good contact between the seeds and the moisture in the substrate. Germination for these species was highest in sand followed by organic soil. In a study involving *Swietenia macrophylla*, a sand:soil substrate gave the best germination results, followed by sand and lastly filter paper (Samaniego, 1995).

The two species in this study are very different in size and likely have different substrate preferences. Therefore, the third test was to determine the effect of substrate (paper, sand and a 1:1 sand:soil mixture) on germination of *A. acuminata* and *P. saman*.

2.3.4. pH

In comparison with temperature, light and substrate, fewer studies have focused on the influence of substrate pH on germination. However, it should not be overlooked as it could have important implications for a species' suitability to various site conditions. This may become particularly evident when, for example, a tree species is used to reforest degraded areas that may be moderately to highly acidic or basic. The pH factor may also influence the type of substrate to be used for germination tests.

Germination can proceed over a fairly wide range of pH, with almost all species germinating readily between pH values of 4.0 to 7.6 (Justice and Reece, 1954, as cited in Copeland and McDonald, 1985). For some species, the pH window is wider than for others. Significant differences in the germination of the tropical tree species caoba (*Swietenia macrophylla*) were not observed when tested at pH levels of 4, 7 and 10 (Samaniego, 1995). However, percent germination of wheat (*Triticum* sp.) was strongly reduced by acid soils in a study by Horne *et al.* (1995). With pH levels of 7.5, 6.8, 6.04 and 4.99, germination was significantly lower for several cultivars at pH 6.04 and even more so at 4.99. High pH, conversely, inhibited germination of several forest and crop species in a study by Henig-Sever *et al.* (1996). In post-fire soils, such as those studied by Henig-Sever *et al.*, characteristically high pH is considered an important environmental factor which negatively influences forest regeneration.

Seeds can usually tolerate acidity extremes better than alkalinity extremes (Baldwin, 1942). Dilute acids may actually encourage germination by stimulating seed

enzymes to hydrolyze reserves, thereby hastening after-ripening. Acidity may also alter cell permeability and therefore affect water absorption and imbibition rates (Baldwin, 1942). Alkalinity, on the other hand, may inhibit the activity of enzymes involved in metabolism of storage compounds, change membrane potential and hinder root cell elongation (Mayer and Poljakoff-Mayber, 1982; Fitter and Hay, 1987; Tang *et al.*, 1993, as cited in Henig-Sever *et al.*, 1996).

Substrate pH may influence germination of the species in this study and could represent a strong link to a species' adaptation to different soil conditions. In light of this, the fourth test in this project investigated the effect (if any) of pH on germination of *A. acuminata* and *P. saman*.

2.4. Dormancy And Pregermination Treatments

The ability to delay germination until time and place are suitable is an important survival technique in plants (Copeland and McDonald, 1985). Seeds are said to be dormant when there exists in the seed a block that must be overcome for germination to occur (Bewley and Black, 1994).

Coat-imposed dormancy is one of several types of dormancy. With this type of dormancy, a hard seed coat prevents germination in one or more of several ways. These constraints include interference with water uptake, mechanical restraint, interference with gas exchange, prevention of the exit of inhibitors from the embryo and the supply of inhibitors to the embryos (Bewley and Black, 1994). Prevention of germination by the seed coat can be very advantageous to the seed. For example, some seeds may germinate only after passage through the acidic gut of a bird or mammal has softened the seed coat. This requirement will also ensure a species' dispersal as the animal travels, depositing seeds here and there. Others may require cracking such as by the heat of a fire. In this case, the seeds would be able to recolonize fire-devastated areas.

Under seed laboratory or tree nursery conditions, coat-imposed dormancy will prevent rapid, uniform germination. Thus, various techniques have been developed to mimic nature and overcome this restriction. Sandpaper or a file may be used to weaken the seed coat mechanically. Alternatively, hot water soaks or submersion in concentrated sulfuric acid may have a similar effect.

Seeds of species with this type of dormancy may be subject to the various methods of scarification to determine which is the most effective. Such knowledge is valuable for nurseries in forestry programs whose aim it is to produce large numbers of seedlings within specified time limits. Brahman (1996) was interested in finding an effective, inexpensive pretreatment for two tropical leguminous tree species, *Hymenaea courbaril* L. and *Enterolobium cyclocarpum* (Jacq.)Griseb. Treatments included 30 or 60 seconds immersion in boiling water followed by cooling, soaking in concentrated sulfuric acid for five to 25 minutes and fire scorching. Hot water was recommended as a cheap and effective treatment. A similar study was carried out by Teketay (1996) using five *Senna* species. They were pretreated with mechanical scarification, concentrated sulfuric acid for 15, 30, 45 and 60 minutes and boiling water for 15, 30, 45 and 60 seconds. The best results were obtained with the 60 minute sulfuric acid treatment and with mechanical scarification.

Of the two species in this study, the first, *A. acuminata*, does not require a pregermination treatment. The second, *P. saman*, has a hard seed coat and consequent coat-imposed dormancy. González (1996) recommends mechanical scarification as the best treatment and one minute immersion in boiling water as a good second choice. Other authors present other recommendations, including submersion for 75 minutes in sulfuric acid by Trujillo (1986) and 24 hour submersion in water at room temperature by SEFORVEN (1992).

While mechanical scarification (a small cut to the testa) is very effective in eliminating the coat-imposed dormancy, it is very time consuming and not practical on a large scale unless perhaps mechanized. Considering this, the fifth test of this project was to determine if there are any differences in germination of *P. saman* when treated with a variety of pregermination treatments.

2.5. Importance Of Seed Size

2.5.1. Germination

In many cases larger seeds have a higher germination energy than smaller seeds. Such seeds contain ample nutrients to enable the seedling independently to achieve what may be a critical size for obtaining resources in competition with surrounding plants

(Fenner, 1985). The work of numerous authors supports this claim, including Spurr (1944), Righter (1945), Hough (1952), Niembro *et al.* (1978), Campos and Ortiz (1989), Weis (1982), Evans and Bhatt (1977), Roy *et al.* (1996) and Sidiras and Karsioti (1996). These studies suggest that before seeding, seed selection according to size could be worthwhile in order to obtain a more rapid and overall higher percent germination along with better stand establishment (Campos and Ortiz, 1989). One should note, however, that the relationship between seed size and germination is not absolute. Agboola (1996), studying three tropical tree species, found that seed size had no effect on germination of two species (*Terminalia* ssp.) and, in terms of germination rate, was actually inversely related for the third (*Gmelina arborea*). Kock *et al.* (1996) likewise found no relation between seedling emergence and seed size in groundnuts (*Arachis hypogaea* L.).

White spruce (*Picea glauca* (Moench) Voss) is a species in which only the best and heaviest seed are used for seedling production. Seeds are sorted to reduce labor costs and to achieve a stand of tall seedlings. A study by Hellum (1976), however, indicates that besides the fact that the size advantage is only short-term, seed sorting could result in genotype sorting as well, favoring th trees that produce the heaviest seeds. This author cautions that seed sorting could lead to the exclusion of important genetic material related to such things as tree form or hardiness.

A seed size study by Campos and Ortiz (1989) with seeds of *A. acuminata* demonstrated a clear relationship between seed size and percent germination. Seeds were divided into four groups using sieves of different sizes. A non-sieved sample was also included as a control. Percent germination ranged from a low of 2.9% in the smallest seed-size class to a high of 11.7% for the largest seed-size class. The control sample had a percent germination of 4.6%. It was also determined that selecting and seeding only larger seeds reduced the costs of production per plant and the amount of seed needed to produce a specified number of plants. The authors speculated that low overall percent germination was due to negative effects of the substrate (a mixture of soil and rice hulls).

Future studies with *A. acuminata* should focus on whether seed sorting of this species leads to sorting by tree and what kind of genetic consequences would result. Whereas the seed size-germination relationship has already been established for *A. acuminata*, it has not for *P. saman*. Seeds of the latter species also vary widely in length,

from 0.73 cm to 1.29 cm and in weight from 0.075 g to 0.328 g per seed. The sixth test in this study was to investigate the possible effect of seed size on germination of *P. saman*.

2.5.2. Early growth

Not only do larger seeds have a greater germination power than smaller seeds, they also produce larger seedlings (Campos and Ortiz, 1989). Sidiras and Karsioti (1996), measuring main and secondary root lengths of lupins of three size classes (small, medium and large), found significant reductions as the seed size decreased. Similar results have been obtained by Evans and Bhatt (1977), measuring dry weights of wheat and Sudhakara *et al.* (1995) measuring height, root collar diameter and number of leaves of the tropical tree *Ceiba pentandra* (L.) Gaertn. Despite the initial advantage of large seeds, some authors indicate that this positive relationship between seed size and plant size diminishes with time (Fowells, 1953 as cited in Campos and Ortiz, 1989; Spurr, 1944). Other researchers claim the advantage persists, indicating that the presence or absence of the relationship is likely dependent on species. Kaufmann and McFadden (1963) obtained significantly higher barley yields from the use of large seeds. Weis (1982) observed that seedlings from large seeds of *Mirabilis hirsuta* M. h. (Pursh) MacM. maintained a consistent size advantage over seedlings from small seeds.

Campos and Ortiz (1989) embarked on a study of the effects of seed size on seedling growth of *A. acuminata* in the tree nursery. Unfortunately the experiment did not run to completion due to a high mortality of plants. The same study included another species, ciprés (*Cupressus lusitanica* Mill.), in which no significant differences were detected in growth rates of plants from different seed size classes. A study of this nature should be repeated for *A. acuminata* to determine what the actual outcome would be.

Although the knowledge of seed size effects on early growth of *A. acuminata* is incomplete, further studies along these lines were not pursued as a part of this thesis project.

Studies of this nature were pursued, however, in the case of *P. saman*. The seventh test of this study was to determine the influence of seed size on the early growth of *P. saman*.

The seven tests of the study, in summary, were:

1. To determine the optimal temperature for germination of *A. acuminata* and *P. saman*.
2. To test for effect of photoperiod on germination of *A. acuminata* and *P. saman*.
3. To determine the effect of substrate on germination of *A. acuminata* and *P. saman*.
4. To investigate the possible effect of pH on germination of *A. acuminata* and *P. saman*.
5. To investigate the effectiveness of several scarification treatments on *P. saman*.
6. To test the possible effect of seed size on germination of *P. saman*.
7. To determine any potential influence of seed size on the early growth of *P. saman*

3. MATERIALS AND METHODS

3.1. Area Of Study

Research for this project took place at the Latin American Seed Bank (*Banco Latinoamericano de Semillas Forestales*, BLSF), located on the campus of the Tropical Agricultural Research and Education Center *(Centro Agronómico Tropical de Investigación y Ensenañza*, CATIE) in Turrialba, Costa Rica. Studies were pursued as part of the seed bank's Forest Seed Project (*Proyecto de Semillas Forestales*, PROSEFOR).

Site conditions in Turrialba include an average annual temperature of 21.5°C, average relative humidity of 87.5% and an elevation of 602 meters above sea level (Samaniego, 1995).

All germination tests were performed within four germination chambers located at the seed bank. Three of the chambers were refrigerator-style 'GRAM' chambers with a capacity of 16 germination boxes with dimensions 22 cm (width) x 30 cm (length) x 6 cm (height) (Samaniego, 1995). The fourth chamber was a much larger, walk-in style germination chamber. Chambers were lit with 39 watt neon bulbs (Samaniego, 1995). Temperature in all chambers was adjustable.

Seedlings for the early growth study of *P. saman* were grown in the CATIE tree nursery.

3.2. Seed Collection And Processing

Two seed sources of *A. acuminata* were collected and compared. Only one provenance *of P. saman* was investigated in the study. The collection and processing details for each are discussed below.

3.2.1. *Alnus acuminata*

3.2.1.1. Provenance 1

The first provenance of *A. acuminata* was collected November 1, 1996 at Rancho Redondo in Goioechea, San José of Costa Rica (BLSF, 1996).

Branches laden with cones were cut from approximately 12 trees. These were brought to the BLSF seed processing area where they were placed on large tarps in the

sun. Three days later the branches and cones were beaten to release the seeds. Following this, the chaff was separated from the seeds using a machine. Seeds were then placed in sealed black plastic containers for storage in a cold chamber at 5°C.

Routine lab results for this lot (lot BL066/96A) revealed the following: 69% purity, 0.46 g TKW, 8.2% moisture and a germination of 642 germinated seeds/g (30% germination) (González, 1996).

3.2.1.2. Provenance 2

The second lot of jaúl seeds were harvested October 21, 1996 in Prusia, Cartago of Costa Rica (BLSF, 1996).

Harvest procedures were identical to those specified for provenance one.

The following lab test results for *A. acuminata*, provenance 2 (lot BL035/96A) were obtained: 87% purity, 0.46 g TKW, 10.4% moisture and a germination of 688 germinated seeds/g (32% germination) (González, 1996).

3.2.2. *Pithecellobium saman*

Seeds of *P. saman* used in this study were collected May 31, 1996 in the county of Abangares in Guanacaste, Costa Rica. Elevation at the sight was 140 m above sea level. The area receives an average of 190 mm of precipitation per month per year which includes a three to four month dry period (BLSF, 1996).

Pods from a total of 12 trees were harvested, yielding 78.5 kg of fruits. Approximately the same number of pods were harvested per tree. Pods free of insect damage were gathered from the ground beneath each tree and placed in sacks. The day after harvest the sacks were taken to the seed bank processing area where the seeds were extracted by hand. Seeds were dried in a drying chamber and then placed in black air-tight plastic containers and stored in a cold chamber at a constant temperature of 5°C (BLSF, 1996).

Lab analysis of this seed lot (BL006/96C) gave the following results: 100% purity, 164 g TKW, 7.8% moisture and 92% germination (González, 1996).

3.3. Germination Protocol

The following experiments were performed to determine the optimum conditions of temperature, substrate, light and pH for the two provenances of *A. acuminata* and for *P. saman*.

All seeds were sown in transparent plastic germination boxes with lids. Containers used for jaúl measured 11 cm (width) x 17 cm (length) x 6 cm (height). Those used for the larger cenízaro seed measured 22 cm (width) x 30 cm (length) x 6 cm (height). Before each use, boxes were washed with soap and water and wiped with a cloth soaked in 95% alcohol.

Seeds of cenízaro were given a scarification treatment in which the testa was given a slight cut with pruning shears at the end opposite the embryo. This treatment is used at the BLSF and was recommended by the lab supervisor Alfonso González (1996). Seeds of jaúl do not require a pregermination treatment (González, 1996).

Germination tests followed the procedures recommended by the International Seed Testing Association (ISTA, 1996). Four repetitions of 100 seeds each were used per treatment for each species.

Seeds were well-watered initially. They were subsequently watered as needed. Paper treatments in particular generally required more than one watering.

Seedlings were assessed when the radicle had reached twice the size of the seed (Samaniego, 1995). Each seedling was evaluated as normal or abnormal. Abnormal seedlings were those that were damaged, deformed or decaying as defined by ISTA (1996). Only normal seedlings were included in calculations of percent germination.

Once seedlings had been evaluated, they were discarded.

Germination was assessed daily at approximately the same time. Germination tests for cenízaro lasted a total of eight days and for jaúl, 12 days.

Results were analyzed statistically using ANOVA and the SAS statistical program. For jaúl, separate analyses were done for the dependent variables percent germination and germination value in the first experiment involving temperature, photoperiod and substrate. As germination value was an inappropriate calculation for cenízaro due to a very rapid germination, peak value of the daily germination speed was used for the second analysis of the first experiment.

The variable germination value evaluates both germination speed and total percent germination (Djavanshir and Pourbeik, 1976). It is considered a better measure of the vigor of a seed lot than percent germination alone because it not only considers the completeness of germination but the onset and rate of germination (Czabator, 1962). Djavanshir and Pourbeik (1976) define germination value as "the expected seedlings from field or nursery sowings," since "the value obtained by this formula is very close to the number of seedlings survived in the field." The formula for germination value is as follows:

$$GV = \frac{\Sigma DGS}{N} * (GP*10)$$

GV=germination value
DGS=daily germination speed calculated by dividing cumulative germination percent by the number of days since the beginning of the test
N=frequency or number of DGS that are calculated during the test
GP=germination percent at the end of the test
(Djavanshir and Pourbeik, 1976)

This formula may be used for tree species with an average daily germination speed less than ten (Djavanshir and Pourbeik, 1976). Values higher than ten give a germination value greater than 100 percent. Although few species are in this category, cenízaro, once it has received a pregermination treatment, does have a DGS greater than ten. Therefore germination value was not used as a variable to evaluate the germinative energy for this species. Besides total percent germination, a second variable, the peak value of daily germination velocity, was used as a measure of germination speed. Peak value is the highest calculated germination percent in relation to the elapsed time from the beginning of the test, or highest DGS (Czabator, 1962).

The variables germination value and peak value were analyzed for the first experiment involving temperature, substrate and light, as temperature (tests 1 to 3) had an important effect on speed of germination. For following experiments (tests 4 to 6), solely percent germination was considered as it gave a good indication of treatment effect. In the last experiment (test 7), height was the measurement of interest.

The assumptions of normality and constant variance were checked for the experimental data. Normality was assessed with a normal probability plot and with the Shapiro-Wilk W test. Constant variance was assessed with a plot of residuals versus predicted values. All percentage data were deemed normal. Although by convention percentage data are often transformed to square root, this was not appropriate in this analysis as the non-transformed data were more normally distributed than transformed data. Calculations of germination value and peak value did not meet normalilty requirements, however, and were therefore transformed to their square root values.

3.3.1. Temperature, photoperiod and substrate

Germination tests were executed using a factorial design with four temperatures (24, 27, 30, 32°C), four photoperiods (0, 8, 16 and 24 hours light per day) and three substrates (paper, 1:1 sand-soil mixture, sand),

Number of germination chambers (four) was a limiting factor to how many treatments could be tested at once. The total of 48 treatments were therefore performed in four sets of 12, each set requiring approximately two weeks to complete. For each set of experiments, three temperature*light combinations (using 24, 27 and 32°C and each of the four photoperiods) were assigned randomly to each of the three refrigerator-style germination chambers and all three substrates were tested within. In the fourth, walk-in style germination chamber, it was necessary to maintain a constant temperature of 30°C for purposes of other germination tests performed at the BLSF. Therefore, all the tests at this temperature were done in this chamber and only photoperiod was assigned randomly for each round of tests.

To ensure that there was no chamber effect, several of the 30°C tests were repeated within the refrigerator-style chambers after all 48 treatments had been completed. Results were the same regardless of chamber. As well, no significant differences among chambers were detected when analyzed statistically using ANOVA.

Temperatures were set by a dial on each of the germination chambers. As mentioned, the large germination chamber was maintained at a constant 30°C. Within the small chambers, one of the three remaining temperatures (24, 27, and 32°C) was randomly assigned for each cabinet for each set of germination tests.

Light was controlled manually. In the refrigerator-style chambers, lights were turned on or off accordingly. For treatments with 0 h and 24 h light per day, lights were permanently left off and on, respectively. The 0 h treatment for *A. acuminata* did receive minimal amounts of light during daily germination counts. Before seeds in this treatment started germinating, exposure was a few seconds per day to check for the onset of germination. Once the seeds began germinating, exposure was approximately one to two minutes per day while germinating seeds were counted and removed. This would have been more of a concern for *A. acuminata* which was seeded on the substrate surface than for *P. saman*, which was covered by a layer of substrate. For treatments with 8 h and 16 h light per day, lights were turned on and off from 8 am to 4 pm to achieve the desired photoperiod.

In the large walk-in chamber, photoperiod was controlled by covering and uncovering the germination boxes with made-to-fit brown construction paper boxes.

For the paper treatment, filter paper was cut to the size of the germination box.

Sand was well washed with water, followed by sterilization with a formaline solution of 50 ml formaline per 21 L water. Treated sand was covered with plastic and sealed for three days before use.

Soil was treated with a stronger formaline solution of 150 ml per 21 L water and also left covered and sealed for three days before use. It was necessary to resterilize the soil before each new set of treatments as it otherwise permitted the proliferation of fungi.

Jaúl was seeded on the surface of all substrates. In the case of cenízaro, seeds were covered by a thin layer (approximately 1X seed width) of substrate for the sand and sand:soil treatments.

A 500 ml scoop was used to measure the sand and sand:soil substrates. One scoop was used per germination container (dimensions 11 cm (width) x 17 cm (length) x 6 cm (height)) for jaúl treatments. Two scoops were used per germination container (dimensions 22 cm (width) x 30 cm (length) x 6 cm (height)) for cenízaro treatments and seeds were covered with an additional scoop.

Results were analyzed with a three-way analysis of variance. Tukey's Honestly Significant Difference was used as a test to compare treatment means for the qualitative main effect of substrate. The main effects temperature and photoperiod, both

quantitative, were analyzed using contrasts and regression. For three-way interactions, trends due to temperature were analyzed for each light*substrate combination. The variation due to linear and quadratic trends was partitioned. If both linear and quadratic trends were significant and the R^2 value was higher for the latter, the quadratic model was used to explain the trend. Regression was used to determine function parameters.

Data analysis was made using a completely random design considering the three independent variables of temperature, substrate and light in the following model:

$$Y = u + a_i + b_j + (ab)_{ij} + c_k + (ac)_{ik} + (bc)_{jk} + (abc)_{ijk} + e_{l(ijk)}$$

Y = observed data

u = overall mean

a_i = temperature effect

b_j = photoperiod effect

$(ab)_{ij}$ = interaction effect of temperature and photoperiod

c_k = substrate effect

$(ac)_{ik}$ = interaction effect of temperature and substrate

$(bc)_{jk}$ = interaction effect of photoperiod and substrate

$(abc)_{ijk}$ = interaction effect of temperature, photoperiod and substrate

$e_{l(ijk)}$ = repetition effect (error)

3.3.2. pH

Germination tests were performed to determine the effect of pH on germination of jaúl and cenízaro. Both species were tested at pH levels of 4, 7 and 10.

Solutions were prepared in the CATIE soils laboratory using distilled water and weak HCl and NaOH solutions to adjust the pH, similar in practice to Samaniego (1995). Actual pH values obtained were 3.87, 6.91 and 10.03.

All tests were done in the walk-in germination chamber at a constant temperature of 30°C and photoperiod of 24 h. Filter paper was used as the substrate for jaúl and sand for cenízaro. The sand was dried and rewetted with the various solutions.

Data analysis required a one-way ANOVA with trend analysis according to the design outlined below. If a linear function was significant for pH, regression was used to determine the function parameters.

$$Y = u + a_i + e_{j(i)}$$

Y = observed data

u = overall mean

a_i = pH effect

$e_{j(i)}$ = repetition effect (error)

3.4. Seed Size Investigation

3.4.1. Seed size and pregermination treatments

Seed size effect on germination of jaúl was studied by Campos and Ortiz (1989) and was not further investigated in this project. The results of their study are reported in Section 2.5.1.

Seeds of cenízaro were separated by hand into three seed sizes: small, medium and large according to Table 3-1. Separation was achieved visually and with the use of calipers.

Table 3-1. Seed size classes for *P. saman*

Size	Average seed weight[a] (mg)	Seed length range[b] (cm)
small	115	≤ 0.89
medium	169	0.90 ≤ length≤ 1.04
large	233	≥ 1.05

[a]Calculated from thousand kernal weight (TKW). [b]Seed length measured along longest axis of the seed.

Weight of eight repetitions of 100 seeds of each class was measured according to ISTA (1976). The mean weight was multiplied by ten to determine the thousand kernal weight (TKW). TKW for each seed size class was 115 g, 169 g and 233 g for the small, medium and large size classes, respectively. Seeds ranged in length from 0.73 cm to 1.29 cm.

Seeds of the three size classes were treated with the following pregermination treatments:

1. 24 h soaking in water at room temperature
2. 1 min submersion in boiling water followed by 24 h soaking in water at room temperature
3. 1 min 40 sec submersion in boiling water followed by 24 h soaking in water at room temperature
4. 2 min 20 sec submersion in boiling water followed by 24 h soaking in water at room temperature
5. 3 min submersion in boiling water followed by 24 h soaking in water at room temperature
6. small cut on end opposite embryo
7. 75 min soaking in 95% sulfuric acid followed by a thorough rinsing with water

As with previous germination tests, four repetitions of 100 seeds each were treated and sown for each size-scarification treatment combination. For treatments 1-5 the number of imbibed seeds after the 24 hour soaking treatment was also recorded to compare with the germination results that followed. Imbibed seeds swelled to approximately twice their original size and their seed coats began to slough off. They were also softer and lighter brown compared to non-imbibed seeds.

All treated seeds were sown in sterilized sand and placed in the walk-in growth chamber at 30°C with constant illumination.

Analysis required a two-way ANOVA as outlined below. Contrasts and regression were used to analyze the imbibition data. For the germination data, the effectiveness of the various scarification treatments was analyzed using orthogonal comparisons.

$$Y = u + a_i + b_j + (ab)_{ij} + e_{k(ij)}$$

Y = observed data

u = overall mean

a_i = seed size effect

b_j = pregermination treatment effect

$(ab)_{ij}$ = interaction effect of size and pregermination treatment

$e_{k(ij)}$ = replication effect (error)

3.4.2. Seed size and early growth in the tree nursery

Cenízaro seeds (four repetitions of 100 seeds each) of the three size classes (Table 3-1) were given a pregermination treatment of one minute in boiling water followed by 24 hours soaking in water at room temperature. They were then sown in sand at 30°C under continuous illumination.

On the fifth day after seeding, the largest, most vigorous seedlings from each size class were transplanted into black plastic tree nursery bags (10 cm x 21 cm) filled with a soil mixture consisting of soil, compost, 10-30-10 fertilizer and sand. The bags were arranged in the CATIE tree nursery in a quasi-experimental design with four blocks. Each block contained 25 trees of each seed size class for a total of 300 trees (4 blocks x 3 size classes x 25 trees).

A shade tent was constructed over the seedlings and maintained for the first seven days, after which it was removed.

Seedlings were watered and weeded regularly.

Height measurements were taken on the third day after planting and then every 15 days for a total of 60 days.

At 70 days, 15 trees were harvested from each treatment from each block to determine fresh and dry weight.

Data analysis for this randomized complete block design was accomplished by ANOVA according to the model below. Regression was used to determine function parameters for the growth trend over time.

$$Y = u + a_i + b_j + (ab)_{ij} + c_k + (ac)_{ik} + (bc)_{jk} + (abc)_{ijk} + e_{l(ijk)}$$

Y = observed data

u = overall mean

a_i = time effect

b_j = block effect

$(ab)_{ij}$ = interaction of time and block

c_k = size effect

$(ac)_{ik}$ = interaction of time and size

$(bc)_{jk}$ = interaction of block and size

$(abc)_{ijk}$ = interaction of time, block and size

$e_{l(ijk)}$ = tree effect (sampling error)

ANOVA was also used to analyze differences in plant fresh and dry weights, and linear effects due to seed size were partitioned. Regression was used to determine the function parameters.

$$Y = u + a_i + b_j + (ab)_{ij} + e_{k(ij)}$$

Y = observed data

u = overall mean

a_i = block effect

b_j = size effect

$(ab)_{ij}$ = interaction of block and size (experimental error)

$e_{k(ij)}$ = tree effect (sampling error)

4. RESULTS AND DISCUSSION

4.1. Germination Protocol

4.1.1. Temperature, light and substrate

4.1.1.1. *Alnus acuminata*

Analysis of percent germination of *A. acuminata* in response to temperature, light and substrate showed that a three-way interaction was in effect (Appendices 7.2, 7.3 and 7.6). The analysis was similar for germination value (Appendices 7.4, 7.5 and 7.6).

For both provenances of this species, percent germination was significantly higher for the substrates sand and paper than for the sand:soil mixture (Table 4-1). Highest percent germination for provenance one was 17%, obtained using both sand and paper. Percent germination was 7% lower using the sand:soil substrate. Highest percent germination for provenance two was 32%, using sand, closely followed by 31% using paper. This value dropped to 21% for the sand substrate. Sand and paper appear to function equally well in providing the seeds with adequate aeration and contact with soil moisture.

Table 4-1. Percent germination (%) and germination value (gv)[a] of *A. acuminata* after twelve days as a response to substrate as a main effect

Substrate	Provenance 1		Provenance 2	
	Germination (%)	g v	Germination (%)	gv
sand	17 a[b]	2.7 a	32 a	8.6 a
paper	17 a	2.5 a	31 a	8.5 a
sand:soil	10 b	1.3 b	21 b	3.9 b

[a]Germination value (gv), as defined by Djavanshir and Pourbeik (1976), is a measure of both the speed and totality of germination. [b]Mean separation within columns by Tukey's HSD ($P<0.05$). See summary of ANOVAs in Appendix 7.6.

Fungal growth was greater on the sand:soil substrate than on either the sand or the paper. Despite sterilization with formaline, this observation was consistently noted as more and more germination tests were run. It is possible that the fungi interfered with germination of the seeds, resulting in lower germination. Due to the negative effect of the sand:soil substrate on germination, it would not be the recommended substrate for this species, especially in facilities where substrate sterilization is not possible. In future

tests, a heat-sterilized soil-containing substrate should be tested to compare with the formaline-sterilized sand:soil substrate. Moisture content of the substrates should also be monitored throughout germination tests to ensure it is not excessive, thereby encouraging the growth of fungi.

Germination value data for substrates gave the same results as analysis of percent germination alone (Table 4-1). For both provenances, highest germination value was observed for both sand and paper, with no significant difference between the two. Germination value was significantly lower for the sand:soil substrate. Thus, when analyzed for both speed and totality of germination, the sand and paper substrates were most advantageous to seeds of both provenances of *A. acuminata.*

Analysis of temperature as a main effect indicated that, as an average over the total range of tests performed, percent germination was highest at temperatures of 24 and 27°C (Table 4-2). Highest percent germination for provenance one was 19% at 27°C. For provenance two, highest percent germination was 37% at 24°C. Lowest percent germination, 8% and 12% for provenance one and two, respectively, occurred at 32°C. Range of treatment means for highest to lowest germination was 11% for provenance one and 25% for provenance two.

Table 4-2. Percent germination (%) and germination value (gv)[a] of *A. acuminata* after twelve days as a response to temperature as a main effect

Temperature (°C)	Provenance 1		Provenance 2	
	Germination (%)	gv	Germination (%)	gv
24	18	2.5	37	9.8
27	19	3.1	36	10.7
30	16	2.4	25	5.9
32	8	0.6	12	1.5
Linear	0.001[b]	0.001	0.001	0.001
Quadratic	0.001	0.001	0.001	0.001
Deviations	ns	ns	ns	ns

[a]Germination value (gv), as defined by Djavanshir and Pourbeik (1976), is a measure of both the speed and totality of germination. [b]Significance levels for indicated trends (ns, not significant). See summary of ANOVAs in Appendix 7.6.

Germination trends due to temperature as a main effect may be demonstrated by highly significant quadratic functions for both provenances (provenance 1: $y = -0.371x^2 + 19.571x + -238.836$, $R^2 = 0.979$; provenance 2: $y = -0.534x^2 + 26.853x + -299.667$, $R^2 = 0.999$). Analysis of germination value gave results very similar to analysis of percent germination alone for both provenances, with the following quadratic functions highly significant: provenance 1: $y = -0.091x^2 + 4.853x + -61.666$, $R^2 = 0.988$; provenance 2: $y = -0.241x^2 + 12.441x + -149.542$, $R^2 = 0.991$ (R^2 calculations based on temperature means) (Table 4-2).

As peak germination for the range of temperatures tested appeared to occur at 24 to 27°C, additional germination tests were run at 18 and 21°C on paper with constant illumination to observe trends as temperature decreased. Percent germination values for provenance one were 10 and 21% for 18 and 21°C, respectively and 21 and 33% for provenance two. The value of 21% for 21°C (provenance one) was slightly higher than the average percent germination for 24 and 27°C and for provenance two (33% at 21°C) slightly lower, but below 21°C percent germination declined notably. One note of caution, however, is that length of time for these germination tests was the same (12 days) as for all other germination tests with this species and had the test run longer, percent germination might have been higher. Germination value, however, was less at both 18 and 21°C for both provenances, corresponding to a lower rate of metabolism within the seeds.

Results for temperature correlate well with the species' adaptation for higher elevation, lower temperature areas of the tropics. This species grows in areas where temperatures range from 4 to 27°C (Section 2.1.1.). Percent germination and rate of germination were highest at the upper end of this range and dropped as temperature increased further.

To maximize germination and prevent seed wastage, seeds of *A. acuminata* should be planted on paper or sand at approximately 24 to 27°C. Germination will be high but slower at slightly lower temperatures (to 21°C). In some nurseries, the use of bottom heat may be desired to achieve a temperature in this range. Higher temperatures than these will be deleterious to seed germination and are not recommended.

With reference to photoperiod, highest percent germination for *A. acuminata*, was achieved with 16 to 24 hours light (Table 4-3). Provenance one reached a high of 19% germination with the 24 h treatment and provenance two 36% germination with the 16 h treatment. Lowest percent germination for provenances one and two were 9% and 12% respectively, both in the 0 h (minimal light) treatment. Range of photoperiod means for highest to lowest percent germination was 10% for provenance one and 24% for provenance two. In other terms, germination slightly more than doubled for provenance one from minimal to continuous light and tripled for provenance two from minimal to 16 -24 h light.

Table 4-3. Percent germination (%) and germination value (gv)[a] of *A. acuminata* after twelve days as a reponse to light as a main effect

Light (hours/day)	Provenance 1		Provenance2	
	Germination (%)	gv	Germination (%)	gv
0	9	0.7	12	1.4
8	14	2.2	28	6.9
16	17	2.5	36	10.0
24	19	3.2	35	9.7
Linear	0.001[b]	0.001	0.001	0.001
Quadratic	ns	ns	0.001	0.001
Deviations	ns	ns	ns	ns

[a]Germination value (gv), as defined by Djavanshir and Pourbeik (1976), is a measure of both the speed and totality of germination. [b]Significance levels for indicated trends (ns, not significant). See summary of ANOVAs in Appendix 7.6.

Analysis of light as a main effect indicated the following germination trends for *A. acuminata*: (provenance 1: $y = 0.403x + 10.067$, $R^2 = 0.960$; provenance 2: $y = -0.067x^2 + 2.584x + 11.621$, $R^2 = 0.999$). Analysis of germination value again led to very similar results as compared to analysis of percent germination alone for both provenances, with the following quadratic functions highly significant: provenance 1: $y = 0.100x + 0.935$, $R^2 = 0.922$; provenance 2: $y = -0.023x^2 + 0.907x + 1.306$, $R^2 = 0.999$ (R^2 calculations based on photoperiod means) (Table 4-3).

