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State-of-knowledge on *Hymenaea courbaril* L. var. *Stilbocarpa* (Hayne) Lee and Lang. (Leguminosae: Caesalpinioideae) for Genetic Conservation in Brazil

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Abstract: This study explores the basis for conservation action on *H. courbaril* var. *stilbocarpa* (Hayne) Lee and Lang. (Leguminosae: Caesalpinioideae), a wide-ranging forest species occurring in Brazil only. It is mostly found in the gallery forests of the Cerrado region, but radiating into the northeastern Caatinga and southern rainforests. It offers insight into the taxon through structured reviews of knowledge of its biology, ecology, silviculture and management. Widely scattered published reports are critically considered and efforts made to highlight and resolve contradictions and inconsistencies therein. Information about this species is scanty and scattered, but some effort has been applied to its biology and ecology. Because little effort has been applied to its domestication and improvement, knowledge of its silviculture and management is insufficient. Gaps in current knowledge relevant for conservation are identified and steps to fill them proposed. Where *in situ* conservation proved to be more appropriate, recommendations are made for the location of additional protected areas. *Ex situ* and enrichment conservation action is highly recommended for specific parts of the range where resource losses are already so extensive that *in situ* measures alone are inadvisable. Provision for refining the limited management and conservation knowledge is made through highlighting priorities for study of the taxon. Finally, future action is discussed in the context of the infrastructure of the national conservation sector.

Key words: Cerrado, Atlantic Coast forest, conservation; forest genetic resources, research

INTRODUCTION

Conservation operating through *in situ* channels has, understandably, been ecosystem focused. There is, however, need to complement this with attention directed at particular target species. Here, this approach is developed for *H. courbaril* var. *stilbocarpa* (Hayne) Lee and Lang., a forest species, which occurs in a distinctive but threatened habitat in central Brazil, the Cerrado. This taxon is included in the listing of 23 priority species for Brazil drawn up by the Brazilian Agricultural Research Organisation through its Genetic Resources and Biotechnology Research National Center (Embrapa-Cenargen, 1988) for the Brazilian Government in connection with the national conservation strategy. Criteria for selection were those recommended by the FAO Panel of Experts on Forest Gene Resources: Restricted ecological distribution, low population densities, heavy exploitation for wood and other products, unknown or deficient silviculture and threatened habitat (Roche, 1987).

Efforts to trace a robust but flexible standard system for acquiring, collating and organising information on named neotropical tree species were not successful. The reasons always reside in problems of standarisation of taxonomic and systematic nomenclature and regional peculiarities of

(and particularly for wide-ranging) woody species, as well as the generally scattered nature of the acquired knowledge on these species. For example, in the *Forestry compendium* of CAB International (2000) *H. courbaril* var. *stilbocarpa* is only briefly treated as an outline data sheet. However, Lorenzi (2000) provides an instructive account, including figures, of this species. Reference to World Conservation Monitoring Center (WCMC-Kew, 1990) indicated that for other tropical areas the situation was no different. Since species are the targets of gene resource conservation, a structured review of existing knowledge has great appeal when conservation strategies are to be formulated. Accordingly, this paper offers a framework for such action, with *H. courbaril* var. *stilbocarpa* serving as a case study.

The form and distribution of knowledge about tropical tree species introduce complications in information retrieval. Un-processed raw data (for example, those recovered from herbarium holdings, ecological literature and species listings) need to be especially reviewed and critically incorporated into the progressing study. In an uncollated state, published information is often very dispersed, much (notably early references) being in obscure or poorly circulated documents. Various languages may be involved and reference may be made under obsolete names, which may reflect broader or narrower concepts of the species than those accepted today. For many wide-ranging species these problems are acute, making the preparation of a unifying account taxing, time-consuming and sometimes laborious. The exercise is nevertheless important as the basis of an authoritative conservation plan.

Few can claim familiarity with all aspects of the existing knowledge of a wide-ranging species: Existing information about a species can be allocated in many fields, each the line of a different group of specialists: Foresters, ecologists, geographers, botanists. Geographical spread complicates matters greatly. Much concern with species is at national rather than range-wide level. Differences in the circumscription and in the nomenclature of species need to be recognised (and perhaps reconciled) and taken into account as the information is integrated. Whether or not this can be achieved in a single step depends on the quantity of published and archival information (including herbarium material), on the species, as well as on the resources and time available to the investigator.

Aimed at producing a current state-of-knowledge account for the species to support genetic conservation programmes in Brazil, the present study has three objectives are to review available information on the biology, ecology, silviculture and management of *H. courbaril* var. *stilbocarpa* relevant to its genetic conservation as a sustainable resource, to create a comprehensive and authoritative monographic account of the species by a critical analysis of available information, highlighting in the process unresolved misinterpretations and inconsistencies which need clarification and to identify the major gaps in current knowledge of the taxon and recommend positive research actions to fill them.

MATERIALS AND METHODS

This research is devoted to an in-depth account of the target taxon included in the programme of conservation of forest genetic resources in Brazil, which occurs in the Central Brazilian Cerrado region. Consequently, it has copious monographic content for the species. Comprehensiveness and authority have been sought by means of the extensive, though scattered information accessed and the scope of the review has enabled a clear picture of the species throughout the neotropics. Comprehensive comments on taxonomic and morphological aspects-at times addressing exposed contradictions and misinterpretations- associated phenology. Distribution and ecology are aspects dealt within the context of the overall taxon range. Silvicultural and management experience was revealed but the information retrieved was inconsistent, scattered, incomplete and seldom widely circulated. As expected utilisation of the resource was particularly related to wood properties, but a variety of comments on alternative non-timber usage for the species were located. Lastly, information on genetic conservation status and priorities was supplied as general introductory statements, which were linked to conservation action to be taken and presented later in the article.

The approach followed has been adapted from that used by Hall and Walker (1991) for *Balanites aegyptiaca* and the schemes of Mondal (1986) for *Maesopsis eminii* and Irozuru (1986) for *Nauclea diderrichii* and the approach followed by Morse (1981) to report the conservation status of an endangered North American shrub species.

The species is considered sequentially with a subdivision allocated for each main aspect. The first subdivision outlines the systematic position and circumscription of the taxon. The nomenclatural history in each case is presented as a tabular chronological summary. The second subdivision is descriptive, covering, in turn, the seedling phase and the mature tree with, for the latter, details of habit, size and form, foliage, flowers and fruits and where known, systematic anatomy. The third subdivision is in three sections covering the reproductive biology of the taxon with respect to phenology, pollination and dispersal and seed biology in natural conditions. The fourth subdivision is in two sections: distribution and ecology. The distribution covers, as far as possible the whole natural range. The ecology is treated first by factor: elevation, climate and soils and then in the phytosociological context (associated species, relations with the natural fauna and with forest disturbance). The fifth subdivision addresses the silviculture and management of the species. In terms of artificial regeneration, experience involving propagation and outplanting and establishment and the performance of planted individuals is reported. On the management side, an account of attention in forest stands is given. The sixth subdivision deals with utilisation. There are three subsections-a description of the wood properties regarding macro- and microscopic, as well as physical and mechanical features; use as timber in terms of seasoning and preservation, durability and workability and final uses; other uses, based on the Booth and Wickens (1988) scheme of non-timber uses for African species. The seventh and fiual subdivision is concerned with the conservation status of the species.

The fragmented and unsatisfactory species information for many species in the neotropics requires today's monographers to invest more thought, effort and time to taxonomic circumscriptions and their geographical implications than their counterparts in Africa, Asia or Australia.

In the present research, a retrospective picture of the taxonomic chronology was a necessary preliminary to an overview of the knowledge base.

More specific comments on the importance of knowledge of the different aspects of a species have been given by Hall (1993 and 1994). Hall reports the general need for monographic accounts rather than only lists, brief profiles, data-sheets and bibliographies on both multipurpose tree species and traditional forestry trees. Monographs can be the most authoritative and comprehensive documents of the state of knowledge on any species. However, it is important that they are based as a sound framework in the form of a set of headings covering all aspects of the tree's biology and resource potential: taxonomy/morphology, distribution, ecology and silviculture/management. Critical assessment of the information gathered is important, especially resolving or explaining nomenclatural contradictions and differences of opinion as far as possible. Hall (1993 and 1994) stress the prominent role distribution maps should play among those headings. This is an exercise, which depends on information from five distinct sources-herbaria, taxonomic literature (basically in the form of floras), inventories, ecological literature and persoual observations. Complementary data sets can cover terrain, climate and soil allowing occurrences to be related to these factors. Hall (1994) also discusses the potential combined role of such information sets in distinguishing genetically determined variation from ecologically determined variation in a wide-ranging species once mapped using all relevant available information. A critical approach to these issues is essential if conservation programmes are to be successful.

