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BUILDING A COMPARATIVE STARCH REFERENCE COLLECTION FOR INDONESIA AND ITS APPLICATION TO PALAEOENVIRONMENTAL AND ARCHAEOLOGICAL RESEARCH

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ABSTRACT
Indonesia has a very long record of hominin occupation involving at least three human species. It also has a rich diversity of plants and a suite of economically important starch-rich staples that include taro (*Colocasia esculenta*), yams (*Dioscorea* spp.), bananas (*Musa* spp.) and sago palms. However very little is known about the prehistory of plant exploitation in the island archipelago. Key archaeological issues that are often discussed and debated, but remain poorly understood, include human adaptations and economic strategies used in different and changing environments, how local economies contributed to the development of plant management systems within the southeast Asian/Pacific regions, and how they might have been influenced by plant management systems initiated and developed elsewhere. Crucial to a burgeoning focus on archaeobotany in island Southeast Asia is the establishment of comparative modern reference collections for the flora of the region. This paper discusses the 'Indonesian Starch Project', the relevance of a comparative modern starch reference collection to Indonesian archaeology and the methods and procedures used in its development. The collection is broad-based and focuses on economically and ecologically importat plant groups. To date 121 families and 451genera are represented in the collection.

KEYWORDS
starch granules, Indonesia, southeast Asia, comparative reference collection

INTRODUCTION

Tom Loy's first forays into starch research began in the early 1980s when he and Richard Fullagar observed starch granules on stone, shell and glass artefacts recovered from a variety of archaeological contexts in North America and Oceania (Fullagar 2006). Tom continued his pioneering starch research into the 1990s. His discovery and identification of Araceae starch granules and raphides on stone tools from the Solomon Islands (Loy *et al*. 1992) was most influential, being the first strong evidence that people were using stone tools to process starchy foods in the Pacific region as long as 28,000 years ago. Since that time, it has been recognised that starch granules can be well-preserved in a variety of archaeological contexts, for example in residues on stone tools, pottery, other artefacts and ecofacts (Torrence and Barton 2006), within dental calculus and coprolites (Englyst *et al*. 1992; Juan-Tresserras 1998), in cereal seeds and other preserved foodstuffs (Samuel 1994; Ugent *et al*. 1987), and in sediments (Haslam 2004; Lentfer *et al*. 2002; Therin *et al*. 1999). Consequently there has been a burgeoning interest in starch research in archaeology with significant outcomes for understanding the prehistory of plant exploitation and manipulation in many regions of the world (e.g. Barton and Paz 2007; Crowther 2005; Fullagar *et al*. 2006; Helena *et al*. 2007; Horrocks *et al*. 2004; Parr and Carter 2003; Piperno *et al*. 2004; Zarillo *et al*. 2008).

The application of starch research to Indonesian archaeology has huge potential for resolving many key archaeobotanical issues in the region. The Indonesian archipelago has a very long record of human occupation extending well beyond a million years and involving three distinct human species (Brown *et al*. 2004; Hutterer 1985; Morwood *et al*. 2004; O'Sullivan *et al*. 2001; Sémah *et al*. 2003). It also has a rich diversity of plants and a suite of economically important species including a range of cereal grasses, fruit and nut bearing trees, and plants with edible roots, tubers, corms and rhizomes. From the beginnings of human colonisation of the archipelago, plant exploitation would most probably have been extensive and complex, specifically adapted to different environments and availability of naturally occurring resources. The nature of plant exploitation, diet and plant food processing would have been influenced through time by climatic and environmental change, as well as by the introduction of new technologies, people, cultures and changing economies. The archipelago lies between the southeast Asian mainland and New Guinea, two well-known centres for independent origins of early agriculture (Bellwood 1997; Denham *et al*. 2003, 2004; Harris 1996; Jiang 1995) and spans the Wallace line, a well-established boundary between the southeast Asian and Australasian biogeographic regions. As indicated by current distributions and phylogenetic relationships of taros, yams, *Musa* section bananas and *Metroxylon* and *Caryota* sago palms (Bellwood 1997; De Langhe and De Maret 1999; Denham *et al*. 2004; Fullagar *et al*. 2006; Lebot 1999; Lentfer and Green 2004; Simmonds 1962; Spriggs 1996; Yen 1990), the archipelago has been influenced from both directions across the Wallace Line. Undoubtedly, plant manipulation in the Indonesian archipelago itself would have contributed significantly to domestication, and similar to adjacent regions, played a substantial role in the development of early agriculture.

Four issues to be addressed by archaeobtanical research include the following:

- the question of plant exploitation and foraging strategies of *Homo erectus*, *H. floresiensis* and early *H. sapiens* - what are the similarities and differences between species and changes through time?;
- the nature of plant exploitation and food processing strategies adopted by humans living in tropical rainforests, sometimes referred to as 'green deserts' (Bailey *et al*. 1991, Dentan 1991);
- the origins and spread of vegeculture and arboriculture; and
- the timing and dispersal of various plant cultivars, particularly how the introduction and dispersal of starch-rich root and tuber crops, sago palms, bananas, sugar cane, breadfruit, certain nut trees and cereal crops, might have been influenced by Austronesian expansion in the region.

There has been a keen interest in these issues for several decades spurred on by certain key publications such as Sauer (1953) and Harris (1996). However, systematic and focused archaeobotanical investigation has not been prioritised in mainstream archaeological research, due partly to a perceived notion that plant remains are poorly preserved in the tropics, especially wet environments. Consequently, there is a dearth of information about the prehistory of plant exploitation, particularly for Indonesia. Direct archaeobotanical information is rare, confined mostly to evidence for cereal cropping in the archipelago during the mid-to-late Holocene (e.g.

Glover and Higham 1996). Besides this, much of our current understanding relies on speculation and inference primarily based on the presence of artefacts with inferred plant related function or association (Glover 1986) and/or plant phylogeny, phytogeography and linguistics used for determining plant origins and patterns of plant dispersal (Bellwood 1996; Matthews and Naing 2005; Spriggs 1996).