The marked increase in percent germination and germination value with increasing photoperiod for this species indicates that its seeds may be photoblastic. Photoblastic seeds require exposure to light, particularly red light to convert phytochrome to its active form and allow germination (Section 2.3.2.). This phenomenon is common to many small seeds and appears to be the case for *A. acuminata* as well. Although even the 0 h treatment received small amounts of light, the trends evident in Table 4-3 suggest that germination might be even lower in complete darkness. A light requirement would be advantageous to this species by preventing germination when too deeply buried, as a seedling from such a small seed would exhaust its food reserves before reaching light. Light may also act as a signal for these pioneer seeds to germinate in forest gaps where conditions would be favorable and competition for light would be less than within the forest itself.

To achieve a high percent germination for seeds of *A. acuminata*, 16 to 24 hours of light per day is recommended for seed laboratory germination tests. Where cost may be a limiting factor, at least several hours of light per day would be beneficial to germination. Alternatively, light received upon outdoor seeding should be adequate where lighting facilities are not available.

For each substrate, light*temperature interactions were analyzed for trends. Many of the interactions were highly significant (Appendix 7.6). In most cases, a linear and/or quadratic relationship fit the temperature trend for each photoperiod-substrate combination. Figures 4-1 through 4-6 show light*temperature interactions for the percent germination data of each provenance, with trendlines demonstrating the functions that best fit the data. With the functions given, percent germination may be estimated for each substrate and photoperiod within the range of 24 to 32°C. In general, percent germination increased with increased photoperiod. Percent germination decreased, however, as temperature increased past 27°C as indicated by negative slopes on the germination vs. temperature graphs. Results from the two seed sources were similar except that the effects just mentioned were more pronounced for provenance two as indicated by steeper downward slopes in the graphs.

Alnus acuminata, provenance one, substrate: paper

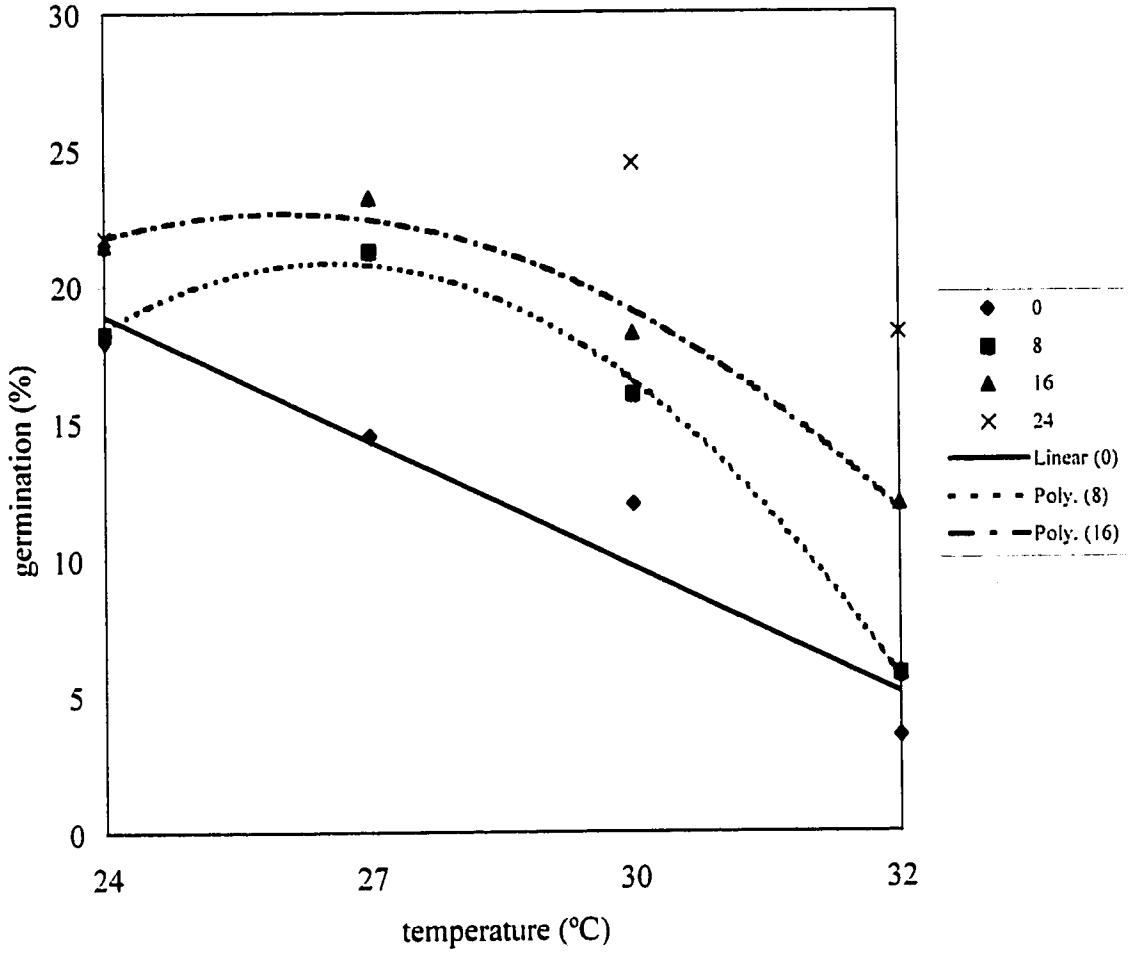

Figure 4-1. Germination trends for *Alnus acuminata*, provenance one, grown in a paper substrate under four photoperiods. Germination tests lasted 12 days. See also Appendix 7.6.

Light (hours/day)	Function	R^{2a}
0	$y = -1.646x + 58.507$	0.870**
8	$y = -0.539x^2 + 28.687x + -359.689$	0.996**
16	$y = -0.344x^2 + 18.050x + -213.600$	0.999*
24	no significant trend	

[a]Calculated based on photoperiod*substrate*temperature means. ** = function significant at P<0.01 * = function significant at P<0.05.

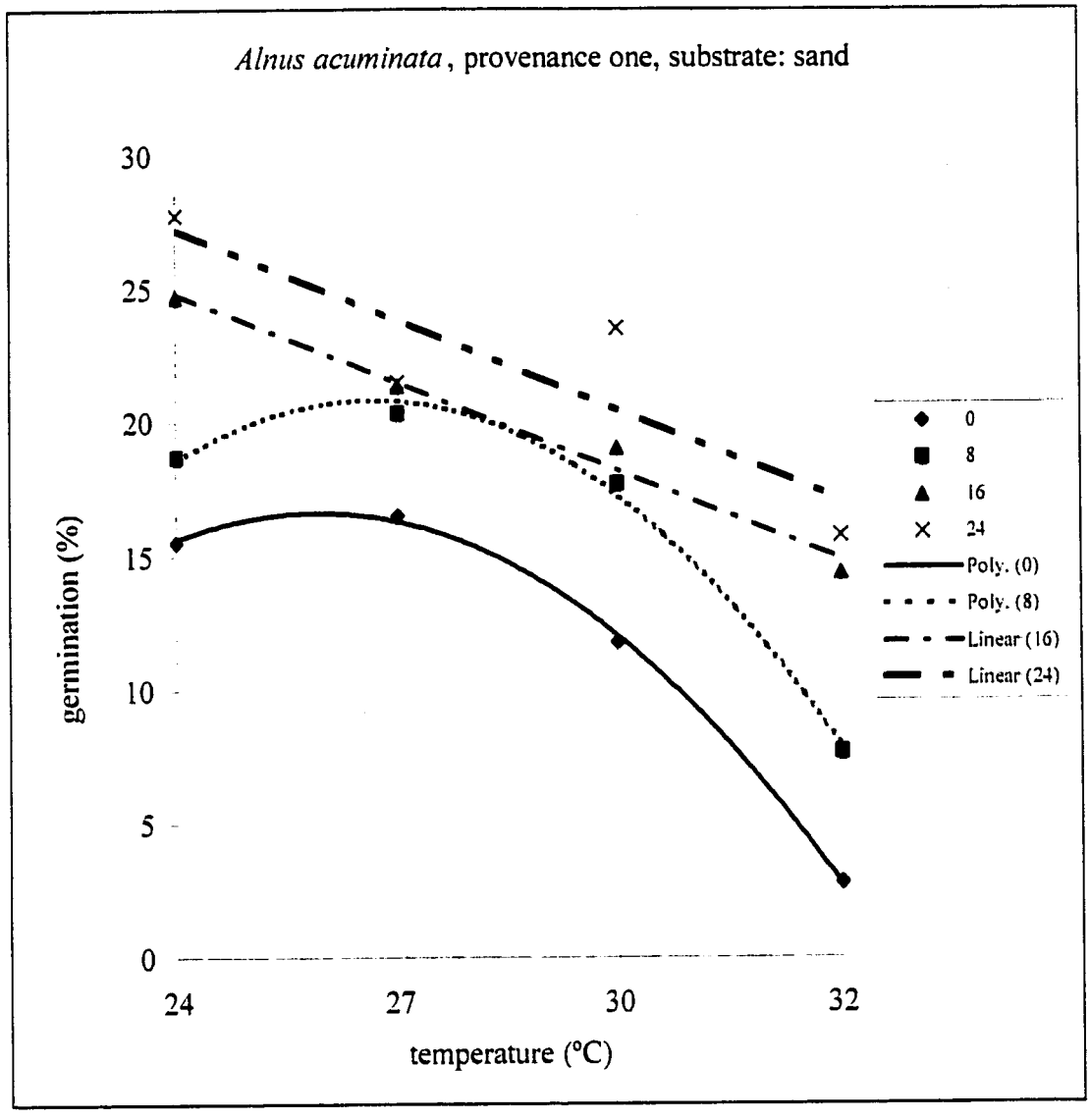

Figure 4-2. Germination trends for *Alnus acuminata*, provenance one, grown in a sand substrate under four photoperiods. Germination tests lasted 12 days. See also Appendix 7.6.

Light (hours/day)	Function	R^{2a}
0	$y = -0.418x^2 + 21.877x + -268.849$	0.994**
8	$y = -0.475x^2 + 25.015x + -306.829$	0.994*
16	$y = -1.168x + 52.444$	0.804**
24	$y = -1.214x + 56.429$	0.727**

[a]Calculated based on photoperiod*substrate*temperature means. ** = function significant at P<0.01 * = function significant at P<0.05.

Alnus acuminata, provenance one, substrate: sand:soil

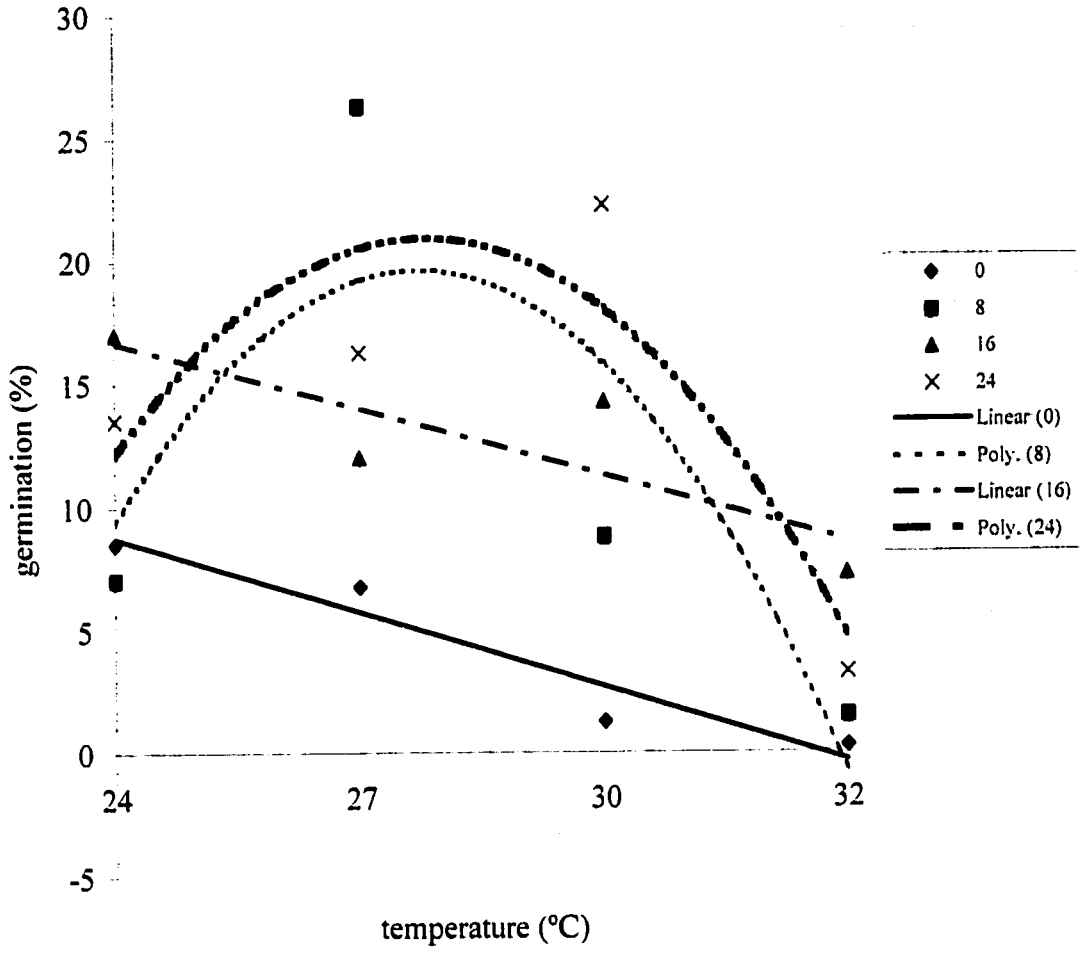

Figure 4-3. Germination trends for *Alnus acuminata*, provenance one, grown in a sand:soil substrate under four photoperiods. Germination tests lasted 12 days. See also Appendix 7.6.

Light (hours/day)	Function	R^{2a}
0	$y = -1.128x + 36.041$	0.948**
8	$y = -1.113x^2 + 61.119x + -817.392$	0.809**
16	$y = -0.956x + 39.626$	0.657**
24	$y = -0.747x^2 + 41.075x + -543.378$	0.654**

[a]Calculated based on photoperiod*substrate*temperature means. ** = function significant at P<0.01 * = function significant at P<0.05.

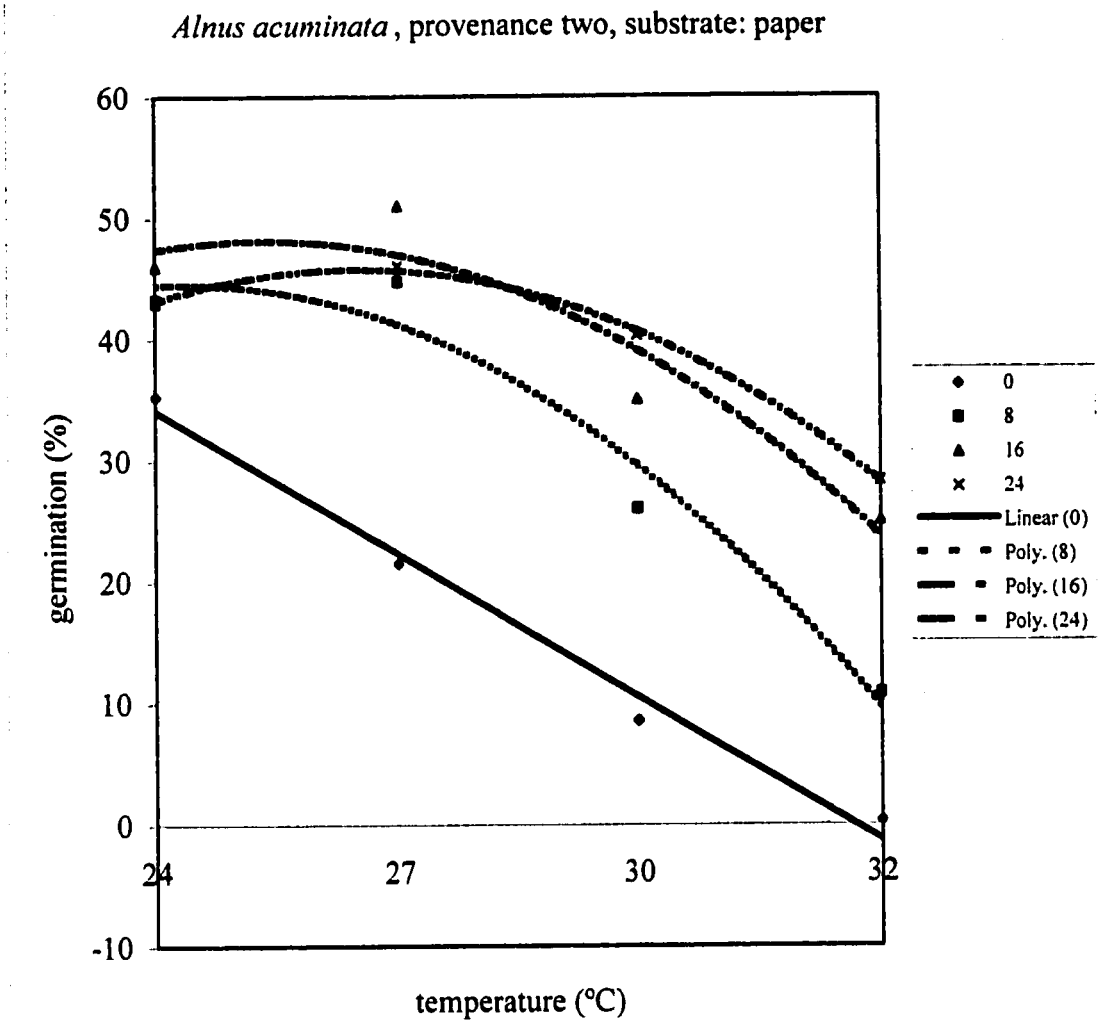

Figure 4-4. Germination trends for *Alnus acuminata*, provenance two, grown in a paper substrate under four photoperiods. Germination tests lasted 12 days. See also Appendix 7.6.

Light (hours/day)	Function	R^2
0	$y = -4.378x + 140.041$	0.999**
8	$y = -0.807x^2 + 40.959x + -474.374$	0.990**
16	$y = -0.705x^2 + 36.621x + -425.886$	0.960**
24	$y = -0.610x^2 + 32.370x + -382.868$	0.994*

[a]Calculated based on photoperiod*substrate*temperature means. ** = function significant at P<0.01 * = function significant at P<0.05.

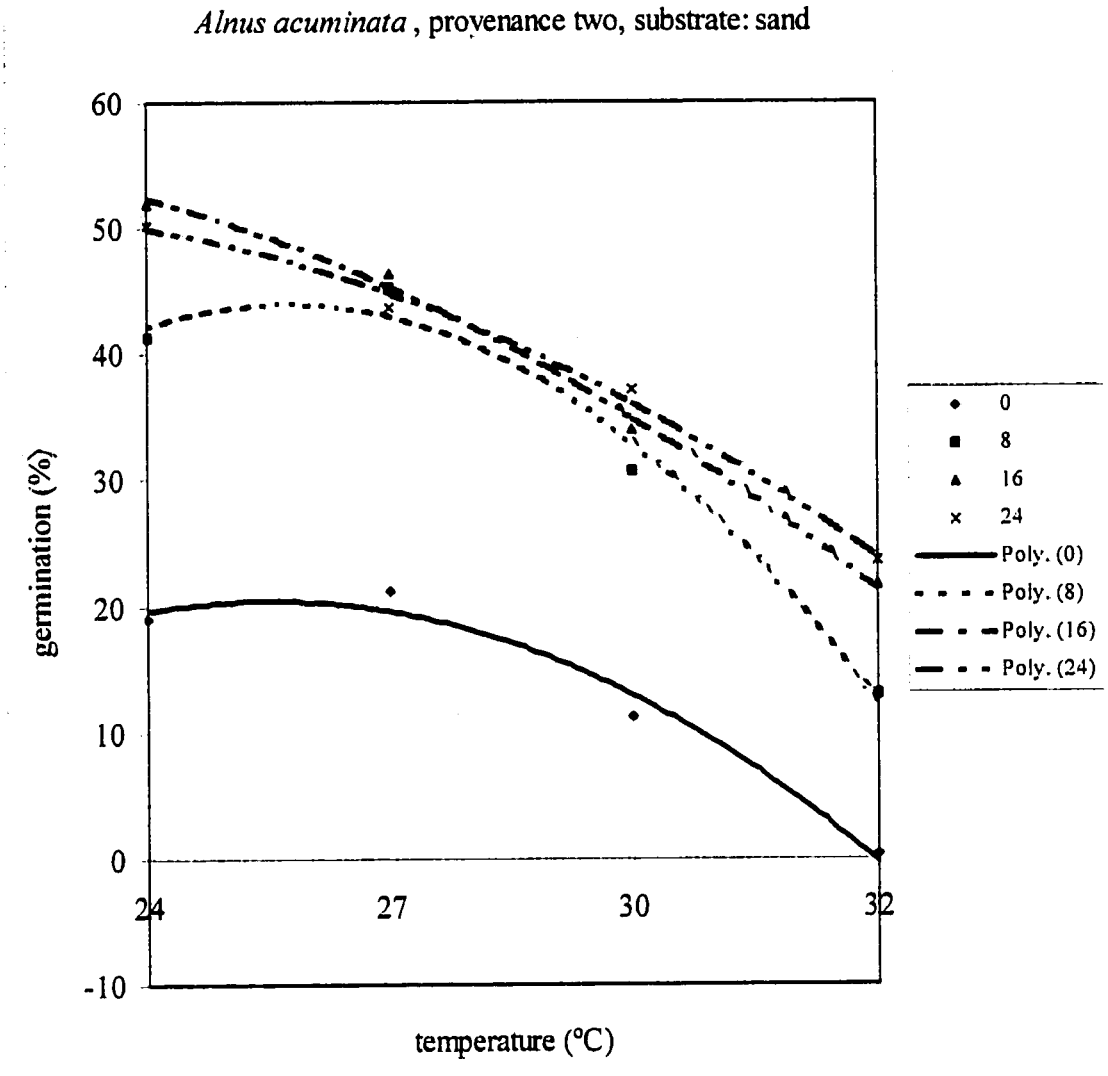

Figure 4-5. Germination trends for *Alnus acuminata*, provenance two, grown in a sand substrate under four photoperiods. Germination tests lasted 12 days. See also Appendix 7.6.

Light (hours/day)	Function	R^2
0	$y = -0.588x^2 + 30.538x + -375.031$	0.998**
8	$y = -1.042x^2 + 54.941x + -678.720$	0.999**
16	$y = -0.471x^2 + 22.701x + -221.919$	0.999*
24	$y = -0.352x^2 + 16.574x + -145.216$	0.976*

[a]Calculated based on photoperiod*substrate*temperature means. ** = function significant at P<0.01 * = function significant at P<0.05.

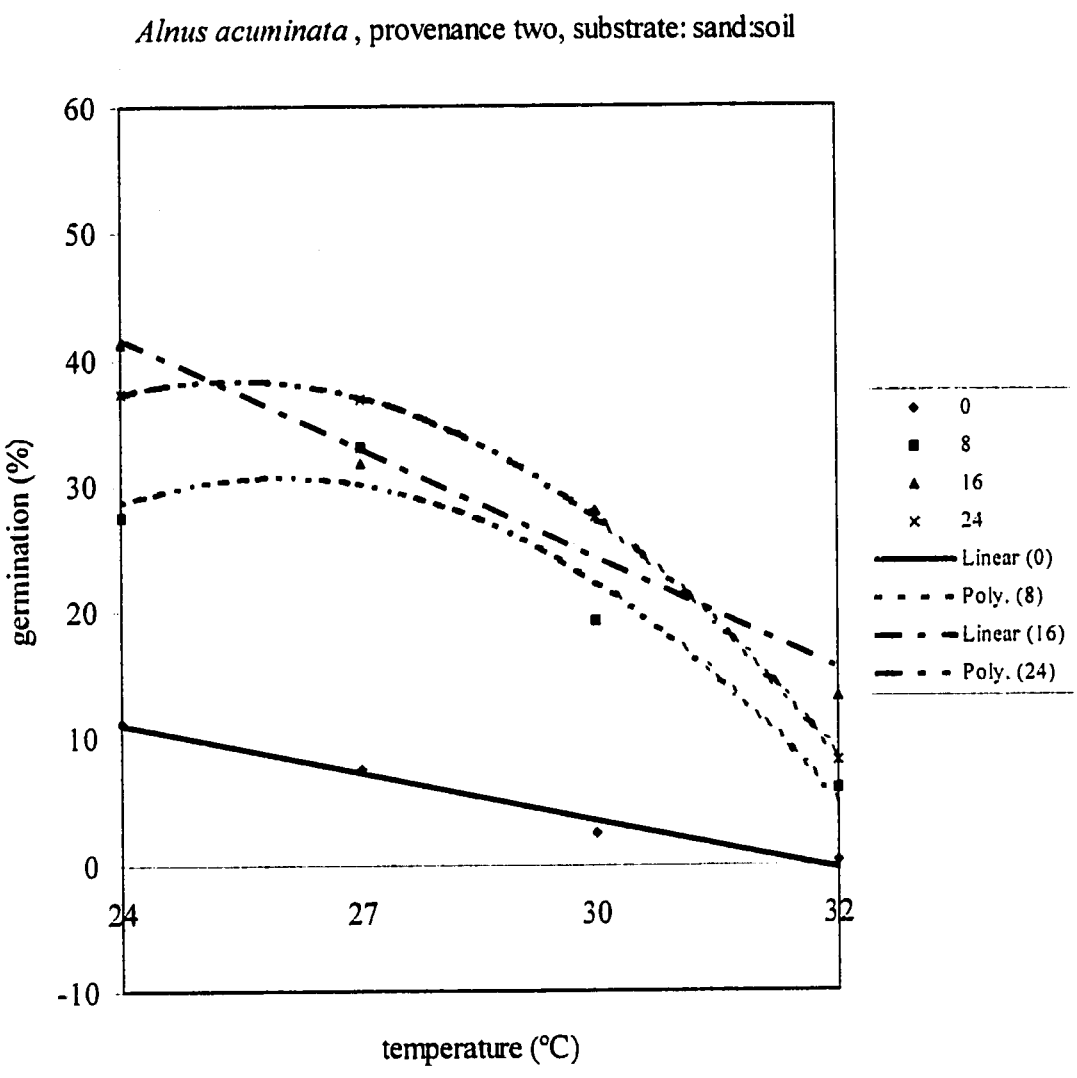

Figure 4-6. Germination trends for *Alnus acuminata*, provenance two, grown in a sand :soil substrate under four photoperiods. Germination tests lasted 12 days. See also Appendix 7.6.

Light (hours/day)	Function	R^2
0	$y = -1.412x + 45.252$	0.995**
8	$y = -0.822x^2 + 43.218x + -535.763$	0.989**
16	$y = -3.165x + 117.973$	0.907**
24	$y = -0.794x^2 + 40.989x + -489.826$	0.987**

[a]Calculated based on photoperiod*substrate*temperature means. ** = function significant at P<0.01 * = function significant at P<0.05.

Figures 4-1 through 4-6 show both linear and quadratic functions used to fit the germination trends. In many cases, when analyzed statistically, the light*temperature interactions had both a linear and quadratic component. The component contributing more to fitting the trend was shown graphically. The fitted curves act as a tool to demonstrate what is occurring biologically. With an increased number of experimental repetitions and a larger range of temperatures tested, one would likely see a rise in percent germination with rise in temperature, a peak in germination, and a subsequent fall in germination as the optimal temperature was surpassed, a phenomenon likely best described statistically as a quadratic function. Quadratic functions were given in many cases in Figures 4-1 through 4-6, and where linear functions were given, it was the linear trend that accounted for more of the variation than did the quadratic trend. In these instances peak in germination occurred below 24°C and only the downward trend of decreasing germination was illustrated. Considering the results from preliminary germination tests at 18 and 21°C in conjunction with all the experimental germination tests at 24 through 32°C, the peak in germination appears to lie in the range of 21 to 27°C, with fastest germination occuring at the higher end of the range. It should also be kept in mind that the temperature*photoperiod interaction indicated that germination responses over the range of temperatures tested depended on photoperiod.

Analysis of germination value gave similar results to analysis of percent germination for both provenances (Tables 4-4 to 4-6). Both speed and totality of germination showed a general decline as temperature surpassed 27°C and a general incline with increasing photoperiod. Functions that best fit the temperature*photoperiod trends in germination value for both provenances of *A. acuminata* are given in Appendix 7.7.

Overall, considering the three variables, substrate, temperature and photoperiod, results for this experiment were very similar for the two provenances of *A. acuminata*. Despite disimilarity in seed source they should be treated the same with regard to temperature, substrate and light in the course of germination tests. A difference that was noted between the two which was not related to the treatments was a consistently higher percent germination with provenance two compared to provenance one, indicating higher viability in the second seed lot (or less dormancy if that were a factor).

Table 4-4. Germination value[a] of two provenances of *A. acuminata* after twelve days grown in a paper substrate under four photoperiods. A summary of ANOVAs is presented in Appendix 7.6. Significant functions are given in Appendix 7.7.

Germination temp. (°C)	Photoperiod (h)									
	0		8		16		24		Average	
	1[b]	2	1	2	1	2	1	2	1	2
24	1.8	7.4	2.4	11.8	4.6	15.3	3.3	9.0	3.0	10.9
27	1.0	2.1	5.0	16.9	4.2	21.3	2.9	14.2	3.3	13.7
30	0.8	0.5	1.5	4.2	2.4	8.9	6.1	14.2	2.7	6.9
32	0.1	0	0.2	0.6	1.1	3.4	2.4	5.9	0.9	2.5
Linear	0.01[c]	0.01	0.01	0.01	0.01	0.01	ns	ns	0.01	0.01
Quadratic	ns	ns	0.01	0.01	ns	0.01	ns	0.01	0.01	0.01
Deviations	ns	ns	ns	0.05	ns	ns	0.01	ns	ns	ns

[a]Germination value (gv), as defined by Djavanshir and Pourbeik (1976), is a measure of both the speed and totality of germination. [b]Provenance number. [c]Significance levels for indicated trends (ns, not significant). Interaction of temperature*photoperiod was significant ($P<0.01$) (Appendices 7.4 and 7.5).

Table 4-5. Germination value[a] of two provenances of *A. acuminata* after twelve days grown in a sand substrate under four photoperiods. A summary of ANOVAs is presented in Appendix 7.6. Significant functions are given in Appendix 7.7.

Germination temp. (°C)	Photoperiod (h)									
	0		8		16		24		Average	
	1[b]	2	1	2	1	2	1	2	1	2
24	1.2	1.9	2.6	9.2	5.1	22.5	5.4	17.2	3.6	12.7
27	1.7	2.6	4.9	18.0	4.0	14.8	3.4	14.8	3.5	12.6
30	0.7	0.7	1.9	6.6	2.5	8.4	6.0	13.0	2.8	7.2
32	0.1	0	0.3	0.8	1.0	2.9	1.5	3.3	0.7	1.7
Linear	0.01[c]	0.01	0.01	0.01	0.01	0.01	0.05	0.01	0.01	0.01
Quadratic	0.01	0.01	0.01	0.01	ns	ns	ns	0.01	0.01	0.01
Deviations	ns	ns	ns	ns	ns	ns	0.01	0.01	ns	ns

[a]Germination value (gv), as defined by Djavanshir and Pourbeik (1976), is a measure of both the speed and totality of germination. [b]Provenance number. [c]Significance levels for indicated trends (ns, not significant). Interaction of temperature*photoperiod was significant ($P<0.01$) (Appendices 7.4 and 7.5).

Table 4-6. Germination value[a] of two provenances of *A. acuminata* after twelve days grown in a sand:soil substrate under four photoperiods. A summary of ANOVAs is presented in Appendix 7.6. Significant functions are given in Appendix 7.7.

Germination temp. (°C)	Photoperiod (h)									
	0		8		16		24		Average	
	1[b]	2	1	2	1	2	1	2	1	2
24	0.3	0.7	0.3	4.4	2.3	10.8	1.0	7.7	1.0	5.9
27	0.3	0.3	6.5	8.5	0.8	6.1	1.8	9.0	2.3	6.0
30	0	0	0.4	2.0	1.2	4.8	4.8	6.9	1.6	3.4
32	0	0	0	0.2	0.3	0.9	0.1	0.4	0.1	0.4
Linear	0.01[c]	0.01	0.01	0.01	0.01	0.01	ns	0.01	0.01	0.01
Quadratic	ns	ns	0.01	0.01	ns	ns	0.01	0.01	0.01	0.01
Deviations	0.05	ns	0.01	0.05	0.01	0.05	0.01	0.01	ns	ns

[a]Germination value (gv), as defined by Djavanshir and Pourbeik (1976), is a measure of both the speed and totality of germination. [b]Provenance number. [c]Significance levels for indicated trends (ns, not significant). Interaction of temperature*photoperiod was significant ($P<0.01$) (Appendices 7.4 and 7.5).

Throughout the course of germination tests with *A. acuminata*, moldy, decaying seeds were removed as they appeared. The number of affected seeds increased with increasing temperature. In all tests, it would have been beneficial at the termination of the test to count the number of non-germinated, non-moldy seeds and test their viability with a cutting test or tetrazolium. However, it would have been difficult due to the small seed size. It is possible that although percent germination for both provenances was low (less than 50%), percent viability of seeds might have been higher.

Germination tests with this species performed by other scientists have given highly variable results, from poor to excellent germination (Section 2.1.1.). There could be several reasons for this. Although several sources state that this species does not require a pregermination treatment, it may be that this species has a dormancy mechanism that has not yet been identified. Experimentation with horomones such as gibberellins or cytokinins could give some clues in that respect. Gibberellins, for instance, can relieve some types of dormancy, such as embryo dormancy, physiological dormancy and thermodormancy (Hartmann *et al.*, 1990). Alternatively, it has already been shown that seed maturity affects seed germination (Vásquez, 1989; Rojas *et al.*,

1991). Seeds involved in the various studies may have been harvested at different maturity levels. It has also been demonstrated that smaller seeds have less germinative power than larger seeds. Empty seeds may also have been present in the harvest. One or more factors such as these may have caused the low germination observed in this study and others.

Future studies with this species should investigate reasons for such variable results in germination tests between seed lots. Higher overall germination success will be more likely if tests of temperature, light and substrate are conducted with viable clean seed.

4.1.1.2. *Pithecellobium saman*

Of the main effects temperature, light and substrate, only substrate showed any significant differences when percent germination of *P. saman* was analyzed. There were significant two-way and three-way interactions, however (Appendices 7.8 and 7.10). When peak value was analyzed there were highly significant main effects, two-way (except temperature*substrate) and three-way interactions (Appendices 7.9 and 7.10).

As was the case with *A. acuminata*, significantly more seeds of *P. saman* germinated with the sand substrate than with the sand:soil substrate (Table 4-7). The seeds also germinated faster with the sand substrate. It was noted that more fungi grew on the seeds placed in the sand:soil substrate than on the sand, despite substrate sterilization with formaline. The fungi also spread quickly in the sand:soil substrate whereas remained fairly contained around infected seeds in the sand. The spread of fungi in the sand:soil substrate led to secondary infection in nearby seeds that had already begun germinating. In both substrates some seeds were overcome by fungi and rotted before germination. Samples of the fungi were sent to the pathology lab at CATIE and determined to be of the following genera: *Aspergillius sp.*, *Fusarium sp.* and *Rhyzopus sp.* These fungi were likely seed-borne and not substrate-borne (Gamboa, 1997). Although, in a practical sense, the difference in percent germination between the two substrates was small (only 4%), sand should be the preferred substrate of the two as it inhibited the seed-to-seed spread of fungi in the substrate thereby preventing mortality of small seedlings due to secondary infection, as was observed in the sand:soil substrate.

