The Swamp-Sago Industry in West Malaysia

ISEAS INSTITUTE OF SOUTHEAST ASIAN STUDIES

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a study of the Sungei Batu Pahat Floodplain

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TAN Koonlin, PhD
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Introduction

THE PEDIGREE, ECOLOGY AND BIOLOGY OF THE SAGOPALM

Historical Role

Palms constitute one of the oldest family of plants on earth, with ancestors that appear to have been the precursors of the monocotyledons. Partial to warmer climes, they are most numerous in the intertropical zones. The few species that linger in temperate latitudes mark the borders of an extensive realm that had flourished in warmer epochs. Their domain lies in Asia, particularly Malaya, while parts of Amazonia possibly shelter another nucleus. More than any other, the palm heartland has survived virtually intact since the Cretaceous era, for it occupies that part of the earth least subjected to global climatic changes - the equatorial belt.

Until the ascendancy of the Graminae family, to which the cereals belong, palms probably were the most bounteous, reliable sources of food to man and beast. Described as the "Princes" of the Vegetable Kingdom (Seeman 1856), their usefulness in lands where they were endemic was noted before cereals became geographically invasive and dietetically dominant. These perennials, when cropped, yield a bounty in shelter, food and drink that has given rise to subsistence strategies which differ markedly from those based on the better-known annuals, i.e. the cereals and tubers. Some yielded important commodities in colonial commerce, especially the oleaginous palms.

Several cultures have developed a largely selfsufficient domestic economy centred round palm arboriculture, e.g. swamp Amerindians of the Amazon-Orinoco on the moriche, _Mauritia flexuosa_, the Arabs of sub-Sahara on the datepalm, _Phoenix_

