YIELD, SUSTAINABLE HARVEST AND CULTURAL USES OF RESIN FROM THE COPAL TREE (*Protium copal;* BURSERACEAE) IN THE CARMELITA COMMUNITY FOREST CONCESSION, PETÉN, GUATEMALA

by

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ABSTRACT

A three-part study was conducted on *Protium copal* (Burseraceae) in the lowland tropical forests of northern Guatemala with the principle objective of providing preliminary data for the potential exploitation of its resin. Part one investigated the potential resin yield of an area within the Carmelita Community Forest Concession (CCFC), in the department of Petén, by tapping copal trees for sixteen weeks using two tapping methods (T1 and T2). A selection of environmental and biological variables was recorded. Part two monitored the tapped trees and a sample of untapped copal trees within the study area for weekly levels of phenological activity. Part three consisted of an ethnobotanical survey of the local knowledge of the copal tree, conducted with twenty individuals from four communities near the study area knowledgeable in local forest plants and their uses. The results from the resin yield study indicated that the variables that described tree size and health were the greatest determinants of resin production, although unpredictable tree-to-tree variability in resin-producing capacity was shown to significantly influence resin yield. No significant difference was observed between the two tapping methods in terms of resin yield, but T1 provided a cleaner resin that required less time and effort to collect. A conservative estimate of resin production in the study area is 2.4 kg/ha, providing a preliminary estimate of 66, 000 kg of resin for the CCFC per year with a tapping period of sixteen weeks from February to May. Overall phenological activity rose significantly from mid to late February (flowering), and from early to late April (fruiting and new foliage). The level of tapping used in the study had a significant and positive effect on phenological activity on two of the sixteen data collection dates. The ethnobotanical survey revealed the resin is the most commonly used part of the copal tree. The resin is best known locally for its use as ceremonial and healing incense, but also has many medicinal functions, including the relief of muscular pain, arthritis, rheumatism, treatment of cavities, removal of various skin ailments and in the treatment of wounds and bruises.

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INTRODUCTION

The development of agriculture, and later, industrialisation, fundamentally changed how the human race interacts with the natural world. A distinctive characteristic that has evolved as industrialised countries continue their rapid development is a perceived independence from the environment. This perception is inaccurate, and threatens the survival of intact ecosystems by disregarding their value, a value that is not only aesthetic but also economic, owing to their inherent biodiversity. Numerous factors have contributed to current circumstances of catastrophic loss of species and habitats in all countries of the world, no more clearly seen than in the rain forests of the tropics. Striving to preserve what remains of these vast repositories of biodiversity is the goal of many conservation initiatives.

Initiatives that work toward maintaining ecosystems must include economic considerations in order to be successful, and in tropical forests that means seeking alternatives to the short-sighted practices of large scale timber extraction, or land conversion to agriculture and livestock production, that offer equal or higher economic gains. One such alternative is the extraction of non-wood or non-timber forest products (NTFPs), a diverse assortment of products ranging from fruits, seeds, nuts and fibres to a variety of plant exudates and extracts for medicinal, aromatic, even herbicidal and insecticidal purposes (Isman *et al* 1997, Laird 1995, Peters 1996). No longer considered "minor" forest products, the potential and realised revenues earned from the harvest of NTFPs have been shown to compete successfully with timber extraction and agriculture (Balick and Mendelsohn 1992, Jahnige *et al.* 1993, Reis 1995 cite Gillis 1986, Myers 1988 and Peters *et al.* 1989).

Jahnige *et al.* (1993) assessed the harvest levels, market prices and extraction costs of a selection of commonly sold NTFPs from three hectares of forest area in the Upper Napo region of Amazonian Ecuador to determine the potential revenues obtainable, and compared those to the potential revenues from timber harvesting and cattle ranching from the same three hectares of forest area. The study found the values of the NTFPs in three sites to be US$2939/ha, US$2721/ha and US$1257/ha, on an annual sustainable basis, while the harvest of timber in the same areas (calculated on a 40-year rotation) was valued at US$188/ha/year, and cattle ranching at US$57/ha/year.

The sustainable harvest and trade of NTFPs can be a viable activity (economically and ecologically) in most tropical forests where there are forest-dependent communities, and can also be integrated with ecologically sensitive timber extraction and small-scale agriculture within well-designed sustainable forest management regimes (Howard and Valerio 1992, Laird 1995, Reis 1995, Richards 1996, Schmincke 1995). In Quintana Roo, Mexico, for example, a community forest management plan combines the sustainable harvest of wood and non-wood products. The two principal species managed are mahogany (*Swietenia macrophylla;* Meliaceae), the wood species, and chicozapote (*Manilkara zapota;* Sapotaceae), the non-wood species. Half of the total revenue comes from the latex and honey of the chicozapote tree (Reis 1995).

Gianno (1986) describes a tradition of resin harvest from *Dipterocarpus kerii* (Dipterocarpaceae) by the Semalai people of Tasek Bera in the lowland forests of central Malaysia in which damar (resin) is harvested from trees that live for more than one hundred years, being passed through multiple generations of a tapping family. The people in this area continue to earn their livelihood through swidden agriculture, fishing, hunting and the forest products trade, living within a forested area without destroying it. The ancient practise of damar collection works to "preserve the ecology of the primary forest while extracting economic products from it" (Gianno 1986). Another resin-tapping culture exists in Honduras, where species of *Pinus* (Pinaceae) are tapped for resin, and a number of other forest products are harvested through sustainable techniques, serving as an example of community-based sustainable forest management in a country facing escalating deforestation; "communal resin tapping is a … collective action that safeguards natural resources and generates income for agriculturalists" (Stanley 1991).

Subsistence levels of non-timber, and timber, forest product harvesting in areas where human populations are low represent systems in which the integrity of the forest ecosystem has long been maintained. Ecological concerns arise when extraction of particular products on a commercial scale is undertaken, or when rapid population increases result in over-exploitation forested areas. In this case, significant management of these resources is required, in which there is sufficient extraction of products and/or cultivation of the land to maintain local communities without depleting the available resources irreversibly (Laird 1995). A good definition of sustainable forest management is given by Howard and Valerio (1996) as follows: "the cultivation and exploitation of timber and non-timber resources for economic gain leading to a perpetual, periodic yield of marketable products with strict preservation of capital". The capital referred to in their definition includes both the soil resources and appropriate species composition and stocking level of forest cover to "maintain the biological potential for production of marketable products" (Howard and Valerio 1996).

Much study has been devoted to the development of management systems that provide constant flow of timber yield without depleting the commercial species, in both tropical and temperate forests. Relatively little is known however, about the ecological needs of commercial timber species in tropical forests, particularly in terms of regeneration, or about the effects that harvesting them has on other species. Even less is known about the commercial harvest of tropical non-timber species. The complexity of tropical forest systems, due largely to high species diversity, makes understanding the effects of forest product extraction on the ecosystem a particularly challenging task. For every product deemed valuable enough to extract, extensive baseline data must be collected before extensive harvesting begins. Equally important is the subsequent monitoring and evaluation of its extraction in the long term (Gould *et al.* 1998, Hall and Bawa 1993, Ndibi and Kay 1997, Peters 1996).

The current study offers preliminary data on a specific NTFP, the medicinal and fragrant resin of the copal tree (*Protium copal;* Burseraceae), a sub-canopy tree found in the lowland forests of the Yucatan, Central America.

In the discussion that follows, literature from three fields of study is reviewed: 1) resin yield studies, 2) phenology of tropical tree species, and 3) ethnobotany. These fields are reviewed because the present investigation incorporates aspects of all three, and objectives and hypotheses relating to each component are given. The information gathered concerning the family Burseraceae, the genus *Protium* and the species *copal* is also presented.

Resin Yield Studies

Due to the absence of scientific studies on *Protium copal,* this component of the review will refer to studies that investigate the yield aspects of other resin-producing species, and is organised into four sections. Section one will distinguish resins from other plant exudates and give a brief history of resin use. Descriptions of a selection of classes of resins and where they are harvested will also be included in this section. Section two will briefly outline the anatomical features and physiological processes involved in resin production, and will discuss a number of variables that affect resin yields. Section three will provide a brief review of live-tree tapping techniques and the use of chemical stimulants. Finally, section four will discuss issues in sustainable resin harvest and the importance of monitoring the effects of resin tapping on individual trees and on species populations.

Yield Section One: Definitions of plant exudates, uses of resins and regions in which they are collected

Humans have harvested many different kinds of plant exudates for thousands of years, and many have gained commercial importance. It is beyond the scope of this review to explore all of these products, but three of the well-known ones – gums, latices and resins – will be introduced here.

Historically, the words "gum", "resin" and "latex" have been used interchangeably to refer to plant exudates in general, especially by the industries that harvest and refine such materials. Rubber, chicle, gum arabic, naval stores (turpentine and rosin), damar and copal are examples of products that have been exploited and traded in the past, and continue in commerce today. There are, however, distinct differences in these materials.

Rubber and chicle are examples of **latices**; milky white fluids characterised by their elasticity, water repellence and electrical resistance (Funk and Wagnalls 1975). They are a homogeneous suspension of droplets of organic matter in an aqueous solution (Coppen 1995). Gum arabic, as the name implies, is classified as a **gum**. Gums are solid mixtures of polysaccharides, and their defining property is that they are essentially soluble in water, or at least absorb water and take on a jelly-like consistency, but are not affected by organic solvents (Coppen 1995, Howes 1949). The opposite is true for **resins**, examples of which are the damars and copals. Resins are essentially soluble in a number of organic solvents, such as alcohol, ether and hexanes, yet are insoluble in water. When heated resins melt to a sticky fluid, provide a flame upon burning and are resistant to most reagents and to decay (Gianno 1986, Howes 1949). The name "oleoresin" is given to resins containing large proportions of oil, such as the oleoresins of the naval stores industry, the source of turpentine and rosin. The oil fraction makes oleoresins characteristically soft, often with the consistency of a viscous liquid. Table 1 briefly outlines some of the major types of exudates that are harvested.

Table 1. Brief overview of some exudates that are harvested for industrial and other uses (compiled from Coppen 1995 and Howes 1949).

EXUDATE GROUP	**LATEX**	**GUM**	**RESIN**		
			HARD RESINS	**SOFT RESINS**	**FLUID RESINS**
Properties	Milky white fluid; elastic, water repellent, electrical resistance	Soluble in water to varying degrees, insoluble in organic solvents	Insoluble in water, soluble in organic solvents	Insoluble in water, soluble in organic solvents	Properties of hard and soft resins, but contains high percentage of oil.
SUB-GROUP			COPAL DAMAR	ELEMI	OLEORESIN BALSAM

The harvesting of resins and resin-like exudates dates back to the earliest histories of aboriginal tribes in Australia, Africa, Asia and America, where they were tapped for use as fuel for torches, boat caulking, food, and medicines (Bhatt *et al.* 1989, Gianno 1986, Ibrahim *et al.* 1987). Ancient Egyptians used resins in embalming. Frankincense and myrrh have been valued sources of incense for milliena, and many early medicines came from the soft and fluid resins (Smith *et al.* 1992). Resins later gained widespread use in the naval industry as a protective coating on wooden ships, hence the name "naval stores" (Howes 1949). More recently, resins have been used in the manufacture of varnishes, lacquers, paints and linoleums, as perfume fixatives, and as constituents in printing inks, sizing materials, plastics, soaps, floor wax, shoe polish, axle lubricants, sealing waxes, water-proofing materials, adhesives and a number of pharmaceuticals (Bhatt *et al.* 1989, Canopy International 1994, Chaudhari *et al.* 1996, Ella and Tongacan 1992, Gonzales *et al.* 1986, Ibrahim *et al.* 1987, Mathauda 1959).

Resins are usually complex mixtures of terpenes, terpenoids and phenolic compounds (Coppen 1995, Langenheim 1990), but they can vary greatly. The majority of the oleoresins are harvested from *Pinus* spp. (Pinaceae), from which turpentine and rosin are distilled in the naval stores industry. The commercial tapping of some species of pine lasted for nearly two centuries in France, Spain and Portugal (Tsoumis 1992). Other countries with a history of tapping for oleoresin are India, Pakistan and the East Indies, Russia, Poland, the Philippines, Brazil, Argentina, Honduras, Mexico and the United States (Coppen and Hone 1995). The high cost of labour in industrialised nations where resin used to be tapped has caused the centres of production to shift to Southeast Asia (Smith *et al.* 1992, Tsoumis 1992). Currently, the People's Republic of China dominates production and world trade in pine resins, followed closely by Indonesia (Coppen and Hone 1995). A substantial body of scientific literature exists concerning this class of resins, and will be reviewed to some extent in later sections.

Copal and damar are two well-known types of hard resins. The copals (not to be confused with *Protium copal*) are a group of resins known for their hardness and high melting points. Obtained today mostly from species of *Agathis* (Auraucariaceae) in Southeast Asia, copals have also historically been collected from the family Leguminosae, from species of *Copifera* (the Congo and West Africa), *Trachylobium* (East Africa), and *Hymenaea* (South America). In the past, the copals were largely collected in fossilised form. Now however, most copal resin intended for industrial use is tapped from living trees. Historically used extensively in varnish, lacquer, paint and linoleum manufacture, a steady demand for copal resins continues to exist today (Coppen 1995, Howes 1949).

The damars are a group of resins harvested from a number of genera in the Dipterocarpaceae, principally in forests of Malaysia and Indonesia. They are different from the copals in that they are not as hard or durable, and are freely soluble in turpentine and coal tar hydrocarbons. Their pale colour and good solubility has made them valuable in the production of white enamels and paper size (Howes 1949).

Of the soft resins, only the elemi resins will be discussed here. They originate almost entirely from the Burseraceae and have been commercially harvested in the Philippines, Mexico, Brazil, the East and West Indies, Africa, Malaysia, China and Indonesia (Howes 1949). They have been employed to a limited extent as constituents in varnishes and printers inks, but have been more commonly used in medicines and pharmaceuticals (Bhatt *et al.* 1989, Morton 1981). Their use as ceremonial incense is also well documented (Bhatt *et al.* 1989, Howes 1949, Von Reis and Lipp 1982). The resin of *Protium copal* is considered an elemi resin (D. Daly, personal communication).

Yield Section Two: Resin formation and factors that affect it

Tapping living trees can be thought of as the controlled wounding of a tree. The subsequent exudation of resin is the tree's defence against the possible microbial or insect attack of the wound (Langenheim 1990). Resin is found in intercellular spaces of resin-producing trees, called resin canals, which extend from leaves to roots. Resin canals are lined with the specialised epithelial cells that produce and secrete resin into the canals (Ella and Tongacan 1992, Tsoumis 1992). Generally, the canals are longitudinally and radially placed in all parts of the stem (bark, cambium, sapwood and heartwood), and are interconnected where they cross. Figure 1 depicts a cross-section of a trunk of Aleppo pine (*Pinus halepensis*) and microscopic views of resin canals (Tsoumis 1992, pp 103-4).

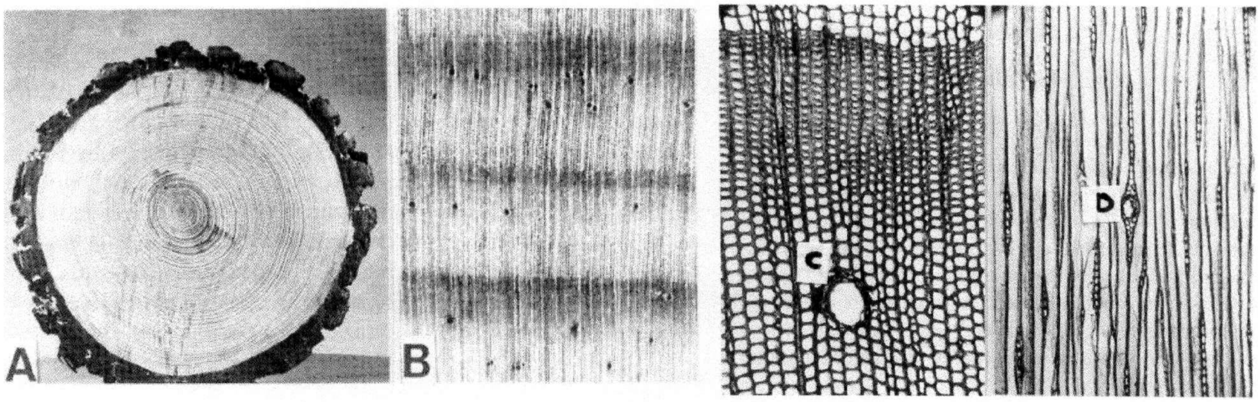


Figure 1. A. Cross-section of a trunk of Aleppo pine (Pinus halepensis) showing heartwood, sapwood and bark. B. Growth rings and resin canals magnified (x 10). Microscopic appearance of C. longitudinal and D. radial resin canals (x 50). Source: Tsoumis 1992, pp 103, 104.

In *Pinus* spp. The traumatic resin canals that form after wounding (e.g. resin tapping) also exude resin, even in species that are not normally considered to be commercially valuable resin-producing species (Tsoumis 1992). This may occur in other resin producing trees as well.

Considerable research has been undertaken to determine the variables that influence resin production in the species of *Pinus* tapped commercially. There are two kinds of variables that affect resin yield: those concerning the characteristics of the trees and the surrounding environment ("biological and environmental" variables), and those placed on the tree by the harvester or experimenter ("imposed" variables). Some of the tree characteristics and environmental factors that have been investigated for their influence on resin yield are diameter at breast height (DBH), crown ratio (the ratio of crown length and total tree height), mean ring width in the last inch of radial growth, seasonal variation, rainfall and location or site.

Studies attempting to determine the relationship between DBH and resin yield have only been able to show general tendencies and weak correlations, but the general conclusion that can be drawn is that larger diameter trees give higher yields of resin (Chaudhari *et al.* 1992, Ella and Tongacan 1987, Gonzales *et al.* 1986, Halimahton and Morris 1989, Low and Abdul Razak 1985, Orallo and Veracion 1984, Ordinario and Tongacan 1979, Schopmeyer and Larson 1955). In a number of these studies, however, yields were found to be lower for some of the trees in the larger DBH classes than for trees in the smaller DBH classes (Chaudhari et al. 1992, Gonzales et al. 1986, Orallo and Veracion 1984, Ordinario and Tongacan 1979). Orallo and Veracion (1984) speculate that it may be the advanced age of large trees that made them less productive, while Gonzales *et al.* (1986) suggest that smaller diameter trees might be physiologically more active than larger trees.

Crown ratio, mean ring width, seasonal variation, rainfall and location are also biological and environmental variables that have been shown to have significant effects on yield. Similar to the relationships seen with DBH, higher crown ratio and greater mean ring width resulted in higher yields in a study conducted by Schopmeyer and Larson (1955).

With regard to seasonal variation and its effect on resin yield, most studies showed higher yields during particular months or seasons, and lower yields in others (Bhatt 1987, Bhatt *et al.* 1989, Chaudhari *et al.* 1996, Gonzales *et al.* 1986, Mathauda 1959, Singh 1964). Seasonal factors in these studies were usually defined as different levels of rainfall rather than temperature because they were conducted in tropical or subtropical regions. The influence of rainfall on resin yield has been shown to be significant (Ella and

Tongacan 1987, Gonzales *et al.* 1986), but the direction of the relationship between resin yield and monthly rainfall (or seasonal variation) was shown in some studies to be negative and others to be positive. Bhatt *et al.* (1989) collected the highest resin yields of *Commiphora wightii* (Bureseraceae) in the dry season at Vasad in the Gujarat State in India. These researchers suggested that yields were highest in the dry months because trees during these months had no leaves and were not undergoing reproductive processes, allowing reserve metabolites to be directed to the production of resin. In the rainy months, when low resin yields were observed, the authors hypothesise that resources were directed to reproduction rather than to resin formation. In contrast, Ella and Tongacan (1987) found oleoresin yields of *Anisoptera thurifera* (Dipterocarpaceae) in Barangay Llavac, Philippines, to be the highest during the months receiving the greatest amount of rain. Speculation as to the causes of the result observed was not offered.

Although it appears that the results of these two studies are conflicting, the regional climate in which these studies were conducted may have had an influence on the way the trees, and therefore resin production, responded to changes in the level of rainfall. The climatic conditions in much of the Philippines are humid, with trees accustomed to high rainfall. It may be that with a decrease in rainfall, resin-producing trees in humid tropical forests respond by slowing the production of resin in order to conserve metabolites, water and nutrients. In much of India, dry climatic conditions prevail for most of the year, punctuated by seasonal monsoon rains, and trees are adapted to these conditions. Sudden and significant increases in rainfall may be the environmental cue for the onset of reproduction that trees in these regions respond to, and resources might then be allocated to reproductive processes before resin production.

Ella and Tongacan (1992) present a summary of what they consider to be some of the most important biological and environmental variables that affect resin yield. They suggest that the **vigour** or health of a tree has considerable influence on the amount of resin it will yield, and that vigour is seen in the crown density and size of a tree. The size of the tree generally refers to the DBH. DBH is directly related to the amount of trunk surface area in which the resin ducts are located. They further submit that crown density is important because the processes of photosynthesis and metabolite production take place in the leaves, and that when more metabolites are produced, more are available for resin production.

A second important influencing factor proposed by Ella and Tongacan (1992) is **location**, or more specifically, **site**. Site characteristics include stand density, soil conditions, drainage, competing vegetation, and microclimatic conditions including humidity, light exposure, and aspect. The importance of site and soil conditions was seen in the 1987 study conducted by Ella and Tongacan, where they hypothesised that soil moisture may be as important, if not more so, than rainfall. Their study resulted in the second highest resin yields being collected in the month that received the lowest rainfall. However, this month was preceded by the three months of very high rainfall and correspondingly high yields. They suggest that due to the previous heavy rainfall the moisture in the soil allowed for high resin production in the following month of low rainfall.

The third variable discussed by these authors is that of the **inherent capacity** of each individual tree to produce resin. This is the genetic component that allows two trees of approximately the same size, in similar physical condition and located in the same site to have completely different resin yields (Gonzales *et al.* 1986). This variable is probably one of the most important factors influencing resin production in tropical forests, based on the lack of success of any of the studies reviewed to provide broadly applicable (across a species) correlations with predictive capacity between any of the variables measured and resin yield.

It is clear from the preceding discussion that a number of biological and environmental variables influence the resin yields obtainable from resin-producing trees, and that probably no single variable can be used to accurately predict these yields. It is only possible to provide general estimations based on a number of physical characteristics and environmental factors that are limited to a particular site.

"Imposed" variables refer to how yield is affected by different tapping techniques or by stimulation through the use of various chemicals, and are discussed in the following section.

<u>Yield Section Three: Resin tapping techniques and stimulants</u>

Detailed descriptions of tapping techniques were difficult to find in the literature but a few brief accounts indicate that methods vary greatly. A number of the traditional methods used now and historically by the indigenous peoples of the neotropics and Southeast Asia are considered by some researchers to be destructive to the trees and therefore unsustainable if practised on a large scale (commercial harvest). Most of these methods use fire to stimulate the flow of resin (Gianno 1986), while others involve beating parts of the trunk (Smith *et al.* 1992). The intention of much of the research documented in the literature is to replace these methods with less destructive techniques.

The common tapping technique used to extract the damar resin of the Dipterocapaceae prominent in Southeast Asia is called "boxing". The sustainability of this method is unknown due to a lack of documentation regarding the effects of its long-term use, but some of these trees are tapped for generations (Gianno 1986). Messer (1990) describes boxing used in Sumatra to harvest the damar of *Shorea javanica* (Dipterocarpaceae). Three or four vertical rows of 30 to 40 small holes (3 cm diameter, 2 cm deep) are cut into the lower 1 to 2 m of the trunk. The holes are then covered with a piece of bark for a month. This process is carried out to "prepare" the tree for later resin tapping, a necessary step to induce good yields. A period of preparation or conditioning to stimulate resin flow is commonly required in many resin-producing species (Bhatt *et al.* 1989, Gianno 1986, Messer 1990, Tsoumis 1992). After a month the bark is removed and any exuded resin or newly formed periderm is stripped away, and the bark is replaced. This procedure is carried out for six to twelve months even though the holes normally fill with resin after three months. When there is sufficient resin exudation from the small holes, larger triangular holes (10 to 15 cm on a side, 5 to 10 cm deep) are cut in the bole where the resin collects (Messer 1990). Gianno (1986) further indicates that these triangular holes ideally have a floor that slopes downward away from the mouth. The tapper returns every seven to eight days to collect the exuded resin (ladled out), after which a fire is lit inside the box. The purpose of the fire is to clean away the hardened resin left after scraping, and to stimulate the flow of the resin. The fire is allowed to burn for approximately three minutes, at which time it is smothered and the blackened tinder is scraped out (Gianno 1986).

A common method that was used on *Pinus* spp. for many years in countries such as Russia, the United States, Pakistan and India is called the "wood chip" method, in which cuts into the sapwood are made. Tissue re-growth, or "healing of the wound" in this case, is slow because wounding is extreme and the cambium is completely removed. Due to slow wound recovery there is significant risk of infection by microorganisms, fungi and/or insects because the xylem cells of the sapwood offer no resistance to microbial attack (Tsoumis 1992). This technique involves chopping a "streak", a horizontal or angled strip of varying widths into the stem, and returning at particular intervals to collect the exuded resin. After each collection, the streak is enlarged, chipping away bark and wood on the upper portion of the original streak. This is called "freshening". This process continues throughout the collecting season or until the "blaze" (the vertical "face" of the cumulative streaks) reaches the highest point of the bole that can be tapped. The process may then be repeated at another point on the trunk (Tsoumis 1992). This method is rarely used now due to the unnecessary damage inflicted on the trees. The damage is unnecessary because in most resin-producing tree species resin canals are found in the bark in equal (or greater) numbers than in the sapwood (Bhatt *et al.* 1989, Ella and Tongacan 1992, Tsoumis 1992).

Shortly after World War Two a new method was developed in which streaks are cut only as deep as the bark, and chemical stimulation is employed (Howes 1949). The chemical most commonly used in resin stimulation is sulphuric acid, at concentrations between 20% and 50%. This method is referred to as the "bark-chip" or "bark-hack" method. The purpose of the chemical stimulant is to prolong the flow of resin by inhibiting coagulation, thereby reducing the necessity of frequent freshening and increasing resin yield. Figure 2 presents excellent photos from Tsoumis' 1992 book *Harvesting Forest Products* showing a variety of tapping and collection systems used in different pine resin producing countries.

Studies that have examined the effects of tapping techniques and chemical stimulation on resin yield have experimented with combinations of different chemical concentrations, varying streak widths and depths and/or frequencies of freshening (Ella and Tongacan 1987, Gonzales et al. 1986, Ibrahim et al. 1987, Low and Abdul Razak 1985, Mathauda 1959, Orallo and Veracion 1984, Ordinario and Tongacan 1979, Sheikh 1984, Singh 1964). These experiments generally showed the same results; that more intense tapping techniques give higher resin yields. Intense tapping is defined as wide blazes or high wood surface area exposure, high concentration of chemicals and high frequency of freshening.

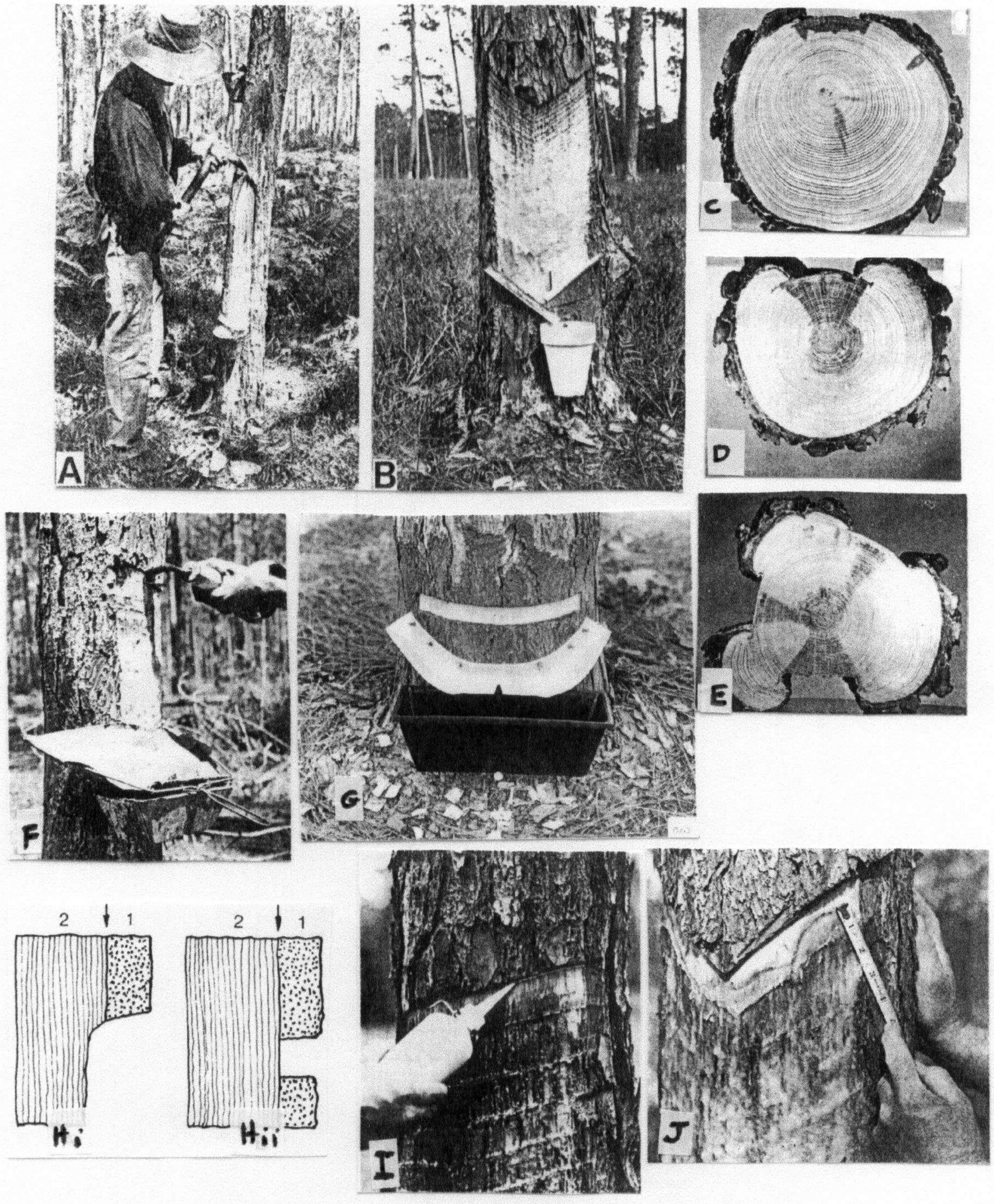


Figure 2. **A.** Old wood chip tapping method used in France and some Mediterranean (and other) countries. **B.** Herring bone (wood chip) tapping method, continues to be used in China. **C., D. & E.** Deformation of tree trunks after wood chip tapping method – four years, 25 years, and 40 years respectively. **F.** Bark streaking (with bark hack) tapping method with metallic collection cup and cover. **G.** Plastic cup and gutter-apron system attached by double-headed nails. **H.** Schematic representations of tapping by i. chipping into wood, and ii. removal of bark strip (the numbers 1 and 2 refer to the bark and wood respectively, the arrow points to the location of the cambium). **I.** Application of acid paste to stimulate resin flow. **J.** Extent of acid penetration, seen when bark is removed. Source: Tsoumis 1992 pp. 106-113.

