LIQUIDAMBAR STYRACIFLUA L. — A SPECIES OF POTENTIAL FOR THE TROPICS

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SUMMARY

The CFI has collected seed of 13 provenances of *Liquidambar styraciflua L.* in Mexico and Central America. Background information is given on the taxonomy, ecology, silviculture and utilisation of the species. Its potential and limitations for tropical plantation are outlined. Site details are presented for all provenances and seed availability for the establishment of an International Provenance Trial is discussed.

RÉSUMÉ

Le CFI a récolté des graines de 13 provenances de *Liquidambar styraciflua L.* au Mexique et en Amerique Centrale. Des renseignements de base sont donnés concernant la taxonomie, l'écologie, la silviculture et l'utilisation de l'essence. Son potentiel et ses limitations comme essence de plantation tropicale sone mentionnés. Pour chaque provenance les charactéristiques du site sont décrites et la disponibilité de graines pour la creation d'Essais Internationals de Provenances est discutée.

RESUMEN

El CFI ha colectado semillas de 13 procedencias de *Liquidambar styraciflua L.* de la parte tropical del rango natural en Mexico y Centroamérica. Se discuten los conocimientos sobre la taxonomía, ecología, silvicultura y aprovechamiento de la especie. Su potencial y limitaciones para plantación en los trópicos se delinean. Se presentan detalles de todos los sitios de recolección y se discute la disponibilidad de semillas para el establecimiento de un Ensayo Internacional de Procedencias.

Introduction

Liquidambar styraciflua L. is a species not unknown to temperate foresters. It was introduced to Western European gardens and arboreta in the seventeenth century (Hillier, 1972) and has since been widely planted as an ornamental. Foresters and timber merchants in the Southern U.S.A. will be familiar with the silviculture and utilisation of the tree. In terms of where and how it grows, its uses and the quantities utilised, it is perhaps the most important hardwood species in the U.S.A. (Johnson and McElwee, 1967; Randel and Winstead, 1976). Liquidambar constitutes some 30% of the hardwood growing stock in the Southern U.S. (USDA, 1974). The species, commonly known as sweetgum or simply Liquidambar extends from Connecticut (41°N) southwards through to central Florida and eastern Texas and as far west as Missouri, Arkansas and Oklahoma.

There is a gap of some 800 km from the most southerly of the U.S. populations to the most northerly recorded site in Mexico, in the state of Tamaulipas. From here the species occurs in fairly small disjunct populations along the Eastern Sierra Madre, through the states of San Luis Potosi, Hidalgo, Veracruz, Oaxaca and into Chiapas. It continues

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through Guatemala and Honduras reaching its southerly limit in central Nicaragua at a latitude of 13°N.

Despite its importance as a commercial timber species in the U.S.A., and the fact that its natural range has been known for hundreds of years, to extend well south into the tropics, the potential of *L. styraciflua* as an exotic plantation species for the tropics has been largely overlooked.

To explore this potential, and in response to an FAO initiative (FAO, 1977) we have undertaken seed collections of provenances of *L. styraciflua* from throughout the tropical range of the species in collaboration with the national forest seed centres of Nicaragua, Honduras and Guatemala, and the Instituto Nacional de Investigaciones Forestales (INIF) in Mexico.

This paper details these collections, outlines the possible potential of the species for plantation in the tropics and discusses seed availability for international provenance trials.

Taxonomy

The genus Liquidambar, in the family Hamamelidaceae, contains three species: *L. formosa* Hance. (a native of Taiwan) and its Chinese form *monticola* Rehd. and Mills., *L. orientalis* Mill. from Turkey and *L. styraciflua* L. native to the eastern U.S., Mexico and Central America.

