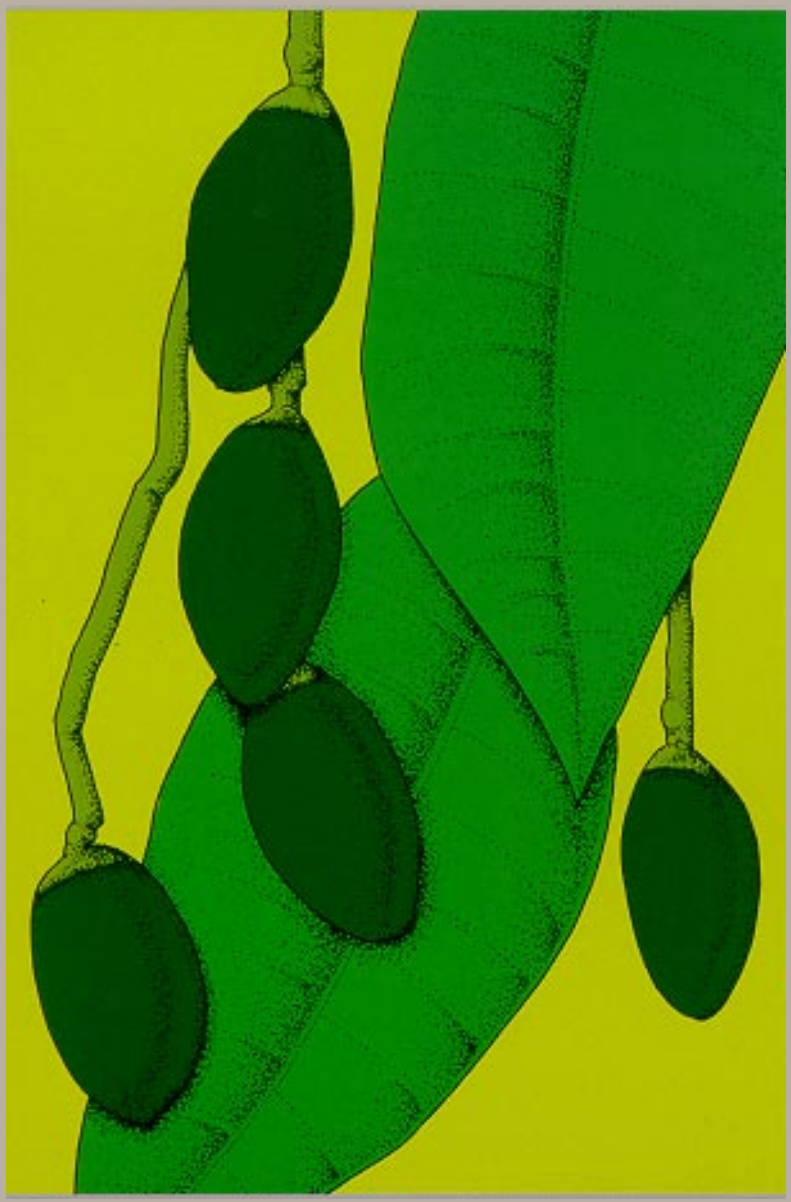
Promoting the conservation and use of underutilized and neglected crops. 6.

Pili nut

Canarium ovatum Engl.

Roberto E. Coronel



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Contents

Foreword

Humanity relies on a diverse range of cultivated species; at least 6000 such species are used for a variety of purposes. It is often stated that only a few staple crops produce the majority of the food supply. This might be correct but the important contribution of many minor species should not be underestimated. Agricultural research has traditionally focused on these staples, while relatively little attention has been given to minor (or underutilized or neglected) crops, particularly by scientists in developed countries. Such crops have, therefore, generally failed to attract significant research funding. Unlike most staples, many of these neglected species are adapted to various marginal growing conditions such as those of the Andean and Himalayan highlands, arid areas, salt-affected soils, etc. Furthermore, many crops considered neglected at a global level are staples at a national or regional level (e.g. tef, fonio, Andean roots and tubers etc.), contribute considerably to food supply in certain periods (e.g. indigenous fruit trees) or are important for a nutritionally well-balanced diet (e.g. indigenous vegetables). The limited information available on many important and frequently basic aspects of neglected and underutilized crops hinders their development and their sustainable conservation. One major factor hampering this development is that the information available on germplasm is scattered and not readily accessible, i.e. only found in 'grey literature' or written in little-known languages. Moreover, existing knowledge on the genetic potential of neglected crops is limited. This has resulted, frequently, in uncoordinated research efforts for most neglected crops, as well as in inefficient approaches to the conservation of these genetic resources.

This series of monographs intends to draw attention to a number of species which have been neglected in a varying degree by researchers or have been underutilized economically. It is hoped that the information compiled will contribute to: (1) identifying constraints in and possible solutions to the use of the crops, (2) identifying possible untapped genetic diversity for breeding and crop improvement programmes and (3) detecting existing gaps in available conservation and use approaches. This series intends to contribute to improvement of the potential value of these crops through increased use of the available genetic diversity. In addition, it is hoped that the monographs in the series will form a valuable reference source for all those scientists involved in conservation, research, improvement and promotion of these crops.

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Los Baños, Laguna
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Introduction

The Philippines is an archipelago of 7100 islands and islets in the Pacific (Zaide 1983). It has a total land area of 297 409 km^2, and a coastline that is 17 360 km long. A tropical country, it is located at latitudes 5^o-20^o N of the equator, and longitudes 117^o -127^o E (Britannica Atlas 1969).

Several fruit trees that bear edible nuts are claimed to have their centre of diversity in the Philippines. The most important of these is the pili species (*Canarium ovatum* Engl.*)*, whose geographic distribution in the country remains limited to areas located relatively close to its centre of origin. For this reason, the present production of the plant is confined to a limited area of the Philippines.

The pili nut has several botanical relatives in the Philippines, as well as in other tropical countries, which could be used as rootstocks in vegetative propagation. These allied species could also be used as parents in hybridization, to improve the productivity of the cultivated pili nut. Furthermore, owing to the high degree of open-pollination which naturally occurs, pili nut trees grown from seeds exhibit a wide range of variability in many important horticultural characters. It has therefore not been necessary to apply artificial hybridization to this species, as desirable genotypes can be selected from the existing genepool.

Because of its economic uses, the pili nut is a highly appreciated species. Its existing genepool might not seem to be under any immediate threat, but in fact, the total pili tree population is being rapidly reduced. Although the pili tree is known to be one of the most typhoon-resistant species, a number of trees are destroyed by the devastating typhoons that hit the area of pili cultivation each year. The greatest threat to the genetic diversity of the species, however, is posed by humans. During periods of food insecurity, such as after a major typhoon, the local population is known to cut down pili trees and sell them as lumber or fuelwood. There is therefore an urgent need for collecting missions, to conserve the remaining diversity of the pili nut genepool. Fortunately, vegetative propagation occurs in the species, which allows trees with useful traits to be conserved exactly as they are. There is a need to continue planting seedlings, however, to ensure that genetic variability in the species is continually increased.

1 Taxonomy and nomenclature

Canarium ovatum Engl. (in A. DC., Monogr. Phan. 4 (1883) 110) belongs to the family Burseraceae. This family consists of 16 genera and about 550 species in the tropical regions of both hemispheres (Leenhouts 1956). In the Philippines, the family is represented by five genera, namely *Canarium*, *Dacryodes*, *Garuga*, *Protium* and *Santiria*. The genus *Canarium* (derived from the Malay name 'kanari', the local name for one of the species), contains about 75 species of trees which are mainly found in tropical Asia and the Pacific, and a few species in tropical Africa (Leenhouts 1956). About 53 species were believed to be found in the Philippines (Merrill 1923), but much later, the number was reduced to nine species (Leenhouts 1956). The known *Canarium* species and their distribution are listed in Appendix I. The distribution of the *Canarium* species of the Malaysian region is shown in Fig. 1.

At present, at least four species are of economic importance. *Canarium ovatum* (known locally as 'pili' and 'pilaui') is the most important nut-producing species in the Philippines. *Canarium indicum* is an important nut-producing species in the Solomon Islands (locally called 'ngali'), Papua New Guinea (locally called 'galip') and Vanuatu (where it is known as 'nangai') (Evans 1993). *Canarium album*, known in English as Chinese olive, 'samo cheen' in Thailand and 'tram trang' in Vietnam, is important in these countries for its edible pulp and kernel (Verheij and Coronel 1991).

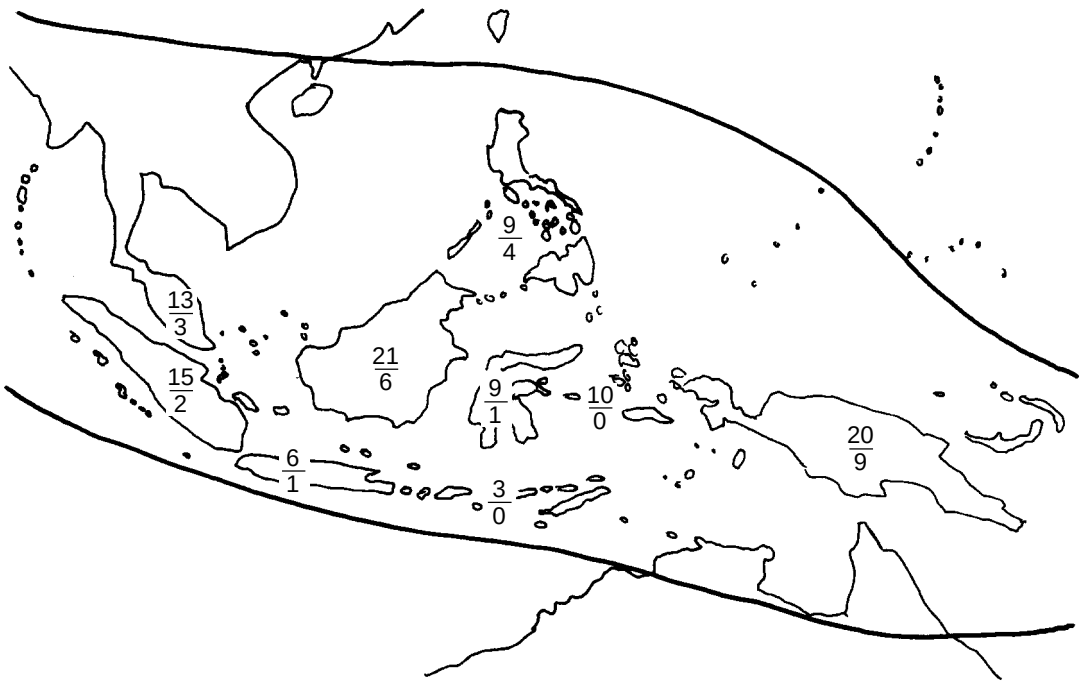


Fig. 1. Distribution of the *Canarium* species of the Malaysian region. The upper number is the total number of species, the lower is the number of endemic species in each island or district (after Leenhouts 1956).

Canarium luzonicum, most commonly known in the Philippines as 'pisa' and 'basiad', is important, not as an edible nut but for its oily resin (known locally as 'sahing'), which is tapped from the trunk (Fig. 2). When processed, it is called 'brea blanca' (white pitch) and is exported as Manila elemi (Manalo and West 1940; Brown 1954; Coronel 1983).

The remaining *Canarium* species are little understood agronomically, although these minor species may in the future prove useful as rootstocks in clonal propagation, or as parents in hybridization of the cultivated species.

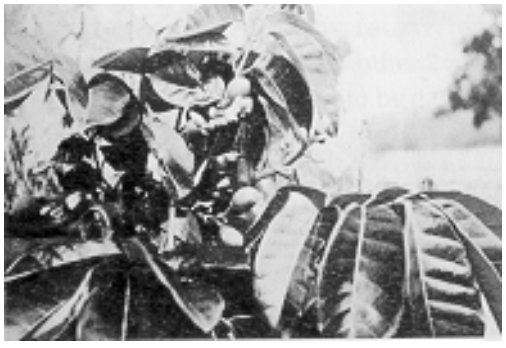
Fig. 2. Trunk of *Canarium luzonicum*, showing resin accumulation after tapping.