Unification of information on a species into a structured and authoritative monograph has been achieved for the African dry zone tree *B. aegyptiaca* (L.) Delile (Balanitaceae) by Hall and Walker (1991). This study serves as a useful model for a monograph but adaptations will be appropriate for other species. In the present case, prominence has been given to the conservation aspect, which has been excluded by Hall and Walker (1991) although separately considered at some length elsewhere (Hall, 1992). This conservation aspect is also covered in more recent monographs such as those

presented by Hall *et al*. (2000) for *Prunus africana* and Pasiecznik *et al*. (2001) in a *Prosopis juliflora-Prosopis pallida* complex account. The present study involves diverse sources of information. For Brazil these are published and unpublished material at Embrapa and Cenargen, National Parks management plans and lists and maps of current protected areas at the Brazilian Institute for the Environment and Renewable Natural Resources-Ibama. Paraguayan Conservation Data Center data sheets on the target taxa were also obtained. In Britain, WCMC's database information on protected areas and assessment of conservation status of the target species were consulted and information assembled through visits to and correspondence with the Royal Botanic Garden, Kew (both herbarium and library). Electronic (Web of Science, CABI TreeCD) and traditional abstracting facilities (Forestry and Biological Abstracts) and a range of periodical publications but particularly Forest Ecology and Management, Forest Genetic Resources Information, Threatened Plants Newsletter and Silvae Genetica were also consulted. For less readily available recent documents Inter Library loans were used. Further information was collected in discussions and correspondence with experts-both in Britain and abroad (Brazil, Paraguay, Switzerland). This review has been done as complementary to field studies carried out with four target species occurring in the gallery forests of the central Brazilian Cerrado -a savanna-like vegetation physiognomy-in the early nineties.

RESULTS

Vernacular Names of *H. courbaril* var. *stilbocarpa*

Portuguese: jatobá, jataí, árvore-copal, jataí-amarelo, jataí-peba, jataí-vermelho, farinheira, jataíba, burandan, imbiúva, jatobá-miúdo, jataí-iba, castanheiro-de-bugre, courbaril, jati, jataicia, jutaí-açu, jutaí-de-envira, jutaí-mirim, jutaí-pororoca, jutaúba, óleo-de-jataí, paqui (Salomão, 1990); jatobá-amarelo, jatobá-mirim, jatobá-de-caatinga (Lee and Langenheim, 1975); jatobazinho, jatobá-sertão (Lewis, 1987).

Systematic Position and Circumscription

The subdivision of *Hymenaea* has been undertaken differently by different workers in the past as the genus is large and uniform enough to be rather critical. In recent years it has become apparent that contrasting taxonomic circumscriptions and rankings have been adopted for regional and national approaches. Immediate interest is in plants which are presently distinguished at species level in Brazilian conservation programmes (as *H. stilbocarpa* Hayne). International literature ranks the taxon as a variety, however: *H. courbaril* L. var. *stilbocarpa* (Hayne) Lee and Lang. The policy followed here has been to accept the varietal rank but to review information available only as it relates to this variety (endemic to Brazil and the target of national conservation policy) in contrast with the type variety which also occurs in Brazil). To undertake a comprehensive review of the complete complex of *H. courbaril* (sensu lato), which ranges from the northern to the southern limits of the neotropics and includes the Caribbean islands, was not realistic within this study and would weaken the emphasis on the distinctive *H. courbaril* var. *stilbocarpa* prioritized for attention by the Brazilian conservation organizations. As, however, there are gaps in the knowledge base for this taxon, information on *H. courbaril* var. *courbaril* is included where necessary on the assumption that the similarities between the taxa extend to ecological and biological characters. It is then worth stressing that *H. courbaril* var. stilbocarpa is endemic to Brazil where, because it is regarded a taxon of specific rank, it has high conservation importance throughout its range.

The five varieties of *H. courbaril* not studied in this thesis occur throughout the species range as shown in Fig. 1 (Lee and Langenheim, 1975).

The genus *Hymenaea* is leguminous, belonging to the tribe Detarieae within the subfamily Caesalpinioideae. *Hymenaea* has long been considered a neotropical genus, but its recent reinstatement

Fig. 1: Distribution of *Hymenaea courbaril*

in the African flora revived its amphi-Atlantic distribution. The genus is of two sections: *Trachylobium* (African species and two neotropical species) and *Hymenaea* (the remaining 11 neotropical species, including *H. courbaril*).

Notwithstanding the fact that all its species, with just one exception, are neotropical, supporting evidence shows an African origin for the genus with the Amazon being a secondary center of distribution. The African species, *H. verrucosa*, is restricted to the Continent's eastern coast and adjacent offshore islands, where it occurs in seasonally dry coastal forests.

Lee and Langenheim (1975) assumed *Hymenaea* and its amphi-Atlantic distribution resulted from a west African rain forest ancestral stock which supplied, during the early Tertiary era, material dispersed by ocean currents to the rain forests of the New World. Poiner Jr (1991) describing an additional (fossil) species, *H. protera*, offers, however, an alternative explanation based on plate tectonics, suggesting the genus may have originated when South America and Africa were united in the middle or late Cretaceous era.

In the New World, the genus ranges between the tropics, from 23°N to approximately 25°S occupying all major ecosystem types-from Amazonian rain forest to thorn forest.

Lee and Langenheim (1974) suggested the existence of 18 species of *Hymenaea* in the Neotropics, although in a paper published earlier they supported the existence of 16 neotropical species (Lee and Langenheim, 1973). In a later review of the genus (Lee and Langenheim, 1975), the number was reduced to 14 species, including the African one.

H. aurea Lee and Lang.
H. courbaril var. *altissima* (Ducke) Lee and Lang.
H. courbaril var. *courbaril* (L.) Lee and Lang.
H. courbaril var. *longifolia* (Benth.) Lee and Lang.
H. courbaril var. *stilbocarpa* (Hayne) Lee and Lang.
H. courbaril var. *subsessilis* Ducke
H. courbaril var. *villosa* Lee and Andrade-Lima
H. eriogyne Benth.
H. intermedia var. *adenotricha* (Ducke) Lee and Lang.
H. intermedia var. *intermedia* Ducke

H. maranhensis Lee and Lang.
H. martiana Hayne
H. oblongifolia var. *davisii* (Sandwith) Lee and Lang.
H. oblongifolia var. *latifolia* Lee and Lang.
H. oblongifolia var. *oblongifolia* Huber
H. oblongifolia var. *palustris* (Ducke) Lee and Lang.
H. parvifolia Huber
H. reticulata Ducke
H. rubriflora var. *glabra* Lee and Lang.
H. rubriflora var. *rubriflora* Lee and Andrade-Lima
H. stigonocarpa var. *brevipetiolata*
H. stigonocarpa var. *pubescens* Benth.
H. stigonocarpa var. *stigonocarpa* Hayne
H. torrei León
H. velutina Ducke
H. verrucosa Gaertner

The taxonomic history relevant to *H. courbaril* var. *stilbocarpa*, including the synonymy is summarized in Table 1.

Description

Seedling

No information on seedling morphology has been traced for *H. courbaril* var. *stilbocarpa* but, as little difference from var. *courbaril* is likely, available information on the shown in Table 1. Flores and Benavides (1990) studied seed germination and seedling morphology of *H. courbaril* in Costa Rica. Duke (1965) described seedlings in Puerto Rico. They reported phanerocotylar (epigeal) germination. The radicle emerges in 20-30 days. Seed coat rupture occurs in 20-35 days, with the developing cotyledons remaining attached to fragments of the testa. The cotyledons (Fig. 2) are opposite, ovate and thick and shed in 52-60 days. Opposite eophylls (protophylls) emerge in 30-35 days. The eophylls are sessile and with deciduous stipules. They have an entire symmetrical,

Table 1: Taxonomic history: *Hymenaea courbaril* L. var. *stilbocarpa* (Hayne) Lee and Lang