The Liquidambar populations of North and Middle America have, however, received various taxonomic treatments in the past. Oersted (1870) referred to the Mexican and Central American material as *L. macrophylla* Oerst., whilst Harns (1930) considered the Mexican populations to be similar to those from the U.S., and called them *L. styraciflua* L., reserving the name *L. macrophylla* (Oerst.) for the Central American material only. Other workers have referred to the Mexican material as *L. styraciflua* var. *mexicana* (Oerst.) Ndz. and to the material from Central America as *L. styraciflua* var. *macrophylla* (Oerst.) Ndz. Many taxonomists, however, consider that the populations in the U.S.A., Mexico and Central America form one species—*L. styraciflua* L.—(*e.g.* Standley and Steyermark, 1946; Ernst, 1963; Williams, 1971)—and that any minor differences there might be can be assumed to be ecotypic. This is certainly our view, having collected and studied herbarium material of the species from throughout its natural range in the Americas—and it is as such that we will refer to all populations in this paper.

Ecology

In Mexico and Central America, *L. styraciflua* forms a large deciduous tree to 45 m height and over 1 m diameter. It is usually found in mixed forest, associated with pine or oak, mostly on mountains between 900 and 1600 m particularly along streams. We have found it, however, at elevations as low as 650 m in Eastern Honduras (Department of Olancho), where it is one of the canopy species in lowland tropical broadleaf forest.

It exhibits excellent form, with straight stems, light branching and narrow crowns and it grows happily in very dense pure stands. The species coppices very readily and also regenerates by means of root sprouts. Barrett and Mullin (1976) note that in several trial plots in Zimbabwe, trees from the centre of the plot were superior in diameter to edge trees. This natural gregariousness of the species make it well suited to plantation culture, in approaching the ideal tree-crop ideotype (Hughes and McCarter, 1983).

Having migrated south from temperate northern regions during the last ice-age, Liquidambar maintains its deciduous habit even in the tropics, although the leafless period is reduced to only one or two months in Central America.

The trees are generally leafless during December and January, the old leaves having

turned vivid shades of reds and yellows before they fall, although the colouring is less conspicuous in Central America than in the U.S. Towards the end of January and during February, just as the dry season is beginning the trees are again conspicuous, because of their bright pale-green foliage; this characteristic colour which is so common in temperate latitudes is decidedly unusual in the tropics. The phenology of leaf-fall of Liquidambar in the tropics appears to be quite variable not only between sites but also between trees on the same site. At one site we visited in central Honduras, total leaf-fall had occurred by early September, whereas leaves persisted in early November at other sites. Leaf flushing is equally unsynchronised and may spread over 4 or 5 weeks within a site. These factors may be exploitable by selection and breeding in the future.

Liquidambar in its native tropical range, generally prefers the moister well-drained acid forest soils. Annual rainfall at the sites from which seed was collected was mostly in the range 1500–1800 mm, with a dry season (loosely defined as any month in which rainfall is less than 60 mm) of 0–6 months. Mean annual temperatures ranged from 13·6°C to 21·4°C (see Table 1).

Frost is probably rare at these sites and it is unlikely that the southern provenances will show any degree of frost tolerance (Williams and McMillan, 1971).

Utilisation

Uses are many and varied. In the U.S.A. the timber is used primarily by the furniture and cabinet making industries. (The heartwood of *Liquidambar* is a distinctive red-brown colour, sometimes beautifully figured with deep markings). Other major uses include boxes, crates, pallets, plywood, particle board and pulp (Putman *et al.*, 1960). Minor commercial uses reported include musical instruments, crossties and sleepers, vehicle bodies and flooring. The timber is readily worked with general machining, nailing, screwing, boring, turning, glueing, staining and painting all widely reported to be "easy" (*e.g.* Farmer, 1972; Brazier and Franklin, 1967). One problem, however, appears to be drying the wood. If this is not done with care, the timber is liable to warp and twist. Radial and tangential shrinkage have been termed "fairly severe" (Isenberg, 1981).

The pulping characteristics of Liquidambar are widely reported (*e.g.* McElwee *et al.*, 1970; Isenberg, 1981). It is considered eminently suitable.