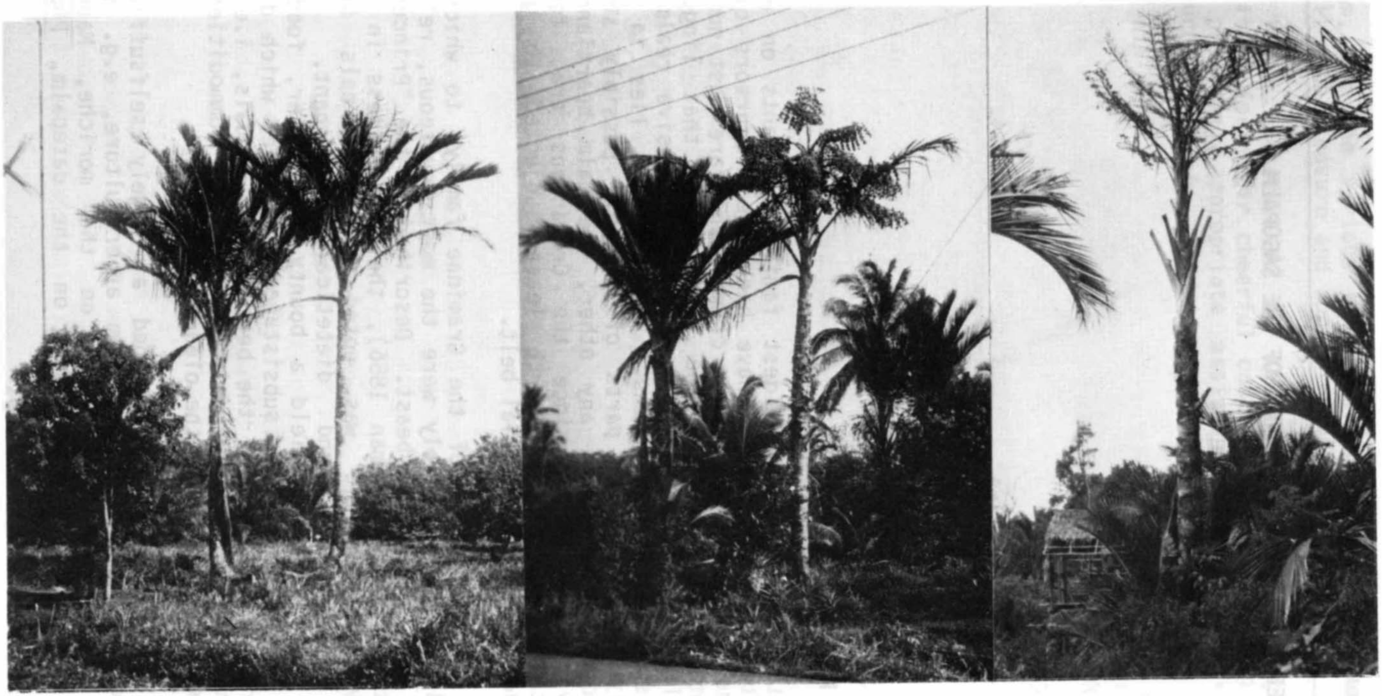

PLATE A

The Sagopalm: Florescent, Fructescent, Senescent

dactylifera, the South Indians on the palmyra, Borassus flabellifer, the noneating Roti Islanders of Indonesia on the lontar, B. sundaicus (Fox 1977), the Indo-Pacific islanders on the coconut, Cocos nucifera, the West Africans on the oilpalm, Elaeis guineensis, and the Papuans and Moluccans on the sagopalm, Metroxylon sagu Rottboll, and its wild kin, M. rumphii Martius.

The sagopalm (Plate A) is a Malesian domesticate originating from Maluku-New Guinea; wild species proliferate on islands further east into the Melanesian foreland (Corner 1966). Several other starch palms favouring drier or hillier habitats, notably species of Arenga, Borassus, Caryota, Corypha and Eugeissona, were used in like manner but, culturally and commercially, they pale in productiveness, extent, significance and sophistication beside the swamp palm. Its selfsustaining ecosystem and ability to manufacture an enormous silo of starch in its stem nurtured planters and gatherers more efficiently, in terms of crop productivity and population capacity, than the environments inhabited by contemporaneous jungle hunter-foragers, swidden and rootcrop cultivators (notably Dioscorea and Colocasia spp), and other arboriculturalists (pandan, Pandanus spp; breadfruit, Artocarpus spp; and banana, Musa spp).

Over the centuries, the inexorable shift from vegetative cropping towards seed planting eastwards in Southeast Asia has left conspicuous vestiges only among the easternmost practitioners (Spencer 1966). But while the ubi (Malay = yam) complexes could be delineated, the sago remains hazy. Pre-Columbian Melaka and the earlier northern East Coast cultures of the Malay Peninsula were flourishing emporia sustained by the produce of swamp or river sago. Colonised by the northwesterly wet-rice culture - whose technology is derived largely from mainland civilisations yet manifests some peculiarly vegetative techniques of cultivation - scions of the truly native sago culture sheltered in the marginal, remote lowlands of the farflung archipelago. By early this century it had become extinct in many peripheral islands, such as Fiji and the New Hebrides. With the expansion of the more prestigious cereal culture in the early 19th century, sago acquired disrepute as food for the poor even in parts of its stronghold.

"Sago is most abundant in the islands most distinguished for the production of clove and nutmeg and the geographical distribution seems co-extensive with that of these palms" (Crawfurd 1820). Few modern studies on forest resources consider the Metroxylon palm as such, or that logging the humid forest for a staple food or locally processed industrial commodity could be even more substantial than lumbering and the collection of famous palm products such as gums and rattans, that had only incidental or fractional value for its inhabitants. Because of the importance of sago in the export economy, especially in Sarawak during its first 50 years of European rule, the north Borneo sultanates were obliged to relinquish much of their territories to British ambitions in the region.

In its cultural ecology, the sagopalm resembles the wild oilpalm in Africa more than 70 years earlier. The semiwild African palmeries were also gathered to supply a cheap vegetable oil to Europe, giving rise to the most outstanding gathered-crop export economy ever to flourish in West Africa until plantations were established. Large areas of otherwise inhospitable coast in the Malay Archipelago became habitable because of the sagopalm. Some areas were productive enough to trade in a grain made from its flour, landang, the only notable food of vegetable origin in the precolonial commerce of the Orient. The Sulu traders supplied "sago of the best kind" from a territory that stretched from northeast Borneo to Mindanao (Moor 1837).