Authority	Event
Linnaeus (1737)	Genus *Hymenaea* established
Linnaeus (1753)	The type species (*H. courbaril*) described with material from Brazil
Hayne (1827)	The name *H. stilbocarpa* introduced but without a description. The name *H. confertifolia* introduced but without a description
Hayne (1830)	Description of *H. stilbocarpa* published but no type specimen designated. Description of *H. confertifolia* published based on *Sellow sn*, from Brazil-material then in B but presumed destroyed later (Lee and Langenheim,1974)
Vogel (1837)	Description of *H. splendida* published based on *Sellow 1025* from Bahia, Brazil-material then in B but presumed destroyed later (Lee and Langenheim, 1974)
Vogel (1867)	Collection of material (*Regnell 11-91*) from Minas Gerais which is at K and in the absence of any designation by Hayne of the specimen used for the description, nominated as the type by Lee and Langenheim (1974)
Bentham (1870)	Distinction of varieties within *H. splendida*: var. *splendida* and var. *longifolia*. First citation of authentic specimens of *H. stilbocarpa* (circumscription of Hayne)
Ducke (1935)	Speculation that *H. courbaril* and *H. stilbocarpa* were conspecific
Lee and Langenheim (1974)	Revised status given to *H. stilbocarpa* as one of six varieties of *H. courbaril*, as var. *stilbocarpa*. *H. confertifolia* and *H.splendida* var. *splendida* reduced to synonymy within var. *stilbocarpa*. *H. splendida* var. *longifolia* treated as a different variety of *H. courbaril*

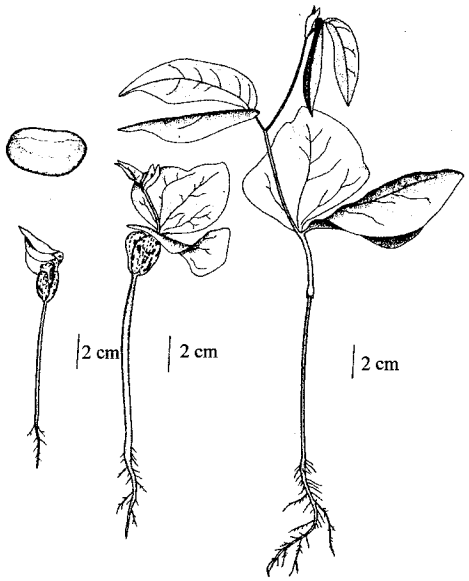

Fig. 2: Seed and early stages of seedling development of *H. courbaril* var. *courbaril* (Flores and Benavides, 1990)

dorsiventral lamina, with an attenuated base and an acute apex. The venation is reticulate and actinodromous. The first metaphylls expand in 35-40 days and are alternate and bifoliolate, with asymmetric dorsiventral leaflets oblique at the base and acute at the apex. The margin is entire and the venation eucamptodromous (Flores and Benavides, 1990). They are petiolate with deciduous stipules.

The secondary metaphylls, which expand in 45-60 days, present the same characteristics as the primary metaphylls and so do older leaves.

As with other tropical species there is leaf differentiation in seedlings and saplings in relation to adult individuals. The former presents leaves much larger, thinner and devoid of hairs, thought to signify adaptations to shade and to enhance chances of survival (Lee and Langenheim, 1975; Cowan and Polhill, 1981).

Langenheim *et al.* (1980) and Langenheim (1981) stress the success of *Hymenaea* seedlings under the parent tree in areas of intense and diverse herbivory. They suggest this results in part from the variation in seedling leaf resin composition which would provide an effective chemical defence system against predators.

Crankshaw and Langenheim (1981) noted variation in resin composition with forest type in *H. courbaril* var. *stilbocarpa* seedling leaves. Caryophyllene sesquiterpene hydrocarbon was predominant in seed material from the Brazilian coastal humid evergreen forest. In seed material from semideciduous forest plants there was a more complex chemical composition: A high (40%) level of selinene, moderately high δ-cadinene (<25%) and α-copaene (>15%) and low caryophyllene sesquiterpene hydrocarbons. Crankshaw and Langenheim (1981) also noted qualitative variation in resin composition in developing *Hymenaea* leaves. They concluded that with generalist herbivores-eg *Spodoptera exigua* (Lepidoptera)-one dominant sesquiterpene was more effective than intermediate amounts of two or more. It thus appears that seedlings of coast forest populations could readily withstand the attacks of generalist herbivores than seedlings from semideciduous forest because of their resin quality. Hence these biochemical features are important to conservation in showing genotypic variability.

Mature Tree

Habit, Size and Form

H. courbaril var. *stilbocarpa* is an evergreen tree with a wide circular crown composed of thick branches terminating in glabrous branchlets. It is a medium to large sized tree, 16 to 35 m in height and 40 up to 140 cm in diameter. The stem is straight and cylindrical and the outer bark is smooth or (on some old individuals) grooved. There are prominent horizontal grey lenticels, 1-10 mm deep. The slash is light-brown coloured while the lenticels get darker when cut. The inner bark is hard, 5-10 mm deep, pinkish-coloured, with a distinctive taste of unripe banana and exuding a wine-coloured resin.

Foliage

The leaves (Fig. 3) are alternate, bifoliolate and shortly-petiolate with petioles 12-20 mm long. Individual leaflets, borne on twisted petioles 4-6 mm long, are medium-sized, falcate to subfalcate, coriaceous and shining glabrous. The lamina is 5.0-10.0 cm long by 2.5-3.5 cm wide and asymmetrically acute to shortly-acuminate at the apex but obliquely-based. The midrib and secondary veins are obscure on the abaxial surface but on the adaxial surface the veinlets are distinctly reticulate (Lee and Langenheim, 1974, 1975; Cowan and Polhill, 1981).

Flowers and Fruits

The inflorescence are composed of a few racemes, each few-flowered, their branches and pedicels rusty sericeous-puberulent. The pedicels are 6-10 mm long. The flowers are medium-sized to large, 3-5 cm across. The buds are velutinous and blackish to dark-brown. The hypanthium has a stalk-like base ca 4-9 mm long. The calyx lobes are orbiculate to broadly ovate in shape, ca 12-18×8-12 mm and densely, dark-brown to rusty-sericeous (or occasionally golden-brown) velutinous outside and golden-brown to golden-yellow sericeous inside. There are five petals, ovate to obovate in shape, ca 18×8 mm, sessile. The stamens are ca 32-35 mm long with anthers ca 6-7 mm long. The ovary is shortly-stipitate, the stipe ca 3-4 mm long and glabrous. There are 10-12+ ovules. The fruits are indehiscent pods 5-12 cm long and 3-5 cm wide, with a thick (2.0-3.5 cm) exocarp. Their shape is

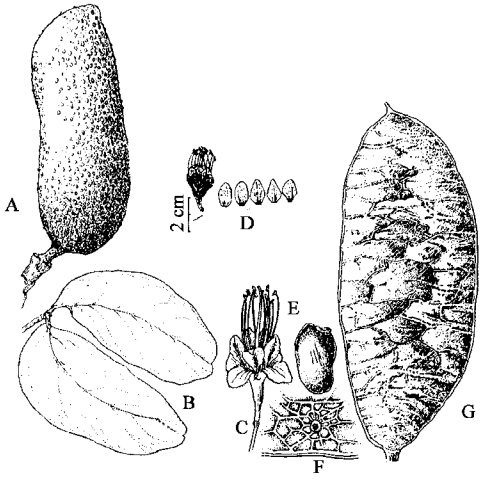

Fig. 3: (A) *H. courbaril* var. *stilbocarpa* fruit ×2/3, (B) Leaf ×2/3, (C) flower ×2/3, (D) Flower and petals, (E) Seed ×2/3, (F) Basal gland on lower surface of leaflet-blade ×6 and (G) Fruit ×2/3, (Modified from Lee and Langenheim, 1975; Lewis, 1987)

oblong, subterete to slightly compressed in shape, obtuse at each end and glossy-brown to dark-brown (occasionally black) in colour. The endocarp is of a thick, floury, sweet, yellowish pulp which is edible although having an unpleasant smell. There are 1-6+, ellipsoid seeds each 20-2×15-18×10-12 mm with a dark brown testa (Lee and Langenheim, 1974, 1975; Cowan and Polhill, 1981).

Systematic Anatomy

Corner (1976) describes the seed of *H. courbaril* var. *courbaril* from cultivated material in Singapore. The dark-brown seeds measure 25×16-18×13-14 mm and are exalbuminous. The testa consists, on the outer epidermis, of a tall palisade layer and is marked along the middle with a dark line. There is a mesophyll layer with hourglass cells, a single layer of stellate cells and a thicker inner layer of tangentially elongate cells, strongly thickened along the raphe-antiraphe. The funicle is thickened into a small white fleshy aril covering the hilum and micropyle, consisting of an outer, rather horny layer of large, contiguous, thin-walled cells and an inner pithy tissue of substellate cells filled with starch, eventually drying up.

The pollen grains are tricolporate, psilate-punctate, verrucate and micro-reticulate to striato-reticulate (Graham and Barker, 1981).

Chromosome Number

The basic chromosome number in *Hymenaea* is n = 12 (Lee and Langenheim, 1975; Cowan and Polhill, 1981).

Reproductive Biology

Phenology

Lee and Langenheim (1975) report synchronization of the flowering period with the dry season or transition to the wet season, from October to December, for the taxon throughout its distribution range.