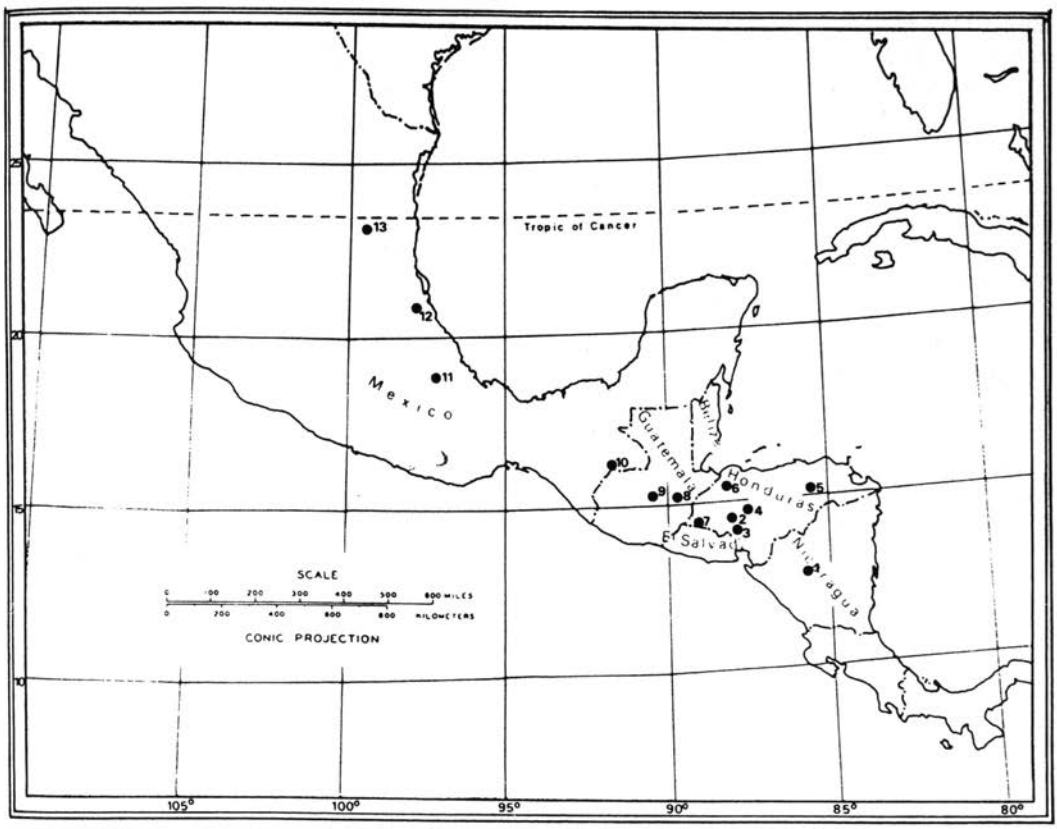
A balsamic exudate obtained from the sap of the tree in some areas (*e.g.* Olancho, Honduras) is used by the medical and perfume industries. In Guatemala, Standley and Steyermark (1946) report that the Indians of Alta Verapaz bathe in a decoction of the leaves and also take the balsam internally as a remedy for gonorrhea.