Recently, following the proven value of starch and phytolith analyses in wet tropical regions, there has been escalating interest in incorporating systematic archaeobotanical investigation in island southeast Asian archaeology. The Niah cave project, Sarawak, the Liang Bua Project in Flores, Indonesia, and various East Timor archaeological projects are key examples where starch and phytolith analyses are being used routinely for palaeoenvironmental reconstruction and residue analyses. Fundamental to this research is a sound knowledge of the range and variation of the various microfossils in plants that occur in the region. There are two major comparative modern phytolith reference collections relevant to the region, however starch reference material is limited. This paper discusses the 'Indonesian Starch Project' and outlines the methods and procedures being used to establish the first major comparative modern starch reference collection and database for the flora of Indonesia.

COMPARATIVE STARCH REFERENCE COLLECTIONS

The establishment of comparative modern starch reference material is of paramount importance to starch research and has been integral to studies seeking to determine taxonomic diagnostics and to identify starch granule provenance. Most collections have been focused on food crops and plant resources relevant to industries, individual studies and regions. For the majority of studies starch storage organs (i.e. tubers, corms, rhizomes, roots, fruits and seeds) have been targeted (e.g. Reichert 1913). Other plant parts with less economic importance and/or assumed to have mainly transitory starch, which occurs in the chloroplasts of plant tissue and is thought to be non-diagnostic (Gott *et al*. 2006), have not been thoroughly examined. Given the general lack of readily accessible, broad-scale collections, therefore, it is often the case that the establishment of new or additional comparative reference collections tailored to suit particular research questions is a mandatory component of research design (Dickau *et al*. 2007; Field and Gott 2006; Loy *et al*. 1992; Perry 2004).

A few collections have been established for the tropical southeast Asian/Pacific region, including those created by Loy, Barton, Therin, Crowther, Fullagar and Horrocks for their various research projects. However, all of these collections, with the exception of Therin's from West New Britain, Papua New Guinea (see Lentfer and Therin 2006) have primarily targeted food plants aroid corms (Araceae) and yam tubers (Dioscoreaceae) in particular. Given that Therin's collection is limited, consisting of a few hundred samples only, comparative modern reference material available for the determination of the range of starch granule variation within and between plant parts for any particular species, and within and between plant species is in short supply. With the possible exception of well-studied and targeted species or parts of particular species, therefore, accurate taxonomic identification is problematic unless starch granules are embedded in identifiable tissue or associated with other diagnostic plant residues. Furthermore, without a sound knowledge of starch production, range of morphologies and variation in any particular ecological setting, definitive taxonomic identification of what are considered to be well-analysed species should be treated with caution until there is more comparative information. Until this time, the approach taken by Paz (2001) and Barton and Paz (2007) should be adopted whereby levels of confidence are recorded according to how closely the archaeological material matches available comparative reference material.

THE INDONESIAN STARCH PROJECT

The aims of the 'Indonesian Starch Project', initiated in 2002 as a collaborative project between Indonesian and Australian researchers, are to facilitate the development of ancient starch analysis in the Indonesian region by systematic and comprehensive sampling of Indonesian flora and to establish a database that allows for more effective application of starch analysis to archaeological, palaeoenvironmental and palaeoethnobotanical studies. Economically important starch-rich plants, other useful plants and a wide variety of other flora in the region are included to enable systematic investigation of starch presence in plants, evaluation of the diagnostic properties of starch granules, and the identification of plants and plant parts with diagnostic starch.

Plant collection, identification and storage

Where possible all parts of plants including leaves, flowers, fruits, seeds, stems, wood, roots, corms, tubers, rhizomes are sampled. Not all plant parts are included in herbarium collections. Hence, although it can be very useful and expedient to sample from established herbarium collections, it is often necessary to obtain supplementary material from living plants. Furthermore, starch gelatinises at temperatures above 50^{o} Celsius, causing it to swell, break and lose its birefringence properties. Therefore, heated starch is often not useful for diagnostic analysis and collection from herbariums where plant specimens have been heat-treated at temperatures above 50^{o} Celsius for long-term safe storage can be problematic.

Currently, there are over 800 plant accessions in the collection. One hundred and twenty one families and 451 genera are represented (see summary list of families and species in Table 1). Field sampling during the initial stages of this project was undertaken in Flores, West Timor, Java and Bali giving priority to known useful plants and important ecological indicators (Figures 1 to 4). Subsequently, these collections have been expanded by sampling in the Bogor Botanic Gardens in west Java where the focus was on obtaining accessions of useful and non-useful species from plant families with economically important members and medicinal plants. Other accessions presently held in the reference collection include wild and domesticated bananas collected in Papua New Guinea and Flores, aroid and yam samples from the Philippines and Sarawak, and additionally, a range of useful comparative plant species from Fiji.

Table 1. List of plant families and genera included in the comparative starch reference collection. (P/I: pending identification; *Diploid and polyploid cultivars are included in *Musa*)

Family	Genus	No. Species
Acanthaceae	*Acanthus*	1
Acanthaceae	*Andrographis*	1
Acanthaceae	*Asystasia*	1
Acanthaceae	*Barleria*	1
Acanthaceae	*Clinacanthus*	1
Acanthaceae	*Gendarussa*	1
Acanthaceae	*Graptophyllum*	1
Acanthaceae	*Pseuderanthemum*	1
Actinidiaceae	*Saurauia*	3
Agavaceae	*Pleomele*	3
Aizoaceae	*Sesuvium*	1
Amaranthaceae	*Deeringia*	1
Amaryllidaceae	*Crinum*	1
Amaryllidaceae	*Curculigo*	3
Amaryllidaceae	*Eucharis*	1
Anacardiaceae	*Anacardium*	1
Anacardiaceae	*Lannea*	1
Anacardiaceae	*Mangifera*	2
Anacardiaceae	*Pentaspadon*	1
Anacardiaceae	P/I	1
Annonaceae	*Annona*	1
Annonaceae	*Cananga*	1
Annonaceae	*Polyalthia*	1
Annonaceae	*Saccopetalum*	1
Anthericaceae	*Chlorophytum*	1
Apiaceae	*Centella*	1
Apocynaceae	*Alstonia*	1
Apocynaceae	*Cerbera*	1
Apocynaceae	*Pagiantha*	1
Apocynaceae	*Plumeria*	1
Apocynaceae	*Thevetia*	1
Aquifoliaceae	*Ilex*	2
Araceae	*Homalomena*	1
Araceae	*Acorus*	1
Araceae	*Aglaonema*	5
Araceae	*Alocasia*	6
Araceae	*Amorphophallus*	3
Araceae	*Anadendrum*	2
Araceae	*Anchormanes*	1
Araceae	*Anthurium*	4