2 Botanical description[1]

The pili is an erect to spreading, deciduous, predominantly dioecious, medium-sized to large tree that may reach a height of 30 m or more. Very old trees can have a trunk diameter of more than 50 cm (Fig. 3). The leaves have persistent deltoid to lingulate stipules, are spirally arranged, imparipinnate and about 40 cm long. The leaflets are ovate to elliptic, 4-24 cm long and 2-12 cm wide, stiff-coriaceous, entire, base oblique, rounded to subcordate, apex abruptly acuminate and with 8-12 pairs of nerves.

Fig. 3. A very old pili tree in a coconut plantation in Guinobatan, Albay.

The flowers are borne on cymose inflorescences at the leaf axils of the young shoots. The inflorescence on female trees is about 7 cm long and has 3-6 flowers (Fig. 4a), while that on male trees is ~10 cm long and has an average of 18 flowers (Fig. 4b).



a

b

Fig. 4. Flowering habit of (a) female and (b) male pili tree.

[1] Summarized from Brown (1954), Coronel (1983, 1991), Galang (1955), Juliano (1937), Merrill (1912), Wester (1921) and Zuño and Coronel (unpublished).

In the female flower, the calyx is saccate, gamosepalous, about 1.5 cm long, 1 cm wide, and has three thick, light green sepals. The three greenish-yellow petals are about 2 cm long and 1 cm wide. The six non-functional stamens arise from the base of the disk. The pistil is about 7 mm long and consists of a functional superior ovary, a simple style about 1.5 mm long and a three-lobed stigma. The ovary has three locules, each with two ovules but normally only one of the six ovules is able to develop a seed. In the male flower, the calyx is also saccate, 6 mm long and 4 mm wide, and is composed of three green sepals, tinged with yellow orange at the tips. The three oblong, inwardly concave, greenish petals are about 10 mm long and 5 mm wide. The pistil is greatly reduced in size and the six functional stamens are also attached to the base of the vestigial ovary. In a small number of male trees, the few hermaphrodite flowers are similar in all respects to the male flowers, except that the former have functional pistils. Such trees are capable of producing fruits, although these are much smaller than those from the females trees.

The fruit, commonly referred to as a nut, but botanically a drupe, is ovoid to ellipsoid, 4-7 cm long, 2.3-3.8 cm in diameter and weighs 15.7-45.7 g (Fig. 5). The pulp is composed of a thin skin (exocarp), which is smooth and shiny, and turns from light green to purple or nearly black when the fruit ripens, and a fibrous, thick flesh (meso-

a

b

Fig. 5. Fruits of (a) *Canarium ovatum* and (b) *Canarium luzonicum.*

carp).

The shell (endocarp) is carpellary in origin. Its inner layer arises from the innermost epidermal cells surrounding the loculi, while its outer layer develops from the numerous hypodermal cells. The shell is elongated and trigonous, and is nearly triangular in transverse section, with its corners rounded and one of its sides wider than the others. The basal end of the shell is pointed, while the apical end is more or less blunt or obtuse. It is tawny to nearly dirty brown outside, and more or less brown, shiny and glabrous inside. On the broad side of the shell, which is often concave or elevated, is the functional locule, containing the mature seed, which also has distinct grooves on the outside that indicate the place where the shell breaks when the seed germinates.

The seed is made up of a brown, papery seedcoat surrounding the embryo, which has two white cotyledons. The kernel weighs 0.74-5.13 g and constitutes 4.4-16.6% of the whole fresh fruit.

2.1 Reproductive biology

The pili is a dioecious species with gametic chromosome number *n*=23 (Villegas and Coronel 1979). The order of blooming is basipetal, i.e. the oldest flower and the first to open is at the tip of the inflorescence and blossoming proceeds downward (Linsangan *et al*. 1979).

Anthesis of both male and female flowers takes place between 4 pm and 6 pm. Anther dehiscence and stigma receptivity take place at anthesis, or immediately afterwards. At anthesis, the flowers emit a fragrant odour, suggesting that the pili flowers are basically insect-pollinated. The anther changes in colour from white to yellowish at dehiscence and turns brown in the morning of the following day. At the time of receptivity, at anthesis, the stigma is yellowish and sticky, and begins to turn brown the following morning.

Fruit set in flowers pollinated at anthesis was recorded at 87.5% (Linsangan *et al*. 1979). Flowers pollinated 24 hours after anthesis failed to set any fruits. From pollination, the fruit was found to take about 10 months to reach maturity (Linsangan *et al*. 1979) and another 2 months to reach full ripening (del Rosario 1984). Ripe pili fruits are believed to be eaten by hornbills, who expel the nuts, dispersing them over a considerable distance. Monkeys also gather the ripe fruits, eat the pulp and throw away the nuts, contributing to their dispersal in the process.

Wild pigs, wild deer and rodents consume the pili pulp of the fallen ripe fruits, leaving the nuts behind. Humans gather the fallen fruits and seeds, and may thus be considered a constraint to the successful dispersal of the species, significantly reducing the natural stand of pili nut seedlings in communities and forests.

3 Origin and geographic distribution

The pili is indigenous to the Philippines (Merrill 1912, 1923; Wester 1921; Brown 1954; Li 1970). The crop's centre of genetic diversity is the Bicol region (Fig. 6), possibly in the virgin rainforests surrounding Mt. Bulusan, in the Province of Sorsogon. In the forests of this province, very old pili nut trees measuring more than 50 m in height can still be found today.

The trees have spread northward to the other three provinces (Albay, Camarines Sur, Camarines Norte) of the region located on the island of Luzon. Old pili trees can still be found in these provinces (Fig. 6). The trees have spread further to the island provinces of Catanduanes in the north and Masbate, in the Bicol region. The trees have also spread out of the Bicol region, to the Province of Quezon in the Southern Tagalog region.

It is only in the present century, however, that the pili nut has been dispersed much more widely. For example, seeds were brought from Oas, Albay to Los Baños, Laguna in 1919, and planted along a road now known as Pili Drive, at the University of the Philippines at Los Baños. Seeds were brought to La Carlota City in the province of Negros Occidental, in the Central Visayas region. Residents of the Bicol region, who either worked in or moved to other parts of the Philippines, took pili seeds with them for planting. The first students at the University of the Philippines College of Agriculture, in Los Baños, took pili seeds home with them for planting, and the pili trees lining Pili Avenue on the campus of Aklan State College of Agriculture in Banga, Aklan (Central Visayas region) were grown from seeds obtained from Los Baños. A municipality in the province of Camarines Sur is named Pili, after the popular nut-producing tree.

Canarium ovatum has not spread much to other countries; even the world-famous botanic gardens in Indonesia and Singapore do not possess living specimens. There are two reasons why this may be so. Historically, there has not been great interest in the pili nut, owing to its thick shell and small kernel. Furthermore, other countries have their own important species. For example, some countries in the South Pacific are growing *C. indicum* (Bourke 1994; Evans 1993). The Hawaiian Islands are the remotest location from the pili nut's centre of origin, where the species is distributed, and some fruit-bearing pili trees can be found at the University of Hawaii Experimental Station at Hilo, on the big island of Hawaii.

Other *Canarium* species are found in the Bicol region (Merrill 1923). These include *C. asperum* (known in the region as 'pili-pili'), *C. gracile* (known as 'pilingokai'), *C. luzonicum* (known as 'malapili'), *C. euryphyllum*, and *C. hirsutum* (known as 'hagushus'). Because of their small nuts, none of these species has economic potential.

3.1 Brief history of cultivation

It is not known precisely when the pili nut was first cultivated in the Philippines, although it must have been in ancient times, when the native inhabitants of the archipelago started gathering pili fruits in the wild. These early inhabitants of the

Philippines learned that, as well as the kernel, the boiled ripe pulp was edible. Later, people dug out pili seedlings in the forest, and planted them near their dwellings. The more resourceful individuals also planted some of the seeds (particularly the large nuts) that they had gathered in the forest. Thus, the process of domesticating and cultivating the pili nut is thought to have begun.

1 Cordillera Administrative Region
- a Kalinga
- b Abra
- c Apayao
- d Mt Province
- e Ifugao
- f Benguet

2 Bicol Region
- g Camarines Norte
- h Camarines Sur
- i Catanduanes
- j Albay
- h Sorsogon
- k Masbate

3 Western Visayas
- l Aklan

4 Central Visayas
- m Negros Oriental

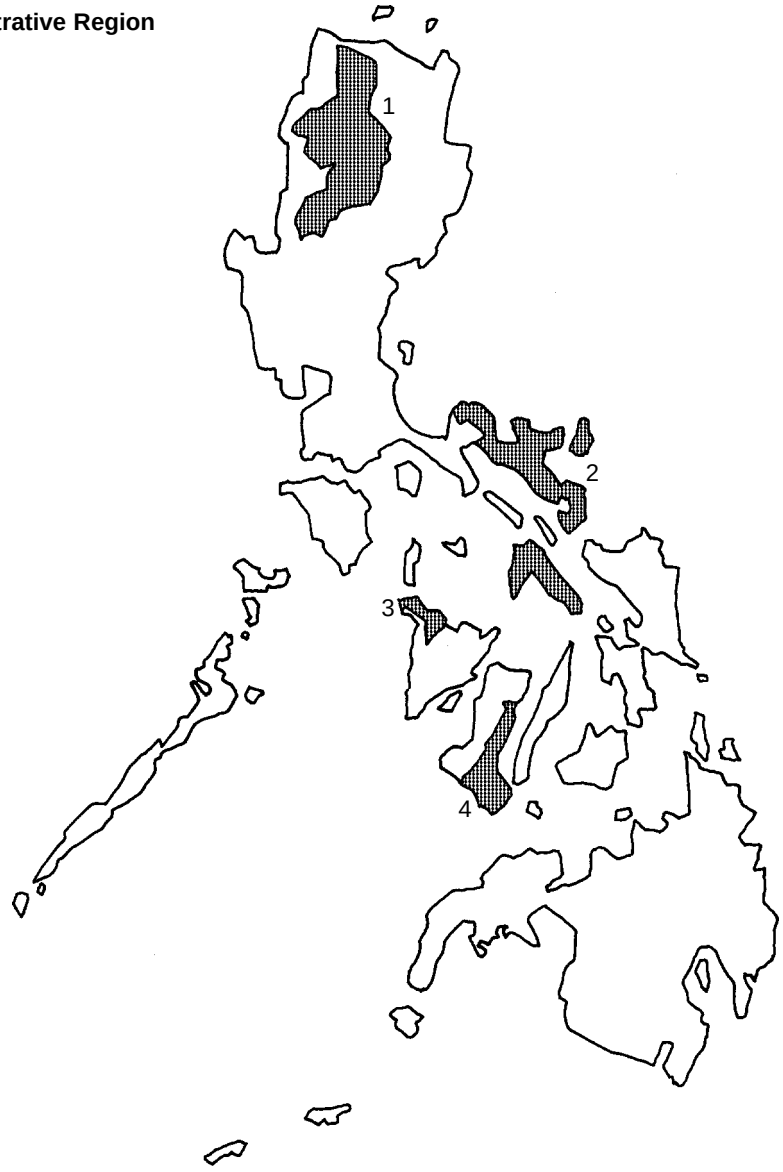


Fig. 6. Map of the Philippines, showing geographic regions and provinces (areas of pili cultivation highlighted).

Visitors from neighbouring provinces were impressed by the tastiness of the pili kernels, and began taking pili seedlings home for planting. Some of them also grew seedlings from the nuts they brought back. In the same manner, local residents who moved to other provinces took pili seedlings or nuts with them for planting.

Despite its long history of cultivation, the pili has remained a home garden tree and a minor source of income for some people. It is only recently that the pili has been designated a priority crop in the Bicol region. Massive production of planting materials is underway, and it is hoped that in the near future, the pili nut will be grown as a commercial crop and will be ranked with the cashew and the macadamia in the world market.

4 Properties

Measurements were taken from a total of 84 female trees, and the ripe pili fruit was found to weigh from 15.7 to 45.7 g (Coronel and Zuño 1980b). The pili pulp, which makes up about 64.5% of the fruit by weight, contains 73% moisture. On a dry weight basis (per 100 g), it contains: 8% protein, 33.6% fats, 3.4% crude fibre, 9.2% ash, 45.8% carbohydrates and 2.2 kJ (Marañon *et al.* 1954). The pulp oil, which is clear and greenish yellow in colour, has the following composition: 56.7% oleic glycerides, 13.5% linoleic glycerides and 29.3% saturated fatty acids.