Most Brazilian authors (e.g., Rizzini, 1978; Salomão, 1990) refer to a flowering period from December to March (the wet season). For gallery forest in Brasília, Cavallari and Gripp (1990) and Silva *et al.* (1990) report over a three year period flowering every September and October (onset of the wet season), whereas fruiting occurred only in alternate years (from January to June). This skipping of one year-or several in the case of *H. courbaril* var. *courbaril* in Central America (Roth, 1987)-without fruiting is one of the ways tropical tree species escape seed predation. It is reported that where the weevil *Rhinochenus stigma* is absent it fruits every year. Another way to avoid total seed predation is mast fruiting-which is also shown by *H. courbaril* var. *courbaril*-with production of large crops that satiate predators.

Silva *et al.* (1990) observed exchange of foliage in August and September, Lee and Langenheim (1975) have pointed out that there is normally an obvious peak of leaf fall in most varieties of *H. courbaril*.

Pollination and Dispersal

Lee and Langenheim (1975) favour outcrossing as the breeding system of *Hymenaea*. They also report evidence of vegetative reproduction in *H. courbaril* var. *courbaril*.

In related taxa it seems that the occurrence of nocturnal anthesis, strongly odoured flowers, short, stout, strongly flexuous inflorescence branches levelling the open shaving brush type flowers, the presence of extensive nectariferous tissue and retention of nectar in a broadly tubular corolla fit well into a bat pollination syndrome. Allied to these is a pattern of anthesis which promotes pollination by vectors visiting the few flowers opening each day over a period of weeks. A quantity of nectar that is attractive but not satiating also substantiates the occurrence of the chiropterophily syndrome (Lee and Langenhein, 1975; Kalin Arroyo, 1981).

Crestana *et al.* (1985) observed bat pollination in very sparsely distributed trees between 1900 and 2200 h (i.e., 1-4 h after sunset). Various daylight visitors to the flowers, such as bees, flies and hummingbirds were also observed (Crestana *et al.*, 1985). Overall, bees are the most frequent visitors (Table 2).

Crestana *et al.* (1985) further observed the anthesis process in the taxon over a 24 h period (Fig. 4).

Flower opening is slow. At stage A, immediately after sunrise, the floral buds are turgid presenting just a slight opening of the sepals. This stage continues until about 2 h after sunrise when the sepals start to separate, exposing a small opening at the apex of the bud, through which is possible

Table 2: Insect capture on *Hymenaea courbaril* var. *stilbocarpa* in two days (Crestana *et al.*, 1985)

Time	Group	Family	Species	No. of individuals
1015	Hymenoptera	Meliponinae	*Trigona spinipes*	5
	Hymenoptera	Vespidae	*Polybia paulista*	3
	Hymenoptera	Apidae	*Apis mellifera*	1
	Hymenoptera	Meliponinae	*Parachatergus pseudo apicalis*	1
				11
1700	Hymenoptera	Meliponinae	*Trigona spinipes*	29
	Hymenoptera	Vespidae	*Polybia paulista*	7
	Hymenoptera	Vespidae	*Polybia ignobilis*	4
	Hymenoptera	Vespidae	*Polybia fastidiosuscula*	2
	Hymenoptera	Vespidae	*Polybia chrysothorax*	1
	Hymenoptera	Apidae	*Apis mellifera*	1
	Hymenoptera	Vespidae	*Parachatergus pseudo apicalis*	1
				45
1015	Hymenoptera	Vespidae	*Polybia paulista*	7
	Hymenoptera	Vespidae	*Polybia jurinei*	1
	Diptera Muscidae			3
	Hymenoptera	Vespidae	*Polybia ignobilis*	1
	Hymenoptera	Apidae	*Apis mellifera*	2
	Coleoptera		*Macrodactylus pumilio*	1
				15
1700	Hymenoptera	Meliponinae	*Trigona spinipes*	8
	Hymenoptera	Vespidae	*Polybia paulista*	5
	Hymenoptera	Apidae	*Apis mellifera*	4
	Hymenoptera	Vespidae	*Polybia jurinei*	1
	Coleoptera		*Macrodactylus pumilio*	1
				19

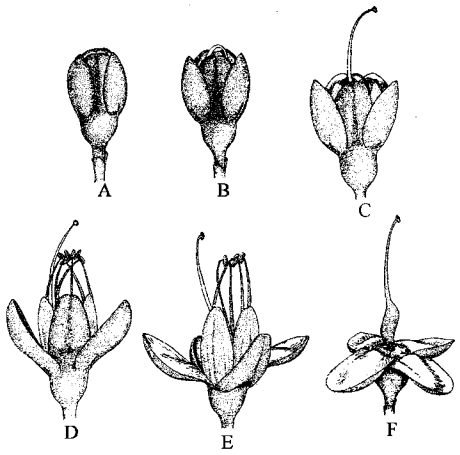

Fig. 4: Anthesis stages in *H. courbaril* var. *stilbocarpa* (Crestana *et al.*, 1985)

to see the downward coiled style. Bud opening goes on slowly until three hours before sunset when the style starts emerging from the bud-Stage B. From this point, the process speeds up. At Stage C all styles are uncoiled-by about two hours before sunset. Approximately one hour later the stamens project out, although remaining slightly folded inwards and nectar-production starts. At this stage (Stage D) the style is fully extended, with the stigma overtopping the anthers. At sunset the filaments are completely unfolded with the anthers facing upwards and nectar production is then copious and accompanied by a fragrant scent. By one hour after sunset the nectar has filled the hypanthium and many anthers have dehisced-a process which is probably initiated earlier by the foraging action of *Trigona* bees. Nectar production is sustained until four hours after sunset by which time the anthers are all dehisced. By sunrise bud opening (Stage E) has been completed and the anthers have shed all their pollen and are being dropped. There is still a little nectar which maintains the fragrant smell of the flower. The petals and filaments are easily detached and by sunset only the sepals remain (Stage F).

As well as bats, pollination agents observed have been bees, wasps, butterflies and humming birds. Such agents are believed, however, to be less effective in the pollination process in *Hymenaea* than bats because, visiting the flowers during the day, they miss the nocturnal flower anthesis (Lee and Langenheim, 1975; López, 1987). Kalin Arroyo (1981) suggests melittophily has provided an evolutionary link to current bat pollination in the genus.

Kageyama (1990) draws attention to the direct association between long distance pollination and seed dispersal and sparsely distributed *H. courbaril* var. *stilbocarpa* trees.

Hydrochory is the main mechanism for seed dispersal (Lee and Langenheim, 1975) of the buoyant fruits. After maturation the seeds fall to the ground and are carried away by running superficial water to watercourses along which they are transported to some distance from the parent tree (Lee and Langenheim, 1975; Leitão Filho, 1982). Fruits of *Hymenaea* are frequently seen floating intact in rivers and this may partially account for the density of various species along streams or rivers in all ecosystems (Lee and Langenheim, 1975). Zoochory is also involved, rodents and mammals dispersing by either transporting the fruit or eating the seeds (Lee and Langenheim, 1975).

Seed Biology in Natural Conditions

Normally water-dispersed seeds germinate near the watercourse down which they have been dispersed. Zoochory, however, generates a more haphazard pattern of distribution.

Seeds have been reported to germinate in ca 8-18 days (Lee and Langenheim, 1975) and 25-28 days (Salomão, 1990).

There is no reported dormancy mechanism and seeds germinate even inside the fruit. Roth (1987) however points out that the seed of *H. courbaril* var. *courbaril* can remain in good condition inside the pod for several months.

No information on germination percentage has been seen for *H. courbaril* var. *stilbocarpa*. Flores and Benavides (1990) report rather high germination-96%-under nursery conditions, initiated within 20-30 days of sowing. Curculionid weevil attacks on seed within the fruit presumably reduce the number of viable seeds dispersed (Salomão, 1990). The insects involved are specialized to penetrate the fruit-however while they penetrate *H. courbaril* var. *courbaril* seed only to a depth of 0.1-0.3 mm (Roth, 1987) they achieve this despite the copious highly viscous and tacky resin which is present as a continuous wall in the exocarp as well as around the seed (Langenheim, 1981). The hardening of such resin in the pod walls is interpreted as defence against generalist herbivores (Janzen, 1981). One kilogram contains ca 270 seeds (Rizzini, 1978; Salomão, 1990).