In addition to sulphuric acid, other chemicals have been tested for their effects on resin stimulation. Two of these are ethephon (2-chloroethylphosphonic acid, or, CEPA) (Bhatt 1987, Bhatt *et al.* 1989, Messer 1990, Sivakumaran *et al.* 1984) and paraquat (a herbicide) (Tsoumis 1992). Both of these chemicals have been shown to substantially increase resin yields. Bhatt (1987) tested ethephon (CEPA) (400 g/L 2-chloroethylphosphonic acid) on *Anogeissus latifolia* (Combretaceae) by injecting 4 ml solutions containing 100, 200, 400, 800, and 1600 mg dilutions of active substance into the bole of study trees and saw resin yield increases of up to 466 times (1600 mg level) that of controls during the peak resin producing season. Bhatt *et al.* (1989) tested ethephon (CEPA) on *Commiphora wightii* (Bureseraceae), and at the 400 mg level of active substance found yields to be 21.75 times that of controls. Levels of the active substance higher than 400 mg were found to induce shoot desiccation and die back in the trees. Messer (1990) saw 110% greater production of resin yields of *Shorea javanica* (Dipterocarpaceae) trees boxed and treated with a 10% solution of CEPA compared to trees boxed without application of the chemical over a 72-hour period.

Paraquat has been investigated for use in the stimulation of oleoresin producing species. Paraquat (at 2% to 5% concentrations) is applied to the living tree (usually species of *Pinus*) and acts by entering the sap stream in the sapwood causing "resin-soaking", or resinosis, of the sapwood that may extend upwards as far as 10 m from the ground. Substantial increases in resin yields have been seen with the use of this chemical, however some aspects of its utilisation need to be considered. As the resin soaks the sapwood, the tracheids are filled with resin, the cell walls are impregnated, traumatic resin canals are formed and the cambium cells are killed. A consequence of this induced physiological state is that the tree is left vulnerable to insect and fungal attack. The tree mortality that can result from insect attack due to the weakening of the tree by paraquat is considered a major factor impeding its use in the American resin industry (Tsoumis 1992). Growth reduction has been observed due to the partial killing of the cambium, and tree mortality may occur if the paraquat reaches the crown. This material is also hazardous to the health of workers and to wildlife. When paraquat has been used in the pine resin tapping industry, it has been necessary to fell the tree after one to two years and the resin harvested by wood chipping and subsequent solvent extraction (Tsoumis 1992). Hence, the use of paraquat may not be appropriate where it is desirable to maintain the health of the tree under sustainable, live-tree resin tapping regimes.

Most studies showed higher yield responses with the application of chemicals in comparison to tapping without chemical application, but this was not true in every investigation. Mathauda (1959) concluded that sulphuric acid application had no real effect on the yield of oleoresin from the blue pine (*Pinus wallichiana* ver. *kail* or *bair*, in the Kasmir valley, India) and Singh (1964) actually found a decrease in the yield of the oleresin of the same species in the Kulu valley, Punjab, due to sulphuric acid application. Additionally, although a number of studies have revealed that stimulation with higher chemical concentrations gives higher yields when compared to stimulation with lower concentrations, it has been shown that there are "threshold" concentrations where yield is negatively affected (Ella and Tongacan 1987, Sheikh 1981), or that tree health is immediately adversely affected (Bhatt *et al.* 1989, Orallo and Veracion 1984). These investigations showed that while chemical stimulants can improve resin yield and decrease the physical damage incurred by trees from tapping, negligent use of these materials may also result in damage, and may not increase yields.

The stimulation of resin flow by fungal inoculation has been also been investigated, with resulting temporary increases in resin yield. These yields, however, do not compete favourably with chemical stimulation in the long term (Clapper 1954, True and Snow 1949).

The review of the literature on the tapping of resin-producing trees demonstrates the prevalence chemical stimulants in resin tapping industries around the world, yet fails to provide studies that tested the effects of different tapping techniques on yields *without* the use of chemicals. Two studies, however, investigated different tapping methods while maintaining a constant concentration of chemical stimulant (Low and Abdul Razak 1985, Sheikh 1984). Both studies showed that higher surface area exposure results in higher resin yields. Sheikh (1984) showed that tapping two faces of Chir pine (*Pinus roxburgii*), in Pakistan, at the same time on the same tree gave more resin per tree than tapping only one face. Low and Abdul Razak (1985) conducted a trial on *Pinus caribaea* var. *hondurensis* in Malaysia, in which tapping methods varied in shape and size (degree of surface area exposure of the inner bark layers), with greater yields observed as blaze size (exposed wood surface area) increased.

Tree responses to tapping in general, different tapping techniques, chemicals or chemical concentrations were measured in terms of quantity of resin produced in most of the studies reviewed, yet studies monitoring changes in vigour, reproductive performance and growth due to resin tapping and chemical application, critical to the sustainability of resin harvesting, were less frequently encountered.

Yield Section Four: Sustainability of resin harvest

The sustainability of resin tapping can be viewed from two perspectives: 1) the maintenance of resin production, and 2) the maintenance of individual tree (and species population) health, both of which work towards the same goal: the production of acceptable levels of resin yield for economic gain. With respect to resin production (1), most research has concentrated on increasing or improving yields, with little emphasis on developing long-term sustained production methods. From this perspective, however, declining yields would indicate non-sustainable harvesting methods, and could be adjusted accordingly.

The subject of the maintenance of tree health (2) however, requires greater research attention than it has received in the past, as it is to the benefit of all aspects of resin extraction (collectors, industry and trees), as well as to the ecosystem as a whole. There are three broad manifestations of declining tree health: disease presence, slowed growth and reproductive disruption. The following discussion will centre on these.

Although it seems reasonable to conclude that symptoms of disease in a tapped tree are caused by the tapping activity, it cannot be used to monitor the effects of tapping for the following reasons. The first is the difficulty in determining the exact cause of an infection. A tree is not necessarily infected with a microbial or insect pathogen because it is undergoing a harvesting activity such as resin tapping. Trees are frequently infected with pathogens in the absence of harvesting activity.

Secondly, microbial or insect attack may have little effect on tree health, life span, or production of the desired product. In fact, the inoculation of fungal pathogens to enhance resin production has been attempted in the past. Investigations of the response of resin flow in various species of Pine (*Pinus* spp.) to the inoculations of the Pitch-Canker Fusarium fungi (*Fusarium lateritium* f. *pini*) showed increased resin flow in trees infected with the pathogen (Clapper 1954, True and Snow 1949).

Finally, monitoring pathogen infection as an indicator of response to tapping cannot be applied to all trees of a population undergoing harvest activities because individual trees react differently to infections, governed by a number of factors including age, microclimate and genetic make-up. Some trees may not manifest the symptoms of an infection, while others may demonstrate extreme signs of disease to the same level of exposure. Also, all tapped individuals may not be exposed to the same pathogens; some individuals may not be exposed to any pathogens at all, or may be exposed at different times. Therefore, because there are so many variables affecting the manifestation of disease, it cannot be used as a definitive indicator of response to harvesting.

Declining girth increment may be an indication of poor tree health, but there are restrictions to using diameter as a short-term measure of growth. The first is that the annual radial increment of many tropical trees is small (Sass *et al.* 1995). Intense competition for light gives many tropical forests (young, secondary, and poor forests in particular) the characteristic of a crowded pole forest (Richards 1996), and it is height rather than girth that is the priority for resource allocation in the early life stages of tropical trees.

Second, the expansion and contraction of the stem is known to occur in tropical trees on a seasonal, even diurnal, basis due to changes in the tree's water status, which is in turn a response to rainfall or drought (Daubenmire 1972, Reich and Borchert 1982, Sass *et al.* 1995). It is therefore often difficult to see stem increment due to actual growth over a few months. Also, increases in stem diameter may not be an indication of good tree health. Hypertrophy of the trunk, for example, is an indication of an incorrectly tapped rubber tree (*Hevea brasiliensis;* Euphorbiaceae). The latex production levels of a tree in this condition can be expected to be lower, as can its growth rate and life span (D. Daly, personal communication).

Finally, the phenomenon of non-uniform distribution of cambial activity around the circumference seen in some tropical species is a further confounding factor (Sass *et al.* 1995). It makes accurate measurement of diameter growth difficult firstly, and secondly, makes it impossible to distinguish normal changes in cambial activity from abnormal. Thus, small increases in size and irregularity in those increases makes radial increment an unreliable measure of the short-term growth and health of tropical trees. Diameter increment may be a useful measurement parameter in the juvenile stages of fast-growing species, but eventually all species reach a mature stage at which annual radial increment due to growth is very small. Moreover, it is not juvenile trees that are normally harvested for a product like resin. If girth increment is to be used to monitor response to resin tapping, conclusions should not be drawn before a significant number of years of measurements have been recorded.

For these reasons, studies in tropical tree girth increment as a measure of exudate tapping effects have produced conflicting results. Sheikh (1981) used changes in girth expansion to measure the effects of chemical stimulation on tapped trees of Chir pine (*Pinus roxburgii*) over a five-year period. A large sample of trees (500) was tapped with three levels of sulphuric acid concentration, one level of NaCl concentration and no chemical application. The girth expansions were compared and no significant difference was observed in the five annual measurements of all five treatments. Peters (1994), however, cites reduction in diameter increment observed in plantation-grown rubber trees (*Hevea brasilensis;* Euphorbiaceae) in Southeast Asia by up to 50% over five years. Additional research should be conducted to resolve the conflicting results of these studies and to clarify the effect of long-term resin tapping and chemical application on diameter increment.

Another way that the effects of harvesting resin can be detected is through the monitoring of the phenological processes of the trees being tapped, and includes flowering patterns, fruit set, viable seed production, seedling survival and recruitment into larger DBH size classes; in other words, species population regeneration. Vigilance of the reproductive success of a harvested species is key to the true sustainability of any forest resource. The long-term strategy of such vigilance is the monitoring of seedling survival and the tracking of the size class distribution of the population (Peters 1994). To monitor regeneration, it is necessary to establish permanent regeneration plots throughout the areas in which harvesting occurs, within which inventories of the total number of seedlings and saplings of the species are made at regular intervals (approximately five years) (Peters 1994). Fluctuations in recruitment of seedlings and saplings into the size classes indicate possible harvest effects.

Over-exploitation of a resource like resin may affect seed viability and seedling growth. The viability of seeds and seedling growth in Benguet pine trees (*Pinus kesiya* Royle *ex* Gordon) tapped for resin was investigated in the Philippines (Noble 1981). The growth trial revealed that the differences in seed viability, seedling height and seedling growth increment for seeds from untapped pines, single-face-tapped pines and double-face-tapped pines were not statistically significant. However, the pines from which these seeds were collected had only been tapped for 1 year, 4 months (single-face tapped) and 2 years, 10 months (double-face tapped). This period of time cannot be considered long-term. It should be pointed out, however, that the results of this study do indicate a general trend, albeit statistically insignificant, that seed viability, seedling height growth and seedling growth increment for the seeds collected from the trees tapped for 2 years and 10 months were lower than that of the control trees and the trees tapped for 1 year and 4 months.

In tropical forests the irregular nature of flowering and fruiting of tropical trees complicates the monitoring of flowering and fruit set; however, if an untapped sample of trees within the tapping area is continuously monitored, significant differences in the patterns of tapped trees compared to the untapped trees may offer indications of adverse tapping effects. This innovation is explored in the present study of *Protium copal* resin harvest, and is described in the phenology component.

Another issue in the sustainability of resin tapping is the question of minimum tapping diameter, which must be established for each species, below which high tree mortality outweighs potential resin yield. This was experimentally demonstrated with Chir pine (*Pinus roxburgii*) in India (Lohani 1970), where tapping small-diameter trees was investigated as a means to possibly increase the overall resin yield obtained. The results showed that the standard minimum tapping diameter of 30 cm could be lowered only as far as 25 cm because the mortality of tapped trees between 15 and 25 cm DBH averaged 29.3% over three years of tapping compared to the 1.1% mortality over the same period for trees with greater than 25 cm DBH.

The use of chemical stimulants, while perhaps the only way to elicit economically sustainable yields, must be closely monitored if the objectives of sustainable harvest are to be met. If dosage and frequency of application are supported by high-level and ongoing experimentation, they may provide benefits to a sustainable tapping regime. For example, the effects of long-term intensive tapping using chemical stimulants (ethephon) in the Para rubber tree (*Hevea brasiliensis;* Euphorbiaceae) was investigated by Sivakumaran *et al.* (1984) in Malaysia. The results of this study indicate that when intensive harvesting is carried out, yield declines, but that it was not the use of ethephon as a stimulant *per se* that caused the decreased yields, but rather the long-term intensive extraction of the latex.

Thus, when addressing the issue of the sustainable harvest of resin with respect to tree health, a number of factors should be taken into consideration. Disease presence is not a useful tool for detecting a tree's response to tapping. Assessing tapping effects on growth should be based on many years of DBH measurements (> five years). Observations of phenological patterns should be made concurrently with tapping activities, and any deviations from the patterns observed in untapped trees in the same area should be taken as an indication of a harvesting intensity that requires downward adjustment. Long-term strategies to monitor the regeneration of the population must be incorporated into an overall management plan. A minimum diameter, below which trees are not tapped, should be established. Finally, chemical stimulants should be employed prudently, if at all.

Peters (1994) states, "When properly conducted, the tapping of (resins) does not disturb the forest canopy, kill the exploited tree, or remove its seeds from the site. In theory, (resin tapping) probably comes the closest to conforming to the ideal of sustainable non-timber forest product extraction". Thus, promoting the sustainable harvest of resins works toward the preservation of the ecosystem in which the trees are found. In preserving an ecosystem, steps are taken toward preserving biodiversity.

Objectives and hypotheses for the resin yield component of the *Protium copal* study

1. To determine factors with significant effect on resin yield and establish which of those are the most meaningful.

   H0: Tree size is not the variable that most affects resin yield.

   HI: Tree size is the variable that most affects resin yield.

2. To determine if there is a significant difference in resin production between two tapping techniques (T1 and T2).

   H0: There is no significant difference in resin yield due to tapping technique one and tapping technique two.

   HI: There is significant difference in resin yield due to tapping technique one and tapping technique two.

3. To provide an estimate of the resin yield in two forest types in the study area.

PHENOLOGY OF TROPICAL TREE SPECIES

Phenology includes the study of flowering, fruit-set, viable seed production, leaf-change, shoot-elongation and radial stem increment. The reproductive cycles of species in tropical forests are unlike those in temperate forests, where the main environmental cue for the onset of reproductive activity is temperature change, linked to the change of seasons. A literature review of phenological studies on tropical trees revealed seemingly endless variation in the timing, intensity and regularity (or irregularity) of the reproductive processes in the trees of tropical forests. Nevertheless, four points for discussion arose and are presented here. Section one explains why it is important to understand the reproductive patterns of tropical trees. Section two relates the complex nature of reproductive patterns in tropical tree species. Section three presents findings regarding phenological responses to water availability in different regions in the tropics. Section four outlines how phenology can be used to monitor the short-term effects of harvesting activities on individual trees, as well as the long-term effect on both individual trees and tree populations.

Phenology Section One: Why understand tropical tree phenology?

The study and understanding of phenological patterns in tropical tree species is important for a variety of reasons. Where the harvest of seeds for food or extracts, or for regeneration in plantations or reforestation is practised, knowledge of the timing of reproductive patterns and factors that might affect it (and/or the quantity and quality of the seeds) is critical. In the Philippines, the seeds of the Benguet pine (*Pinus kesiya* Royle *ex* Gordon) are widely used for reforestation and industrial plantations, and there is significant demand for viable seeds (Noble 1981). Research in this region therefore works to understand the factors that influence the reproduction of this important species.

The successful production of tropical fruits also depends on a detailed comprehension of the reproductive patterns of the species of commercial interest. Tropical tree fruits such as lychee (*Litchi chinensis;* Sapindaceae) and mango (*Mangifera indica* L.; Anacardiaceae) have relatively large international markets, and variability in flowering and fruiting in these species hinders the production of consistent crops (Anuar *et al.* 1992, Batten 1986). Efforts continue to provide greater knowledge and control of the phenology of these species.

Another, less well-documented reason to understand reproductive patterns is to detect any deviation from "normal" reproductive patterns in response to the harvesting of some part or parts of the tree. In the interest of the sustainable harvest of such products as roots, bark, foliage, extracts and exudates, discerning the effects of these practices on the health of individual trees, and tree populations, is critical (Peters 1994). The complex inter-dependencies unique to species-rich tropical forest ecosystems, however, complicate using phenological patterns as a measure of the sustainability of resin tapping.

Phenology Section Two: Complexities in tropical phenology

There is great variability among and within tropical species with respect to phenology. There are species that flower annually, twice annually or more often. Other species flower continually, or flower continually but peak annually, or twice annually (Bullock and Solis-Magallanes 1990). Many tropical species have particular flowering patterns in one location that are different in another location; or the flowering patterns may be the same in different locations, but staggered in timing (Daubenmire 1972). There are also species that flower at irregular intervals, where two to ten years will pass with little or no reproductive activity, and then in certain years all individuals of the local population, and even individuals of other species within the same area, will "mass" flower or flower "gregariously" (Ashton *et al.* 1988, Ng 1981). Yet the same species that undergoes mass flowering in one area may flower at regular intervals in another location (Ng 1981). Many studies have been conducted in tropical forests with the objective of defining the environmental cues that trigger changes in reproductive activity. Section three will present the results and conclusions of some of this work.

Phenology Section Three: Water availability and response of tropical trees in different regional climates

Although most tropical forests experience seasonal changes in temperature and day length, the degree of change is not as significant as in subtropical or temperate forests. Of the literature reviewed, evidence is provided to support the hypothesis that the phenological patterns in tropical forests are correlated to water availability. Water availability, expressed as humidity, rainfall or soil moisture, has been shown to affect the phenology of tropical species (Ashton *et al.* 1988, Bullock and Solis-Magallanes 1990, Daubenmire 1972, Lieberman 1982, Ng 1981, Spencer *et al.* 1996).

The phenological response of vegetation in tropical forests to changes in water availability is influenced by the regional climate. Within the tropical zone (24^0 north and south of the equator) there is a range of climate types that influence the phenology of the forest flora in these regions. Holdridge's classification of world life zones (Holdridge 1947, Holdridge *et al.* 1971) divides the tropical zone into eight different life zones, when based on annual precipitation alone, which are summarised in Table 2.

Table 2. Tropical life zones according to Holdridge's World Life Zones model (Holdridge 1947 from Holdridge et al 1971).

Tropical life zone	**Annual rainfall (mm)**	**Humidity province**
Desert	62.5 – 125	Semiparched
Desert scrub	125 – 250	Superarid
Thorn woodland	250 – 500	Perarid
Very dry forest	500 – 1000	Arid
Dry forest	1000 – 2000	Semiarid
Moist forest	2000 – 4000	Subhumid
Wet forest	4000 – 8000	Humid
Rain forest	8000 +	Perhumid and Superhumid

In areas where there is a yearly dry season, many species demonstrate seasonality in their phenological activity. Studies conducted in tropical forests with such climatic regularity have shown that many tropical tree species undergo leaf senescence at the onset of the dry season (Daubenmire 1972, Killman and Thong 1995, Reich and Borchert 1982, Spencer *et al.* 1996). It is speculated that this is a water conservation mechanism to reduce the evapotranspiration surface of the leaves during rainfall deficit. Also observed at the outset of drought conditions is marked stem shrinkage (Reich and Borchert 1982). Researchers speculate that the observed stem contraction is caused by higher rates of evapotranspiration in the leaves than rates of moisture uptake by the roots, resulting in a declining xylem pressure potential. The response to this is leaf senescence. Once all leaves have dropped, rapid stem expansion is observed. This is attributed to an increase in xylem pressure potential due to the complete absence of evapotranspiration from the leaves (Daubenmire 1972, Reich and Borchert 1982). After leaf drop many species flower, as it appears that the slow absorption of residual soil moisture after leaf drop is sufficient to support reproductive processes (Reich and Borchert 1982 cite Borchert 1980).

In regions that lack any marked period of water or rainfall deficit, the environmental cues that trigger flowering and fruiting are more difficult to define. Some of the theories put forth in the literature are briefly described here. Ng (Killman and Thong 1995 cite Ng 1988) hypothesises that it is the increase in the number of cloudless daylight hours accompanying the onset of the dry season that induces flowering. Ashton *et al.* (1988) observed the onset of flowering in species of Dipterocarpaceae in Malaysia after a 2^0 C drop in minimum night temperature for a period of three or more days.

Killman and Thong (1995) suggested it is small temperature changes like this that may be the environmental trigger that brings about flowering, but speculate that this drop in temperature may be due to the prevalence of clear, cloudless skies after the rainy season. Finally, Aston *et al.* (1988) suggest that a sudden and significant drop in humidity may be an environmental cue for the onset of reproductive activity, having observed a mass flowering event after the invasion of a dry air mass (el Niño) in a region of Malaysia where a climate of consistently high humidity predominates year-round.

Whether it is a drop in humidity, a drop in temperature, an increase in light, or a combination of these, the environmental cues that serve to induce flowering in tropical trees may never be fully identified. It can be concluded, however, that any one of these factors may affect different species differently. And when the same environmental cue acts on the same species in different locations, with different microclimatic conditions and different pollinators, it is not unlikely that the phenological activity will also manifest itself differently. The question remaining then is – how can phenology in tropical forest trees be used as an indicator of response to resin tapping or other NTFP harvesting activities?

Phenology Section Four: How phenology can be used to monitor the short-term effects of resin harvest

From the preceding discussion it is clear that phenological studies should focus on specific regions, species and period. When a sample of control trees (not tapped) of a species undergoing harvest is monitored for phenological activity within the same area during the same tapping period, any differences in the reproductive patterns of control and tapped trees can be detected. Significant differences may be an indication of response to tapping, thereby providing a short-term evaluation for the sustainability of the level of harvesting and the technique used.

Objectives and hypotheses for the phenology component of the *Protium copal* study

4. To record the reproductive patterns of *Protium copal* in the study area for the months of the study period.

5. To determine if tapping for resin has significant effects on phenology.

   H0: Tapping for resin has no significant effect on phenology.

   HI: Tapping for resin has a significant effect on phenology.

6. To determine if the two tapping techniques tested have a significantly different effect on phenology.

   H0: There is no significant difference between tapping techniques on phenology.

   HI: There is a significant difference in phenology due to different tapping techniques.

ETHNOBOTANY

Ethnobotany is the study of indigenous or traditional knowledge of plants and their uses. This knowledge usually involves more than familiarity with local plants and their uses, indeed it encompasses a whole systems approach to the harvesting and management of forests and forest products that meets the ecological, economic and cultural needs of local populations. The study and documentation of the vast body of knowledge held by indigenous cultures is rising in importance as the reservoir that holds unknown or unexplored plant species shrinks, and as we begin to recognise their great potential value. Briefly discussed in the following pages are three prominent reasons to both expand the field of ethnobotany and increase the application of its results. Two of these are benefits that stand out for the people of developed countries: 1) the discovery of plant species that cure and treat illnesses previously untreatable, and 2) the provision of models for sustainable forest resource management, the conservation of forest ecosystems having become a global concern. The third reason is the creation of economic benefits to the people of the third world, created in turn by the value placed on "newly discovered" forest products by wealthier nations.

Ethnobotany Section One: "Bio-prospecting": the under-exploited compounds of tropical forest plants

The potential value of ethnobotanical information is slowly gaining greater recognition as the unique properties of a number of species have been "discovered" in recent years in the laboratories of industrialised nations. One of the more famous of these is the Madagascar rosy periwinkle (*Catharanthus roseus;* Apocynaceae) from which two drugs are now made; a chemotherapeutic drug called vincristine, which has taken the long-term survival rate for childhood leukaemia to 90%, and vinblastine, which is helping to cure most cases of Hodgkin's disease (Swerdlow 2000). Other such plant species include the Pacific yew (*Taxus brevifolia;* Taxaceae), used in the treatment of ovarian cancer, ginkgo (*Ginkgo biloba;* Ginkgoaceae) for dementia, echinacea (*Echinacea purpurea;* Asteraceae) for weak immunity and neem (*Azadirachta indica;* Meliaceae) an Indian tree well known to the Ayurveda and Unani systems of medicines for thousands of years (National Research Council 1992, Swerdlow 2000).

The neem tree is a particularly good example of the value of traditional ethnobotanical knowledge. The neem tree's service to humans seems limitless. It is documented to have antiseptic, antifungicidal, antibiotic and antiviral properties. It is used also in dental hygiene, to treat dermatological conditions, to treat malaria, to relieve pain and fever, for birth control, and in veterinary medicine (National Research Council 1992). Additionally, it is used to manufacture soap, wax, cosmetics, lubricants, fuels, and has applications as an agricultural fertiliser and insecticide. The neem tree's well-documented insecticidal properties (Isman *et al.* 1997, Isman 1999) go beyond its success in crop protection. Chagas disease affects millions of rural Latin Americans and is caused by a parasite of the nerve and muscle cells called *Trypanasoma cruzi,* spread by the faeces of "kissing bugs" *(Rhodnius* spp.) that live in cracks and crevices of rural dwellings. The kissing bugs, seeking a blood meal, bite individuals while they are sleeping, leaving an itchy welt that causes the victim to scratch, thereby introducing the faeces of the insect into the bloodstream. In Germany research has shown that neem prevents young kissing bugs from moulting, thereby arresting their development. In Brazil, when neem-laced blood was fed to parasite-infected kissing bugs, the kissing bugs were parasite-free twenty days later (National Research Council 1992).

Given its many uses, the neem tree is unique, and it cannot be hoped that *Protium copal* would eventually provide as many products. Nevertheless, preliminary anecdotal evidence suggests that the copal tree has many medicinal uses. The plants described in the preceding paragraphs represent a very small sample of those known to western medicine, and an even smaller sample of those known to indigenous cultures of the species-rich forests of the tropics. Why then have so few serious investigations of the potential pharmaceutical benefits of tropical forest plants been undertaken?

There are significant obstacles to the exploitation and development of pharmaceutical products from tropical forests, the principal ones being: 1) the increasing pressure on remaining forests from the needs of rising populations and their concomitant poverty, seemingly most quickly (albeit marginally) alleviated by acquiescing to commercial logging, mining and agricultural interests and, 2) the exceptionally complex nature of plant chemistry.

The difficulty associated with the isolation of active compounds in medicinal plants has been the main barrier to sustained interest in the exploration of plants and extracts from tropical forests (Swerdlow 2000). The costs involved in the development of pharmaceutical products from natural sources are often deemed to outweigh the potential dividends, and few companies are able to take these risks. In 1991 however, Merck & Co, a multinational corporation, entered into an agreement with the National Biodiversity Institute of Costa Rica (INBio) in which INBio would provide samples from Costa Rican conservation areas and Merck would evaluate the samples for human health, animal health and agricultural compounds. The agreement is extensive and provides many benefits to both partners. It was renewed in 1994 with appropriate modifications (Anonymous 1 1998 – electronic communication, Reis 1995) and continues to set an example of a co-operative relationship that facilitates the understanding, and thereby protection, of vulnerable ecosystems.

<u>Ethnobotany Section Two: Indigenous forest management systems</u>

Indigenous cultures in every part of the world have long traditions of plant use and sustainable harvesting techniques, many of which work to increase the production of desired plants. These systems, although fairly well documented, are generally not incorporated into regional resource management policies. They are, however, slowly but steadily receiving increased attention. Reis (1995) describes indigenous forest management systems as polycyclic, as opposed to the monocyclic systems of shifting cultivation involving forest clearing and intensive management of re-growth or secondary regeneration. Reis (1995) reports the polycyclic systems to have certain characteristics in common: low-intensity, simultaneous management for a variety of species; little or no major canopy opening (as most NTFP can be harvested non-destructively and require intact canopy growing conditions); are employed casually (as part of harvesting activities, not as separate management operations); apply selective weeding and thinning; practice enrichment planting of preferred species; and engage in light, occasional, selective, low-intensity harvesting of wood species, which provides the small canopy openings that drive the ecosystem and provide wood for housing and other construction purposes.

In tropical Mexico, management systems with the above characteristics survive from pre-colonial times. Gomez-Pompa and Kaus (1990) describe a mixed system of shifting agriculture *(milpas)* (that operates on secondary forests, leaves relic trees and incorporates long periods of fallow); plantation trees with understory crops; and managed forest gardens of useful native tree species. The relic trees left and protected in the *milpas* may be used to provide fruit, seeds, nectar, medicine, shade, material for construction, and aid in the reforestation of the area after shifts in crop production. Plantation systems and forest gardens are commonly comprised of coffee and cacao plantations shaded by native legume trees, and may include other species such as allspice (*Pimenta dioica;* Myrtaceae), a variety of edible palms (*Chamaedorea* spp.; Arecaceae), vegetable and bean crops, as well as different kinds of fruit trees (Gomez-Pompa and Kaus 1990).

Similarly, in the floodplain of the Amazon estuary, Anderson (1990) cites three basic land units utilised by the local inhabitants. The first is the house garden, which is intensively managed and used to cultivate herbs, remedies and condiments, as well as to raise domestic animals. The second is the dense floodplain forest, in which forest products such as fruits, palm hearts, latex, wood, fertiliser, ornamental plants, fibres, honey, oilseeds, medicines and utensils are gathered and species like pacas, agoutis, porcupines, sloths and feral pigs are hunted. The final land unit identified by Anderson (1990) is the swidden agricultural plot, established at a distance from the village and its domesticated animals, is usually less than one hectare in size and is farmed for short periods of time. All three land units work together to maintain low-impact utilisation of the surrounding environment while allowing forest ecosystems to continue to function with some degree of health.

A final example of indigenous forest manipulation is that of the Karuk people of the Klamath National Forest in the Pacific Northwest United States, who have traditionally collected the Tanoak mushroom (*Tricholoma magnivelare*). An ethnobotanical study by Richards (1997) described the various methods employed by the tribe to ensure, not only that there would be a healthy mushroom crop for next year, but also that harvesting activities would not disturb the forest ecosystem as a whole. The study provided evidence that the native peoples carefully observed the fruiting habits of the mushrooms when they first began collecting them. These astute observations have resulted in the development of the sustainable management practices that have been passed down through generations, and maintain a yearly crop of mushrooms to date. One of the methods still practised is that leaf litter is always replaced when moved to look for the mushrooms, whether mushrooms are found or not, thereby providing the necessary insulation required by immature buttons. Also, small button mushrooms are left to continue to fruit and older mushrooms are left to spore. Finally, older mushrooms are occasionally cast downhill to distribute spores, thereby probably contributing to the prevalence of the mushrooms in their territory (Richards 1997).

The techniques described in the preceding paragraphs illustrate sustainable management systems in tropical and temperate forest ecosystems, where local populations benefit, and the integrity and biodiversity of the environment are not compromised.

Ethnobotany Section Three: Socio-economic benefits to forest societies

In virtually all third world rural societies located in the vicinity of forests of any quality, non-timber forest products are inevitably used to some degree, and probably provide a source of revenue to the cash-poor population as well. It is becoming widely recognised that in many regions, income from the harvest of NTFPs is significant, not only relative to the individual harvesters (Akoroda 1990, Comerford 1996, Gianno 1986, Gould *et al.* 1998, Kainer and Duryea 1992, Stanley 1991) but also relative to the income that could be derived from harvest of commercial wood species or the introduction of intensive or large-scale agriculture in the same forest areas (as described in the general introduction), both in the short term and in the long term.

The results of ethnobotanical research on NTFPs increase the opportunities for individuals and families to generate income and in most cases, to relieve the extreme poverty faced in so many countries in tropical regions. In Acre, Brazil, women are the main extractors of minor non-timber forest products, and provide a significant proportion of the household income through their sale. Their desire to increase their market involvement was demonstrated in 1989 in a small village in the area, Xapurí, where a rural women's group organised two product fairs (Kainer and Duryea 1992). Forest products such as jams, baskets, rubber goods, juices, nuts and honey were collected and processed within the forest reserves and transported to Xapurí for sale.