Table 4-7. Percent germination (%) and peak value (pv)[a] of *P. saman* after eight days as a response to substrate as a main effect

Substrate	Germination (%)	pv (cumulative %/day)
sand	95	20.2
sand:soil	91*	18.4*

[a]Peak value (pv), as defined by Czabator (1962), is a measure of germination speed.
*Mean separation within columns by Tukey's HSD ($P<0.05$). See summary of ANOVAs in Appendix 7.10.

Temperature analyzed as a main effect did not affect percent germination. Percent germination was very high at all temperatures, averaging 93% (Table 4-8). Peak value, representing the speed of germination, however, was affected by temperature.

This variable ranged from a low of 15.5 at 24°C to 22.2 at 32°C, increasing linearly with increasing temperature within the range tested ($y = 0.845x + -4.585$, $R^2 = 0.992$ (R^2 calculation based on temperature means) (Table 4-8).

Table 4-8. Percent germination (%) and peak value (pv)[a] of *P. saman* after eight days as a response to temperature as a main effect

Temperature (°C)	Germination (%)	pv (cumulative %/day)
24	93	15.5
27	93	18.5
30	93	21.0
32	92	22.2
Linear	ns	0.001[b]
Quadratic	ns	ns
Deviations	ns	ns

[a]Peak value (pv), as defined by Czabator (1962), is a measure of germination speed.
[b]Significance levels for indicated trends (ns, not significant). See summary of ANOVAs in Appendix 7.10.

These findings indicate that *P. saman* is adapted to germinate through a fairly wide range of temperatures and, as far as depends on temperature, probably germinates equally well in cool forest shade as in warm open pasture. The advantage of the warmer temperatures is faster germination, which would result in faster establishment of the seedling.

At the conclusion of this experiment, germination tests at 35 and 38°C under constant illumination were run to determine how the trend in peak value would proceed. Percent germination values were 91 and 58% for 35 and 38°C, respectively, with pv values of 25.4 and 12.4. Of note, speed of germination was even higher at 35°C than at 32°C (pv = 22.2), although mold and fungal growth were a serious problem at the higher temperature. At a temperature of 38°C, percent germination and peak value dropped drastically and numerous abnormal seedlings were observed, suggesting deleterious effects on seed metabolism. Most abnormal seedlings had a defective primary roots which were stunted, stubby, split from the tip, spindly, negatively geotropic or trapped in the seed coat (ISTA, 1996).

In field or nursery conditions, any temperature ranging from 24 to 35°C should be adequate for germination of this species. Germination will be faster at the higher

temperatures by approximately one to four days. The higher the temperature the greater the severity of fungal growth. As a standard for laboratory conditions, 30°C would provide a good compromise, allowing rapid germination while only moderate fungal growth. In the future, it would be interesting to investigate at what temperature (below 24°C) percent germination begins to decline for this species as it would give even further indication of this species' environmental range.

There was no significant main effect of light on percent germination of scarified seeds (Table 4-9). Percent germination was very high (average 93%) and varied very little for all photoperiods. Speed of germination was slightly higher at 8 hours of light per day than at any other photoperiod, but as the range of peak values was so slight (from 18.7 to 19.9), this observation should not be overstressed.

Table 4-9. Percent germination (%) and peak value (pv)[a] of *P. saman* after eight days as a response to light as a main effect

Light (hours/day)	Germination (%)	pv (cumulative %/day)
0	93	19.1
8	93	19.9
16	92	18.7
24	93	19.4

[a]Peak value (pv), as defined by Czabator (1962), is a measure of germination speed. See summary of ANOVAs in Appendix 7.10.

Results indicated that scarified seeds of *P. saman* are insensitive to light for germination. Unlike *A. acuminata*, *P. saman* seeds in the 0 h light treatment did not receive minimal amounts of light when initially checking for germination as they were covered with a layer of substrate. As seeds began germinating the substrate surface may have been disturbed, exposing some other ungerminated seeds to light for short periods. However, this likely had little effect on the seeds as even those that were never exposed germinated quickly. With respect to light conditions alone, seeds of *P. saman* should germinate equally well under exposed conditions as buried under forest litter provided that they are already scarified. Because of the seed's larger size the seedling would have adequate food reserves to support seedling development if buried. Photoperiod should not be of concern to seed lab technicians or nursery workers interested in propagating this

species. It may be preferable to allow the seeds at least some light as seeds sown in darkness produced etiolated seedlings.

Considering the three-way interactions between temperature, light and substrate, temperature*light interactions were compared for each substrate. Several trends were observed when percent germination was analyzed, but in general differences in percent germination were small in the range of temperatures and photoperiods tested (Tables 4-10 and 4-11). When peak value was analyzed, however, trends shown in Figures 4-7 and 4-8 indicated that temperature had an important effect on the speed of germination. In general, peak value increased with increasing temperature, as indicated by a significant main effect of temperature.

Non-scarified seed of *P. saman* may behave differently than scarified seed. Further experimentation could focus on possible effects of light on non-scarified seed as it may give a greater indication of this species' germination characteristics in nature.

Table 4-10. Percent germination of *P. saman* after eight days grown in a sand substrate under four photoperiods. A summary of ANOVAs is presented in Appendix 7.10.

	Photoperiod (h)				
Germination temp. (°C)	**0**	**8**	**16**	**24**	**Average**
24	91	95	98	97	95
27	95	95	93	92	94
30	93	93	95	96	94
32	97	94	97	94	95
Linear	0.01[a]	ns	ns	ns	ns
Quadratic	ns	ns	0.01	ns	ns
Deviations	0.05	ns	ns	0.05	ns

[a]Significance levels for indicated trends (ns, not significant). Interaction of temperature*photoperiod was significant (P<0.01) (Appendix 7.8).

Table 4-11. Percent germination of *P. saman* after eight days grown in a sand:soil substrate under four photoperiods. A summary of ANOVAs is presented in Appendix 7.10.

	Photoperiod (h)				
Germination temp. (°C)	**0**	**8**	**16**	**24**	**Average**
24	93	87	96	96	90
27	92	97	88	93	92
30	88	92	91	97	92
32	96	94	81	85	89
Linear	ns[a]	0.01	0.01	ns	ns
Quadratic	ns	0.01	ns	0.01	ns
Deviations	ns	0.01	0.01	0.05	ns

[a]Significance levels for indicated trends (ns, not significant). Interaction of temperature*photoperiod was significant (P<0.01) (Appendix 7.8).

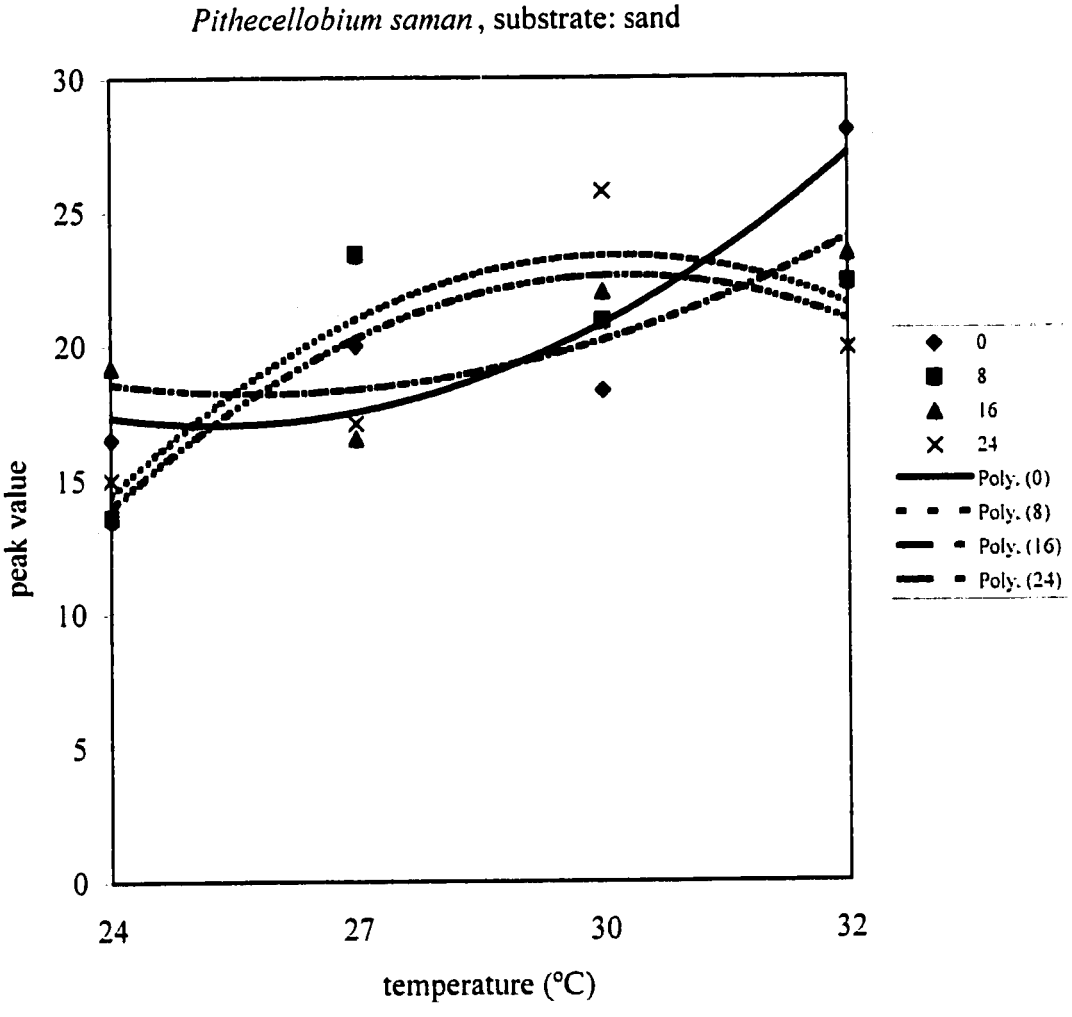

Figure 4-7. Peak value trends for *Pithecellobium saman* grown in a sand substrate under four photoperiods. Germination tests lasted eight days. See also Appendix 7.10.

Light (hours/day)	Function	R^2
0	$y = 0.223x^2 + -11.359x + 161.218$	0.741**
8	$y = -0.281x^2 + 16.748x + -226.118$	0.838**
16	$y = 0.197x^2 + -10.354x + 153.798$	0.841**
24	$y = -0.208x^2 + 12.587x + -168.072$	0.621**

[a]Calculated based on photoperiod*substrate*temperature means. ** = function significant at P<0.01 * = function significant at P<0.05.

Pithecellobium saman, substrate: sand:soil

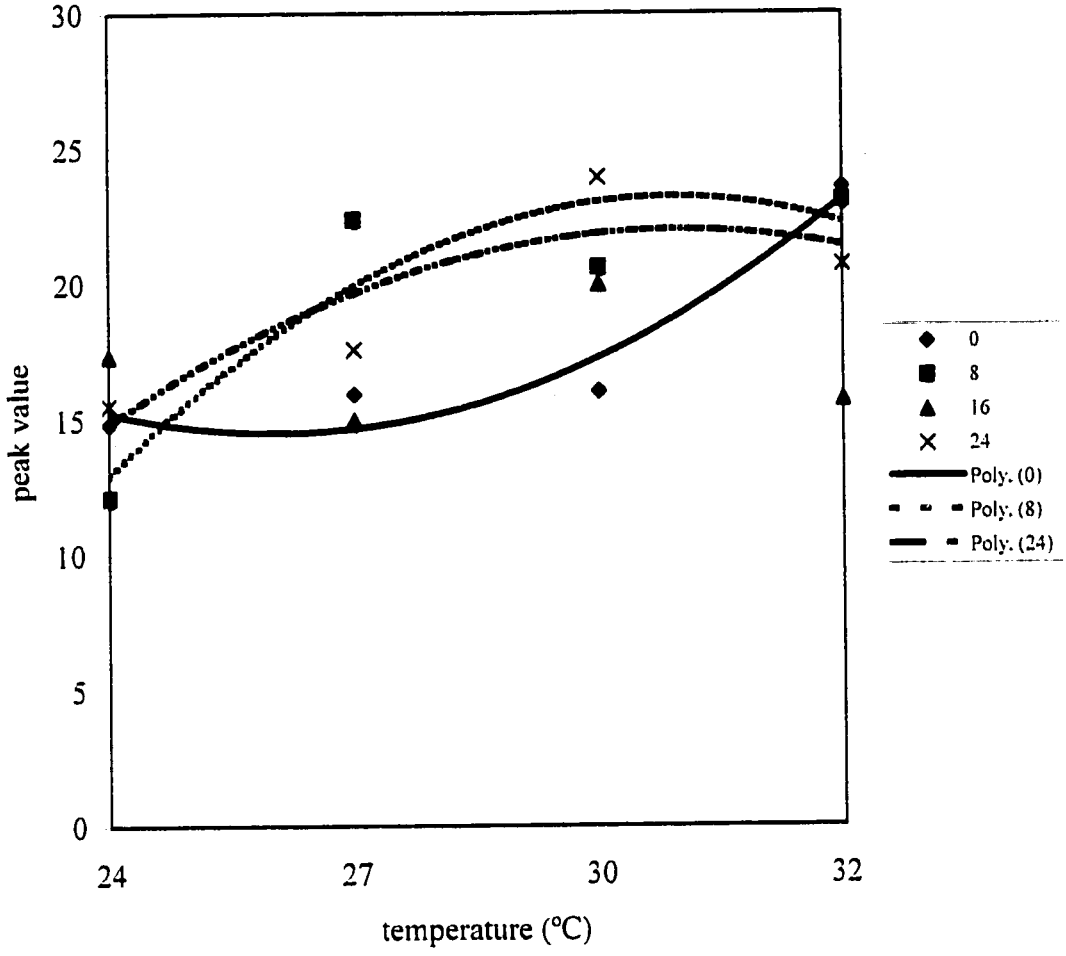

Figure 4-8. Peak value trends for *Pithecellobium saman* grown in a sand:soil substrate under four photoperiods. Germination tests lasted eight days. See also Appendix 7.10.

Light (hours/day)	Function	R^2
0	$y = 0.243x^2 + -12.692x + 179.850$	0.859**
8	$y = -0.283x^2 + 16.980x + -232.039$	0.852**
16	no significant trend	
24	$y = -0.131x^2 + 8.204x + -106.296$	0.746**

[a]Calculated based on photoperiod*substrate*temperature means. ** = function significant at P<0.01 * = function significant at P<0.05.

4.1.2. pH

4.1.2.1. *Alnus acuminata*

For both seed sources of *A. acuminata*, there was a positive linear trend in germination with increasing substrate pH within the range of values tested (provenance 1: $y = 0.833x + 13.667$, $R^2 = 0.971$; provenance 2: $y = 2.333x + 15.667$, $R^2 = 0.842$ (R^2 calculations based on pH means) (Appendix 7.11 and Table 4-12). In a practical sense, difference in percent germination over the range of pH tested was low (5%) for provenance one. Highest percent germination for provenance one was 22% at a pH of ten and lowest was 17% at a pH of four (Table 4-12, Figure 4-9). For provenance two, a 15% reduction in germination percentage occurred as pH decreased from ten to four (Appendix 7.12, Table 4-12, Figure 4-9).

Table 4-12. Percent germination of *A. acuminata* after twelve days at 30°C as a response to pH level

	Germination (%)	
pH	**Provenance 1**	**Provenance 2**
10	22	37
7	20	36
4	17	23
Linear	0.05[a]	0.001
Deviations	ns	0.05

[a]Significance levels for indicated trends.

Results indicate that highly acidic conditions may be detrimental to the germination of *A. acuminata*, particularly for provenance two. Difference in acid sensitivity between the two provenances may relate to their adaptation to the locations from which they came. Under field conditions, soil pH should be considered before seeding of the second provenance, as both germination and seedling growth may be adversely affected by strong acidity.

The tolerance of both provenances to alkalinity may indicate an adaptation of this species to soils with this characteristic. This finding is contrary to many forest seeds which tolerate acidity better than high alkalinity (Baldwin, 1942, see Section 2.3.4).

Use of buffers would have improved this experiment by ensuring a more stable pH in the media throughout the duration of the germination tests. It is possible that

leachates from the imbibing seeds may have altered the pH level and contributed to experimental error.

The results of this experiment lead to numerous new study possibilities. Researchers may want to investigate the reasons for this species' alkaline tolerance (or apparent acid intolerance), both at the cellular level in the seed and as an environmental adaptation feature. Moreover, although this experiment dealt with only three pH levels (4, 7 and 10), further germination tests should be conducted within and beyond this range. It is possible that although a pH of four had adverse effects on seed germination of provenance two of *A. acuminata*, a milder acidic condition might be more tolerable. Seedling growth on soils of various pH levels should be another topic of study. With this knowledge, it could be determined whether or not acidic soils should be avoided for plantations of jaúl. As well, experimentation with additional seed sources would determine if the trends observed in this pH study are typical to the species as a whole. Soil characteristics at the sites where the two seed sources were collected for this experiment were not analyzed but should be included in further studies.

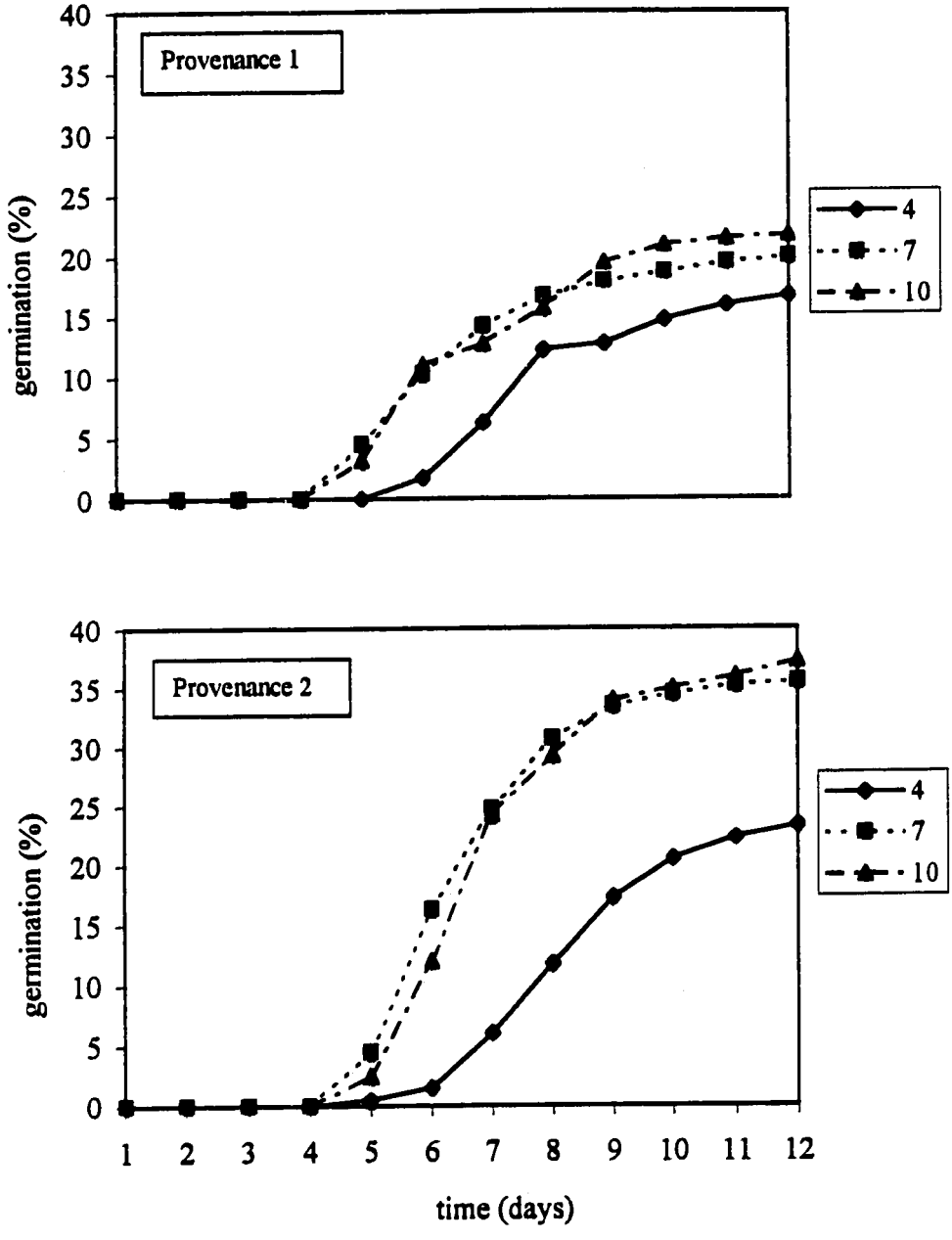

Figure 4-9. Germination response of two provenances of *A. acuminata* to pH level (4,7,10)

4.1.2.2. *Pithecellobium saman*

Level of pH had no significant effect on germination of scarified seeds of *P. saman* (Appendix 7.13). Seeds germinated equally well (average = 95%) at pH 4, 7 and 10 (Figure 4-10).

P. saman, once scarified, is adapted to germinate well under a wide range of soil pH. Soil pH would therefore not be an important site consideration for this species when considering germination alone. Neither would pH of the germination media in a seed laboratory or tree nursery. As with *A. acuminata*, however, seedling growth under various levels of pH should be studied to determine if it, like germination, is insensitive to this variable and if in fact this species is well-suited to such a broad range of soil environments. An additional pH study with non-scarified seeds should also be conducted as acidic soil conditions may serve to scarify the seeds and thereby be beneficial to the germination of this species.

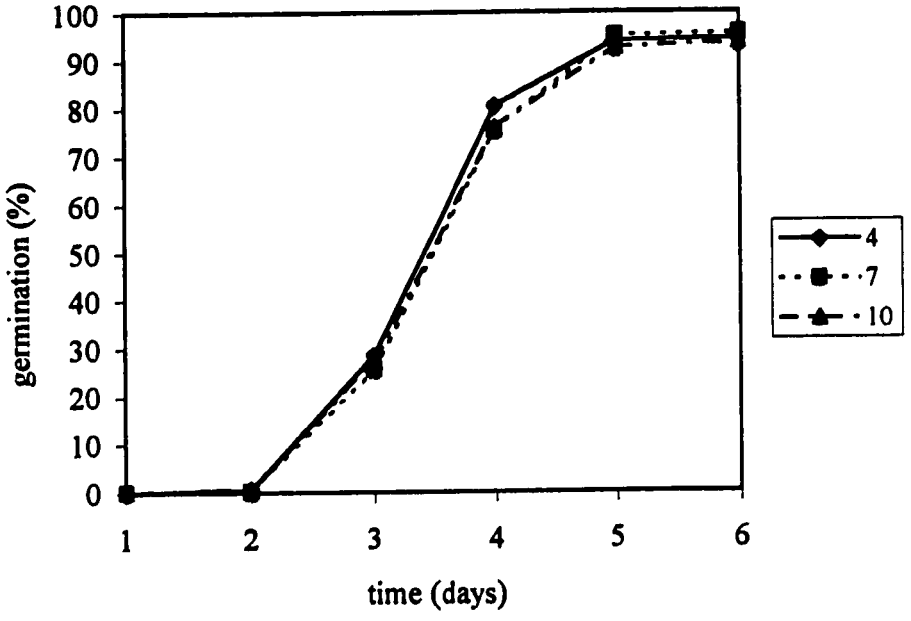

Figure 4-10. Germination response of *P. saman* to pH level (4, 7, 10)

4.2. Seed Size Investigation With *Pithecellobium saman*

4.2.1. Seed size and scarification treatments

4.2.1.1. Imbibition

Seed size and length of time in boiling water interacted to affect the percentage of seeds to imbibe water by 24 hours after treatment (Appendix 7.14 and Figure 4-11). Quadratic functions fit the trends in imbibition response for each seed size as seen in Figure 4-11 (small: $y = -0.006x^2 + 1.462x + 11.482$, $R^2 = 0.949$; medium: $y = -0.003x^2 + 0.968x + 8.379$, $R^2 = 0.962$; large: $y = -0.002x^2 + 0.636x + 1.834$, $R^2 = 0.920$).

Percentage of seeds to imbibe water after boiling treatments (which were followed by 24 hours in water at ambient temperature) increased as time in boiling water increased, plateauing at approximately 100 to 140 seconds (Figure 4-11). Hot-water-treated small seeds imbibed water more readily than medium seeds, which in turn imbibed water more readily than large seeds (Figure 4-11).

It is plausible that smaller seeds are not as mature as larger seeds and therefore have thinner testas. Smaller seeds would therefore imbibe water faster after treatment as

boiling water would weaken the seed coat. Larger seeds would in turn require more time in boiling water for the same effect to occur.

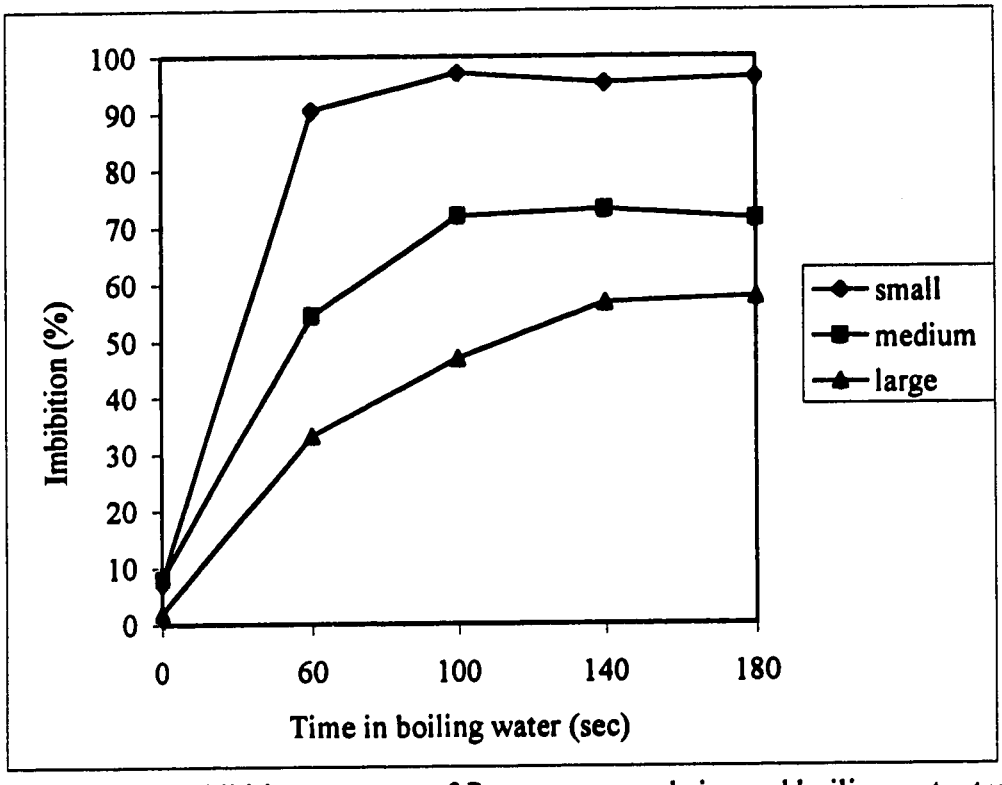

Figure 4-11. Imbibition response of *P. saman* to seed size and boiling water treatment after 24 hours soaking in water at ambient temperature (23°C). Seed size defined on basis of average weight per seed: small, 115 mg, medium, 169 mg, large, 233 mg. F-value for the interaction of time in boiling water*seed size was significant at the 0.001 level. See also Appendix 7.14.

4.2.1.2. Germination

Seed size and scarification treatment had a significant effect on both percentage of seeds to imbibe water after 24 hours and on the number of seeds to germinate within eight days (Appendix 7.15 and Figure 4-12). This analysis included the treatments of mechanical scarification (a cut to the testa opposite the side of the embryo) and acid scarification (75 minute submersion in concentrated sulfuric acid) in addition to the boiling water treatments described in Section 4.2.1.1.

Mechanical scarification and acid scarification were the most effective treatments for breaking coat-imposed dormancy in *P. saman* (Table 4-13). Germination results for these treatments were 93 and 95%, respectively. Use of orthogonal comparisons indicated that these two treatments differed significantly from the hot water treatments.

Germination decreased linearly with increased time in boiling water for the hot water treatments within the range of time tested.

Table 4-13. Germination response of *P. saman* to scarification treatment after eight days at 30°C

Scarification Treatment	Time	Germination (%)[a]
1. H_2SO_4 (36N)	75 min	95
2. Cut to testa	-	93
3. None[b]	-	18
4. H_20 (100°C)	60 sec	65
5. H_20 (100°C)	100 sec	61
6. H_20 (100°C)	140 sec	51
7. H_20 (100°C)	180 sec	41
	H_2SO_4 vs. Cut to testa[c]	ns[d]
	H_2SO_4 and Cut to testa vs. hot H_20[e]	0.001
	None vs. hot H_20	0.001
	Hot H_20 time linear	0.001

[a]Seeds sown in sand substrate at 30°C under constant illumination and scored after eight days. [b]Seeds soaked in water at ambient temperature (23°C) for 24 hours. Treatments 4-7 also followed by soaking in water at ambient temperature for 24 hours. [c]Orthogonal comparisons. [d]Significance levels for indicated comparisons. [e]Hot H_20 treatments include treatments 4-7.

Over the range of pregermination treatments, large seeds did not germinate as well (average 56%) as the medium (average 63%) or small seeds (average 62%) ($P<0.01$). However, seed size interacted with scarification method to affect germination (Figure 4-12). When the mechanical and acid scarification treatments were analyzed alone, seed size was not significant. This indicates that seeds of all sizes have equal germinative power. Reduced germination for large seeds occurred only with the boiling water treatments, which thus led to the seed size*method interaction (Figure 4-12). As mentioned, this may have been related to seed maturity and the thickness of the seed coat.

It is interesting to note the discrepancy between the imbibition data and the germination data. Although number of seeds to imbibe showed a general increase with the length of the boiling treatment (Figure 4-11), number of seeds to germinate decreased (Figure 4-12). Perhaps because of the close proximity of the embryo to the hilum, the embyos were damaged as the length of the boiling treatment increased, regardless of seed size and regardless of the effect of the hot water on the testa. Alternatively, it may be noted that the difference in percentage of seeds to imbibe as compared to percentage of seeds to germinate was greatest for small seeds. If those seeds indeed had thinner seed coats than larger, more mature seeds, they would not only imbibe water more readily after treatment but would be more susceptible to damage by boiling water. Medium to large seeds were not as responsive in imbibing after boiling water treatments but neither was the germinative power affected as greatly as in small seeds.

Since mechanical scarification treatment is so time-consuming, acid scarification for 75 minutes in concentrated sulfuric acid appears to be the best choice for an easy, quick, inexpensive method of pretreatment for seeds *of P. saman*. Fungal growth on acid scarified seeds was also slightly less than on the cut seeds. With reference to seed size, seed sorting is unnecessary when using this treatment as seeds of all sizes had a very high percent germination.

Should a device to mechanically scarify seeds (such as a rotating drum) be available to a nursery grower, that person may want to experiment with pretreating seeds of *P. saman* in that way. If it also met the criteria of an easy, inexpensive, non time-consuming method, and was as effective as mechanical scarification by cutting, it would provide a good alternative to acid scarification and would prevent the need for use of concentrated acid which might be unavailable to some nursery growers.

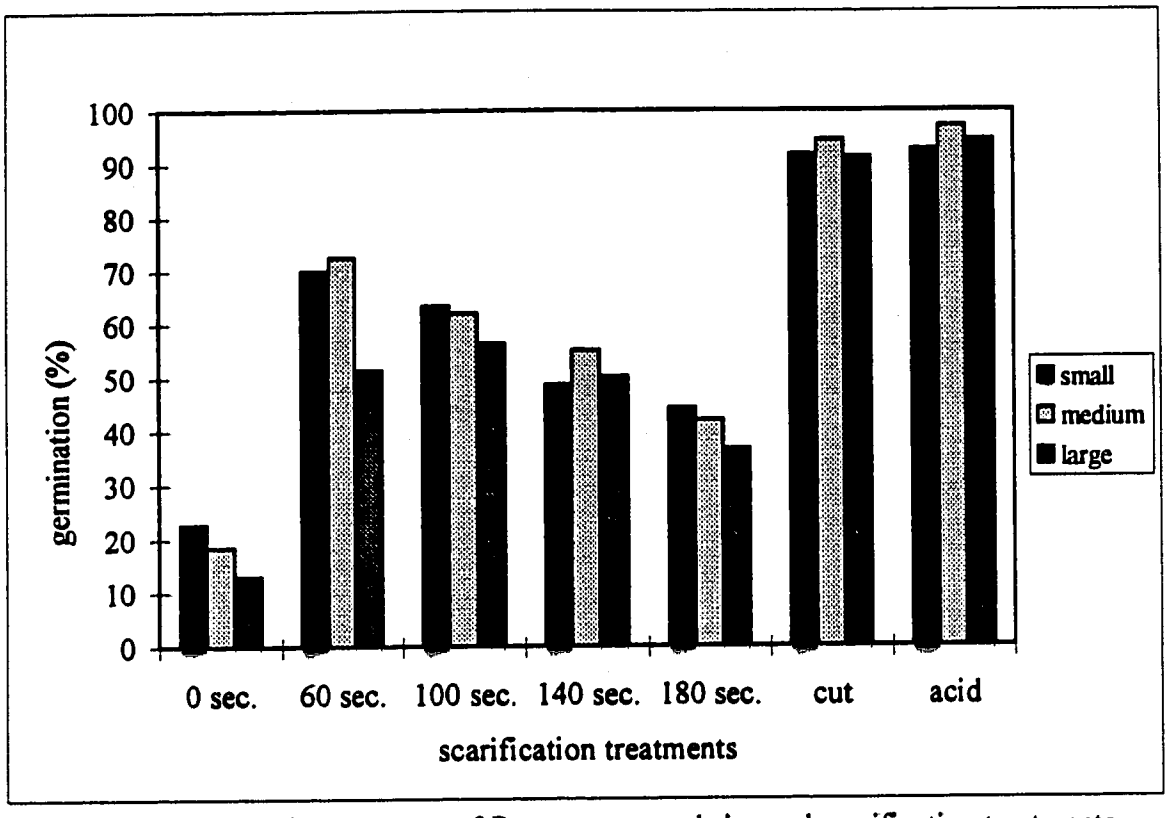

Figure 4-12. Germination response of *P. saman* to seed size and scarification treatments. Sec. refers to seconds in H_20 at 100°C. Cut refers to a treatment involving a small cut to the seed testa on the end opposite the embryo. Acid refers to a treatment of submersion for 75 min. in concentrated H_2S0_4. Seed size was defined on basis of average weight per seed: small, 115 mg, medium, 169 mg, large, 233 mg. F-value for the seed size*scarification treatment interaction was significant at the 0.05 level (Appendix 7.15).