Potential and limitations

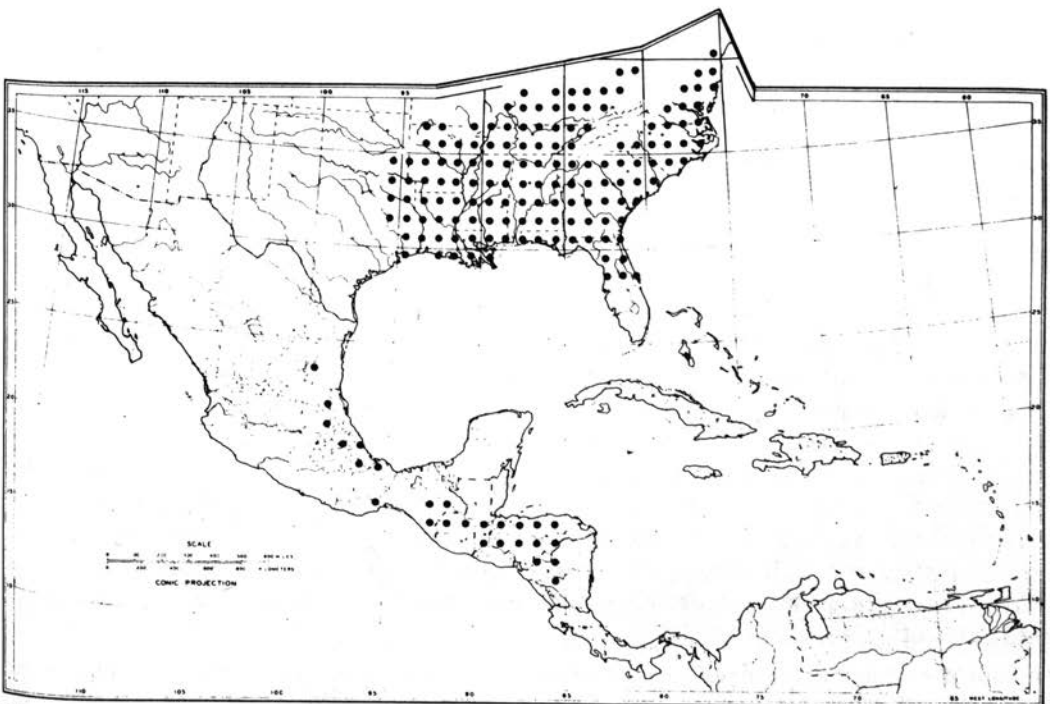
L. styraciflua has been tested only sporadically in the tropics to date, and then only over a limited range of sites and environments. Little has been published on its performance. Despite the fact that seed for these early trials has mostly come from the U.S. or Mexican sources rates of growth have been acceptable and tree form consistently impressive in those countries where limited introductions have been made—*e.g.* Brazil (Galvão *et al.*, 1980), Chile (Peñaloza, 1984), Peru (Picard and Willar, 1982), South Africa (Poynton, 1957 and 1972) and Zimbabwe (Barrett and Mullin, 1976). The southern provenances from Central America which are likely to have the greatest potential for tropical plantation in terms of adaptability and volume production have been almost totally neglected. Results from provenance trials, and research on natural stands within the U.S.A. provide good evidence of provenance variation in many silvicultural and wood property characteristics *e.g.* height growth, volume production, specific gravity, fibre

Table 1
Summary of Seed Collection Site Data

No. on map	Provenance	Country	Latitude	Longitude	Altitudinal range (m)	Rainfall (mm)	Mean Annual Temp. (°C) (estimated)	Dry Season (months) (<60 mm rainfall)	No. of trees contributing to bulk collection
1	Yucul, Matagalpa	Nicaragua	12°55′N	85°48′W	800–1100	1400–1600 (est.)	20	5	36
2	Los Alpes, Siguatepeque	Honduras	14°33′N	87°58′W	1250–1350	1400–1600 (est.)	18	3	40
3	Tutulé, La Paz	Honduras	14°12′N	87°50′W	1400–1700	1500–1800 (est.)	17	4	50
4	Las Lajas, Comayagua	Honduras	14°48′N	87°34′W	1100–1200	1500–2000 (est.)	21·5	4	34
5	San Esteban, Olancho	Honduras	15°22′N	85°35′W	640–800	1400–1600 (est.)	21	5	33
6	Buenos Aires, Sierra de Omoa	Honduras	15°30′N	88°11′W	900–1060	1800–2400 (est.)	18	2	40
7	El Portillo, Ocotepeque	Honduras	14°26′N	89°06′W	1570–1650	1400–1600 (est.)	18	5	36
8	Finca las Victorias, Sierra de las Minas	Guatemala	15°12′N	89°22′W	800–1000	1400–1600 (est.)	20	4	45
9	Tactic, Coban	Guatemala	15°19′N	90°21′W	1380–1420	2076	17·5	0	48
10	Montebello, Chiapas	Mexico	16°04′N	91°44′W	1460–1540	1800–2200 (est.)	18	2	39
11	Huatusco, Veracruz	Mexico	19°05′N	96°58′W	1350–1550	1746	15·5	4	37
12	Zacualtipan, Hidalgo	Mexico	20°42′N	98°37′W	1800–1870	2047	13·5	4	40
13	Gomez Farías, Tamaulipas	Mexico	23°06′N	99°10′W	1100–1450	1800–2400 (est.)	17	1	40



Sites of CFI Provenance Collections of *Liquidambar styraciflua* L.