Araceae	*Colocasia*	3
Araceae	*Culcasia*	1
Araceae	*Cyrtosperma*	2
Araceae	*Dieffenbachia*	8
Araceae	*Dracontium*	1
Araceae	*Homalomena*	3
Araceae	*Monstera*	1
Araceae	*Philodendron*	2
Araceae	*Raphidaphora*	1
Araceae	*Rhodospathia*	1
Araceae	*Schismatoglottis*	4
Araceae	*Scindapsus*	1
Araceae	*Spathiphyllum*	2
Araceae	*Xanthosoma*	3
Araliaceae	*Arthrophyllum*	1
Araceae	P/I	-
Araceae	P/I	-
Araliaceae	*Harmsiopanax*	1
Araliaceae	*Macropanax*	1
Araliaceae	*Trevesia*	1
Asclepiadaceae	*Asclepias*	1
Asclepiadaceae	*Calatropis*	1
Asclepiadaceae	*Dischidia*	1
Asclepiadaceae	*Finlaysonia*	1
Aspidiaceae	*Dryopteris*	1
Aspidiaceae	*Stenosemia*	1
Aspleniaceae	*Asplenium*	1
Asteliaceae	*Cordyline*	1
Athyroiodeae	*Athyrium*	1
Averrhoaceae	*Averrhoa*	2
Begoniaceae	*Begonia*	1
Bignoniaceae	*Crescentia*	1
Bignoniaceae	*Kigelia*	1
Bignoniaceae	*Stereospermum*	1
Bignoniaceae	*Tabebula*	1
Blechnaceae	*Blechnum*	1
Bombacaceae	*Bombax*	1
Bombacaceae	*Durion*	1
Boraginaceae	*Cordia*	2
Bromeliaceae	*Ananas*	1
Burseraceae	*Canarium*	3
Butomaceae	*Limnocharis*	1
Cactaceae	*Opuntia*	1
Cannaceae	*Canna*	2
Capparaceae	*Capparis*	3
Caryophylaceae	*Drymaria*	1
Celastraceae	*Elaeodendron*	1
Chloranthaceae	*Sarcandra*	1
Combretaceae	*Lumnitzera*	1
Combretaceae	*Quisqualis*	1
Combretaceae	*Terminalia*	2
Commelinaceae	*Aneilema*	1
Commelinaceae	*Commelina*	1
Commelinaceae	*Murdannia*	1
Commelinaceae	*Palisota*	1
Compositae	*Ageratum?*	1
Compositae	*Bidens*	2
Compositae	*Blumea*	2
Compositae	*Emilia*	1
Compositae	*Erechtites*	2
Compositae	*Eupatorium*	1
Compositae	*Galinsoga*	1
Compositae	*Pterocaulon*	1
Compositae	*Sida*	1
Compositae	*Sonchus*	1
Compositae	*Synedrella*	1
Compositae	*Vernonia*	3
Compositae	*Wedelia*	1
Compositae	P/I	-
Compositae	P/I	-
Compositae	P/I	-
Compositae	P/I	-
Convallariaceae	*Ophigon*	2
Convallariaceae	*Tupistra*	1
Convolvulaceae	*Ipomoea*	6
Convolvulaceae	P/I	-
Convolvulaceae	P/I	-
Crassulaceae	*Kalanchoe*	1
Cucurbitaceae	*Benincasa*	1
Cucurbitaceae	*Coccinia*	1
Cucurbitaceae	*Cucurbita*	1
Cucurbitaceae	*Lagenaria*	1
Cucurbitaceae	P/I	-
Cunioniceae	P/I	-
Cunioniceae	P/I	-
Cyclanthaceae	*Carludovica*	1
Cyclanthaceae	*Cyathea*	1
Cyperaceae	*Carex*	1
Cyperaceae	*Cyperus*	2
Cyperaceae	*Lipocarpha*	1
Cyperaceae	*Mapania*	1
Cyperaceae	*Rhynchospora*	1
Cyperaceae	*Scirpus*	1
Davaliaceae	*Nephrolepis*	1
Dilleniaceae	*Dillenia*	2
Dioscoreaceae	*Dioscorea*	10
Dracaenaceae	*Sanservieria*	5
Ebenaceae	*Diospyros*	1
Equisetaceae	*Equisetum*	1
Euphorbiaceae	*Acalypha*	1
Euphorbiaceae	*Aleurites*	1
Euphorbiaceae	*Antidesma*	1
Euphorbiaceae	*Bischofia*	1
Euphorbiaceae	*Codiaeum*	1
Euphorbiaceae	*Euphorbia*	3
Euphorbiaceae	*Excoecaria*	1
Euphorbiaceae	*Glochidion*	1
Euphorbiaceae	*Jatropha*	3
Euphorbiaceae	*Macaranga*	1
Euphorbiaceae	*Mallotus*	1
Euphorbiaceae	*Manihot*	1
Euphorbiaceae	*Melanolepis*	1
Euphorbiaceae	*Omalanthus*	2
Euphorbiaceae	*Ricinis*	1
Euphorbiaceae	*Sauropus*	1
Euphorbiaceae	P/I	1
Euphorbiaceae	P/I	-
Flacourtiaceae	*Scolopia*	1
Flagellariaceae	*Flagellaria*	1
Gesneriaceae	*Cyrtandra*	1