An outstanding example of income generation through the local harvest of a NTFP is that of *La Chiclería,* or the harvest of the latex of the chicozapote tree (*Manilkara zapota;* Sapotaceae) in the Petén, Guatemala (Bolt 1961, Schwartz 1990). For nearly a century, chicle latex was extracted from the forests of the Petén, and during some of that time the industry dominated the Guatemalan economy. Chicle was known as *oro blanco,* white gold. Towns came into existence because of the chicle harvest, roads were built into previously remote and completely isolated areas to facilitate the transportation of the latex, and the chicle harvesters, *chicleros*, became some of the wealthiest members of Peteñero communities – "a chiclero does not ask for change" – was a common saying at the height of the industry. Between 1932 and 1962 exports of chicle are estimated at 20 million quetzals (Q). The quetzal at that time was on par with the American dollar. Between 1962 and 1982, the estimated value of chicle exports varies from Q36 to Q44 million, at an average of Q1.8 million per year. The value of the chicle industry to the Guatemalan economy peaked in 1945, when chicle contributed 8.5 percent of total exports from the country (Schwartz 1990).

In the promotion of the use of medicinal plants, ethnobotanical research has been cited as one of the innovations that have demonstrated the potential to generate income for local communities and provide for long-term forest maintenance (Schmincke 1995). Thus it is clear that in investigations of "new" or unexploited NTFPs, ethnobotanical studies are essential. Although the current examination of the resin of *Protium copal* is preliminary in nature, it could not have been considered complete without the inclusion of a minor section on the ethnobotanical perspective of this product.

Objectives for the ethnobotany component of the *Protium copal* study

Interview, with a standardised questionnaire, a sample of twenty individuals from towns near the study area who are knowledgeable in local plants and their uses and:

7. Document all current uses of *P. copal* and what is known about its importance to ancient Maya culture.
8. Determine the harvest and management systems that exist for the resin of *P. copal.*
9. Determine the present market activity for the resin of *P. copal.*

FAMILY BURSERACEAE, GENUS *PROTIUM*, SPECIES *COPAL*

The Burseraceae family has been called the torchwood family because so many of the tree and shrub species within the family produce resins that have traditionally been burned, either for light or as incense. The family includes at least 20 genera and over 500 species, found in the tropics of both hemispheres (Daly 1992a, Schultes and Raffauf 1990, Standley and Steyermark 1946). Recent work suggests there may be further unidentified species (Daly 1992a&b). Three of the genera well represented in Central and South America are *Bursera, Protium* and *Tetragastris,* and many of the species in all of these genera are resin and/or essential oil producers (Schultes and Raffauf 1990).

References to species of *Protium* indicate the genus is widespread in tropical America, ranging from Mexico to Brazil. Species of *Protium* have been studied in Mexico (Rzedowski and Calderon de Rzedowski 1996), Belize (Anonymous 2 – electronic communication, Rzedowski and Calderon de Rzedowski 1996), Guatemala (Lundell 1937, Rzedowski and Calderon de Rzedowski 1996, Standley and Steyermark 1946), Costa Rica (Holdridge *et al.* 1971, Morton 1981), Panama (Richards 1996 cite Kenoyer 1929, Morton 1981, Von Reis and Lipp 1982), Columbia (Morton 1981, Von Reis Altschul 1973 cite Record 1930), Ecuador (Daly 1992 (VI)), Amazonia (Daly 1992 (VI), Richards 1996 cite Moreas and Pires 1967), Venezuela (Coomes and Grubb 1995, Daly 1992 (VI), Morton 1981, Von Reis and Lipp 1982 cite Steyermark 1962), Trinidad (Richards 1996 cite Beard 1946), Guyana, Surinam and French Guiana (Morton 1981), Peru (Von Reis and Lipp 1982) and Brazil (Daly 1992 (V), Meira-Neto *et al.* 1997, Morton 1981, Richards 1996 cite Pires and Prance 1977). All species were generally characterised as abundant in the "B story" of dry, often second growth, forests.

References to the species *Protium copal* in the literature are rare, and only six sources were encountered for the present review, although a brief search on the internet revealed a number of sites mentioning *Protium copal* specifically. The range of *P. copal*, although unconfirmed, may be restricted to most of southern Mexico, northern Guatemala and Belize (Rzedowski and Calderon de Rzedowski 1996). Lundell (1937), in *The Vegetation of the Petén,* describes *P. copal* as one of the trees valued by the Maya for resin. He reports that the tree is referred to as copal or pom and is common in Petén's forests, due in part to Maya influence. Based on the current practice of leaving certain valuable tree species standing when forests are cleared for agriculture, Lundell suggests the assumption could be made that the ancient Maya also practised this. Leaving trees standing during forest clearing not only ensured the survival of individual trees, but also gave that tree a reproductive advantage when the areas were abandoned. Lundell also recorded that *P. copal* is associated with forest types characterised as *zapotal,* or forests dominated by the chicozapote tree (*Manilkara zapota;* Sapotaceae), and occupies the lower tree tier in open forest areas (Lundell 1937).

In 1946, Standley and Steyermark, in *Flora of Guatemala,* document *P. copal* as the probable principal source of the "copal" or "pom" that is used in religious rites, particularly by the Indians of the Guatemalan highlands in the southern portion of the country. Obtained from *P. copal* trees (reported by these authors to reach up to 30 m) in the moist or wet forests of the Petén, Alta Verapaz, Izabal, Zacapa, San Marcos and Huehuetenango departments in Guatemala, as well as in southern Mexico, the resin is referred to not only as copal and pom but also as "chom" and "pom-te" (Standley and Steyermark 1946). They suggest that the resin has been a part of Maya ceremonies for centuries, and report that in addition to its current traditional use as ceremonial incense, it is also used as a varnish and in folk medicine.

More recently, *P. copal* is cited in Morton's *Atlas of Medicinal Plants of Middle America, Bahamas to Yucatan* (1981). Although copal as a vernacular term is applied to numerous species from four different plant families in this volume, *P. copal* is briefly mentioned as being found in the Yucatan and its resin used by the Maya as a styptic on cuts and sores. Later, Gomez-Pompa and Kaus (1990) listed *P. copal* as an abundant tree in the mature vegetation of Mexico and Central America, used for its aromatic resin.

Rzedowski and Calderon de Rzedowski (1996) in *Flora de Veracruz,* offer the most thorough description of *P. copal* found by the author. In addition to providing drawings of the leaves, fruits and flowers (male and female), as well as a map of specific copal tree locations in Mexican states along the Gulf of Mexico, they give common names for the tree not seen elsewhere: “aceitillo”, “jom” and “jomte”. They report *P. copal* to grow at altitudes from sea level to 1200 m, in evergreen, deciduous and semi deciduous forests. They also describe that there is a tree known as *Protium glabrum* Rose in Veracruz, Mexico, which may actually be a variety of *P. copal* (*P. copal* var. *glabrum* (Rose) Swart). They conclude their report stating that the tree requires a taxonomic re-evaluation, based on the analysis of a large sample of leaves, fruits and flowers from multiple locations in Central America, as well as a collection of direct observations from rural populations regarding the tree.

Finally, Comerford (1996) includes *P. copal* in his documentation of 81 medicinal plants used in San Andrés, Petén. He reports that its resin is burned and used to fumigate the body to expel illness, and is also rubbed on joints to treat rheumatism and placed on teeth to relieve toothaches.

<u>Rationale for the choice of the resin of *Protium copal* over other NTFPs in Petén for the present study</u>

It was Comerford’s 1996 study that inspired the present investigation of the yield, phenology and ethnobotany of *Protium copal*. The results of his study, in addition to abundant anecdotal evidence, suggest that there is great potential for medicinal products to be made from the resin. Also, the tree’s presence in the forests of Petén had been inventoried at 7.1 to 10 trees per hectare, which is very high for tropical forests. The high species diversity in tropical forests normally results in very few trees of the same species to be found in one hectare, usually no more than one or two. The high level of copal trees inventoried in the forests of Petén addresses the initial resource sustainability issues regarding the harvest of the resin, as well as some of the concerns about supply with respect to product marketing, and was the main reason that this NTFP was chosen for study over the many other, equally interesting, NTFPs.

The resin of *P. copal*, although a relatively minor component of the extensive suite of NTFPs that are gathered, utilised and traded in Petén, has a historical significance to the local people, having been used by the ancient Maya for millennia, and is therefore not a new or unfamiliar product. Also, it continues to have an important role in religious ceremony today with a small percentage of the population, the indigenous Maya of the southern highlands of Guatemala.

The daily financial struggles of Petén's population observed by the author made the main goal of the investigation to provide useful data towards the development of a new and viable industry in the harvest of the resin. The price per pound paid to the few copal harvesters in Petén is very low, due to at least two factors: 1) the resin is used primarily as incense, valued by a small percentage of the population and used only intermittently (for ceremony), and 2) the market for the resin is mostly domestic, and most Guatemalans are not able to pay high prices for any item. So the harvest of copal resin provides little income, usually supplemental, to a few families in Petén. The relatively high level of supply, coupled with the preliminary evidence for potential products, gave rise to interest in further investigation, and the present study was undertaken. The period spent tapping the resin, monitoring the reproductive activity and recording the local knowledge of the copal tree was too brief to provide all the information required to develop a resin tapping industry, but it does contribute basic data as a platform from which to begin.

DESCRIPTION OF STUDY AREA

Environmental and social context

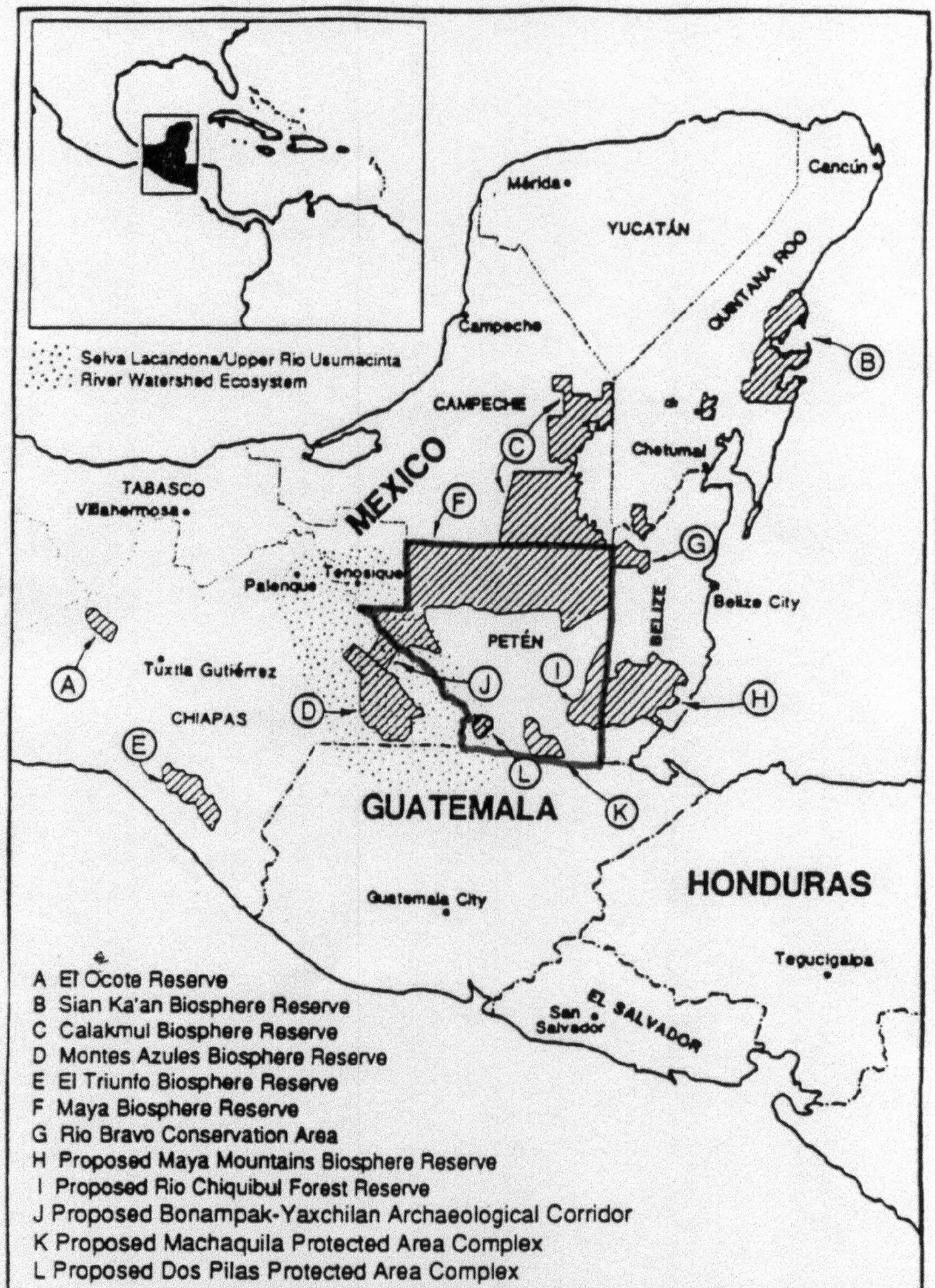
All fieldwork was conducted in Petén, Guatemala's largest department (similar to a province or state). Petén is the country's northernmost department, located between 16° and 17° 90' north latitude and 89° 25' and 91° west longitude, bounded by Mexico to the west and north and by Belize to the east (Map 1). Accounts vary on the exact size of the department, from 35, 854 to 40, 000 km^2 (Lundell 1937, Schwartz 1990), but it is certainly an extensive area; larger than, for example, the Netherlands (Schwartz 1990). Most of Petén has historically been covered by secondary forest, although the progress of deforestation for agricultural and other purposes has been significant in recent years. Although these forests are not among the most productive in the world, there is great species diversity, in both flora and fauna.

The region receives approximately 1100 to 1500 mm of rain annually, most of which falls during the rainy season (June to October). Mean monthly temperature is approximately 26° C, with highs reaching 37° C and lows 12° C. Percent relative humidity ranges from 68% to 93% (Estación Tikal, latitude 17°13', longitude 89°60', elevation 200 m). The seasonal climate of the region gives rise to semi-deciduous dry forest (Holdridge *et al.* 1971) that experiences drought-like conditions from the end of January to the end of May.

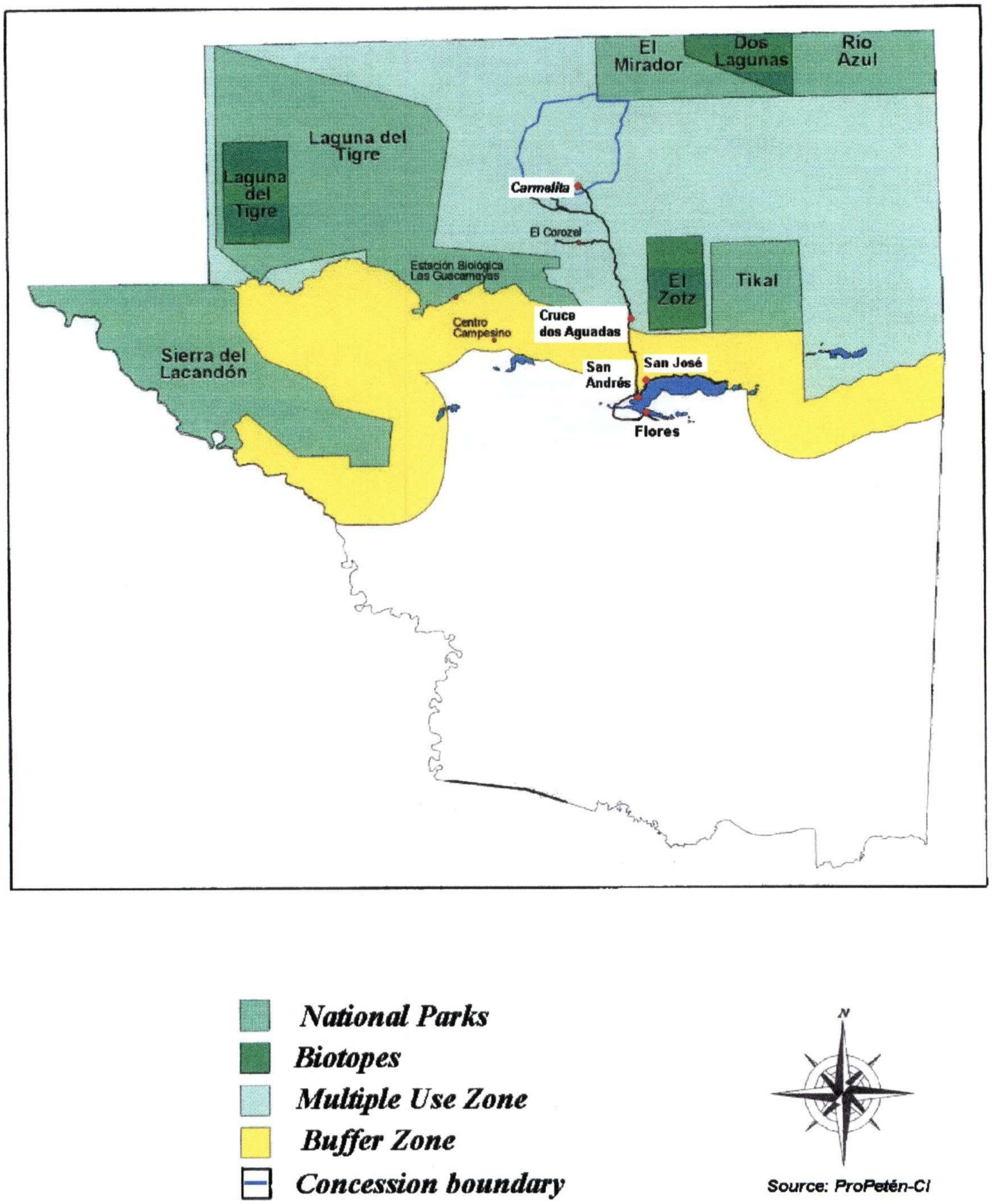
Petén society has long integrated the surrounding forest in their day-to-day lives, extracting everything from firewood and construction materials to food and medicine. A variety of non-timber forest products (NTFPs) are collected for sale, providing income to thousands of families. The most economically significant of these products include chicle (latex of *Manilkara zapota;* Sapotaceae), a chewing gum base; allspice (fruit of *Pimenta dioica;* Myrtaceae), dried and used as a condiment; and xate (fronds of two palm species: *Chamaedorea oblongata and Chamaedorea elegans;* Arecaceae), used in wreaths in the United States and Europe.

Most of Petén, was a sparsely populated frontier until the mid-1960's, when national government policies began making land available to the landless residents of the over-populated southern departments of Guatemala. Since then, the population of Petén has increased dramatically, from 21,330 in 1960 to an estimated 300,000 in 1986 (Schwartz 1990). The current annual population increase in Petén is estimated to be approximately 10% (Comerford, Gould; personal communications). The rise in population has resulted in the expansion of agricultural areas, both crop and livestock, as well as increased commercial logging, oil exploration, and, to some degree, urban encroachment of previously forested areas.

In early 1990, the Maya Biosphere Reserve (MBR) was established in 40% of Petén's northern forests as a first step toward the preservation of what is left of these forests. The MBR covers approximately 15, 000 km^2 (Comerford 1996, Gould *et al.* 1998, Reis 1995) (Map 2) and contains several completely protected ecologically sensitive areas ("biotopes"), national parks, a 15 km wide buffer zone and a multiple use zone or extractive reserve (Comerford 1996, Reining *et al.* 1991). The multiple use zone is, in turn, divided into numerous community forest concessions, each of which is linked to their respective main villages. Each concession represents the resource allocation of the people that live within it, and approximates the area historically utilised by these residents. The delineation of the CCFC by the governing body responsible for



Map 1. Petén and surrounding countries. Source: Reining *et al.* 1991.



Map 2. Map of Petén, showing Maya Biosphere Reserve (shaded regions) and location of Carmelita Community Forest Concession within it. Source: ProPetén-CI 1998.

the nation's natural resources (Consejo Nacional de Areas Protegidas: CONAP) in 1996, functions as a form of official land tenure, a critical prerequisite for the stewardship of lands, forests and all they contain by rural populations. The present study was conducted in the Carmelita Community Forestry Concession (CCFC), located in the central and northern area of the multiple use zone in the MBR. The concession is named for its principal settlement, the village of Carmelita, which is located approximately 100 km from Petén's capital city, Flores (see Map 2). This concession was chosen for the location of the present study of copal because there is a distinct lack of employment and opportunity in Carmelita, due in part to the decline of the chicle market. The people in the CCFC are actively involved in the planning of management strategies aimed at improving their economic situation without depleting their resources. The concession is one of the areas in which ProPetén, the Guatemalan branch of Conservation International, offers assistance to local inhabitants in the promotion and development of the sustainable extraction and management of their forest resources.

<u>Classification of the forests in the CCFC</u>

Within the CCFC, four different forest types were identified, and the area they occupy in the concession quantified, by the Natural Forest Management department (MBN) of ProPetén-CI. The forest types, known as "strata", are primarily dependent upon substrate They differ in species composition, although many species are found in more than one strata. These forest types are described in the following paragraphs.

Strata one forest types are located on relatively high altitude, well-drained terrain, characterized by hillsides of moderate slope and occasional rocky outcrops. The forest vegetation is considered dense, with a canopy height of approximately 25 m. This forest type constitutes 10.7% of the CCFC. Strata two forest types are also relatively high altitude, dense forests (canopy ~ 25 m), but the terrain is generally flat, though also well drained. This forest type constitutes 40.4% of the CCFC. These two forest types are considered to be the most productive of the four defined in the forests of the CCFC, and it is within them that ProPetén recorded the highest densities of *Protium copal*. Strata three is a more open forest with a canopy height that varies according to the dominant species (10 to 30 m), and is characterized by poor drainage, experiencing prolonged periods of inundation. This strata makes up about 12.3% of the CCFC. Finally, strata four forests grow in "low spots", areas of very poor drainage and may be considered "swamp forests", with canopy heights reaching 8 to 10 m. Species growing in these areas are subject to seasonal floods during the rainy season and xerophytic conditions in the dry season. Strata four forests make up 30.2% of the CCFC (ProPetén-CI 1996).

<u>Location and layout of the transects within study area</u>

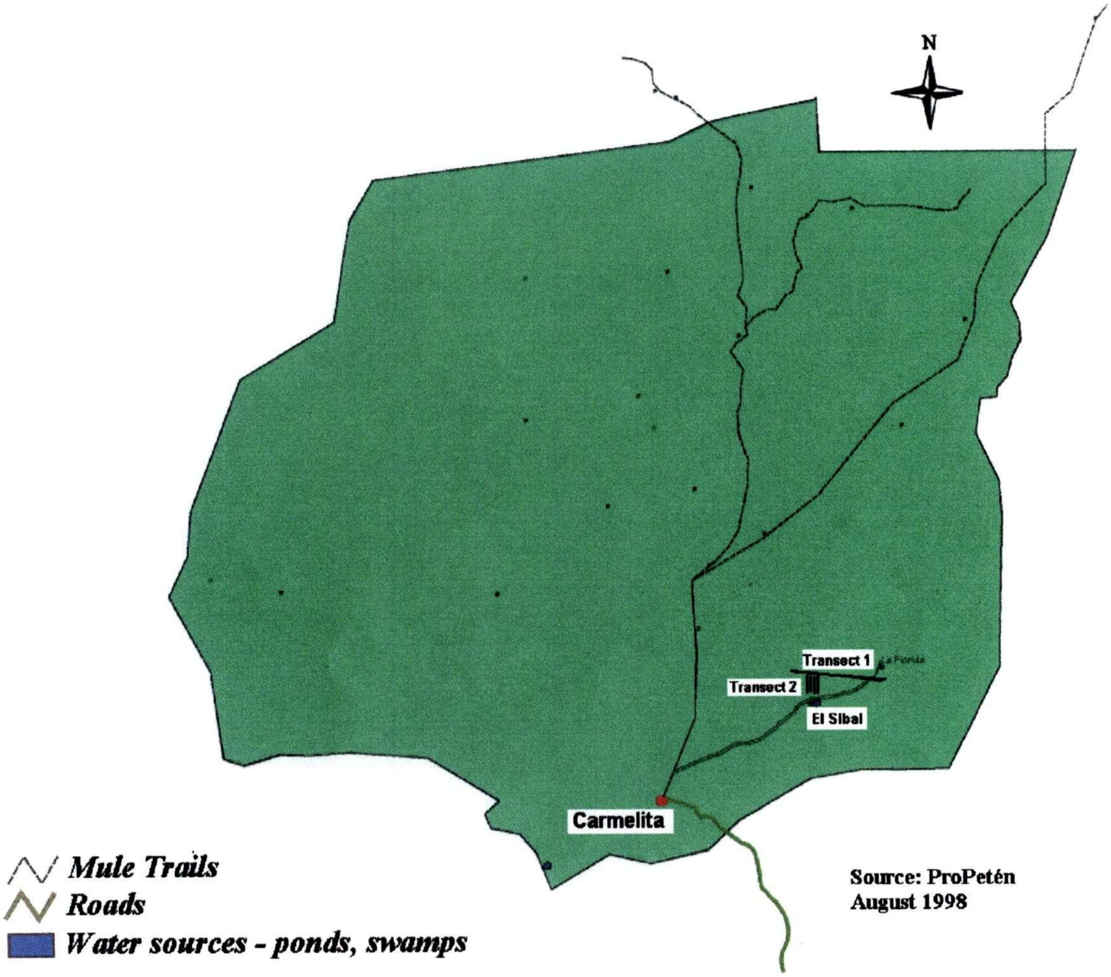
The yield and phenology studies were carried out in strata one and two forest types in the CCFC because these forests are considered to be the most productive in the concession, and the average number of copal trees per hectare in these forests had been previously documented to be higher than in the other two strata (strata 1 = 7.1 trees/ha, strata 2 = 10.0 trees/ha, strata 3 = 1.1 trees/ha, strata 4 = 1.0 trees/ha) (ProPetén-CI 1996). Copal was the 16th most abundant tree in strata one, and the 10th most abundant tree in strata two, compared to 58th and 54th in stratas three and four, respectively. The high species diversity that exists in Petén's forests (strata 1 = up to 106 species/ha, strata 2 = up to 122 species/ha, strata 3 = up to 109 species/ha, strata 4 = up to 88 species/ha)

(ProPetén-CI 1996), like most tropical forests, means that a tree species found at 7-10 per hectare is an abundant species.

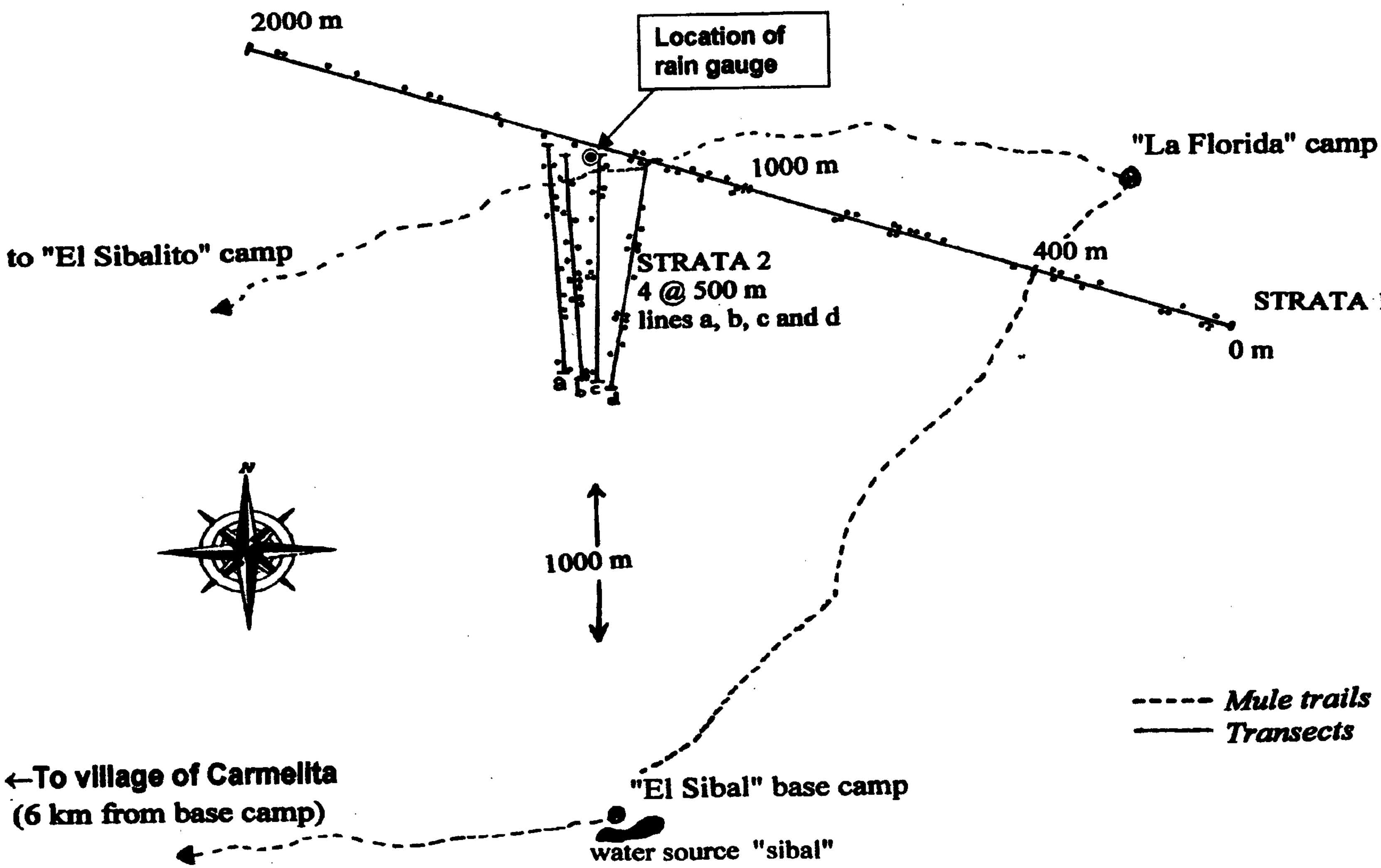
Local guides were consulted as to the area in which to establish the study area, in which both strata one and strata two forest types could be studied. The area suggested was an area known as "La Florida", and base camp was subsequently established there, at a shallow pond called "El Sibal", located approximately six kilometres north east of the village of Carmelita (Map 3). One transect in each of forest strata one and two was established and all copal trees 10 m on either side of each transect were identified and used in the study (Map 4).

The study area consisted primarily of strata one vegetation type. The transect in strata one (transect one) began approximately 1870 m north west of the base camp and ran 2000 m south east, ending approximately 1630 m north east of the base camp. Within the 20 m area along transect one, 50 copal trees were located (Map 4). The area within the 2000 m by 20 m transect comprises 4 ha.

A small, flat plateau near transect one had the vegetation characteristics of strata two forest type, so transect two was established within this area as four 500 m by 20 m lines, also representing 4 ha (Maps 3 and 4). The size of the plateau could not accommodate a 2000 m transect like that of transect one. Each of the four 20 m wide transects in strata two began 10 m apart, and the intent was to establish four parallel transects, running south to north. Transects were labelled S2a, S2b, S2c and S2d from west to east. Transects S2a and S2b (first two established) ran parallel, beginning and ending 10 m apart. Transects S2c and S2d (last two established) began with 10 m between each other and S2b, but ended with 73.6 m between S2b and S2c, and 92.5 m



Map 3. Location of transects of *Protium copal* study within Carmelita Community Forest Concession. Source: ProPetén-CI 1998.



Map 4. Schematic map of transects and location of study trees (points) along transects (Mendez 1998).

between S2c and S2d (Map 4). All four transects, however, were maintained within vegetation strata type two. Within the four lines of transect two, 52 copal trees were located.