The sago complex manifests an impressive spectrum of technical skills required to fell large trees and mill their pithy stems for a staple food that belies its image of cultural primitiveness. Sago is the meal within the stem which either is pounded and sifted or is leached via kneading or trampling to yield the starch which is made into flour, pearl, biscuit and bread; these may be nutritively enhanced via a preparatory fermentation or fortified with meat, rice bran, nuts, coconut, etc. Toasted bread, roti papua or sagu maruku, and other dry products keep for years. These once victualled ships of the region, were even fed to the Papuan slave cargo, antedating the similar role of the tapioca in the Negro trade of the New World. So intrigued was Wallace (1898) by the sago food technology in the easterly Indonesian islands, that he digressed from his epic zoological pursuits there to describe in curious detail the art of sago breadmaking in east Seram in 1860. The starchy diet is enriched with other swamp resources, e.g. fish, crustacea and wild pig, and maggoty palms provide a living larder of fat when slashed to encourage a weevil to lay in rotting pith, the "microcow" of this aboriginal diet (Stanton 1972). Sugar and wine come from the nipa, thriving in more brackish fringes.

Sago is still the staple of many pre-Malay populations in the huge eastern swamps of the region. Mindanao, Maluku, Sulawesi, Borneo and Sumatra contain dwindling numbers of sago eaters; Borneo was long famed for its sago, hence its native appellation, "Pulau Kalimantan" or "island of raw sago". Basically an efficient food acquisition system, the sago diet has been found to be superior to the cereal on occasions. In New Guinea "population density ... per square mile of 100 to 250 is largely due to a great reliance on sago and/or fishing for subsistence. In the hills and mountains there is a more general tendency for high population densities to be associated with intensive use of land for cultivation; nevertheless, even here ... (they) are partly sustained by ... sago" (Haantjens et al. 1972); the tribal lands in the Maprik area exceeding 400 persons per sq mile are the most densely settled in lowland New Guinea (Haantjens et al. 1968).

Ecology

The sagopalm occupies a habitat close to but distinct from that of the coconut:

> "In most parts of the Indian Archipelago two kinds of alluvial soil are found in greater or less abundance, one consisting chiefly of sand often thrown up in long banks, and the other chiefly of decomposed vegetable matter.... For these two descriptions of soil, nature has provided two kinds of palm adapted in a wonderful manner to the necessities of man. On the barren sand she has planted the coconut, and in the morass the sago tree.... Low marshy situations shut out, but at no great distance from the sea, and well watered by fresh-water seem most productive" (Logan 1849).

In the ASEAN region extensive tracts of freshwater swamp dominate the eastern coast of Sumatra, the north and south coasts of Borneo, and the larger alluvial basins of New Guinea (Plate B), with smaller swamps spotting the coastal fringe of many islands of the archipelago; in favoured sites their exceptional denizen is the sagopalm. Europeans who coasted by this environment frequently found it unprepossessing, even hostile: "The sago and mangrove swamp areas are inimical to human life ... furnished with conditions which to European life would be most inhospitable, if not almost altogether insufferable ... unfit for habitation ... [with] a tendency to depress the pioneering enterpriser and to retard settlement" (Thomson 1892).

For all its pestilent air, this unique equatorial habitat, "dry land ... in the wettest sense ... The Land Behind the Sea", has had indispensable value to its inhabitants since prehistorical times. "The flora of the wetlands, the swamp, is far more important in almost every way than that of the hillside undergrowth of the rain forest.... As a source of produce requiring no kind of care, the swamp is a mud-mine of lasting merit" (Harrisson 1970); also "with the rivers and the easy productiveness of the sago palm an alternative of large, concentrated communities was added" (Maher 1961). Thus, the