Distribution of *Liquidambar styraciflua* L.

length, (Sprague and Weir, 1973; Ezell and Stewart, 1981; Stubblefield, 1983 and many others). It is likely that the disjunct distribution of the species in Central America and Mexico and the great environmental variation between sites (*e.g.* in photoperiod and temperature (Williams and McMillan, 1971)) will reveal similar or greater provenance variation.

The species has many promising features for plantation. To realise this potential, however, sites must be chosen with care. Liquidambar, whilst tolerant of a wide range of soils, reaches its best development on deep, moist, clay or loam soils of river bottoms or flood plains (Fowells, 1965). It has been successfully planted on relatively acid strip-mine spoil banks in the Central U.S. (Deitschman, 1950). It also tolerates seasonal flooding and moderate drought. The species is very susceptible to fire and browsing. No major disease or insect problems have been found to date (FAO, 1979). As with most hardwoods, Liquidambar does not grow well on exposed sites (Ashby *et al.*, 1979).

The species depends on an endomycorrhizal association for optimum growth. In a greenhouse study, potted Liquidambar seelings in soils inoculated with a mixture of vesicular-arbuscular mycorrhizal (VAM) fungi grew significantly faster than those in a sterilised soil. An eight-fold increase in height, four-fold increase in diameter and increases of thirty- to fifty-fold in root stem and leaf weights were recorded over the controls, after six months (Kormanik *et al.*, 1982). *Glomus* spp., the most common of the VAM fungi associated with Liquidambar are frequently found in tropical soils (Harding, 1984), so lack of suitable fungi is not envisaged as a problem. Difficulties could arise in the nursery if sterilised soil is used.

The silviculture and management of Liquidambar in plantations is widely covered in the literature.

Germination in the nursery and field establishment are straight forward.

Seed collections

Seed was collected from 13 provenances ranging from the species southern limit, 12°55′N in central Nicaragua to just south of the Tropic of Cancer in Tamaulipas, Mexico, during September and October, 1983.

To collect seed from so many sites over such a large area in one short collecting season was a major logistical and practical challenge. The success of the expedition was due to a combination of factors, namely:

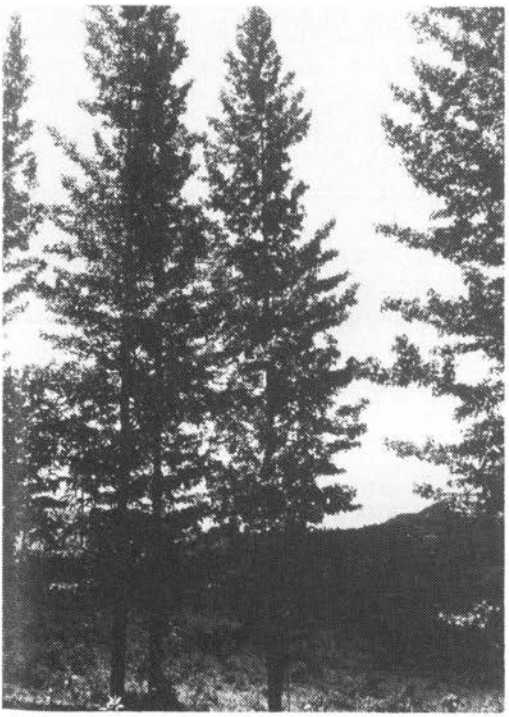
1. Having the infrastructure of vehicles, equipment and trained men, based in Honduras.
2. Our fore-knowledge of many of the Central American sites based on 15 years of seed collecting and exploration in the region by CFI and the valuable support of the national forest seed centres.
3. The fact that even within sites, fruit ripening is not synchronised and that even if all the fruits on some trees had opened, on others they were still quite green.* We were too late at only one site, La Esperanza, Intibuca, Honduras, where all the trees had already lost their leaves and most of their fruits by early September.

We concentrated our efforts on the southern-most provenances: 10 of the 13 sites fall between 13°N and 16°N. The emphasis on Honduran sites was in part due to the curtailment of our collecting activities in neighbouring Nicaragua. Security problems in the mountainous area bordering Honduras, where Liquidambar is known to occur, made collecting seed there unwise.