The ethnobotanical portion was composed of interviews with community members in four towns between Flores and Carmelita – San Andrés, San José, Cruce dos Aguadas and Carmelita (see Map 2) using a standardised set of survey questions. The harvest and use of copal in Petén is minor, and most people encountered either knew nothing or very little about the tree. And if the occasional person had heard of copal, all they usually knew was that it had something to do with the ancient Maya. Thus, the choice of survey participants was simply based on whether they knew anything at all about the copal tree. As many individuals as possible with this qualification were contacted and interviewed. The development of the survey questionnaire is described in the ethnobotany component of the methods section.

METHODS

All copal trees found within 10 m on either side of both transects described in the previous section were included in the study. Each tree was randomly labelled with metal tags, upon which was etched one of four treatments (T1, T2, T3, C), three of which were different tapping techniques (T1, T2, T3), and the remaining treatment was a set of control (untapped) trees (C).

CONFIRMATION OF IDENTIFICATION OF STUDY SPECIES

A sub-sample of the study trees was selected according to the feasibility of reaching the crown. Leaf samples were clipped from these trees and immediately pressed and labelled, and then dried. These samples were sent to New York Botanical Gardens for confirmation of species identification by New World Burseraceae expert Douglas Daly.

RESIN YIELD

Description of treatments

Three tapping methods (treatments) were investigated for effect on resin production, resin quality and sustainability of resin extraction.

Tapping method one (T1): This method was chosen for the study because it is the dominant tapping technique used by a small number of copal resin harvesting families in Cruce dos Aguadas, a town approximately halfway between Flores and Carmelita, that is the centre of copal resin harvest in Petén. The method used by local copal tappers consists of shaving a small round of bark (approximately 2 cm diameter) with a machete, cutting to the depth of, but not into, the wood. Similar cuts are made at equally spaced positions around the trunk, all at about the same height from the ground. The number of cuts is dependent on the size (diameter) of the tree. Smaller trees (15 – 20 cm diameter) get two or three cuts; larger trees (25 – 30 cm diameter) receive four or five. The viscous resin flows slowly down the trunk and is collected after three days by simply running a machete up the flow and scraping the collected resin onto a handheld pallet. The cut is then reopened (freshened) by slicing off 1 – 2 mm of bark from the top of the cut. The tree is revisited in three days when the resin is again collected and the cut freshened. This process is repeated during the tapping period. In this manner, the cut area slowly increases in length upwards, while the bottom portion heals.

For the yield component of the study, this method was called treatment one and was adapted to one cut every 5 cm of the DBH of the tree. All taps were placed at a height of approximately 20 cm from the ground (Figure 3). Returning every three days to collect resin and renew the cut, as is the normal practice in Cruce dos Aguadas, was not possible for this study. Weekly visits to each study tree were made during which all resin was collected and each tap was subsequently freshened in the manner described above. Fourteen resin collections from each study tree treated with tapping method one were made from March 1 to May 27, 1998.

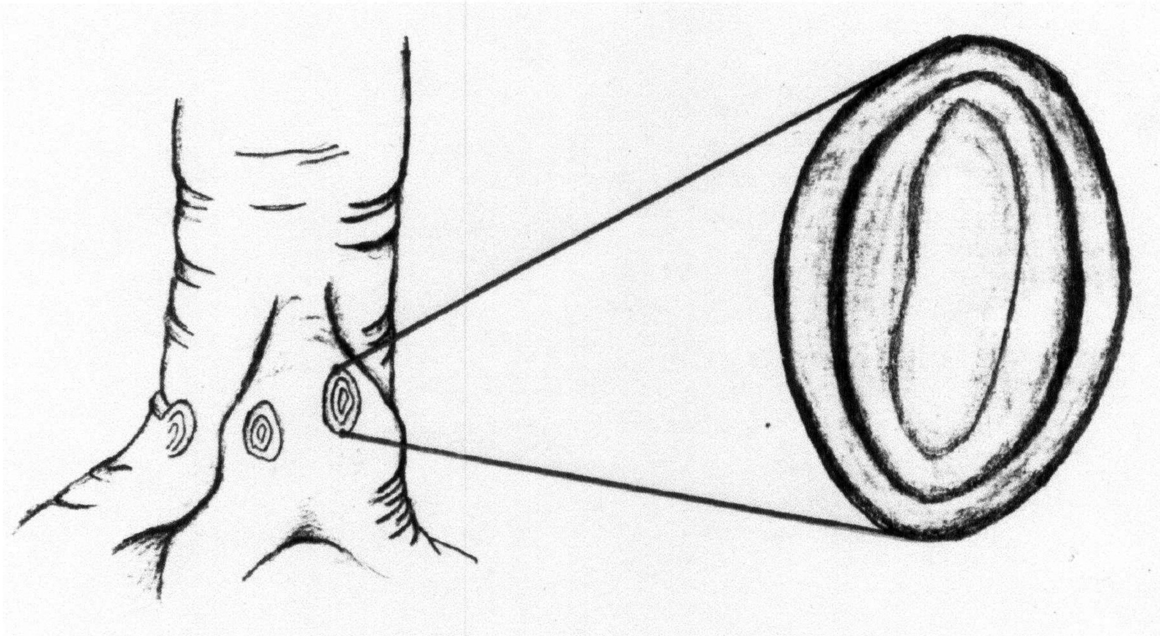


Figure 3. Tapping method one, treatment one (T1) for resin of *P. copal* (Vermeer 1999).

The resin was collected from tapped trees at each visit by scraping and removing using sharpened sticks. The resin from each tree was placed in separate and clearly marked small, lightweight cellophane bags, acquired in the market near Flores (1lb market bags). To collect the resin the bags were placed inside out over one hand with the bottom portion of the bag forming a collection vessel between the fingers (Figure 4).

Figure 4. Collection of resin of *P. copal* using sharpened stick and cellophane bag.

The resin was placed in the bag beginning at the bottom. When all of the resin of a particular tree was collected, the bag was turned back and simply pressed shut utilising the sticky resin to seal the bag. Once the resin had adhered to the thin plastic, it was impossible to remove it. Therefore, when samples were later weighed for analysis, the weekly resin yield from each tree had to be weighed together with its cellophane bag. The average weight of twenty empty cellophane bags was calculated and subtracted from the weight of each sample. The resulting sample weight was used in later data analysis.

Tapping method two (T2): This tapping method is described in the literature on pine tapping (*Pinus* spp.), and most commonly involves the removal of a narrow (1 – 2 cm) strip of bark (streak), in a horizontal or diagonal orientation. Pine oleoresin is fluid-like, so a gutter and collection cup system is usually attached to the streak (see Figure 2). The standard period between resin collection and streak freshening is one week.

This tapping method, treatment two (T2), was applied to study trees as a horizontal streak of 0.5 cm width and 1/3 DBH length, at a height of 20 cm from the ground (Figure 5).

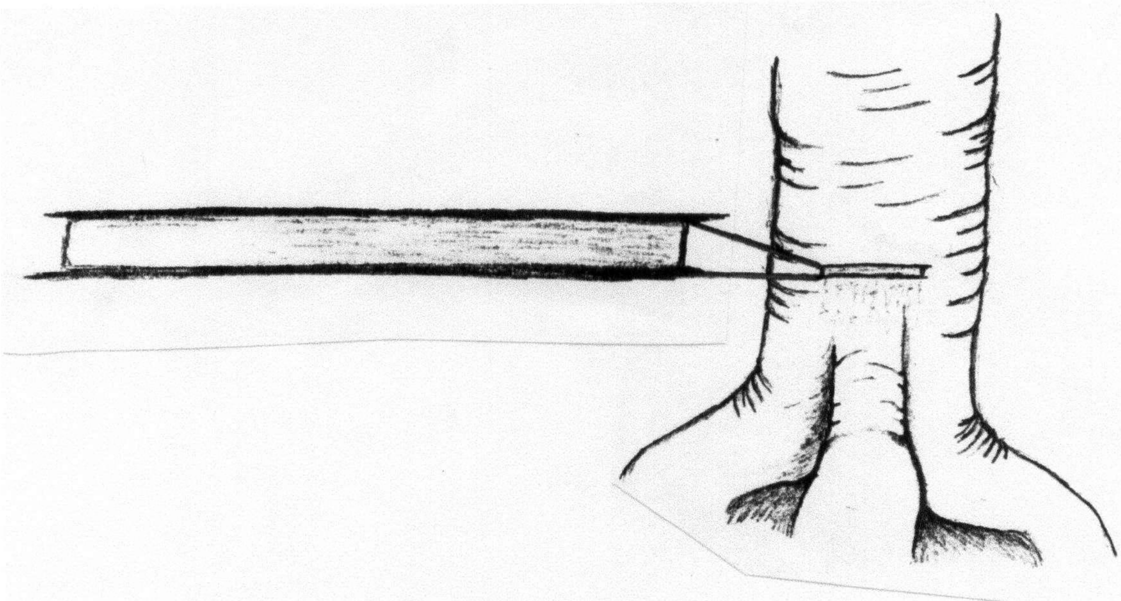


Figure 5. Tapping method two, treatment two (T2) for resin of *P. copal* (Vermeer 1999).

The resin of *Protium copal* is viscous, so a collection gutter and cup system was not deemed necessary. The streaks were made using simple penknives. Resin was collected weekly and in the same manner as described for treatment one (T1). Streaks were freshened after the resin was collected by cutting and removing a thin strip of bark (1 – 2 mm) from the top of the streak. Fourteen resin collections of T2 trees were made from March 1 to May 27, 1998. T2 resin samples were later weighed using the same methodology as the T1 resin samples.

Tapping method 3 (T3): This tapping method was included in response to a suggestion made by local guides, experienced in the harvest of non-timber forest products, and because the literature on resin tapping had revealed that higher areas of bark removal had resulted in higher resin yields. The technique consisted of scraping a vertical face of bark from the trunk, to the depth of the wood. The extent of the wound would be great and the possibility that the resulting resin yield would be greater than that of T1 and T2 would be explored. It was included as a treatment representing high intensity tapping.

Study trees designated T3 were treated with vertical scrapes beginning 20 cm from the ground, extending upwards 15 cm and having a width of about 4 cm (Figure 6). The number of scrapes per tree followed the methodology in T1, with one scrape per 5 cm of the tree's DBH. When trees of T3 were revisited, the resin was collected as it was in T1 and T2, and the scraped areas were freshened by removing a thin strip of bark from around the entire cut, thereby increasing the area of exposed wood. The collected resin samples were later weighed in the same manner as the samples from T1 and T2.

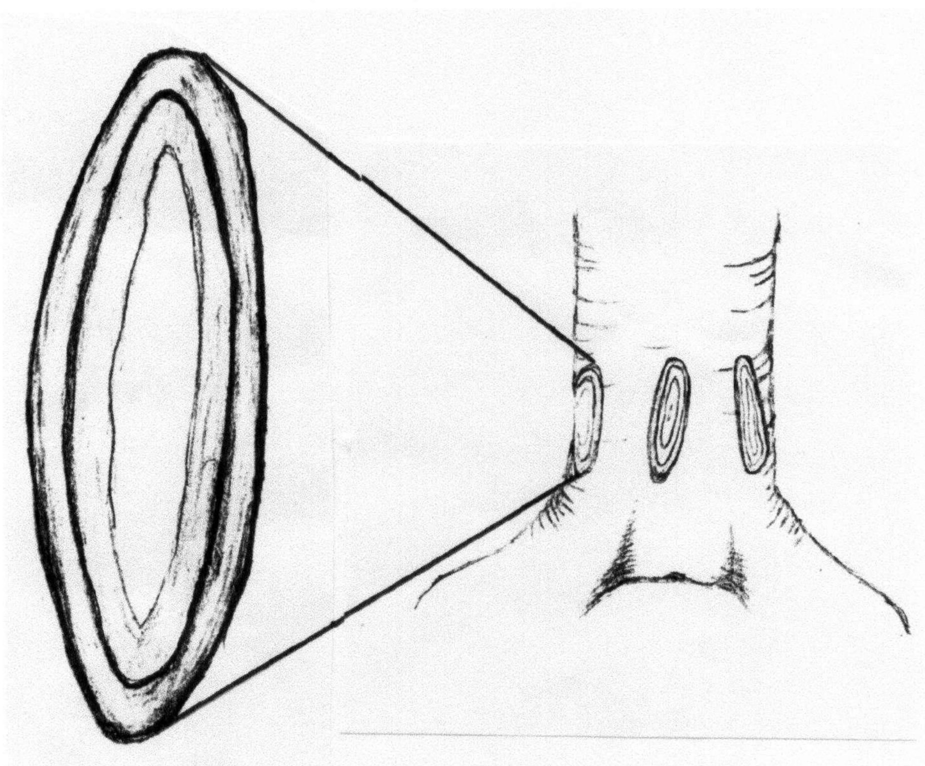


Figure 6. Tapping method three, treatment three (T3) for resin of *P. copal* (Vermeer 1999).

Copious amounts of resin were not seen in the first, second or third collections of resin from the trees treated with tapping method three. After the taps had been freshened five times, it became apparent that a great deal of damage was being done to the trees and the decision to discontinue treatment three was made. This method is one that was meant to provide high resin yield over a short time. This result was not observed, therefore after the third resin collection the taps were no longer freshened. The taps were monitored, however, for their progress of healing from the following visit (collection four, March 18-20) until the end of the tapping period.

The set of control trees were not tapped or manipulated in any way. Weekly phenological data was taken of the control trees, and of all the treated trees. The methodology used to collect these data is described in the phenology component of the methods.

All trees in T1, T2 and T3 were tapped in visit one (Feb. 15 – 18). During the second visit (Feb. 22 – 24) it was noted that negligible amounts of resin had been produced in the majority of trees, thus resin was not collected and all T1, T2, and T3 trees had their taps freshened. Previous research, both in the literature and in conversation with local tappers, revealed that resin production often requires stimulation. This stimulation can take the form of introducing fire to the base of the trunk, physically beating the trunk, applying chemical stimulants in a variety of ways, or simply by tapping. Local copal resin harvesters maintained that several weeks of tapping provide the necessary stimulation required to induce flow. Although local advice was to tap three times before collecting, study trees were tapped twice and on the third visit (Mar. 1 – 4) the first resin collection was made.

Sample size

Study trees were randomly assigned one of the four treatments (T1, T2, T3 and C) described above. In each transect, 12 trees were assigned to each of T1, T2, T3 and C, resulting in 48 trees per transect, for a total of 96 study trees in both transects. In the second week of tapping (not yet collecting resin) another copal tree was found in transect one and was randomly assigned to one of the tapping treatments. It was included as a tapped tree because it was early enough in the tapping period to maintain a complete resin yield data set, although the tree was one week behind in stimulation. The tree was designated S1T1-13.

In the third week of tapping (first resin collection), one more copal tree was located in transect one and was included as a control tree (S1C-13). Also in the third week of tapping, four more copal trees were found in transect two, and were added as control trees (S2C-13, S2C-14, S2C-15, S2C-16). The final sample size was therefore expanded to 102 trees.

The tapping period for the study began February 15 and ended May 27, 1998, with sixteen visits made to all trees (Figure 7). Sixteen taps and fourteen resin collections were made to all trees in T1 and T2. Four taps and three resin collections were made to all trees in T3.

There were exceptions to the weekly tapping and collection regime. In early March, taps 3, 4 and 5 (collections 1, 2 and 3) were each separated by three days. It was necessary to modify the tapping schedule from weekend tapping to mid week tapping for transportation reasons. Another exception to the weekly visits was between taps 8 and 9 (collections 6 and 7), when transportation to Carmelita was unavailable due to a national week of holiday, and two weeks rather than one elapsed between visits. Finally, between each of taps 13, 14 and 15 (collections 11, 12 and 13) three days elapsed. At this time, expertise was made available by ProPetén to confirm and document certain characteristics of the study trees and the study area, and it was necessary to extend the stay at Carmelita to await the arrival of the forestry professional. The opportunity was utilised to add an additional resin collection and freshening to obtain more yield data.

February

Mon	Tues	Wed	Thurs	Fri	Sat	Sun
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15 **tap #1 strata 2**
16 **tap #1 strata 2**	17 **tap #1 strata 1**	18 **tap #1 strata 1**	19	20	21	22 **tap #2 strata 2**
23 **tap #2 strata 2**	24 **tap #2 strata 1**	25	26	27	28	

March

Mon	Tues	Wed	Thurs	Fri	Sat	Sun
						1 **tap #3 collect 1**
2 **tap #3 collect 1**	3 **tap #3 collect 1**	4 **tap #3 collect 1**	5	6	7 **tap #4 collect 2**	8 **tap #4 collect 2**
9 **tap #4 collect 2**	10 **tap #4 collect 2**	11 **tap #5 collect 3**	12 **tap #5 collect 3**	13 **tap #5 collect 3**	14	15
16	17	18 **tap #6 collect 4**	19 **tap #6 collect 4**	20 **tap #6 collect 4**	21	22
23	24	25 **tap #7 collect 5**	26 **tap #7 collect 5**	27	28	29
30	31					

April

Mon	Tues	Wed	Thurs	Fri	Sat	Sun
		1 **tap #8 collect 6**	2 **tap #8 collect 6**	3	4	5
6	7	8	9	10	11	12
13	14	15 **tap #9 collect 7**	16 **tap #9 collect 7**	17	18	19
20	21	22 **tap #10 collect 8**	23 **tap #10 collect 8**	24	25	26
27	28	29 **tap #11 collect 9**	30 **tap #11 collect 9**			

May

Mon	Tues	Wed	Thurs	Fri	Sat	Sun
				1	2	3
4	5	6 **tap #12 collect 10**	7 **tap #12 collect 10**	8	9	10
11	12	13 **tap #13 collect 11**	14 **tap #13 collect 11**	15	16 **tap #14 collect 12**	17 **tap #14 collect 12**
18	19 **tap #15 collect 13**	20 **tap #15 collect 13**	21	22	23	24
25	26 **tap #16 collect 14**	27 **tap #16 collect 14**	28	29	30	31

Figure 7. Resin tapping and resin collection events of resin yield study, *Protium copal.*

Variables affecting yield

Each study tree was described by the variables listed in Table 3, many of which were used in later analyses to determine their influence on resin production or yield.

Table 3. Variables measured on study trees of *Protium copal.*

#	VARIABLE	#	VARIABLE
1	Diameter at breast height (DBH) (cm)	12	Incline of tree (estimated)
2	Trunk height (m)	13	Canopy characteristics (code)
3	Total tree height (m)	14	Slope of ground around tree (code)
4	Trunk characteristics and overall tree health (code)*	15	Visible soil level competition (estimated)
		16	Resin type (code)
5	Crown characteristics (code)	17	Resin bee presence, resin removal (code)
6	Crown position (code)	18	Rainfall (mm)
7	Crown illumination (code)	19	Taps with resin (T1 and T3 only)
8	Lianas in crown and on tree (code)	20	State of healing of scars (T3) (code)
9	Number of lianas in tree	21	Estimation of resin present (T3) (code)
10	Level of termite presence (code)	22	Final height of taps (T1) or faces (T2) (cm)
11	Extent of bark "condition"** (code)		

*Codes were developed by the author or were previously established and used by the forestry department of the NGO assisting with the study.

** The bark condition seen in some of the copal trees manifested itself as bark that was cracked and flaking off. It was generally seen as spots or patches on the trunk in which bark flakes were curled up at the edges. Different levels of the condition was seen on different trees, with some trees exhibiting extensive affected areas. It was of interest to observe if this condition had any noticeable negative or positive effect on the yield of resin.

Diameter at breast height was measured in centimetres with a standard diameter tape, at 130 cm from the ground. *Trunk height* and *total tree height* were measured using clinometers. W*eekly rainfall* measurements were made using a rain gauge (installed at a point between both transects (Map 4) from March 25 to May 27), while the *final height of taps (T1) or faces (T2)* was measured using a simple ruler.

Variables 4 – 8, 10 – 11, 13 – 14, 16 – 17 and 20 – 21 were codes established by ProPetén or developed by the author and are defined in Table 4. C*rown characteristics* and *crown illumination* are also illustrated in Figures 8 and 9 respectively. Variables 9, 12 and 19 were counted, estimated and documented respectively. Variable 15, soil level competition, was estimated. *Protium copal* is a heavily buttressed tree, as are many species of *Protium* (Richards 1996), and was often observed growing close to other heavily buttressed species, such as the Ramon tree (*Brosimum alicastrum*). The extent to which the buttressed roots of other tree species encroached upon the roots or buttresses of the study trees was estimated and recorded.

Table 4. Summary of definitions for variables with codes.

Variable # from Table 3	Variable	Definition
4	Trunk characteristics and overall tree health	1 straight and healthy, 2 slightly twisted and healthy, 3 very twisted, 4 straight and unhealthy, 5 twisted and unhealthy
5	Crown characteristics	1 perfect, 2 good, 3 fair, 4 poor, 5 very poor (Figure 8)
6	Crown position	1 dominant, 2 subdominant, 3 beneath canopy
7	Crown illumination	1 emergent (crown completely free), 2 vertical exposure (top of crown receives light vertically), 3 partial vertical (receives little direct vertical light), 4 obscured (crown partially covered), 5 no direct light (crown completely covered) (Figure 9)
8	Lianas in crown and on tree	1 free of lianas, 2 loose on trunk, not in crown, 3 loose on trunk, present in crown, 4 tightly woven around trunk, present in crown, 5 covered with lianas, loss of growth
10	Level of termite presence	0 no evidence of termite presence, 1 evidence of past presence, 2 current presence, lines with insects visible, 3 infestation
11	Extent of bark condition	0 no evidence of condition, 1 occasional spots, 2 occasional patches, 3 larger sections or areas, 4 large areas, vertically and/or around the circumference, 5 most of the trunk affected
13	Canopy characteristics	1 open canopy, 2 partly open, 3 closed, dense
14	Slope of ground around tree	0 flat, 1 very slight slope, 2 slight slope, 3 significant slope
16	Resin type	1 fluid, honey-like, 2 soft, viscous, develops "skin" on exposure to air (2a cloudy, 2b clear), 3 crystal-like, hard and clear, 4 hard, white, like a sticky powder
17	Resin bee presence, resin removal	0 no bees, no evidence of bees on resin, 1 evidence of bees having been on resin, 2 few bees present, or caught in resin, 3 many bees present, removing resin
20	State of healing of scars	1 no change from previous week, 2 slight evidence of bark closing over wood, 3 lifting of interior layer of bark, scar formation beginning, 4 lifted bark around scar, evidence of closing of wound
21	Estimation of resin present (T3) *	0 no resin exuding from any scars, 1 very little resin, droplets, 2 larger quantities seen, long drops on trunk, 3 significant quantities, resin has run down bark, some on ground

* After tap freshening on T3 trees was discontinued, resin continued to exude from the taps. The quantity of resin seen on each T3 tree was classified as one of the three quantity levels at each visit, and then removed and discarded.

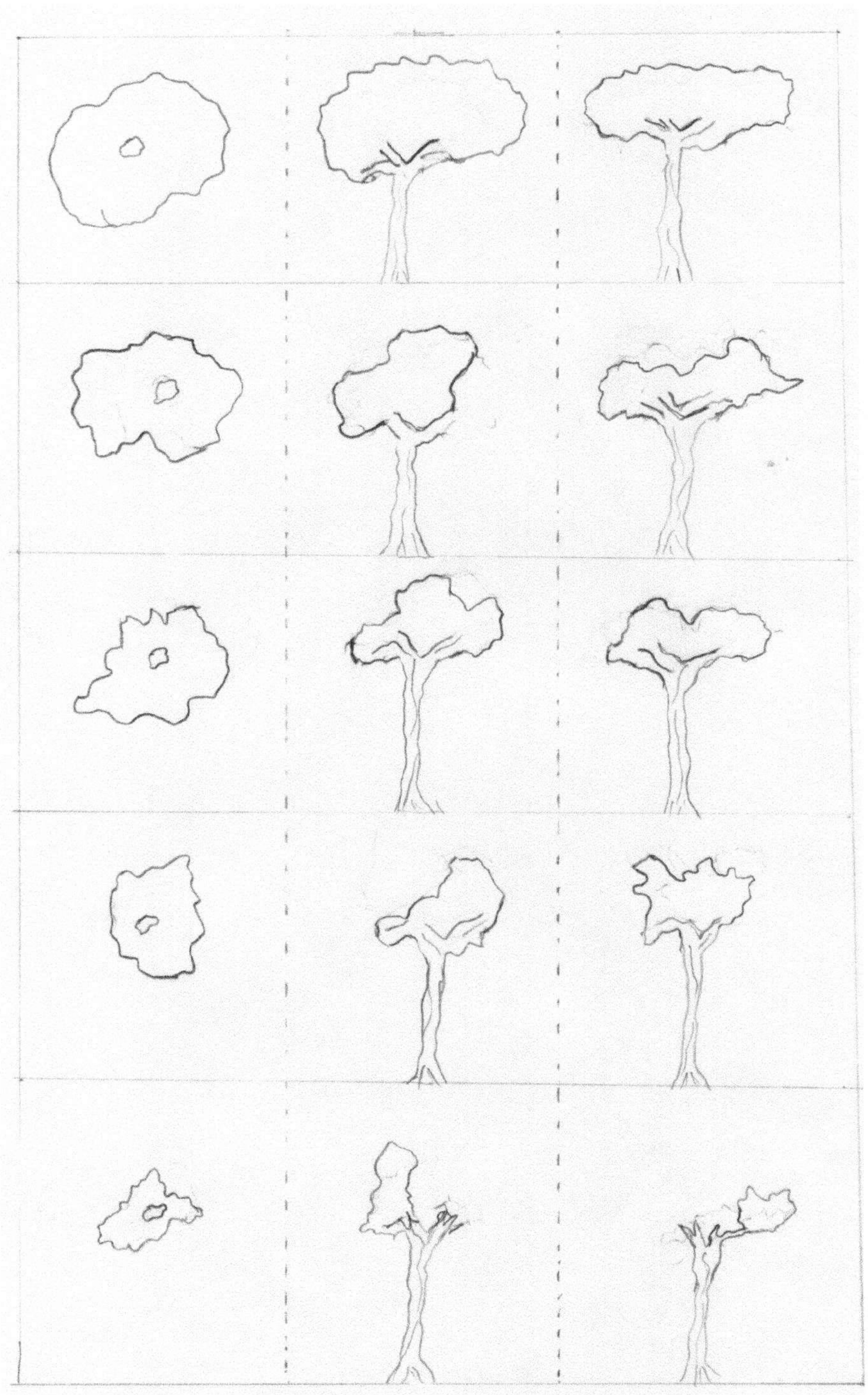


Figure 8. Crown characteristics (code) (Mendez 2000).

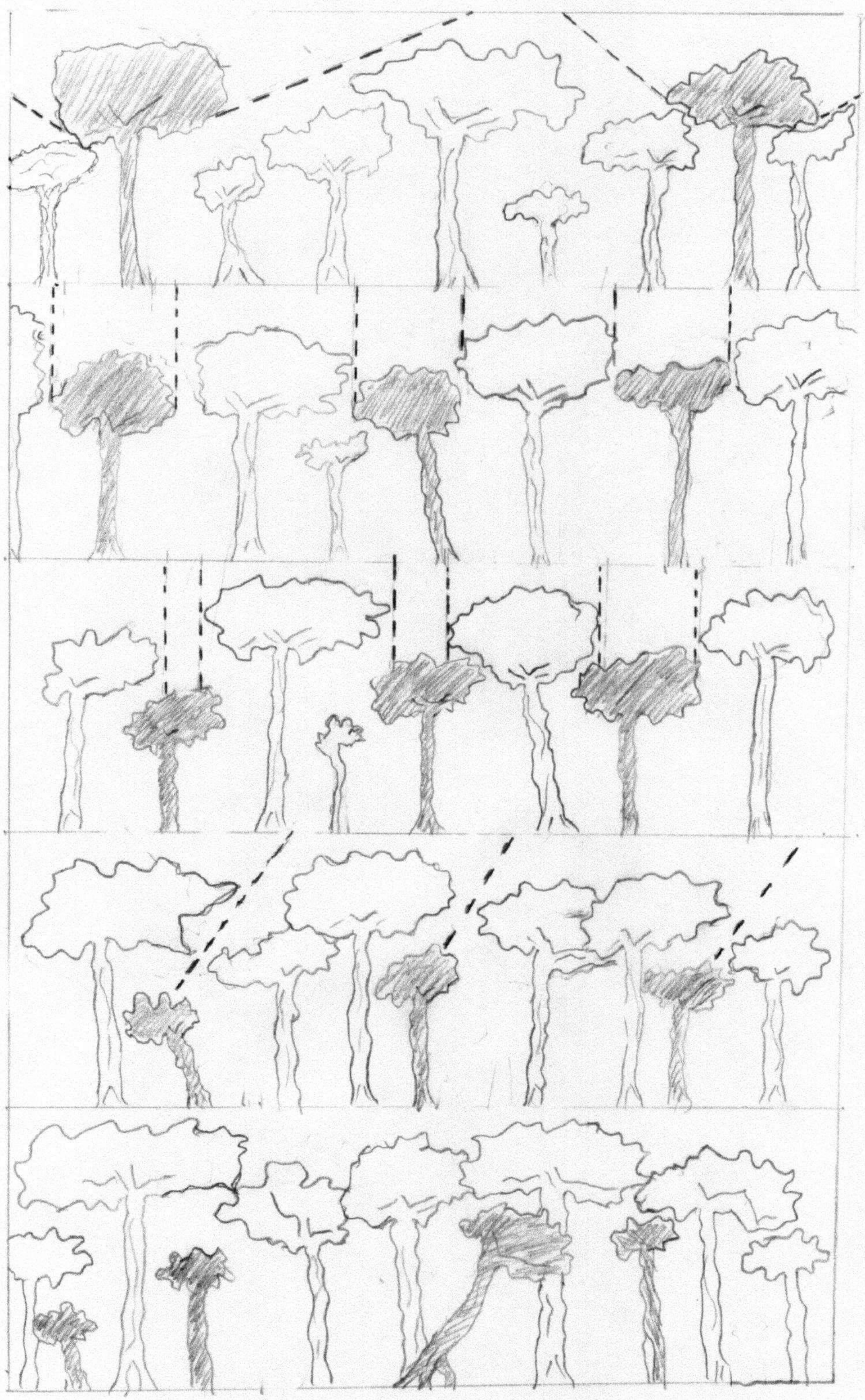


Figure 9. Crown illumination (code) (Mendez 2000).

Statistical analysis

Covariance analysis was conducted on the DBH by yield regressions of the four treatment-by-strata combinations (S1T1, S1T2, S2T1, S2T2) to determine significant differences in slope and / or level.

The mean resin yields of treatments and strata were compared using a two-factor analysis of variance to determine significant differences in the yields of treatments or strata (location), based on a completely randomised design (CRD) with two treatments and eleven replication in two locations / strata. Statistical hypotheses are stated as follows:

$H0_1$: $\mu_{T1} = \mu_{T2}$ $H0_2$: $\mu_{S1} = \mu_{S2}$

HI_1: $\mu_{T1} \neq \mu_{T2}$ HI_2: $\mu_{S1} \neq \mu_{S2}$

T = treatment S = strata (location)

Mean resin yields per tree per collection date were calculated for the pooled data of both treatments and strata and were compared using the Bonferroni adjustment for multiple comparisons of 14 mean resin yields of 48 trees.

H0: $\mu_1 = \mu_2, \mu_2 = \mu_3, \ldots \mu_{13} = \mu_{14}$.

HI: $\mu_1 \neq \mu_2, \mu_2 \neq \mu_3, \ldots \mu_{13} \neq \mu_{14}$.

Variables 1, 3 – 5, 7 – 15 and 18 from Table 3 were regressed with yield. Trunk height was not regressed because it was felt that the total tree height regression would represent the relationship adequately. Trunk height was only measured in order to calculate the crown height. Crown position was not regressed because all trees were classified as position two (sub-canopy). The remaining variables were not regressed because they were not recorded for their effects on resin production. Also regressed with yield were volume index (total height of tree * DBH), crown index (crown characteristics code + crown illumination code), crown height (total tree height – trunk height) and phenology. All variables significant at $\alpha = 0.05$ were used in multilinear analysis. The DBH and yield data were transformed to natural logarithmic functions and regressed as well.