PLATE B
A Characteristic Floodplain Habitat

Alluvial floodplain of the lower Ramu River, Northeast Territory of New Guinea, about 45 miles from the estuary, is characterised by scrolls, levees, oxbows and backplains; it forms a contiguous swampforest with the Sepik further west. A mosaic of forest, sagopalm and herbaceous swamplands, in various stages of silting up in the cutoff meanders, reflects the influence of the seasonal flood cycle. Sagopalms are abundant as the understorey in swamp woodland, grading to the climax vegetation in the waterlogged sites. This region in general has low agricultural potential without water control. (Illustration courtesy of Dr K. Paijmans-CSIRO, Canberra)

coastal lowlands, up to 2,500 ft in the islands west of Sumatra eastwards to Fiji at least, frequently harboured sedentary, ostensibly nonagricultural people who developed a food technology for the sagopalm that paralleled in essence and sophistication that of the Amerindians who domesticated for their staple food a poisonous tuber, the tapioca (manioc, cassava), Manihot esculenta.

The sagopalm grows by riparian banks, "all the way down to the mouth of the river" (Oosterwal 1961), on lake margins, in "creeks and gullies" (Thomson 1892), "inland forests" (Dilmy 1971), and "damp cuts in the hillsides" (Burridge 1969), "where it seems to thrive equally well as when exposed to the influx of salt or brackish water kept constantly full of moisture by the rains, and by the abundance of rills which trickle down among them" (Wallace 1898). This early perception on its salt tolerance in the Seram swamps has been affirmed experimentally (Flach et al. 1977). The sagopalm's ecology recalls that of the wild oilpalm in its own hearth where it naturalised also near saline sites (Zeven 1965; Adejuwon 1970).

A good sago plantation or forest is "a bog knee-deep" (Crawfurd 1820), in "low marshy situations shut out, but at no great distance from the sea, and well watered by freshwater seem most productive" (Logan 1849). The sagopalm thrives within the environment characterised by silt depositions and a flowing and ebbing water-table which aerates and stimulates the root systems of swamp vegetation. Even where fastidiously cultivated, manuring is nowhere practised, and would be superfluous within this Nile-like environment, which succinctly illustrates the dictum: "Feed the soil life and it will feed the crops" (Vail 1979).

Systematic land use studies in New Guinea (CSIRO) reveal a characteristic sequence of sagopalm adaptation: Extensive mixing of fresh and brackish waters in a floodplain creates a fairly uniform type of swamp in which sago initially occurs as small scattered circular groves in clearings beneath a forest canopy 70-140 ft high, grading in the wetter sites to a dominant understorey at a height of 40-50 ft, with fronds up to 30 ft long, and the occasional emergence of a flowering spike up to 65 ft (Plate C). Where the drainage is impeded, the tree canopy becomes more open or lower. Progressively, sago forms the climax vegetation complex with virtually no undergrowth, the only ground cover consisting of its abundant pneumatophores, which project above the regular water table.

However, wild palmeries are too poor for commercial exploitation. A natural palmery becomes useful only "where it is accessible and vigorous enough to come into flower ... probably the sagopalms growing under forest conditions are usually not vigorous enough to warrant exploitation. Sago production ... could be considerably increased by the clearing of forest trees, planting, and proper spacing of good-quality sago palms" (Haantjens et al. 1968, 1972). Edaphic and hydrological conditions may also influence the density of palms that flower. In swamps that are liable to seasonal drought, severe brackish inundation or are deficient in nutrition or aeration, such as waterlogged soils, the palms form a dense cover but few will grow

PLATE C

Sago Swampforest Complex

Alluvial plain in Gulf District (south Papua) subject to wet-season flooding: imperfectly to poorly drained land with mid-height (70-100 ft), moderately closed mixed forest interspersed with sago in swampy patches. Some sagopalms are in various reproductive stages, particularly evident in right foreground. (Illustration courtesy of Dr K. Paijmans-CSIRO, Canberra) to more than 20 ft or flower; instead they vegetate into vigorous stoloniferous clumps.