Distribution and Ecology
Distribution
Present Distribution

Even though the genus *Hymenaea* occurs in all South American countries except Uruguay and Chile (Lee and Langenheim, 1973), *H. courbaril* var. *stilbocarpa* occurs only in Brazil. López (1987) reported the presence of the taxon for the whole of Tropical America, including Antilles and Mexico and down to Paraguay and Argentina but the information gathered by this author from holdings of several herbaria does not confirm presence beyond Brazil and in this is consistent with the most comprehensive reviews of the genus (e.g., Prado, 1991). Reports of occurrences outside of Brazil probably refer to other varieties of *H. courbaril*, or even completely different species and endemic status for *H. courbaril* var. *stilbocarpa* rather than López' view is adopted for present purposes.

Range

The core region of occurrence of the taxon is the Brazilian Cerrado[3,5] from which there is radiation into the northeastern thorn forests of Caatinga[2] and the southern rainforests[4]. An isolated occurrence is reported for Amazonia[1] (Fig. 5).

Ecology
Environment
Elevation

The only recorded altitude information on herbarium slips is a record of 640 m (*Harley 16752*) at K. This is likely to be below the upper limit since there are occurrences in the Brasília region where average elevation is 1,100 m.

Soils

The dominant soils where *H. courbaril* var. *stilbocarpa* is prominent are poor. Luvisols, in the northeast and gleysols, in Amazonia, are more fertile but distribution of

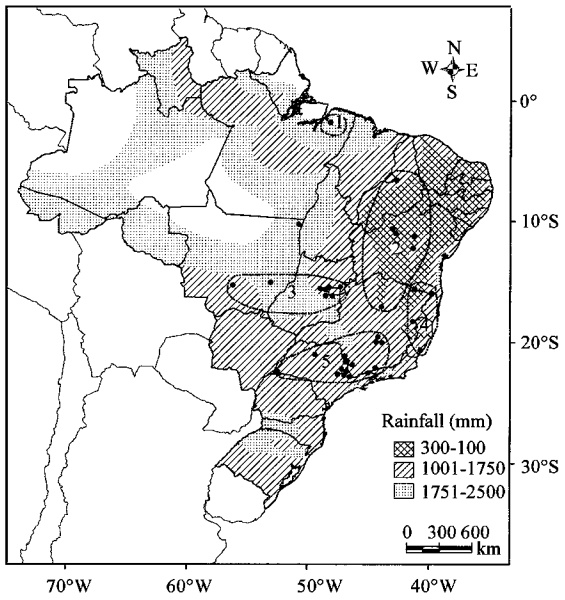

Fig. 5: Distribution of *H. courbaril* var. *stilbocarpa* in S. America. Numbers denote sub-regions and countries as follows: 1, northern Brazil; 2, northeastern Brazil; 3, central Brazil; 4, eastern Brazil; 5, southeastern Brazil

the taxon in such areas is sparse. Overall, association with poor soils, mostly over gentle topography, is characteristic of this taxon.

Climate

Comments relate to a detailed mean annnal rainfall map of South America (WMO *et al*., 1975) and association with the distribution map (Fig. 5). The range of *H. courbaril* var. *stilbocarpa* falls mainly between the 1,200 mm and the 2,000 mm isohyets.

Mean annnal rainfall of the order of 1,200 mm is consistent with Lee and Langenheim's (1975) conclusion that occurrences of the taxon related to the transition from the wet tropics to the well-defined seasonality of the Cerrado and Caatinga.

Site

Ratter (1985) associates the taxon with Acric Ferralsols and Ferralic Cambisols in the central Brazilian state of Tocantins.

***Hymenaea courbaril* var. *stilbocarpa* in a Phytosociological Context**

Associated Species

Lee and Langenheim (1975) report association of *H. courbaril* var. *stilbocarpa* with the conspecific *H. courbaril* var. *courbaril* in northern areas of the Brazilian Cerrado. Southwards there is replacement of this mixture by pure *H. courbaril* var. *stilbocarpa*.

In a study in the National Park of Araguaia, Ratter (1985) found *Apuleia molaris* and *Vitex* cf. *polygama* consistently associated with the taxon, in four different forest types: semideciduous seasonal forest, evergreen seasonal (dry) forest, the Cerrado/dystrophic facies of the Cerradão and in the dystrophic facies of Cerradão/dry forest.

Relations with the Natural Fauna

As already stated, bats play the most important part in the pollination of the taxon (Lee and Langenheim, 1975; Kalin Arroyo, 1981; Crestana *et al*., 1985). Bees, wasps, butterflies and humming birds (Lee and Langenheim, 1975) are less important in pollination. López (1987) stresses the important role of the taxon in bee keeping, due to the preference of such insects for it.

Animals also play a role in dispersal which is important but secondary to that of water. Lee and Langenheim (1975) and López (1987) point out the dispersal of seed by animals such as rodents and peccaries but some controversy surrounds the way these animals 'disperse' the seeds. It is not known whether the seeds survive the journey through the animal's gut and after expulsion are in suitable conditions for germination.

Lee and Langenheim (1975) consider van der Pijl's (1975b) claims that *H. courbaril* var. *courbaril* fruits are dispersed both by tree and ground mammals unfounded, basing their argument on the fact that the woody, indehiscent fruit of that taxon contains a floury endocarp, which is dispersed by ground animals only.

Relationships with herbivores are likely to be influenced by secondary compounds in the leaves. Attention has been drawn (Langenheim *et al*., 1980) to the likely deterrent effect of resin phenolic compounds on mammalian herbivores (sloths, monkeys and rodents) observed feeding on *Hymenaea* leaves.

Arrhenius and Langenheim (1983 and 1986) attributed inhibition of pathogens, such as the leaf fungus, *Pestalotia subcuticularis* (Deuteromycetes), to resin present in *H. courbaril* var. *stilbocarpa*. Langenheim *et al*. (1982) examining resin leaf pockets of *H. courbaril* var. *stilbocarpa* (Fig. 6) found them presenting similar volumes and density both in center and leaf margin areas. This would deter generalist herbivores which feed at both margin and center of the leaf.

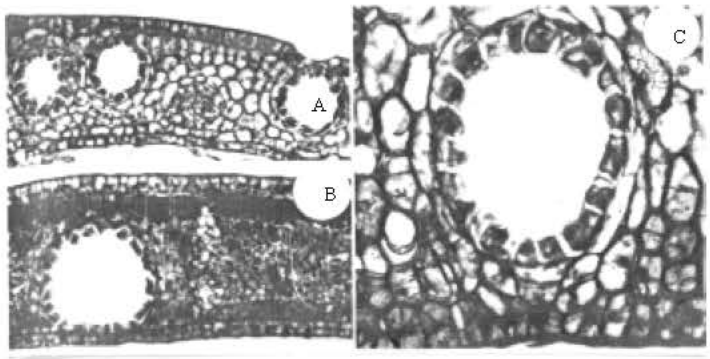

Fig. 6: Cross sections of *H. courbaril* var. *stilbocarpa* leaves. (A): pockets of developing leaf in bud, enclosed in stipules (x20). (B): Section of mature leaf showing location of pocket in spongy mesophyll below palisade tissue (x20) and (C): pocket in young leaf (x50). Source: Langenheim *et al*. (1982)

The composition of sesquiterpene hydrocarbons in the leaf resin detectable in seedling leaves persists as the leaf matures, at least qualitatively. One dominant sesquiterpene, caryophyllene, was found at all leaf life stages, though the amount was higher in seedlings and new leaves (Stubblebine and Langenheim, 1980; Crankshaw and Langenheim, 1981).

Relations with Forest Disturbance

There are few reports of occurrences in secondary vegetation but this may reflect the neglect of such habitats in vegetation survey. López (1987) reported presence in openings, at forest boundaries and in scrub vegetation and there are herbarium specimens at K from cut-over woodland in the Caatinga region (Lewis, 1987).

Silviculture and Management

Experience with Artificial Regeneration

Propagation

H. courbaril var. *stilbocarpa* is generally reported to reproduce only by seed (Salomão, 1990; Gurgel Filho *et al*., 1982). Lee and Langenheim (1975), however, point out that vegetative regeneration takes place, under natural conditions, with the conspecific *H. courbaril* var. *courbaril* (Mexico and Costa Rica).

Outplanting and Establishment

No known account of outplanting procedures has been seen but Salomão (1990) suggests for planting, a spacing of 4×2 m.

Performance of Planted Individuals

Not many planted stands of *H. courbaril* var. *stilbocarpa* seem to exist. It is planted in one site in the State of São Paulo and reported to be grown in two localities in Minas Gerais State (Lee and Langenheim, 1975; Salomão, 1990).

The best established silvicultural trial was set up in the 1950's and 1960's by Gurgel Filho *et al*. (1982). These authors investigated growth rates at different spacings: 1×1 m, 1×2 m and 2×2 m. Growth was slow, as in *H. courbaril* var. *courbaril* (Pereira, 1982).