The per hectare resin productivity of the study area was estimated based on the yields obtained and on the regression models calculated.

PHENOLOGY

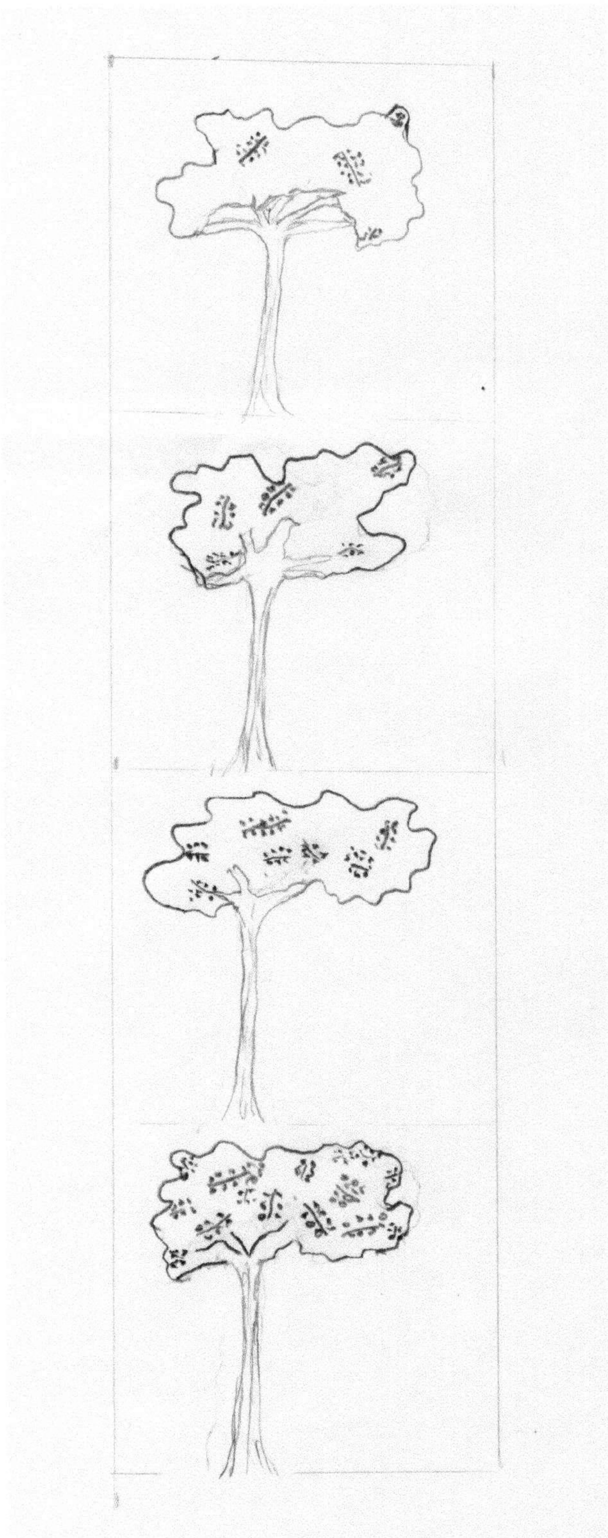
Site visit monitoring of phenology

All study trees were monitored for reproductive activity at every visit. The crown of each tree was evaluated by a local guide with experience in local forests and their flora and fauna. Using binoculars, the phenology was categorised into one of four levels: 0-25%, 26-50%, 51-75% and 76-100% (Figure 10). Reproductive activity was defined as flowers, buds (of flowers, fruits or leaves) immature fruit, mature fruit and new leaves.

For the trees of transect one, reproductive activity was recorded for mid January (Jan. 17-18) because it was established at that time. Beginning February 15 phenology was recorded for all study trees at each of the subsequent visits until May 27.

Collection of fruit litter on last visit

On the last visit to the study trees, the quantity and type of copal fruit litter around each study tree was documented. In this way, particularly reproductively active study trees were noted. Four types of copal fruit litter were documented: mature fruits, buds (of immature fruits), fruit skins (from mature fruits) and damaged fruits.



0 – 25% flowers, buds, fruits or new leaves

26 – 50% flowers, buds, fruits or new leaves

50 – 75% flowers, buds, fruits or new leaves

76 – 100% flowers, buds, fruits or new leaves

Figure 10. Representation of guidelines followed for the determination of level of phenology in study trees (Mendez 2000).

The damaged fruits were probably largely the result of parrot feeding, the main consumers of *Protium copal* fruits according to local sources. Litter quantity was classified into one of four levels: 0 no litter found, 1 few and dispersed, 2 a scattered handful, 3 obvious quantities easily seen all around the tree.

Statistical analysis

The mean levels of overall phenological activity per collection date were plotted with time, by group, and by pooling the data of all trees. The pooled phenology means of consecutive collection dates were compared using the Bonferroni adjustment for multiple comparisons of 16 mean resin yields of 102 trees.

H0: $\mu_1 = \mu_2, \mu_2 = \mu_3, \ldots \mu_{15} = \mu_{16}$.

HI: $\mu_1 \neq \mu_2, \mu_2 \neq \mu_3, \ldots \mu_{15} \neq \mu_{16}$.

Pooled mean phenology data of all 102 trees per collection were separated to components: flowers, "buds" (round green structures of fruit development or vegetative growth), new leaves, immature fruit and mature fruit. The separated data were plotted with time.

For each set of phenological data obtained at every visit (February 15 – May 27), orthogonal contrasts and one-way analysis of variance were used to determine if tapping had any effect on the overall phenology, or if phenology was affected differently by T1 or T2.

Contrast 1:	$H0_1$:	$2C - T1 - T2 = 0$	The phenology of tapped trees is not different from that of the control trees.
	HI_1:	$2C - T1 - T2 \neq 0$	The phenology of tapped trees is different from that of the control trees.

Contrast 2:	$H0_2$: $0 + T1 - T2 = 0$	The phenology of tapping method one is not different from that of tapping method two.
	HI_2: $0 + T1 - T2 \neq 0$	The phenology of tapping method one is different from that of tapping method two.

Pooled overall phenology means for each collection date were regressed with the corresponding DBH and yield data.

ETHNOBOTANY

The methodology used for this component was qualitative, and was used in order to obtain as much detailed information on the cultural role of this resin as possible. Personal interviews were chosen because it was necessary to select participants for their knowledge of local forest plants and their uses, and specifically for their experience with the copal tree, given the lack of familiarity in the general population. This qualitative approach was also appropriate due to the general lack of information regarding most aspects of the tree. The main function of the survey was the gathering of information. The methodology is loosely modelled on a study from the literature that faced the same general lack of knowledge on the study subject (Richards 1997).

Survey questionnaire of local residents

A four-part survey was developed with the aid of members of ProPetén staff (staff ethnobotanist and head of scientific investigations), a sample of which is found in Appendix 1. The four sections of the questionnaire are: 1) general uses of the copal tree, 2) knowledge of the historical use of the copal tree, 3) knowledge of the resin in the local market, and 4) information on various harvesting techniques.

The resin of *Protium copal,* although well known and much utilised as ceremonial incense in the southern departments of Guatemala, is less familiar to much of the population of the northern department of Petén. For this reason, all individuals between Flores and Carmelita who had any familiarity with *Protium copal* were contacted and interviewed. Twenty individuals from four communities – San Andrés, San José, Cruce dos Aguadas and Carmelita – were identified and included in the survey.

The interviews were conducted in an informal manner, usually at the residence of the individual being interviewed. The questions on the survey were simply orally posed and the interviewer (in all cases, the author) recorded the response.

Summary of data

Data from the survey were summarised in tabular format. Statistical analysis was not applied due to the qualitative nature of the methodology.

RESULTS

CONFIRMATION OF STUDY SPECIES

All leaf samples sent to the New York Botanical Gardens were confirmed by D. Daly, as belonging to *Protium copal*, Burseraceae.

RESIN YIELD

Summary of resin yields obtained during the study period

The cumulative sums of the resin yield data are summarised in Table 5.

Table 5. Summary of cumulative *Protium copal* resin yields.

	Strata 1 (4 ha)	**Strata 2 (4 ha)**	**Strata 1 and 2 combined (8 ha)**
	Total yield all trees in group (g)	Total yield all trees in group (g)	Total yield all trees in group (g)
Treatment 1 -14 resin collections -13 trees strata 1 -12 trees strata 2	3,220.4	2,696.5	5,916.9
Treatment 2 -14 resin collections -12 trees strata 1 -11 trees strata 2*	2,459.2	3,407.7	5,866.9
Treatments 1 & 2 combined -14 resin collections -25 trees strata 1 -23 trees strata 2	5,679.6	6,104.3	11,783.9
Treatment 3 -3 resin collections -12 trees strata 1 -12 trees strata 2	178.9	377.5	556.4
Treatments 1, 2 & 3 combined -37 trees strata 1 -35 trees strata 2	5,858.5	6,481.8	12,340.3

*Study tree S2T2-11 produced negligible amounts of resin and was not included in any calculations or analyses.

The total resin collected from fourteen resin collections of all trees in T1 and T2 and in both strata was 11,781.4 g (11.8 kg, 26.0 lb.). With the addition of the resin from three collections of the T3 trees, the total resin collected during the study was 12,323.4 g (12.3 kg, 27.2 lb.).

Average resin yields **per tree** for the entire collection period, and for each collection (approximately weekly), are presented in Table 6.

Table 6. *Protium copal* per tree resin yield averages - cumulative and per collection date.

	Strata 1 (4 ha)				**Strata 2 (4 ha)**				**Strata 1 and 2 combined (8 ha)**			
	entire collection period		per collection		entire collection period		per collection		entire collection period		per collection	
	ave. resin yield per tree (g)	SD, min, max, N	ave. resin yield per tree (g)	SD, min, max, N	ave. resin yield per tree (g)	SD, min, max, N	ave. resin yield per tree (g)	SD, min, max, N	ave. resin yield per tree (g)	SD, min, max, N	ave. resin yield per tree (g)	SD, min, max, N
Treatment 1	247.7	363.1, 5.9, 1029.1, 13	17.7	30.4, 0.0, 141.3, 182	224.7	180.6, 4.0, 571.7, 12	16.1	15.9, 0.0, 81.7, 168	236.7	284.6, 4.0, 1029.1, 25	16.9	24.5, 0.0, 141.3, 350
Treatment 2	204.9	150.0, 23.2, 557.7, 12	14.6	13.1, 0.0, 62.3, 168	308.8	177.6, 71.2, 590.0, 11	22.1	17.8, 0.1, 73.6, 154	255.1	168.7, 23.2, 590.0, 23	18.2	16.0, 0.0, 73.6, 322
Treatments 1 and 2 combined	227.2	276.9, 5.9, 1029.1, 25	16.2	23.8, 0.0, 141.3, 350	265.4	180.4, 4.0, 590.0, 23	19.0	17.1, 0.0, 81.7, 322	245.5	234.0, 4.0, 1029.1, 48	17.5	20.9, 0.0, 141.3, 672

There are no obvious trends as to which treatment or which strata produced the most resin. When the resin yield data of all trees in T1 and T2 in both strata are pooled, the overall mean yield per tree for the whole tapping period is 245.5 g, range = 4.0 – 1029.1, SD = 234.0, N = 48, and the mean yield per tree per collection is 17.5 g, range = 0 – 141.3, SD = 20.9, N = 672.

Yield data by group

Yield data from trees in the treatment-by-strata combinations of S1T1, S1T2, S2T1 and S2T2 (groups) were first examined separately. The results of the by group regressions of DBH with yield are presented in Table 7, and the regression lines of each treatment-by-strata combination are shown in Figure 11.

Table 7. Regression statistics of DBH with yield in treatment-by-strata combinations.

Group	N	R^2	F	P
S1T1	13	0.768	36.42	8.49E-05
S1T2	12	0.771	33.74	1.71E-04
S2T1	12	0.397	6.58	0.0281
S2T2	12	0.563	11.59	0.00782

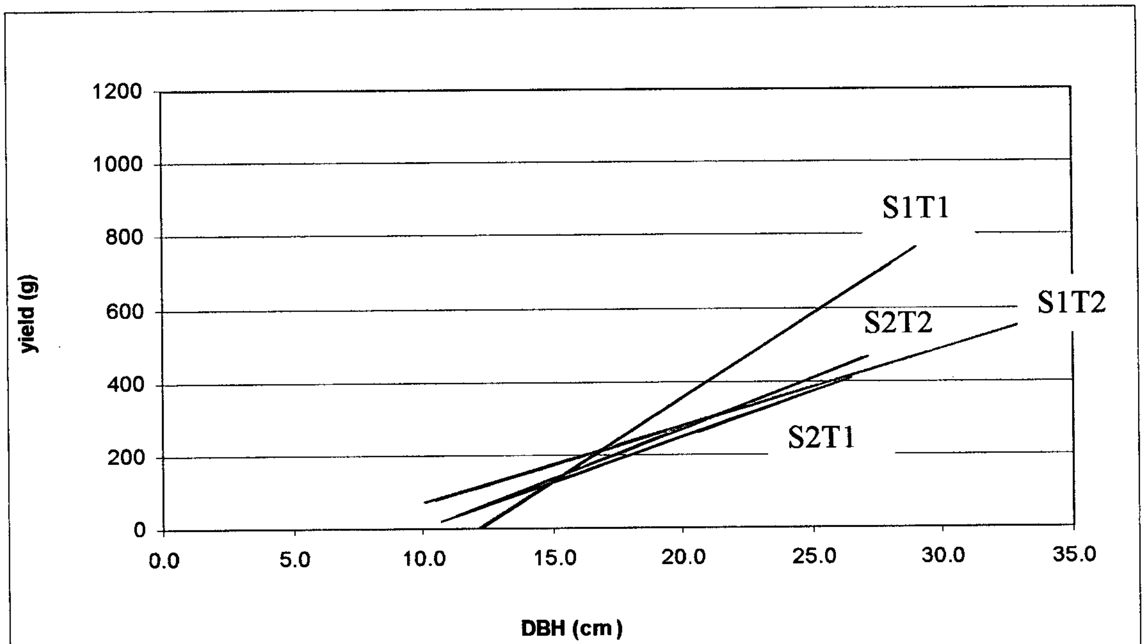


Figure 11. Linear regression lines of DBH with yield by group.

All four group regressions of DBH with yield were significant at $\alpha = 0.05$. A covariance analysis of the four regressions was conducted to determine if there was significant difference in either the slope or in the levels of the regression lines. The analysis showed that there was a significant difference in the slope of at least one of the regression lines. Two further analyses of covariance were carried out. The first was a covariance analysis on the data of the three groups most visually similar – S1T2, S2T1 and S2T2 – which revealed no significant difference in either slope or level of any of the three regression lines. The last analysis of covariance was conducted on the data of group S1T1 and the pooled data of groups S1T2, S2T1 and S2T2. This final covariance analysis showed that there was significant difference between the slope of the regression of group S1T1 and that of the other three regressions.

Analysis of variance

The cumulative mean resin yields of the trees in each of the treatment-by-strata combinations – S1T1, S1T2, S2T1 and S2T2 – were compared using a two-factor analysis of variance with eleven replications in two locations or strata, based on a completely randomised design (CRD).

It is noted here that study tree S2T2-11 produced negligible amounts of resin compared to other tapped trees for the first three collections. After the fourth collection, the tap on this tree was no longer freshened, and resin was no longer collected. To conduct the analysis of variance with equal numbers of replications in each group, the yield data from tree '11' of each group was removed. The yield data from S1T1-13 were also removed for this and one other reason: of all the study trees, S1T1-13 had the highest incidence of resin removal by peccaries (wild pigs, *Tayassu tajacu*). The results of the analysis of variance are presented in Table 8.

Table 8. Two-factor ANOVA on completely randomised design (CRD) with 2 treatments and 11 replications, in two locations (strata).

Source	**df**	**SS**	**MS**	**F**	**F critical value**
treatment	k - 1 = 2 - 1 = 1	969.04	969.04	0.016215	161.4
strata	n - 1 = 2 - 1 = 1	3127.19	3127.19	0.052329	161.4
treatment by strata	(n - 1)(k - 1) = 1	64701.75	64701.75	1.082693	4.08
experimental error	nk(m-1) = 2*2(11 - 1) = 40	2390401.17	59760.03		
total	nkm - 1 = 2*2*11 - 1 = 43	2459199.16			

n = strata = 2 k = treatments = 2 m = replications = 11

The two null hypotheses stated in the methods ($H0_1$: treatment means are not significantly different; $H0_2$: strata means are not significantly different) cannot be rejected. The analysis of variance indicates that neither the treatment means nor the strata means are significantly different. It also shows that the interaction between strata and treatments is not significant. The MS experimental error (59760.03), however, is very high; indicating that tree-to-tree variation is high.

<u>Pooled resin yield data over tapping period</u>

Due to the results of the analysis of variance, subsequent analyses of the yield data were largely conducted using the pooled resin yield data of all groups (S1T1, S1T2, S2T1 and S2T2). The average yield per tree using these pooled yield data was calculated for every collection date and plotted with time, and is presented in Figure 12.

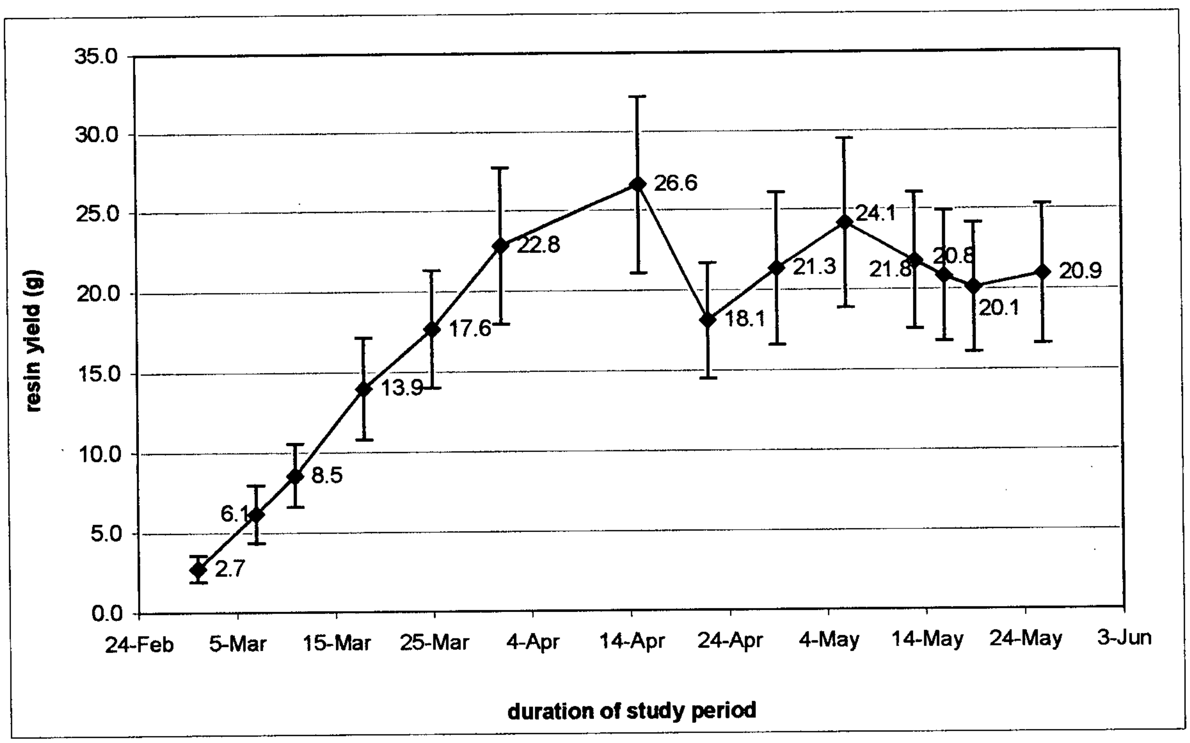


Figure 12. Line graph of average resin yield per tree per collection from March 1 - May 27 of all trees in treatments 1 and 2, and in forest strata 1 and 2 with standard error bars (N = 48).

The fourteen mean resin yields were compared using the Bonferroni adjustment for multiple comparisons, and the results are presented below in Table 9 in time sequence, with letters indicating statistically equal means at α = 0.05.

Table 9. Results of Bonferroni adjustment for multiple comparison for 14 mean resin yields of 48 trees.

Mar 1	Mar 7	Mar 11	Mar 18	Mar 25	Apr 1	Apr 15	Apr 22	Apr 29	May 6	May 13	May 16	May 19	May 26
2.7	**6.1**	**8.5**	**13.9**	**17.6**	**22.8**	**26.6**	**18.1**	**21.3**	**24.1**	**21.8**	**20.8**	**20.1**	**20.9**
a	ac	ad	ae	bcde	be	be	bcde	bde	be	bde	bde	bcde	bde

A significant increase in mean resin yield was seen between March 1 and March 25, after which mean resin yields no longer differed significantly over time.

Regression analyses

All variables measured and recorded were regressed with the pooled cumulative resin yield data, and the results are summarised below in Table 10.

Table 10. Summary of linear regression statistics of variables regressed with yield.

Variable	**R^2**	**F-value**	**P-value**
volume index (total tree height * diameter at breast height)	0.677	96.466	7.190E-13
diameter at breast height (DBH) (cm)	0.612	72.646	5.0675E-11
total tree height (m)	0.428	34.363	4.6601E-07
crown index (crown characteristics code + crown illumination code)	0.238	14.382	0.0004
crown height (m)	0.236	14.190	0.0005
crown characteristics (code)	0.187	10.606	0.002
crown illumination (code)	0.112	5.779	0.020
phenology (estimated % of potential)	0.346	6.347	0.027
slope of ground around tree (estimated)	0.093	4.702	0.035
extent of bark condition (code)	0.062	3.036	0.088
lianas in crown and on tree (code)	0.056	2.751	0.104
rainfall (mm)	0.157	1.307	0.290
number of lianas in tree	0.022	1.015	0.319
visible soil level competition (estimated)	0.013	0.595	0.444
incline of tree (estimated)	0.008	0.366	0.548
trunk characteristics and overall health (code)	0.076	0.256	0.609
level of termite presence on trees (code)	0.002	0.114	0.737
canopy characteristics (code)	0.001	0.024	0.879

α = 0.05, N = 48

The variable *volume index* was derived by multiplying the total height of each tree with its DBH, calculated to provide a crude index of the volume, and thereby size, of each tree. The variable *crown index* is the result of adding the codes for crown characteristics and crown illumination of each tapped tree to create a descriptive variable of the crown, and thereby an indication of the health, of each tapped tree.

When regressed with yield, volume index was the variable seen to be the best predictor of yield, P = 7.190E-13, R^2 = 0.677. The strength of the relationship from the regression of crown height with yield, P = 0.0005, R^2 = 0.236, was similar to that of relationship of the crown index variable with yield, P = 0.0004, R^2 = 0.238.

Multilinear regression analysis

All variables listed in Table 10 significant at $\alpha = 0.05$ were included in a forward stepwise multilinear regression analysis. Two variables remained in the resulting model, volume index and crown index. A multilinear regression analysis was conducted using these two variables in which the normality test failed. Subsequently, a multilinear regression analysis was conducted using the square root of the total yields, the square root of the volume index and the unaltered crown index. The regression passed both the normality test and the constant variance test, and the resulting model is presented below.

sqrt(total yields) = -3.550 + (13.928 * sqrt(volume index)) - (1.016 * crown index)

N = 48 I^2* = 0.720 Estimated standard error of the estimate = 125.244

	P	VIF
sqrt(volume index)	**<0.001**	**1.196**
crown index	**0.031**	**1.196**

*The I^2 value is the correlation coefficient in the original measured units. The R^2 value would be the correlation coefficient of the transformed data – sqrt(yield , sqrt(volume index) – and is not presented when the dependant variable of a regression analysis has been altered) (Spurr, 1952).

The P values indicate that sqrt(yield) and sqrt(volume index) are essentially linearly related, modified by crown index. The small VIF values show that the variables sqrt(volume index) and crown index are not strongly correlated to each other.

Single-variable curvilinear regression (ln_DBH with ln_resin yield)

The linear model that resulted from the regression of DBH with yield, predicted negative yields at small (≤10 cm) DBH trees (intercept coefficient = -325.2). The yield and DBH values were transformed to their natural logs and a linear regression analysis on the transformed data provided the following model.

ln(yield) = -3.903 + 3.068ln(DBH)
Estimated standard error of the estimate = 152.828

N = 48 I^2 = 0.583 P = 8.993E-10

Figure 13 presents the graph of the transformed yield and DBH data with the predicted regression line.

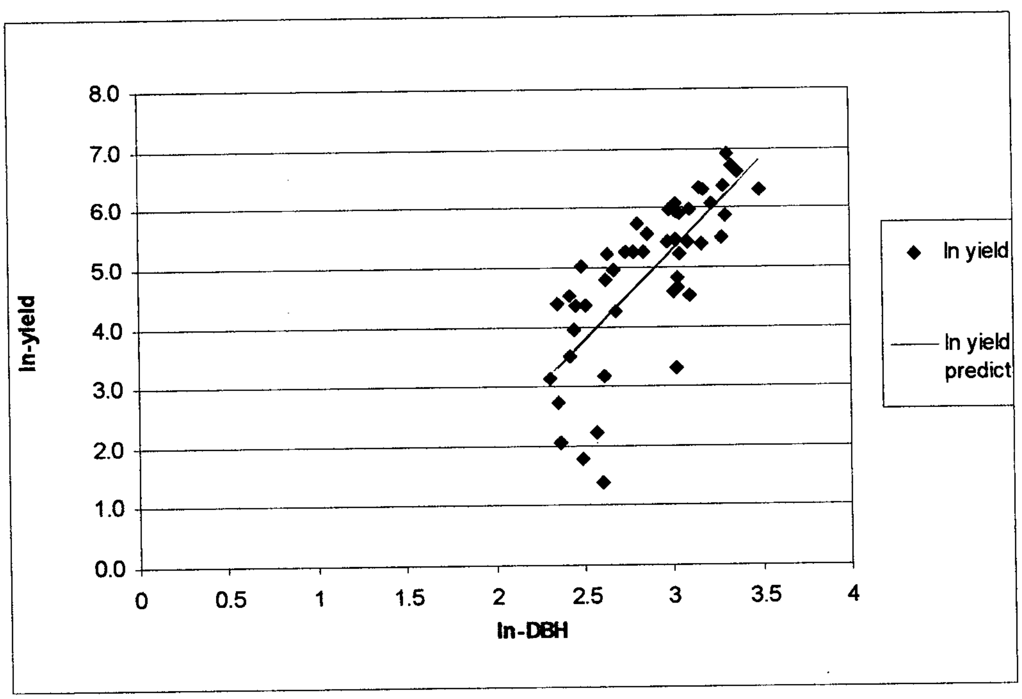


Figure 13. ln-yield vs ln-DBH and y-predict-ln-y.

Figure 14 presents the anti-ln of the above model's predicted yields plotted with the measured DBH of all study trees.

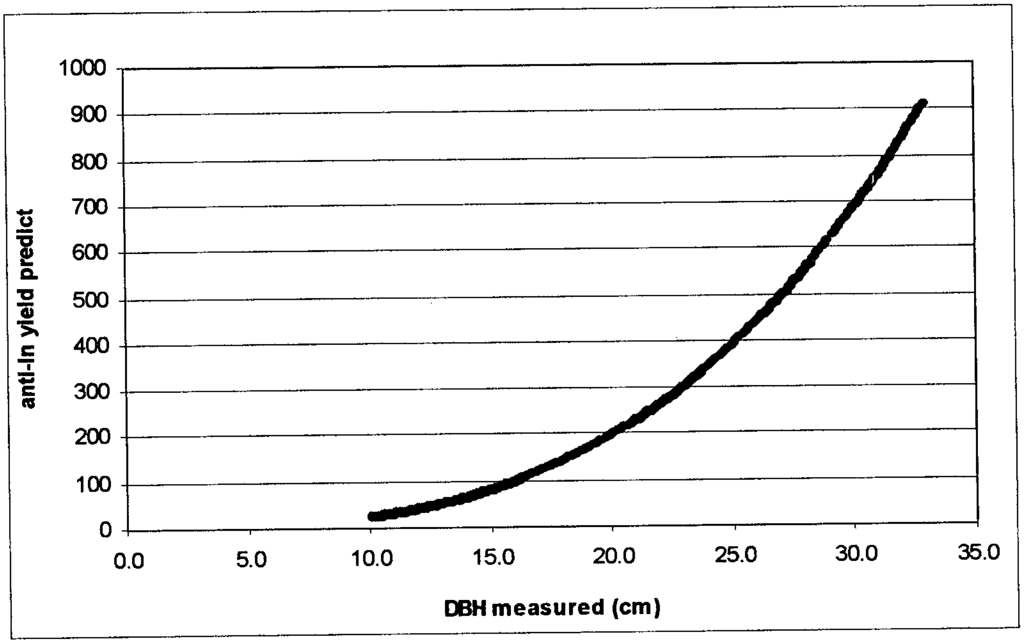


Figure 14. Anti-ln yield predict versus DBH measured.

Potential yields of study area

Resin yield data for the entire tapping period was obtained only for the trees of T1 and T2 in both strata, which represents approximately half of the *Protium copal* trees located within the transects. Table 11 presents, per hectare, how much resin could be produced from February 15 to May 27 in the study area based on the cumulative average resin yields per tree of each of the treatment by strata combinations (from Table 6). Table 12 gives the per hectare resin yield estimates using the curvilinear and multilinear relationships that resulted from previous analyses.

Table 11. Productivity per hectare based on cumulative average resin yield per tree.

	Treatment 1	Treatment 2	Treatments 1 & 2
Strata 1 (50 trees, 4 ha)			
mean yield (g) / ha	3096.5	2558.5	2838.3
95% CI (per ha)	2635.1	1140.3	1400.2
upper (g / ha)	5731.7	3698.8	4238.4
lower (g / ha)	461.4	1418.2	1438.1
yield (g) / tree	247.7	204.7	227.2
Strata 2 (52 trees, 4 ha)			
mean yield (g) / ha	2921.3	4027.3	3450.2
95% CI (per ha)	1428.2	1478.7	1014.9
upper (g / ha)	4349.4	5506.0	4465.1
lower (g / ha)	1493.1	2548.6	2435.4
yield (g) / tree	224.7	309.8	265.4
Strata 1 & 2 (102 trees, 8 ha)			
mean yield (g) / ha	3017.6	3250.6	3129.3
95% CI (per ha)	1392.5	815.1	835.3
upper (g / ha)	4410.1	4065.7	3964.6
lower (g / ha)	1625.1	2435.6	2294
yield (g) / tree	236.7	255.1	245.5

*CI = mean_y ± $(t_{n-1, 1-\alpha/2})$ * S_{y_mean}
S_{y_mean} = sqrt(s^2/n)
S^2 = variance of n values

Table 12. Summary of resin yield estimates using the curvilinear and multilinear equations.

All trees in strata 1 & 2 (102 trees, 8 ha)				
	Yield of all trees predicted with multilinear equation*	Yield of all trees predicted with curvilinear equation**	Actual yields (T1 & T2) + predicted yields (T3 & C) using multilinear equation	Actual yields (T1 & T2) + predicted yields (T3 & C) using curvilinear equation
mean yield (g / ha)	2340.1	2441.4	2416.2	2664.1
max (g / ha)	840.8	911.5	1029.1	1029.1
min (g / ha)	8.9	24.3	4.0	4.0
mean yield (g / tree)	183.5	191.5	189.5	208.9

*sqrt(total yield (g)) = -3.55 + (13.928 * sqrt(volume index)) – (1.016 * crown index)
volume index = total tree height * DBH
crown index = crown characteristics code + crown illumination code
**ln(total yield (g)) = -3.9 + 3.1ln(DBH)

The per hectare yield potential of the study area is notably larger when the estimates are based on yields collected during the study (Table 11) than when estimates are based on the predictions of either of the regression models (Table 12). The per hectare productivity estimate of the entire study area based on actual mean resin yield per tree (Table 11) is 3129.3 g/ha. The per hectare resin yield estimate for the study area based on the curvilinear relationship is 2441.4 g/ha, and on the multilinear relationship is 2340.1 g/ha. When the actual yields of T1 and T2 trees are summed with the predicted yields of T3 and C trees using the multilinear equation, the predicted yield for the study area is 2411.5 g/ha. When the same calculation is made using the curvilinear equation, the yield is estimated to be 2664.1 g/ha.