The kernel, which weighs 0.74-5.13 g and which comprises 4.4-16.6% of the whole fruit by weight, contains: 35.6-51.4% moisture, 11.5-15.7% protein, 69.2-76.6% fats and 2.59-4.32% carbohydrates. Its food energy was reported to be 2.7 kJ/100 g, with the following mineral and vitamin contents (per 100 g): 119 mg calcium, 508 mg phosphorus, 2.6 mg iron, 489 mg potassium, 45 IU vitamin A, 0.95 mg thiamine, 0.12 mg riboflavin, 0.4 mg niacin and traces of vitamin C (Intengan *et al.* 1968). Other authors have reported on the chemical composition of the pili kernel (Brill and Agcaoili 1915; Padilla and Soliven 1933; Garcia 1941).

In comparison, 20-30% of seed kernel of the cashew, a more popular tropical nut than the pili, is edible. The kernel contains 7.6-16.0% moisture, 18.0-25.4% protein, 43.4-57.4% fats and 19.2-21.0% carbohydrates (Coronel 1983; Verheij and Coronel 1991). The pili kernel therefore contains more oil and less protein and carbohydrates than the cashew kernel.

The kernel oil is composed almost entirely of the gylcerides of oleic (59.6%) and palmitic (38.2%) acids. The oil is light yellow, has an agreeable odour and taste, is suitable for culinary purposes and keeps perfectly for as long as 6 months (West and Balce 1923).

The pili shell has 3.2% moisture content, 11.9% volatile combustible matter, 11.1% ash and 77% fixed carbon.[2]

[2] Figures provided by the Biomass Energy and Facilities Engineering Section, Chemical Processing Division, Forest Products Research and Development Institute, Department of Science and Technology.

5 Uses

5.1 The tree

The pili is a plant with various uses (West and Brown 1920; Gonzalez and Bunoan 1947; Brown 1954; Galang 1955; Coronel 1966; Lanuza 1969-70). It makes an excellent avenue and border tree, and a verdant shade tree for lawns. Its remarkable resistance to strong winds makes it a good living windbreak for other crops such as bananas and papayas. The pili is also suitable for agroforestry. The young shoot is edible and can be used in cooking and in making green salads. The resin-rich wood makes an excellent firewood, and the wood of other local *Canarium* species may be used for house-framing and for making boxes, crates and musical instruments (Tesoro and Aday 1990).

The resin or elemi, particularly from *C. luzonicum*, is tapped from the trunk (Fig. 2) and exported under the name 'Manila elemi' (Manalo and West 1940). In pharmacy, elemi is used as an ingredient in plasters and ointments. In industry, it is a valuable raw material in the manufacture of adhesives, printing inks, fireproof and waterproof materials, paints, varnishes, etc. Elemi is also used in engraving and lithography.

5.2 The fruit

Economically, the pili nut kernel is the most important part of the fruit and has many uses (West and Balce 1923; Garcia 1941; Brown 1954; Galang 1955; Oñate 1967). When eaten raw, it is crispy and has a delicious flavour. It is also eaten roasted, fried or sugar-coated. It is frequently used as an ingredient in cakes, puddings and ice cream, and when cooked in syrup, makes a good preserve. The roasted kernel is sometimes used in chocolate-making. It is also rich in oil, which is suitable for culinary purposes. At present, extraction of the oil from the pili kernel is not being explored owing to an inadequate supply of nuts, even for the kernel industry.

The green pulp can be made into pickle, which is best done soon after the shell has hardened, but before the pulp becomes too fibrous (Mercado 1942). The boiled ripe pulp is edible and is usually eaten seasoned with salt, pepper, or with a salted fish sauce (Wester 1915; Garcia 1941; Brown 1954; Galang 1955; Coronel 1966). It resembles boiled sweet potato in texture, but has a rather insipid taste. It can also be made into a spread (Dipad 1979). No data are available regarding the quantity of pulp consumed as a foodstuff. The pulp also contains an oil that is used for cooking and lighting (West and Brown 1920; West and Balce 1923; Garcia 1941; Gonzalez and Bunoan 1947; Brown 1954). Oil from the pili pulp could also be used in the manufacture of soap and other products, although these potential industrial uses have not yet been exploited.

The hard, stony shell of the pili seed is chiefly used in cooking, for which it makes an excellent fuel (Gonzalez and Bunoan 1947; Lanuza 1969-70). It is also well suited as a component of the growing medium for orchids and anthuriums (Coronel 1983). When polished and varnished, the shell makes an attractive keyholder, and

ornaments fashioned out of the shells of other *Canarium* species are popular with local and foreign tourists in Indonesia (Gonzalez and Bunoan 1947; Coronel 1966). The use of the pili shell in the manufacture of charcoal has not yet been explored (Coronel 1983). The same is true of the testa or seedcoat of the pili kernel, although when its chemical composition is determined, some industrial uses may be found for this part of the fruit (Coronel 1983).

No data exist on local consumption of the different raw and processed products, or on what percentages of the nuts produced go into the processing industry. No exports have been recorded in recent years, and the most recent export figure available is that for 1977, when 3790 kg of various pili nut products were sold to Australia and Guam (Coronel 1983).

A number of processed pili products are currently available in local markets. Pili candies are prepared from whole or halved kernels, which are coated with a glaze of brown (unrefined) or white (refined) sugar, cooled, placed in plastic bags or jars, and sealed. Pili 'turron' is made from a mixture of ground pili kernel, sweet potato and sugar, which is flavoured with sesame and vanilla. The mixture is cooked until it reaches a desired consistency, cooled, cut into uniform pieces and wrapped in plastic. Pili pudding, the last of these products, is made from a mixture of mashed sweet potato, ground pili kernel, condensed milk, butter, sugar and eggs. The mixture, flavoured with vanilla, is poured into small rectangular paper trays and is baked in a moderately hot oven, until it turns a light brown colour.

6 Genetic resources

6.1 Range of diversity in major plant characters

The pili is a highly variable species. Numerous observations have confirmed that seedling trees possess high variability in many important botanical and horticultural characters (Table 1). The first investigation to study the genetic variability of pili seedling trees was conducted at the campus of the University of the Philippines, College of Agriculture in Los Baños, Laguna (Gonzalez and Bunoan 1947). The trees were found to differ in their sex; almost half of the trees evaluated were male and the rest were female, confirming its dioecious nature. The same ratio of male and female trees was obtained in a later survey (Zuño and Coronel 1982). In a recent collecting trip in Banga, Aklan, the author observed the same ratio of male and female trees in an avenue lined with pili trees.

Table 1. Plant characters observed to differ among pili trees of seedling origin.

Character	Reference
Plant	
Sex (male and female)	Gonzalez and Bunoan (1947), Zuño and Coronel (1982)
Growth habit (erect to spreading)	Gonzalez and Bunoan (1947)
Seasonality of fruiting (seasonal to everbearing)	Angeles (1981), Gonzalez and Bunoan (1947)
Yield (low to high)	Gonzalez and Bunoan (1947)
Response to asexual propagation (low to high)	Coronel *et al*. (1972, 1982)
Shoot	
Stem diameter (0.4-2.1 cm)	Coronel *et al*. (1982), Angeles (1981)
Period of flushing (March-June)	del Rosario (1984)
Period of scion available (November-January)	del Rosario (1984)
Leaf	
Size/weight (5.2x12.8-7.7x17.0 cm)	Angeles (1981)
Number per shoot (6.1-9.7)	Angeles (1981), del Rosario (1984)
Petiole length (22.3-37.8 cm)	Angeles (1981)
Nutrient content (low-high)	Angeles (1981)
Period of leaf abscission (May-August)	del Rosario (1984)
Flower	
Number of flower clusters/shoot (1.8-2.8)	del Rosario (1984)
Number of flowers/cluster (3-21.5)	del Rosario (1984)
Period of flowering (March to June)	del Rosario (1984)

Fruit	
Number of fruit clusters/shoot (6-12)	Angeles (1981)
Number of fruits/shoot (3-8)	Angeles (1981)
Moisture content (35.6-51.4%)	Coronel and Zuño (1980b), Garcia (1941)
Fruit weight (15.7-45.7 g)	Coronel and Zuño (1980a, b), Gonzalez and Bunoan (1947)
Fruit length (4.03-6.76 cm)	Coronel and Zuño (1980a, b), Angeles (1981)
Fruit diameter (2.33-3.85 cm)	Coronel and Zuño (19801, b), Angeles (1981)
Fruit shape (short to long (oblong))	Coronel and Zuño (1980a, b), Gonzalez and Bunoan (1947)
Pulp weight (11.4-28.4 g)	Coronel and Zuño (1980a, b), Garcia (1941), Gonzalez and Bunoan (1947)
Pulp thickness (3.88-5.35 mm)	Coronel & Zuño (1980a, b), Operio (1979), Operio and Coronel (1980)
Pulp colour (yellow to cream)	Gonzalez and Bunoan (1947)
Pulp flavour (poor to acceptable)	Gonzalez and Bunoan (1947)
Pulp chemical composition (low to high)	Angeles (1981), Coronel and Zuño (1980b), Garcia (1941)
Shell weight (5.4-13.0 g)	Coronel and Zuño (1980b)
Shell thickness (1.8-4.2 mm)	Coronel and Zuno (1980b), Operio (1979), Operio and Coronel (1980)
Kernel weight (0.74-5.13 g)	Coronel and Zuño (1980a, b), Gonzalez and Bunoan (1947)
Kernel percent (4.40-16.61%)	Coronel and Zuño (1980a, b), Garcia (1941)
Kernel chemical composition (low to high)	Angeles (1981), Coronel and Zuño (1980b), Garcia (1941)
Period of fruit setting (May-July)	del Rosario (1984)
Period of fruit development (9-10 months)	del Rosario (1984)
Nut	
Soaking time to soften pulp (3.5-93 hours)	Operio (1979), Operio and Coronel (1980)
Time to germination (46-70 days)	Operio (1979), Operio and Coronel (1980)
Percent germination (46.7-98.3%)	Operio (1979), Operio and Coronel (1980)

A low percentage of supposedly male pili trees produced a few hermaphrodite flowers in the inflorescence (Zuño and Coronel 1982). These bisexual flowers were similar in all respects to the male flowers, except that the former had functional ovaries that were capable of developing into mature fruits. The fruits, however, were much smaller than those from female trees. Pollen from the bisexual flowers was also able to pollinate female flowers.

Gonzalez and Bunoan (1947) also observed that some seedling trees had a spreading growth habit; others had more upright branches. Among the female trees, some were prolific while others were less productive. Some were also seasonal in

their fruiting, whereas others produced fruits all year round. The latter were later erroneously called 'everbearing' pili trees.

With regard to other plant characters, pili trees of seedling origin also differ in their precocity, density or profuseness of branching, stem girth of shoots, earliness or lateness of the season of fruit ripening, and length of period of fruit development. The number of inflorescences / fruit clusters per shoot, number of flowers per inflorescence, and number of fruits set per inflorescence, also differ among seedling trees. The number of fruits set, number of flowers per inflorescence, number of inflorescences per shoot and number of shoots per tree are determinants of the number of fruits produced (or yield) per tree, which also varies among seedling trees.

The stem girth of the shoot is important in asexual propagation. It has been observed that the diameter of pili shoots differs among seedling trees (Coronel *et al.* 1982). Trees that have smaller shoots would easily match the stem diameter of 1- to 2-year-old seedling rootstocks used in grafting.

Variability also exists in the different fruit characters (Gonzalez and Bunoan 1947; Coronel and Zuño 1980b), i.e. nut weight and shape (Fig. 7); pulp weight, thickness, flavour and fibre content; shell thickness; kernel size, colour and flavour. The length of time taken to soften the pulp when soaked in water also differs among seedling trees, as does the chemical composition of the pulp and kernel. The proportion of saturated and unsaturated fatty acids contained in the oil varies, as does the percentage of filled nuts and the percentage kernel recovery in seedling trees.

Leaves from different seedling trees vary in size, number per shoot, petiole length and chemical composition. The nuts from different trees also differ in storage behaviour (i.e. some nuts have longer storage life than others), number of days to germination and percentage germination.