The freshwater swamp is one of the most underrated daerah minus ("deprived region": Fox 1977) in the archipelago; "the popular conception ... is of vast sago swamps which offer no opportunities for economic development" (Ryan 1972). Yet where there are pure stands of non-timber resources such as the sagopalm, the swampforest has a value equal to the lowland rainforest (Whitmore 1975). "The huge Metroxylon forests of New Guinea represent enormous potential resources in starch for export and industrial uses and deserve new research.... The living conditions of the swamp forest peoples ... could be improved by an industrialisation and marketing of sago ... as a source of revenue in these poverty-stricken areas" (Barrau 1959).

Logan (1849) made this remarkable assessment of the sagoswamps of insular Southeast Asia: "the Archipelago can furnish any required amount of meal". Hijandi et al. (Stanton and Flach 1980) estimated that there are about a million ha of exploitable sagopalms in Maluku and Irian Jaya; there may even be 1.5 million ha in Irian Jaya alone (Sinar Harapan 1979). Of unknown quality is another substantial reserve in Sumatra which still has commercial production in Riau. The Indonesian Minister of Research & Technology made "an appeal to all sago producing provinces in the country not to damage sagopalm trees or plantations but instead to increase the number" (The Indonesia Times 1979), in recognition of the value of the sagoswamp as a supplementary granary for the country. In 1979, Indonesia had to subsidise the import of 1.5 million tonnes of rice, even more in other years. Papua New Guinea has over a million ha, of which 300,000 ha are accessible and harvestable (Newcombe et al. 1980); Essai (1961) singled out the swamp 2,400 sq mile in extent between the Huntschein Range and the Sepik estuary as a potential sago centre.

Palm Biology

The Metroxylon spp encompass the more robust members of the Lepidocaryoideae (scaly-fruited) subfamily, characterised (except for one species in Micronesia) by hapaxanthy,[1] a predilection for particularly humid homes, and a prominent relict trait of palm ancestry, spinosity, manifest in a spiny lower stem, spiny spathes and combs of spines along the frond base in the wild sago. The lepidocaryoid palm is also marked by its loricate fruit, covered with imbricating scales; Barrau (1959) distinguished between the fruits of 18 vertical series of scales in the New Guinea centre and of 24-28 further east.

Taxonomic studies of the genus are still inadequate and there is no comprehensive identification of all members yet; about seven species are recognised. In the 19th century confusion dogged the taxonomy of even the cultivated species, a problem that commonly bedevilled the study of the species-rich tropics. The sagopalm bore other generic and specific names, such as Sagus laevis. The consensus is that M. sagu is probably not a distinct species, but an antithetic phenotype or hybrid of its wild kin, because both species cross readily, giving rise to polymorphic seedlings ranging between the two extreme forms. A proportion of spinous or berduri progeny is liable to result even from nonspinous crosses.

Open to question is the degree of "wildness" of the westerly palms, although improvement of the two useful species under aboriginal agronomy for several millennia has been entirely empirical. The selection of smooth forms to provide building materials would have promoted the evolution of M. sagu even in areas where it was not a foodcrop. Precolonial intraisland settlement and trade facilitated the westward dispersal of the species, e.g. by Malay traders returning to their homeland in Sumatra, where the smooth palm was to flourish in an environment in which the pig was suppressed under Arab-Indian influence, even while the wild palm, with its fearsome armature to promote its survival in cultures in which this pest was prized as food, continued to flourish in its hearth. The modified Wallace Line (west instead of east of Sulawesi) more or less bifurcates the distribution of the two species. The persistent, remnant concentration in this part of the Pacific Ocean of this insular genus of palms with their uncharacteristic flowering propensity has beguiling Atlantean overtones (Whitmore 1973).

In Sumatra, Malaya and Sulawesi the palm is better known as rumbia, and further east as labia, or their cognates. Largely on the basis of the spinous variations, numerous vernacular names arose throughout its geographical span, distinct from those used for other starch palms, which is regarded as evidence of its antiquity as a foodcrop in the region (Crawfurd 1820). The sagopalm is considered to be intrinsically wild in its genetic constitution because no scientific breeding has ever been undertaken. Dwarfer varieties were developed as a more manageable crop by tribes where, because of taboos against male participation, women had to fell the palm; but generally varietal evolution has been towards massive forms that are more productive and incidentally require a longer period of growth, a factor of no consequence under aboriginal economics of production but critical for plantation exploitation.