Gleicheniaceae	*Gleichenia*	1
Gramineae	*Andropogon*	1
Gramineae	*Bambusa*	3
Gramineae	*Bambusa*	2
Gramineae	*Bothriochloa*	1
Gramineae	*Centotheca*	1
Gramineae	*Chloris*	1
Gramineae	*Coix*	1
Gramineae	*Cymbopogon*	1
Gramineae	*Dendrocalamus*	1
Gramineae	*Echinochloa*	1
Gramineae	*Eleusine*	1
Gramineae	*Eragrostis*	1
Gramineae	*Erianthus*	1
Gramineae	*Heteropogon*	1
Gramineae	*Imperata*	1
Gramineae	*Neololeba*	1
Gramineae	*Oplismenus*	1
Gramineae	*Oryza*	1
Gramineae	*Panicum*	2
Gramineae	*Paspalum*	3
Gramineae	*Pennisetum*	1
Gramineae	*Saccharum*	2
Gramineae	*Setaria*	1
Gramineae	*Shizostachyum*	1
Gramineae	*Sorghum*	3
Gramineae	*Spinifex*	1
Gramineae	*Sporobolus*	1
Gramineae	*Themeda*	3
Gramineae	*Thuarea*	1
Gramineae	*Thysanolaena*	2
Gramineae	*Tribulus*	1
Gramineae	*Urochloa*	1
Gramineae	*Zea*	1
Guttiferae	*Garcinia*	3
Gramineae	P/I	-
Gramineae	P/I	-
Gramineae	P/I	-
Heliconiaceae	*Heliconia*	5
Hypericaceae	*Hypricum*	1
Icacinaceae	*Gonocaryum*	1
Icacinaceae	*Platea*	1
Iridaceae	*Neomarica*	3
Labiatae	*Coleus*	1
Labiatae	*Hyptis*	3
Labiatae	*Ocimum*	1
Labiatae	*Orthosiphon*	1
Labiatae	P/I	-
Labiatae	P/I	-
Labiatae?	P/I	-
Lauraceae	*Cinnamomum*	1
Lauraceae	*Cryptocarya*	1
Lauraceae	*Litsea*	3
Lauraceae	*Persea*	1
Lecythidaceae	*Barringtonia*	3
Leeaceae	*Leea*	1
Leguminosae	*Abrus*	1
Leguminosae	*Acacia*	2
Leguminosae	*Adenanthera*	1
Leguminosae	*Albizia*	2

Leguminosae	*Archidendron*	1
Leguminosae	*Bauhinia*	1
Leguminosae	*Caesalpinia*	1
Leguminosae	*Cajanus*	1
Leguminosae	*Calliandra*	1
Leguminosae	*Canavalia*	1
Leguminosae	*Cassia*	2
Leguminosae	*Centrosema*	1
Leguminosae	*Crotalaria*	2
Leguminosae	*Cynometra*	1
Leguminosae	*Derris*	2
Leguminosae	*Desmodium*	1
Leguminosae	*Erythrina*	1
Leguminosae	*Glyricidia*	1
Leguminosae	*Indigofera*	1
Leguminosae	*Leucaena*	1
Leguminosae	*Mimosa*	1
Leguminosae	*Moghania*	2
Leguminosae	*Mucuna*	1
Leguminosae	*Parkia*	1
Leguminosae	*Peltophorum*	1
Leguminosae	*Phaseolus*	2
Leguminosae	*Pithecellobium*	1
Leguminosae	*Pometia*	1
Leguminosae	*Pongamia*	1
Leguminosae	*Pongamia*	1
Leguminosae	*Pterocarpus*	1
Leguminosae	*Sesbania*	1
Leguminosae	*Tamarindus*	1
Leguminosae	*Tetrapleura*	1
Leguminosae	*Vigna*	1
Leguminosae	P/I	-
Leguminosae	P/I	-
Leguminosae	P/I	-
Liliaceae	*Asparagus*	1
Liliaceae	*Aspidistra*	2
Liliaceae	*Cordyline*	1
Liliaceae	*Herreria*	1
Liliaceae	*Pleomele*	1
Lomariopsidaceae	*Teratophyllum*	1
Lythraceae	*Lagerstroemia*	1
Lythraceae	*Pemphis*	1
Magnoliaceae	*Manglietia*	1
Magnoliaceae	*Michelia*	1
Malvaceae	*Abutilon*	1
Malvaceae	*Gossypium*	2
Malvaceae	*Hibiscus*	3
Malvaceae	*Sida*	1
Malvaceae	*Thespesia*	1
Malvaceae	*Urena*	1
Marantaceae	*Calathea*	4
Marantaceae	*Maranta*	1
Marantaceae	*Monotagma*	1
Marantaceae	*Phrynium*	1
Marattiaceae	*Angiopteris*	1
Melastomataceae	*Medinilla*	1
Melastomataceae	*Melastoma*	2
Melastomataceae	*Osbeckia*	1
Meliaceae	*Dysoxylum*	1
Menispermaceae	*Anamirta*	1