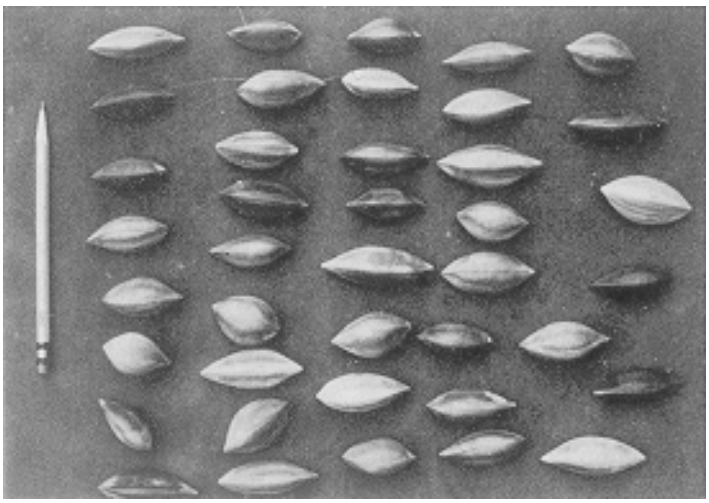


Fig. 7. Variation in the size and shape of pili nuts from seedling trees.

6.2 Wild relatives

The pili has some 74 relatives, about eight of which are found in the Philippines (Leenhouts 1956). However, not much is known about their usefulness in the improvement of the species. Limited trials carried out in the Philippines showed that seedlings of *C. luzonicum* can be used as rootstocks in grafting/budding the pili (Wester 1916; Galang and Elayda 1924). The other wild species should be investigated to determine their usefulness in the improvement of pili nut.

6.3 Germplasm conservation

An organized approach to the collecting and conservation of pili germplasm was begun when the Institute of Plant Breeding's National Plant Genetic Resources Laboratory was established in 1976. The range of variability of the pili trees grown on the campus of the University of the Philippines at Los Baños was investigated, as well as that of those at a nearby government research station (Coronel and Zuño 1980b). In Laguna, 84 female seedling trees were evaluated (Table 2). Several trees of this collection were considered outstanding, in terms of the fruit characters selected, and these were later given variety names (Coronel *et al.* n.d.). Three of these varieties ('Katutubo', 'Mayon' and 'Oas') were later approved for registration by the National Seed Industry Council, formerly the Philippine Seed Board (PSB 1993).

Table 2. Number of pili accessions collected in different provinces.

Region/Province	Number of accessions
Southern Tagalog	
Laguna	84
Bicol	
Albay, including Iriga City	56
Camarines Norte	4
Camarines Sur	33
Sorsogon	86
Others	15
Total	278

Results of fruit evaluation of the 84 trees in Laguna showed that there were wide variations in fruit and kernel characters among trees (Table 3). The other fruit characters such as weight and thickness of pulp and kernel also varied greatly among the trees. Proximate analyses of kernel from 17 pili trees showed that the trees also differed in the moisture, fat, protein and starch content of the kernel.

Seedling trees respond differently to the different asexual propagation methods such as marcotting, cleft-grafting and patch-budding. Using some of the pili trees at the University of the Philippines, Los Baños, an investigation of the asexual propa-

gation methods applicable to the pili was conducted from 1979 to 1981 (Coronel *et al.* 1972). It was found that, out of 14 trees used, none was responsive to propagation by stem-cutting. Of 38 trees, 19 responded favourably to marcotting, with a success rate of 10-100%. Among those seedling trees that responded, the number of days to rooting also varied greatly. These findings on marcotting corroborated earlier results (Coronel *et al.* 1972, n.d.). Out of a total of 21 trees, seven were successfully cleft-grafted, but with a maximum success rate of 25%. Measurements of the shoot diameter of 37 trees ranged from 0.4-2.1 cm, with an average of 1.2 cm. Of a total of 23 trees, 18 were successfully patch-budded, with a success rate of up to 72%.

Table 3. Variations in fruit and kernel characters and proximate analyses of pili trees. (Source: Coronel and Zuño 1980a).

Parameter	Range	Mean	SD
Fruit*			
Weight (g)	15.72 - 45.69	25.71	0.94
Length (cm)	4.03 - 6.76	5.32	0.57
Diameter (cm)	2.33 - 3.85	2.87	0.30
Kernel*			
Weight (g)	0.74 - 5.13	2.73	0.08
Percent	4.40 - 16.61	10.71	0.25
Proximate analyses (%)**			
Moisture [1]	35.6 - 51.4	41.8	4.6
Fat [2]	69.2 - 76.6	73.1	2.3
Protein [2]	11.5 - 15.7	13.9	1.3
Starch [2]	2.59 - 4.32	3.26	0.47

* Based on 84 trees; ** based on 17 trees.
[1] Harvest moisture.
[2] 14% moisture.

All the pili nut collections in Laguna are being maintained in the sites where they were originally planted. In addition, the three registered varieties are being maintained as cleft-grafted or patch-budded trees at the Institute's field genebank.

During subsequent collecting missions, pertinent passport and collecting data were obtained for each tree. Each pili tree identified represented one accession. Ten ripe fruits were randomly gathered from each tree, evaluated individually, and the average calculated for each character. The following measurements were recorded in fresh samples: whole fruit weight, fruit length and diameter, pulp weight and

thickness, shell weight and thickness, kernel weight with testa, testa weight and kernel weight. Percent kernel (the kernel as a proportion of the seed) was calculated, based on fresh weight of nut.

Fruit samples from all the pili collections from Bicol and other regions / provinces (Table 2) have been evaluated at least once. The original trees are being maintained in their natural habitats. It was originally planned in 1976 that all the pili accessions would be propagated asexually. This was based on the recommendations contained in the Revised Tropical Fruit Descriptors (IBPGR 1980) that all tropical fruit germplasm collections be conserved in field genebanks as vegetatively propagated trees, genetically identical to the original parent trees. During the collecting trips, therefore, fruits were gathered only for evaluation, and not to grow seedlings for planting in the genebank. Instead, scions were collected for asexual propagation, but since pili nut scions do not transport well, no asexually propagated plants were produced.

Since 1995, ripe fruits from the original tree collections in Laguna and Bicol, which have been maintained in their natural habitats, have been gathered, and seedlings representing these collections have been planted in the field genebank at the University of the Philippines, Los Baños. In the field genebank in Los Baños, each pili accession is represented by 3-4 grafted or budded plants. In the case of sexual propagation, each accession contains 10 seedlings.

6.4 Erosion of genetic resources

The pili is now a partly cultivated crop, although many people have not fully understood its long-term potential. Much valuable genetic material may have been lost already, but the species does not seem to be in any danger of extinction. Many natural factors have ensured the continuous regeneration and survival of the genetic resources of the pili: its dioecious nature, and the obligatory cross-pollination; its high fruit set; the natural dispersal of nuts by wild birds and other animals; high seed germination percentage, aided by the availability of high moisture during the fruiting season, and tolerance to hostile growing conditions.

However, the statistics indicate that the pili nut tree population has been declining rapidly, principally because of human activity. Local people gather pili nuts for food, significantly reducing the potential number of seedlings that could have sustained the natural population. Seedlings are seldom replanted, and areas that were previously planted with pili trees have been built on. Deforestation also has been caused by trees being deliberately cut down for fuelwood and many other purposes.

While humans currently represent the greatest threat to the preservation of the pili nut genepool, human intervention is also needed to preserve the genetic diversity of the species. A first step in this direction would be a local or national ban on the felling of pili trees. A second step might be to encourage the planting of pili seedlings for reforestation, agroforestation and landscaping. Non-governmental organizations (NGOs) could play an active role in such initiatives. Thirdly, pili trees (both male and female) that possess important and potentially useful characters

should be identified, properly labelled and carefully maintained. These trees should also be propagated asexually, by marcotting, cleft-grafting or patch-budding. Asexually propagated plants from these trees should be planted and maintained in duplicate genebanks, where they could be thoroughly characterized and evaluated.

7 Varietal improvement

Varietal improvement of pili nut trees can be achieved by selection of superior trees from existing seedling populations, and by conventional breeding methods, such as hybridization, to further improve existing varieties.

7.1 Selection

The first method of varietal improvement of the pili is by selection of superior trees from existing seedling populations. This method is presently the most practical, and is likely to be used for some years to come.

By virtue of its being a predominantly dioecious species, cross-pollination in nature is the rule in the pili. This has resulted in a great variation among seedling trees and many desirable and useful horticultural characters.

The earliest observations on the existence of different forms in the pili were made by Wester in 1915. On the basis of fruit size, he identified two forms: the short form, with fruits of 4.5-6.0 cm in length, and the long form, with fruits of 5.5-7.0 cm. Proximate analysis of both forms of the kernel produced similar results (Brill and Agcaoili 1915), although the short form was the one usually sold in the markets.

Wester (1929) also selected the first pili tree that produced thin-shelled nuts, belonging to the long, slender form. The tree bearing these thin-shelled nuts was found in Magkasili, Guinobatan, Albay and was named 'Albay,' after the province in which it originated. Wester (1929) also reported another tree with thin-shelled nuts, this time belonging to the short form. The tree bearing these thin-shelled nuts was found in Mauraro, also in Guinobatan, Albay and was named 'Red', in honour of its discoverer.

Table 4. Correlation coefficients (r) between some fruit characters of the pili nut (Coronel and Zuño 1980a).

Fruit characters compared	Correlation coefficient (r)
Kernel weight and fruit weight	0.48531**
Kernel weight and fruit length	0.53049**
Kernel weight and fruit diameter	0.61582**
Kernel weight and length-diameter ratio	0.05431
Percent kernel and kernel weight	-0.57533**
Percent kernel and fruit weight	-0.02696
Percent kernel and fruit length	0.02026
Percent kernel and fruit diameter	-0.14010
Percent kernel and length-diameter ratio	0.16545

** Highly significant

A more systematic evaluation of the species was conducted in Los Baños, Laguna in 1946 (Gonzalez and Bunoan 1947). A total of 95 pili trees, whose seeds came from Oas, Albay and which were planted in 1920, were evaluated for sex expression, productiveness, fruiting season, growth habit, physical and chemical properties of the fruits, and other morphological features. Two trees were selected as outstanding on the basis of their yield and fruit qualities. One of these was later named 'Katutubo' (Coronel 1983).

More recent selection work on the pili, conducted in Laguna, the Bicol provinces and other locations, identified 40 promising trees, on the basis of kernel weight (Coronel and Zuño 1980b). Correlation studies of the various pili fruit characters have shown that fruit weight, length and diameter were highly positively correlated with kernel weight (Table 4). Thus, any of these three external fruit characters may be used as a basis for preliminary evaluation or selection of a large number of seedling trees.

In addition to kernel weight, other desirable characters are early bearing, high productivity, short fruiting season, good pulp and kernel qualities, and thin shell (Coronel 1966, 1978a, 1978b, 1983).

Several pili varieties have been selected from among the promising seedling trees in Laguna and the Bicol region. The six pili varieties selected in Los Baños, Laguna are briefly described in Table 5 (Coronel *et al.* 1982). Figures 8a-f show that all the fruits of 'Katutubo', 'Oas', 'Mabunga', 'Ibalon' and 'Isarog' varieties are oblong, whereas the fruits of `Mayon' variety are short-oblong.

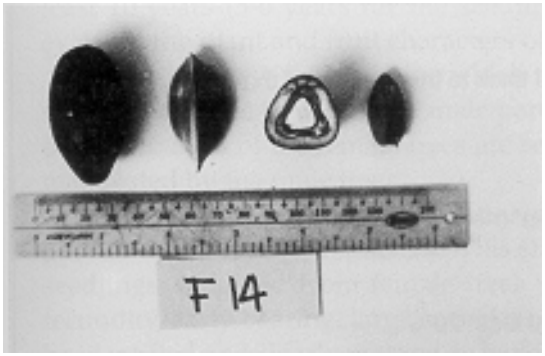
Table 5. Some fruit characters of pili varieties (Coronel *et al.* 1982).

Fruit character	Variety					
	'Katutubo' (76-18*)	'Oas' (76-6)	'Mabunga' (76-14)	'Ibalon' (76-17)	'Mayon' (76-27)	'Isarog' (76-65)
Fruit weight (g)	39.58	33.64	26.55	29.72	31.29	29.84
Pulp weight (g)	28.33	19.90	17.80	19.02	18.50	19.25
Pulp thickness (mm)	5.03	3.93	5.07	4.60	5.08	6.22
Nut weight, dry (g)	13.01	13.74	8.75	10.70	13.29	10.59
Shell thickness (mm)	3.02	4.14	2.22	2.30	3.64	2.17
Kernel weight, dry (g)	2.65	2.96	2.02	2.50	3.03	2.86
% kernel	20.37	21.54	23.09	23.09	22.00	27.00
Kernel fats (%)	74.60	72.10	73.90	69.90	76.40	75.50
Kernel protein (%)	14.00	14.50	13.50	15.10	11.50	12.00
Kernel starch (%)	2.88	4.31	2.76	3.74	3.58	2.88

* Accession numbers have the prefix UPL-P1-.

a

b



c

d

e

f

Fig. 8. Pili fruit: (a) 'Katutubo' (F18); (b) 'Oas' (F6); (c) `Mabunga' (F14); (d) 'Ibalon' (F17); (e) 'Mayon' (F27); (f) 'Isarog' (F65).