The sagopalm shares the rooting characteristics of most palms. The dense adventitious root system enables the palm to tap the fertility in the alluvium; like the oilpalm it has breathing roots, pneumatophores, which also function as silt traps. Below the frond bases root tips are visible, and a fine lacy mat of growths envelop the stem, coursing upwards; perhaps this is a supplementary feeding system which imbibes the humidity of the air and supports its survival as a hygrophyte particularly where groundwater is brackish or insufficient.

The sagopalm is polycarpic, viz. it produces, even neotenously, stolons that spring from axillary buds from the base to the lower stem. Some authors state that it suckers only after flowering or fruiting. Regeneration "by radical shoots, exactly in the same manner as the common cultivated plantains, is peculiar and is not observed in the true palms" (Logan 1849). Thus vegetative propagation is commonly practised under cultivation although the palm seeds itself. Sago planters eschew seeding also because seedlings are variable, and palms left to fruit tend to be runts that had been rejected for their food worth, hence undesirable parent material. The habit facilitates perpetual cloning and leads to the concentration of particular varieties in a specific area, giving rise to fairly homotypic groves. Where feral, it vegetates into dense clumps like bamboos; as a weed or squatter, it is most at home on abandoned riceland, since the cereal occupies a similar habitat or has usurped its natural niche.

Being monocotyledonous, i.e. without cambial growth, the stem's girth and potential for growth are predetermined during infancy in its apical meristem, which caps the "heart" or "cabbage" of the palm; the stem elongates only when its full diameter is reached, so that environmental influences during its early years are critical to its future productiveness. "The width of the trunk expresses the welfare of the palm apex" (Corner 1966); any subsequent thickening is due to the expansion of the parenchyma cells and vascular bundles in the pith in response to improved conditions of growth, especially sunlight. The sagopalm is heliophilous, for insolation seems to have a marked effect on its growth, and leaf formation influences starch accumulation during immaturity (Flach 1980). The first palms of a new planting have uniform girth of stem, whereas "succeeding palms mostly show a clear increase in girth at the top of the trunk" (Flach 1977); they are also taller (Morris 1953). About two pinnate-leaved fronds are produced a month, borne in a one-third phyllotaxis, a spiral foliage sequence where the fourth frond is emplaced above the first, etc. that is characteristic of the species.

Economic value of palm florescence

Palms have a relatively long vegetative phase of infantile growth to form the stem and store the food reserves for reproduction. In the hapaxanthic palms, where immaturity may endure for 20 years in the sagopalm and over 40 in the Corypha, this immense store of nourishment is mobilised and exhausted in a single fatal outburst, aptly described as "the capitalistic nature of plants" (Corner 1966). It is not known what factors cause the palm to bolt, but photoperiodism, or light duration, rather than light intensity may be the decisive influence. The hapaxanthic trait, comparatively rare in palms, may spring from a terminal axillary bud rather than the meristem itself (Corner 1966; this appears to be illustrated by Tupamahu 1909).

Flowering is protandrous, i.e. the pollen is shed before the stigma is receptive. The Papuans occasionally disbud the palm shortly before flowering. Aborting its development at this critical moment prevents bolting and probably prolongs starch accumulation or conserves the starch reserves, because a hapaxanthic palm left to fruit has no value as a food source. Where used for food then, the sagopalm is unable to seed itself. Some cultivars develop into cultigens probably because vegeculture depresses their ability to flower or produce fertile seed (Crawfurd 1820; Burkill 1935). Low (1848) and Burkill noted this infertility in some westerly cultivars in particular.