Menispermaceae	*Arcangelisis*	1
Menispermaceae	*Tinospora*	1
Menispermaceae	P/I	-
Moraceae	*Artocarpus*	2
Moraceae	*Ficus*	16
Moringaceae	*Moringa*	1
Musaceae	*Ensete*	1
Musaceae	*Musa*	24*
Musaceae	*Strelitzia*	1
Myristicaceae	*Myristica*	2
Myrsinaceae	*Aegiceras*	1
Myrtaceae	*Eucalyptus*	1
Myrtaceae	*Eugenia*	1
Myrtaceae	*Psidium*	1
Myrtaceae	*Syzygium*	4
Nephrolepidaceae	*Nephrolepis*	1
Orchidaceae	*Calanthe*	1
Orchidaceae	*Eria*	2
Orchidaceae	*Goodyera*	1
Orchidaceae	*Malaxis*	1
Orchidaceae	*Vanilla*	1
Orchidaceae	P/I	-
Oxalidaceae	*Oxalis*	1
Palmae	*Areca*	2
Palmae	*Arenga*	6
Palmae	*Borassus*	1
Palmae	*Calamus*	2
Palmae	*Caryota*	3
Palmae	*Cocos*	1
Palmae	*Corypha*	1
Palmae	*Cyrtostachys*	2
Palmae	*Elaeis*	1
Palmae	*Eugeissona*	1
Palmae	*Licuala*	4
Palmae	*Livistonia*	1
Palmae	*Metroxylon*	1
Palmae	*Nypa*	1
Palmae	*Oncosperma*	2
Palmae	*Phoenix*	1
Palmae	*Pinanga*	1
Palmae	*Ptychosperma*	2
Palmae	*Salacca*	2
Palmae	*Verschaffeltia*	1
Pandanaceae	*Freycinetia*	3
Pandanaceae	*Pandanus*	10
Phormiaceae	*Dianella*	2
Piperaceae	*Piper*	6
Plantaginaceae	*Plantago*	1
Podocarpaceae	*Podocarpus*	1
Polygalaceae	*Polygala*	1
Polygonaceae	*Polygonum*	2
Polypodaceae	*Diplazium*	1
Polypodaceae	*Drypoteris*	1
Polypodiaceae	P/I	-
Rhamnaceae	*Ziziphus*	1
Rhizophoraceae	*Bruguiera*	1
Rhizophoraceae	*Ceriops*	1
Rhizophoraceae	*Rhizophora*	1
Rosaceae	*Prunus .*	2
Rosaceae	*Rubus*	3
Rubiaceae	*Borreria*	1
Rubiaceae	*Lepisanthes*	1
Rubiaceae	*Morinda*	2
Rubiaceae	*Mycetia*	1
Rubiaceae	*Ophiorrhiza*	1
Rubiaceae	P/I	-
Rubiaceae	P/I	-
Rubiaceae	P/I	-
Rutaceae	*Acronychia*	1
Rutaceae	*Citrus*	1
Rutaceae	*Clausena*	1
Rutaceae	*Eudoia*	2
Rutaceae	*Feroniella*	1
Rutaceae	*Glycosimis*	1
Rutaceae	*Pleiospermum*	1
Rutaceae	*Swinglea*	1
Rutaceae	P/I	-
Rutaceae ?	P/I	-
Sabiaceae	*Meliosma*	1
Salicaceae	*Salix*	1
Salvadoraceae	*Azima*	1
Santalaceae	*Santalum*	1
Sapindaceae	*Blighia*	1
Sapindaceae	*Cardiospermum*	1
Sapindaceae	*Nephelium*	1
Sapindaceae	*Schleichera*	1
Sapotaceae	*Chrysophyllum*	1
Sapotaceae	*Planchonella*	1
Saxifragaceae	*Itea*	1
Saxifragaceae	*Polyosma*	2
Selaginellaceae	*Selaginella*	1
Solanaceae	*Brugmansia*	1
Solanaceae	*Datura*	1
Solanaceae	*Solanum*	2
Sonneratiaceae	*Sonneratia*	1
Sterculiaceae	*Heritiera*	1
Sterculiaceae	*Melochia*	1
Sterculiaceae	*Pterospermum*	1
Sterculiaceae	*Theobroma*	1
Theaceae	*Adinandra*	1
Thelypteridaceae	*Sphaerostephanos*	1
Thymelaeaceae	*Phaleria*	1
Tiliaceae	*Grewia*	1
Tiliaceae	*Microcos*	2
Tiliaceae	*Schoutenia*	1
Tiliaceae	P/I	-
Ulmaceae	*Celtis*	1
Urticaceae	*Cypholopus*	1
Urticaceae	*Debregeasia*	1
Urticaceae	*Dendrocnide*	1
Urticaceae	*Leucosyke*	1
Urticaceae	P/I	-
Urticaceae	*Pipturus*	1
Urticaceae	*Villebrunea*	1
Verbenaceae	*Avicennia*	1
Verbenaceae	*Clerodendron*	3
Verbenaceae	*Lantana*	1
Verbenaceae	*Premna*	1
Verbenaceae	*Stachytarpheta*	2
Verbenaceae	*Tectona*	1

Verbenaceae	*Teijsmanniodendron*	1
Verbenaceae	*Vitex*	1
Verbenaceae	P/I	-
Verbenaceae	P/I	-
Verbenaceae	P/I	-
Verbenaceae	P/I	-
Verbenaceae	P/I	-
Zingiberaceae	*Alpinia*	4
Zingiberaceae	*Amomum*	5
Zingiberaceae	*Catimbium*	2
Zingiberaceae	*Costus*	12
Zingiberaceae	*Cucurma*	7
Zingiberaceae	*Etlingera*	2
Zingiberaceae	*Globba*	1
Zingiberaceae	*Hedychium*	4
Zingiberaceae	*Hornstedtia*	1
Zingiberaceae	*Kaempferia*	1
Zingiberaceae	*Languas*	1
Zingiberaceae	*Tapeinocheilos*	2
Zingiberaceae	*Zingiber*	4
Zingiberaceae	P/I	-
Zingiberaceae	P/I	-
Zingiberaceae	P/I	-
Zygophyllaceae	*Tribulus*	1
** 27 further accessions	P/I	-

Figure 1. Collecting plants at Liang Bua, Flores Indonesia (photo: C. Lentfer).

Figure 2. Dr Polhaupessy sampling plant products from markets in Kupang, West Timor (photo: C. Lentfer).

Plant specimens, including roots and other starch storage organs, are prepared following conventional herbarium procedures. The specimens are immersed in methylated spirits or ethyl alcohol at 70% dilution to avoid fungal growth during field collection and stored between paper in plant presses. This technique allows specimens to be stored wet for considerable periods in humid tropical conditions. For long-term storage they are slowly dried at temperatures not exceeding 35^{o} Celsius. Taxonomic identification of specimens has been undertaken in the field and/or laboratory and cross-checked against herbarium specimens. Accessions are presently stored at the Bogor Herbarium, Indonesia and the University of Queensland, Australia.

Figure 3. Display of medicinal plant products beside garden house in West Flores (photo: C. Lentfer).