Appendix 2 presents all the trees in the study (in the order and location in which they were found along the transects) with the actual cumulative yields of T1 and T2 trees, and the predicted yields of all the study trees using both the multilinear and the curvilinear equations. The table is useful for comparing the predictive power of the models with the actual yields obtained from the tapped trees and also for comparing the actual yields of trees with similar or different physical characteristics found growing close to, or distant from, each other.

<u>Summary of observations and other data</u>

Additional data were collected once the study was underway. The number and size of taps and streaks were documented, and an accounting was kept of how many taps on T1 trees had resin at every collection date. The resin type of every tree at every collection date (code) was recorded, as was the presence of resin bees, and resin removal by resin bees (code) and peccaries.

Most the trees treated to tapping method one (T1) had resin in every tap at every visit. Occasionally however, one or more taps of some trees did not contain resin. In some cases, as in tree S1T1-13, resin was periodically completely removed from one or all of the taps because wild peccaries had consumed it. In other cases, certain trees were observed to be low resin producers and the occasionally seen dry taps could be attributed to this.

The classification of resin types was undertaken because distinctively different consistencies of resin were seen among tapped trees. The most common resin types seen were classified as 'codes 2a and 2b', being cloudy or clear white, viscous, developing a 'skin' that, when collection commenced, would break and release softer, stickier resin beneath. Other resin types, such as very fluid and clear resin (code 1), hard, clear and crystal-like resin (code 3) and hard, white and opaque resin (code 4) were also seen. In addition to the variation in resin consistency observed, one tree (S1T1-12) produced a resin with a distinctly different odour than the other study trees. This did not change from week to week, unlike the resin consistencies.

The removal of resin due to resin bees and peccaries was documented because it became more common to see evidence of resin removal as the dry summer season progressed. Black, flying insects were regularly observed to be collecting the copal resin on their legs. Some study trees on some collection dates had dozens of these insects working around the taps. Occasionally, a significant quantity of resin removal was suspected. Therefore, from April 22 (collection eight) to the end of the tapping period, every tree was monitored for its degree of resin bee presence or evidence of presence since the last collection.

The observations made about the trees in T3 are separated from those of T1 and T2 trees because the freshening of the T3 taps was discontinued after the third resin collection. The T3 data recorded are an accounting of taps with resin, estimation of quantity of resin in taps (code), recording of presence of resin bees (code) and documentation of progress of healing of scars (code).

The number of taps with resin on T3 trees decreased as the season progressed, although in most trees, some resin continued to exude from at least one tap until the end of the study period. The quantity of resin exuding from the T3 taps also decreased with time. Resin bees were rarely seen around the taps of T3 trees.

Changes in the scars of T3 taps were not seen until collection seven (April 22-23), five weeks after freshening of the taps was discontinued. After the collection seven visit, the progress of the healing of the scars was discernible. At the last visit (approximately seven weeks later), eighteen of the twenty-four T3 trees had one or more taps that were obviously closing, forming raised scar tissue that would eventually meet (code four). All other T3 trees also evidenced signs of healing.

PHENOLOGY

Overall phenology data by group

None of the study trees in transect one exhibited any reproductive activity at the time of transect establishment, January 17-18.

All 102 trees were monitored for level of phenological activity at every visit from February 15 to May 27. All phenological activity (flowering, fruiting, budding, new leaves) was combined, and the average level of activity of all trees was calculated for every visit, for each treatment-by-strata combination, or group (S1C, S1T1, S1T2, S1T3, S2C, S2T1, S2T2, S2T3) and plotted with time. Figure 15 presents the phenology data of all the groups on the same graph, where each line represents a single group.

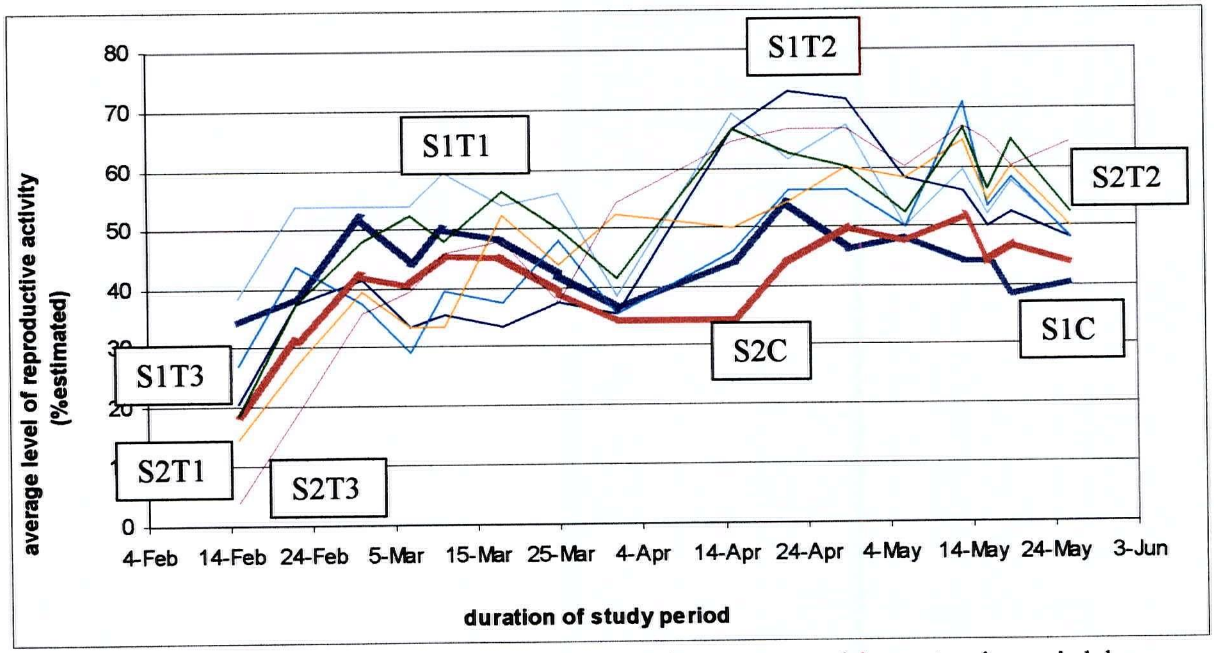


Figure 15. Plot of average level of combined phenology of each tree at every visit over tapping period, by group.

No consistent trend of phenology was seen among the eight groups, with high variability observed between them. Overall phenology of the control trees (heavy lines) were generally lower than that of tapped trees.

<u>Pooled overall phenology data over tapping period</u>

Figure 16 describes the average reproductive activity (combined phenology) of every tree at every collection period when the data from all 102 trees are pooled.

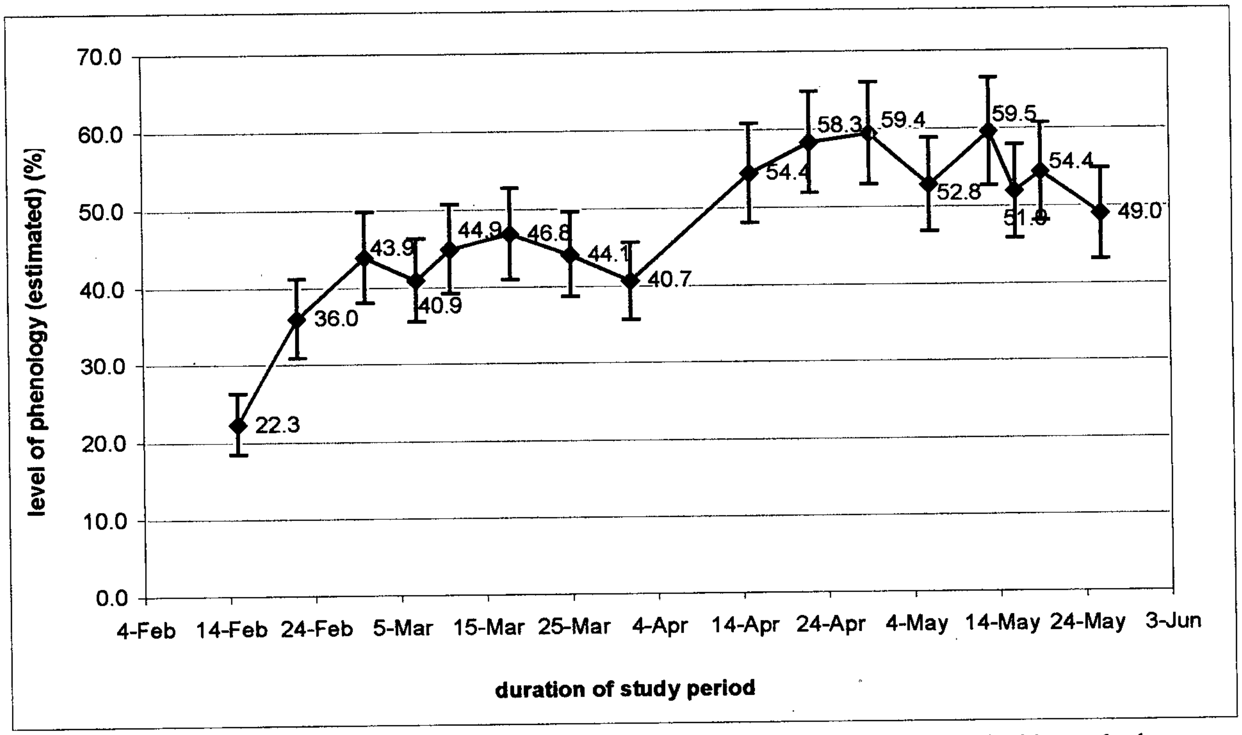


Figure 16. Plot of average level of phenology of each tree at every visit over tapping period with standard error bars; pooled data of 102 trees.

The mean phenology levels for the sixteen site visits were compared using the Bonferroni adjustment for multiple comparisons. The means are presented below in Table 13 in time sequence, with letters indicating statistically equal means at $\alpha = 0.05$.

Table 13. Results of Bonferroni adjustment for multiple comparisons for 16 mean resin yields of 102 trees.

Feb 15	Feb 22	Mar 1	Mar 7	Mar 11	Mar 18	Mar 25	Apr 1	Apr 15	Apr 22	Apr 29	May 6	May 13	May 16	May 19	May 26
23.3	**36.0**	**43.9**	**40.9**	**44.9**	**46.8**	**44.1**	**40.7**	**54.4**	**58.3**	**59.4**	**52.8**	**59.5**	**51.9**	**54.4**	**49.0**
a	ab	bc	bd	be	bf	bg	Bh	cdefgh	cefg	cefg	bcdh	cefg	bcdh	cdefgh	bcd

The mean phenology level of trees rose significantly from mid to late February, and again from early to late April, after which means were no longer significantly different.

Phenological activity separated into components (flowers, buds, new leaves, immature fruit and mature fruit

Phenology data was separated into its components, and the mean per tree levels of each component (flowers, "buds", new leaves, immature fruits and mature fruits) throughout the study period are presented in Table 14 and in Figures 17a-e below. "Bud" was the name given to round, green structures observed throughout the study period, that were either precursors to developing fruits (reproductive structures) or new leaves (vegetative structures).

Table 14. Summary of mean per tree levels of phenology components (flowers, "buds" new leaves, immature fruit and mature fruit) over tapping period.

	Feb 15	Feb 22	Mar 1	Mar 7	Mar 11	Mar 18	Mar 25	Apr 1	Apr 15	Apr 22	Apr 29	May 6	May 13	May 16	May 19	May 26
Flowers	15.0	22.0	1.0	7.0	11.0	18.0	25.0	1.0	15.0	22.0	29.0	6.0	13.0	16.0	19.0	26.0
"Buds" *	5.5	9.6	25.8	8.9	7.4	29.4	40.4	39.7	42.9	46.1	50.5	44.7	47.5	42.8	47.4	42.2
New leaves	0.0	0.0	0.1	0.7	1.1	0.0	0.0	1.0	11.5	12.3	6.9	4.9	7.6	4.8	2.7	2.0
Immature fruit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	3.2	3.1	3.7	3.7	3.8
Mature fruit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.4	0.5	0.6	1.0

*Buds were round, green structures observed throughout the study period, that were either precursors to developing fruits (reproductive structures) or new leaves (vegetative structures).

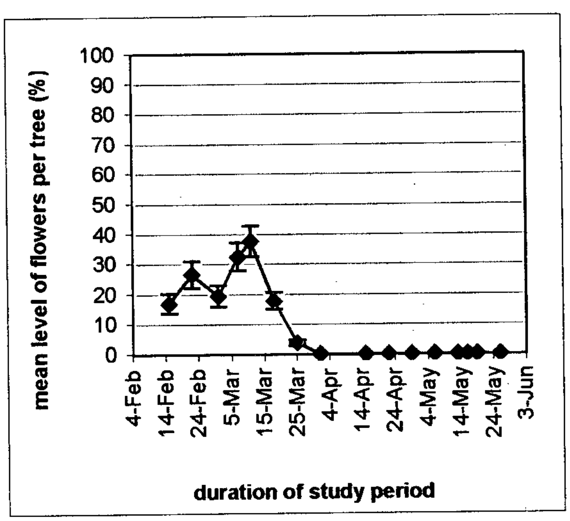


Figure 17a. Mean level of flowers.

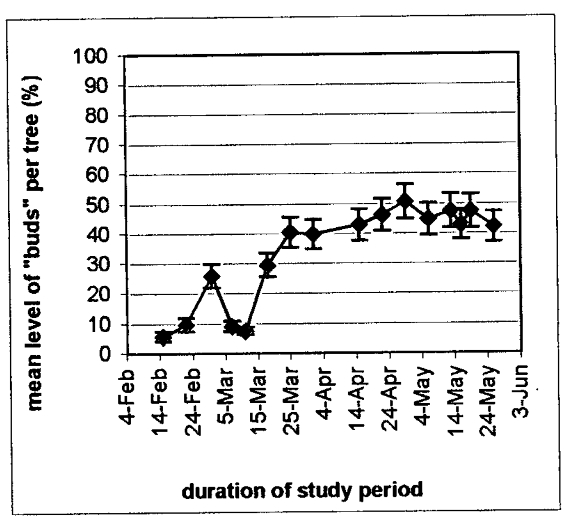


Figure 17b. Mean level of buds.

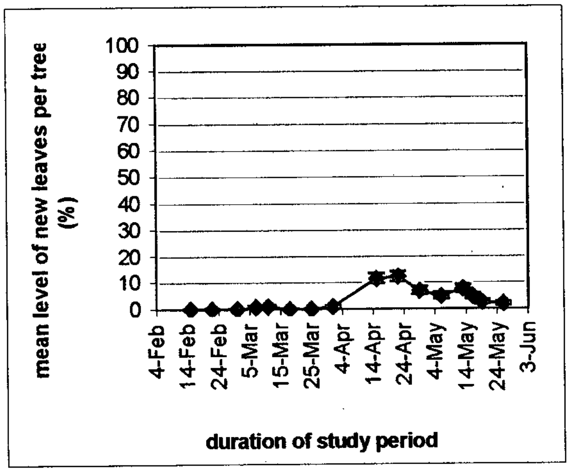


Figure 17c. Mean level of new leaves.

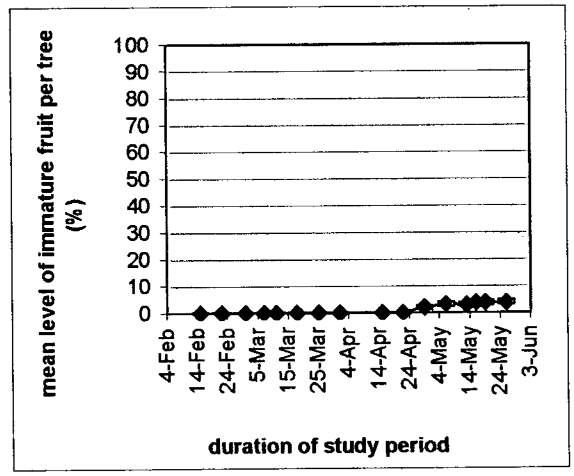


Figure 17d. Mean level of immature fruits.

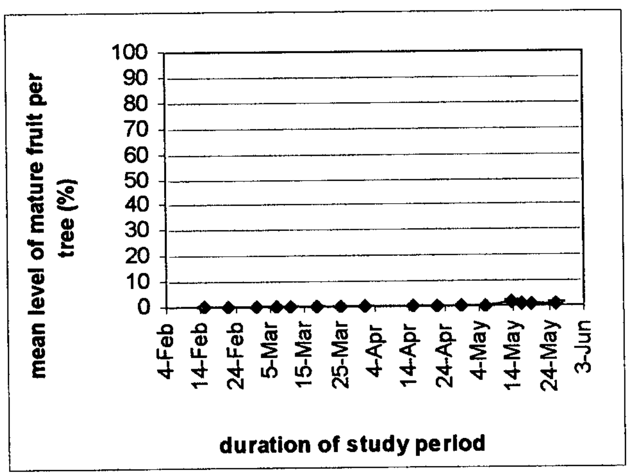


Figure 17e. Mean level of mature fruits.

Flowering concluded at the end of March. The appearance of small round, green structures, "buds", were observed throughout the study period, increasing after mid March and remaining at elevated levels (40-50%) to the end of the study period. New leaves were seen from the first of March until the end of the study period, peaking throughout the month of May. Fruits (immature and mature) were seen through the month of May.

Orthogonal contrasts

Orthogonal contrasts were conducted on the mean phenology levels of the control, T1 and T2 trees for every visit. The results of the analysis revealed that tapping in general had a significant effect on phenology on the April 15-16 visit and the May 19-20 visit. Also seen in the analysis of the May 19-20 visit was a significant difference in phenology between the two strata, indicating a location or strata effect. This strata effect was also seen in the orthogonal contrasts of the April 1-2 and May 16-17 visits.

Regression of phenology data with DBH

The phenology data regressed with DBH resulted in a significant and positive relationship ($P = 1.0459E-07$, $R^2 = 0.247$, $N = 102$), with larger trees generally demonstrating higher levels of reproductive activity.

Regression of phenology data with yield

The phenology data regressed with yield also resulted in a significant and positive relationship ($P = 0.0269$, $R^2 = 0.346$, $N = 102$). Trees with high levels of reproductive activity generally had high yields.

Fruit litter

Copal fruit litter was quantified on the last visit to the study trees. Two trees (1.96% of study trees) had quantities of litter at their bases that were given '3' classifications (code for highest quantity seen), five trees (4.90%) were given '2' classifications and thirteen trees (12.75%) were classified as '1' (lowest quantity seen). At the remaining 82 trees (80.39%), no fruit litter was found.

ETHNOBOTANY

Personal data of the survey participants

The twenty people interviewed were, in most cases, community members in what is considered the middle class, several of whom offered valuable services to the community (as a healer or midwife). Table 15 summarises the personal data of the survey participants that was given in the interviews.

Table 15. Data on participants of ethnobotany survey of local knowledge of *Protium copal.*

Name	Sex	Age	Occupation	Birthplace	Residence	Location of interview
José Neptalí Duran	m	38	NTFP harvester	San Benito	Carmelita	Carmelita
José Luis Morales Rodas	m	63	Agriculturalist and NTFP harvester	San Antonia, La Paz	Carmelita	Carmelita
Josefina Contreras Hernandez	f	57	Midwife	Carmelita	Carmelita	Carmelita
Ricardo Caal Téul	m	36	Agriculturalist, shopkeeper	Coban	Cruce dos Aguadas	Cruce dos Aguadas
Mateo Coc Choc	m	40	Agriculturalist, copal harvester	Coban	Cruce dos Aguadas	Cruce dos Aguadas
Cristobal Coc Maquin	m	42	Agriculturalist	Coban	Cruce dos Aguadas	Cruce dos Aguadas
Maria Audelina Ramirez	f	30	Housewife	Chicimula	Cruce dos Aguadas	Cruce dos Aguadas
Reginaldo Gómez Moratalla	m	40	Artisan, guide, xate harvester	Tansuelas, Santa Rose	Cruce dos Aguadas	Cruce dos Aguadas
Reginaldo Chayax Huex	m	58	Agriculturalist	San José	San José	San José
Irma Chayax Huech de Coyé	f	50	Herbalist	San José	San José	San José
Marcial Chablé Muños	m	66	Agriculturalist	San Andrés	San Andrés	San Andrés
José Chí	m	85	Agriculturalist	San Andrés	San Andrés	San Andrés
Rosendo Camal Zin	m	60	Agriculturalist	San Andrés	San Andrés	San Andrés
Erudina Cortes Camal	f	57	Healer, herbalist	San Andrés	San Andrés	San Andrés
Lí Duvina Chatá	f	72	Healer, Herbalist	San Andrés	San Andrés	San Andrés
Benito Soza	m	78	Agriculturalist	San Benito	Melchor	San Andrés
Sotero Camal Sin	m	45	Agriculturalist	San Andrés	San Andrés	San Andrés
Fernanda Camal Quixchan	f	56	Healer, children's health	San Andrés	San Andrés	San Andrés
Jesus Quezal Camal	m	49	Agriculturalist	San Andrés	San Andrés	San Andrés
Zacarías Quixchan	m	57	Agriculturalist	San Andrés	San Andrés	San Andrés

Fourteen of the survey participants were male, ranging in age from 36 to 85, twelve of which considered themselves to be primarily agriculturalists. Five of the six women interviewed named their occupations as herbalists, healers and midwife and ranged in age from 30 to 72.

The individuals interviewed in Carmelita were two NTFP harvesters and a midwife. The NTFP harvesters reported the successful and frequent use of the resin to draw out spines. These individuals spent a large amount of time in the forest, and said they often had thorns and spines in their skin as a result. These spines were sometimes so deep that they could not be removed easily, as they often completely disappeared beneath the skin. The stories told to the author, by the survey participants and others, of the usefulness of the fresh copal resin to actually draw out these spines were detailed and frequent. The resin would either be placed on the entry point, or, if one only became aware of the spine after it began to travel (down a finger or leg) months after it had entered, wherever the spine seemed to be exiting. The midwife in Carmelita described the successful use of the resin to draw out cysts and boils, infection and to cure muscular pain of any kind, as well as to cure headaches. The burning of the resin for purification or other purposes was not reported in Carmelita.

In Cruce dos Aguadas, most of the survey participants were immigrants from the southern departments of Guatemala, where copal is commonly burned, thus, the main use of the resin reported by the survey participants in this town was burning as incense: in religious ceremony, to bless a new crop planting, to expel illness with the purifying smoke, or simply because it is customary to do so. Other uses were also described, such as the removal of an infected molar, and the extraction of deep spines.

San José is the last town in Petén that continues to speak their dialect of the Maya language (Itzá), and actively cultivates their Maya traditions and culture. The two individuals interviewed in San José were brother and sister, who were the main healers in that town. Both described many medicinal uses of the resin. They also explained at length the significance of the copal tree to the inhabitants of Petén and the strong connection that exists through the tree to their past and to the ancient Maya. Don Reginaldo also said that when a child is born in San José, on the nine consecutive Fridays after the birth, the resin of copal is burned for the child's protection.

And finally, in San Andrés, both healers and forest harvesters were located, the population being relatively large (3000 - 4000 people). The NTFP harvesters most often described the "miraculous" effects of the resin in curing back pain, arthritis and rheumatism, as well as to remove spines and bot fly. The healers that were interviewed in San Andrés (four) reported that their main use of the resin was as healing incense, where the burning resin (placed on burning embers in a pot or pan) would be placed beneath the patient's bed and the healing smoke would cure all illnesses.

The survey results were tallied and used to create four tables that provide insight into cultural aspects of *Protium copal.*

<u>Cultural uses of the copal tree</u>

Table 16 presents the various uses of the different parts of the copal tree and information pertaining to these uses.

Table 16. Survey results on uses of *Protium copal*.

TREE PART THAT IS USED		USES		PREPARATION FOR USE	PURPOSE OR MANNER OF USE			FREQUENCY OF USE			
Tree part	# persons com-menting	Use	# persons com-menting	Preparation	Personal use	Administer to others	Have heard of this use	One time	A few times	Often	Very often
resin	20	Ceremonial burning	7	The resin is frequently mixed with other herbs, dried until hard, and is placed on burning embers	2		7		2	1	2
		Burn to purify houses and churches	9	Same preparation as for ceremonial burning	4		6			2	5
		Burn to purify persons, healing purposes	4	Same preparation as for ceremonial burning		3	1				4
		Remove deep thorns and spines	5	Resin must be soft, taken straight from the tree, or heated to soften	4		1	1	1	1	1
		Tooth (molar) pain	6	Same preparation as for removing spines	2		4	2		2	
		Muscular pain, rheumatism and arthritis	11	Resin is put on a cloth, heated from below until soft, then placed resin-side down on the affected area	10	3	3		1	8	2
		Headache	4	Resin is place on small cloths, heated and placed on the forehead or temples	3	1	2		1	3	
		Remove bot fly ('colmoyote')	3	Soft resin (fresh or heated) is placed on the area	2		3		1	2	
		Remove microbial skin parasite ('mosca chiclera')	1	Same preparation as for removal of bot fly	1	1			1		
		Treat cysts and boils	1	Same preparation as for removal of bot fly		1				1	
		Treat wounds	2	Same preparation as for removal of bot fly		2				2	
		Massage sore muscles	1	Resin is warmed between the hands and used in massage		1			1		
		Decongestant	1	Resin is warmed on a cloth and the cloth is placed on the back over the lungs			1		1		
		Treat bruises	1	Soft resin is place on the bruise	1					1	
wood	2	Fire wood	1	No preparation			1		1		
		Construction	1	No preparation			1		1		
bark	3	Ceremonial burning	3	Finely chopped and placed on burning embers		1	2			1	2
leaves	2	Headache	1	Young, fresh leaves are tied around the head	1					1	
		Purification burning	1	Dried leaves are placed on burning embers			1			1	
fruits	2	Eaten	2	No preparation	2		2			2	
seeds	1	Planted	1	No preparation			1		1		
Thick outer skin of fruit	2	Ceremonial burning	2	Fruit skins are dried and placed on burning embers			1			2	

The survey revealed that the most commonly used part of the copal tree is its resin, and every one of the interview participants considered the burning of it for ceremonial or purification purposes its primary use (first three rows in Table 16; 7 + 9 + 4 = 20 survey participants). All other uses of the resin reported were medicinal.

The second most common use of the resin was for the relief of sore muscles, arthritis, rheumatism and headaches by heating the resin, spreading it on a cloth and applying it to the affected area. The resin was also considered useful to draw out spines, cysts, boils and a variety of skin parasites. Equally frequently described was the use of the fresh, soft resin to treat molars with painful cavities when access to a dentist is not available (i.e. when working in the forest). The treatment of cavities with the resin entails the removal of the tooth, as the resin functions by breaking up, or destroying, the tooth.

Other minor medicinal uses of the resin included the treatment of wounds, its use to aid in the healing of bruises, to massage sore muscles and to relieve lung congestion by application to the upper back.

The wood of the copal tree seemed to be of little value according to the survey participants. One person mentioned it could be used in the construction of shelters, and another said it could be used as firewood. Some of those interviewed said that the bark of copal was used occasionally in ceremonial burning, as were the leaves and fruit skins. The leaves of copal were considered valuable to only one survey participant, who described tying fresh young copal leaves around the head to relieve headaches. The fruits and seeds seemed to be little used, other than occasional consumption (fruits), and cultivation (seeds).

Knowledge of historical use of the copal tree

Table 17 summarises what survey participants knew of the historical use of the copal tree.

Table 17. Local knowledge of history of use of *Protium copal.*

QUESTION	ANSWER	# PERSONS
Did the ancient Maya use the copal tree?	Yes	17
	No	2
	Don't know	1
What parts of the tree did they use?	Just the resin	16
	Resin and bark, fruits, peels, leaves, roots	1
For what purpose did the ancient Maya use these parts of the tree?	Burning in ceremony and sacrifice	15
	Medicine	8
	Remove spines	1

Almost all of the participants were aware of the use of the copal tree's use in ancient Maya culture, particularly in ceremony. Some of those interviewed felt the Maya also used the resin medicinally.

Copal resin market

Table 18 presents the survey results about *Protium copal* resin in the local market.

Table 18. Survey results on local knowledge of resin market of *Protium copal.*

PURCHASE RESIN			**KNOW PEOPLE WHO BUY RESIN**		**QUANTITY PAID ($US)**	**WHERE ARE PURCHASES MADE**	**WHERE DOES THIS COPAL COME FROM (IF KNOWN)**	**HAVE SEEN THE RESIN OF *Protium copal* IN THE FLORES CITY MARKET**		
Yes		No	Yes	No				Yes	No	Yes but don't know if it is *P.copal*
Personal use	For resale									
4	1	15	7	8	2.55 / kg	Cruce	Cruce	7	7	6
					2.18 / kg	Cruce	Cruce			
					116.76 / kg	San Andrés	San Andrés			
					9.12 / kg	San Andrés	San Andrés			
					14.60 / kg	San Andrés	Cruce			

Only seven survey participants out of twenty had seen resin for sale at the main city market, but six of those seven were not sure it was the resin of *P. copal.* Few of the people interviewed actually bought the resin they used, only five people. The other fifteen survey participants either had the resin given to them regularly, or took it from the forest themselves. Of those who did not purchase resin, eight did not even personally know anyone who did buy it. Prices paid by the five survey participants who did buy copal resin varied greatly, ranging from as low as US$2.18/kg to as high as US$116.76/kg. The lowest prices were those paid to the actual copal collectors, in Cruce dos Aguadas, by two of the survey participants. One was a woman who had immigrated from the south and the burning of copal resin was a part of her culture. The second was a shopkeeper in Cruce dos Aguadas who resold the resin in his shop, and periodically took a load south to Coban for resale as well. The highest price was paid by a healer in San Andrés, who bought it by the ounce (Q20/ounce), and who maintained a supply in her house because she used it often to treat others. All who purchased the resin bought it locally (in their own town, not in the Flores city market). Most of those questioned had seen resin for sale in the city market but of those, almost half were not sure if what they had seen was the resin of *Protium copal.*

<u>Harvest of copal resin</u>

Finally, Table 19 summarises the results of questions pertaining to the harvest of the resin.

Table 19. Survey results on *Protium copal* resin harvest.