López (1987), in contrast, reported moderate growth for *H. courbaril* var. *courbaril* (diameter increment to 1.3 cm $year^{-1}$) in good sites. Nevertheless, on poor soils slow growth resulted.

Management Attention in Forest Stands

Gurgel Filho *et al.* (1982) considered that due to the slow initial growth and sympodial branching (Troll's model-Hallé *et al.*, 1978), pruning of lateral branches is necessary at any tested spacing. They suggested growing *H. courbaril* var. *stilbocarpa* at wide spacing but associated with agricultural crops (taungya system) or in mixture with other tree species. They concluded also that the tree would not respond identically on different qualities of soil but that on the generally poor Cerrado soils it nevertheless grew satisfactorily. López (1987) also suggested the use of the tree through enrichment techniques due to its bad form in open stands.

Utilization

Wood Properties

Macro- and Microscopic Features

Information on wood properties is based on *H. courbaril* var. *courbaril*. Information specific to *H. courbaril* var. *stilbocarpa* is lacking.

López (1987) reviewing *H. courbaril* var. *stilbocarpa* -although probably referring to *H. courbaril* var. *courbaril*-reported yellowish white sapwood and dull pink to dark dull purplish heartwood. Other accounts for *H. courbaril* var. *courbaril* describe the heartwood as russet to reddish brown, often more or less streaked and rather dull on the surface but with a subdued golden glow beneath. It is sharply demarcated from the white or grey sapwood and without any distinctive odour or taste. The texture is medium to rather coarse and the grain is fairly straight to irregular (Loureiro and Silva, 1968; Record and Hess, 1972). Titmuss (1971) implies more variation, referring to broad, pinkish to yellowish sapwood and orange to dark brown heartwood and a medium-coarse and uneven texture with variable grain.

Loureiro and Silva (1968) and Titmuss (1971) present a macroscopic description for the genus *Hymenaea* as follows: diffuse porous structure, growth rings distinct to the naked eye, the boundaries indicated by lines of terminal parenchyma; vessels large and distinct to the naked eye, solitary, or subdivided radially, few in number, mostly open, with simple perforations in long, straight lines distinct to the naked eye; rays fine, usually visible to the naked eye in transverse section, where they are quite numerous, distinct on the radial surfaces, not distinct to the naked eye on the tangential surfaces; wood parenchyma very distinct to the naked eye, in concentric lines or bands, aliform about the vessels, with a tendency to become confluent; terminal parenchyma delimiting growth rings present; vertical gum ducts occasioually present.

Physical and Mechanical Features

It is a hard and heavy wood. The main physical and mechanical properties are shown in Table 3.

Use as Timber

Seasoning and Preservation

As with wood properties, information concerns *H. courbaril* var. *courbaril* in the absence of any on *H. courbaril* var. *stilbocarpa*.

With regard to seasoning, Chudnoff (1984) reports the wood as slightly difficult to air-dry but seasoning at a fast to moderate rate with only slight checking and warp. American kiln schedules are suggested for 4/4 (10×10 cm sample) and for 8/4 (20×10 cm sample) stocks.

Heartwood is not treatable using open-tank or pressure-vacuum systems but sapwood responds well to preservation (Chudnoff, 1984).

Durability and Workability

Loureiro and Silva (1968) and López (1987) point out the high durability of the wood of *H. courbaril* var. *courbaril* in contact with the ground. Conversely Titmuss (1971) stressed non-

Table 3: Physical and mechanical properties of *Hymenaea courbaril* var. *courbaril*

Property	Value
Density	753-1057 kg m^{-3}
Crushing strength	
Perpendicular to the grain	63.8 N mm^{-2}
Parallel to the grain	77.3 N mm^{-2}
Static bending	
Fibre stress at elastic limit	58.6 N mm^{-2}
Modulus of rupture	108.2 N mm^{-2}
Modulus of elasticity	14 844.9 N mm^{-2}
Endwise compression	59.7 N mm^{-2}
Hardness	
Radial	7251 N
Tangential	7429 N
End	8434N
Shrinkage	
Radial	4.5%
Tangential	8.5%
Volumetric	12.7%

Sources: Loureiro and Silva (1968), Titmuss (1971), Record and Hess (1972), Pereira (1982), Chudnoff (1984) and López (1987)

resistance to the depredations of wood-rotting fungi, advising use away from exposure to the weather. Record and Hess (1972) point out the disadvantage of using *H. courbaril* var. *courbaril* wood in contact with the ground due to its susceptibility to decay, even though there is considerable variation in the wood in this respect.

The timber is not easy to work by hand but is less problematical if machinery is used and finishes smoothly under a machine planer (Loureiro and Silva, 1968; Titmuss, 1971; Record and Hess, 1972).

Uses

Hymenaea courbaril var. *courbaril* wood used to be well known in European markets when there was an adequate supply for use in carpentry and all kinds of construction, such as civil construction, naval building, furniture, cabinet work, poles and rail sleepers (Lee and Langenheim, 1975; López, 1987).

Other Uses

Folk Medicine

The resin of a *H. courbaril* var. *courbaril* living tree is used as a tonic, as is the bark. The resin has increasingly been used as source of pharmaceutical drugs for various illnesses (Lee and Langenheim, 1975; López, 1987).

Indian Handicraft

The very thick bark is used to make canoes. The bark of a large standing tree is stripped in one entire large piece, sewn together at the ends, then waterproofed along the seams with resin and finally a wooden crosspiece is fitted to give the canoe shape (Lee and Langenheim, 1975).

Tannin

The bark contains tannin used commercially (Lee and Langenheim, 1975).

Resin

One very important product is the resin (South American Copal), exploited primarily in Brazil, for use in making varnish and, to a minor extent, incense. The main source of copal is the subsoil surrounding the roots of a tree or better still the former site of a large tree, long since decayed (Lee and Langenheim, 1975).

Food

Fruits are sold in local markets-the sought ingredient is the pulpy tissue surrounding the seeds (Lee and Langenheim, 1975; López, 1987).

Honey

The nectar produced by *H. courbaril* var. *courbaril* is much appreciated by bees (López, 1987).

Insects and Fungi Attack Protection

In a number of studies (e.g., Langenheim, 1981 and 1984) cited by Arrhenius and Langenheim (1986) defence properties in the leaf resin against the actions of insects and fungi have been identified.

Conservation Status

Present Conservation Status

The current conservation status for *H. courbaril* var. *stilbocarpa* is uncertain. There is no record of the taxon in the IUCN Red Data Book (WCMC Personal Communication, 1992).

Protection varies in effectiveness where the taxon occurs in federal, state or private protected areas, in Brazil.

Lee and Langenheim (1975) consider, however, that there is no significant threat regarding overexploitation because it is little in demand as commercial timber.

Individually, the small areas of gallery forests, which today are typical habitats, are vulnerable to degradation or even destruction and any *H. courbaril* var. *stilbocarpa* population present would suffer.

Present Conservation Priorities

Hymenaea courbaril var. *stilbocarpa* has been listed as a priority species for potential industrial use of the wood by the FAO Panel of Experts in Forest Gene Resources (Roche, 1987). The FAO Panel of Experts continues to list *H. courbaril* as high, global, regional and/or national priority species for programme conservation of forest genetic resources (FAO, 2002). It is also identified by Cenargen as a target taxon for the Cerrado region (Salomão, 1990). The potential is for use in the regional building industry and as a heavy hardwood: accordingly, conservation interest is in placing the resource under organized management to prolong and sustain availability.

DISCUSSION

This research deals with the conservation issue seen from a species-oriented viewpoint rather than the more commonly seen community-centered strategies. The approach followed draws on current conservation theory adapted to the circumstances peculiar to the reviewed taxon. Biological and genetic conservation frameworks for the species are then presented together with suggestions of priority conservation action.

Success in conserving the genetic variation of widely-distributed taxa depends upon sampling enough of the overall genetic diversity inherent to such taxa. This means that the protected populations must include a sufficient spectrum of genetic variability and therefore also an adequate spectrum of ecological variability. The importance of clinal variation, common in wide-ranging tropical species, has become increasingly understood through comparative provenance trials (Roche, 1984). For species-oriented programmes of genetic conservation it is essential that intraspecific genetic variation takes precedence over interspecific variation (Roche, 1984).

For successful implementation of genetic conservation, there must be a clear strategy reflecting the character of the species. Tropical woody species, such as *H. courbaril* var. *stilbocarpa* have long life cycles, are normally allogamous, have large individuals and mostly survive in a wild state. Consequently, relevant objectives for the strategy are refinement of biological knowledge and development of capability to introduce and breed the species where and as required. Such objectives also define which method of conservation suits a given species and, theoretically, dictates the size of population that must be conserved.