Figure 4. The author identifying plants collected from Rana Mese, West Flores and preparing herbarium specimens (photo: J. Collins).

Preparation of starch for microscopic analysis

Following this, sub-samples of all plant specimens including all parts of plants are stored in vials in 70% ethyl alcohol. Following this sub-samples of plant parts are prepared separately by grinding with a pestle and mortar in distilled water. Ground residue is stored in separate vials in 70% ethyl alcohol. For microscopic analysis 100 μl sub-sample of ground residue is mounted onto microscope slides and dried at temperatures at or below 35^{o} Celsius. Corners of coverslips are secured onto glass slides with nail polish. Prior to analysis dried samples are re-hydrated with distilled water to allow for rotation of granules.

Starch granule analysis

All slide residues are analysed using light microscopy at x400, x600 and x1000 magnification. Qualitative analysis of starch granule assemblages is used initially. Presence or absence of starch is noted for every plant part for each plant specimen. Descriptors for all different types of granules in assemblages are recorded according to abundance, type (i.e. whether compound or simple), size range, and morphological characteristics of granules (see the 12 attributes listed in Table 2). During the initial recording stage attribute descriptions are separated by a slash (e.g. a/s/s/sr/hsph/0/cc/s/t/c/sv/stel). Photographs of all different starch granule morphotypes present in each plant part are taken with microscope dedicated digital cameras using non-polarized and polarized light. Figures 5 to 11 show examples from the collection of starch granules found in significant economic plants (photos by C. Lentfer and A. Crowther). Descriptors are transferred to an electronic database to facilitate searches and comparative analyses. Field collection records, plant uses, the presence or absence of starch granules in plant parts, and images of starch granules are also stored in an electronic database. The microscope slides and sub-samples in vials are presently stored at the University of Queensland and a sub-set is held at the Geological Research and Development Centre, Bandung, Indonesia.

The second stage of analysis is the determination of the diagnostic value of starch granules for species/plant tissue differentiation. This involves rigorous morphometric analysis of starch granule assemblages using quantitative statistical methods. It will be especially important for plants and tissues with starch granules that are similar and difficult to differentiate.

Table 2. List of attributes used for the description of starch granules

1. Abundance		2. Type		3. Size (Max. dim.)		4. 2D shape		5. 3D shape	
absent (0)	a	simple	s	< 5 µm	vs	subround	sr	hemispherical	hsph
rare									
(<20 granules)	r	compound	c	>5-10 µm	s	round	r	elongate hemisph.	el.hsph
common (>20-50)	c	semicompound	sc	>10-20 µm	m	ovate	ov	spherical	sph
abundant (>50-100)	ab			>20-50 µm	l	sub-ovate	sub.ov	subspherical	subsph
v. abundant (>100)	vab			>50 µm	vl	triangular ovate	tri.ov	ovoid	ov
						rectangular ovate	rect.ov	sub-ovoid	sub.ov
						elongate ovate	el.ov	triangular ovoid	tri.ov
						irregular ovate	irr.ov	rectangular ovoid	rect.ov
						irregular triangular ovate	irr.tri.ov	elongate ovate	el. ov
						elongate irregular ovate	el.irr.ov	irregular ovoid	irr.ov
						polygonal	plygl	irregular triangular ovoid	irr.tri.ov
6. Protrusion		7. Facet		8. Texture		irregular	irr	elongate irregular ovoid	el.irr.ov
present	+	none observed	0	wrinkle	wr	elongate irregular	el.irr	globose	gl
absent	0	flat	fl	smooth	s	crescent	cr	polyhedral	plyhdl
		concave	cc	rough	r	kidney	kid	quadrilateral	qu
		multifaceted flat	mff	ridged	rdg	elongate kidney	el.kid	irregular	irr
		multifaceted concave	mfc			triangular	tri	elongate irregular	el.irr
						square	sq	globose elongate	gl. el
						bell	bell	kidney	kid
						unilobate	unilob	elongate kidney	el. Kid
								cone	cone
								disc	di
								bell	bell
								unilobate	unilob
9. Lamellae		10. Hilum - Position		11. Hilum - Type		12. Hilum - Fissure		Additional notes	
present	+	eccentric	e	large vacuole	lv	none	0		
absent	0	centric	c	small vacuole	sv	stellate	stel		
		highly eccentric	he	crystal	cr	simple	s		
				slot	sl	open slot	os		
				irregular	irr	open irreg.	oi		
				papilla	pap	tri	tri		
						disc	d		