4.2.2 Seed size and early growth in the tree nursery

Monitoring the growth of cenízaro seedlings for 60 days revealed that larger seeds gave rise to larger seedlings. Mean heights of seedlings were 11.7, 14.4 and 15.1 cm for small, medium and large seeds respectively at the end of the two month period. A time course for growth in seedling height is shown in Figure 4-13. No time by seed size interaction was observed in this experiment (Appendix 7-16). Seedling height increased linearly with time for each seed size ($P<0.001$). Growth rates of seedlings averaged 0.77 mm/day.

At 70 days, seedlings were harvested to determine fresh and dry weights. Both fresh and dry weight increased linearly with increasing seed size (fresh weight: y =

0.011x + 1.148, R^2 = 0.904; dry weight: y = 0.003x + 0.226, R^2 = 0.902 (R^2 calculations based on seed size class means) (Table 4-14).

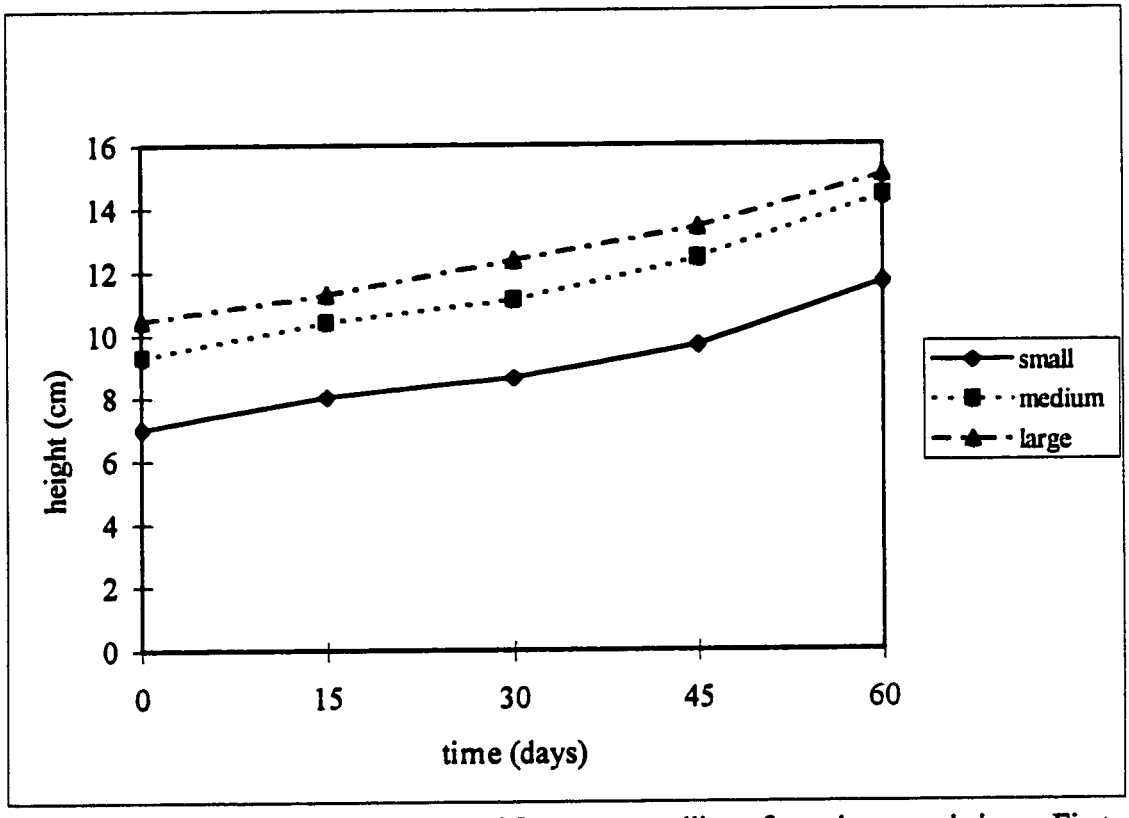

Figure 4-13. Time course for growth of *P. saman* seedlings from three seed sizes. First height measurement (0 days) took place three days after transplantation into soil mixture. Seedlings were eight days old at that time. Seed size defined on basis of average weight per seed: small, 115 mg, medium, 169 mg, large, 233 mg. See also Appendix 7.16.

Despite the initial larger size of seedlings from large seeds, rate of growth was essentially the same for all seed sizes (i.e. slopes were the same). Although larger seedlings would initially be better able to compete for light and nutrients than smaller seedlings, these differences would likely be negligible over the long term, as would the actual height differences. This finding, as well as the fact that all seed sizes had a very high germination percentage indicates that sorting the seeds of *P. saman* according to size, unlike some other species, was not worthwhile under nursery conditions. A similar experiment under variable field conditions, however, might yield different results, making the larger size of seedlings from large seeds more advantageous.

In Section 2.5.1 it was mentioned that seed sorting could be deleterious to the conservation of a wide range of genetic material for that species (Hellum, 1976). This could occur when, of the numerous trees that are harvested, a few trees produce heavier or larger seeds than the rest. When the seeds are graded by size or weight, it would be the seeds of only those few trees that were selected. Harvest of trees with small seeds would have been a waste of time as those seeds would be discarded. This is an important consideration for a seed size study for not only is percent germination of a seed lot important but the conservation of that species' genetic diversity which is tied in to its adaptability.

Table 4-14. Fresh and dry weight analysis of *P. saman* for 70-day-old seedlings

		Seedling weight (g/plant)[a]	
Seed size	Average seed weight (mg/seed)[b]	Fresh	Dry
large	233	3.56	0.93
medium	169	3.22	0.83
small	115	2.26	0.55
	Linear	0.001[c]	0.001
	Deviations	0.01	0.01

[a]Seedling weights included roots and shoots (ie. whole plant). [b]Average seed weight was based on the TKW for each size class. [c]Significance levels for indicated trends (ns, not significant).

Further studies with any species should take this into account. Seed size studies on germination should be accompanied by studies that determine if and how seed size is tied to individual trees, whether or not most trees tend to produce a range of seed sizes or mostly large or mostly small seeds and if and how this may change from year to year. If it is determined that a seed sort according to size would exclude the seeds of some trees, the sorting should be halted, forgoing seedling size advantages and selecting by genotype and phenotype instead (Hellum, 1976).

5. CONCLUSIONS

Adequate biological knowledge about native tropical trees is currently lacking and is required to diversify reforestation by including a wider selection of native trees that are well adapted to the sites in which they are planted. One way to approach this need is research into the germination requirements of native trees.

The propagation manual (Appendix 1) included in this thesis documented what has been learned to date by trial and error by nursery growers about the propagation and nursery management of numerous tree species found in the Monteverde region of Costa Rica. There are many indications of the great need for more research on the majority of these species, such as the inability to store many seeds and a very slow germination in others, despite pregermination treatments. For yet other species some information is lacking altogether. Species by species these trees could represent a wealth of potential research projects for the future.

Experiments included in this study were aimed at increasing knowledge of the germination behavior of two tropical tree species, *A. acuminata* and *P. saman*. The results have practical application in the seed laboratory or tree nursery. Conclusions that may be drawn are as follows:

1. Recommended laboratory germination conditions for the two provenances of *A. acuminata* tested are: temperature of between 24 and 27°C, photoperiod of 16 to 24 hours per day and a substrate of either sand or paper. Tree nursery germination conditions need not be as strict but exposure to some light will be beneficial, and temperatures should not exceed 30°C.

Strongly acidic substrate conditions affected the germination of this species negatively. This observation was stronger in provenance two than in provenance one. For provenance two (the seed lot from the province of Cartago) neutral to basic germination media would be preferable. More study is needed to determine if soil acidity affects seedling growth as well, so that more conclusive recommendations may be given as to site suitability for *A. acuminata*.

Further work with this species should address the question of why percent germination of this species is so variable between seed lots and why it is often so low.

2. For *P. saman*, recommended conditions for germination are: temperature of between 24 and 35°C and a sand substrate. Seeds will germinate faster at the higher temperatures but percent germination will be very high throughout the given range. Photoperiod is not a concern for this species as it germinates equally well in the dark as in the light. Likewise, strong germination was observed throughout a pH range of four to ten. Thus, pH would not be an important site consideration for scarified seeds of *P. saman*.

Overall this species germinated very quickly (in eight days or less) and had a high percent germination (often over 90%) when scarified.

3. Upon comparison of seven pregermination treatments, scarification with concentrated sulfuric acid for 75 min and mechanical scarification by cutting the testa were most effective in breaking coat-imposed dormancy in the seeds of *P. saman*. Acid scarification is recommended as it is the simpler and faster of the two methods.

According to the literature, pretreatment of seeds of *A. acuminata* is unnecessary. Additional studies should focus on determining methods to achieve more consistent germination for this species, whether that involves a possible pretreatment, cleaning of seed or controlled times for collection.

4. Although seedlings from large seeds of *P. saman* produced larger seedlings than small seeds, small seeds germinated equally well as medium or large seeds and the size advantage was deemed small in the long run when grown in a nursery. Growth rates for seedlings from small, medium and large seeds were not significantly different. Seed sorting according to size is not recommended for this species.

A similar study performed under field conditions would provide information on whether the size advantage of seedlings from large seeds is beneficial for establishment in nature.

Campos and Ortiz (1989) determined that higher percent germination could be obtained from large seeds of *A. acuminata* compared to smaller seeds. Early growth studies for this species should be undertaken to determine if there is any size and/or growth rate advantage for larger seeds of this species.

Future studies of this nature with any tree species should include a consideration of seed size distribution between trees harvested and from year to year. It is important that the exclusion of genotypes from the seed collection be avoided.

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7. APPENDICES

Appendix 7.1. Propagation manual for the trees of Monteverde, Costa Rica

The Trees of Monteverde: Morphology and Tree Nursery Propagation

Introduction

The following manual documents information on the morphology and propagation of numerous tree species found in the Monteverde region of Costa Rica. These species have been propagated in the Cerro Plano and/or San Luis tree nurseries, under the management of the Monteverde Conservation League. The majority of the information comes from Edwin Méndez, who has worked in the Cerro Plano tree nursery since 1988. Additional information comes from Milton Brenes, the San Luis tree nursery manager, as well as various sources of literature.

Despite the large quantity of information contained within, I view this manual as a beginning, not an end. This region contains a great, rich diversity of trees; each one is unique and guards its own secrets. As investigation continues in the nurseries or among interested persons, additions will be made (and are welcome) to this manual. It is my hope that the documentation of this information will help facilitate the progress of reforestation in this region.

There are various basic nursery practices that, although they are not repeated throughout the manual, should be mentioned at the beginning. Seeds arriving at the nursery are cleaned if necessary and seeded in beds of sand. The seed beds are in the open air, although protected under a roof. Seeds of all species are watered regularly. In general, the depth of seeding varies with the size of the seed; larger seeds are planted deeper than smaller seeds. A good rule is to seed at a depth of two times the diameter of the seed. The seedlings are transplanted from the seed beds to black plastic bags (13X20 centimeters) filled with soil. These are moved immediately to an open area where they continue to grow until they are moved to their final destination.

The species are numbered alphabetically by family. Within each family, the species are ordered alphabetically according to scientific name.

I hope the information is simple and helpful. Please note that some information (for example, when the trees flower and fruit) applies only to the Monteverde region and may vary as one moves to a different area.

LIST OF SPECIES

Lauraceae	Ira marañon *(Ocotea tonduzii)*	126
Lauraceae	Quizarrá quetzal *(Ocotea valeriana)*	127
Lauraceae	Canelo *(Ocotea veraguensis, Nectandra salicina)*	128
Lauraceae	Ira rosa *(Ocotea whitei)*	129
Lauraceae	Aguacatillo *(Persea americana)*	130
Lauraceae	Yema de huevo *(Pleurothyrium palmanum)*	131
Malvaceae	Burío colorado *(Hampea appendiculata)*	132
Meliaceae	Cedro amargo *(Cedrela odorata)*	133
Meliaceae	Cedro dulce *(Cedrela tonduzii)*	134
Meliaceae	Cocora *(Guarea kunthiana)*	135
Meliaceae	Caoba *(Swietenia macrophylla)*	136
Meliaceae	Uruca *(Trichilia havanensis)*	138
Moraceae	Ojoche *(Brosimum alicastrum)*	139
Moraceae	Higuito *(Ficus pertusa)*	140
Moraceae	Higuerón *(Ficus tuerckheimii)*	141
Myrsinaceae	Ratoncillo *(Myrsine coriacea)*	142
Myrtaceae	Murta negro *(Eugenia acapulcensis)*	143
Myrtaceae	Murta blanco *(Eugenia guatemalensis)*	144
Myrtaceae	Albajaquillo *(Myrcianthes fragrans* or *Myrcianthes* sp.*)*	145
Myrtaceae	Manzana rosa *(Syzygium jambos)*	146
Oleaceae	Come negro *(Chionanthus panamensis)*	147
Proteaceae	Papa *(Panopsis suaveolens)*	148
Proteaceae	Danto *(Roupala glaberrima)*	149
Rosaceae	Nispero dulce *(Eriobotyra japonica)*	150
Rutaceae	Matasano *(Casimiroa edulis)*	151
Rutaceae	Limón agrio *(Citrus aurantifolia)*	152
Rutaceae	Naranja agria *(Citrus aurantium)*	153
Rutaceae	Limoncillo *(Zanthoxylum fagara)*	154
Rutaceae	Lagarto amarillo *(Zanthoxylum monophyllum)*	155
Sapindaceae	Dantisco *(Exothea paniculata)*	156
Sapotaceae	Nispero colorado *(Pouteria exfoliata?)*	157
Sapotaceae	Tempisque *(Sideroxylon stenospermum)*	158
Sapotaceae	Zapotillo lechoso	159
Sapotaceae	Zapotillo negro	160
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Most of the information about general phenology, propagation methods and diseases was obtained through the experience of Edwin Méndez in the Cerro Plano tree nursery. The information therefore applies to this same region. When mentioned in 'Tree nursery experience' that a species was seeded in San Luis as well, it is specified what information applies to the San Luis tree nursery and what applies to the Cerro Plano tree nursery. The following information is given in this manual (NA indicates information not available):

SPECIES
Latin name: previously used latin names also given if applicable as well as author names where available
Family:
Common name:

Tree nursery experience: how many years the species was seeded and in which tree nursery, the demand in number of seedlings to leave the tree nursery per year

HABITAT
Elevation: the elevation range in meters above sea level where this species may be found. Where I found two sources of information in disagreement, I combined the two elevation ranges.
Localization: the communities in the Monteverde district where this species may be found
Specific habitat: primary or secondary forests, forest edge, pastures, river sources

MORPHOLOGY (a description of each of the following)
Height:
Bark: (refers to the mature tree)
Leaves:
Flowers:
Fruit:
Seeds:
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: in which months the trees flower
Fruit: in which months mature seeds may be found

TREE NURSERY
Collection: how to know when the seeds are mature (change of color, size), how they are collected (from the tree or the ground)
Storage: if the seeds may be stored and for how long
Pregermination treatments: how to accelerate the germination if possible, such as soaking the seeds in water, for example. 'None' indicates that either no pretreatment is necessary or that none have been attempted. Which case is applicable may be determined by the following section, 'Germination'. For instance, if no pregermination treatment is listed for a species yet number of days to germinate is high, then 'none' signifies that no pregremination treatment has been attempted even though such treatment may speed up germination.
Germination: number of days to emergence from the seed bed (this differs from experimental work in this thesis project in which germination was determined by the length of the radicle)
Percentage: based on experience in the tree nursery, what germination percentage may be anticipated after seeding
Germination to transplant: number of days between germination and transplantation into bags
Transplant to field: number of days between transplantation and planting in the field
Growth: a general idea of the speed of growth, between and including very slow to very fast

NOTES
diseases or insects that may be a problem for this species in the tree nursery (diseases encountered in the field not included), fertilization requirements, etc.

USES

human or ecological benefits

SPECIES
Latin name: *Tapirira mexicana* Marchand; *T. brenesii*
Family: Anacardiaceae
Common name: Cirrí

Tree nursery experience: This species was seeded in the San Luis tree nursery with an average demand of 399 trees per year (1). It was also seeded in the Cerro Plano tree nursery from 1990 to 1995 (16).

HABITAT
Elevation: 1000-1600 meters (1,10)
Localization: San Luis, Cerro Plano, Monteverde (1)
Specific habitat: Primary forests, all types of soils (10,18)

MORPHOLOGY
Height: Cirrí reaches a medium to large size (20-30 meters) (10).
Bark: Between light and dark, very rough (16)
Leaves: Compound, with 2-4 pairs of opposite leaflets and a terminal leaflet. A typical leaf is approximately 26 centimeters long, with leaflets to a length of 9-11 centimeters. In general the leaves are held up at an angle from the rachis (10).
Flowers: Small and white, in dense axillary inflorescences (10)
Fruit: 2.5-4 centimeters long, oval or oblong, purple-black in color (10,11)
Seeds: Irregular in shape, overall round to oval and fissured with holes, approximately 1-1.5 centimeters in diameter (16)
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: June (Cerro Plano) (16)
Fruit: November (Cerro Plano); September-October (San Luis) (1)

TREE NURSERY
Collection: As the fruits mature, they change from green to purple in color. They may be collected from the tree or from the soil (16).
Storage: These seeds may be stored two months in sand (16).
Pregermination treatments: Clean the seeds and sow them (16).
Germination: According to information from the Cerro Plano tree nursery, the seeds begin to germinate in 36 days (16). In San Luis, the figure is 25-30 days (1).
Percentage: 50-70% (San Luis) (1)
Germination to transplant: 4 days (Cerro Plano) (16)
Transplant to field: approximately 3 months (Cerro Plano) (16), 4-5 months (San Luis) (1)
Growth: Fast (Cerro Plano, San Luis) (1,16)

NOTES
Milton Brenes of the San Luis tree nursery mentions that a problem with 'acaros', a type of insect, is common when the seedlings are about 4 months old. To control them, you may use Brisol detergent @ 30cc/litre of water. He also notes that you should fertilize the seedlings with 10-30-10 fertilizer the month they are transplanted (1). In the Cerro Plano tree nursery, Edwin Méndez has observed a problem with aphids. These may be controlled with an application of water and soap (16).

USES
The fruits are edible (10). They are popular with brown jays and emerald toucanets (16). The wood is very hard and red and can resist rot for up to 30 years (18). This species may also be used for fenceposts and in windbreaks (6).

SPECIES
Latin name: *Montanoa guatemalensis* B. L. Rob. & Greenm.; *Montanoa dumicola*
Family: Asteraceae
Common name: Tubú

Tree nursery experience: In the San Luis tree nursery, tubú was seeded from 1989 to 1995 with a demand of 4550 trees/year (1). It was also seeded in the Cerro Plano tree nursery from 1990 to 1995 (16).

HABITAT
Elevation: 1000-1200 meters; also as high as 1500 meters where seeded in windbreaks (10)
Localization: San Luis, Los Llanos, Los Cerros (1)
Specific habitat: Dry crests, in windbreaks (10)

MORPHOLOGY
Height: Tubú is a tree of small-medium size (3-15 meters).
Bark: Dark, smooth (16)
Leaves: May reach 13X17 centimeters; with hair on the underside (10)
Flowers: Like small daisies, 5 centimeters in diameter, with white rays surrounding an orange center (10). Pollinated by bees (16).
Fruit/Seed: The seeds are dry, brown, and approximately 3 millimeters in size (16).
No. of seeds/kg: 552,000 (1)

GENERAL PHENOLOGY
Flowers: December-January (Cerro Plano) (10)
Seeds: January-February (Cerro Plano and San Luis) (1,10) (In lower parts (Lan Lindora, Los Llanos, San Luis), the seeds may be collected in January)

TREE NURSERY
Collection: The seeds are mature when dry. Despite this fact, it has been discovered that if the seeds are cut from the tree between green and fully mature, they germinate almost immediately. Mature dry seeds will only germinate when the rainy season begins (in May). After cutting the dry inflorescences from the tree, they are put in the sun until they open. When open, they are shaken so that the seeds fall and may be collected (16).
Storage: The seeds may be stored almost a year in paper bags or glass containers although they lose some of their viability (1,16).
Pregermination treatments: The seeds may be sown immediately on top of the sand or at a very shallow depth (16).
Germination: Cerro Plano: In winter, the seeds begin to germinate in 5 days, in summer, in 11 to 15 days (when cut between green and mature). Mature dry seeds do not germinate until the rainy season begins (in May) (16). San Luis: According to Milton Brenes, the seeds germinate in 6-8 days (1).
Percentage: NA
Germination to transplant: 5 days (Cerro Plano) (16)
Transplant to field: Cerro Plano: 4 months (16); San Luis: 3 months (1)
Growth: Very fast (16)

NOTES
San Luis: In this tree nursery, Milton Brenes has encountered problems with several insects, such as 'acaros' (mites?), 'chinchas' (something similar to ticks?) and slugs. The first may be controlled with an application of Brisol detergent @ 30cc/liter of water, the second with Diazinon @ 2cc/litre of water, and the third with salt placed around the designated area before the bags containing the trees are placed within. It is recommended to give a second application in May or June around the edges of the trees. Milton also recommends a fertilization with 10-30-10 upon transplanting. Cerro Plano: Edwin Méndez has encountered a problem with aphids in this tree nursery. These may be controlled with water and soap. As Milton, he recommends fertilization upon transplanting.

USES

Tubú is very common in windbreaks. It may also be used for fenceposts (live or dead) and firewood (16). Other uses include: apiculture, live fenceposts, durable wood and ornamental, (6).

SPECIES
Latin name: *Alnus acuminata* ssp. *arguta* (Schlechtendal) Furlow
Family: Betulaceae
Common name: Jaúl

Tree nursery experience: This species was seeded once at the Cerro Plano tree nursery (in 1990). The seeds were from CATIE (in Turrialba, Costa Rica) (16).

HABITAT
Elevation: >1000 meters (16)
Localization: This species is found in Peñas Blancas and along the 'trocha' (the road to San Luis) (16).
Specific habitat: Jaúl grows in cool, high elevation areas that receive a lot of rain. It is often found along rivers. Although it grows in poor soils, it performs better in deep, well-drained soils (5,16).

MORPHOLOGY
Height: Jaúl is a tree of medium to large size (10-30 meters) (5,16).
Bark: Dark gray with white patches, smooth (5,16)
Leaves: Simple and alternate, dark green and with a doubly serrated edge (5)
Flowers: In yellow inflorescences (16)
Fruit: Small round cones with scales (5)
Seeds: The small seeds (0.5 centimeters or less in size) are dark brown and winged (they are wind-dispersed) (5,16).
No. of seeds/kg: 650,000-4,400,000 (5)

GENERAL PHENOLOGY
Flowers: September-February
Fruit: September-January (section 2.1.1)

TREE NURSERY
Collection: Cones are harvested when they change from green to dark yellow or brown. When placed in the sun, the cones will open to release the seeds.
Storage: The seeds that had been received from CATIE had been stored for a year. Results on storageability are variable. It is necessary to store them in a cool place (5,16). At CATIE they are stored in black plastic containers at 5°C.
Pregermination treatments: None
Germination: The seeds begin to germinate in 5-6 days.
Percentage: Tests give variable results. Values from 10% to 97.5% have been obtained (section 2.1.1).
Germination to transplant: 10 days (16)
Transplant to field: 5 months (16)
Growth: Moderately fast in this region (16). A growth per year of 3 meters in height and 2.7 centimeters in diameter is reported by CATIE (5).

NOTES
Edwin Méndez has noted a problem with ants and caterpillers eating the leaves. An ant poison and Bolatón (a chemical powder) for the caterpillers should be effective against these problems.

Results from this thesis project indicate that this species will have a higher percent germination at temperatures between 24°C and 27°C under a 16 to 24 hour photoperiod and sown in a paper or sand substrate.

USES
Jaúl is used to protect water sources (16). The wood is easy to work but is not very resistent to rot nor insects. It is used for many things such as pencils, coffins and furniture. The firewood burns well. The species also fixes nitrogen and may be used to improve soils. As well, jaúl functions in windbreaks and as an ornamental tree (5).

SPECIES
Latin name: *Tabebuia rosea* (Bertol.) DC.
Family: Bignoniaceae
Common name: Roble sabana

Tree nursery experience: This species was seeded from 1989 to 1995 in the San Luis tree nursery, with a demand of 527 trees per year (1). It was also seeded in 1994 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: <1000 meters (16)
Localization: Pozo Azul, Sarmientos, Guacimal (1)
Specific habitat: In pastures and secondary forests. It is also found along fences, possibly because the seeds get caught and are deposited there. The species grows well in rocky soils and also in calcareous clay soils (1, 15).

MORPHOLOGY
Height: Roble sabana can reach a medium-large size (approximately 15 meters) (1,16).
Bark: Vertically fissured, dark gray (11, 15)
Leaves: Opposite, each leaf with 5 large leaflets, leaflets smooth with a slight pubescence (11,15)
Flowers: Showy and large, with pink to white inflorescences in terminal panicles (11,15)
Fruit: Long dehiscent capsules, like slim bean pods (11,15). The pods are approximately 25 centimeters long (16).
Seeds: White and winged. Including the wings, they reach 4.5 centimeters (approximately 1-1.5 centimeters without). The wings are transparent and like fine paper (16).
No. of seeds/kg: 40,000 (1); 37,000-54,000 (15)

GENERAL PHENOLOGY
Flowers: December-January (Cerro Plano) (16)
Fruit: March-April (Cerro Plano and San Luis) (1,16)

TREE NURSERY
Collection: You may begin collecting as soon as you see that some of the pods are opening. Collect the pods that are changing from green to slightly brown. This should be done early in the morning or later in the afternoon. The wind carries the seeds easily (1,16).
Storage: Milton Brenes suggests that the seeds may not be stored (the embryos die quickly). Despite this, Edwin Méndez suggests that the seeds may be stored for up to a year.
Pregermination treatments: None (1,16)
Germination: San Luis: According to Milton Brenes, the seeds begin to germinate in 9-12 days. Cerro Plano: Edwin Méndez has observed the seeds germinating in 17 days.
Percentage: 70-90% (1)
Germination to transplant: 7 days (16)
Transplant to field: San Luis: 3.5-4 months (1); Cerro Plano: 5-6 months (16)
Growth: Slow (San Luis and Cerro Plano) (1,16)

NOTES
San Luis: Small moths tend to perforate the leaves. They may be controlled with an application of Diazinon @ 2cc/liter of water (1). Cerro Plano: To date, there have been no problems with this species (16).

USES
The wood of Roble sabana is good for furniture and framework. It is yellowish and similar to that of *Quercus* sp (11). Roble sabana may also be used as an ornamental tree, for dead or live fence posts, for firewood and for shade (6,15).

SPECIES

Latin name: *Bombacopsis quinatum* (Jacq.) Dugand
Family: Bombacaceae
Common name: Pochote

Tree nursery experience: This species was seeded in the San Luis tree nursery from 1989 to 1995 with a demand of 900 trees per year (1). It has not been seeded in the Cerro Plano tree nursery.

HABITAT

Elevation: 0-900 meters (3)
Localization: Lagartos, Sarmientos, Guacimal, La Guaria (1)
Specific habitat: Forest edges, along rivers and streams, hillsides, rocky soils. It grows best in level, well-drained sites with deep fertile soils (1,3).

MORPHOLOGY

Height: It can reach a height of 30 meters (3).
Bark: Very spiny, cinnamon-gray, thick (3,16)
Leaves: Alternate and compound, with 5 leaflets. The leaves fall in summer (3).
Flowers: Pochote has large flowers, 7-11 centimeters in length. Pollinated by bats and moths (3).
Fruit: Capsules 6 centimeters long and 3-5 centimeters wide with 5 valves and numerous seeds, light brown in color (3).
Seeds: Covered with a woolly aril (3)
No. of seeds/kg: 38,000 (1); 12,000-32,000 (3)

GENERAL PHENOLOGY

Flowers: NA
Fruit: March-April (San Luis) (1)

TREE NURSERY

Collection: The seeds are collected when the fruit is between immature and mature and the capsule has not yet opened. The capsules are dried in the sun, covered to prevent the wind from carrying the seeds away (1).
Storage: The seeds may be stored dry in covered glass containers or in sacks protected from humidity. It is preferable to leave the seeds in their wool-like covering (1).
Pregermination treatments: None
Germination: The seeds germinate in between 7 and 10 days (1).
Percentage: 75-90%
Germination to transplant: 8-15 days (3)
Transplant to field: 4 months when planted in bags; 8-10 months when seeded directly in the soil
Growth: NA

NOTES

Pochote may be attacked by an insect ('cochinillas') in the tree nursery. They may be controlled with an application of Brisol @ 30cc/liter of water (1).

USES

Pochote may be used for live or dead fence posts, in apiculture, as food for wildlife, and for its excellent wood. The wood is easy to work and employed in fine carpentry work (1,3,7).

SPECIES
Latin name: *Cordia alliodora* (Ruiz & Pav.) Oken
Family: Boraginaceae
Common name: Laurel

Tree nursery experience: Laurel was seeded in 1993 and 1995 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: <1000 meters (16)
Localization: El Dos, San Luis, La Guaria (16)
Specific habitat: The species is found in pastures and secondary forests (16).

MORPHOLOGY
Height: Medium-large in size (it can reach 30 meters in height) (16,23).
Bark: Dark with white patches, rough (16)
Leaves: Simple, alternate, elliptic, from 8 to 18 centimeters in length and 3-8 centimeters in width, with a petiole 3.5 centimeters long. Many star-shaped tricomes on the underside (23).
Flowers: White, with 5 stamens and an inferior ovary. In panicles (16,23).
Fruit: The size of a grain of rice, the fruits of laurel are dark brown and have a thin dry skin. This skin and also the petals of the flower remain attached to the seed when they mature (they have a persistent corolla) (16,23).
Seeds: The shape of rice grains (like the fruit), white and approximately 0.5 centimeters long (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: February-March (16)
Fruit: June-July (16)

TREE NURSERY
Collection: At maturity, the flower changes from white to light brown to dark brown and the fruit changes from green to dark brown. When both are dark brown, they begin to fall. As they begin to fall, they should be collected from the tree. Only those fruits in the center section of the tree will germinate; those from the very top or bottom will not (16).
Storage: The seeds cannot be stored more than two months (16).
Pregermination treatments: None
Germination: The seeds begin to germinate in 30 days (16).
Percentage: NA
Germination to transplant: 15 days (16)
Transplant to field: 8 months (16)
Growth: Slow (16)

NOTES
To date, no problems have been encountered with this species in the Cerro Plano tree nursery (16).

USES
The wood of this species, although soft, is very resistant to deterioration by exposure to water. It is strong and durable and a very light yellow in color. The species is popular in Costa Rica where it is used for floors, furniture, cabinets, decorative panels and general carpentry (16,23).

SPECIES
Latin name: *Cordia cymosa* (Donn. Sm.) Standl.
Family: Boraginaceae
Common name: Burioble

Tree nursery experience: Burioble was seeded in the Cerro Plano nursery for the first time in 1995 (16).

HABITAT
Elevation: Approximately 1200 meters (16)
Localization: Burioble is found in parts lower than Cerro Plano, such as Cañitas, La Lindora, Los Tornos, Los Llanos, Cabeceras and San Luis (16).
Specific habitat: Found in pastures (where they have been left or intentionally planted) (16)

MORPHOLOGY
Height: Medium (10-12 meters) (16)
Bark: Dark, smooth (16)
Leaves: Leaves are simple, alternate and approximately 20 to 40 centimeters long and from 13 to 29 centimeters wide, with a soft, dense skin on the underside (23).
Flowers: During flowering season many small white flowers (three millimeters in diameter) appear, each with five stamens (16,23).
Fruit: Round and red, approximately one centimeter in diameter (16).
Seeds: White, 0.5 centimeters in diameter (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: June-July
Fruit: September-October (16)

TREE NURSERY
Collection: As they mature, fruits change from green to red. The red fruits are then collected from the tree (16).
Storage: NA
Pregermination treatments: Leave seeds one day soaking in water (16).
Germination: Seeds begin to germinate in 20 days (16).
Percentage: NA
Germination to transplant: 5 days (16)
Transplant to field: NA
Growth: Moderate rate (16)

NOTES (NA)

USES
This species offers good protection to watersheds. The fruits are eaten by birds (16).

SPECIES
Latin name: *Ehretia latifolia* DC. Prodr.
Family: Boraginaceae
Common name: Raspa

Tree nursery experience: This species has never been seeded in the Cerro Plano nursery (16).

HABITAT
Elevation: 1000-1300 meters (16)
Localization: San Luis, La Lindora, Los Llanos, Monteverde (16)
Specific habitat: NA

MORPHOLOGY
Height: NA
Bark: Dark and fissured (16)
Leaves: NA
Flowers: NA
Fruit: White (16)
Seeds: Similar to the seeds of campana, but smaller (16)
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: NA
Fruit: NA

TREE NURSERY
Collection: NA
Storage: NA
Pregermination treatments: Soak seeds in water for 10 days (16).
Germination: Seeds germinate in 35 days (16).
Percentage: NA
Germination to transplant: 8 days (16)
Transplant to field: 6 months (16)
Growth: Moderate rate (16)

NOTES (NA)

USES
Raspa may be used in windbreaks and also provides food for birds (16).

SPECIES
Latin name: *Viburnum costaricanum* (Oerst.) Hemsl.
Family: Caprifoliaceae
Common name: Paraviento

Tree nursery experience: Paraviento was seeded in 1993 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1200-1600 meters (10,16)
Localization: Las Nubes, Monteverde, Cerro Plano, Santa Elena, San Bosco (16)
Specific habitat: Common in secondary forests, forest edges and along roadsides, also in very windy areas (10,16). Survives in most types of soils (18).

MORPHOLOGY
Height: Small-medium (3-12 meters), often shrubby (10)
Bark: Dark and fissured (16)
Leaves: There are three glabrous leaves in a whorl at each node. Each widest at the center, with dimensions approximately 4X8 centimeters (10).
Flowers: Flowers are very fragrant. They are small and white, approximately 5 millimeters in diameter and in umbels. Pollinated by *Trigona* sp. (10).
Fruit: Black, shiny berries, 8 millimeters in diameter, containing one seed (10).
Seeds: Seeds very similar to the fruit but brown in color (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: March-June
Fruit: August-November (10)

TREE NURSERY
Collection: Fruits should be cut down from the tree after turning from green to black (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: Soaking in water for 8 days (16).
Germination: Germination begins in 72 days (16).
Percentage: NA
Germination to transplant: 4 days (16)
Transplant to field: 7 months (16)
Growth: Slow (16)

NOTES
Aphids attack the leaves of this species in the tree nursery, a serious problem that has yet to be solved. A treatment of water and soap will kill the aphids but they will return within eight days. Continued treatment with water and soap will eventually kill the tree (16).