Although in its physiology and habitat sago hardly resembles the tapioca, it shares two outstanding features with this other hardy foodcrop. The first is "the capacity to yield a crop of sorts even under the poorest conditions ... and be left in the ground for considerable periods without serious loss and harvested whenever needed" (Coursey and Haynes 1970). Second, the useful part is produced without the operation of the sexual process and often before the plant is sexually mature, in contrast to the cereals, with its "structural engineering" contributing to its high biological efficiency.

The sagopalm's actual production of dry matter is higher than the potential productivity of rice (Flach 1977), viz. the primitive palm is already superior in biomass production to the overbred cereal. The biomass is translocated during immaturity to its immense photosynthetic machinery of foliage. When the vegetative phase peters out, there is a reverse flow towards the stem, the "mere shell" (Crawfurd 1856) which it reverts to after fruiting. The stem has considerable structural resilience and an enormous starch-storing capacity, which may be likened to the puny organs of dormancy of the aroids and tubers. Protected by a half-inch thick, water and pest resistant cortex, the sagopalm is virtually indestructible after surviving infancy, even by fire, except for weevil damage to soft crown tissue.

From the evidence on tapping pleonanthic palms (with successive axillary flowering), especially Arenga, Borassus and Caryota spp, starch content in the hapaxanthic palm is presumed to be at its peak while the inflorescence is forming but before its resources are dissipated in reproduction. The empirical intuition of indigenous cultures that exploit carbohydrate-rich palms for food and drink in insular Southeast Asia is evident in the common practice of harvesting them at the critical phase when vegetative growth gives way to the reproductive. However, the precise stage when starch accumulation is at its highest or the earliest stage when it is economical to harvest the palm is not known. The period of immaturity is as short as six years for seedling palms (Cantley 1886) and seven years for the wild, smaller palm (Forrest 1780), but most modern writers are inclined to attribute a longer immaturity to it. The general practice is to harvest between incipient emergence of the inflorescence spadix and its imminent fruiting, which coincide with two apparent peaks in starch content (Flach 1977; Wee: Tan 1977).

The general belief among planters is that the domesticated sagopalm averages 9-10 years of growth on more fertile soils before it can be felled for its starch. Maturity is judged in New Guinea at incipient to full flowering, in Sarawak from early florescence to early fructescence, and in Batu Pahat even earlier. Impending maturity is heralded by "a mealy appearance" on the frond bases, which is "the earliest of six stages in the progress of the maturity of the medullary matter" recognised by the Moluccans (Crawfurd 1820); other features are displacement of the fronds from their characteristic phyllotactic arrangement, reduced frond growth, followed by tapering of the crown. The quality of the starch may vary at the different stages of maturity.

The sagopalm probably saturates its pith with starch from the base of the stem upwards (Flach 1977), though its lowest and uppermost segments are never the starchiest; the starch at the base is presumed to be diverted for the nourishment of its progeny. Understanding the process of carbohydrate formation would aid in determining the earliest useful harvesting time before fullterm biological maturity, as the sagopalm's long immaturity is regarded as the solitary, overwhelming impediment to its extensive culture.

The sterile cultivars yield 400 kg of flour at 35-40% moisture (Barrau 1959), which is higher than most estimates, ranging from 152 kg (Forrest 1780) to 408 kg (Wallace 1898). The best of the New Guinea cultivars are said to be more massive than those found in Malaya (T. Power 1981, Angoram, pers. comm.), as are also the Sarawakian (Flach 1977); in Irian Jaya 30 tumang of wet sago (30 kg each) can be obtained per palm (Sinar Harapan 1979). A well-tended sagopalmery could annually yield 22 tonnes/ha of flour, equivalent to 35 million Calorie, with less agronomic input per unit volume and area than any other staple foodcropping system. The sagopalm was found to be at least 10 times more productive a food supplier (after considering an immaturity phase of 15 years) than wheat or potato before the temperate countries embarked on the genetic and agronomic improvement of their staple foodcrops (Logan 1849).

NOTE

1 Hapaxanthy (once-flowering) and pleonanthy (multiple florescence) are used here as by palm botanist, J. Dransfield (Tan 1977), and are not synonymous respectively with monocarpy (solitary, non-clumping) and polycarpy (clustered).