	COPAL RESIN HARVEST TECHNIQUES		**INTENSITY OF HARVEST TECHNIQUE**			**HAVE SEEN DAMAGE TO THE TREE DUE TO HARVEST**		**PREFERRED SEASONS IN WHICH TO HARVEST**				
	Harvest techniques	**Personally harvest copal resin**	**Tap the same tree year after year**	**Harvest from different trees**	**Collected resin only once and only very little**	**Yes**	**No**	**Dry season**	**Wet season**	**Between wet and dry seasons**	**All year**	**No opinion**
1	Resin is collected from naturally occurring cracks in the tree bark or broken branches	1		1				1				
2	One small cut is made in bark	1			1		1		1			
3	Tap with same technique as chicozapote tree	2	1	1		1	1	2				
4	Tap with same technique as chicozapote tree but not as deep, not into the wood	2		2			2			1	1	
5	Small cuts are made into the bark of the tree, resin is collected and cuts are reopened every three days	1	1				1				1	
6	Parallel cuts are made into the trunk, not removing the bark nor cutting into the wood – opened bark is used as collection vessel	3	2	1			3		1		1	1
7	A mix of techniques are used: bark is scraped (resin weeps out) &/or chicozapote method &/or diagonal cuts are made	3		3			3	2	1			
	TOTALS	13	4	8	1	1	11	5	3	1	3	1

Thirteen of the twenty people interviewed had harvested or collected the resin themselves and related the techniques they used. One person only collected resin that was exuding naturally from broken branches of copal trees; the other twelve practised some form of tapping in order to harvest the resin. One of the more commonly utilised techniques was to cut a series of parallel and diagonal streaks into the bark, without removing the bark, using it as a collection vessel. This technique was first introduced to the author through the survey and is a method that should be investigated further. Some individuals employed the methods used in the latex harvest of the chicozapote tree (*Manilkara zapota;* Sapotaceae), which is to make opposing diagonal cuts, forming a 'V' in the bark or the wood, up one entire side of the trunk. None of the survey participants used tapping method two from the study (a horizontal streak), and only one person interviewed used the present study's tapping method one (small circular taps around the base of the tree).

Most of the thirteen harvesters rotated the trees they collected from (eight individuals), although four said that they went back to the same tree year after year. One of the thirteen admitted they had seen damage to the copal tree that was probably due to the harvesting method they used (chicozapote method). No consensus resulted from the survey as to a tapping 'season'. To the question, "When is the best time to tap copal?" the following answers were given: "only in summer" (dry season), "only in winter" (wet season), "only in between summer and winter" (July), "it doesn't matter, can tap all year", and finally, no opinion.

DISCUSSION

RESIN YIELD

Factors affecting resin yield – regression analyses

Previous research has investigated many factors for their effects on resin yield. Therefore, in the yield component of this study, every variable deemed to have potential influence on resin production was recorded. The regression analyses showed that the factors that most significantly affected yield in this study were similar to those in the literature: tree size and crown condition. Tree size (DBH and height) was determined to have the greatest effect on the quantity of resin produced, and is therefore the most important variable to consider when selecting trees for tapping. The second most influential variable was shown to be crown condition, in this study characterised by an index of the crown created by combining codes for crown characteristics and degree of crown illumination. Crown height (measured in meters), however, was very similar to crown index with respect to significance of effect on yield.

The distinction of these variables above the others examined in this study indicates that, of those variables that can be measured or qualified, physical characteristics of trees are of greater influence on resin yield than environmental factors. This cannot be definitively concluded, however, until further tapping studies that investigate the effects of seasons (dry and wet) on resin flow are conducted. Nor can the superiority of measurable physical characteristics be considered absolute, because they do not take into account the differences in the inherent (genetic) capacity of individual trees, which are currently difficult to quantify.

It can be hypothesised that the importance of these two aspects of tree morphology on resin yield are to a large degree a function of greater numbers of resin canals in the trunks of larger trees, and increased biosynthetic capacity of large, healthy crowns to produce the metabolites which are the precursors of resin.

In the multilinear regression analysis, the volume index and crown index emerged as the most significant variables with respect to resin yield. Upon transformation of both yield and volume index to square roots, the multilinear model provides the best fit of the actual yield data, but requires four types of input data for its calculation (DBH, total tree height, crown characteristics and crown illumination). The model resulting from the regression of the natural logs of both yield and DBH data was also significant, and has the advantage of requiring only DBH to calculate yield predictions. Both models have advantages and may be useful in the prediction of resin yield from copal trees in forests similar to the study area.

Tree-to-tree variation cannot, however, be taken into account by these models. Predicting the yield of a single tree may never be a useful exercise for this reason, but predicting the yield *per hectare* may provide relatively accurate estimates. The best prediction of the yield of the study area is proposed to be a combination of actual resin yield data (T1 and T2 trees) and predicted yields of untapped or partially tapped trees (C and T3) using the multilinear relationship, the relationship that best fit the actual data. The resin yield estimate of the study area using this method is 2416.2 g/ha (2.4 kg/ha). It is offered as the most accurate estimate of the study area because some of the tree-to-tree variability (in the tapped trees) is accounted for. Ultimately, however, it is difficult to estimate the resin yield of any area in the tropics because of the inherent intra-specific diversity that is characteristic of tropical forests.

It must also be remembered that the regression models developed from this research came from data collected from trees growing in eight hectares within the CCFC, and cannot be extrapolated to areas ecologically distinct, or geographically distant, from the study area. One estimate is given for both forest types because the analysis of variation indicated no difference in yield in the two forest types examined. The estimate 2.4 kg/ha can be considered to be conservative because of the lack of tapping skill utilised in the study, the proportion of small DBH trees included in the sample, and the relatively low visitation rate (weekly rather than every third day, commonly practiced by the main copal tapping family in Cruce dos Aguadas). This estimate could be applied to the areas classified as strata one and two within the CCFC for the purpose of preliminary market development.

Regression analysis by group

The separate regressions of the yield data with DBH of the groups (S1T1, S1T2, S2T1, S2T2) showed that the group S1T1 had significantly different slope and level than that of the other three groups. Comparison of the plotted data of the groups, however, reveals the effect of three points on the regression of group S1T1. The points represent the cumulative yields of three trees (S1T1-4, S1T1-5 and S1T1-8) that produced much higher yields than any of the study trees, all three of which were located in strata one and treated with tapping method one by random selection. Appendix 2 highlights these three trees. All three have large crowns and are of similar DBH, but other trees have larger crowns yet did not produce resin in quantities such as these three trees. It can be surmised that the high production observed in these trees, that from outward appearance were no more remarkable than other trees in terms of size or health/vigour, is probably an example of the differences in inherent capacity, due to the genetic variation, of physically comparable trees subject to similar soil and growing conditions. The author proposes that the difference in slope seen in the DBH by yield regression of the trees in group S1T1 compared to those of groups S1T2, S2T1, S2T2 is due not to the significance of the treatment-by-strata combination, but rather to the phenomenon of inherently high-producing trees. The high MSee (tree-to-tree variability) in the results of the analysis of variance further supports this.

Difference between tapping techniques one and two – analysis of variance

The analysis of variance indicated that there was no significant difference in tapping techniques (T1 and T2) with regard to yield, nor did the different forest types (strata 1 and strata 2) have any significant effect on yield. The lack of difference in productivity of these two forest types observed in this study, however, does not suggest that this would be the case in other strata one and two forests in the CCFC, or in the rest of Petén. The primary forest type of the study area, as described in earlier sections, was strata one, with the strata two sample located on an island-like plateau in its midst. There are two possible explanations for the results of the analysis of variance: 1) resin production from *Protium copal* is unaffected by its surrounding forest environment and substrate, or 2) the representation of strata two in the study area was not sufficiently different from the surrounding strata one forest type for true differences in productivity to be seen. Further research must be done before we can conclude that there are any differences (or lack thereof) in the productivity of the two forest types.

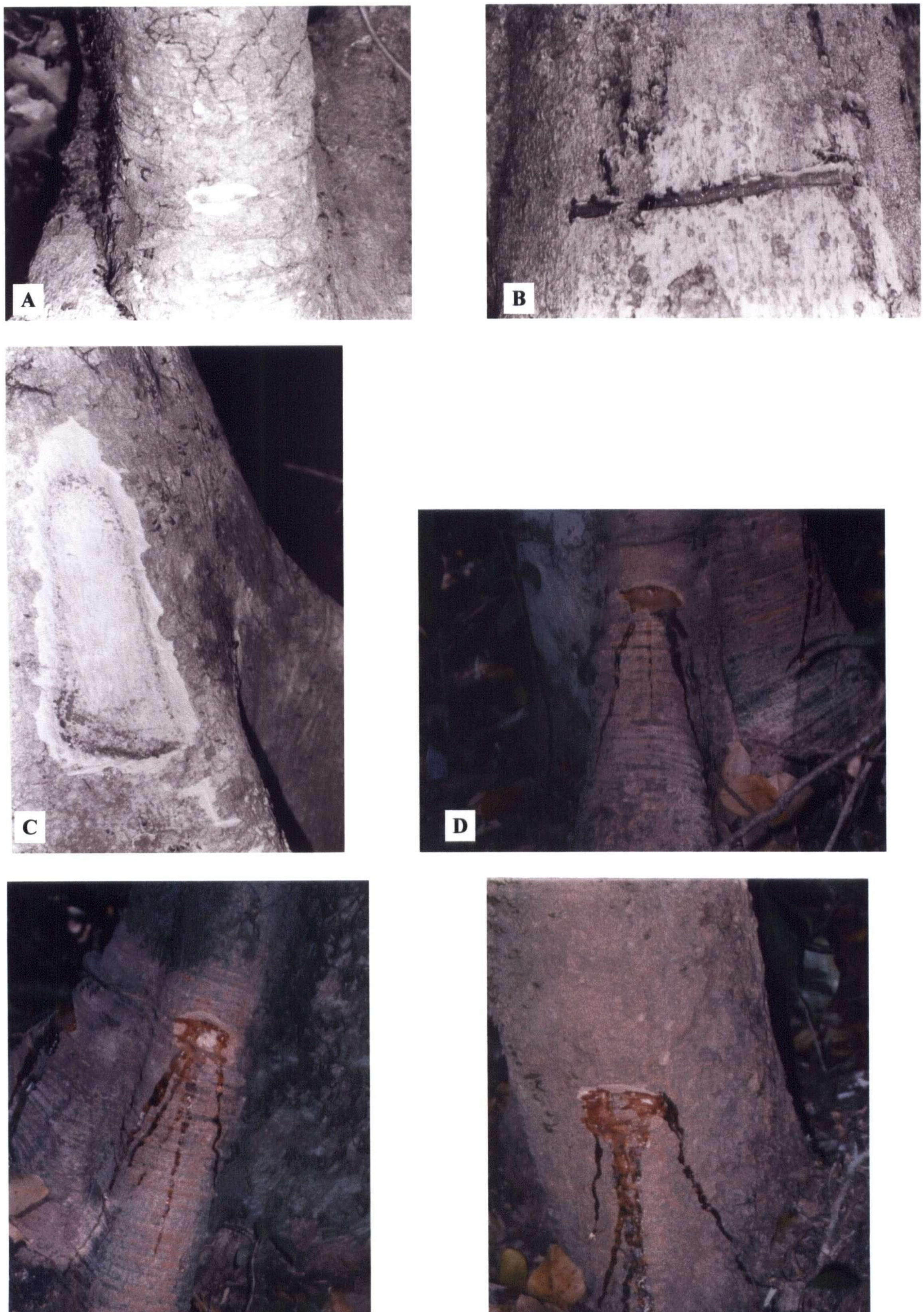
Although no significant difference was seen in the yields of treatment one and two, there were differences in resin quality and ease of resin collection between the two tapping techniques. The T1 method yielded much "cleaner" – debris-free – resin than the T2 method. In the T2 method, a greater area of bark was disturbed (long horizontal line), providing more opportunity for slivers of bark to get caught in the resin over the week, and while scraping during collection. Also, the nature of the T2 tap encouraged the entry of bark debris into the resin, with streaks that cut across the grain of the bark. In contrast, in the T1 tap, the slice of bark that was removed more or less followed the grain of the bark.

The T2 method also required a great deal more time and effort than T1. Cutting a horizontal streak into the bark with a penknife was time and energy consuming, as was the freshening of the cut every week, whereas the machete in the T1 method was used to make simple cuts that generally required no more than a single motion, and the weekly tap freshening was equally quick and simple. As well, the long shape of the T2 tap gave rise to a much larger area from which resin flowed, making collecting of the resin, again, time consuming, while the flow from T1 taps was generally concentrated to fewer single lines, usually facilitating an easier and faster collection process. Plate 1 presents some photos taken of the study trees (early in the tapping period) that illustrate the three tapping techniques; and the nature of resin flow from the three tapping methods.

T1 was based on the copal harvesting technique used by the main copal tapping family in Cruce dos Aguadas. The numerous factors experienced in this study that lead to the conclusion that T1 is the more useful of the two tapping techniques serve to confirm the soundness of traditional methodology.

The collection process for both tapping methods, however, was inadequate for the high yielding trees, where resin was often observed to have flowed as far as the buttressed roots, and onto the ground, picking up varying quantities of bark, forest litter, insects (particularly ants) and soil on its way. To try to keep the resin clean at these trees, plastic was placed on the ground and the resin was then collected from these pieces of plastic. It was, however, an arduous process, requiring 20 – 30 minutes to be spent at these trees, and debris from the ground and trunk inevitably entered the resin despite best efforts to keep it clean. Plate 2 illustrates the resin flow from high-yielding trees (photos taken in the later part of the tapping season).

Plate 1. Initial taps for A. tapping technique one (T1), B. tapping technique two (T2), and C. tapping technique three (T3). Resin flow from D. E. F. T1 trees, G. H. I. T2 trees and J. K. L. T3 trees.


A
B
C
D
E
F

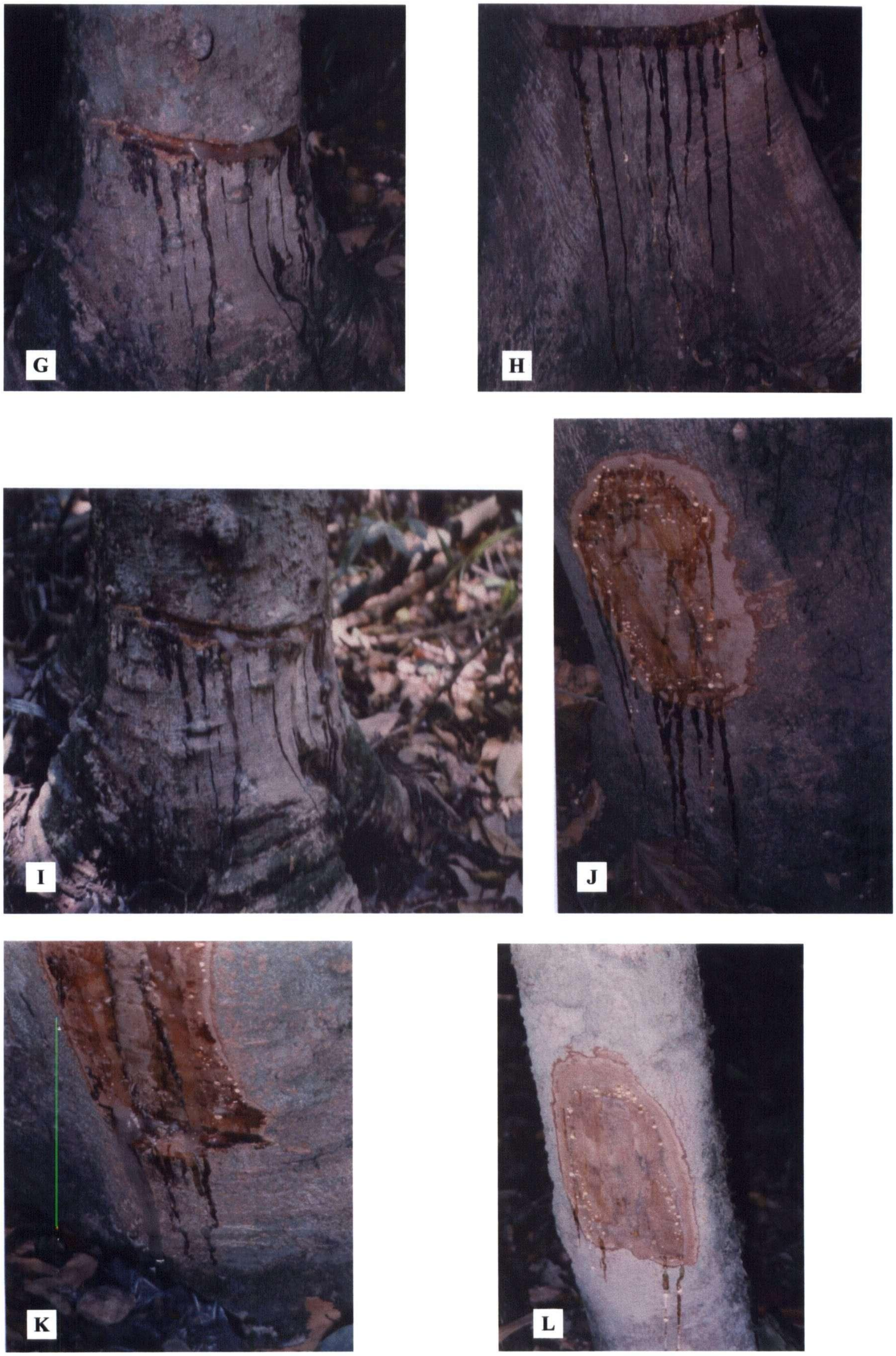
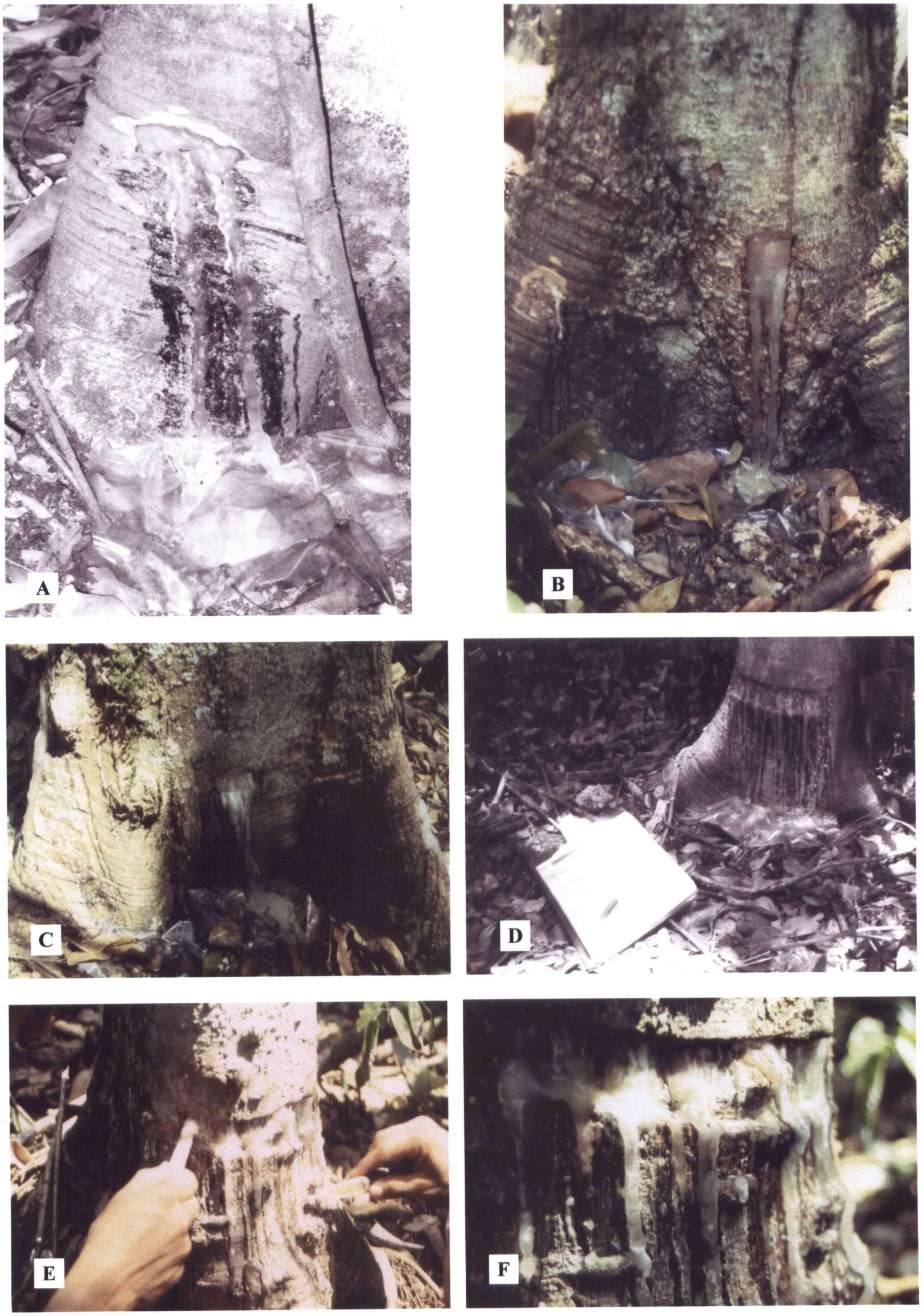

G
H
I
J
K
L

Plate 2. Resin flow from high-yielding trees: A. B. C. T1 trees, D. E. F. T2 trees. Colour photo credits Simon Comerford.


A
B
C
D
E
F

Because the ultimate objective of a copal resin industry would indeed be to find and tap as many high-producing trees as possible, a collection system that contains the resin and protects it from rain, falling litter and insects, would have to be developed. Local copal collectors currently have little concern for the cleanliness of their product, as the traditional practice has been to deliver the resin wrapped in the leaves of the escoba palm (*Cryosophila argentea;* Arecaceae) without inspection for quality (and therefore value assessment) from the buyer. These packages of resin are later transported to the south of Guatemala to be used almost exclusively as ceremonial incense, and forest debris caught in the resin is of no consequence when the resin is used in this manner. If the resin were to be collected for a medicinal market, it would certainly require several phases of purification. The need to maintain, and more importantly, improve the quality of the natural resin would be extremely important if larger, international, markets for the product were to be retained, especially if medicinal applications are anticipated (Coppen 1995). Therefore, the cleaner the resin can be maintained during collection, the less post-harvest cleaning would be required. The resin sold by the collectors themselves would then be of higher value (Coppen 1995, Smith *et al.* 1992).

A final note on the results of the analysis of variance concerns the high MS experimental error, which indicates very high tree-to-tree variability in resin yield. The phenomenon of radically different levels of yield production in neighbouring trees of similar size has been discussed, and has also been observed by other researchers (Ella and Tongacan 1992, Gonzales *et al.* 1986, Jahnige *et al.* 1993). The MS experimental error calculated in this experiment suggests that the tree-to-tree variability is so high that it may in fact have masked possible treatment or strata effects. In the light of the inherent diversity of species in tropical forests, the effects of tree-to-tree differences should be anticipated when tapping for resin in wild populations. This should not, however, pose a deterrent to the development of a resin tapping industry in tropical forests. In a well-managed tapping system, collectors would gain a familiarity with the trees in the tapping area. Such a familiarity can only benefit tapping operations, firstly by making them efficient – trees that consistently produce minimal quantities of resin would not be tapped, while tapping efforts would focus on high yielding trees – and, secondly, by allowing questions regarding the sustainability of harvesting practices to be immediately addressed – declining yields or abnormal reproductive patterns could indicate over-harvesting and would require modifications to be made to harvesting methodology.

<u>*Protium copal* resin productivity of the study area</u>

The best estimate of the resin productivity of the study area was determined to be 2.4 kg/ha. When compared to pine oleoresin tapping – where the average production *per tree* must be 3 – 4 kg annually to sustain a viable industry – the question of whether this quantity is sufficient to sustain a viable resin harvesting industry is raised. The answer is dependent on the intended use of the resin and the value placed on it as a consequence of this use. It is probable that this level of production would not support the development of an industry for products such as a varnish or paper size. However, in a medicinal capacity, this quantity may be sufficient.

The literature reveals that the amount of resin obtained in this study is similar to yields obtained from other *Protium* species in other regions. In Ecuador, Jahnige *et al.* (1993) obtained resin yield data from three species of *Protium* (*P. fibriatum, P. nodulosum,* and *P. sagotianum*). The total yield of eighteen trees within three hectares (six trees/ha) harvested for the data used in their study was 4.1 kg/ha, almost twice that estimated for the area of the present study, which contained 12.75 trees/ha. The DBHs of the tapped trees were not included in the publication, although it is suspected that they were large because the authors state that not all of the trees in the three hectares of study area were tapped, but that the best producers were selected by local tappers.

The exact length of the tapping season upon which this value is based was not given either, although the authors do imply that resin harvesting can occur "all year". However, Coppen (1995) states "high temperatures are conducive to good resin flow, while prolonged periods of high rainfall are not". Also, increases in resin flow of slash pine (*Pinus elliottii*) in Georgia were observed in the hottest months of the growing season (July and August) (Jackson 1968), and the preferred collection period for balsams in Central America is the dry (hot) season (Smith *et al.* 1992). In the present study, the quantity of resin produced increased as the tapping period progressed, as did its viscosity (Plates 1 and 2). In the early part of the tapping period, residual soil moisture may have given rise to a high percentage of water in the resin, thereby contributing to the observed fluidity of the resin. It may be that the summer dry period in Petén is the best time to harvest resin, as is the opinion of the copal resin collectors of Cruce dos Aguadas, but this has not yet been shown to be true.

It may also be possible, however, to harvest the resin sustainably year round, provided the resin is protected between collections from heavy rainfall, which could effectively wash it away. For the period that the rain gauge was installed in the transects, (March 25 – May 27) rainfall was almost zero, with only one reading (May 7) showing 14 mm of rainfall between collections. It is essential to ascertain the effects of rain on resin yield during the wet season to determine if tapping all year is possible, or advantageous. The exact length of the optimal period for *Protium copal* in any region has not yet been fully defined, and therefore nor has its annual yield.

Significance of sustained stimulation for maintained resin flow

Weekly resin yields increased significantly until collection six (April 15-16), when a decrease (though not statistically significant) was observed. It is speculated that the yield increases seen in the first six collections were due at least in part to the stimulation of weekly tapping, and perhaps also to the progression of the summer season. The drop in mean per tree resin yield between collection seven and eight (April 15-16 and April 22-23) that may have been a direct response to the absence of tapping stimulation between collections six and seven (April 1-2 and April 15-16). Two weeks passed between these visits, instead of the usual week. Tap freshening at the beginning of the two-week period (collection six) provided the stimulation required to maintain the rate of resin flow. The amount of resin that was present two weeks later for collection (collection seven) was in keeping with the yields of previous weeks, although the resin at numerous trees was stiff and hard, often difficult to remove. At collection eight, however, resin yields were notably reduced, and it is hypothesised that this reduction occurred due to the two-week lapse in tapping stimulation. Not until collection ten (May 6-7) did resin yields regain the levels seen before the lapse, nor did they ever again reach the levels seen at collection seven (April 15-16).

The weekly freshening carried out in this study is less frequent than that practised by the copal tapping family in Cruce dos Aguadas, who collect resin and freshen the taps every three days. This may have resulted in less stimulation and lower resin flow rates, in addition to the lower overall yield due to less collection dates on a weekly regime, as compared to a semi-weekly regime.

Tapping method three is unsuitable for resin harvest because the nature of resin producing species appears to require sustained stimulation of some kind to elicit and maintain flow (Bhatt *et al.* 1989, Gianno 1986, Messer 1990, Tsoumis 1992). This may be a characteristic unique to resin-producing species. Latex producing species, for example, do not seem to have this requirement, although chemical stimuli are regularly used to enhance flow. Rather, latex appears to be a material that is "drained" from a tree, after which the tree requires a rest period of variable length (species-dependant) to re-grow removed bark and to recover from the loss of latex. The rest period can be weeks or months, even years (Bolt 1961, Schwartz 1990, Sivakumaran *et al.* 1984, Van Brandt 1975).

Comments on other observations and data

Taps without resin

The incidence of taps without resin has two possible explanations, lack of production or removal of resin produced. Very few trees had taps lacking resin that could be attributed to a lack of production, but it was observed occasionally in trees that consistently produced very little resin (S2T2-7, S2T2-8). It was more common, however, to see taps without resin because it had been removed.

Issues surrounding resin removal during the tapping period were the following. Firstly, the incidence of resin removal by wild peccaries was common in the second half of the tapping period. It was concluded that it was indeed peccaries removing/consuming the resin due to the obvious signs left by them, such as the strong musk odour detected upon reaching the vicinity of the affected tree, the disturbance of the ground litter, and the presence of tracks and hairs. The resin yields of certain trees were significantly affected by the activities of the peccaries some weeks, resulting in artificially low yield results for the tree, as well as for the overall total and average yields.

Secondly, resin removal by "resin bees" increased as the season progressed (Plate 3. A). Again, resin yields were negatively affected, and at times 25% or more of the resin may have been taken by the time of collection. It is speculated that these insects began targeting the resin in the second half of the tapping season (April / May) because the heavy flowering of February and March had finished by then. In discussions with local guides, they related that they had commonly observed these insects attracted to anything with a strong smell, i.e. perfumed flowers, fragrant resin, damp leather, sweating skin, etc. They also maintained that the intended use of the collected resin by these insects was not for consumption, but rather, for the construction of their "clay-like" hives. They concluded that these insects were not specifically "resin" bees, but opportunists that collect pollen and nectar, as well as resin and other building materials, when available.

It is suspected that these insects are species of *Trigona*, stingless bees. A description of *Trigona fulviventris fulviventris,* given by Johnson (1983), matches several aspects of the insects present at the study trees during resin collection. The size (5-6 mm), coloration (black with orange abdomen), range (Mexico to Brazil) and habitat (low to mid elevations in tropical dry to wet forests) of *T. fulviventris* are those of the insects observed. Additionally, a distinguishing characteristic of *T. fulviventris* is the diversity of loads carried to the nest, such as mud, fungi, faeces and plant exudates including resin. This trait fits the comments made by local guides.

Other insects were also seen around the resin exuding from the taps of the study trees, such as ants (Plate 3. B) and termites, but did not appear to be removing it. They did, however, commonly become entrapped in the sticky resin. Where possible they were removed, but often had to remain part of the resin sample.

Plate 3. A Resin bees removing, or caught in, resin of *Protium copal*. B. Ant caught in resin of *P. copal.* Colour photo credit Simon Comerford.


A


B

Resin types and classifications

Different resin types were seen at different times on the same tree, as described in the results section. Different resin types were also seen at the same time on the same tap of the same tree. Very little can be offered here as to why so much variation in resin consistency was observed. To some degree, the differences are probably due to environmental factors, such as water availability. The resin classified as type four (hard, opaque, white in colour) may have been caused by moisture evaporation from the exuded resin, and type two resin seems to the predominant form the resin takes. It is less clear though, why resin types one and three were regularly observed.

The reason that study tree S1T1-12 consistently produced resin with a noticeably different scent is equally unclear. This tree may indeed be a different variety of *Protium copal,* but it is unlikely that it is a different species because a sample of its leaves was included in the sub-sample of study tree leaves that was sent to New York Botanical Gardens for identification by their expert in New World Burseraceae. The leaves of this tree were identified as belonging to *Protium copal.*

Scar healing

The rate of healing of the taps on T3 trees was noticeable by the collection seven, and obvious by the end of the tapping period (Plate 4). This rate of healing may be characteristic of the species and / or a function of the vertical nature (along the natural grain of the bark) of the tap. A lack of healing progress (compared to T3 taps) was observed in the streak of S2T2-11, a study tree that was also discontinued early in the tapping period. This could be due to the state of this tree's health (which was questionable), or to the nature of the tap. The bottom edge of the taps on all T2 trees did not show obvious signs of healing throughout the tapping period, while in many T1 trees, the bottom portions of their taps were beginning to close toward the end of the tapping period. The horizontal streak of tapping method two appears to result in slower healing of the taps, and is therefore another reason not to incorporate it into future tapping systems.

Plate 4. Healing of taps from tapping method three.

PHENOLOGY

Reproductive patterns of *Protium copal*

There were two statistically significant increases over the course of the study period: mid to late February, which corresponded to flowering, and early April to late April, loosely corresponding to fruiting and increased appearance of new foliage. The data indicate that by late May, levels of phenology appear to be decreasing; though the decrease is not statistically significant. New leaves were evident at a low level from collection three until the end of the study period, but was more frequently seen in April and May. There was never a time when copal trees were completely bare and leaf change appeared to be an ongoing process.