In view of our chronic lack of knowledge of many aspects of tropical species biology and ecology, *in situ* conservation measures merit the greatest investment of effort. This is because the *in situ* approach provides for maintenance of dynamic genetic variability more effectively than *Ex situ*. Whilst a level of management intervention may be needed to stabilize populations, our ability to achieve this is usually greater than our ability to create *Ex situ* stands containing an adequate representation of the gene pool.

The appeal of *Ex situ* conservation in recent years has been heavily based on theoretical considerations which do not apply for most tropical high forest species. Implementation of this approach appears most practicable for species which are not part of climax forests; this includes species of more open tropical formations and particularly those which are aggressive, light demanding and widely distributed (e.g., *Balanites aegyptiaca*-Hall, 1992). For the majority of species from the most humid tropical environments, however, very little has been achieved on the development of reliable methods of storage because of seed recalcitrance (FAO, 1990). Additionally, lack of research restricts our understanding of the extent to which seed storage is a safe method of conserving tropical woody species (Roche, 1975). Alternative approaches such as tissue culture remain unproven as realistic practical methods facilitating *Ex situ* conservation.

Efforts have been made to link key genetic conservation research areas presented by Roche (1975) and with knowledge on the target taxon. Gaps in our knowledge, such as those revealed in this study, were given particular attention. Despite these gaps, the available information can be used as a foundation for offering practical suggestions on potentially rewarding conservation approaches, following Hall's (1992) model for *Balanites aegyptiaca*.

The types of information needed to develop a conservation strategy are presented in Table 4, together with the appropriate data for *H. courbaril* var. *stilbocarpa*. A good deal is known about the

Table 4: Type of information required for conservation

Type of Information	Current knowledge relevant to the conservation of *H. courbaril* var. *stilbocarpa*;
1. Population status and structure	
Reflect mainly levels of stocking (individuals ha^{-1}) and prominence, represents distinctiveness of the species among constituents of the habitat.	Stocking levels uureported. Less than 4 trees = 15 cm dbh ha^{-1} (this study). Prominence mostly in central Brazil Cerrado.
2. Resilience	
(a) Physical	
The importance of resilience to physical disturbance agents, normally natural browsing, drought) or management' activities (selective logging, clear-felling, girdling) is in the definition of methods of protection and intervention to favour the species.	Little information on occurrences in disturbed areas remain doubtful whether this taxon is adapted for these
(b) Herbivores and/or pathogens	
The role of herbivores and/or pathogens is important to consider when com-mercial species are involved.	Leaves attacked by Lepidoptera and fungi and seed by curculionid.
3. Level of exploitation	
Exploitation of the resource relates to the degree towhichthe species is seen as economically important and under pressure in the current context.	Wood-based uses only locally exploited, then particularly for external applications. Non-wood uses promising-particularly resin-tapping and gathering activities.

Table 4: Continued

Type of Information	Current knowledge relevant to the conservation of *H. courbaril* var. *stilbocarpa*;
4. Level of rehabilitation	
Level of rehabilitation and resource creation cover capability in securing regen-eration as desired and in controlling agents antagonistic to establishment.	Some indications of success in enrichment plantings, but only moderately satisfactory growth and then often poor form in monospecific stands. Few silvicultural trials established.
5. Quantification and characterization of genetic variability	
Quantification and characterization of genetic variability are achieved through careful examination of collected material within the range of the species look-ing for variation at an infraspecific level, mainly by observation of phenotypic traits such as shape and size of leaves, fruits, seeds, bark.	Species with wide infraspecific variation, with six varieties. No assessment of variation among provenances from drier and wetter formations.
6. Ecological amplitude	
(a) Site	
Site represents the small-scale environmental variation (eg soil texture and composition and topographic features).	No available information.
(b) Vegetation formations	
Relates to the various phytogeographic forest formations present in the range of the distribution.	Mostly typical of gallery forests within the medium-tall grassland broad-leaved tree synusia (Cerrado) but also extending to thorny scrub (Caatinga) in the northeast and tropical evergreen lowland forest (Atlantic forest) on the coast.
7. Breeding system and reproductive biology	
(a) Sexual system	
Breeding systems and reproductive biology are important to ascertain by which type of reproductive system species populations are perpetuated.	Outcrossing is indicated for this monoecious taxon.
(b) Pollination and dispersal	
Important is insight into agents responsible for pollination and seed dis-persal.	Chiropterophily main pollination syndrome. Hydrochory main seed dispersal mechanism but zoochory also noteworthy
8. Seed biology	
Seed biology knowledge, involving knowledge of phases subsequent to fertilization (seed crop, pre-dispersal predation and dormancy patterns) is important for prediction of how much is produced and the proportion likely to germinate successfully.	
(a) Seed crop	Mast fruiting observed for conspecific var. *courbaril*. Seed weight = 270 kg^{-1}.
(b) Seed pre-dispersal predation	Weevil attacks on fallen fruits-despite physical (thick exocarp) and chemical (resin) barriers.
(c) Seed dormancy	No dormancy mechanism involved; seeds readily germinate.
9. Nursery technology	
Nursery technology, involving raising planting stock both as selected seedlings and as cuttings, is important for enrichment planting and intervention in a management scheme.	
(a) Seedling production	Germination high in nursery, but direct planting usually advised.
(b) Clonal production	Possibilities of planting cuttings worth investigating if sparse comments on sprouting ability for conspecific var. *courbaril* also confirmed for this taxon.
10. Forest policy	
The forest policy aspect relates to the extent of involvement of the legal authority and how actively it promotes law enforcement regarding con-servation matters for the species and how threats to it are curbed.	No immediate threat because demand is low and this disinterest could hamper efforts to conserve this endemic taxon.

wood properties, taxonomy and morphology of *H. courbaril* var. *stilbocarpa*. The available information about the distribution of the species could be used as a basis for locating potential *in situ*

conservation areas or for planning germplasm collections for provenance trials. However, to pinpoint precise locations to conserve the genetic variability of this taxon requires further refining of the maps; this must be based on visits to previous collection points as well as to new areas, in order to assess more fully the level of infraspecific variation. The species should also be considered in relation to its total range-a level of attention not feasible in the present study. *Hymenaea courbaril* var. *stilbocarpa*, as only one of several infraspecific taxa, needs appraisal in the context of the ranges and distribution patterns of the other varieties as well. Our ecological knowledge about the species, despite the relatively high number of sources, is inconsistent and incomplete. Our present information on reproductive biology of the taxon is also unsatisfactory. For *Hymenaea courbaril* var. *stilbocarpa* there are no indications of stocking.

Comparison of the distribution of the taxon with major soil units was made using the FAO-UNESCO (1971) soil map. *H. courbaril* var. *stilbocarpa* showed weaker relationships with fertile soils, while only patchy occurrences of the species are associated with richer soils. Information concerning the species artificial regeneration and management performance is poor.

Information on the conservation status is very little. More noteworthy, however, is the consistent association with several other target taxa on the FAO Panel of Experts on Forest Gene Resources list (Roche, 1987). This was the basic document used by Cenargen to choose target species for the national programme of genetic conservation in Brazil. The main priorities of this programme are the establishment of genetic reserves wherever possible and particularly in existing protected areas. Additionally, *Ex situ* conservation is sought through setting up germplasm banks and provenance and progeny trials. *In situ* genetic reserves should, however, be as large as possible to alleviate problems of genetic drift and consequent depression of genetic variability that can be expected in the existing small reserves. Both *in situ* and *Ex situ* methods require management. Comments on non-immediate threat to *H. courbaril* var. *stilbocarpa* as resource should be treated with particular caution.

In summary, despite our limited knowledge about *H. courbaril* var. *stilbocarpa*, we conclude that is typical of many thinly dispersed, outcrossing, tropical forest trees which are at risk as forest disturbance levels increase and individuals become increasingly isolated. The species also stands alone for its hydrochory and high seed weight.

Of the recognized protected areas (Sharpe, WCMC, Personal Communication, 1992) in Brazil, theoretical conservation suggests few qualify as effective both in size and legal status for the long term conservation goals of forest genetic resources. A more practical listing of potentially viable protected areas is one according with Ibama's definition (Gonchorosky, Personal Communication, 1992) of conservation units of indirect use natioual parks, biological reserves, ecological stations) and direct use (natioual forests and extractive reserves).

Consideration of the species and its distribution within Brazil in relation to the WCMC map of protected areas (Sharpe, Personal Communication, 1992) can be done only on a very tentative basis at present. Nevertheless, it is appropriate to associate occurrences of the taxon with the protected areas to the extent possible.

This was done by showing the distribution of protected areas which have had some more attention regarding their floristic composition, enabling, therefore, to have a picture of the occurrence of the species in such areas (IBGE, 1993). Figure 7 shows a map where these areas are located.