USES
At least eight bird species eat the fruits of paraviento. It is ideal for use in windbreaks due to its rapid growth and ability to resprout. It is also used for poles, fence posts and firewood (10,16, 18).

SPECIES
Latin name: *Casuarina equisetifolia* L. (non-native)
Family: Casuarinaceae
Common name: Casuarina

Tree nursery experience: Casuarina was seeded from 1988 to 1995 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 0-1700 meters (16)
Localization: Planted in all areas (16)
Specific habitat: Windbreaks and block plantations. Survives well in hardened acid soils (to pH 4.9) (2,16).

MORPHOLOGY
Height: Usually medium height (12 meters), but can reach 40 meters (2, 16).
Bark: Dark and smooth (16)
Leaves: Long and fine, very slim like the needles of pine trees (16)
Flowers: Tiny, purple (16)
Fruit: One centimeter in diameter and with lots of little spikes all around, brown in color upon maturity (16).
Seeds: Dry and winged, from four to five millimeters in length including the wing, light brown (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: All times of the year
Fruit: All times of the year (16)

TREE NURSERY
Collection: Fruits change from light brown to a darker brown upon maturity. Mature fruits are cut down from the tree and left in the sun or placed above lights for three days so that they open and release the seeds (16).
Storage: Seeds may be stored for a year in paper bags, but a supply is always available from the trees themselves (16).
Pregermination treatments: None
Germination: Seeds germinate in 17 days (16).
Percentage: NA
Germination to transplant: 15 days (16)
Transplant to field: 4 months (16)
Growth: Fast (16)

NOTES
Trees should be inoculated one month after transplant. To make the inoculum, roots are collected from mature, healthy trees. The roots are shaken and mashed in a wheelbarrow, to which water and sour lemon is added. The following day, the liquid is applied to young trees with a watering can. A fungus in the inoculum aids the trees in absorbing nitrogen. Trees should be fertilized with 10-30-10 fertilizer fifteen to thirty days after inoculation (16).

USES
Casuarina is used for windbreaks (it is very resistant to the wind) and firewood. The wood is very hard. In this region birds frequently sleep in blocks of Casuarina. The birds disperse ingested seeds of other tree species (such as trees in the Lauraceae family) in these blocks. For this reason a diversity of trees is often found growing underneath the Casuarina in these areas. This species also resprouts well after cutting (2,16).

SPECIES
Latin name: *Cornus disciflora* DC.
Family: Cornaceae
Common name: Llorón

Tree nursery experience: 1995 was the first year llorón was planted in the Cerro Plano tree nursery (16).

HABITAT
Elevation: Found at elevations greater than 1400 meters (16).
Localization: This species is found in the highest regions, from the Biological Station and above and also in San Bosco (16).
Specific habitat: Llorón survives in primary and secondary forests (16). It requires relatively good soils (18).

MORPHOLOGY
Height: Reaches heights of between 8 and 10 meters (16).
Bark: Light in color and fissured (16)
Leaves: Lemon green in color, opposite and oblong with conspicuous venation. Leaves reach 7 to 14 centimeters in length and 2 to 6 centimeters in width and have a petiole approximately one to two centimeters long. When a leaf is ripped in half, the veins remain joined together like fine white strings (16,23).
Flowers: White, tiny and in inflorecences in the form of heads (23)
Fruit: In groups of five or six, each approximately one centimeter in diameter, round and purple with small white dots (16).
Seeds: Seeds are slightly less than a centimeter long, slightly fissured and brown (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: Most times of the year (23)
Fruit: June-July (16)

TREE NURSERY
Collection: Fruits change from green to white (sasón) to purple (mature). As birds eat the fruits, the clean seeds may be found on the ground beneath the tree and they may be collected from there (16).
Storage: NA
Pregermination treatments: In the tree nursery, the seeds have been left soaking in water for 10 days (16). According to Zamora (1993), another method to accelerate the germination is a treatment of water and sun for two weeks.
Germination: Seeds begin to germinate in 58 days with the first treatment (16).
Percentage: NA
Germination to transplant: 4 days (16)
Transplant to field: NA
Growth: NA

NOTES (NA)

USES
Llorón has fine, heavy wood with black stripes. It is used for furniture, floors and walls. It also provides food for birds (16,18,23).

SPECIES
Latin name: *Cupressus lusitanica* Mill. (non-native)
Family: Cupressaceae
Common name: Ciprés

Tree nursery experience: Ciprés has been seeded in the Cerro Plano tree nursery from 1988 to 1995 (16).

HABITAT
Elevation: 0-1700 meters (16)
Localization: Planted in all parts of the Monteverde region (16).
Specific habitat: Windbreaks, block plantations (16)

MORPHOLOGY
Height: In the Monteverde region trees generally reach a medium height (10 meters) (16). According to CATIE, ciprés can reach up to 40 meters (4).
Bark: Dark, some trees with fissures (16)
Leaves: NA
Flowers: Very small, yellow and green (16)
Fruit: Round and with several pointed tips, one centimeter in diameter (16)
Seeds: Light brown, 0.5 centimeters in diameter, flat (16)
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: All times of the year
Fruit: All times of the year (16); according to CATIE, seeds are collected between December and February in Costa Rica (4)

TREE NURSERY
Collection: Fruits open upon maturity. Before opening, they are collected and placed in the sun for five days. The seeds are collected as the fruits open (16).
Storage: Seeds may be stored for one year in paper bags (16).
Pregermination treatments: None
Germination: Seeds germinate in 22 days (16).
Percentage: NA
Germination to transplant: 5 days (16)
Transplant to field: 4 months (16)
Growth: Moderate rate (16)

NOTES
Three weeks after transplanting, fertilization with 10-30-10 is recommended. An ant poison may be applied should ants be eating the leaves (16).

USES
This species is used for firewood, windbreaks and for its wood. The wood is yellowish white and is used for indoor construction and to make furniture and handicrafts. The wood is aromatic (4, 16).

SPECIES
Latin name: *Croton gossypiifolius?*
Family: Euphorbiaceae
Common name: Taguá paraviento

Tree nursery experience: This species was planted in 1991 and 1992 in the Cerro Plano vivero (16).

HABITAT
Elevation: Approximately 1200-1400 meters (16)
Localization: Los Llanos, Santa Elena, Cañitas, Cerro Plano, San Bosco, Monteverde (16)
Specific habitat: See Targuá nacientes on the following page (information is the same for both species)

MORPHOLOGY
Height: Small-medium (5-25 meters) (16)
Bark: Dark with white patches, smooth (16)
Leaves: Leaves are rough with long petioles and a pair of glands at the base of the blade. Often there are some orange leaves among the green ones on the tree (16,18).
Flowers: See Targuá nacientes
Fruit: See Targuá nacientes
Seeds: NA
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: NA
Fruit: May-June (16)

TREE NURSERY
See Targuá nacientes (Collection, etc.)
Germination to transplant: 5 days (16)
Transplant to field: 5 months (16)
Growth: Rapid (16)

NOTES
There is a problem with ants attacking the leaves in the tree nursery, but this may be controlled with an ant poison (16).

USES
This species serves well in windbreaks (16). It may also be used to distract ants from more valuable species nearby as well as for firewood, soil reclamation and in medications (6)

SPECIES
Latin name: *Croton monteverdensis* Huft.?
Family: Euphorbiaceae
Common name: Targuá nacientes

Tree nursery experience: This species was seeded in the Cerro Plano tree nursery in 1992 (16).

HABITAT
Elevation: 1300-1500 meters (10)
Localization: San Luis, La Guaria, La Lindora (in lower areas) (16)
Specific habitat: Pastures, secondary forests, occasionally in primary forests (10)

MORPHOLOGY
Height: Small-medium (5-25 meters)
Bark: Dark with many white patches, smooth (16)
Leaves: Leaves are simple, 9X17 centimeters with long petioles and a pair of raised glands at the base of the leaves. Very rough (16).
Flowers: Flowers are small and green with a beige pubescence (10).
Fruit: The capsules of targuá nacientes are approximately 0.5-1 centimeter in size, brown and with three seeds inside. The capsules explode with a dry pop (10).
Seeds: Two to three millimeters in length (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: September
Fruit: January (16)

TREE NURSERY
Collection: The time to collect is when a few of the capsules begin to pop open. Unopened capsules are then harvested and placed in the sun covered with a mesh. When the capsules explode the seeds may be separated from the debris (16).
Storage: In refrigeration (17°C) and in sealed plastic bags the seeds of this species may be stored seven months (16).
Pregermination treatments: None
Germination: Seeds begin to germinate in 22 days (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: 6 months (16)
Growth: Rapid (16)

NOTES (NA)

USES
The sap of this tree serves as an ulcer treatment (10). The tree is also useful in watershed protection (16).

SPECIES
Latin name: *Croton niveus* Jacq.
Family: Euphorbiaceae
Common name: Colpachí

Tree nursery experience: Colpachí was seeded in the Cerro Plano tree nursery in 1990 and 1995 (16).

HABITAT
Elevation: 1000-1350 meters (16)
Localization: Santa Elena, Los Tornos, Monteverde, San Luis, Cabeceras, San Rafael, Las Nubes, Cañitas (16,20)
Specific habitat: Windbreaks, in forests at medium elevations, in deep fertile soils (20)

MORPHOLOGY
Height: The species reaches medium height (10 meters) and has multiple trunks (7).
Bark: Brown, thin and smooth (16,20)
Leaves: Shiny green, lighter on the underside, in a triangular form from 10-15 centimeters in length and 10 to 12 centimeters in width. With many clear dots (glands) and a pleasant odor when crushed (20).
Flowers: Yellow, in inflorescences arranged with the male flowers in the upper part and the female flowers at the base. Each flower measures approximately 0.5 centimeters in diameter (20).
Fruit: Green, 1.5 centimeters or more in diameter, with sutures where the fruit eventually opens, three cavities in the interior and three seeds. Fragrant like the leaves (20).
Seeds: Similar to large beans, 1.5 centimeters in length and one centimeter in width, with a pulpy tissue (20).
No. of seeds/kg: 1 370 (20)

GENERAL PHENOLOGY
Flowers: January-March
Fruit: July-October (20)

TREE NURSERY
Collection: NA
Storage: Seeds may not be stored more than one month (20).
Pregermination treatments: None
Germination: Seeds germinate in 17 days (20).
Percentage: 27.2-57% (20)
Germination to transplant: 12 days (16)
Transplant to field: 4 months (16)
Growth: Rapid (16)

NOTES (NA)

USES
This species provides food for wildlife, such as parakeets, parrots, doves and squirrels (20). The seeds are also good for chickens (20).

SPECIES
Latin name: *Sapium glandulosum* (L.) Morong ; *S. oligoneurum*
Family: Euphorbiaceae
Common name: Yos

Tree nursery experience: This species has never been seeded in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1300-1550 meters (16)
Localization: Monteverde, Cerro Plano, Santa Elena, Cañitas, San Bosco, Las Nubes, Río Negro (16)
Specific habitat: In pastures and occasionally in primary forests. Well adapted to a wide range of soil types (10,18).

MORPHOLOGY
Height: Medium-large (10-30 meters) (10)
Bark: White and black, smooth (16,18)
Leaves: Glabrous, lanceolate and leathery, with dimensions 5X9 centimeters. There is a pair of one millimeter long glands at the base of the leaf blade (10).
Flowers: Flowers are tiny, green-red, lacking petals and in spikes. They are pollinated by wasps and bees (10,16).
Fruit: Fruits are capsules with a diameter of one centimeter and three lobes. They are dehiscent and contain one to three seeds inside (10).
Seeds: Seeds are black with a red aril (10).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: March-May; November-December
Fruit: May; August-November (10)

TREE NURSERY
Collection: The seeds are mature when the capsules open. Both open and closed capsules may be cut from the tree (the seeds do not fall). Should the closed capsules not open quickly they should be placed in the sun until they do (16).
Storage: These seeds may not be stored (16).
Pregermination treatments: None
Germination: Seeds begin to germinate in 20 to 30 days (16).
Percentage: NA
Germination to transplant: 5 days (16)
Transplant to field: 4 months (16)
Growth: Very rapid (16)

NOTES (NA)

USES
The latex may be used for rubber, but caution should be taken as contact with the eyes can cause temporary blindness. This species is also used for shade, windbreaks, ornamental use and forage for cattle (6). It supports many ephiphytes (18). Haber *et al.* report that 22 bird species feed on the seeds. Yos is also good for live fence posts and firewood (16). Méndez mentions that for firewood, the wood should be green as the latex acts like gasoline.

SPECIES
Latin name: *Brassica guachapele?*
Family: Fabaceae
Common name: Guallaquil

Tree nursery experience: This species was seeded in the San Luis tree nursery for several years with a demand of 315 trees per year (1). In the Cerro Plano tree nursery it was planted in 1994 (16).

HABITAT
Elevation: 150-368 meters (1)
Localization: Pozo Azúl, Lajón, Chomes, Guacimal (1)
Specific habitat: Edges of secondary forests, hillsides of low elevation areas, shady sights (1)

MORPHOLOGY
Height: NA
Bark: Dark and very rough and peeling (16)
Leaves: NA
Flowers: NA
Fruit: NA
Seeds: NA
No. of seeds/kg: 34 000 (1)

GENERAL PHENOLOGY
Flowers: NA
Fruit: February to the middle of March (1)

TREE NURSERY (Information from the San Luis nursery)
Collection: Collection should be done when the pods are at the sasón stage (between green and dry) (1).
Storage: Seeds may be stored one year in closed glass flasks (1).
Pregermination treatments: Seeds should be soaked in cold water for one day (1).
Germination: Seeds germinate in 4-6 days with the pregermination treatment (1).
Percentage: 70-85% (1)
Germination to transplant: NA
Transplant to field: 5-6.5 months (1)
Growth: Slow (1)

NOTES
Milton Brenes has noticed yellowing of the leaves at about 5 to 6.5 months of age. This is natural and occurs before a change of leaves. He has also observed a problem with grasshoppers which may be controlled with Diazinón at 2cc per liter of water. Trees should be fertilized with 10-30-10 the month of transplantation (1).

USES
Guallaquil is useful for its wood and also for fence posts (1).

SPECIES
Latin name: *Dalbergia retusa* Hemsl.
Family: Fabaceae (Papilionoideae)
Common name: Cocobolo

Tree nursery experience: Cocobolo was seeded in the San Luis tree nursery in 1992 and 1995 with a demand of 750 trees per year (1). It has not been seeded in the Cerro Plano tree nursery.

HABITAT
Elevation: 150-368 meters (1)
Localization: Guacimal, Sardinal, Lagartos (1)
Specific habitat: Uncommon, found in secondary forests, hillsides at low elevations and along rivers. Grows in clay soils (1).

MORPHOLOGY
Height: Small-medium (11)
Bark: Dark, greyish-black, exfoliating, very rough (11,16)
Leaves: Compound with 7-15 leaflets, oval or oblong. They can vary between 2.5 and 12 centimeters long and between 2 and 7 centimeters wide (11).
Flowers: Flowers are in panicles from 5 to 20 centimeters long, white and purple (11).
Fruit: Oblong pods, from 6 to 13 centimeters in length and 1.5 to 2.5 centimeters in width. They contain 1-5 seeds (11).
Seeds: Similar to beans, but irregular in form, approximately 0.5 centimeters long (16).
No. of seeds/kg: 16 000 (1)

GENERAL PHENOLOGY
Flowers: NA
Fruit: January-Febrary (1)

TREE NURSERY
Collection: NA
Storage: Seeds may be stored at least 10 months in closed glass containers (1).
Pregermination treatments: None
Germination: San Luis: Seeds germinate in 5-7 days (1). Cerro Plano: Seeds germinate in 17 days (16).
Percentage: 60% (1)
Germination to transplant: NA
Transplant to field: 4.5 months (1)
Growth: Growth is very rapid initially but slows down after transplantation in the field. Milton Brenes suggests planting cocobolo with other species that grow faster and do no produce a lot of branches (1).

NOTES
Cocobolo is plagued by 'acaros' (mites?) and small caterpillars. The 'acaros' may be controlled by Brisol @ 30 cc/litre of water and the caterpillars with a treatment of Diazinón @ 2cc/litre of water (1).

USES
The wood of this species is highly sought-after for its exceptional quality. It is used for cabinet-making and handicrafts, and is sold by weight (16).

SPECIES

Latin name: *Diphysa robinioides* Benth.
Family: Fabaceae (Papilionoideae)
Common name: Guachipelín

Tree nursery experience: In the San Luis nursery this species was seeded from 1989 to 1995 with an annual demand of 4 600 trees (1). It was also seeded in the Cerro Plano nursery in 1992 (16).

HABITAT

Elevation: Found at low to medium elevations (1).
Localization: San Luis, La Guaria, Fernandez, La Lindora (1)
Specific habitat: Hillsides in low-elevation areas, sites with shade (1)

MORPHOLOGY

Height: Medium (16 meters) (21)
Bark: Light colored, fissured with many long vertical cracks, peels regularly (16)
Leaves: Alternate and compound with 10 to 18 round leaflets, each leaflet approximately 2 to 3 centimeters long, odd-pinnate (21).
Flowers: Yellow, in axillary racemes, each flower 1.5 centimeters long (21), similar to pea flowers.
Fruit: Light brown pods approximately 6 centimeters long and 1.5 to 2 centimeters wide (21).
Seeds: Small, flat and light brown in color (21).
No. of seeds/kg: 36 000 (1)

GENERAL PHENOLOGY

Flowers: January-February (San Luis) (21)
Fruit: February (San Luis) (1)

TREE NURSERY

Collection: Fruits may be collected when they change from green to brown in color (16).
Storage: Seeds may be stored at least eight months in sealed glass containers (1).
Pregermination treatments: Placing the pods in sealed plastic bags with moisture for one day will speed up the process of germination. This treatment softens the seed coats and allows the seeds to inflate (1).
Germination: Germination begins in 6-8 days (1).
Percentage: 75-90% (1)
Germination to transplant: 6 days (16)
Transplant to field: San Luis: 2.5-3 months (1); Cerro Plano: 7 months (16)
Growth: San Luis: Very rapid (1); Cerro Plano: Rapid (16)

NOTES

The year this species was planted in Cerro Plano, no problems were encountered. In the San Luis tree nursery however, guachipelín has been attacked by little caterpillars and grasshoppers. Both may be controlled with an application of Diazinón @ 2cc/litre of water (1).

USES

Guachipelín has hard, high quality wood for fence posts, carpentry, cabinet-making, bridges and handles for heavy tools. It is also used for firewood, shade, nitrogen production, forage for cattle, food source for fauna (for example, iguanas and wild rabbits), dyes, green fertilizer, as an ornamental and in live fenceposts (1,6,21).

SPECIES

Latin name: *Erythrina lanceolata* Standl.
Family: Fabaceae (Papilionoideae)
Common name: Poró

Tree nursery experience: Poró was seeded in the Cerro Plano tree nursery in 1993 (16).

HABITAT

Elevation: 900-1400 meters (10,16)
Localization: From San Luis to Tilarán (16)
Specific habitat: Secondary forests and edges (10), fences

MORPHOLOGY

Height: In general reaches 4 to 8 meters in height (10).
Bark: Dark and covered with many spines (11, 16)
Leaves: Alternate and compound with three glabrous heart-shaped leaflets. The petiole and rachis have spines. The leaflets reach 8 to 15 centimeters in length and 4 to 8 centimeters in width (11,18).
Flowers: In groups, with the appearance of small red machetes (10,11).
Fruit: Long black pods that twist upon opening to display the red seeds (10,11).
Seeds: The red seeds measure approximately one centimeter or slightly less and remain attached to the pod (11).
No. of seeds/kg: NA

GENERAL PHENOLOGY

Flowers: February-March
Fruit: May-June (10)

TREE NURSERY

Collection: When the pods open, the seeds are mature and may be collected from the tree (16).
Storage: Seeds of poró may be stored one year (possibly more) in paper bags (16).
Pregermination treatments: None
Germination: Seeds begin to germinate in 17 days (16).
Percentage: NA
Germination to transplant: 5 days (16)
Transplant to field: 5 months (16)
Growth: Moderate rate (16)

NOTES

A small beetle makes holes in the leaves of poró. The beetles may be controlled by an application of Botalón.

USES

Stakes of this species are planted for live fence posts (10). It also provides green fertilizer, a food source for fauna, nitrogen, forage for cattle, shade in coffee plantations and pastures and may function as an ornamental (6). The flowers are edible. They may be cooked and eaten like green beans. The young leaves may also be eaten.

SPECIES
Latin name: *Gliricidia sepium* (Jacq.) Steud.
Family: Fabaceae (Papilionoideae)
Common name: Madero Negro

Tree nursery experience: Madero negro was seeded in the Cerro Plano nursery in 1993 (16).

HABITAT
Elevation: Found at low to medium elevations in parts with dry to very humid environments (11).
Localization: San Luis and below, Guanacaste (common in many areas) (16)
Specific habitat: Fences, cacao plantations (17)

MORPHOLOGY
Height: Medium (approximately 6 meters) with a narrow crown (11).
Bark: Dark with white patches, very smooth (16)
Leaves: Odd-pinnate with 7 to 17 leaflets, each one 3 to 7 centimeters long and grey on the underside (11). Deciduous.
Flowers: Flowers are pink, purple or black and in racemes 5 to 10 centimeters long (11).
Fruit: Fruits are pods 10-15 centimeters long and 1-1.5 centimeters wide, with approximately 8 seeds per pod (11,16).
Seeds: Seeds, less than one centimeter in diameter, are flat, brown and semi-soft (16).
No. of seeds/kg: 8 000 (14)

GENERAL PHENOLOGY
Flowers: February-March
Fruit: July (16)

TREE NURSERY
Collection: Pods change from green to dark brown upon maturity. These open and the seeds fall. Pods may be harvested from the tree or the seeds from the ground beneath (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: Three days soaking in water (16).
Germination: Seeds begin to germinate in 14 days (16).
Percentage: NA
Germination to transplant: 5 days (16)
Transplant to field: 6 months (16)
Growth: Moderate rate (faster at lower elevations) (16)

NOTES (NA)

USES
As with other legume species, madero negro is capable of nitrogen fixation and is good for soil improvement. It is used for both live and dead fence posts. As it lasts well underground, it is used for foundations (17). As cattle forage it has a high percent of crude protein (30%) in the leaves. The species also has edible leaves and may be used as a shade tree, for firewood, for heavy construction and to make natural insecticides and rodenticides (6,14,16).

SPECIES
Latin name: *Inga sierrae* Britton & Killip; *I. brenesii*
Family: Fabaceae (Mimosoideae)
Common name: Guaba, Guaba peludo

Tree nursery experience: Guaba was seeded in the Cerro Plano tree nursery in 1994 (16).

HABITAT
Elevation: 1200-1400 meters (16)
Localization: Los Llanos, Santa Elena, Monteverde, Cañitas (16)
Specific habitat: Pastures and edge habitat, in all soil types (10,18)

MORPHOLOGY
Height: Medium-large (10-25 meters) (10)
Bark: Light colored, smooth (16)
Leaves: Pubescent and thick, dark green
Flowers: White with many stamens and a fragrant odor by night. Flowers 2-3 centimeters long (10).
Fruit: Dark brown pubescent pods, 3-4 centimeters wide (10).
Seeds: NA
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: September-February, at times during other months also
Fruit: May-October (10)

TREE NURSERY
Collection: Pods are collected from the tree when they have thickened. Due to a very high percent germination, seeds may be planted in seedbeds or directly in bags (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: None
Germination: Seeds begin to germinate in 19 days (16).
Percentage: ? (very high)
Germination to transplant: 5 days (16)
Transplant to field: 5 months (16)
Growth: Moderate rate (16)

NOTES (NA)

USES
Some mammals eat the white aril surrounding the seeds (10). The species is also used for firewood, green fertilizer, apiculture, as a nitrogen fixer, for shade and for its wood (6,16). The wood is useful for many things; it is yellow and very strong (16).

SPECIES
Latin name: *Inga punctata* Willd.
Family: Fabaceae (Mimosoideae)
Common name: Cuanjiniquil, Guanijiquil

Tree nursery experience: This species was seeded in the Cerro Plano tree nursery in 1992 (16).

HABITAT
Elevation: 1000-1300 meters (16)
Localization: Los Llanos, Santa Elena, Cerro Plano, Cañitas, Cebadilla (16)
Specific habitat: Common in secondary forests, pastures (16)

MORPHOLOGY
Height: Medium (10 meters) (11,16)
Bark: Thin branches have fine lenticels (11). Bark is light colored and smooth (16).
Leaves: Leaves have two to three pairs of leaflets with a gland between each pair (leaflets of terminal pair 6-17 centimeters long and 3-7 centimeters wide). The rachis is wingless (11).
Flowers: White, with many stamens, three centimeters in diameter (16).
Fruit: Pods with 4-7 seeds, approximately 12-15 centimeters long and dark brown in color. Between the seeds is a white cottony material (16).
Seeds: Light brown, 1-1.5 centimeters, fleshy (16)
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: December-January
Fruit: July, August and into September (16)

TREE NURSERY
Collection: At maturity, pods are green and thick (flat when immature). The pods should be collected from the tree (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: None
Germination: Seeds begin to germinate in 11 days (16).
Percentage: NA
Germination to transplant: 5 days (16)
Transplant to field: 4 months (16)
Growth: Moderate rate (16)

NOTES
If a problem with insects ('vaquitas') is encountered, it may be controlled with an application of Bolatón (16).

USES
Cuanijiquil provides firewood, green fertilizer, nitrogen to the soil, shade and food for animals (6,16). Parrots, squirrels and agoutis feed on the seeds and the cottony substance between the seeds. This substance is also consumed by people (16).

SPECIES
Latin name: *Ormosia cruenta* Rudd
Family: Fabaceae (Papilionoideae)
Common name: Nene

Tree nursery experience: Fifty seeds of this species were seeded in 1991 in the Cerro Plano vivero. Of the fifty, only seven seeds germinated (16).

HABITAT
Elevation: approximately 1300 meters (16)
Localization: Cañitas, Cerro Plano, Santa Elena (16)
Specific habitat: Primary forests (16)

MORPHOLOGY
Height: Nene is a tall species (20 meters) (16).
Bark: Dark and rough (16).
Leaves: Similar to the leaves of vainillo (16).
Flowers: Approximately two centimeters in diameter, brown in the center and with lilac petals (16).
Fruit: Ovoid, 3-3.5 centimeters long, opening on one side and containing one seed (16).
Seeds: Approximately one centimeter in diameter, red (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: February or March
Fruit: July, August (16)

TREE NURSERY
Collection: Fruits change from green to brown at maturity. The red seeds may be collected from the ground (16).
Storage: NA
Pregermination treatments: Eight days soaking in water (16).
Germination: With the above pregermination treatment the seeds germinate in 50 days (16).
Percentage: NA
Germination to transplant: 8 days (16)
Transplant to field: NA
Growth: NA

NOTES (NA)

USES
The yellowish wood is good for construction and to make posts (16).

SPECIES
Latin name: *Pithecellobium costaricense* (Britton & Rose) Standl.
Family: Fabaceae (Mimosoideae)
Common name: Cabello de ángel

Tree nursery experience: Cabello de ángel was seeded in 1990 and 1992 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1400-1600 meters (10)
Localization: Monteverde, Monte de los Olivos, San Bosco (16)
Specific habitat: Primary forests and pastures (10)

MORPHOLOGY
Height: Medium (5-15 meters) with a wide crown (10,11).
Bark: Dark with white patches, smooth (16).
Leaves: Bipinnate with between 4 and 8 pairs of pinnae, each one with 7-13 pairs of tiny leaflets. There is a gland between each pair of pinnae (10).
Flowers: Flowers are small and white with many stamens, in round heads (10,11). Flowers open at night and are pollinated by moths (10).
Fruit: Similar to the fruit of poró. Pods are red and twisted and open to display the black seeds inside (16).
Seeds: Black and shiny, one centimeter or less in length.
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: February-April (occasionally flowering during other months)
Fruit: March; August-September (occasionally from June to February) (10)

TREE NURSERY
Collection: Seeds may be collected from the tree when the pods open (16).
Storage: Seeds of this species may not be stored (16).
Pregermination treatments: None
Germination: Seeds begin to germinate in 11 days (16).
Percentage: NA
Germination to transplant: 4 days (16)
Transplant to field: 7 months (16)
Growth: Very slow (16)

NOTES (NA)

USES
Cabello de ángel is an attractive ornamental tree.

SPECIES
Latin name: *Pithecellobium saman* (Jacq.) Benth
Family: Fabaceae (Mimosoideae)
Common name: Cenízaro/Genízaro

Tree nursery experience: This species was seeded from 1992 to 1995 in the San Luis nursery with a demand of 150 trees per year (1). It has never been seeded in the Cerro Plano nursery.

HABITAT
Elevation: 0-500 meters (13)
Localization: Pozo Azul, Guacimal, Fernández (1)
Specific habitat: Pastures, forest and river edges, adapted to hard rocky soils (1,16)

MORPHOLOGY
Height: Large (30 meters) (13)
Bark: Bark is dark grey and fissured (11,13). Peels regularly (16).
Leaves: Leaves are compound with 2-6 pairs of pinnae. Each pinna has 2-8 pairs of leaflets, approximately 2-4 centimeters long, which close at night. Alternate (11,13).
Flowers: The flowers of cenízaro are found in dense umbels and have many pink stamens (11).
Fruit: Pods are thick and roundish, with 4-13 seeds. They are 10-20 centimeters long and 1-2 centimeters wide (11,16).
Seeds: Seeds are hard and brown, approximately 0.5 centimeters long and with a yellow circle on each side (16).
No. of seeds/kg: 5 100 (1); 4 400-7 000 (13)

GENERAL PHENOLOGY
Flowers: March-April
Fruit: San Luis: February-March (1); Cerro Plano: March-April (16)

TREE NURSERY
Collection: Pods change in color from green to black upon maturity. At this point they fall and may be collected from the ground (if the cattle don't eat them first). Seeds are extracted manually (16).
Storage: The hard seeds of cenízaro may be stored one year in closed glass containers (1,16). Under refrigeration at 5°C they will last for at least several years.
Pregermination treatments: Experimental work from this thesis project indicated that, of several boiling water treatments, mechanical and acid scarification treatments, the mechanical and acid scarification treatments were most effective in breaking the coat-imposed dormancy characteristic of these seeds. The mechanical scarification treatment was a small cut to the testa on the side opposite the seed embryo. Acid scarification involved a 75 minute submersion in concentrated sulfuric acid. Acid scarification was by far the less time-consuming of the two methods.
Germination: With a pregermination treatment, seeds will begin germinating on the second day if at a temperature of 30°C or more. Germination is slower at lower temperatures.
Percentage: 90-100%
Germination to transplant: 4 days (16)
Transplant to field: San Luis: 4-5 months (1); Cerro Plano: 7 months (16)
Growth: San Luis: ?; Cerro Plano: Moderate (16)

NOTES
Milton Brenes has noticed yellowing in the leaves at five months of age. The tree eventually sheds the leaves and grows new ones. He has also encountered a problem with grasshoppers which may be controlled with an application of Diazinón @ 2cc/liter of water (1).

Sand is recommended as a substrate for cenízaro based on results of this study. Germination appears insensitive to the amount of light provided. Germination rate increases as temperature increases up to 35°C at which fungal growth becomes a serious problem. The species also germinates well over a wide pH range.

USES

Cenízaro is a good shade tree in pastures and cacao plantations. Cattle eat the pods. The wood is useful for framework, general construction, cabinets, posts (treated) and cartwheels (11,13,16).

SPECIES
Latin name: *Styphnolobium monteviridis* M. Sousa & Rudd
Family: Fabaceae (Papilionoideae)
Common name: Vainillo

Tree nursery experience: This species was seeded in the Cerro Plano nursery from 1993 to 1995 (16).

HABITAT
Elevation: 1300-1400 meters (16)
Localization: Monteverde, in the higher parts of the San Luis Valley (through the entire Cordillera de Tilarán) (16)
Specific habitat: Humid forests (10)

MORPHOLOGY
Height: Tall (5-40 meters) (10)
Bark: Dark with white patches, smooth (16)
Leaves: Leaves are alternate and spiraled with 17-19 subopposite leaflets. The entire leaves can reach a length of 30 centimeters (10).
Flowers: Purple and in groups. One cenimeter long (10).
Fruit: Yellowish brown pods, 3-4 centimeters long and containing 1-3 seeds. Around the seeds is a yellow gelatin (10,16).
Seeds: Dark brown 'beans', 2.5 centimeters in length.
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: NA
Fruit: NA

TREE NURSERY
Collection: Pods change in color from green to yellowish. These pods should be cut down from the tree (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: None
Germination: Seeds begin to germinate in 11 days (16).
Percentage: NA
Germination to transplant: 6 days (16)
Transplant to field: 4 months (16)
Growth: Rapid (16)

NOTES (NA)

USES
It is possible that the gelatinous substance surrounding the seeds is attractive as a food source for monkeys and other mammals. The wood is used for general construction but the quality is not very good and there is a problem with a beetle that bores through it (10,16). Other uses include fence posts and ornamental (6).

SPECIES
Latin name: NA
Family: Fabaceae
Common name: Ipil ipil

Tree nursery experience: 1995 was the first year in which ipil ipil was seeded in the Cerro Plano tree nursery (16).

HABITAT
Elevation: Found at slightly lower elevations (approximately 1000 meters) (16).
Localization: San Rafael, Fernández (16)
Specific habitat: River sources, sites where they have been planted (16)

MORPHOLOGY
Height: Small (8-10 meters) with a very open crown (16).
Bark: Dark, smooth (16)
Leaves: Compound, biparapinnate, similar to those of the Guanacaste tree (16).
Flowers: NA
Fruit: Pods 13-14 centimeters long with approximately 12 seeds (16).
Seeds: Flat seeds 0.5-1 centimeter long (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: All times of the year
Fruit: All times of the year, the majority in June (16)

TREE NURSERY
Collection: At maturity, pods change in color from green to brown and dry out a lot. Pods may be collected from the tree or either the pods or seeds may be collected from the ground below (16).
Storage: The seeds are very fleshy and may not be stored (16).
Pregermination treatments: Two days soaking in water (16).
Germination: Seeds begin to germinate in 5 days (16).
Percentage: NA
Germination to transplant: 5 days (16)
Transplant to field: 4 months (?) (16)
Growth: NA

NOTES (NA)

USES
Cattle eat the leaves of ipil ipil. Squirrels and some birds eat the seeds (16).