Box 1. Varietal selection standards for the pili.

1. Fruit characters
   - 1.1. Whole fruit (fresh)
     - 1.1.1. Size: medium to large (at least 25 g)
     - 1.1.2. Shape: short-oblong to globose
   - 1.2. Nut (dry basis)
     - 1.2.1. Size: medium to large (at least 10 g)
     - 1.2.2. Shape: short-oblong to globose
     - 1.2.3. % filled nuts: at least 90%
   - 1.3. Shell (dry basis)
     - 1.3.1. Thickness: medium thick to thin (not more than 4.00 mm)
   - 1.4. Kernel (dry basis)
     - 1.4.1. Size (including testa): medium to large (at least 2.5 g)
     - 1.4.2. Colour: white
     - 1.4.3. Shelling recovery: at least 20%
2. Tree characters
   - 2.1. Growth habit: spreading
   - 2.2. Vigor: strong
   - 2.3. Branching: profuse with thinner shoots
   - 2.4. Yield: heavy (for 25-year-old tree, at least 5000 fruits per season)
3. Reaction to pests and environmental stresses
   - 3.1. Resistance to insect pests: tolerant to resistant
   - 3.2. Resistant to diseases: tolerant to resistant
   - 3.3. Resistance to environmental stress: resistant to typhoons
4. Ease of asexual propagation
   - 4.1. Cleft-grafting: high (80-85%)
   - 4.2. Patch-budding: high (70-75%)

Fruit evaluation and tree characterization are continuing for many more seedling trees in order to select better pili varieties. Using the 'Katutubo' pili as the check variety, in 1994 the Fruit and Plantation Crops Varietal Improvement Group of the Philippines National Seed Industry Council established a set of varietal selection standards for the pili (Box 1). An outstanding pili tree should be precocious, prolific, with profuse branching, bear large, short-oblong fruits, with thin shell and medium-to-large kernels that ripen over a very short period. It is readily propagated by cleft-grafting and/or patch-budding.

7.2 Hybridization

The dioecious nature of the species makes controlled hybridization in the pili a particularly complicated and difficult process, which has not yet been attempted. Like other perennial plant species, a breeding cycle for the pili would require at least 10 years (5-6 years for the seedlings to bear fruits, and another 4 years to evaluate the plant and fruit characters of the new hybrids).

While it is easy to determine which trees to use as the female parents, selecting which male trees to use as the male parents is more problematic, especially as the fruit characters of the female trees are selected for, and because these traits are not manifested by the male trees.

The first step in a pili hybridization programme is to establish which male trees possess the desirable characters. This should be done by growing open-pollinated seedlings, obtained from female trees with known desirable characters, such as fecundity, early bearing, large kernel, etc. All the male trees thus produced should be identified and clearly marked as male seedling trees from known female parents. For example, male seedling trees from the 'Mabunga' pili (known for its high yield) can be used as a pollen source for the controlled pollination of the 'Katutubo' pili, to develop hybrids that are more prolific than the latter variety.

8 Production areas

Table 6 shows that the production areas of the pili are primarily concentrated in the Bicol region, in the provinces of Sorsogon, Albay, Camarines Norte and Camarines Sur (Wester 1915, 1921). In these provinces, the main supply of nuts comes from certain municipalities and districts, which are usually located near mountainous areas (Lanuza 1939; Despi 1965). Production of nuts is mainly from unselected seedling trees.

The Southern Tagalog region (principally the province of Quezon) and the Eastern Visayas region (principally the provinces of Northern and Western Samar) also produce a quantity of pili nuts (Table 6). The other regions of the Philippines either do not produce pili nuts, or their production is negligible.

Table 6. Number of bearing trees and production (mean of 5 years 1989-93). (Source: Bureau of Agricultural Statistics, Department of Agriculture.)

Region/Province	Bearing trees	Production (kg)
Southern Tagalog	16868	19198
Oriental Mindoro	188	3856
Quezon	16680	15342
Bicol	50274	3119539
Albay	14494	202970
Camarines Norte	2190	235800
Camarines Sur	3120	328177
Sorsogon	29436	2344940
Western Visayas	64	1920
Capiz	64	1920
Eastern Visayas	7926	652752
Eastern Samar	3000	73600
Leyte	280	3116
Northern Samar	2882	72168
Western Samar	1764	103868
Southern Mindanao	44	1839
Davao City	44	1839
Total	75176	3795248

The production figures given in Table 6 are estimated values. If the yield per tree is calculated, it can be seen that there is a wide variation in production among locations. For example, the yield per tree in the Southern Tagalog region is 0.9 kg in Quezon and 20.5 kg in Oriental Mindoro. In the Bicol region, the yield per tree ranges from 14.0 kg in Albay to 107.7 kg in Camarines Norte. This large discrepancy can be attributed in part to the considerable age range of the bearing trees.

Despite the recent availability of selected varieties, and the development of vegetative propagation methods, the pili is still not planted commercially in the Philippines today. A systematic assessment of the reasons for this is called for. Furthermore, should the economic prospects of the crop be found to be sufficiently good, assistance from the government will be needed to promote the large-scale production of the crop.

9 Ecology

The pili does not have strict soil requirements, and is known to thrive on a wide range of soil types and over a wide range of climatic conditions in the Philippines (Coronel 1966; Lanuza 1969-70). At the Paete Land Grant of the University of the Philippines, Los Baños, pili trees grow well, even in very acid soils. For optimum production, however, soils that are deep, fertile and well drained are ideal (Coronel 1966; Lanuza 1969-70).

The pili is a purely tropical species (Chandler 1958). In its native habitat, the Bicol region, the total annual rainfall is about 3300 mm (Table 7). Rainfall is well distributed throughout the year (225 rainy days), although there is more rain from June to January (average 332.6 mm / month) than from February to May (average 167 mm / month). The four regions in Mindanao (Fig. 1) also enjoy well-distributed rainfall and should be able to grow the pili successfully.

The pili also grows well in the province of Laguna, where the total annual rainfall is moderate (1980 mm) and there are distinct dry and wet seasons (January-April and May-December, respectively). There are also several other areas of the Philippines with a similar rainfall pattern, which should be able to grow the pili successfully.

The pili grows well from sea level up to an elevation of 400 m (Coronel 1966; Lanuza 1969-70). It has been reported to grow at much higher elevations in the Cordillera Administrative Region. However, it cannot tolerate the cool period and slight frost of southern Florida (Chandler 1958; Mortensen and Bullard 1964).

Temperature and relative humidity in the Philippines remain more or less constant throughout the year, with a mean annual temperature of about 27°C and mean annual relative humidity of about 80%. The Bicol region is within the typhoon belt and experiences several strong typhoons each year. The pili is known to be extremely resistant to these annual hurricanes. Some people in the region even call the pili the 'spouse of typhoons', because of their belief that the stronger the typhoon the pili trees experience, the more fruitful they become. This is related to another belief concerning the harvesting of the pili nuts. The usual harvesting method is to repeatedly thrash the fruiting branches with a stick, severely defoliating the tree in the process. It is widely believed in the Philippines that this 'punishment' encourages the pili tree to produce more flowers and fruits during the next fruiting season. The practice has a scientific basis, however, in that it achieves the correct balance of carbon and nitrogen in the plant.

Table 7. Climatological normals at agromet stations in Legaspi City, Albay (1961) and Los Baños, Laguna (1950-93). (Source: Philippine Geophysical Aeronautic Services Administration).

Month	Rainfall (mm)		Rain-days		Mean temp. (°C)		Relative humidity (%)	
	Albay	Laguna	Albay	Laguna	Albay	Laguna	Albay	Laguna
January	293.3	46.2	20	12	25.5	25.1	84	82
February	188.6	20.9	16	7	25.7	25.6	83	79
March	157.9	29.9	16	6	26.5	26.8	82	75
April	153.4	35.1	16	6	27.5	28.4	82	74
May	167.9	160.7	14	12	28.4	29.0	81	76
June	251.7	237.6	17	18	28.2	28.3	82	80
July	267.0	267.7	19	20	27.8	27.7	84	82
August	280.8	254.8	19	20	27.8	27.5	84	83
September	272.7	242.1	20	20	27.7	27.4	85	83
October	340.6	274.8	22	19	27.2	27.1	85	84
November	479.9	251.0	23	18	26.8	26.5	85	83
December	475.0	159.3	23	17	26.0	25.5	84	83
Total/mean	3328.8	1980.1	225	176	27.1	27.1	84	80

10 Agronomy

10.1 Growth and development

The germination of the pili seed begins with the uptake of water through a heart-shaped, grooved opening at the basal end of the broadest side of the nut (Fig. 9). The shell of the nut may crack open as early as 30 days after sowing. First, the radicle appears, followed by the surfacing hypocotyl, with the shell still enclosing the two cotyledons. Then the hypocotyl becomes erect, with the cotyledonary leaves still closed (Fig. 10a). About 70 days after sowing, the seedling has a mature pair of true leaves (Fig. 10b), the cotyledonary leaves have withered after unfolding briefly, and numerous root hairs and secondary roots are present.

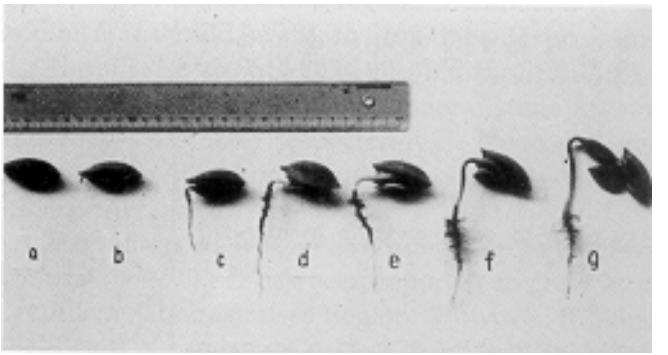
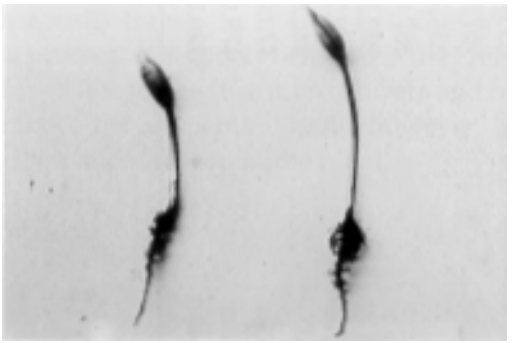
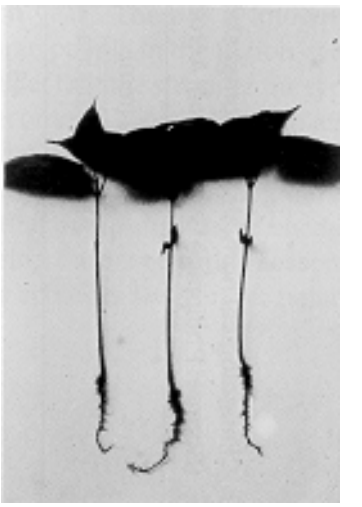


Fig. 9. Sequence of events during germination of the pili seed: (a) shell starts to open, (b) radicle emerges from shell, (c–d) radicle continues to elongate, (e) root hairs proliferate, (f) hypocotyl emerges from soil surface, (g) cotyledon emerges from shell.



a



b

Fig. 10. Pili seedlings: (a) at the cotyledonary-leaf stage, and (b) with a mature pair of true leaves.

Initially, the pili seedling grows slowly after transplanting, but the growth rate soon accelerates, stem height and girth increase rapidly and new leaves unfold continuously. After 3-4 entire leaves have developed, leaves with 3 leaflets follow, until in the mature trees, the leaves have 5, 7 or 9 leaflets.

The juvenile pili tree produces lateral shoots rather late. They may grow to a height of 2 m or more over a period of about 3-4 years, before the first branching occurs. At this stage, the tree may produce its first flowers. Lateral shoot growth ultimately gives the tree a more or less round canopy.