Hymenaea courbaril var. *stilbocarpa* is supposedly represented in some of protected areas: The Natioual Parks of Chapada Diamantina (Caatinga), Araguaia, Brasília (Cerrado), Itatiaia and Serra do Cipó and the Biological Reserve of Poço das Antas, in the center-south.

There is need for enhanced protection in a number of areas throughout the ranges of the taxa (Fig. 7). For *Hymenaea courbaril* var. *stilbocarpa* there is clear need for protection measures to secure survival of the disjunct populations in Amazonia (neighbouring Belém, in the State of Pará), to the north of Brasília and localities in the interior of the State of São Paulo. Protection of outlying populations is important due to the likely genetic variability existent in them when compared to the core of the range populations.

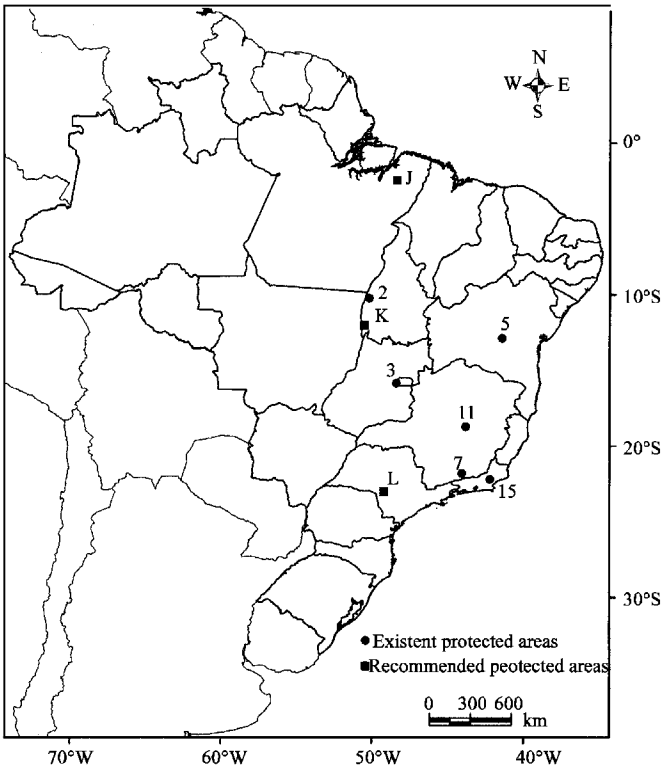

Fig. 7: Distribution of existent protected areas with *Hymenaea courbaril* var. *stilbocarpa*: the National Park of Chapada Diamantina (5) in the Caatinga; the National Parks of Araguaia (2), Brasília (3) in the Cerrado and the National Parks of Itatiaia (7) and Serra do Cipó (11) and the Biological Reserve of Poço das Antas (15), in the center-south. Recommended potential protected areas in Brazil regarding *Hymenaea courbaril* var. *stilbocarpa* conservation: in Amazonia -neighbouring Belém, in the State of Pará- (J), to the north of Brasília (K) and localities in the interior of the State of São Paulo (L). Current protected areas based on IBGE's (1993) map.

Basically, there are three practical options for tackling the conservation problem: traditional *in situ* reserves, normally in existing protected areas or specifically designated genetic conservation reserves; traditional *Ex situ* stands, mostly provenance and progeny-sometimes silvicultural-trials; a compromise approach which is based on enrichment action to favour the targeted species.

Considering the current situation of protected areas in Brazil, the geographical distribution patterns of the taxon and the little that is known of its population structure, some recommendations can be put forward for genetic conservation programmes. *Hymenaea courbaril* var. *stilbocarpa* should be conserved *in situ* in additional areas in the northern Cerrado region. These should be established in gallery forests, as much as possible along major watercourses presenting adult individuals at their banksides to facilitate water dispersal of propagules to downstream areas.

With present capabilities, the species is refractory in schemes of enrichment plantings and planted stands, possessing seed not amenable to nursery work because of poor germination levels. Nor is it suited for pure plantings-enrichment stands are more appropriate for it. Provision to exclude fire and protect seedlings recently planted out is vital-implying their use within established mixed stands. With

so many gaps in the silvicultural/management/conservation picture it is important that new initiatives should be on a planned and focused basis centered on identified priorities and not merely opportunistic. For *Hymenaea courbaril* var. *stilbocarpa*, while hydrochory is accepted as the primary main dispersal mechanism, a role believed to be of considerable importance is played by animals-since there are trees at high points in the landscape adjacent to gallery forests and other riverine habitats which are never submerged.

The organizations with a mandate to advise on national conservation policy need to make a convincing case to the legal authorities and decision-makers of the implications of neglecting to declare the additional protected areas needed to secure a viable gene pool of the resources considered in this study and pinpointed in Fig. 7. One vital area of experience is in seed collection expeditions: already there has been successful collecting of other target species seed and, additionally, extending activities to storage and testing and nursery establishment would constitute logical extension of the work done on those species to others requiring similar action. Longer-term, more involvement in provenance and progeny trials-as has already started with other species-can be foreseen for other taxa. Teams dealing with reconnaissance surveys or inventories to identify areas (protected or with potential) containing the target taxon should also pay special attention to assessing population structure aiming at future rehabilitation (compromise) action. A major role is played by the 'Instituto Florestal' (Forestry Institute) of the State of São Paulo in forest genetic conservation in Brazil. Because most of the actions utilizing *Ex situ* and the compromise (enrichment) approaches are concentrated in a region around that State, it is wise to have their collaboration in these programmes. It is clear, after what has been discussed in this study, that despite the dearth of current knowledge, technical solutions for the conservation of forest genetic resources followed by action (breaking away the notorious verbosity generally encountered in the subject) are possible. Hopefully, scientific advice will be followed by political will to fulfil expectations.

CONCLUSIONS

The background level of effectiveness and versatility of the system of protected areas in Brazil is still poor, as far as conservation of forest genetic resources is concerned. Few examples of the main categories of protected areas with a bearing on conservation and management (national forest and extractive reserve) of the resource, through intervention, contain the species (Fig. 7). Indeed, the majority of existing areas containing *Hymenaea courbaril* var. *stilbocarpa* are 'indirect use' categories (national park, biological reserve, ecological station), as shown in Fig. 7 and no management actions are expected to favour the species studied here due to the non-intervention policy followed by Ibama. Such management actions are better directed to the conservation problem, in genetic reserves (*in situ* conservation) and formal planted stands (*Ex situ* conservation) established by the scientific authority, as can be shown in Fig. 7. There is no initiative concentrating on alternative conservation approaches, such as enrichment planting, to complement traditional ones.

There has also been little implementation in the country of conservation options developed over the last few years from the increasing ecological understanding of tropical forest ecosystems. Much current activity takes insufficient account of the high diversity and low population densities of neotropical forest tree species. The vulnerability of the Cerrado formations to conversion for other land use makes application of effective conservation an urgent need.

Hymenaea courbaril var. *stilbocarpa* is a relatively well-known taxon in terms of biology, with a much sounder taxonomy than the others. As commercial use has declined, this has been reflected in currently reduced silvicultural interest. Inclusion on Embrapa's list indicates the need to revive this interest.

Vital aspects important for traditional *in situ* and *Ex situ* conservation are lacking and, additionally, there is poor legal protection in established areas. Compromise measures, basically through enrichment (e.g., mixture) with local seed source, are therefore urged to compensate for this. As conservation target, *Hymenaea courbaril* var. *stilbocarpa* is noteworthy for its association with watercourses in less disturbed forest.

RECOMMENDATIONS

The following recommendations are made, with respect to the conclusions above, to assist the national conservation programme.

The patchy characteristics of forest formations in central Brazil Cerrado and the increasing fragmentation of more populated areas in the northeast and the center-south, require that tackling the conservation problem should take into account the island-like nature of the habitats-habitats where conditions favour high rates of inbreeding, progressive loss of genetic diversity and, in the long run, extinction of species. To curb this, a network of local or, ideally, regional protected areas has to be established containing preferably direct categories, but not disregarding the possibility of creating 'indirect' categories when the opportunity arises. A significant increase in the number of even small protected areas contributing to a larger network would increase chances of survival of species for long term purposes. This network has to be supported by complementary approaches to favour thinly dispersed forest species by including sites which serve as links between more widely separated areas.

This could involve the use of enrichment techniques with germplasm from nearby sources.

Hymenaea courbaril var. *stilbocarpa* as only an infraspecific taxon should have conservation attention extended to the whole species circumscription and the seed technology should be investigated in more detail to allow a vigorous expansion of the network of trials and, additionally implementation of vigorous *in situ* and *Ex situ* schemes, adopting progressive strategies such as planting in mixture.

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