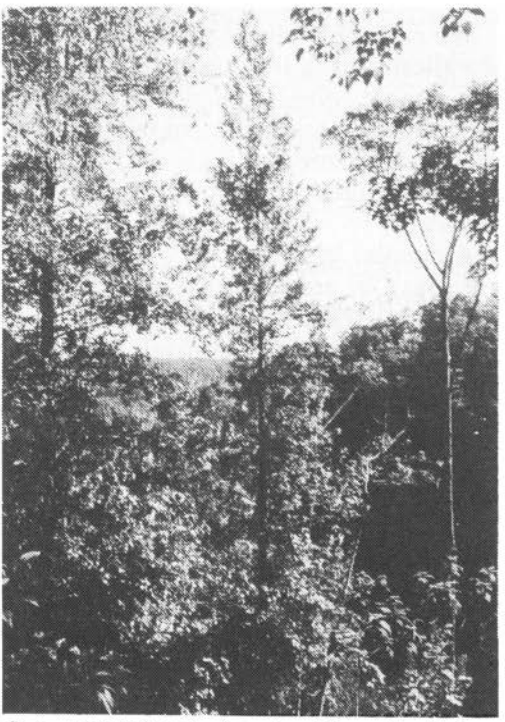
*It should be noted that time of fruiting is frequently under close genetic control, and may be correlated with other tree characteristics: Sampling of purely early or late fruiting individuals at any one site therefore, may not be truly representative of the total genetic variation.

a) Coppice-regrowth in a natural stand of *L. styraciflua* L., near La Esperanza, Honduras (1800 m).
(Photo by: P. S. McCarter)

b) Natural stand of *L. styraciflua* L. near Matagalpa, Nicaragua (900 m).
(Photo by: R. D. Barnes)



c) *L. styraciflua* L. in open pasture, Los Alpes, Siguatepeque, Honduras (1300 m).
(Photo by: C. E. Hughes)



d) *L. styraciflua* L. in mixed broadleaf/pine forest. Sierra de Omoa, Honduras (900 m).
(Photo by: C. E. Hughes)

Seed extraction while on the move was also a problem. Liquidambar fruits are collected green, and require 4 to 7 days drying under shade followed by 2 to 3 days in the sun to open satisfactorily. Extraction of the seed by shaking the fruits takes a further 1 or 2 days' work. Our observations and methods of collecting and extracting Liquidambar seed along with other technical seed information are reported elsewhere (McCarter and Hughes, 1984).

On average 40 trees were sampled from each provenance. Mild phenotypic selection for stem straightness and branching characters was applied, with neighbour-trees being excluded to avoid relatedness through common parentage.

As with all current CFI seed collections seed was kept separate by parent tree until after extraction, when we kept 15 g of seed from each of 25 trees of each provenance separate and bulked the rest. This provides the opportunity to carry out particular research studies (*e.g.* isoenzyme, germination), allows the establishment of combined provenance/progeny trials providing additional genetic information and a sounder basis for establishment of future breeding work and ensures the percentage contributions of individual trees to a bulk lot are known and can be controlled.

Seed availability

Seed is now available from the CFI for the establishment of provenance trials of *L. styraciflua*. Three levels of trials are suggested: (Hughes and McCarter, 1984).

1. Combined progeny/provenance trials, including 10 families from each of the 13 provenances.
2. Range-wide provenance trials using bulked seed lots of all provenances.
3. Pilot tests of 3 to 5 selected provenances covering the extremes of the range. —suitable for inclusion in a species trial of limited provenance trial.

We envisage that the greatest potential for Liquidambar will be on the mid to high elevation sites in the tropics *e.g.* East Africa, Himalayan foothills, Andes or Central America. It will also be valuable, however, to test the species on sub-tropical sites in, for example, Australia, southern China, southern Africa or Brazil. Given that pine provenances from the same seed collection sites in Central America as the Liquidambar are performing well at lower elevations near the equator these site types too should be included.

A circular letter has been sent to the Forest Departments and other participants in previous CFI provenance trials offering research quantities of seed of Liquidambar free of charge. Readers of the *Review*, who might not have received this letter, but who are interested in establishing trials are invited to write to the authors at the CFI Oxford, giving any information which would help select suitable provenances for their sites.

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