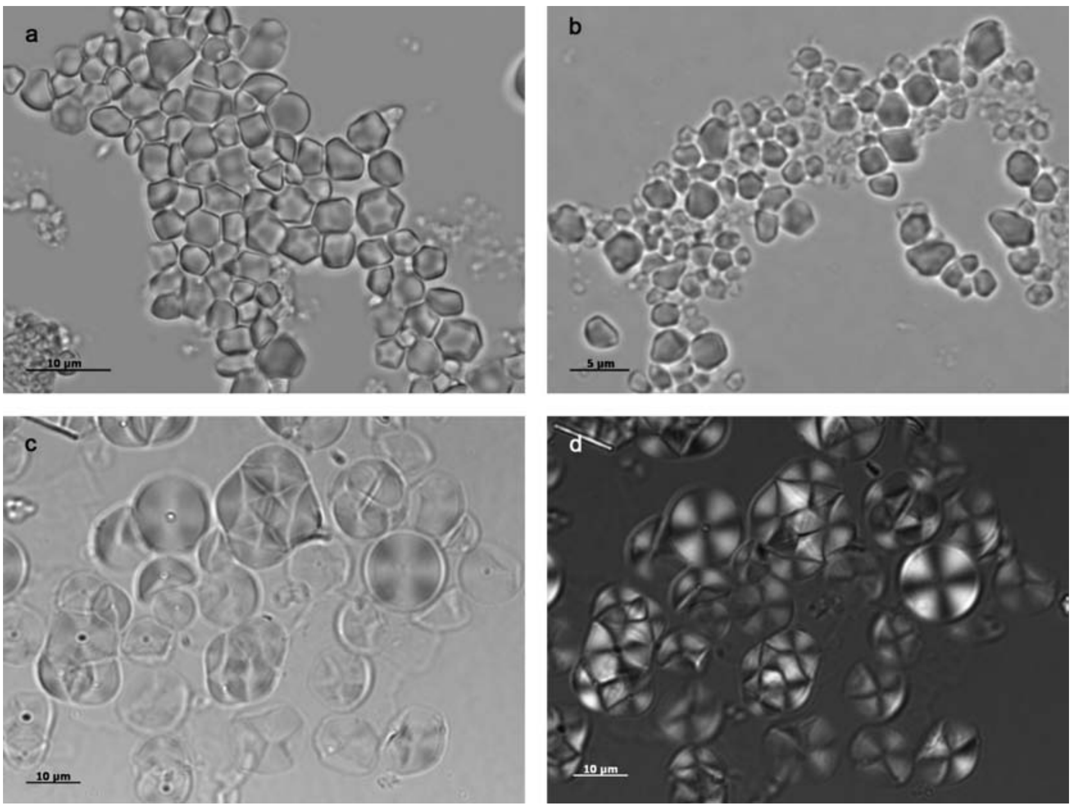

Figure 5. (a) *Alocasia* sp. starch, showing typical multifacetted morphology (CL uncoded, corm). (b) *Colocasia esculenta* starch, showing typical multi-facetted morphology and small granule size (CL uncoded, corm). (c and d) *Cyrtosperma chamissonis* starch, showing simple and compound granule forms (c) and centric extinction cross, visible in cross-polarised light (d) (TL-IV69-4tuber) (scale bars in a, c and d = 10 µm; b = 5 µm).

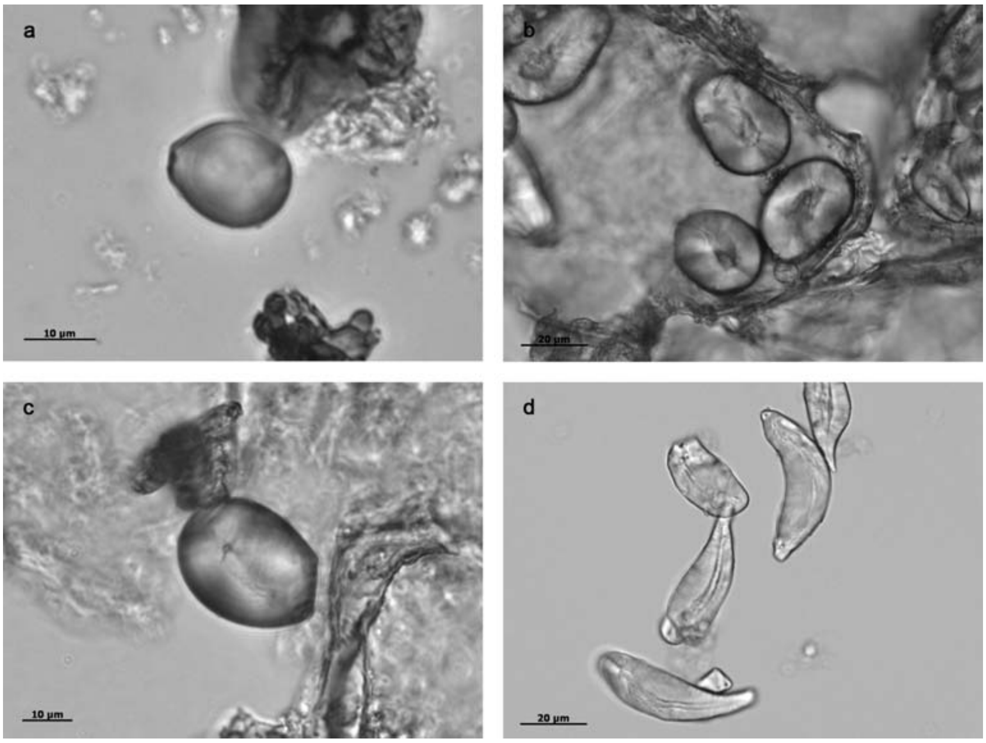

Figure 6. (a) *Caryota rumphiana* (CL05160wood). (b) *Eugeissonia utilis* (CL05150wood). (c) *Metroxylon sagu* (CL05176trunk). (d) *Salacca affinis* (CL05182trunk) (scale bars in a and c = 10 µm; b and d = 20 µm).