In the Philippines, the pili tree flushes in March to May, with such flushes abscissing a year later, from March to September (Fig. 11). The following year, when leaves from the previous season's flush are starting to fall, new leaf and flower buds begin to open. As leaf abscission progresses, flowering and leaf development continue, and when the last leaf falls, the current season's flush has grown to its fully mature size. This sequence of events makes pili a deciduous tree. However, the overlapping of the previous and the current season's leaf development makes the pili appear to be an evergreen tree.

Flowering in the Philippines occurs from March to June (simultaneously with flushing) and the flowers open in April-July (Fig. 11). In the female trees, fruits set from May to July and they ripen in May to August of the following year, about the time that the fruits of the previous season's flush are ripening, and new fruits are setting and starting to develop. This gives rise to shoots bearing young, green mature and ripe fruits. In turn, this gives the (wrong) impression that the pili is an everbearing tree, when in fact flowering and fruiting are highly seasonal events.

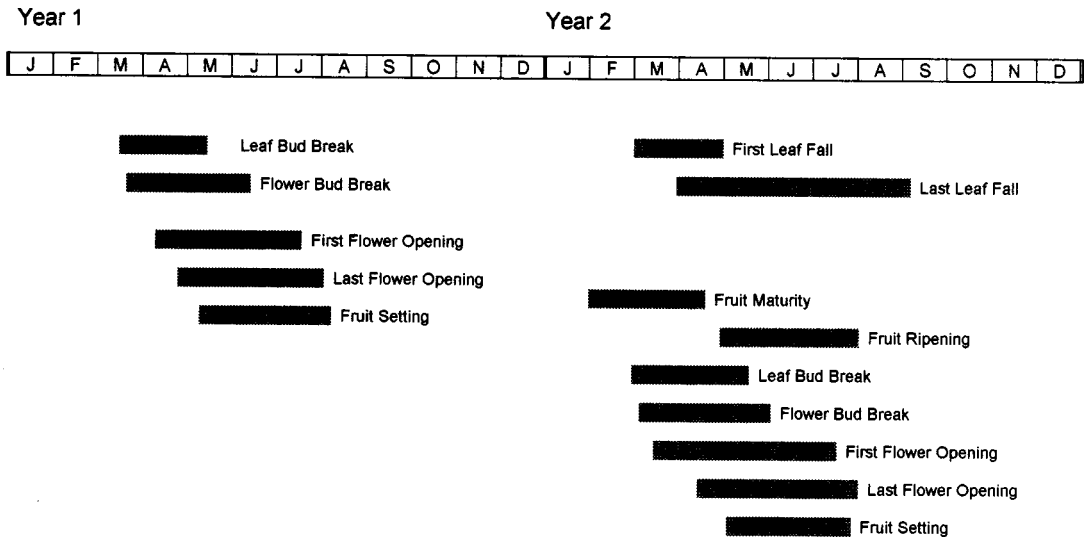


Fig. 11. Summary of a 2-year timetable of flushing, flowering and fruiting in the pili.

Growth of the pili fruit exhibits a sigmoid curve (Fig. 12). When pollination is successful, the ovary begins to enlarge after 1 week, and the petals start to drop off. By 2 weeks after pollination, the young fruit is dark green, and there is no significant difference between fruit length and diameter. Fruit growth then becomes rapid, up to the 10th to 12th week, with a more rapid increase in length, compared with diameter. Growth gradually slows down, and levels off as the fruit approaches maturity (at about 10 months after pollination). Fruit ripening, however, takes a further 2 months, at which stage the fruit skin colour turns to dark purple or almost black.

It is interesting to note that the kernel (anatomically, the cotyledons with the tiny embryo within) remains relatively undeveloped, even when the fruit has reached its maximum size. It does not begin substantial development until the fruit has reached maturity, and the kernel growth occurs during fruit ripening.

On the average, pili seedling trees start flowering and fruiting 5-6 years after seed germination. Most flushes in mature trees are reproductive, and the trees may live to be more than 100 years old. Female trees are usually smaller than male trees of the same age, owing to the exhausting and dwarfing effect of fruiting.

10.2 Nut selection and germination

Pili nuts intended for commercial planting, or for use as rootstocks in asexual propagation, should be obtained from fully ripe fruits from outstanding trees, preferably of known cultivars. Removing the pulp before sowing the nuts is advisable, because clean nuts germinate earlier, with a higher germination percentage than whole fruits (Dalisay 1961). The pulp is easily removed by soaking the newly harvested fruits for 24-48 hours in water, until the pulp becomes soft and is readily separated

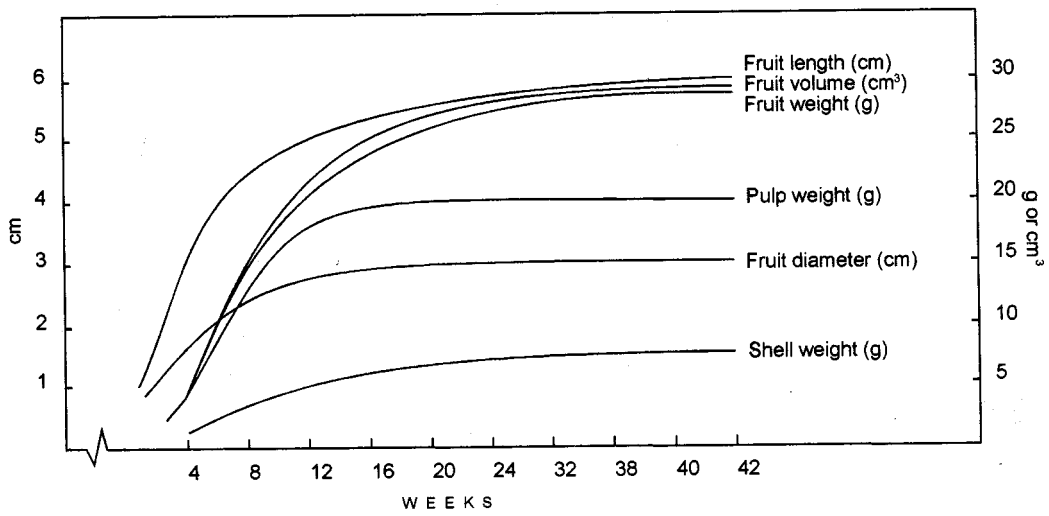


Fig. 12. Average weekly development of the pili fruit.

from the nut by hand. The nuts are thoroughly rinsed to remove all the slimy material that adheres to the shell. All nuts that float are discarded, as they are either empty or have undeveloped seeds that germinate poorly (Dalisay 1961). The nuts are simply air-dried. Sun-drying of nuts reduces seed viability (Lanuza 1969-70).

Pili seeds are recalcitrant, and the nuts should be sown immediately because the seeds lose viability quite rapidly when kept, even at room temperature. Nuts kept at low temperature (4-13°C) lose viability after 5 days. These may be shipped without moist packing, but should be sown immediately upon arrival at their destination (Wester 1924). Percentage germination decreases rapidly as the duration of storage at room temperature increases (Dalisay 1961). Nuts planted immediately after harvest give 98% germination, while those sown 12 weeks later have only 19% germination. Cabrera (1932) found that pili seeds lost all viability in about 137 days.

Pili seeds have a long dormancy, which brings about a marked delay in their germination (Coronel 1966; Adriano 1977). This is mainly owing to the thick, hard shell, which impedes gas exchange and water absorption (Juliano 1937; Adriano 1977). Efforts to break seed dormancy by cracking or removing the shell have not produced encouraging results, because although these practices hasten germination, percentage germination is greatly reduced (Cabrera 1932; Adriano 1977).

Pili nuts are sown in a seedbed, using very light porous soil (Wester 1916), such as sand, or an equal mixture of sand and garden soil as media (Coronel 1966). Coir dust and sawdust may also be used as the germinating medium. The nuts are laid flat, with the broadest side facing down, at a depth of not more than 2 cm, and at a distance of about 1-2 cm between rows, and between nuts in a row. They may also be sown directly in individuals containers, thus reducing the cost of transplanting. On the average, the seeds will germinate 57 days after sowing (Operio 1979; Operio and Coronel 1980).

Seedlings are transplanted in black polyethylene bags (polybags), preferably using an equal mixture of sand, garden soil and compost (Coronel 1966). Transplanting may be done when the seedlings are at the cotyledonary-leaf stage, or when the first pair of leaves has matured (Fig. 10). The seedlings need shade for about 1 week, but later should be fully exposed to the sun. They are watered as the need arises, given a small dose of nitrogen fertilizer, preferably every 2 months, and treated against pests and diseases. Seedlings that are established during the harvest season in the Philippines in May-June may be planted in the field, during the onset of the rainy season in May-June of the following year. It is advisable to plant in the second year, when the seedlings are larger, however.

10.3 Propagation

Propagation of the pili can be accomplished using seeds / seedlings, or by asexual methods, such as marcotting, grafting and budding (Galang and Elayda 1924; Cabrera 1932; Gonzalez 1934; Galang 1955; Coronel 1966; Dacanay 1968; Lanuza 1969-70; Coronel *et al.* 1972, n.d.). Today, almost all of the pili trees in the Philippines have been grown from seeds. However, seed propagation is being discouraged for

the following reasons:

- being a dioecious species, 50% of the resulting trees would turn out to be male
- the long juvenile period of seedling trees
- the high degree of variability in many horticultural characters among seedling trees (Coronel 1994).

Marcotting, or air-layering, has been found successful (Dacanay 1968) and is the simplest propagation method for the pili (Coronel 1994). However, it is a very slow process, both in terms of the time it takes to root the branches and the number of propagules that can be produced from one tree.

Individual seedling trees respond differently to marcotting, and the success rate in rooting the branches can range from 0 to 100% (Dacanay 1968; Coronel *et al.* n.d., 1972; Tuazon 1978). The cultivar 'Katutubo', for example, responds well to marcotting, with almost 100% rooting success, at about 55 days after girdling.

The biggest problem encountered in marcotting the pili is the low survival rate of the successfully rooted branches after they have been severed from the mother tree. Misting the fresh marcots in the nursery has been found to improve their survival rate.

Cleft- or wedge-grafting is one of the two methods recommended to propagate the pili commercially (Coronel 1994). The seedling rootstocks need to be established in large black polybags (at least 25 cm x 35 cm) or directly in the field, so that they attain sufficient stem girth faster, to match the diameter of the terminal shoots to be used as scions. It is better to use previously defoliated shoots as scions. Cleft-grafting done in the cool and dry months of November to February can give a success rate as high as 85%.

Patch-budding or bud-grafting is the most efficient way to propagate the pili, and is recommended for its large-scale propagation (Coronel 1994). As in cleft-grafting, the seedling rootstocks are best established in large black polybags, or directly in the field, to induce them to attain sufficient stem girth more quickly. Frequent watering and monthly applications of a small dose of nitrogen fertilizer help condition the seedlings to grow actively. Previously defoliated budwoods are the best source of buds, and young, growing pili trees are better sources of budwood materials than old, dormant trees. This is because in young pili trees, the nodes on the shoots are far apart and the buds are more active. When performed during the cool and dry months between November and February, and with a lot of practice, patch-budding success rates can be as high as 75-80%.

10.4 Cultural practices

At present, there are not enough asexually propagated planting materials to establish pili orchards. Therefore, seedlings are still the major form of planting materials to be used in the years to come. The seeds should be obtained from trees of named varieties, or from other outstanding trees. In the field, the seedlings should be planted at least 12 m apart. Since it is expected that about 50% of the trees will turn out to be male, it is recommended that two seedlings be planted at each tree posi-

tion, 30-50 cm apart. When the trees start to flower, at which time their sex can be determined, all male trees should be cut down, leaving only a few to serve as a pollen source. A ratio of 1 male to 20-25 female trees would be adequate. In the hills, when both plants turn out to be male, one can be cut down, and the other cut back and grafted with a known variety.

Until such time that dwarfing rootstocks become available, asexually propagated planting materials (marcots, grafts and budlings) should be planted at least 8 m apart. It is also necessary to interplant male pili trees, especially when the planting is quite isolated. Either the triangular or square system may be followed in setting the pili trees in the field. In areas with well-distributed rainfall, planting may be done in any month of the year. In other locations, the best time to plant is at the onset of the rainy season. Marcots lack a primary root system, and may not be able to withstand strong winds. It is therefore recommended that 2-3 seedlings be planted around the marcot and grafted onto its main stem to form a multiple rootstock, designed to strengthen its root system.