SPECIES
Latin name: *Quercus brenesii* Trel.
Family: Fagaceae
Common name: Roble encino

Tree nursery experience: This species was seeded in 1992 and 1994 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1300-1600 meters (16)
Localization: Monteverde, Santa Elena, San Bosco (16)
Specific habitat: Primary and secondary forests, pastures (16)

MORPHOLOGY
Height: Tall (20 meters) (16)
Bark: Dark, smooth (16)
Leaves: Simple and shiny, with several large serrations near the tip of the lamina.
Flowers: Situated at the ends of the branches. Inflorescences are 6-7 centimeters long and have many tiny brown flowers. Non-fragrant. Wind-pollinated (16).
Fruit: Light brown acorns, 2.5-3 centimeters long and a cap on top (16).
Seeds: See Fruit
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: April-May
Fruit: October-November (fruits begin to fall in November) (16)

TREE NURSERY
Collection: At maturity, the cap of the acorn remains on the tree and the seed falls. When they fall it is very easy to collect them from the ground (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: None
Germination: Percent germination is very high (90-95%) and therefore seeds may be planted directly in bags. Seeds begin to germinate in 22 days (16).
Percentage: 90-95% (16)
Germination to transplant: 4 days (16)
Transplant to field: 3 months (16)
Growth: Rapid (16)

NOTES (NA)

USES
Roble encino has good quality wood and may also be used for firewood, fence posts, tannins, and as a food source for squirrels and agoutis (6,16). It also serves well in windbreaks (16).

SPECIES
Latin name: *Quercus corrugata* Hook.
Family: Fagaceae
Common name: Roble negro

Tree nursery experience: This species was seeded from 1992 to 1994 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1550-1800 meters (10)
Localization: Monteverde, Santa Elena, San Bosco (16)
Specific habitat: Primary and secondary forests, common along the crests of the cloud forest (10,16)

MORPHOLOGY
Height: Tall (20-35 meters) (10)
Bark: Light colored, very rough, peels regularly (16).
Leaves: Leaves measure 6X19 centimeters and are wider slightly above the center of the lamina. There is a soft orange pubescence on the underside. The leathery leaves are spiraled around branches. Deciduous (10,18).
Flowers: Flowers are very similar to those of roble encino. Inflorescences reach 10 centimeters long (16).
Fruit: Acorns, 4 centimeters in diameter (16).
Seeds: See Fruit
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: March-May
Fruit: September-November (10)

TREE NURSERY
Collection: Like the acorns of roble encino, those of roble negro fall when mature. They may be collected from the ground (16).
Storage: The acorns may be stored two months in plastic bags (16).
Pregermination treatments: None
Germination: Seeds begin to germinate in 40 days (16).
Percentage: NA
Germination to transplant: 4 days (16)
Transplant to field: 4 months (16)
Growth: Rapid (16)

NOTES (NA)

USES
This wood of this species is hard and striped with white, yellow and red. It is very resistant against decay. Squirrels, tepescuintles and agoutis feed on the seeds (16).

SPECIES
Latin name: *Macrohasseltia macroterantha* (Standl. & L. O. Williams) L. O. WIlliams
Family: Flacourtiaceae
Common name: Layo

Tree nursery experience: This species was seeded in 1992 and 1993 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: approximately 1400 meters (16)
Localization: Monteverde, Santa Elena, Río Negro, San Bosco, Las Nubes (16)
Specific habitat: Primary forests (16)

MORPHOLOGY
Height: Tall (20-25 meters) (16)
Bark: Light colored, peels regularly (16).
Leaves: Simple and alternate, with serrated edges (8).
Flowers: Without petals (8)
Fruit: Round but with one pointed end, one centimeter long (16).
Seeds: Small, one millimeter long and with fine hairs on one end. Wind-dispersed (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: December-January (earlier in colder parts)
Fruit: May-June (16)

TREE NURSERY
Collection: Fruits should be cut down from the tree when dark brown. These are then placed in the sun until they open and release the seeds (16).
Storage: The seeds of this species should not be stored. They lose viability after one month of storage (16).
Pregermination treatments: None
Germination: Seeds begin to germinate in 50 days (16).
Percentage: NA
Germination to transplant: 15 days (16)
Transplant to field: 7 months (16)
Growth: Slow (16)

NOTES (NA)

USES
This species is useful for posts and underground construction. Wood kept underground remains green (16).

SPECIES
Latin name: *Billia hippocastanum* Peyr.
Family: Hippocastanaceae
Common name: Cucaracho

Tree nursery experience: This species was seeded from 1992 to 1994 in the Cerro Plano vivero (16).

HABITAT
Elevation: 1000-1400 meters (16)
Localization: From San Luis to Santa Elena (16)
Specific habitat: Primary forests, pastures, in all types of soils (16)

MORPHOLOGY
Height: Tall (15-35 meters) (10)
Bark: Greyish, peeling regularly (11,16).
Leaves: Opposite and compound with three leaflets. Deciduous (10,16).
Flowers: Red with five petals and long stamens (10).
Fruit: Brown capsules, 4-6 centimeters wide and dividing into three parts.
Seeds: Fruits contain one large, round, brownish-red seed, approximately four centimeters in diameter (10,16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: February-June
Fruit: September-November (16)

TREE NURSERY
Collection: At maturity the fruits fall and may be collected from the ground (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: None
Germination: Seeds begin to germinate in 30 days (16).
Percentage: NA
Germination to transplant: 3 days (16)
Transplant to field: 2 months (16)
Growth: Rapid at outset, then slow (16,18)

NOTES
Small moths often attack this tree species. It is recommended that the seedlings be covered with netting to protect them (16).

USES
Cucaracho has hard wood with red stripes (a young tree has white, yellow and/or red stripes). The wood is used for making handicrafts. It is also used for firewood, windbreaks or as an ornamental. Rodents eat the seeds (6,11,18).

SPECIES
Latin name: *Alfaroa costaricensis* Standl.
Family: Juglandaceae
Common name: Gaulín

Tree nursery experience: This species was seeded in 1993 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1300-1600 meters (16)
Localization: Cerro Plano, Santa Elena, San Bosco (16)
Specific habitat: Pastures, primary forests (16)

MORPHOLOGY
Height: Medium-tall (10-20 meters) (16)
Bark: Dark, smooth (16)
Leaves: Opposite and compound with 10-20 leaflets each 10-20 centimeters long and 1.5-5 centimeters wide (11). Young leaves are reddish (16).
Flowers: Flowers are small and white, on branching twigs (16).
Fruit: Fruits are nuts 2.5 centimeters long and wide. They have a dry thin exocarp (11).
Seeds: The seed is very similar to the fruit. It is dark brown and hard (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: February or March
Fruit: July (16)

TREE NURSERY
Collection: Fruits change from green to brown and begin to fall as they mature. These may be collected from either the tree or the ground (16).
Storage: Seeds may not be stored for long time periods (a maximum of one month stored in the refrigerator (16).
Pregermination treatments: Place the seeds in a dark dry spot for 20 days. When the seeds crack they should be planted (16).
Germination: With the above pregermination treatment, seeds begin to germinate in 28 days (16).
Percentage: NA
Germination to transplant: 4 days (16)
Transplant to field: 7 months (16)
Growth: Slow (16)

NOTES (NA)

USES
The wood of gaulín is used in construction (9).

SPECIES
Latin name: *Juglans olanchana* Standl. & L. O. Williams or *Juglans* sp. (non-native)
Family: Juglandaceae
Common name: Nogal

Tree nursery experience: Nogal was seeded in the Cerro Plano tree nursery in 1989 and 1995 (16).

HABITAT
Elevation: Found at medium elevations (approximately 300 meters? (16)) in wet to very wet climates (11).
Localization: Los Llanos, Los Tornos, Cañitas, Heredia (sites where they have been planted) (16)
Specific habitat: Pastures (where they have been planted) (16)

MORPHOLOGY
Height: Tall (18 meters) (11,16)
Bark: Light colored, fissured (11,16)
Leaves: Similar to those of cedro dulce, with 7-12 pairs of leaflets, each one 5-10 centimeters long. Large and membranous (11).
Flowers: According to Holdridge aand Poveda (1975), this species is monoecious, with female flowers in spikes and male flowers in dense racemes
Fruit: Hard meaty nuts, indehiscent, 4-5 centimeters in diameter (11).
Seeds: Hard, fissured, brown and 3-4 centimeters in diameter. The shape is similar to that of a heart (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: NA
Fruit: June-July (16)

TREE NURSERY
Collection: Fruits change from green to yellow (sasón) to black (mature). As they turn black, the seeds fall and may be collected underneath the tree (16).
Storage: Seeds of nogal may be stored approximately one and a half years (16).
Pregermination treatments: 1. Seeds placed in boiling water for five minutes. Water then removed from heat source and left to cool. Seeds are planted the following day. 2. Seeds are placed in a closed plastic bag. The bag is placed in the shade and underneath the soil (16).
Germination: With the first treatment, seeds germinate in one year. With the second treatment they begin to germinate in 80 days. Without treatment the seeds require one to two years to germinate (16).
Percentage: NA
Germination to transplant: 7 days (16)
Transplant to field: 5 months (16)
Growth: Moderate (16)

NOTES (NA)

USES
In the central valley of Costa Rica, nogal is planted as a shade tree in coffee plantations. There is an edible meat within the seeds similar to peanuts (the seeds need to be broken first). This species also provides a food source to squirrels (16).

SPECIES
Latin name: *Bielschmiedia* **sp.**
Family: Laureae
Common name: Chancho blanco

Tree nursery experience: Chancho blanco was seeded in 1992 and 1994 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1000-1400 meters (16)
Localization: Los Llanos, Santa Elena, Cañitas (16)
Specific habitat: Primary and secondary forests (16)

MORPHOLOGY
Height: NA
Bark: Dark with many white patches, smooth (16).
Leaves: NA
Flowers: NA
Fruit: Oblong drupes, 3-5 centimeters long with a thin soft skin (16).
Seeds: Brown, similar to the fruit but slightly smaller (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: NA
Fruit: August-September (16)

TREE NURSERY
Collection: Fruits change in color from green to dark purple or black. Not all fruits mature at the same time in the same tree. The seeds may be collected from the ground before or after they have started to germinate. Non-germinated seeds should be placed in the soil and covered with leaves (16).
Storage: Seeds of this species may not be stored (16).
Pregermination treatments: After germination, seeds may be seeded directly in bags (16).
Germination: Seeds collected before germinating begin to germinate in 70 days (16).
Percentage: NA
Germination to transplant: 5 days (16)
Transplant to field: 5 months (16)
Growth: Moderate rate (16)

NOTES (NA)

USES
Birds and squirrels use the fruits of chancho blanco as a food source (16). According to the Monteverde Conservation League's reforestation department, other uses include: firewood, ornamental, fence posts, watershed protection, shade and windbreaks (6).

SPECIES
Latin name: *Beilschmiedia* sp.
Family: Lauraceae
Common name: Chancho metro

Tree nursery experience: Chancho metro was seeded in 1995 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1200 meters (16)
Localization: Cañitas. Uncommon (16).
Specific habitat: Primary forests (16)

MORPHOLOGY
Height: Medium (10 meters) (16)
Bark: Dark, smooth (16)
Leaves: Leaves are 7-9 centimeters long with a short petiole and a rounded point. New leaves are brownish (16).
Flowers: NA
Fruit: Egg-shaped drupes, up to 3 centimeters long with a thin purple skin. Without a cap (16).
Seeds: The same shape as the fruit, 2.5 centimeters long, brown (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: December-January?
Fruit: May-June (16)

TREE NURSERY
Collection: As with other chancho species, fruits change from green to black. Either the fruits or the seeds may be collected, from the tree or the ground below (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: 5 days soaking in water (16)
Germination: With the pregermination treatment, seeds begin to germinate in 42 days (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: 5 months? (16)
Growth: NA

NOTES (NA)

USES
Chancho metro has good wood and is a food source for animals (16).

SPECIES
Latin name: *Beilschmiedia pendula* (Sw.) Hemsl.?
Family: Lauraceae
Common name: Chancho rosado

Tree nursery experience: Chancho rosado was seeded from 1993 to 1995 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1000-1200 meters (16)
Localization: San Rafael, Cañitas, Cerro Plano (16)
Specific habitat: NA

MORPHOLOGY
Height: NA
Bark: Light colored, peeling (16)
Leaves: NA
Flowers: NA
Fruit: NA
Seeds: NA
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: NA
Fruit: NA

TREE NURSERY
Collection: Fruits may be collected when they have turned from green to black (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: 8 days in water (16)
Germination: Without the pregermination treatment, seeds germinate in 4 months. With the treatment, in 60 days (16).
Percentage: NA
Germination to transplant: 7 days (16)
Transplant to field: 6 months (16)
Growth: Moderate rate (16)

NOTES (NA)

USES (NA)

SPECIES
Latin name: *Cinnamomum cinnamomifolium* (Kunth) Kosterm.
Family: Lauraceae
Common name: Quizarrá negro

Tree nursery experience: Quizarrá negro was seeded in the Cerro Plano tree nursery from 1992 to 1994 (16).

HABITAT
Elevation: 1000-1400 meters (16)
Localization: Los Llanos, Cañitas, Santa Elena, Cerro Plano (16)
Specific habitat: Primary and secondary forests (as seeds are bird-dispersed, this species is found in almost all parts of the Monteverde region) (16).

MORPHOLOGY
Height: Medium (15 meters), with a large crown (16).
Bark: Dark, peeling (16)
Leaves: Leaves are glabrous and have a slight twist. They are approximately 5.5-12.5 centimeters long and 2.5-5 centimeters wide (16).
Flowers: Small and white, in branching inflorescences (16).
Fruit: Mature fruit are oblong drupes, 1.5 centimeters long and black with a red cap (16).
Seeds: Light brown, one centimeter long (16)
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: End of December
Fruit: March (but producing fruit only once per every three years) (16)

TREE NURSERY
Collection: Immature fruit are green with green caps. These change to black with red caps. At this stage the fruits may be collected from the tree (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: 5 days in water (16)
Germination: With the pregermination treatment, seeds begin to germinate in three months (six months without the treatment) (16).
Percentage: NA
Germination to transplant: 8 days (16)
Transplant to field: 7 months (16)
Growth: Moderate rate (16)

NOTES
This species loses its leaves in summer and resprouts at the beginning of the rainy season (16).

USES
This species provides a food source for fauna, firewood, posts, watershed protection, shade and a source of soft wood. It also serves in windbreaks and as an ornamental tree (6,16).

SPECIES
Latin name: *Licaria triandra* (Sw.) Kosterm. or other *Licaria* sp.
Family: Lauraceae
Common name: Licaria

Tree nursery experience: This species was sown in the Cerro Plano tree nursery in 1992, 1993 and 1995 (16).

HABITAT
Elevation: 1200-1500 meters (16)
Localization: Santa Elena Reserve (16)
Specific habitat: Primary forests (16)

MORPHOLOGY
Height: Tall (15 meters) (16)
Bark: Light colored, peeling (16)
Leaves: Simple, 5-6 centimeters long, narrower than those of chancho metro (16).
Flowers: NA
Fruit: Similar to the fruits of chancho blanco and chancho rosado (drupes) but smaller, approximately 2.5 centimeters long, oblong and covered with a thin black skin (16).
Seeds: Two centimeters long and brown (16)
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: NA
Fruit: June-July (16)

TREE NURSERY
Collection: At maturity, fruit change from green to black. The seeds may be collected on the ground below the tree (16).
Storage: Seeds of this species may not be stored (16).
Pregermination treatments: 5 days in water (16)
Germination: Seeds begin to germinate in 60 days (16).
Percentage: NA
Germination to transplant: 7 days (16)
Transplant to field: 8 months (16)
Growth: Slow (16)

NOTES (NA)

USES
Licaria is sometimes used in the last line of a multi-species windbreak. It is also used for its wood. Agoutis and birds eat the fruits (16).

SPECIES
Latin name: *Ocotea floribunda* (Sw.) Mez
Family: Lauraceae
Common name: Quizarrá quina

Tree nursery experience: Quizarrá quina was seeded from 1992 to 1994 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: Medium elevations (1000-1400 meters) (16)
Localization: From San Rafael to the Monteverde reserve, including Los Llanos, Santa Elena, Cañitas, Monteverde (not found in the Santa Elena reserve nor in San Bosco) (16).
Specific habitat: Primary and secondary forests, pastures (16)

MORPHOLOGY
Height: Medium (15 meters) with a smaller crown than that of quizarrá negro (16).
Bark: Dark and very rough (16)
Leaves: Similar to those of quizarrá negro but lacking the curve in the leaves and with a lighter green color. The length is approximately 8 to 9 centimeters (16).
Flowers: Tiny and white (16)
Fruit: Round drupes, 1.5 centimeters in diameter. The skin of the fruit as well as the cap are black at maturity (16).
Seeds: Round with two small points, one at each end. Approximately one centimeter in diameter, light brown (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: January-February
Fruit: August-September (16)

TREE NURSERY
Collection: Fruits change from green to black and fall from the tree. They may then be collected from the ground. In some trees the majority of seeds are plagued with caterpillars. Fruits should be collected from healthy trees. Moreover, seeds should be soaked in a weak chlorine solution to kill the caterpillars (16).
Storage: Seeds cannot be stored more than one month (16).
Pregermination treatments: Seeds should be soaked in water (with chlorine if caterpillars present) for 10 days to facilitate the removal of the skin as well as to act as a pregermination treatment (16).
Germination: Seeds germinate in 3 months (9 months without the pregermination treatment) (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: 8 months (16)
Growth: Moderate rate (16)

NOTES
Edwin Méndez has observed a problem with ants eating the leaves. These may be controlled with an application of ant-control poison (16).

USES
This species has good wood and also provides a food source for birds and agoutis (16). Other potential uses include firewood, watershed protection, shade, windbreaks and ornamental (16).

SPECIES
Latin name: *Ocotea monteverdensis* W. C. Burger
Family: Lauraceae
Common name: Quizarrá aguacate?

Tree nursery experience: This species was sown in 1991 and 1995 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1300-1400 meters (16)
Localization: Monteverde, Cerro Plano, Cañitas, San Bosco (16)
Specific habitat: NA

MORPHOLOGY
Height:
Bark: Dark and very rough (16)
Leaves: Smooth and shiny, approximately 12 centimeters long and 4 centimeters wide. There is an orange pubescence between the leaves on the young branches as well as on the petioles and veins on the underside of the lamina. Quizarrá aguacate is the only species in the Lauraceae family (in this region) that has this pubescence (16).
Flowers: NA
Fruit: NA
Seeds: NA
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: December and January
Fruit: May and June (16)

TREE NURSERY
Collection: NA
Storage: NA
Pregermination treatments: 8 days in a solution of water and chlorine (16)
Germination: Seeds begin to germinate in 36 days (16).
Percentage: NA
Germination to transplant: 5 days (16)
Transplant to field: 3 months (16)
Growth: Moderate rate (16)

NOTES
This tree loses its leaves and grows new ones in summer like quizarrá negro (16).

USES
Like other quizarrá species, quizarrá aguacate has the following uses: food source for wildlife, firewood, posts, watershed protection, shade, windbreaks, ornamental and soft wood for general usage (6).

SPECIES
Latin name: *Ocotea tonduzii* Standl.
Family: Lauraceae
Common name: Ira marañon

Tree nursery experience: This species was sown from 1990 to 1993 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1450-1550 meters (10)
Localization: This species is found along the entire Tilarán mountain range (for example, in Monteverde, Río Negro, San Bosco, Las Nubes) (16).
Specific habitat: Mature forests and pastures, in good soils (10,18)

MORPHOLOGY
Height: Medium-tall (15-30 meters) (10)
Bark: Dark, peeling regularly, very rough (16)
Leaves: Leaves to 8X18 centimeters, leathery and thick, in the shape of a spatula with a round tip and very short petiole (10).
Flowers: Small and yellow, in dense inflorescences (10)
Fruit: A black drupe with a red cap, 1.5 centimeters long (10)
Seeds: Brown and fissured (16)
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: February-May (varying from year to year)
Fruit: October-August, every second year (the majority between March and May) (10,16)

TREE NURSERY
Collection: Fruits should be collected from the tree after changing in color from green to black (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: 20 days in water (16)
Germination: Seeds begin to germinate in four months with the treatment in water. Without the treatment seeds germinate in approximately nine months (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: 8 days (16)
Growth: Slow (16)

NOTES (NA)

USES
Quetzals eat the fruits of this species. The wood is used for general construction (but is inferior to that of other ira species) (10).

SPECIES
Latin name: *Ocotea valeriana* (Standl.) W. C. Burger
Family: Lauraceae
Common name: Quizarrá quetzal

Tree nursery experience: Quizarrá quetzal was sown in 1992 and 1995 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: In the Monteverde region, this species is found in the highest and coldest parts (approximately 1500 meters), where it is very windy (16).
Localization: San Bosco, Las Nubes (16)
Specific habitat: Secondary forests (16)

MORPHOLOGY
Height: Small (8 meters) (16)
Bark: Light colored and smooth (16)
Leaves: Leaves are very similar to those of ira marañon, only smoother and with a small point at the tip of the lamina (16).
Flowers: Small and pink, similar to those of quizarrá quina (16).
Fruit: Oblong drupes, similar to fruits of chancho blanco but larger (approximately 6-7 centimeters long). There is a dark flesh surrounding the seed and a red cap (16).
Seeds: Seeds are slightly smaller than the fruit, oblong and brown (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: December
Fruit: March-April (16)

TREE NURSERY
Collection: Upon ripening, fruits turn from green to black. They may be collected from the tree (the fruits) or the ground (fruits and seeds) (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: Before seeding, seeds should be placed 22 days in water (16).
Germination: Without the above treatment, seeds will begin to germinate in one year; with the treatment, in six months (16).
Percentage: NA
Germination to transplant: 8 days (16)
Transplant to field: 4 months (16)
Growth: Moderate rate (16)

NOTES
At times this species is attacked by a caterpillar that eats the leaves. They may be controlled with an application of Bolatón (16).

USES
This species is useful for firewood, fenceposts, watershed protection, ornamental purposes, windbreaks, shade, a food source for birds and soft wood for general use (6,16).

SPECIES
Latin name: *Ocotea veraguensis* (Meissn.) Mez, Jahrb.; *Nectandra salicina* C. K. Allen
Family: Lauraceae
Common name: Canelo

Tree nursery experience: Canelo was sown in the Cerro Plano tree nursery in 1993 (16).

HABITAT
Elevation: 800-1000 meters (16)
Localization: Guacimal, Fernández (16)
Specific habitat: Pastures, river and stream sources (16)

MORPHOLOGY
Height: Small-medium (8-10 meters) (16)
Bark: Dark with white patches, smooth (16)
Leaves: NA
Flowers: NA
Fruit: Drupes, 1-2 centimeters in diameter, black with red caps at maturity (16).
Seeds: Slightly oblong, brown, 1-1.5 centimeters in diameter (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: November
Fruit: April-May (16)

TREE NURSERY
Collection: Seeds may be collected from the tree when they turn black (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: 12 days in water (16)
Germination: Seeds begin to germinate in 70 days (16).
Percentage: NA
Germination to transplant: 8 days (16)
Transplant to field: 8 months (16)
Growth: Small (16)

NOTES (NA)

USES
This species protects watersheds and provides a food source for birds (16).

SPECIES
Latin name: *Ocotea whitei* Woodson
Family: Lauraceae
Common name: Ira rosa

Tree nursery experience: This tree was sown in the Cerro Plano tree nursery from 1990 to 1995 (16).

HABITAT
Elevation: 1300-1500 meters (10)
Localization: Monteverde, Santa Elena, Cañitas, Los Tornos (16)
Specific habitat: NA

MORPHOLOGY
Height: Tall (10)
Bark: Bark is brown and peels finely (10).
Leaves: Approximately 2.5 centimeters wide and 9 centimeters long, with a long twisted apical end (10).
Flowers: Small and yellowish orange (10).
Fruit: Oblong drupes, 3-4 centimeters long, black with a red cap at maturity (10).
Seeds: Also oblong, brown and slightly smaller than the fruit (10).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: June-July
Fruit: May (flowers and fruits once every three years) (16)

TREE NURSERY
Collection: After the fruits have changed from green to black they may be collected from the tree or the ground below where they have fallen. It is also possible to find seeds cleaned by birds in the soil (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: 8 days soaking in water (16)
Germination: Seeds begin to germinate in 36 days (16).
Percentage: NA
Germination to transplant: 5 days (16)
Transplant to field: 4 months (16)
Growth: Rapid (16)

NOTES (NA)

USES
Fruits are consumed by quetzals. The dark red wood is good for making furniture (10).

SPECIES
Latin name: *Persea americana* Mill.
Family: Lauraceae
Common name: Aguacate/Aguacatillo (Avocado)

Tree nursery experience: Aguacatillo was sown in 1993 and 1994 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1200-1500 meters; down to 1000 meters in the San Luis valley (10)
Localization: Very common in all parts of the region (16)
Specific habitat: Pastures and edge habitats, occasionally in mature forests (10)

MORPHOLOGY
Height: Medium-tall (10-30 meters) (10)
Bark: Dark with white patches, peeling regularly (16)
Leaves: To 9X15 centimeters, dark green and with long slim petioles (approximately 1.5-2 centimeters). Greyish green on the underside (10).
Flowers: Small and yellowish-green, in long inflorescences (10)
Fruit: Round, 3-5 centimeters in diameter, from green to brown and with a thick leathery skin (10). Unlike the fruits of other Lauraceae trees, aguacate fruits do not have a cap (16).
Seeds: The fruits contain one large round seed, reddish to light brown (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: February-May
Fruit: October-January (10)

TREE NURSERY
Collection: Fruits mature in the tree without changing color. At maturity fruits are green and soft. To collect, one may wait until they fall and the seeds are cleaned by animals that eat the pulp (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: None
Germination: Aguacate seeds require 30 days to germinate. Percent germination is so high (100%) that they may be seeded directly in bags (16).
Percentage: 100% (16)
Germination to transplant: 5 days (16)
Transplant to field: 3 months (16)
Growth: Rapid (16)

NOTES
The species *Persea americana* includes wild and cultivated varieties of aguacate (avocado). This information refers to the wild variety, aguacatillo, which is very similar to the cultivated variety but has narrower leaves and in general has more leaves and branches (16).

USES
The wood of this species is hard, good for yokes. Spider monkeys eat the fruits (10).

SPECIES
Latin name: *Pleurothyrium palmanum* (Mez & Donn. Sm.) Rohwer
Family: Lauraceae
Common name: Yema de huevo

Tree nursery experience: Yema de huevo was sown from 1992 to 1995 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1000-1400 meters (16)
Localization: San Luis, Los Llanos, Cañitas, Cebadilla (16)
Specific habitat: Secondary forests (16)

MORPHOLOGY
Height: Medium (8 meters) with a very round crown (16).
Bark: Dark and peeling (16)
Leaves: Narrow and shiny, to approximately 10 centimeters long.
Flowers: Small and pink with an intense aroma like that of a rose (16)
Fruit: Oblong drupes, approximately 2.5 centimeters long, black with red caps (16).
Seeds: Light brown with a yellow, pointed end, approximately 2 centimeters long (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: March
Fruit: August-September (16)

TREE NURSERY
Collection: At maturity, after the fruits have changed from green to black, the fruits or seeds may be collected from the tree or ground (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: 8 days in water (16)
Germination: Seeds begin to germinate in 58 days (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: 6 months (16)
Growth: Slow (16)

NOTES (NA)

USES
The fruits of yema de huevo are an important food source for birds (16).

SPECIES
Latin name: *Hampea appendiculata* (Donn. Sm.) Standl.
Family: Malvaceae
Common name: Burío colorado

Tree nursery experience: Burío colorado was sown in 1992 in the Cerro Plano nursery (16).

HABITAT
Elevation: 900-1600 meters (10,16)
Localization: This species may be found throughout the Cordillera de Tilarán (16).
Specific habitat: Pastures, secondary forests, occasionally in primary forests (in sunny clearings), in all types of soils (10,18).

MORPHOLOGY
Height: Medium tall (8-25 meters) (10)
Bark: Dark, smooth (16)
Leaves: Alternate, 10X15 centimeters. On the underside is a beige-red pubescence and a gland near the center of each of the principle veins (5 in total) (10).
Flowers: Flowers have five yellow petals and many yellow stamens; flowers 1.5 centimeters in diameter (10).
Fruit: Brown capsules that open into three parts, similar to yos capsules. Capsules 2-3 centimeters long (10,16).
Seeds: Fruits contain 3-6 seeds. Each seed is black with a yellow aril (10,16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: May-August
Fruit: February-May (10)

TREE NURSERY
Collection: Like yos capsules, the capsules of this species open upon maturity. When the first capsules in the tree begin to open, the capsules should be harvested from the tree. The capsules will open later when placed in the sun (16).
Storage: Seeds of this species may not be stored (16).
Pregermination treatments: None
Germination: Seeds begin to germinate in 22 days (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: 4 months (16)
Growth: Rapid (16)

NOTES (NA)

USES
The fibres of this species have been used to make cords. Although the wood is soft, the bark is so hard that with time it tends to push nails out. Burío colorado attracts more than 20 bird species as well as the white faced monkey (10).

SPECIES

Latin name: *Cedrela odorata* L.
Family: Meliaceae
Common name: Cedro amargo

Tree nursery experience: Cedro amargo was sown in the San Luis nursery from 1989 to 1995 (with an annual demand of 571 trees) and in the Cerro Plano nursery in 1995 (1,16).

HABITAT

Elevation: 150-700 meters (1)
Localization: Pozo Azul, Sarmientos, Guacimal (1)
Specific habitat: Primary forests, occasionally along the edges of rivers or streams in low elevation zones (1)

MORPHOLOGY

Height: Reaches 25-30 meters, with a large crown and an irregular form (22).
Bark: Grey-brown, very rough (16,22)
Leaves: Compound, parapinnate (even pinnate) with opposite entire leaflets (22).
Flowers: Small, whitish, in panicles (22)
Fruit: Oblong-ellipsoid capsules, 4 centimeters long and containing 28-30 seeds (22)
Seeds: Winged, dispersed by the wind (22)
No. of seeds/kg: 54 000 (1); 42 000-58 000 (22)

GENERAL PHENOLOGY

Flowers: NA
Fruit: San Luis: February to the middle of March (1)

TREE NURSERY

Collection: NA
Storage: According to Milton Brenes, there is an excellent production of seeds each year making it unnecessary to store the seeds (1).
Pregermination treatments: None
Germination: Seeds germinate in 12 days (1).
Percentage: 80-90% (1)
Germination to transplant: 7 days (16)
Transplant to field: San Luis: 3.5 months (1); Cerro Plano: 4 months (16)
Growth: Cerro Plano: Moderate rate (16)

NOTES

In the San Luis nursery, there have been problems with insects ('cochinillas' and 'palomillas exipilas') attacking cedro amargo. The first of these may be controlled with an application of Brisol detergent at 30cc/liter of water. To control the 'palomillas exipilas' (a type of small moth) it is recommended to plant cedro amargo together with other species to diminish the aromatic concentration of the cedar, which attracts the small moths (1). Another method to control them is to put a mesh around the trees (1). The problem with the moths also occured in Cerro Plano, where they were controlled by covering the trees with netting (16).

USES

According to the reforestation department of the Monteverde Conservation League, cedro amargo is useful for apiculture, live fenceposts, dead fenceposts and watershed protection. The wood has good stability for construction work (1).

SPECIES

Latin name: *Cedrela tonduzii* C. DC.
Family: Meliaceae
Common name: Cedro dulce

Tree nursery experience: Cedro dulce was seeded in the Cerro Plano tree nursery from 1991 to 1995 (16).

HABITAT

Elevation: 1300-1500 metres (10)
Localization: Monteverde, Cerro Plano, Santa Elena, La Cruz (16)
Specific habitat: Leftover in pastures, occasionally in mature forests, in general in very wet climates in areas with moderately good soils (10,11,18)

MORPHOLOGY

Height: Very tall (20-40 meters) and with a very dense crown (10,11)
Bark: Light in color and covered in square-shaped fissures (11,16).
Leaves: Leaves are large (0.5-1 meter long), alternate and compound, with 7-10 pairs of leaflets, each one 15-20 centimeters long (10). Trees lose leaves in summer (December-April) (16).
Flowers: Flowers are small, yellowish-green and in large panicles. They have an odor like burnt garlic. Dioecious (10,11).
Fruit: Fruits are hard capsules with 5 valves, from 5-7 centimeters long and brown. After releasing numerous seeds the capsules fall (10,11).
Seeds: Flat and dry with a long wing. They are approximately 1.5 centimeters long (including the wing) and brown in color (10,16).
No. of seeds/kg: NA

GENERAL PHENOLOGY

Flowers: March-May
Fruit: January-February (10)

TREE NURSERY

Collection: When a few capsules begin to open, the remaining closed capsules should be harvested from the tree. These will open when placed in the sun (16).
Storage: Seeds of this species retain their viability one year when stored in paper bags (16).
Pregermination treatments: None
Germination: Seeds begin to germinate in 11 days (16).
Percentage: NA
Germination to transplant: 5 days (16)
Transplant to field: 3 months (16)
Growth: Rapid (16)

NOTES

As with cedro amargo, this species is attacked by a small moth that consumes the growing points of the tree. Trees may be protected by a covering of netting (16). Another methods to control this problem is by vigilant weeding around the seedlings until the trees reach a height of 1.5 meters or more (the insect cannot fly long distances) (18).

USES

Fruits are eaten by squirrels and birds such as brown jays, parrots and macaws (16,18). The wood is soft, smooth, red and resistent to insects (10). Other suggested uses include apiculture, live fenceposts, dead fenceposts and watershed protection (6).

SPECIES
Latin name: *Guarea kunthiana* A. Juss.
Family: Meliaceae
Common name: Cocora

Tree nursery experience: Cocora was sown in 1995 for the first time in the Cerro Plano nursery (16).

HABITAT
Elevation: 1500-1700 meters (to 800 meters on the Atlantic side) (10)
Localization: Found in all parts of the Tilarán mountain range (16)
Specific habitat: Mature cloud forests and marshy areas (10)

MORPHOLOGY
Height: Medium-tall (10-30 meters) (10)
Bark: Dark with white patches, smooth (16)
Leaves: Compound, 0.3-1 meter long and with three pairs of leaflets with dimensions 10X20 centimeters, with rounded tips. The rachis always has a curved bud at the tip (10).
Flowers: Fragrant and white, one centimeter in size, with 4 curved petals and a square-shaped tube in the centre. Dioecious (10).
Fruit: Yellowish-brown capsules with four valves, 7 centimeters long. Leathery (10).
Seeds: Capsules contain 1-4 hard red seeds (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: March-June (10)
Fruit: July (16)

TREE NURSERY
Collection: See cedro dulce. After harvest, the capsules open with or without sun (16).
Storage: Seeds cannot be stored (16).
Pregermination treatments: 15 days soaking in water (16)
Germination: Seeds begin to germinate in 90 days (16).
Percentage: NA
Germination to transplant: NA
Transplant to field: NA
Growth: NA

NOTES (NA)

USES
This species has good quality red wood and is also good for firewood (16). Birds such as the 'pavon azul' (black guan or great currasow?) and the emerald toucanet eat the seeds (10).