Effect of resin tapping, and different tapping techniques, on phenology

The statistical analysis indicated that for fourteen of the sixteen dates when phenology levels were recorded, the level of resin tapping employed in this study had no significant effect (negative or positive) on the reproductive processes of the study trees, suggesting that both tapping methods represent sustainable harvesting technology.

The two occasions where the analysis indicated significant effects on phenology as a result of tapping (April 15-16 and May 19-20) are not random events. The level of phenology of the control trees was significantly ***lower*** than the tapped trees (T1 and T2) on these two occasions. Whether the tapping activity actually induced the higher levels of phenology in the tapped trees as compared to the untapped trees, or whether some other factor was working to cause this effect, should be investigated further.

The three incidents of significant effects on phenology between strata are not related to the tapping techniques investigated. The strata were located very close to each other; therefore it is doubtful that the effects seen in the orthogonal contrasts represent true differences in phenology between the two strata.

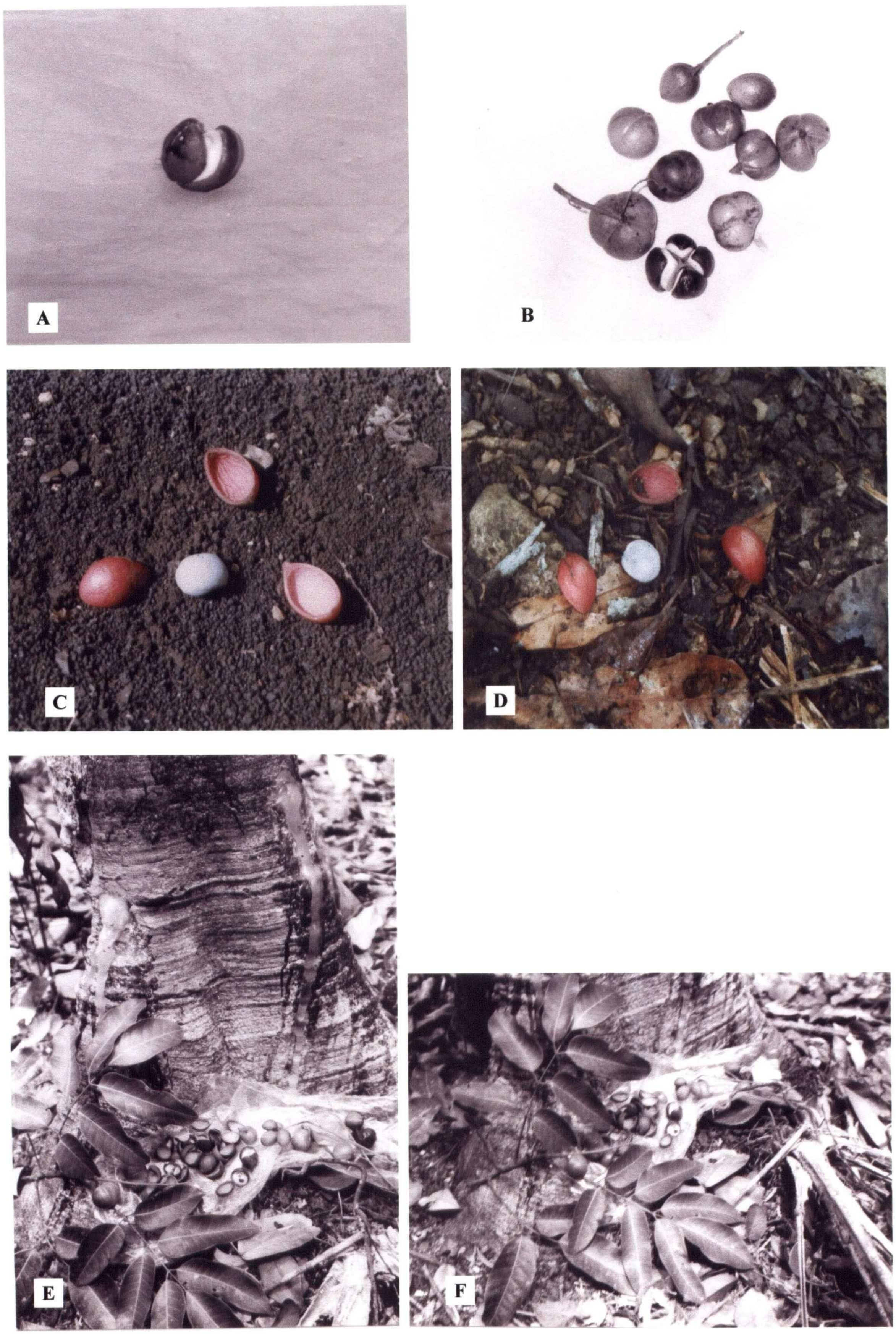
Regressions of phenology with DBH and yield

Both regressions indicated significant and positive relationships. It is reasonable to assume that DBH may account for 24.7% of the variability in the phenological activity of the study trees (large trees are usually older and more mature than smaller trees and are therefore capable of higher levels of reproduction as well as larger quantities of resin). The relationship seen between yield and phenology, however, is likely nothing more than correlation, in which the two factors are related through a third factor, DBH.

Fruit litter

The documentation of fruit litter on the last visit gave some indication of the trees that produced particularly high levels of fruits and seeds (Plate 5), and provided the opportunity to observe and document seeds, fruits and fruit skins. Much work remains to be done with respect to the phenology of *Protium copal,* including the morphology of the flowers, seeds and fruits; its pollinators; and the patterns and timing of its reproductive processes.

Plate 5. Fruit, fruit skins, seeds, buds and leaves of *Protium copal*. A. & B. Entire fruits at various stages of maturity, some of which are open, exposing the white fruit within. C. & D. Seed enclosed by fruit (white) separated from fruit skins (fucia). E. & F. Collection of fruits and leaves of *P. copal* placed on plastic at base of study trees. Colour photo credits Simon Comerford.


A
B
C
D
E
F

ETHNOBOTANY

Uses and role of *Protium copal* in the culture of past and present forest societies in study area

Resin from *Protium copal* has had an important role in Maya culture for hundreds, if not thousands, of years (Lundell 1937, Schwartz 1990), and it continues to be an intrinsic part of indigenous ceremony and religious festival today. The ethnobotanical survey illustrates the resin's current and potential applications in medicine. The broad spectrum of its uses suggests a number of different active compounds in the resin. It was beyond the scope of this thesis to investigate the constituents that function to treat wounds and bruises, work to relieve muscular pain, arthritis, rheumatism, draw out spines, cysts, boil, parasites, and treat cavities. Determining the chemistry and activity of the resin of *Protium copal* merits future investigation. The preliminary analyses of the resin that have been conducted to date are presented in Appendix 3.

Harvest and management systems of copal resin

Different techniques, intensity and timing of copal resin harvesting were reported by the small sample of individuals surveyed. The overall level of copal harvesting in Petén is quite low. In approaching four different communities, only twenty individuals who had some knowledge of the copal tree were identified. Only thirteen of these collected their resin, twelve of which actively tapped the tree. Of those twelve individuals, only four returned to the same tree year after year. The issue of sustainable harvesting is not an issue in Petén currently, due to this low tapping activity.

It is certainly possible, as suggested by Lundell (1937), that the relative abundance of *Protium copal* in the forests of Petén is due to past Maya management systems, in which copal trees (among others) were left standing and even cultivated. And if the exploitation of this species were to increase substantially, adaptation of such practices, particularly cultivation, would need to be revisited.

The low-level management systems described in the introduction are ideal means to maintain the integrity of forest ecosystems while providing products and income required by rural populations. Of particular interest in this regard is the domestication of valued species that can be carried out in three ways: 1) enrichment planting in the forest, 2) small holder cultivation, or 3) commercial or community plantations (Schmincke 1995). Cultivating valued species relieves pressure on wild populations, and preserves the reservoirs of genetic diversity of those valued species.

Current presence of copal resin in local markets

The ethnobotanical survey revealed that the domestic market for the resin is not centred in Petén since not a single participant actually bought the resin at the main city market, and few (seven) even saw the resin there, only one of which knew it to be *P. copal*. Only five of those surveyed purchased the resin (in their home towns), and of the remaining fifteen, eight did not personally know anyone that purchased the resin. Survey participants reported that the resin is commonly traded among the indigenous people, for use in ceremony. Areas in which a high percentage of the population is indigenous are the southern departments of Guatemala. A brief internet survey indicates rapidly increasing interest in resins like copal for use as incense. International market interest may not be difficult to attract in the coming years.

The presence of resins in the international marketplace is far from negligible. Coppen (1995) maintains that millions of people in consuming countries use resin-based products in their everyday lives, and that tens of thousands of people living in all regions of the world depend on the collection of plant exudates as a means of cash income. Products from the resin of *Protium copal* could one day become an important commodity if further work, both in the harvesting of the resin and in its chemical analysis, is carried out. The main barrier to local residents entering this market with copal resin are, as alluded to in the introduction, a lack of interest to date in the undertaking of the analysis of the resin; its characterization and its potential activities.

CONCLUSIONS

This investigation contributes to the understanding of the tropical tree *Protium copal* as follows. Variables that describe tree size and vigour, such as DBH, tree height, and size and vigour of the crown, are the most indicative of the level of resin production that can be expected from a given copal tree, thus there is not enough evidence to accept **H0: Tree size is not the variable that most affects resin yield.** However, intrinsic genetic diversity is sufficiently great that ultimately, high-producing trees will only be discovered through actual tapping activity and familiarity with individual trees.

Of the three tapping techniques investigated, tapping method one, was found to be the most convenient with respect to time and effort, produced the cleanest resin and was the least damaging to the tree, seen in the simultaneous healing of the scar over time while tapping for resin. This tapping method was modelled on the method used by the main tapping family in Cruce dos Aquadas, a technique that is known to them through their ancestry. This brief study has shown that the technique use to tap copal used by those experienced in it is indeed an ideal method, probably developed over years of trial and error. Neither of the two tapping techniques practised for the duration of the study period gave rise to greater resin production than the other, thus there is not enough evidence to reject **H0: There is no significant difference in resin yield due to tapping technique one and tapping technique two.**

The best estimate of the productivity of the study area was 2.4 kg/ha. If this estimate could be extrapolated to the hectares of strata one and strata two forests in the CCFC, the minimum annual production for the concession could conservatively be estimated at 66, 000 kg.

The level of phenology for *Protium copal* was observed to increase significantly from mid to late February, corresponding to flowering, and from early to late April, the height of fruiting and increases in new foliage. Leaf change was a subtle and ongoing process for most of the study period. On two collection dates (April 15-16 and May 19-20) tapping in general significantly and positively affected reproductive activity of tapped trees when compared to untapped trees, thus there is not enough evidence to reject **H0: Tapping for resin has no significant effect on phenology.** Neither of the two tapping techniques studied had significantly different effects on the level of phenology, and **H0: There is no significant difference between tapping techniques on phenology** is accepted.

Local inhabitants best know the copal tree for its resin, and it is most commonly used as incense for ceremonial purposes. Among community members knowledgeable about local plants and their uses, the resin of *Protium copal* has many medicinal attributes, particularly in the relief of muscular pain. Regular harvest of the resin by survey participants, either for personal or economic objectives, is minimal. The presence of the resin of *Protium copal* in local markets is also minimal. With the establishment of new value to the resin, there is the potential for economic growth with this NTFP.

FUTURE RESEARCH

The present study was preliminary and should be considered a pilot study. To better address a number of questions, much work remains to be done on this species. First and foremost, a thorough chemical characterisation of the resin is required, as is an examination (at concentrations higher than 100 mg/ml solvent) of its potential antibiotic, anti-viral, or other, activities. Its therapeutic uses should also be investigated, such as its utilisation as a treatment for arthritis, rheumatism and other muscular ailments. Justification for further exploration of the yield potential of the CCFC, or of the Petén or Yucatán is difficult if the potential value of the product has not yet been determined.

Seasonal effects on resin yield and resin quality must be investigated. Further tapping studies should be carried out over at least a full year. The resin collected throughout the year should be periodically tested for the proportion of water contained in it. For a study that examines resin yield and quality over an entire year, a collection system that protects the resin from debris, insects and rainwater must be developed. Also, rain gauges must be placed within each of the tapping areas due, to the high variability in rainfall within short distances in tropical forests.

A more accurate estimation of potential resin yield from the CCFC should be obtained by simultaneously sampling areas distant from each other, and should occur over a previously determined optimum tapping period or season. At least three sites of the same forest type (strata one or two) should be sampled in this way. Ideally, three sites of each of strata one and strata two would be sampled simultaneously. Such a study would give a better estimate of the productivity of the whole concession than the present study, and would also give a better indication of the possible difference in the productivity of the two forest types.

A set of control trees in each of the tapping areas in such a study should also be established to monitor phenological patterns between tapped and untapped trees within the same area, and also to compare the phenological patterns of different areas over the same period of time.

Effort should be made in any future tapping studies to ensure that trees are given exactly the same interval between every freshening for the entire tapping period to eliminate any variation in stimulation effects on resin flow. Additionally, taps should be freshened at least two or three times after the first incision before resin is collected to ensure enhanced resin flow.

The variable volume could be investigated through regression to determine its relationship with yield. The diameter of the base of study trees, as well as total tree height, would need to be measured in order to calculate the volume of the trees by assuming a cone, using the formula $1/3\pi R^2 h$.

Other indigenous harvesting methods should be investigated. The ethnobotanical survey of the present study revealed an intriguing method; that of diagonal slashes made into the bark, leaving the bark in place to act as a collection vessel. If it is determined that tapping is only feasible during the dry season, physically, due to possible problems of rain washing the resin away, and economically, due to potentially low yield during this season, then this method may be useful, provided the yield and quality of the resin is comparable to that obtained in this study. There may also be other tapping methods used by individuals in areas outside the study area that could be investigated.

The full range of *Protium copal* should be determined. Within this range any differences in reproductive patterns, habitat requirements, resin quality and quantity, as well as local cultural uses, should be recorded.

If a new market for the resin were to develop in the future, it would be important that socio-economic studies investigating the integration of increased resin harvest in the local society be undertaken. The impacts of a new market such as this on remote communities and their members, and the overall economic impact of a new industry in the department of Petén, indeed of the whole country, should be assessed, to assure that benefits (financial or otherwise) reach the caretakers of the forests from which the product arises, the local inhabitants of Petén's forests.

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- **Tania Vermeer.** British Columbia artist.

APPENDIX 1

TRADITIONAL USES, HARVEST AND MARKET
OF COPAL RESIN (*Protium copal*)

SURVEY INFORMATION

Date: ____________________

Place of interview: ____________________

PERSONAL INFORMATION:

Name of individual: ____________________

Age: __________ Place of Birth: ____________________

Sex: __________ Place of Residence: ____________________

Profession: ____________________

Description of individual ____________________

USES OF THE COPAL TREE

1. Are you familiar with the Copal tree? __________
2. Does the tree have any uses? __________
3. Which parts of the tree are useful? ____________________
4. What are these parts used for? ____________________
5. How are these parts prepared for use? ____________________

____

____

____

6. Have you, yourself, used these parts on yourself or on others? Did it work? ____________________

____

7. How often do you use these parts of the tree? ____________________
8. If you yourself do not use these parts, where did you hear of their use? ____________________

____

COMMENTS: ____________________

____

____

____

____

____

HISTORY OF COPAL USE

9. Did the ancient Maya use the copal tree? __________
10. What parts of the tree did they use? ____________________
11. For what purpose did the Maya use these parts of the tree? ____________________

____

____

COMMENTS: ____________________

____

____

____

HARVEST OF THE RESIN OF THE COPAL TREE

12. Do you tap the copal tree? ____________
13. Where do you go to tap the tree (how far)? ____________
14. How many trees do you tap? ____________
15. How often do you tap? ____________
16. How do you harvest copal (tapping technique, equipment)? ____________

____

____

____

17. What amount of resin do you harvest? ____________
18. Are there specific seasons for tapping copal? ____________
19. What is the difference between tapping in summer and tapping in winter? ____________

____

____

20. Have you tapped copal throughout the whole year? ____________
21. If not, do you know someone who has tapped throughout the whole year? ____________

____

22. Do you tap the same tree year after year? If not, how much time between tapping of the same tree, or do ever return to the same tree? ____________

____

23. Have you seen changes (damage like yellowing or falling leaves) due to tapping the tree? ____________

____

24. What do you do with the resin after tapping (how transported)? ____________

____

25. Do you sell the resin, or is it for personal use? ____________
26. If you sell the resin, to whom and where do you sell it? ____________

____

27. For how much, per pound, do you sell the resin? ____________

COMMENTS: ____________

____

COPAL RESIN MARKET

28. Do you buy copal resin? ____________
29. Do you know people who buy the resin? ____________
30. Who do you know who buys the resin? ____________

____

31. How much do you pay, per pound, for the resin? ____________
32. Where do you buy the resin? ____________
33. What do you buy the resin for? ____________

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34. Do you know where the resin that you buy comes from? ____________

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APPENDIX 2

Strata 1

Actual yields of T1 and T2 trees and predicted yields of all trees using both regression models.

#	tree	distance from beginning of transect (m)	diameter at breast height (dbh) (cm)	total tree height (m)	crown height (m)	crown code	crown illum. code	volume index (dbh x ht) (m^2)	crown index (crwn code + crwn illumination)	total yields (g)	multilinear prediction	curvilinear prediction
1	S1T1-6	36.5	20.7	15.0	4.5	4	2	3.1	6	106.5	221.9	220.0
2	S1T2-7	42.0	20.2	17.0	5.0	4	3	3.4	7	100.1	229.5	204.1
3	S1T2-11	42.0	11.7	16.5	8.0	3	3	1.9	6	77.6	94.2	38.2
4	**S1T3-6**	49.0	10.6	14.0	5.0	3	2	1.5	5		69.5	28.2
5	S1T2-8	52.0	16.1	20.0	6.0	4	2	3.2	6	195.0	235.5	101.7
6	S1T1-7	106.0	12.0	10.5	4.0	3	3	1.3	6	5.9	35.9	41.3
7	S1T2-2	125.0	10.1	9.0	3.0	2	4	0.9	6	23.0	13.2	24.3
8	S1T1-12	127.0	17.2	19.0	5.5	2	3	3.3	5	196.1	273.9	124.6
9	**S1C-10**	275.0	14.5	12.5	4.5	2	3	1.8	5		102.4	73.8
10	S1T1-1	301.0	13.7	11.0	6.5	3	4	1.5	7	23.7	41.4	62.0
11	**S1C-11**	320.0	18.1	15.0	3.0	4	2	2.7	6		177.0	145.7
12	**S1T3-5**	356.0	10.5	9.5	4.5	4	3	1.0	7		10.6	27.4
13	**S1C-12**	359.0	13.5	9.0	3.5	5	2	1.2	7		22.0	59.3
14	**S1C-4**	370.0	13.6	11.0	5.5	2	3	1.5	5		70.7	60.6
15	**S1T3-3**	448.0	22.0	16.0	9.0	2	3	3.5	5		306.3	265.2
16	**S1T3-1**	597.0	16.1	10.0	5.0	2	3	1.6	5		81.8	101.7
17	S1T2-3	625.0	17.5	15.0	5.0	2	2	2.6	4	265.2	223.6	131.4
18	**S1C-8**	650.0	12.5	9.0	3.0	3	2	1.1	5		37.7	46.8
19	**S1T3-11**	662.0	16.8	10.5	3.5	2	3	1.8	5		97.4	115.9
20	S1T1-8	688.0	29.0	23.0	7.0	2	3	6.7	5	738.7	747.5	618.9
21	S1T2-4	692.0	32.9	21.0	10.0	2	2	6.9	4	557.4	840.8	911.5
22	**S1C-7**	695.0	15.4	10.5	4.0	2	3	1.6	5		82.5	88.8
23	S1T1-5	696.0	27.5	16.5	9.0	2	2	4.5	4	1029.1	486.4	525.8
24	**S1T3-4**	778.0	18.1	13.0	4.0	2	5	2.4	7		114.6	145.7
25	S1T1-10	799.0	12.3	16.0	7.0	3	4	2.0	7	76.8	78.8	44.5
26	**S1T3-12**	805.0	21.4	14.0	4.0	3	2	3.0	5		239.6	243.6
27	**S1C-5**	809.0	24.0	14.0	3.0	2	2	3.4	4		321.0	346.3
28	S1T1-9	1013.0	11.5	10.0	4.0	3	3	1.2	6	52.7	28.0	36.2
29	S1T2-10	1014.0	10.5	12.5	3.5	2	2	1.3	4	79.8	69.6	27.4
30	**S1C-1**	1038.0	15.5	13.5	4.5	2	3	2.1	5		132.7	90.5
31	S1T2-1	1075.0	20.9	18.0	3.0	3	2	3.8	5	367.0	338.0	226.6
32	**S1C-3**	1082.0	23.0	14.0	5.5	3	3	3.2	6		235.5	303.9
33	**S1T3-2**	1105.0	16.7	14.5	5.5	3	2	2.4	5		170.1	113.8
34	**S1C-13**	1105.0	30.0	12.5	2.5	2	2	3.8	4		374.7	686.7
35	S1T2-9	1133.0	16.5	20.0	8.0	2	3	3.3	5	306.9	277.9	109.7
36	**S1T3-10**	1155.0	16.6	12.5	4.0	3	2	2.1	5		130.7	111.7
37	**S1T3-8**	1202.0	13.8	11.0	7.5	2	3	1.5	5		72.8	63.4
38	S1T2-5	1207.0	14.0	15.0	6.0	3	3	2.1	6	187.2	111.0	66.3
39	S1T1-2	1225.0	10.5	10.5	4.0	3	3	1.1	6	15.6	24.8	27.4
40	S1T2-6	1228.0	12.0	17.5	3.5	4	3	2.1	7	154.2	90.7	41.3
41	S1T1-4	1346.0	28.0	20.0	6.0	2	2	5.6	4	840.2	642.4	555.7
42	**S1C-9**	1405.0	23.9	15.5	6.0	2	3	3.7	5		330.4	341.9
43	**S1T3-7**	1495.0	15.5	10.5	3.0	3	2	1.6	5		83.5	90.5
44	**S1C-6**	1512.0	19.1	11.0	4.0	4	4	2.1	8		72.4	171.9
45	S1T1-3	1544.0	11.3	8.5	4.0	4	3	1.0	7	33.8	8.9	34.3
46	**S1T3-9**	1597.0	17.5	10.0	4.5	2	3	1.8	5		95.9	131.4
47	S1T2-12	1790.0	14.4	9.5	4.0	5	3	1.4	8	142.8	21.3	72.2
48	S1T1-11	1850.0	13.0	9.0	5.2	4	3	1.2	7	9.4	19.4	52.8
49	**S1C-2**	1938.0	17.4	11.5	6.0	2	3	2.0	5		122.6	129.1
50	S1T1-13	1941.0	22.2	12.0	6.5	3	4	2.7	7	92.0	145.7	272.6

Strata 2

Actual yields of T1 and T2 trees and predicted yields of all trees using both regression models.

#	tree	distance from beginning of transect (m)	diameter at breast height (dbh) (cm)	total tree height (m)	crown height (m)	crown code	crown illum. code	volume index (dbh x ht) (m^2)	crown index (crwn code + crwn illumination)	total yields (g)	multilinear prediction	curvilinear prediction
51	**S2T3-3**	0.0	11.7	8.0	2.5	3	3	0.9	6		14.7	38.2
52	S2T1-10	17.3	20.6	9.5	5.0	2	1	2.0	3	27.5	166.1	216.7
53	**S2C-12**	119.0	23.1	14.0	8.0	2	1	3.2	3		340.4	308.0
54	**S2T3-6**	129.9	14.4	10.5	4.0	3	3	1.5	6		56.0	72.2
55	S2T2-2	166.8	23.7	13.0	8.5	3	2	3.1	5	218.1	250.2	333.2
56	**S2T3-4**	229.6	24.0	9.0	3.5	3	3	2.2	6		117.2	346.3
57	**S2C-5**	341.0	24.7	13.0	3.5	2	2	3.2	4		300.8	378.2
58	S2T1-11	358.2	20.5	14.0	6.0	3	3	2.9	6	235.7	194.6	213.5
59	**S2T3-10**	382.0	30.0	13.0	6.0	3	2	3.9	5		356.3	686.7
60	**S2C-13**	455.8	17.9	9.0	2.5	4	3	1.6	7		49.2	140.8
61	S2T2-12	455.8	27.1	15.0	8.0	2	3	4.1	5	354.6	378.4	502.7
62	S2T1-8	0.0	13.5	10.5	3.5	2	4	1.4	6	4.0	48.1	59.3
63	**S2T3-12**	0.0	13.9	13.0	3.0	3	3	1.8	6		82.4	64.8
64	**S2T3-1**	161.0	18.7	11.5	5.0	2	2	2.2	4		164.1	161.1
65	S2T1-7	165.7	10.7	10.5	5.0	2	3	1.1	5	7.9	37.6	29.0
66	**S2C-10**	165.7	20.0	12.5	1.5	4	2	2.5	6		153.2	197.9
67	S2T1-9	199.0	26.5	19.3	5.1	3	3	5.1	6	242.6	477.5	469.4
68	**S2C-7**	214.0	10.7	11.0	4.0	2	3	1.2	5		42.0	29.0
69	S2T1-1	214.0	15.4	17.3	3.3	3	3	2.7	6	194.8	171.3	88.8
70	**S2C-9**	223.0	23.2	13.5	5.0	2	2	3.1	4		290.2	312.1
71	S2T2-7	261.0	26.9	17.8	7.1	2	2	4.8	4	590.0	520.8	491.4
72	**S2T3-5**	290.0	12.3	10.0	4.5	4	4	1.2	8		14.2	44.5
73	S2T2-6	302.0	22.0	13.5	7.0	2	3	3.0	5	232.9	236.3	265.2
74	**S2C-1**	350.0	15.1	11.0	3.0	3	3	1.7	6		69.0	83.6
75	S2T2-3	372.0	23.9	14.5	5.0	2	2	3.5	4	553.7	335.4	341.9
76	**S2C-14**	440.0	16.2	11.0	4.5	2	2	1.8	4		120.5	103.7
77	S2T2-1	444.0	20.5	15.3	7.3	2	3	3.1	5	441.8	255.9	213.5
78	S2T1-6	25.0	20.7	12.0	5.0	2	1	2.5	3	124.5	235.7	220.0
79	**S2T3-2**	225.0	14.4	8.0	2.5	4	3	1.2	7		18.4	72.2
80	**S2T3-9**	229.0	18.5	11.5	5.5	2	2	2.1	4		161.3	155.8
81	S2T2-5	233.8	11.3	9.0	4.0	2	2	1.0	4	90.6	41.4	34.3
82	**S2C-6**	255.5	22.0	10.5	5.5	2	3	2.3	5		157.2	265.2
83	**S2T2-11**	358.0	17.0	7.5	2.0	3	2				12.6	120.2
84	**S2C-3**	405.0	17.3	13.5	5.0	2	2	2.3	4		186.9	126.8
85	S2T1-3	415.0	22.2	16.5	6.5	2	3	3.7	5	394.3	325.0	272.6
86	**S2C-15**	425.0	14.6	8.5	1.5	2	2	1.2	4		62.4	75.4
87	S2T1-2	470.0	19.8	18.9	8.6	2	2	3.7	4	394.6	373.6	191.9
88	S2T2-4	470.0	19.6	15.1	5.3	2	2	3.0	4	229.7	267.2	186.0
89	**S2C-4**	73.0	31.6	10.3	4.3	3	3	3.2	6		237.8	805.4
90	**S2C-11**	92.0	22.1	14.0	8.0	3	1	3.1	4		285.1	268.9
91	**S2T3-11**	134.0	15.5	8.0	5.0	2	2	1.2	4		62.3	90.5
92	S2T2-10	144.0	21.0	15.0	7.5	2	3	3.2	5	185.6	258.9	229.9
93	**S2C-8**	150.0	16.5	11.5	1.5	3	2	1.9	5		111.4	109.7
94	S2T1-12	157.0	20.5	17.5	8.0	2	2	3.6	4	379.0	352.2	213.5
95	**S2C-16**	157.0	10.9	9.5	5.0	2	5	1.0	7		12.3	30.7
96	**S2T3-7**	250.0	20.5	16.0	9.0	3	3	3.3	6		242.7	213.5
97	**S2T3-8**	308.0	17.7	11.5	6.0	2	2	2.0	4		150.2	136.1
98	S2T2-9	308.0	14.6	10.5	4.5	3	1	1.5	4	71.2	92.8	75.4
99	S2T1-4	316.0	23.5	16.0	4.0	2	2	3.8	4	571.7	376.1	324.6
100	S2T2-8	340.0	25.0	15.5	5.5	2	1	3.9	3	439.5	433.4	392.5
101	S2T1-5	365.0	13.8	13.0	2.5	3	3	1.8	6	120.1	81.2	63.4
102	**S2C-2**	417.0	16.5	10.0	5.5	2	3	1.7	5		85.8	109.7

APPENDIX 3

ANALYSIS OF *PROTIUM COPAL* RESIN

University of San Carlos in Guatemala

In a co-operative venture, ProPetén-CI provided the University of San Carlos in Guatemala City with sample of the resin and fruit skins of *Protium copal*. The Faculty of Chemistry and Pharmacy conducted a preliminary analysis on the samples and found the skins to contain an essential oil that is 90% pure. In the resin, a clear lac was identified, in addition to a wax that demonstrated anti-fungal properties.

University of British Columbia – Faculty of Agricultural Sciences, Agroecology

The resin was tested for insecticidal properties in the Insect toxicology laboratory. The resin was incorporated into an artificial diet at a concentration of 0.1%. Neonate *Spodoptera litura* larvae were placed in individual compartments with 1 g of either the control or treated diets (n=20). Larvae were maintained at 26°C with a photoperiod of 16L:8D. After 7 and 10 days, larvae were weighed and mean weights were calculated. Average larval weight at 7 days was 73.3% of controls and 55.6% of controls at 10 days.

University of British Columbia – Faculty of Science, Department of Botany

The resin was tested for activity against selected microorganisims in the Towers laboratory. The resin was extracted with 95% ethanol overnight. The solvent was removed under reduced pressure and the residue was freeze-dried and dissolved in ethanol at a concentration of 100 mg/ml. Two mg of this sample was spotted on 6.5 mm diameter discs of Schleicher & Schuell analytical paper #740-E. The dry disks were placed on agar plates, each spread with one of the following microorganisms:

G(+) bacteria: *Staphylococcus aureus, Bacillus subtilis* and *Enterococcus faecalis*
G(-) bacteria: *Escherichia coli* and *Pseudomonas aeruginosa*
Acid-Fast bacterium: *Mycobacteriuim phlei*
Fungus: *Candida albicans*

Duplicate plates were incubated for 24 hours, one series maintained in the dark, and the other irradiated. Positive controls (antibiotic gentamicin and antifungal nystatin) were included in the tests as well. Ethanolic extract of resin was found to be inactive against tested bacteria and fungus at the concentration (100 mg/ml) of resin used.

Comments on analysis of *Protium copal* resin to date

Very little detail is provided with the information given by the University of San Carlos, particularly with respect to methodology, thus these conclusions require further investigation.

The results of the tests on the resin for insecticidal activity merit further investigation, as average larval weight was reduced to almost half of that of the control. Seeds and fruit skins were not tested here, and may yet yield some insecticidal properties.

The lack of activity seen against the selected microorganisms tested could be explained in two ways. First, it may indicate that this resin is not useful against bacteria or fungi. The ethnobotanical survey revealed only two people who used the resin to treat wounds. The majority of local healers indicated that they apply the resin to treat sore muscles (general muscular pain, rheumatism and arthritis) or to remove skin ailments (thorns, cyst and parasites). The second explanation for the lack of antibiotic or anti-fungal activity observed is that the concentration tested was too low to show activity. All descriptions of the use of the resin given by survey participants describe the resin being applied directly to the affected areas, undiluted with any other material. Fruit skins and seeds were not tested here either, and may contain active constituents.