Little is known about the cultural requirements of the pili tree. Basic knowledge about its the growth and development, however, suggests the adoption of certain practices. Marcots usually form lateral branches early and do not require training. Seedling, grafted and budded trees initially tend to grow upright, and need to be trained at an early age to induce the formation of lateral branches. This is done by pinching off the terminal bud when the tree is about 0.5-1 m tall. This should be done repeatedly on all the subsequent shoots, until the youngest set of shoots becomes reproductive, a process that may take 2-4 years. Once the pili tree starts fruiting, very little pruning is necessary.

In the Bicol region, and in other places with a well-distributed rainfall pattern, irrigating the pili tree is not necessary. Limited experience in other areas of the country suggests that the first dry season after planting is critical to the successful establishment of the pili tree, and it is therefore necessary to provide the trees with adequate water during this period. In areas with a distinct and long dry season, irrigation is also beneficial to those trees of bearing age. Although leaf abscission takes place from March to May in the Philippines, flushing and flowering also occur during this period, and these latter processes require an adequate supply of water to the trees.

The fertilizer requirements of the pili trees may be determined using the results of studies of nutrient content and uptake (Angeles 1981). These have shown that nitrogen content is high in the kernel (2.49%), leaf blade (1.16%) and pulp (1.03%). Phosphorus content is high in the kernel (0.47%), petiole (0.37%), stem (0.31%) and shell (0.24%). Potassium content is high in the pulp (2.62%), peduncle (1.74%) and stem (1.40%). Expressed as nutrient uptake (kg per tree), nitrogen uptake is high in the leaf blade (0.53 kg), fruit pulp (0.20 kg) and kernel (0.31 kg). Phosphorus uptake is high in the shell (0.24 kg). Potassium uptake is high in the leaves (0.18 kg) and fruit pulp (0.50 kg).

The nutrients that are absorbed by the leaves are returned to the soil when the leaves

fall and decompose. After harvest, the fruits are removed from the site of production and the nutrients they contain are considered lost from the soil. Thus, the total nitrogen removed annually by the fruits of a pili tree is 0.60 kg; the total amount of phosphorus lost is 0.10 kg and potassium loss is 0.74 kg. In terms of fertilizer equivalents, these would correspond to an application of 3 kg ammonium sulphate (20% N), 0.52 kg superphosphate (20% P_2O_5) and 1.23 kg muriate of potash (60 K_2O).[3]

When conducting tissue analysis to determine the nutrient requirements of pili trees, it is recommended that the 6th and 7th leaves from the tip of the shoot be collected in September-December.

The pili tree is not known to have been attacked by any serious pests and diseases, and for this reason no control measures are necessary. On average, seedling pili trees start fruiting 4-5 years after planting. Marcots are productive 2-3 years after planting, while grafted and budded trees are productive after 3-4 years. Assuming an average yield per tree of 2000 nuts per season, for 10-to-15-year-old trees this would be equivalent to 20 kg dried nuts per tree (a dried nut weighs 10 g, on average). At the present price of P20 per kg, gross income is P400 per tree.[4]

10.5 Harvest

The harvest season in the Philippines extends over a long period, from May to October, and has its peak in June-August. The fruits on a tree do not ripen at the same time, and it is best to harvest only well-ripened fruits (whose skin colour is nearly black). The present system of harvesting is a laborious process. The harvester climbs the tree and, with a wooden stick, repeatedly thrashes the fruiting branches, in the process detaching even the immature fruit and severely defoliating the tree. As mentioned earlier, there is a locally held belief (which has a scientific basis) that this 'punishment' is in fact beneficial to the tree, as it induces the tree to produce more flowers and fruits the next fruiting season. Should commercial pili orchards be established, however, ripe fruits may simply be allowed to fall to the ground for collection manually or by a machine.

10.6 Processing

The harvested pili fruits are usually placed in sacks or bags and taken to people's homes for processing. Since the fresh pulp is not edible, processing becomes an integral part of the pili industry. The first step in processing is the removal of the pulp. A de-pulping machine has not yet been developed, and two methods of separating the fleshy pulp from the nut presently exist, both of which involve softening the pulp. The first involves soaking the fruits in tap water until the pulp becomes soft. On average, it takes 24-48 hours for the pulp of all the fruit in a batch to become soft. This method is recommended when the nuts are intended for germination to produce seedlings.

The other method currently used to remove the pulp is to soak the fruits in

[3] As the studies were based on the nutrient uptake of 60-year-old pili trees, the fertilizer equivalents appear to be high.

[4] 1 US$=25.9 Philippine Pesos (UN exchange rate for August 1996).

water that has been heated to 40-50°C (Austria 1932). This method softens the pulp of all fruits within a few hours, but nuts cleaned this way have poor germination. After removal of the softened pulp, the nuts are rinsed thoroughly, to remove the slimy material adhering to the shell. All nuts that float in water are discarded at this point.

When they are to be used for germination, the clean nuts are simply air-dried. When they are to be stored as merchandise, the nuts have to be sun-dried for 2-3 days. Figure 13 shows sun-dried pili nuts being sold in a public market in Guinobatan, Albay. Studies have shown that oven-drying the pili nuts at a temperature of 30°C for 27-28 hours reduces the (harvest) moisture content from 40-50% to 3-5% (Villamor 1979). Kernels dried this way are milky white in colour, are not saturated with oil and have a pleasant flavour. Properly dried nuts will keep until the next harvest season.

The next step is kernel extraction from the shell, which is a purely manual operation at present. With the use of a 'bolo', a knife specially designed for this purpose, the worker cuts the shell crosswise, at the midsection. Great skill is required to ensure that the blade of the bolo does not cut through the kernel. An experienced worker can easily process 40 kg (2 sacks) of nuts per day. The whole kernel, with the testa still intact, is simply pulled out of the halved shell. The kernel may be eaten raw or roasted, with or without the testa. When the kernel is used for making cakes and ice cream, etc., the testa is removed with the fingers, after being soaked in warm water.

Fig. 13. Sun-dried pili nuts being sold in a public market in Guinobatan, Albay.

11 Limitations

- Although the pili was identified and described in 1883, and has been cultivated in the Philippines since ancient times, it is still a relatively new commercial crop. Importantly, little is known about its entire genetic diversity, information which is vital to the varietal improvement of the species.
- The true climatic adaptability of the pili has not been formally investigated, and there is a need to conduct multilocational trials of known pili varieties to determine the most suitable ones to grow under a specific set of climatic conditions.
- Although numerous basic studies of the botany, growth and development, varietal selection and asexual propagation of the pili have been conducted, little is known about its cultural requirements as a commercial crop. Probably for this reason, very few growers have gone into pili production.
- Processing of the pili nuts is presently carried out manually. While this system employs many people, production of the crop on a commercial scale would require at least partial mechanization of processing.
- It is known that the pili pulp and kernel contain substantial quantities of oil. However, the economic feasibility of pili nut oil processing has not been investigated, nor have the commercial uses of the shell and the seedcoat been explored.
- Although the oil of the pili nut kernel is high in unsaturated fatty acids, it also contains a substantial amount of saturated fatty acids. Given the high level of health consciousness in many countries today, it needs to be determined whether these acids are of the medium-chain type, which are not harmful to human health, if the pili nut is to be successfully promoted in foreign markets.

12 Prospects

The pili has a bright future as a commercial crop, for a number of reasons:

- Superior varieties are available for cultivation, which are early bearing, prolific, responsive to asexual propagation, free from damage by pests and diseases, and responsive to low production inputs.
- Pili nuts keep well, and the trees can therefore be cultivated in remote rural areas without any fear that the fruits will spoil if they are not marketed immediately. If properly dried and stored, the pili nuts can be kept until the next harvest season, thus ensuring a regular supply of raw materials for processing during the non-harvest months. This is advantageous to pili nut growers, whose produce would fetch higher prices during this period.
- The pili nut pulp and kernel are extremely nutritious, forming good-to-excellent sources of minerals, vegetable fats and proteins.
- The pili nut kernel can be used in the preparation of many food products, and is also the source of an edible oil of excellent quality.
- There is an unmet local demand for the pili nut, which is popular with Filipinos; there is also a ready export market, should enough of the crop become available. Furthermore, the commercial utilization of all the by-products of the pili fruit would further increase the income derived from pili nut production.

The following initiatives are being proposed to encourage pili production:

- Government-established demonstration orchards in strategic locations in the Bicol region and other locations with similar climatic conditions, to show farmers the available production technologies.
- Regular seminars on pili production for interested farmers, organized by the government.
- Availability to farmers of reasonably priced, high-quality propagating materials.
- Regular visits to the farmers' orchards by extension personnel, to provide technical assistance.
- Government assistance to pili farmers in marketing their produce.

13 Institutions involved in pili research and development

Much of the present knowledge about the pili has been generated from research conducted by the various units of the University of the Philippines at Los Baños, particularly the Department of Horticulture and the Institute of Plant Breeding. Information provided by the Department of Horticulture was generated through the completion of undergraduate and graduate theses, some of which were undertaken under the supervision of the author (Tuazon 1978; Linsangan *et al.* 1979; Operio 1979; Villamor 1979; Angeles 1981; Javier 1983). The Institute of Plant Breeding, on the other hand, has been collecting pili germplasm since 1976 (Coronel 1980b), has registered three pili varieties with the National Seed Industry Council (PSB 1993), and has developed rapid asexual propagation methods for the pili (Coronel *et al.* n.d.).

The Crops Research Division of the Philippine Council for Agriculture, Forestry and Resources Research and Development (PCARRD) is coordinating two collaborative projects involving the pili. The first is concerned with the identification of outstanding pili trees, and the second with the mass production of pili planting materials. The PCARRD has made the pili a research and development priority in the Bicol region, and the Department of Science and Technology, the Department of Environment and National Resources, the Department of Agriculture, the College of Agriculture and Forestry of the Bicol University at Guinobatan, Albay, and the Camarines Sur State Agricultural College in Pili, Camarines Sur are working together to upgrade the pili industry.

The Demontaño Foundation, Inc., a non-governmental organization, has recently been established to disseminate information on the pili and planting materials (Arribas 1994). The names and addresses of persons involved in research and development of the pili in the Philippines are given in Appendix II.

14 Research and development needs

- Collecting, characterization / evaluation, propagation and conservation of pili germplasm, and selection of superior trees, should be pursued with greater vigour, and emphasis should be placed not only on the identification of superior scion varieties, but also on the selection of desirable rootstock varieties. Research should be extended to include wild relatives of the pili, to determine their suitability as parents in varietal improvement and as rootstocks in asexual propagation of the pili.
- Research and development should also concentrate on training farmers and field technicians on rapid asexual propagation methods for the pili. At present, one of the obstacles to promoting the commercial planting of the pili is the lack of asexually propagated planting materials. At the University of the Philippines, in Los Baños, it has been shown that the pili could be propagated by cleft-grafting and patch-budding. However, very few plant propagators have mastered these techniques[5], and more training on this subject is required.
- Basic research on the micropropagation of the pili, using the *in vitro* technique, should be initiated as an alternative to macropropagation, or to supplement it. Studies on appropriate culture media should be started.
- Multilocational trials of the registered pili varieties should be conducted urgently, to discover the soil and climatic ranges of the pili and to determine the best varieties for a particular set of soil and climatic conditions.[6]
- Experimental orchards need to be set up so that specific studies of the cultural requirements of the pili (e.g. training, pruning, irrigation and fertilization) can be conducted. The comparative economic advantages of (i) harvesting the pili nuts, using the traditional method, versus simply collecting the fallen fruits, and (ii) manually versus mechanically extracting the kernels, can be investigated. Furthermore, as stated in the previous section, the experimental orchards could also serve to demonstrate the available commercial production technologies to farmers.
- There is a need to develop new and better processed pili products. Since the Philippines also cultivates cacao (*Theobroma cacao* L.) commercially, the development of chocolate-coated pili nuts could be considered.
- More emphasis should be given to improved packaging that meets international standards.

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5 In July 1988, four agricultural technicians from the Department of Agriculture in the Bicol region underwent a 5-day training course in pili propagation, at the Institute of Plant Breeding of the University of the Philippines, Los Baños.

6 In October 1995, the Fruit and Plantation Crop Varietal Improvement Committee, of which the author was the chairperson, recommended to the National Seed Industry Council that such multilocational variety trials be conducted by the Department of Agriculture in the Bicol and Southern Mindanao regions.