SPECIES

Latin name: *Swietenia macrophylla* Jaq.
Family: Meliaceae
Common name: Caoba

Tree nursery experience: This species was seeded in 1995 for the first time in the Cerro Plano tree nursery (16).

HABITAT

Elevation: < 1000 meters (12)
Localization: Pozo Azul, Sarmientos, Guacimal, La Guaria (1)
Specific habitat: Pastures, hillsides of low elevation areas, secondary forests in high light intensity sites, preferably in deep well-drained soils rich in organic material (1,12).

MORPHOLOGY

Height: Medium-tall (to 45 meters) (12)
Bark: Chestnut colored, very rough with flat scales and deep cracks (12,16).
Leaves: Alternate and parapinnate (with 6-12 leaflets) (12).
Flowers: The small yellowish-green to whitish flowers are found in terminal panicles (12).
Fruit: Large dehiscent capsules containing 45-70 seeds (12)
Seeds: Winged, brown and spongy, from 8 to 10 centimeters long and 2 to 2.5 centimeters wide (12).
No. of seeds/kg: 2 200 (1); 2 000-3 000 (12)

GENERAL PHENOLOGY

Flowers: NA
Fruit: San Luis: November-December (1)

TREE NURSERY

Collection: Seeds should be collected when the fruits have not yet opened in the tree (1).
Storage: Seeds may be stored approximately 6-8 months in closed glass containers (1). IRENA reports that the seeds may be stored 2 years at a temperature of 4°C (12).
Pregermination treatments: Milton Brenes suggests one day in cold water (also see NOTES) (1); according to IRENA the seeds do not require a pregermination treatment (12).
Germination: 12-20 days (1); in 15-25 days according to IRENA (without the pregermination treatment) (12).
Percentage: 40-65% (1)
Germination to transplant: NA
Transplant to field: 4-5 months (1)
Growth: Slow (12)

NOTES

From six months on, Milton Brenes of the San Luis tree nursery has noticed a problem with caterpillers in the stem. This insect may be controlled with an application of Diazinón at a rate of 2cc/liter of water. He also recommends fertilizing the trees with 10-30-10 fertilizer after transplanting (1). The following are additional recommendations for the germination of caoba:

1. sow the seeds in beds of sand
2. sow the seeds vertically
3. maintain a low relative humidity
4. sow seeds immediately after preparation (pregermination treatment)
5. sow seeds 2 centimeters apart
6. leave the upper part of the vertical seed uncovered
7. select only good seeds before sowing (1)

USES

The wood of this species is easy to work, resistant to decomposition and insects, dries well and is useful for many things, such as floors, luxury furniture, musical instruments, matches, light constructions and

moldings (12).

SPECIES
Latin name: *Trichilia havanensis* Jacq.
Family: Meliaceae
Common name: Uruca

Tree nursery experience: Uruca was sown in the Cerro Plano tree nursery from 1990 to 1992 (16).

HABITAT
Elevation: Medium (8-20 meters) (10).
Localization: San Luis, Monteverde, La Cruz, Santa Elena, Cañitas, Cebadilla, Cabeceras (16)
Specific habitat: Common in primary forests and pastures, in general found in sites with wet to very wet climates (10,11).

MORPHOLOGY
Height: Medium (8-20 meters) (10)
Bark: Dark with white patches, smooth (16)
Leaves: Imparappinate with 3-4 pairs of leaflets and a terminal leaflet. Often the leaflets have rounded tips. Deciduous (10,18).
Flowers: Small and white, with five petals. In axillary inflorensces (10).
Fruit: Capsules with 3 lobes, slightly smaller than one centimeter and in clusters.
Seeds: The capsules open to display three red seeds, from 0.5 to 0.8 centimeters in length (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: March-May (10)
Fruit: April-May; December-February (10); also in October-November, but more common in December (16)

TREE NURSERY
Collection: Seeds are collected from the tree once the capsules have already opened (16).
Storage: Seeds are very fleshy and soft and cannot be stored (16).
Pregermination treatments: None
Germination: Seeds germinate in 46 days (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: 8 months (16)
Growth: Slow (16)

NOTES (NA)

USES
According to Holdridge and Poveda (1975) the branches of uruca are used to adorn homes, churches and/or streets in religious processions. It is also used as a windbreak species although there is a problem with caterpillars eating the leaves (16). Cattle leave uruca alone (6). The species provides a food source for birds (tityras and emerald toucanets, for example) and squirrels (16,18). Uruca is also used for firewood, shade, live fences and as an ornamental (6).

SPECIES
Latin name: *Brosimum alicastrum* Swartz
Family: Moraceae
Common name: Ojoche

Tree nursery experience: Ojoche was sown in the San Luis nursery from 1993 to 1995 with a demand of 300 trees per year (1).

HABITAT
Elevation: 150-700 meters (1)
Localization: Pozo Azul, Fernández, San Luis (1)
Specific habitat: Slopes of primary forests, river edges, rocky soils (1)

MORPHOLOGY
Height: NA
Bark: NA
Leaves: NA
Flowers: NA
Fruit: NA
Seeds: NA
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: NA
Fruit: San Luis: June (1)

TREE NURSERY
Collection: NA
Storage: Seeds may not be stored (1).
Pregermination treatments: One day in cold water with chorine at 2cc/liter of water (seeds should be cleaned first); seeds may be seeded directly in bags which are placed in the shade for 12-18 days (1).
Germination: Seeds germinate in 12-18 days (1).
Percentage: 63% (1)
Germination to transplant: NA
Transplant to field: 4-5 months (1)
Growth: NA

NOTES
Trees should be fertilized with 10-30-10 the month of transplant (1).

USES
Ojoche has good quality wood and provides a food source for fauna (1).

SPECIES
Latin name: *Ficus pertusa* L. f.
Family: Moraceae
Common name: Higo/Higuito

Tree nursery experience: This species has not been sown in the San Luis tree nursery nor the Cerro Plano tree nursery.

HABITAT
Elevation: 1200-1600 meters (16)
Localization: Las Nubes, San Bosco, La Cruz, Santa Elena, Los Llanos, Monteverde (16)
Specific habitat: Secondary forests, pastures, in all types of soils (16,18)

MORPHOLOGY
Height: Small (6 meters) (16)
Bark: Light colored and smooth, with a white latex (16).
Leaves: Small, simple and glabrous (10)
Flowers: The tiny flowers are found within the figs themselves and are pollinated by wasps (10,16).
Fruit: Round or slightly oblong pink figs which change in color to dark purple or black, 1-1.5 centimeters long (10,16).
Seeds: The fruits contains many tiny seeds (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: NA
Fruit: September-December (16)

TREE NURSERY
Collection: NA
Storage: NA
Pregermination treatments: NA
Germination: NA
Percentage: NA
Germination to transplant: NA
Transplant to field: NA
Growth: Slow (grows faster as a live post) (16)

NOTES (NA)

USES
Higuito is a good live fencepost species (16). As well, like higuerón, it is used for cattle forage, firewood, medicines, ornamental purposes, dead posts, shade, windbreaks and a food source for fauna (6).

SPECIES
Latin name: *Ficus tuerckheimii* Standl.
Family: Moraceae
Common name: Higuerón

Tree nursery experience: Higuerón has never been sown in either tree nursery (16).

HABITAT
Elevation: 1200-1500 meters (10,16)
Localization: Monteverde, Cerro Plano, Santa Elena. La Cruz, Cañitas (16)
Specific habitat: Common in pastures and forests, in many habitat types (10)

MORPHOLOGY
Height: Tall (20-40 meters) (10). Higuerón is one of the tallest species in the region (10,16).
Bark: The trunk has many fissures which appear like thick fused cords; it is also buttressed at the bottom. Large trees have a smooth gray bark whereas the bark of young trees is reddish brown. The bark exudes a white latex when cut (10,16).
Leaves: Leaves are oval, smooth, thick and elastic, measuring 8-12 centimeters in length (10).
Flowers: Like higuito, there are many tiny flowers within the fruit (the syngonium) (10). They are pollinated by wasps (10,16).
Fruit: Red, nearly round berries with a cap of black bracts on top. One and a half centimeters in diameter (10,16).
Seeds: The fruits contain many tiny seeds (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: August-October
Fruit: April-May, September-December (10)

TREE NURSERY
Collection: The berries turn from green to red with a black cap. These drop at maturity and may be collected from the ground (16).
Storage: NA
Pregermination treatments: None
Germination: Seeds begin to germinate in 3 months (16).
Percentage: The seeds of higuerón have a very low percentage germination. According to Edwin Méndez, approximately one seed germinates per fruit.
Germination to transplant: NA
Transplant to field: NA
Growth: NA

NOTES
In general this tree is parasitic, depending on other trees for support. It may also germinate in the soil and grow independently (16,18).

USES
Higuerón may be used for live fenceposts and in windbreaks (6,16). The fruits are eaten by birds (for example, emerald toucanets, parrots and quetzals) and animals (squirrels, coatimundis, sloths, howler monkeys) (16,18). Other uses include cattle forage, firewood, medicines, ornamental and shade provision (6).

SPECIES
Latin name: *Myrsine coriacea* (Sw.)R. Br. ex Roem. & Schult.
Family: Myrsinaceae
Common name: Ratoncillo

Tree nursery experience: Ratoncillo was sown in 1992 in the Cerro Plano tree nursery but was not very popular with farmers due to its tendency to sprout from the base and from the roots (16).

HABITAT
Elevation: 1200-1600 meters (10)
Localization: Santa Elena, Monteverde, Cerro Plano, La Cruz, Río Negro (16)
Specific habitat: Very common in pastures, edge habitats and secondary forests, in all types of soils (10,18).

MORPHOLOGY
Height: Small-medium (5-25 meters) (10)
Bark: Light colored and smooth (16)
Leaves: Spiraled, smooth and in dense groups near the ends of small branches, 2X8 centimeters (10). Leaves of seedlings or sprouts from roots have larger leaves that are not as lustrous as those of older branches (16).
Flowers: Tiny (3 millimeters) and with 4-5 petals, in groups (10)
Fruit: Round black berries, 2-3 millimeters in diameter, containing one seed (10)
Seeds: NA
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: October- December
Fruit: April-July (16)

TREE NURSERY
Collection: Seeds are harvested from the branches. Only those that are black are sown (the green fruits are immature) (16).
Storage: Seeds may be stored 5 months in plastic bags (16).
Pregermination treatments: 5 days soaking in water (16)
Germination: Seeds begin to germinate in 75 days (16).
Percentage: NA
Germination to transplant: 7 days (16)
Transplant to field: 6 months (16)
Growth: Moderate rate (16)

NOTES (NA)

USES
Ten or more bird species eat the seeds of ratoncillo (10). The wood is too soft to be useful (16).

SPECIES
Latin name: *Eugenia acapulcensis* Steud.
Family: Myrtaceae
Common name: Murta negro

Tree nursery experience: This species was sown in the Cerro Plano tree nursery from 1990 to 1994 (16).

HABITAT
Elevation: Found in high elevation areas with lots of wind (16).
Localization: Monte de los Olivos, San Bosco, Las Nubes (16)
Specific habitat: High elevation, windy areas (16)

MORPHOLOGY
Height: Small (5-6 meters) (16)
Bark: Very similar to albajaquillo but non-peeling (the bark of albajaquillo is always peeling). It is smooth and dark with white patches (16).
Leaves: Leaves are opposite and shiny, approximately 7-8 centimeters long and with fine veins. The young leaves are often red (16).
Flowers: Very small and pink (16)
Fruit: Round, 0.5 centimeters in diameter, purplish-black with one seed inside (16).
Seeds: Slightly smaller than the fruits, white (16)
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: July
Fruit: October (16)

TREE NURSERY
Collection: The fruits of this species turn from pink to black at maturity. At this point the berries may be picked from the tree. They should be paced in water to facilitate cleaning the skin from the seeds (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: None
Germination: Seeds germinate in 8 days (16).
Percentage: NA
Germination to transplant: 5 days (16)
Transplant to field: 4 months (16)
Growth: Moderate rate (16)

NOTES (NA)

USES
Murta negro is a good windbreak species and is also a source of firewood and food for birds (16). This tree also has medicinal uses and is attractive as an ornamental (6).

SPECIES
Latin name: *Eugenia guatemalensis* Donn. Sm.
Family: Myrtaceae
Common name: Murta blanco

Tree nursery experience: Murta blanco was sown in 1992, 1993 and 1995 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1000-1500 meters (10,16)
Localization: Los Llanos, Santa Elena, Cerro Plano, Monteverde, La Cruz, Cañitas (16)
Specific habitat: Forests, old pastures and edge habitats. Survives in rocky soils (10,18).

MORPHOLOGY
Height: Medium (8-25 meters) (16)
Bark: Dark, smooth (16)
Leaves: Leaves are compound, glabrous, slightly leathery and to 4X8 centimeters in size. They have an aromatic smell (10).
Flowers: Fragrant and white with many stamens, with the appearance of a small pompom, one centimeter in diameter.
Fruit: Fruits are light green and ovoid with many irregularities, containing 1-2 seeds and 2.5 centimeters in length (10). They have the same frangrance as the leaves. Bat-dispersed (16).
Seeds: Approximately 1.5-2.4 centimeters long, light brown and smooth in texture (10,16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: July-October
Fruit: April-July; October-November (10); not all trees of this species flower at the same time (16)

TREE NURSERY
Collection: Fruits turn from brown and hard to green and soft. These fall and may be collected from the soil (16).
Storage: Seeds may be stored six months in paper bags (16).
Pregermination treatments: 1. 22 days soaking in water; 2. one month in a well closed plastic bag (16).
Germination: 1. Seeds require one year to germinate with the water treatment; 2. Seeds begin to germinate in one month (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: 7 months (16)
Growth: Moderate rate (16)

NOTES (NA)

USES
Murta blanco provides good firewood, hard wood for general usage and fruits for bats, emerald toucanets and squirrels (6,10,16). It may be used in windbreaks or as an ornamental tree (6).

SPECIES
Latin name: *Myrcianthes fragrans* (Sw.) McVaugh or *Myrcianthes* sp.
Family: Myrtaceae
Common name: Albajaquillo

Tree nursery experience: Albajaquillo was sown in the Cerro Plano tree nursery in 1992, 1993 and 1995 (16).

HABITAT
Elevation: 1000-1500 meters (10,16)
Localization: Los Llanos, Monteverde, Santa Elena, Cañitas, La Cruz, Cebadilla (16)
Specific habitat: Pastures, mature forests, crests, in all types of soils (10,18)

MORPHOLOGY
Height: Medium-tall (10-30 metres) (10)
Bark: The bark peels generously and leaves a smooth trunk with a red, brown and grey pattern (10).
Leaves: Opposite, with each pair situated at 90 degrees to the next, 3X5 centimeters (10).
Flowers: Similar to those of murta blanco, white with many stamens, in the shape of a pompom, approximately 7 millimeters in diameter and with an agreeable fragrance (10).
Fruit: Edible berries containing 1-2 seeds, 8 millimeters in diameter (10).
Seeds: Yellowish brown, 0.5 centimeter in diameter.
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: April-July; September-October (10)
Fruit: December-January (10); September-November (16)

TREE NURSERY
Collection: Fruits turn from green to dark purple. The dark purple fruits may then be harvested from the tree (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: None
Germination: Seeds begin to germinate in 38 days (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: 8 months (16)
Growth: Very slow (16)

NOTES
This species is occasionally plagued with a diseased termed 'roya'. Afflicted trees have burnt new leaves. This may be controlled with Baycor (16).

USES
Albajaquillo makes very good firewood. The wood is so strong that often farmers do not cut the trees down but rather leave them in pastures (10). The fruits are eaten by birds and coatimundis and are suitable for human consumption (16).

SPECIES
Latin name: *Syzygium jambos* (L.) Alst. (non-native)
Family: Myrtaceae
Common name: Manzana rosa

Tree nursery experience: Manzana rosa was sown from 1992 to 1995 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1000-1400 meters (16)
Localization: San Luis, Los Llanos, Cañitas, Las Nubes, Cabeceras (16)
Specific habitat: Pastures, windbreaks (16)

MORPHOLOGY
Height: Small (8 meters) (16)
Bark: Light colored and smooth (16)
Leaves: Opposite and lanceolate
Flowers: Yellow with many stamens, approximately 6 centimeters in diameter (16).
Fruit: Yellow 'apples', 8 centimeters in diameter and containing 1-4 seeds (16).
Seeds: 1.5 centimeters in diameter (16)
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: All times of the year
Fruit: All times of the year (majority in July-August) (16)

TREE NURSERY
Collection: At maturity, fruits turn from green to yellow and soft. At this stage the 'apples' may be harvested and the seeds removed and cleaned (16).
Storage: Seeds may not be stored (seeds lose their viability after one month of storage) (16).
Pregermination treatments: None
Germination: Manzana rosa seeds have a very high percent germination (perhaps 100%), so they may be seeded directly into bags. From one seed five trees may grow. Seeds begin to germinate in 38-39 days (16).
Percentage: Very high (near 100%) (16)
Germination to transplant: 7 days (16)
Transplant to field: 5 months (16)
Growth: Moderate rate (16)

NOTES
This species, like albajaquillo, suffers from 'roya' (see albajaquillo).

USES
Manzana rosa is used for windbreaks and firewood. The fruits are very sweet and may be consumed by both humans and animals (16).

SPECIES
Latin name: *Chionanthus panamensis* (Standl.) Stearn; *C. dominguensis*
Family: Oleaceae
Common name: Come negro

Tree nursery experience: This species was sown in the Cerro Plano tree nursery in 1992 and 1993 (16).

HABITAT
Elevation: 1400-1500 meters (16)
Localization: Found throughout the Tilarán mountain range (16)
Specific habitat: Primary and secondary forests, in dry, windy, rocky, steep conditions, grows in all types of soils (16,18).

MORPHOLOGY
Height: Tall (20 meters) (16)
Bark: Dark with white patches, young branches have white lenticels (16).
Leaves: Opposite and glabrous
Flowers: White (18)
Fruit: In the shape of a flattened pear, 2 centimeters long and with an olive-like odor.
Seeds: Slightly pointed at both ends, fissured, beige, 1.5 centimeters long (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: NA
Fruit: September-October (16)

TREE NURSERY
Collection: Fruits turn from green to white as they mature. They fall from the tree and may be collected from the soil (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: 2 days soaking in water (16)
Germination: Seeds begin to germinate in 45 days (16).
Percentage: NA
Germination to transplant: 8 days (16)
Transplant to field: 5 months (16)
Growth: Moderate rate (16)

NOTES
Edwin Méndez has noticed that ants eat the leaves of come negro. This problem may be controlled with an ant poison (16).

USES
Provides firewood and fruit for birds (16). As well, a study by Robertson (1988) indicates that the wood is very strong and may be used for posts and general construction.

SPECIES
Latin name: *Panopsis suaveolens* (Klotzsch & H. Karst.) Pittier
Family: Proteaceae
Common name: Papa

Tree nursery experience: Papa was sown in the Cerro Plano tree nursery from 1989 to 1992 (16).

HABITAT
Elevation: 1200-1600 meters (16)
Localization: Los Llanos, Cerro Plano, Santa Elena, Cañitas, La Cruz, Las Nubes, Monte de los Olivos (16)
Specific habitat: Mature forests, in good soils (10,18).

MORPHOLOGY
Height: Tall (15-40 meters) (10)
Bark: Dark, smooth, with holes in the inner bark (16,18).
Leaves: Leaves are smooth and spiralled with a rounded tip, 4X12 centimeters in size (10).
Flowers: In pairs on spikes, white and tiny with four petals. Fragrant at night, attracting moths (10).
Fruit: In the shape of a lemon, green to brown in color, hard, approximately 5 centimeters long, containing one seed (10).
Seeds: Three centimeters long and fissured, with the appearance of a brain (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: June-August
Fruit: February, April-July, September (10)

TREE NURSERY
Collection: Papa fruits fall at the sasón stage, without opening. These may be collected from the ground. To extract the seed one may cut the fruit along the visible line it has down its length (16).
Storage: NA
Pregermination treatments: None
Germination: A seed extracted from the fruit germinates in approximately 32 days (16).
Percentage: NA
Germination to transplant: 5 days (16)
Transplant to field: 4 months (16)
Growth: Moderate rate (16)

NOTES (NA)

USES
The seeds taste like potatoes. They are edible raw or fried. They are also a food source for squirrels, agoutis and tepescuintles. The wood is used for construction (10,16).

SPECIES
Latin name: *Roupala glaberrima* Pittier
Family: Proteaceae
Common name: Danto

Tree nursery experience: Danto was sown in the Cerro Plano tree nursery from 1992 to 1994 (16).

HABITAT
Elevation: 1200-1600 meters (16)
Localization: Monteverde, Los Llanos, San Bosco, Río Negro, La Cruz, Monte de los Olivos, Las Nubes (16)
Specific habitat: Primary forests, pastures (16)

MORPHOLOGY
Height: Tall (20 meters) (16)
Bark: Dark, very rough and with a smell of rot (16).
Leaves: Mature trees: Dark green, simple, thick, pointed, slightly serrated (18). Young trees: Dark green, compound with approximately 11 subopposite leaflets, irregularly serrated. Leaves are approximately 29 centimeters long and leaflets approximately 9 centimeters long. They have a very unpleasant odor.
Flowers: Very similar to the flowers of papa, although slighly smaller (16).
Fruit: Flat, in the shape of an eye with a pointed tip, approximately 4 centimeters long and containing one seed (occasionally 2) (16).
Seeds: Very flat, in the shape of a heart with a wing surrounding the heart; the seed including the wing is approximately 2.5 centimeters long (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: June
Fruit: January (16)

TREE NURSERY
Collection: At maturity, fruits turn from green to yellow. The yellow fruits may then be collected from the trees (16).
Storage: Dry seeds may be stored (in a dry place) for 5 months (16).
Pregermination treatments: None
Germination: Seeds begin to germinate in 43 days (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: One year (16)
Growth: Very slow (16)

NOTES
There is a problem with ants that eat the leaves. This problem may be controlled with an application of ant poison (16).

USES
This species is used for posts, floors, carts and firewood. The wood is resistant to insects (16,18).

SPECIES
Latin name: *Eriobotrya japonica* (Thunb.) Lindl. (non-native)
Family: Rosaceae
Common name: Níspero dulce

Tree nursery experience: Níspero dulce has been sown in the Cerro Plano nursery from 1989 to 1995 (16).

HABITAT
Elevation: 1300 metres (16)
Localization: Monteverde, Cerro Plano, Santa Elena (16)
Specific habitat: Windbreaks, near homes (16)

MORPHOLOGY
Height: Small (6 meters) (16)
Bark: Dark with white patches, smooth (16).
Leaves: Thick, oval, serrated, dark green in color (18).
Flowers: In branching inflorescences. Each flower is 1.5 centimeters long and has white petals surrounding a brownish center (16).
Fruit: Round with a nipple at one end; 3 centimeters long and containing one to six seeds (16).
Seeds: Oblong, size depending on the number of seeds contained within (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: May-June
Fruit: September-October (16)

TREE NURSERY
Collection: Fruits turn from green to yellow upon maturity. In October, as the fruits begin to ripen, they may be collected from the trees (16).
Storage: Seeds of this species may not be stored (16).
Pregermination treatments: 4 days soaking in water (16)
Germination: With the treatment in water, seeds begin to germinate in 32 days (without the treatment, in 46 day) (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: 3 months (16)
Growth: Moderate rate (16)

NOTES
A problem can arise with caterpillars eating the apex of the seedlings. These may be controlled with an application of Bolatón (16).

USES
Both people and birds enjoy eating the fruits. It is also used for firewood, in windbreaks, for apiculture, for medicines and as an ornamental tree (6,16).

SPECIES
Latin name: *Casimiroa edulis* La Llave & Lex.
Family: Rutaceae
Common name: Matasano

Tree nursery experience: Matasano was sown in 1993 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 900-1500 meters (10)
Localization: Cañitas, Monteverde (16)
Specific habitat: Mature wet forests (10)

MORPHOLOGY
Height: Medium-tall (20-35 meters) (10)
Bark: Brown or grey with cream colored spots, very smooth (11,16)
Leaves: Large with 3-5 rough leaflets with translucent dots (10)
Flowers: Small and white with four petals and stamens, in short panicles (10,11)
Fruit: Round with soft edible flesh, 5-8 centimeters in diameter (10,11)
Seeds: Round, soft, 2 centimeters in diameter (16)
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: February, July-September (10)
Fruit: August, September (10)

TREE NURSERY
Collection: Fruits change from green to yellow. At maturity, the fruits may be collected from the tree, cleaned and sown (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: None
Germination: Seeds begin to germinate in 25 days (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: 6 months (16)
Growth: Moderate rate (16)

NOTES (NA)

USES
The fruit of matasano is edible and reputed to induce sleepiness (10,11).

SPECIES
Latin name: *Citrus aurantifolia* (Christm.) Swingle (non-native)
Family: Rutaceae
Common name: Limón agrio

Tree nursery experience: Limón agrio was sown in the Cerro Plano tree nursery from 1992 to 1994 (16).

HABITAT
Elevation: 700-1500 metres (16)
Localization: In areas where they have been planted (16).
Specific habitat: Pastures, near homes (16)

MORPHOLOGY
Height: Small (4 meters) (16)
Bark: Dark with white patches, smooth (16).
Leaves: Oval to elliptical, approximately 6 centimeters long, smooth, dark green (11).
Flowers: Small, white and yellow, in axillary groups, approximately 1.5 centimeters long (11,16).
Fruit: Globose, approximately 7 centimeters in diameter with a varying number of seeds inside. The green pulp is very acidic (11,16).
Seeds: Less than one centimeter long, white and similar to orange seeds (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: All times of the year
Fruit: All times of the year (16)

TREE NURSERY
Collection: The lemons may be collected once they have turned from green to yellow. The seeds are extracted from the fruit (16).
Storage: Seeds may not be stored (16).
Pregermination treatments: None
Germination: Seeds germinate in 40 days (16).
Percentage: NA
Germination to transplant: 11 days (16)
Transplant to field: 7 months (16)
Growth: Slow (16)

NOTES
If a problem with ants eating the leaves arises, an ant poison may be applied (16).

USES
The fruits are edible and used in juices, tea and on fish. The tree also has useful medicinal properties and is found in windbreaks (6,11,16).

SPECIES
Latin name: *Citrus aurantium* L. (non-native)
Family: Rutaceae
Common name: Naranja agria

Tree nursery experience: This species was sown from 1992 to 1994 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 700-1500 meters (16)
Localization: In all parts where they have been planted (16)
Specific habitat: Along fences, in pastures and windbreaks, near houses (16)

MORPHOLOGY
Height: Small (4 meters) (11,16)
Bark: Dark with white patches, smooth (16)
Leaves: From 7 to 10 centimeters long, serrated, elliptical, with a winged petiole (11).
Flowers: Three centimeters in diameter, white, axillary (11,16).
Fruit: Globose, orange, from 7-8 centimeters in diameter, with an acidic pulp and many seeds (11,16).
Seeds: Less than a centimeter long, white-cream in color (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: All months of the year
Fruit: All months of the year (16)

TREE NURSERY
Collection: The fruits of this species turn from green to orange. At maturity, the fruits may be collected and the seeds extracted (16).
Storage: Seeds may not be stored (possibly in the refrigerator?) (16).
Pregermination treatments: 4 days in water (16)
Germination: Seeds germinate in 16 days (16).
Percentage: NA
Germination to transplant: 11 days (16)
Transplant to field: 7 months (16)
Growth: Slow (16)

NOTES
As is the case with limón agrio, ants also eat the leaves of naranja agria. They can be controlled with an ant poison (16).

USES
Naranja agria is found in windbreaks, is used as a stock on which to graft naranja dulce (sweet oranges) and is also used to make marmelade. It is said that cows eat the fruits and disperse the seeds throughout the pasture (11,16).

SPECIES
Latin name: *Zanthoxylum fagara* (L.) Sarg.; *S. insulare*
Family: Rutaceae
Common name: Limoncillo

Tree nursery experience: Limoncillo has been sown in the Cerro Plano tree nursery from 1992 to 1994 (16).

HABITAT
Elevation: 500-1400 meters (19)
Localization: San Luis, Monteverde, Cerro Plano, Cañitas, Cebadilla, San Rafael (16)
Specific habitat: Primary forests, pastures, windbreaks, live fences (16)

MORPHOLOGY
Height: Small (8 meters) (16)
Bark: White with many thorns (16)
Leaves: Alternate, pinnate with 7-15 leaflets, each small leaflet 1.5-3.5 centimeters long and finely serrated (in young trees), rachis slightly winged. Leaves are smooth and smell of lemon (10,11,18).
Flowers: Axillary inflorescences with tiny white-yellow flowers (8,10,11,16).
Fruit: Round, dry, two-valved capsules, less than 0.5 centimeter in diameter and contatining one seed (10,16).
Seeds: Round, shiny and black (10)
No. of seeds/kg: 46 382 (19)

GENERAL PHENOLOGY
Flowers: August
Fruit: January-February (16)

TREE NURSERY
Collection: The seeds are mature when the fruit turns brown. At this time the fruits may be cut down from the tree and the seeds extracted (16).
Storage: Seeds may be stored for one year in paper bags (16).
Pregermination treatments: 1. Place the seeds in a pot above fire for one to two minutes (19); 2. Submerge the seeds in concentrated (100%) sulfuric acid for two hours (19); 3. Place the seeds in the sun for eight days (16).
Germination: With one of the above pregermination treatments the seeds germinate in approximately two months. Without treatment, seeds germinate in approximately one year (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: One year (16)
Growth: Rapid (16)

NOTES
Thirty days after transplanting, trees should be fertilized with 10-30-10 (16).

USES
This species is often used for both dry and live fenceposts; it is also included in windbreaks (16,18). Birds eat the fruits (18). Other uses include apiculture, cattle forage, firewood, medicines and as an ornamental (6).

SPECIES
Latin name: *Zanthoxylum monophyllum* (Lam.) P. Wilson
Family: Rutaceae
Common name: Lagarto amarillo

Tree nursery experience: This species was sown in 1993 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1200-1300 meters (16)
Localization: San Rafael, Monteverde, Los Llanos (16)
Specific habitat: Along fences

MORPHOLOGY
Height: Small (11)
Bark: Dark and thorny (16)
Leaves: Leaves spiral the branches, are oval or elliptical, 5-15 centimeters long and have many translucent dots (11).
Flowers: Flowers have five petals and sepals and are in short panicles (11).
Fruit: Four millimeters long (11)
Seeds: Black and shiny (11)
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: NA
Fruit: NA

TREE NURSERY
Collection: Seeds may be collected when they have turned from green to yellow (16).
Storage: Seeds may be stored for one year in glass containers (16).
Pregermination treatments: 8 days in water (16)
Germination: Seeds germinate in 45 days (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: 6 months (16)
Growth: Moderate rate (16)

NOTES (NA)

USES
The reforestation department of the Monteverde Conservation League lists the following uses: windbreaks, live fences, dead fenceposts, food source for animals, apiculture, and firewood. Leaves are not eaten by cattle (6).

SPECIES
Latin name: *Exothea paniculata* (Juss.) Radlk.
Family: Sapindaceae
Common name: Dantisco

Tree nursery experience: This species was seeded in the Cerro Plano tree nursery in 1991 and 1992 (16).

HABITAT
Elevation: 1000-1300 meters (16)
Localization: Cañitas, San Luis (16)
Specific habitat: Primary and secondary forests, pastures, dry and windy sites (16,18)

MORPHOLOGY
Height: Medium (12-15 meters) (16)
Bark: Dark with white patches, peeling, very rough (16)
Leaves: Compound with smooth subopposite leaflets approximately 10 centimeters long (16).
Flowers: Small and whitish, in inflorescences (16).
Fruit: Subglobose, 1.5 centimeters long (11)
Seeds: Light brown, one centimeter in diameter (16)
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: August
Fruit: February-March (16)

TREE NURSERY
Collection: Upon maturity, fruits turn from green to wine in color. If possible, seeds may be collected all at once from the ground where they have been cleaned by birds; if not, they may be collected from the tree (16).
Storage: Seeds may not be stored. They lose their viability very quickly, especially after falling and being left in the sun (16).
Pregermination treatments: None
Germination: Seeds germinate in 38 days (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: One year (16)
Growth: Very slow (16)

NOTES
In summer the leaves turn crisp and fall; these sprout again in winter (16).

USES
The wood of this species is very hard and fine. It may be used for construction purposes and for dry posts. The wood does not rot underneath the soil. It also provides firewood and food for fauna such as toucans and squirrels (11,16,18).

SPECIES
Latin name: *Pouteria exfoliata* T. D. Penn.?
Family: Sapotaceae
Common name: Níspero colorado

Tree nursery experience: Níspero colorado was sown in 1994 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 800-1000 meters (16)
Localization: Campos de Oro, Las Juntas (16)
Specific habitat: River edges, pastures, in hot areas (16)

MORPHOLOGY
Height: Very tall (25 meters) (16)
Bark: Light, very rough (16)
Leaves: NA
Flowers: NA
Fruit: The round fruits are 3.5 to 4 centimeters in diameter, brown whether immature or mature and containing 1-6 seeds (16).
Seeds: Semi-round, light brown, two centimeters long (16)
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: September-October
Fruit: January-February (16)

TREE NURSERY
Collection: When the fruits fall from the tree they may be collected from the ground and the seeds cleaned (16).
Storage: Seeds may be stored for one month, but storage for longer time periods has not been attempted (16).
Pregermination treatments: 8 days soaking in water (16)
Germination: With the pregermination treatment, seeds germinate in 40 days (16).
Percentage: NA
Germination to transplant: 12 days (16)
Transplant to field: One year (16)
Growth: Very slow (16)

NOTES (NA)

USES
Posts, corrals, food source for fauna (16).

SPECIES
Latin name: *Sideroxylon stenospermum* (Standl.) T. D. Penn.
Family: Sapotaceae
Common name: Tempisque

Tree nursery experience: This species was sown in the Cerro Plano tree nursery from 1991 to 1993 (16).

HABITAT
Elevation: 1000-1500 meters (10,16)
Localization: San Luis, Monteverde, Cerro Plano, Santa Elena, Cañitas, La Cruz (16)
Specific habitat: Wet mature forests (16)

MORPHOLOGY
Height: Very tall (20-40 meters) (10)
Bark: Light colored, very rough and fissured (16)
Leaves: Dark green, lanceolate, 3X12 centimeters; undersides of young leaves covered in white and orange hairs (10).
Flowers: In dense groups, fragrant, small and white (10)
Fruit: Round drupes, 2 centimeters long, softening at maturity (10,16)
Seeds: Brown-black, round with an oval scar, hard, approximately 1.5-2 centimeters in diameter (10,16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: July-September (10)
Fruit: March-May (10)

TREE NURSERY
Collection: Tempisque fruits turn from green to purple. If possible to find, it is easier to collect the seeds from the ground rather than climbing the trees as they are very tall (16).
Storage: The dry seeds have been stored for six months in paper bags (16).
Pregermination treatments: 1. Three days soaking in water; 2. Fifteen days in closed bags plastic bags placed in a shaded spot (16).
Germination: With one of these pregermination treatments, seeds germinate in two months. Without the treatment they will germinate in approximately seven months (16).
Percentage: NA
Germination to transplant: 15 days (16)
Transplant to field: 7 months (16)
Growth: Moderate rate (16)

NOTES (NA)

USES
The green wood of this species is used for general construction (after drying it is difficult to nail), but rots quickly when wet. The wood is hard and cream-colored (10). It is also used for firewood and is a food source for animals (16).