15 Summary

1. The pili nut (*Canarium ovatum* Engl.) is endemic in the Philippines, with the Bicol region as its centre of genetic diversity. The species has been confined to this region for quite a long time, and has not been introduced to many other countries.
2. There are about 75 known *Canarium* species, nine of which are found in the Philippines. At least four species are of economic importance: *C. ovatum, C. indicum, C. album* and *C. luzonicum*.
3. The production areas of the pili are likewise concentrated in the Bicol region. Production is mainly from unselected seedling trees.
4. The pili grows well over a wide range of soil conditions, including very acid soils, from sea level up to medium elevations. The species is adapted to areas with well-distributed rainfall, as well as those with distinct wet and dry seasons. It is a typhoon-resistant species.
5. The pili is a dioecious, deciduous, medium-sized to large tree. The leaves are imparipinnate, spirally arranged and about 40 cm long. The cymose inflorescences are axillary on young shoots. The fruit is a drupe, ovoid to ellipsoid, 4-7 cm long and 2-4 cm in diameter. It has a thin, black exocarp (skin), a fibrous, fleshy mesocarp (pulp) and a hard, thick endocarp (shell). The seed has a brown papery seed coat and an embryo with two large white cotyledons.
6. Anthesis of male and female flowers, anther dehiscence and stigma receptivity take place in the late afternoon. The emission of a fragrant odour suggests that the flowers are insect-pollinated. Fruit set is high (about 88%). From pollination, the fruits take about 12 months to ripen. The pili nuts are dispersed by hornbills, monkeys, wild pigs and deer. Humans gather the pili nuts for food, and therefore effectively reduce the natural stands of pili trees.
7. The pili is a very variable species. Seedling trees differ in many important botanical and horticultural characters, and the species therefore possesses considerable genetic diversity.
8. The National Plant Genetic Resources Laboratory of the Institute of Plant Breeding at the University of the Philippines, Los Baños has collected and evaluated fruits of about 260 pili accessions, 180 of which were from the Bicol region. Some accessions were planted in Los Baños, but many are being maintained in the areas of collection. The Department of Agriculture and the Bicol University College of Agriculture and Forestry are also involved in the collecting and evaluation of pili germplasm.
9. Although natural calamities (e.g. typhoons and volcanic eruptions) could have contributed to the erosion of the pili genepool, the greatest threat to the species today is humankind. Humans gather pili nuts for food (including those naturally dispersed by animals), seldom replanting the seeds, and fell the trees for building purposes and for fuelwood.
10. Varietal improvement of the pili is mainly done by selection of superior trees from existing seedling populations. Varietal selection standards have been es-

tablished for the pili, and three varieties have so far been registered with the National Seed Industry Council.

11. The pili seed takes an average of 57 days to germinate. About 70 days after sowing, the seedling has a pair of mature leaves. It initially grows slowly, after transplanting from the seedbed, but its growth rate soon accelerates rapidly. After 3-4 entire leaves have emerged, leaves with 3 leaflets follow. In the mature tree, the leaves have 5, 7 or 9 leaflets. On average, seedling trees start fruiting 5-6 years after seed germination. Pili trees may live to more than 100 years.
12. The pili can be propagated using seeds, or by asexual methods such as marcotting, grafting and budding. Almost all the pili trees that exist today have been grown from seeds. Seed propagation is not recommended, because half of the resulting trees would be male, and the female trees are highly variable in many horticultural characters and take much longer to fruit.
13. Marcotting may be used for small-scale propagation of the pili. Cleft-grafting and patch-budding are recommended for large-scale propagation.
14. Sexually propagated planting materials should be planted in the field, at least 12 m apart. A total of two seedlings should be set in a hole, and all male trees should be cut down as soon as their sex can be determined, leaving only one male tree for every 20-25 female trees. Vegetatively propagated trees should be spaced at least 8 m apart.
15. Little is known about the cultural requirements of the pili. However, basic knowledge of the growth and development of the pili plant may suggest certain practices (i.e. training and pruning, irrigation and fertilization). Pest control measures are not necessary because the pili tree and its parts are not known to be attacked by any serious pests or diseases.
16. Seedling trees start fruiting 4-5 years after planting. Asexually propagated trees are productive 2-4 years after planting. A 10-to-15-year-old tree that produces 2000 fruits per season would yield about 20 kg dried nuts. The peak harvesting period is June-August. Harvesting is traditionally done by repeatedly thrashing the fruiting shoots, thereby detaching even the immature fruits and severely defoliating the tree.
17. Processing of the pili fruits begins with removal of the pulp by soaking the fruits in water. The clean nuts are sun-dried for 2-3 days, and the kernel is extracted by cutting the shell with a 'bolo' knife. The testa is removed by soaking the kernel in warm water.
18. The pili tree is excellent for landscaping, as a windbreak, and for agroforestation. The young shoot is edible and the resin-rich wood makes excellent firewood. The green pulp can be made into pickle, while the ripe pulp is edible after boiling. It also contains an oil that may be used for lighting, cooking and in the manufacture of soap and other industrial products. The shell makes an excellent cooking fuel and can be made into attractive ornaments. The kernel is edible raw, roasted, fried or sugar-coated, and is also used in making cakes, puddings

and ice cream. It is rich in oil, which is suitable for culinary use.

19. The pili pulp contains 8% protein, 37% fats, 46% carbohydrates, 3% crude fibre and 9% ash. The pulp oil contains 57% oleic glycerides, 14% linoleic glycerides and 29% saturated fats. The kernel contains 12-16% protein, 69-77% fats and 3-4% carbohydrates. It is also rich in minerals, but poor in vitamins. The kernel oil has 60% oleic glycerides and 38% palmitic glycerides.
20. The pili has a bright future as a commercial crop. Superior varieties, rapid asexual propagation methods and workable production technologies are available to prospective growers. The nuts keep well, and can be stored for several months. The pulp and kernel are highly nutritious, and can be used in the preparation of many food products, including edible oil.
21. Limitations to the pili include scarce knowledge of the true range of its genetic variability, its range of climatic adpatability, its cultural requirements as an orchard crop, mechanized nut processing, and commercial oil production from the pulp and kernel. The pili nut kernel's high oil content may prove to be a hindrance to its success in international markets.
22. The University of the Philippines at Los Baños, notably its Institute of Plant Breeding and Department of Horticulture, has been very active in pili research and development. Some government agencies in the Bicol region (e.g. the Department of Agriculture, Camarines Sur State Agriculture College, Bicol University) are also involved in pili research and development. One non-goverment organization (Demontaño Foundation, Inc.) is promoting the cultivation of the pili.
23. The research and development needs of the pili include: collecting and conservation of pili germplasm and selection of elite trees; training of technicians on rapid asexual propagation methods; micropropagation; multilocational trials of registered varieties; the establishment of experimental and demonstration orchards, and studies of different cultural requirements and processing techniques.

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Appendix I. *Canarium* species and their geographic distribution.

Species	Distribution	References*
C. acutifolium (DC.) Merr.	Moluccas, New Guinea, Central Celebes	11, 13
C. album (Lour.) Raeusch.	Annam, Tonkin, S. China, Hainan	1, 13, 16, 18
C. apertum H.J. Lam	Sumatra, Malay Peninsula, Borneo	11, 13
C. asperum Benth. subsp. *asperum* subsp. *papuanum* (H.J. Lam) Leenh.	Solomon Is., Bawean and Kangean Is., Lesser Sunda Is., Borneo, Philippines, Celebes, Moluccas, New Guinea	11, 13
C. australianum F.v.M	N. Australia, SE New Guinea	1, 11, 13
C. baileyanum Leenh.	Queensland, NS Wales	13
C. balansae Engl.	Loyalty Is.	1, 13
C. balsamiferum Willd.	Celebes, Moluccas, New Guinea	1, 11, 13, 15
C. luzonicum (Bl.) A. Gray	Philippines	5, 11, 13
C. macadamii Leenh.	New Guinea	11, 12, 13
C. madagascariense Engl. subsp. *madagascariense* subsp. *obtusifolium* (S.Elliot) Leenh.	Madagascar, Tanganyika, Mozambique	1, 13
C. maluense Laut. subsp. maluense subsp. *borneense* Leenh.	Central Celebes, Moluccas, New Guinea	6, 11, 13
C. manii King	Middle and S. Andaman	11, 13
C. megacarpum Leenh.	W. New Guinea	11, 12, 13
C. megalanthum Merr.	Sumatra, Malay Peninsula, Borneo	8, 11, 13
C. merrillii H. J. Lam	Borneo	8, 11, 13
C. muelleri F.M. Bailey	Australia (Queensland)	11, 13, 14
C. odontophyllum Miq.	Sumatra, Borneo, Philippines	1, 11, 13
C. oleiferum Baill.	New Caledonia	1, 11, 13
C. oleosum (Lamk) Engl.	New Britain, Lesser Sunda Is., N. Celebes, Moluccas, New Guinea	11, 13
C. ovatum Engl.	Philippines	1, 5, 11, 13, 16, 17
C. paniculatum (Lamk) Benth. ex Engl.	Mauritius	13
C. parvum Leenh.	Tonkin, N. Annam	13, 14
C. patentinervium Miq.	Sumatra, Malay Peninsula, Banka, Anambas Is., Borneo	11, 13, 15, 18
C. perlisanum Leenh.	Malay Peninsula	10, 11, 13
C. piloso-sylvestre Leenh.	W. New Guinea	11, 13
C. pilosum Benn. subsp. *pilosum* subsp. *borneensis* Leenh.	Sumatra, Malay Peninsula, Borneo	11, 13
C. pimela Leenh.	S. China, Hainan, Tonkin, Laos, Annam, Cambodia	13
C. polyphyllum K. Sch.	New Guinea	2, 11, 13, 16
C. pseudodecumanum Hochr.	Sumatra, Malay Peninsula, Borneo	3, 11, 13, 15
C. pseudopatentinervium H.J. Lam	S. Sumatra, Banka, Borneo	9, 11, 13

C. pseudosumatranum Leenh.	Malay Peninsula	11, 12, 13
C. rigidum (Bl.) Zipp. ex Miq.	New Guinea	1, 11, 13
C. salomonense B.L. Burtt subsp. *salomonense* subsp. *papuanum*	Solomon Is., E. New Guinea	9, 11, 13, 19
C. samoense Engl.	Samoa	1, 11, 13
C. schlecteri Laut.	New Britain, E. New Guinea	6, 11, 13, 20
C. schweinfurthii Engl.	Trop. W and Central Africa	1, 11, 13
C. smithii Leenh.	Fiji	12, 13
C. strictum Roxb.	SW Deccan, Sikkim, Assam, Upper Burma	1, 13, 16
C. subulatum Guill.	S. China, Hainan, Tonkin, Laos, Annam, Cambodia	4, 13
C. sumatranum Boerl. and Koord.	Sumatra, Malay Peninsula	4, 11, 13
C. sylvestre Gaertn.	Moluccas, New Guinea	1, 11, 13
C. trifoliatum Engl.	New Caledonia	1, 13
C. trigonum H.J. Lam	Central Celebes	7, 11, 13
C. vanikoroense Leenh.	New Hebrides, Fiji	12, 13
C. vitiense A. Gray	Fiji	1, 13, 19
C. vrieseanum Engl.	Philippines, Central and N. Celebes	1, 11, 13, 15, 18
C. vulgare Leenh.	Kangean and Bawean Is., Lesser Sunda Is., Celebes, Moluccas	11, 12, 13, 15
C. whitei Guill.	New Caledonia	8, 13
C. zeylanicum (Retz.) Bl.	Sri Lanka	1, 13, 15

*: 1 - Hooker and Jackson (1892); 2 - Durand and Jackson (1901-1906); 3 - Prain (1908); 4 - Prain (1913); 5 - Merrill (1923); 6 - Hill (1926); 7 - Hill (1929); 8 - Hill (1933); 9 - Hill (1938); 10 - Salisbury (1947); 11 - Leenhouts (1956); 12 - Taylor (1958); 13 - Leenhouts (1959); 14 - Taylor (1965); 15 - Danimihardja and Notodihardjo (1978); 16 - Martin *et al.* (1987); 17 - Coronel (1991); 18 - Verheij and Coronel (1991); 19 - Bourke (1994); 20 - French (1994).

Appendix II. Personnel working on research and development of the pili in the Philippines.

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