SPECIES
Latin name: NA
Family: Sapotaceae
Common name: Zapotillo lechoso

Tree nursery experience: Zapotillo lechoso was sown in the Cerro Plano tree nursery in 1993 (16).

HABITAT
Elevation: Approximately 1500 meters (16)
Localization: San Bosco, Cerro Plano (16)
Specific habitat: Primary forests (16)

MORPHOLOGY
Height: Tall (20 meters) (16)
Bark: Dark and fissured, peeling. Exudes a white latex when cut (16).
Leaves: Approximately 7 centimeters long (16).
Flowers: In branching inflorescences (16)
Fruit: Approximately three centimetres long, ovoid, green, containing one seed (16).
Seeds: Two centimeters long, brown with a white scar, like a small sapote seed (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: NA
Fruit: June (16)

TREE NURSERY
Collection: The fruits do not change color as they mature (they stay green) but a sign of maturity is the appearance of many fruits below the tree whose seeds have been eaten by animals. When this is observed the fruits should be harvested from the tree and the seeds cleaned (16).
Storage: NA
Pregermination treatments: 8 days soaking in water (16)
Germination: Seeds germinate in 37 days (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: One year (16)
Growth: Very slow (16)

NOTES (NA)

USES
Parrots eat the seeds of zapotillo lechoso. The wood of this species is also useful for firewood and for general purposes (16).

SPECIES
Latin name: NA
Family: Sapotaceae
Common name: Zapotillo negro

Tree nursery experience: This species was seeded in the Cerro Plano tree nursery from 1993 to 1995 (16).

HABITAT
Elevation: 1300-1500 meters (16)
Localization: Throughout the Tilarán mountain range (16)
Specific habitat: Primary and secondary forests, pastures (16)

MORPHOLOGY
Height: Medium (10-12 meters) (16)
Bark: Dark, very rough and peeling (16)
Leaves: Smooth, entire, alternate, with a petiole approximately one centimeter long. Deciduous (16).
Flowers: Yellow? (16)
Fruit: Round, soft at maturity, 1.5 centimeters long (16)
Seeds: Ovoid, beige with brown spots, one centimeter long (16)
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: January-February
Fruit: June (16)

TREE NURSERY
Collection: As the fruits mature, they soften and change in color from green to yellow (sasón) to red. The seeds are bat-dispersed, so one can look for a pile of seeds under a roosting spot and collect them if they are mature; otherwise, they may be collected from either the tree or the ground below (16).
Storage: These seeds may not be stored (16).
Pregermination treatments: 5 days soaking in water (16)
Germination: Seeds germinate in 27 days (16).
Percentage: NA
Germination to transplant: 11 days (16)
Transplant to field: 6 months (16)
Growth: Moderate rate (16)

NOTES
An ant poison should be used if there is a problem with ants eating the leaves (16).

USES
Bats and birds enjoy the fruits of zapotillo negro. The species is also used for firewood (16).

SPECIES
Latin name: *Acnistus arborescens* (L.) Schltdl.
Family: Solanaceae
Common name: Guitite

Tree nursery experience: Guitite was sown in the Cerro Plano tree nursery in 1994 (16).

HABITAT
Elevation: 200-1600 meters (16)
Localization: Liberia, San Luis and higher elevation areas in the region (16)
Specific habitat: Roadsides, pastures, in all types of soils (10,18)

MORPHOLOGY
Height: Small (2-10 meters) (10)
Bark: Light colored, soft and with many fissures (10).
Leaves: Smooth, large, up to 25 centimeters long (16)
Flowers: White and bell-shaped, one centimeter long, in dense groups attracting many insects such as bees, butterflies, wasps, beetles and flies (10).
Fruit: Small round berries, 7 millimeters in diameter, containing many seeds (11).
Seeds: Tiny and flat (10)
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: May-June (may flower at other times as well)
Fruit: July-September (10)

TREE NURSERY
Collection: Fruits turn from green to orange. These may be picked from the tree. To extract the seeds, fruits should be squeezed in a bucket of water and the seeds fall to the bottom (16).
Storage: NA
Pregermination treatments: None
Germination: Seeds germinate in 20 days (16).
Percentage: NA
Germination to transplant: 20 days (16)
Transplant to field: 3 months (16)
Growth: Rapid (16)

NOTES
Seedlings are very tiny. It is faster to produce guitite using cuttings, although it is said that cuttings must be of a fairly large diameter (16,18).

USES
Guitite is used for the following: food source for fauna (more than 40 bird species eat the fruits) and for humans, live fences, posts to support orchids or the chayote plant, natural insecticides, firewood, medicinal treatments (a tea made of the leaves is good for the liver and to curb vomitting) and windbreaks. This species also distracts harmful insects (6,10,18).

SPECIES
Latin name: *Styrax argenteus* C. Presl.
Family: Styraceae
Common name: Recino

Tree nursery experience: This species was sown in 1992 and 1993 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1300-1600 meters (16)
Localization: Monteverde, Cerro Plano, Santa Elena, Cañitas, La Cruz, San Bosco (16)
Specific habitat: Common in primary and secondary forests and in pastures (16)

MORPHOLOGY
Height: Tall (20 meters) (16)
Bark: Dark, rough and peeling (16)
Leaves: Simple, brownish, silvery-grey on the underside (16).
Flowers: White with six petals, approximately one centimeter in diameter, in racemes (16).
Fruit: Round, yellow at maturity, fleshy, three centimeters in diameter (16).
Seeds: Two centimeters long, both ends pointed, beige in color (16,18).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: January-February
Fruit: June-July (16)

TREE NURSERY
Collection: Fruits turn from green to yellow and soft. When the fruits fall they may be collected from the ground and the seeds extracted (16).
Storage: As the seeds are very fleshy they may not be stored (16).
Pregermination treatments: 8 days soaking in water (16)
Germination: Seeds germinate in 46 days (16).
Percentage: NA
Germination to transplant: 10 days (16)
Transplant to field: 6 months (16)
Growth: Moderate rate (16)

NOTES (NA)

USES
Agoutis, squirrels and birds eat the seeds of this species. The soft wood is used for floors, walls, 2X4's and furniture (16,18).

SPECIES
Latin name: *Symplocos limoncillo* Humb. & Bonpl.
Family: Symplocaceae
Common name: Campana, Symplocos

Tree nursery experience: This species was sown in the Cerro Plano tree nursery in 1992 and 1993 (16).

HABITAT
Elevation: 1200-1500 meters (16)
Localization: Los Llanos, Cerro Plano, Santa Elena, San Bosco (16)
Specific habitat: Primary forests and forest edges, in dry windy sites (10,18)

MORPHOLOGY
Height: Tall (15-25 meters) (10)
Bark: Dark, very smooth (16)
Leaves: Slightly serrated, spiraled at the ends of branches, shiny, dark green, 3.5X8 centimeters (10,16).
Flowers: Fragrant, small, very light pink, in short inflorescences (10).
Fruit: Fruits are drupes with a round scar at one end, up to 1.5 centimeters long and with blue or purple flesh at maturity (10,16).
Seeds: Ovoid, fissured and with a rounded scar at one end, 1-1.5 centimeters long (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: March-May
Fruit: October-February (10)

TREE NURSERY
Collection: Fruits turn from green to purple. As birds often eat the fruits, clean seeds may be found on the ground beneath the tree. Either the seeds or the fruits may be collected from the ground or the tree (16).
Storage: Dry seeds may be stored one year in paper bags (16).
Pregermination treatments: Seeds should be placed in water for 15 days followed by one day in the sun, then sown (16).
Germination: With the above treatment, seeds germinate in nine to ten months. Without treatment, they will take a year or more (16).
Percentage: NA
Germination to transplant: 8 days (16)
Transplant to field: One year (16)
Growth: Slow (16)

NOTES (NA)

USES
From July to September the fruits are an important food source for quetzals in the Monteverde community. The wood of campana is pinkish-beige and is used for construction where it will not get wet and rot (10).

SPECIES
Latin name: *Citharexylum costaricensis* Moldenke; *C. integerrimum*
Family: Verbenaceae
Common name: Dama

Tree nursery experience: Dama was sown from 1992 to 1994 in the Cerro Plano tree nursery (16).

HABITAT
Elevation: 1000-1500 meters (16)
Localization: San Luis, Monteverde, Cerro Plano, Santa Elena, Las Nubes, La Cruz (16)
Specific habitat: Pastures, forest edges, secondary forests, in all types of soils (10,18)

MORPHOLOGY
Height: Medium (6-20 meters) (10)
Bark: Dark and fissured, branches square in cross-section (16)
Leaves: Elliptical, 4X13 centimeters, smooth, opposite (10).
Flowers: Tiny and white, each with 5 lobes, in spikes, fragrant by night (10).
Fruit: Round, one centimeter in diameter, with one to two seeds, turning from orange to black (10,16).
Seeds: Similar to a small, clean grain of rice (16).
No. of seeds/kg: NA

GENERAL PHENOLOGY
Flowers: January-May
Fruit: April-June (10)

TREE NURSERY
Collection: As the fruits mature they turn from orange to black. To collect them, branches full of seeds may be cut from the tree (16). According to Robertson (1988), as the seeds are prepared to be sown, the fruit should not be allowed to dry out as the skin will stick to the seeds and can impede germination (18).
Storage: According to Edwin Méndez, seeds may be stored seven months in paper bags (16). In another study, however, seeds stored for 4 to 5 months in plastic bags did not germinate (18).
Pregermination treatments: None
Germination: Seeds germinate in 32 days (16).
Percentage: NA
Germination to transplant: 7 days (16)
Transplant to field: 5 months (16)
Growth: Moderate rate (16)

NOTES
This species loses its leaves in winter when there is a lot of rain (16).

USES
According to Haber *et al.*, this species is recommended for live fences (10). The fruits attract more than 20 species of birds (including the quetzal). Green wood of this species may be used as firewood. Dama is also found in windbreaks and is used as an ornamental tree (6,10).

Footnotes

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Appendix 7.2. ANOVA table for *Alnus acuminata*, provenance one: percent germination response to temperature, substrate and light

General Linear Models Procedure
Class Level Information

Class	Levels	Values
TEMP	4	24 27 30 32
SUBST	3	paper sand sand:soil
LIGHT	4	0 8 16 24

Number of observations in data set = 192

General Linear Models Procedure

Dependent Variable: YDATA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	47	10083.8698	214.5504	17.50	0.0001
Error	144	1765.2500	12.2587		
Corrected Total	191	11849.1198			

R-Square	C.V.	Root MSE	YDATA Mean
0.851023	23.49661	3.50124	14.9010

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TEMP	3	3672.09896	1224.03299	99.85	0.0001
SUBST	2	1977.26042	988.63021	80.65	0.0001
LIGHT	3	2596.09896	865.36632	70.59	0.0001
TEMP*SUBST	6	114.82292	19.13715	1.56	0.1627
TEMP*LIGHT	9	846.83854	94.09317	7.68	0.0001
SUBST*LIGHT	6	65.82292	10.97049	0.89	0.5005
TEMP*SUBST*LIGHT	18	810.92708	45.05150	3.68	0.0001

Appendix 7.3. ANOVA table for *Alnus acuminata*, provenance two: percent germination response to temperature, substrate and light

General Linear Models Procedure
Class Level Information

Class	Levels	Values
TEMP	4	24 27 30 32
SUBST	3	paper sand sand:soil
LIGHT	4	0 8 16 24

Number of observations in data set = 192

General Linear Models Procedure

Dependent Variable: YDATA

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	47	44273.4167	941.9876	50.87	0.0001
Error	144	2666.5000	18.5174		
Corrected Total	191	46939.9167			

R-Square	C.V.	Root MSE	YDATA Mean
0.943193	15.56538	4.30318	27.6458

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TEMP	3	18784.5000	6261.5000	338.14	0.0001
SUBST	2	4650.9479	2325.4740	125.58	0.0001
LIGHT	3	18233.4583	6077.8194	328.22	0.0001
TEMP*SUBST	6	208.9688	34.8281	1.88	0.0879
TEMP*LIGHT	9	837.2917	93.0324	5.02	0.0001
SUBST*LIGHT	6	109.2604	18.2101	0.98	0.4388
TEMP*SUBST*LIGHT	18	1448.9896	80.4994	4.35	0.0001

Appendix 7.4. ANOVA table for *Alnus acuminata*, provenance one: response of germination value to temperature, substrate and light (data transformed to root of gv/100). Untransformed data are presented in Tables 4-4 through 4-6.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
TEMP	4	24 27 30 32
SUBST	3	paper sand sand:soil
LIGHT	4	0 8 16 24

Number of observations in data set = 192

General Linear Models Procedure

Dependent Variable: SQROOTY

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	47	0.96237772	0.02047612	22.81	0.0001
Error	144	0.12926373	0.00089766		
Corrected Total	191	1.09164145			

R-Square	C.V.	Root MSE	SQROOTY Mean
0.881588	23.97687	0.02996	0.12496

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TEMP	3	0.30327155	0.10109052	112.61	0.0001
SUBST	2	0.15234414	0.07617207	84.86	0.0001
LIGHT	3	0.25918529	0.08639510	96.24	0.0001
TEMP*SUBST	6	0.01073425	0.00178904	1.99	0.0704
TEMP*LIGHT	9	0.17322805	0.01924756	21.44	0.0001
SUBST*LIGHT	6	0.00603392	0.00100565	1.12	0.3534
TEMP*SUBST*LIGHT	18	0.05758051	0.00319892	3.56	0.0001

Appendix 7.5. ANOVA table for *Alnus acuminata*, provenance two: response of germination value to temperature, substrate and light (data transformed to root of gv/100). Untransformed data are presented in Tables 4-4 through 4-6.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
TEMP	4	24 27 30 32
SUBST	3	paper sand sand:soil
LIGHT	4	0 8 16 24

Number of observations in data set = 192

General Linear Models Procedure

Dependent Variable: SQROOTY

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	47	3.4689676	0.0738078	60.05	0.0001
Error	144	0.1769997	0.0012292		
Corrected Total	191	3.6459674			

R-Square	C.V.	Root MSE	SQROOTY Mean
0.951453	15.54056	0.0351	0.2256

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TEMP	3	1.3249532	0.4416511	359.31	0.0001
SUBST	2	0.3753868	0.1876934	152.70	0.0001
LIGHT	3	1.3981257	0.4660419	379.15	0.0001
TEMP*SUBST	6	0.0223404	0.0037234	3.03	0.0081
TEMP*LIGHT	9	0.1903711	0.0211523	17.21	0.0001
SUBST*LIGHT	6	0.0183135	0.0030522	2.48	0.0257
TEMP*SUBST*LIGHT	18	0.1394770	0.0077487	6.30	0.0001

Appendix 7.6. Summary of ANOVAs for percent germination and germination values of *Alnus acuminata*, provenances one and two, sown with various temperatures, substrates and photoperiods

Source of variation	Provenance 1		Provenance 2	
	%	gv	%	gv
T[a]	0.01[b]	0.01	0.01	0.01
T_L	0.01	0.01	0.01	0.01
T_Q	0.01	0.01	0.01	0.01
L	0.01	0.01	0.01	0.01
L_L	0.01	0.01	0.01	0.01
L_Q	ns	ns	0.01	0.01
S	0.01	0.01	0.01	0.01
T x S	ns	ns	ns	0.01
T x L	0.01	0.01	0.01	0.01
S x L	ns	ns	ns	0.05
T x S x L	0.01	0.01	0.01	0.01
T_L x S_P x L_O	0.01	0.01	0.01	0.01
T_Q x S_P x L_O	ns	ns	ns	ns
T_L x S_S x L_O	0.01	0.01	0.01	0.01
T_Q x S_S x L_O	0.01	0.01	0.01	0.01
T_L x $S_{S:S}$ x L_O	0.01	0.01	0.01	0.01
T_Q x $S_{S:S}$ x L_O	ns	ns	ns	ns
T_L x S_P x L_8	0.01	0.01	0.01	0.01
T_Q x S_P x L_8	0.01	0.01	0.01	0.01
T_L x S_S x L_8	0.01	0.01	0.01	0.01
T_Q x S_S x L_8	0.05	0.01	0.01	0.01
T_L x $S_{S:S}$ x L_8	0.01	0.01	0.01	0.01
T_Q x $S_{S:S}$ x L_8	0.01	0.01	0.01	0.01
T_L x S_P x L_{16}	0.01	0.01	0.01	0.01
T_Q x S_P x L_{16}	0.05	ns	0.01	0.01
T_L x S_S x L_{16}	0.01	0.01	0.01	0.01
T_Q x S_S x L_{16}	ns	ns	0.05	ns
T_L x $S_{S:S}$ x L_{16}	0.01	0.01	0.01	0.01
T_Q x $S_{S:S}$ x L_{16}	ns	ns	ns	ns
T_L x S_P x L_{24}	ns	ns	0.01	ns
T_Q x S_P x L_{24}	ns	ns	0.05	0.01
T_L x S_S x L_{24}	0.01	0.05	0.01	0.01
T_Q x S_S x L_{24}	ns	ns	0.05	0.01
T_L x $S_{S:S}$ x L_{24}	0.05	ns	0.01	0.01
T_Q x $S_{S:S}$ x L_{24}	0.01	0.01	0.01	0.01

[a] T, temperature, L, light, S, substrate, T_L, linear temperature trend, T_Q, quadratic temperature trend, S_P, paper substrate, S_S, sand substrate, $S_{S:S}$, sand:soil substrate, L_O, 0 hour photoperiod, L_8, 8 hour photoperiod, L_{16}, 16 hour photoperiod, L_{24}, 24 hour photoperiod. [b] Significance levels for indicated sources of variation (ns, not significant).

Appendix 7.7. Best-fit functions for germination value[a] trends for two provenances of *Alnus acuminata* after twelve days sown in various substrates under four photoperiods. Data are presented in Tables 4-4 through 4-6.

Provenance	Substrate	Light (hours/day)	Function[b]	R^{2c}
One	Paper	0	$y = -0.195x + 6.450$	0.953**
		8	$y = -0.172x^2 + 9.290x + -120.914$	0.823**
		16	$y = -0.462x + 16.085$	0.937**
		24	ns	ns
	Sand	0	$y = -0.052x^2 + 2.743x + -34.607$	0.950**
		8	$y = -0.171x^2 + 9.228x + -120.073$	0.886**
		16	$y = -0.501x + 17.327$	0.975**
		24	$y = -0.302x + 12.630$	0.265*
	Sand:soil	0	$y = -0.046x + 1.446$	0.922**
		8	$y = -0.287x^2 + 15.838x + -213.667$	0.596**
		16	$y = -0.210x + 7.059$	0.703**
		24	$y = -0.176x^2 + 9.891x + -135.540$	0.468**
Two	Paper	0	$y = -0.907x + 28.111$	0.872**
		8	$y = -0.438x^2 + 22.835x + -282.891$	0.858**
		16	$y = -0.537x^2 + 28.298x + -353.980$	0.900**
		24	$y = -0.496x^2 + 27.498x + -365.573$	0.939**
	Sand	0	$y = -0.072x^2 + 3.779x + -46.966$	0.894**
		8	$y = -0.638x^2 + 34.429x + -448.579$	0.884**
		16	$y = -2.409x + 80.209$	0.998**
		24	$y = -0.296x^2 + 15.014x + -173.122$	0.925**
	Sand:soil	0	$y = -0.085x + 2.643$	0.949**
		8	$y = -0.273x^2 + 14.619x + -188.464$	0.797**
		16	$y = -1.144x + 37.991$	0.948**
		24	$y = -0.308x^2 + 16.417x + -208.985$	0.976**

[a]Germination value (gv), as defined by Djavanshir and Pourbeik (1976), is a measure of both the speed and totality of germination. [b]For indicated functions, y = germination value; x = temperature (°C). [c]For indicated R^2 values, ** = significant at $P<0.01$; * = significant at $P<0.05$. R^2 calculated based on temperature*substrate*photoperiod means.

Appendix 7.8. ANOVA table for *Pithecellobium saman*: percent germination response to temperature, substrate and light. Data are presented in Tables 4-10 and 4-11.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
TEMP	4	24 27 30 32
SUBST	2	sand sand:soil
LIGHT	4	0 8 16 24

Number of observations in data set = 128

General Linear Models Procedure

Dependent Variable: YDATA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	31	1972.3671875	63.6247480	7.55	0.0001
Error	96	808.7500000	8.4244792		
Corrected Total	127	2781.1171875			

R-Square	C.V.	Root MSE	YDATA Mean
0.709200	3.131221	2.9024953	92.695313

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TEMP	3	19.77343750	6.59114583	0.78	0.5066
SUBST	1	438.82031250	438.82031250	52.09	0.0001
LIGHT	3	19.21093750	6.40364583	0.76	0.5192
TEMP*SUBST	3	123.83593750	41.27864583	4.90	0.0033
TEMP*LIGHT	9	709.50781250	78.83420139	9.36	0.0001
SUBST*LIGHT	3	143.52343750	47.84114583	5.68	0.0013
TEMP*SUBST*LIGHT	9	517.69531250	57.52170139	6.83	0.0001

Appendix 7.9. ANOVA table for *Pithecellobium saman*: response of peak value to temperature, substrate and light (data transformed to root of pv/100)

General Linear Models Procedure
Class Level Information

Class	Levels	Values
TEMP	4	24 27 30 32
SUBST	2	sand sand:soil
LIGHT	4	0 8 16 24

Number of observations in data set = 128

General Linear Models Procedure

Dependent Variable: SQROOTY

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	31	0.24162659	0.00779441	47.11	0.0001
Error	96	0.01588172	0.00016543		
Corrected Total	127	0.25750830			

R-Square	C.V.	Root MSE	SQROOTY Mean
0.938325	2.944239	0.0128621	0.4368577

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TEMP	3	0.11214430	0.03738143	225.96	0.0001
SUBST	1	0.01309452	0.01309452	79.15	0.0001
LIGHT	3	0.00248371	0.00082790	5.00	0.0029
TEMP*SUBST	3	0.00143925	0.00047975	2.90	0.0389
TEMP*LIGHT	9	0.09548245	0.01060916	64.13	0.0001
SUBST*LIGHT	3	0.00925153	0.00308384	18.64	0.0001
TEMP*SUBST*LIGHT	9	0.00773084	0.00085898	5.19	0.0001

Appendix 7.10. Summary of ANOVAs for percent germination and germination values of *Pithecellobium saman*, sown with various temperatures, substrates and photoperiods

Source of variation	%	pv
T[a]	ns[b]	0.01
T_L	ns	0.01
T_Q	ns	ns
L	0.01	0.01
L_L	ns	ns
L_Q	ns	ns
S	ns	0.01
T x S	0.01	0.05
T x L	0.01	0.01
S x L	0.01	0.01
T x S x L	0.01	0.01
T_L x S_S x L_O	0.01	0.01
T_Q x S_S x L_O	ns	0.01
T_L x $S_{S:S}$ x L_O	ns	0.01
T_Q x $S_{S:S}$ x L_O	ns	0.01
T_L x S_S x L_8	ns	0.01
T_Q x S_S x L_8	ns	0.01
T_L x $S_{S:S}$ x L_8	0.01	0.01
T_Q x $S_{S:S}$ x L_8	0.01	0.01
T_L x S_S x L_{16}	ns	0.01
T_Q x S_S x L_{16}	0.01	0.01
T_L x $S_{S:S}$ x L_{16}	0.01	ns
T_Q x $S_{S:S}$ x L_{16}	ns	ns
T_L x S_S x L_{24}	ns	0.01
T_Q x S_S x L_{24}	ns	0.01
T_L x $S_{S:S}$ x L_{24}	ns	0.01
T_Q x $S_{S:S}$ x L_{24}	0.01	0.01

[a] T, temperature, L, light, S, substrate, T_L, linear temperature trend, T_Q, quadratic temperature trend, S_S, sand substrate, $S_{S:S}$, sand:soil substrate, L_O, 0 hour photoperiod, L_8, 8 hour photoperiod, L_{16}, 16 hour photoperiod, L_{24}, 24 hour photoperiod. [b] Significance levels for indicated sources of variation (ns, not significant).

Appendix 7.11. ANOVA table for *Alnus acuminata*, provenance one: response to pH level

General Linear Models Procedure
Class Level Information

Class	Levels	Values
PH	3	four seve ten

Number of observations in data set = 12

General Linear Models Procedure

Dependent Variable: YDATA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	51.50000000	25.75000000	2.65	0.1246
Error	9	87.50000000	9.72222222		
Corrected Total	11	139.00000000			

R-Square	C.V.	Root MSE	YDATA Mean
0.370504	15.98999	3.118048	19.5000000

General Linear Models Procedure

Source	DF	Type III SS	Mean Square	F Value	Pr > F
PH	2	51.50000000	25.75000000	2.65	0.1246

Appendix 7.12. ANOVA table for *Alnus acuminata*, provenance two: response to pH level

General Linear Models Procedure
Class Level Information

Class	Levels	Values
PH	3	four seve ten

Number of observations in data set = 12

General Linear Models Procedure

Dependent Variable: YDATA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	465.5000000	232.7500000	24.79	0.0002
Error	9	84.5000000	9.3888889		
Corrected Total	11	550.0000000			

R-Square	C.V.	Root MSE	YDATA Mean
0.846364	9.575404	3.064129	32.0000000

Dependent Variable: YDATA

Source	DF	Type III SS	Mean Square	F Value	Pr > F
PH	2	465.5000000	232.7500000	24.79	0.0002

Appendix 7.13. ANOVA table for *Pithecellobium saman*: response to pH level

General Linear Models Procedure
Class Level Information

Class	Levels	Values
PH	3	four seve ten

Number of observations in data set = 12

Dependent Variable: YDATA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	6.16666667	3.08333333	0.62	0.5594
Error	9	44.75000000	4.97222222		
Corrected Total	11	50.91666667			

R-Square	C.V.	Root MSE	YDATA Mean
0.121113	2.357549	2.229848	94.5833333

Dependent Variable: YDATA

Source	DF	Type III SS	Mean Square	F Value	Pr > F
PH	2	6.16666667	3.08333333	0.62	0.5594

Appendix 7.14. ANOVA table for *Pithecellobium saman*: imbibition data for seed size/scarification experiment. Data are presented graphically in Figure 4-11.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
TIME	5	0 1 3 1.67 2.33
SIZE	3	large med small

Number of observations in data set = 60

General Linear Models Procedure

Dependent Variable: YDATA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	59874.50000	4276.75000	152.68	0.0001
Error	45	1260.50000	28.01111		
Corrected Total	59	61135.00000			

R-Square	C.V.	Root MSE	YDATA Mean
0.979382	9.204439	5.292552	57.5000000

Dependent Variable: YDATA

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TIME	4	42055.83333	10513.95833	375.35	0.0001
SIZE	2	14483.70000	7241.85000	258.53	0.0001
TIME*SIZE	8	3334.96667	416.87083	14.88	0.0001

Appendix 7.15. ANOVA table for *Pithecellobium saman*: germination data for seed size/scarification experiment. Data are presented graphically in Figure 4-12.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
SIZE	3	large medium small
METHOD	7	1m 1m40s 2m20s 3m acid cut water

Number of observations in data set = 84

General Linear Models Procedure

Dependent Variable: YDATA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	20	55327.57143	2766.37857	74.96	0.0001
Error	63	2325.00000	36.90476		
Corrected Total	83	57652.57143			

R-Square	C.V.	Root MSE	YDATA Mean
0.959672	10.05307	6.074929	60.4285714

General Linear Models Procedure

Dependent Variable: YDATA

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SIZE	2	766.57143	383.28571	10.39	0.0001
METHOD	6	53687.23810	8947.87302	242.46	0.0001
SIZE*METHOD	12	873.76190	72.81349	1.97	0.0419

Appendix 7.16. ANOVA table for *Pithecellobium saman*: early growth experiment. See Figure 4-13.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
TIME	5	1 2 3 4 5
SIZE	3	1 2 3
BLOCK	4	1 2 3 4
PLANT	25	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Number of observations in data set = 1500

General Linear Models Procedure

Dependent Variable: YDATA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	59	7638.2533333	129.4619209	79.33	0.0001
Error	1440	2349.9800000	1.6319306		
Corrected Total	1499	9988.2333333			

R-Square	C.V.	Root MSE	YDATA Mean
0.764725	11.59931	1.2774704	11.013333

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TIME	4	4069.2916667	1017.3229167	623.39	0.0001
BLOCK	3	22.5840000	7.5280000	4.61	0.0032
TIME*BLOCK	12	59.8510000	4.9875833	3.06	0.0003
SIZE	2	3297.4013333	1648.7006667	1010.28	0.0001
TIME*SIZE	8	17.5403333	2.1925417	1.34	0.2174
SIZE*BLOCK	6	132.4160000	22.0693333	13.52	0.0001
TIME*SIZE*BLOCK	24	39.1690000	1.6320417	1.00	0.4624

General Linear Models Procedure
Tests of Hypotheses for Mixed Model Analysis of Variance

Dependent Variable: YDATA

Source: TIME *
Error: MS(TIME*BLOCK)

DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
4	1017.3229167	12	4.9875833333	203.9711	0.0001

* - This test assumes one or more other fixed effects are zero.

Source: BLOCK
Error: MS(TIME*BLOCK) + MS(SIZE*BLOCK) - MS(TIME*SIZE*BLOCK)

DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
3	7.528	7.75	25.424875	0.2961	0.8274

Source: TIME*BLOCK
Error: MS(TIME*SIZE*BLOCK)

DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
12	4.9875833333	24	1.6320416667	3.0560	0.0096

Source: SIZE *
Error: MS(SIZE*BLOCK)

DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
2	1648.7006667	6	22.069333333	74.7055	0.0001

* - This test assumes one or more other fixed effects are zero.

Source: TIME*SIZE
Error: MS(TIME*SIZE*BLOCK)

DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
8	2.1925416667	24	1.6320416667	1.3434	0.2705

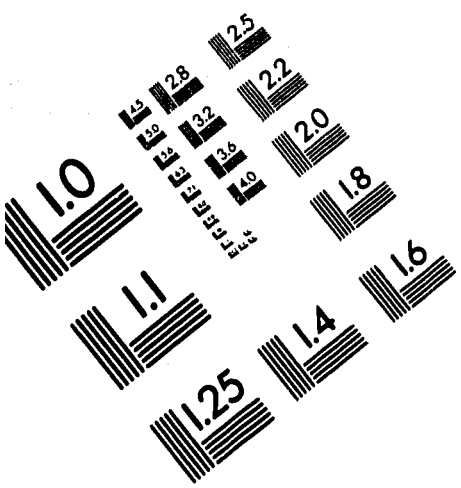
Source: SIZE*BLOCK
Error: MS(TIME*SIZE*BLOCK)

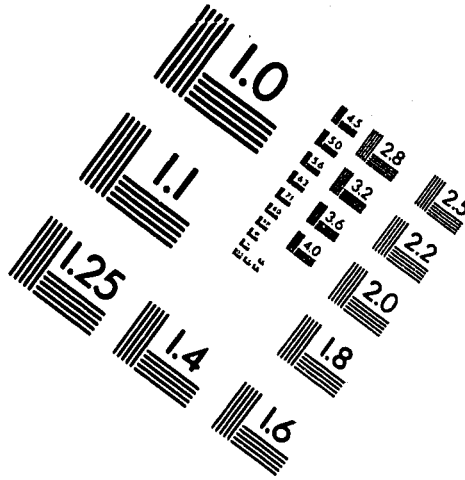
DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
6	22.069333333	24	1.6320416667	13.5225	0.0001

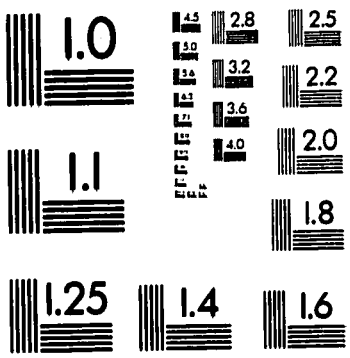
Source: TIME*SIZE*BLOCK
Error: MS(Error)

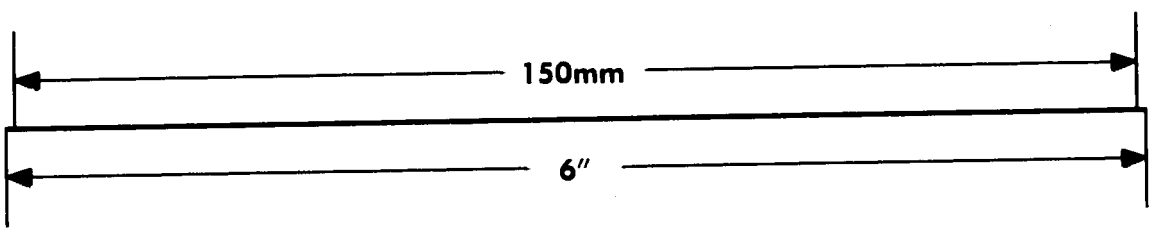
DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
24	1.6320416667	1440	1.6319305556	1.0001	0.4624

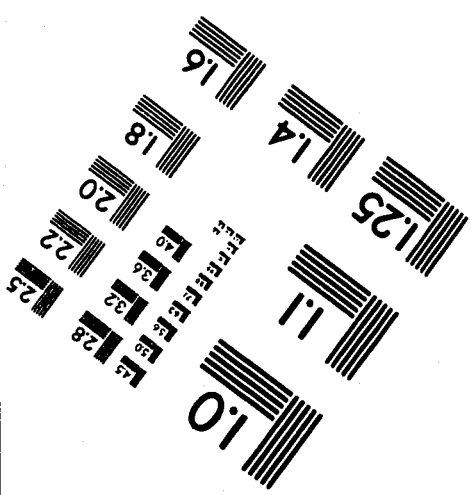
IMAGE EVALUATION
TEST TARGET (QA-3)

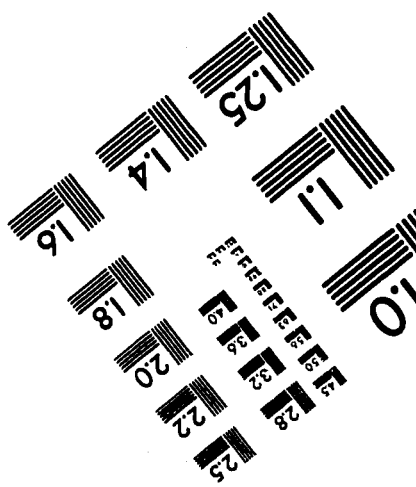












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