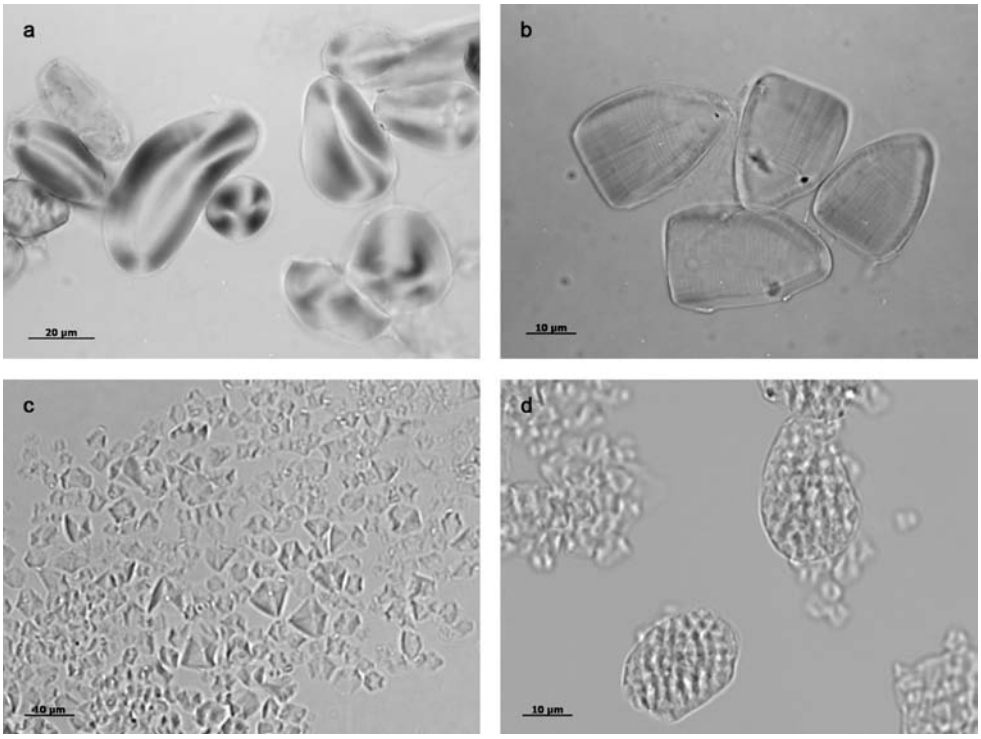

Figure 7. (a) Rounded ovoid to elongate-ovate starch forms in *Dioscorea alata* (TL-IV69-8tuber). (b) Flat-based, rectilinear-triangular starch type produced by *Dioscorea bulbifera* (TL-IV69-14tuber). In addition to lamaellae, these granules have strong longitudinal striae that are very visible at the distal end. (c) Small, angular (multi-facetted) granules from *Dioscorea esculenta* (TL-IV69-7tuber). (d) Ovate-shaped compound grains in *Dioscorea esculenta* (TL-IV69-7tuber) (scale bar in a = 20 µm; b, c and d = 10 µm).

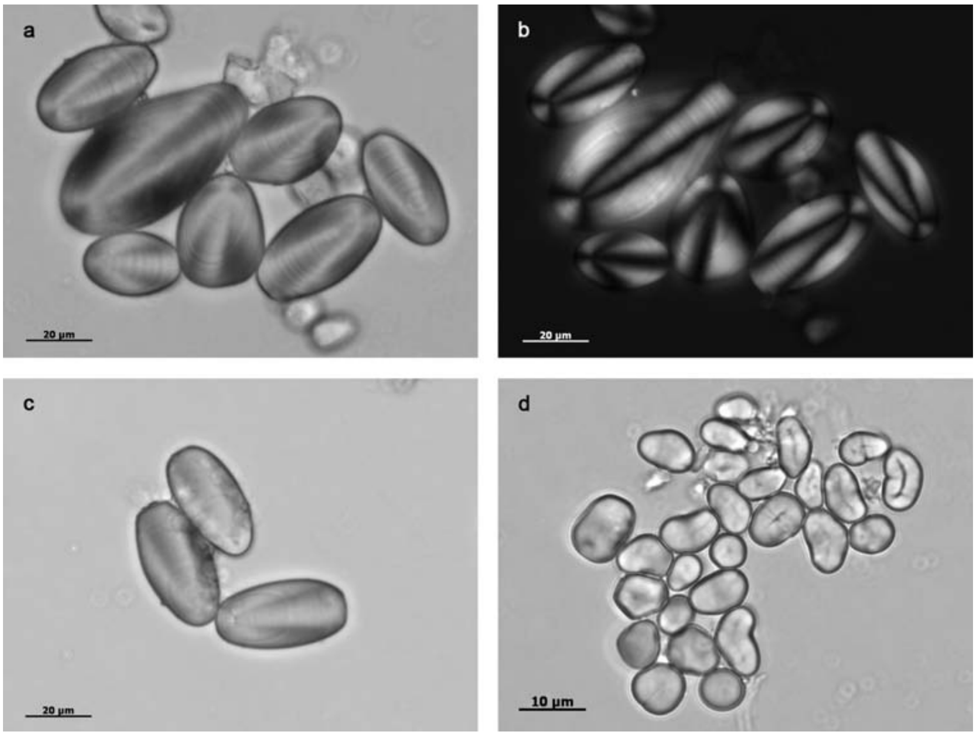

Figure 8. (a and b) Starch from *Heliconia caribea* (CL05197stem), showing typical rounded-rectilinear ovate granule form observed in all *Heliconia* sp. examined. (c and d) *Heliconia dasyantha* starch granules, showing the two distinctive starch types that occur within the seed (CL05288seed) (scale bars in a, b and c = 20 µm; d = 10 µm).

CURRENT STATUS OF THE REFERENCE COLLECTION

The comparative modern starch reference collection and database supplements other such collections of starch, phytolith, pollen, parenchyma and macrobotanical remains. It has enormous potential to contribute to our scientific knowledge in a wide variety of academic research disciplines including archaeology plant phylogenetic studies, palaeobotany, palynology and studies involving climatic and environmental change in the tropics throughout the Quaternary. Included in the accessions are plant families, genera and species common to tropical regions throughout the world, and as such, the reference collection and database have relevance to Indonesia, the wider Indo/Pacific region, and tropical regions elsewhere. By incorporating a broad range of economically and ecologically important plants and plant groups hitherto unexamined, and by treating plant parts as separate entities, it provides for rigorous comparative analyses of starch granules, thereby building onto our knowledge about the range and variation of morphologies and their diagnostic value for palaeobotanical analysis. The first stage of analysis involves recording descriptors and images of starch granules. This is nearing completion for a number of economically important plant families including the Araceae, Dioscoreaceae, Heliconiaceae, Musaceae, Zingiberaceae, Palmae and Pandanaceae (see Table 3). Analysis of other plant families is in progress. Following initial qualitative analyses, morphometric analysis using quantitative statistical methods will be undertaken. This will be on an ad hoc basis as the need arises, giving precedence to plant groups relevant to specific research problems.

The comparative modern starch reference collection is a growing archaeobotanical resource and will be expanded as new accessions are obtained. A record of accessions and work in progress is included in unpublished reports presented to the Pacific Biological Foundation (Lentfer 2008). I thank Tom Loy's enterprise, his long-standing and strong interest in ancient starch research and the groundwork he laid for the establishment of the Archaeological Microscopy Laboratory in the School of Social Science at the University of Queensland where the bulk of the analytical work for the 'Indonesian Starch Project' is being undertaken.

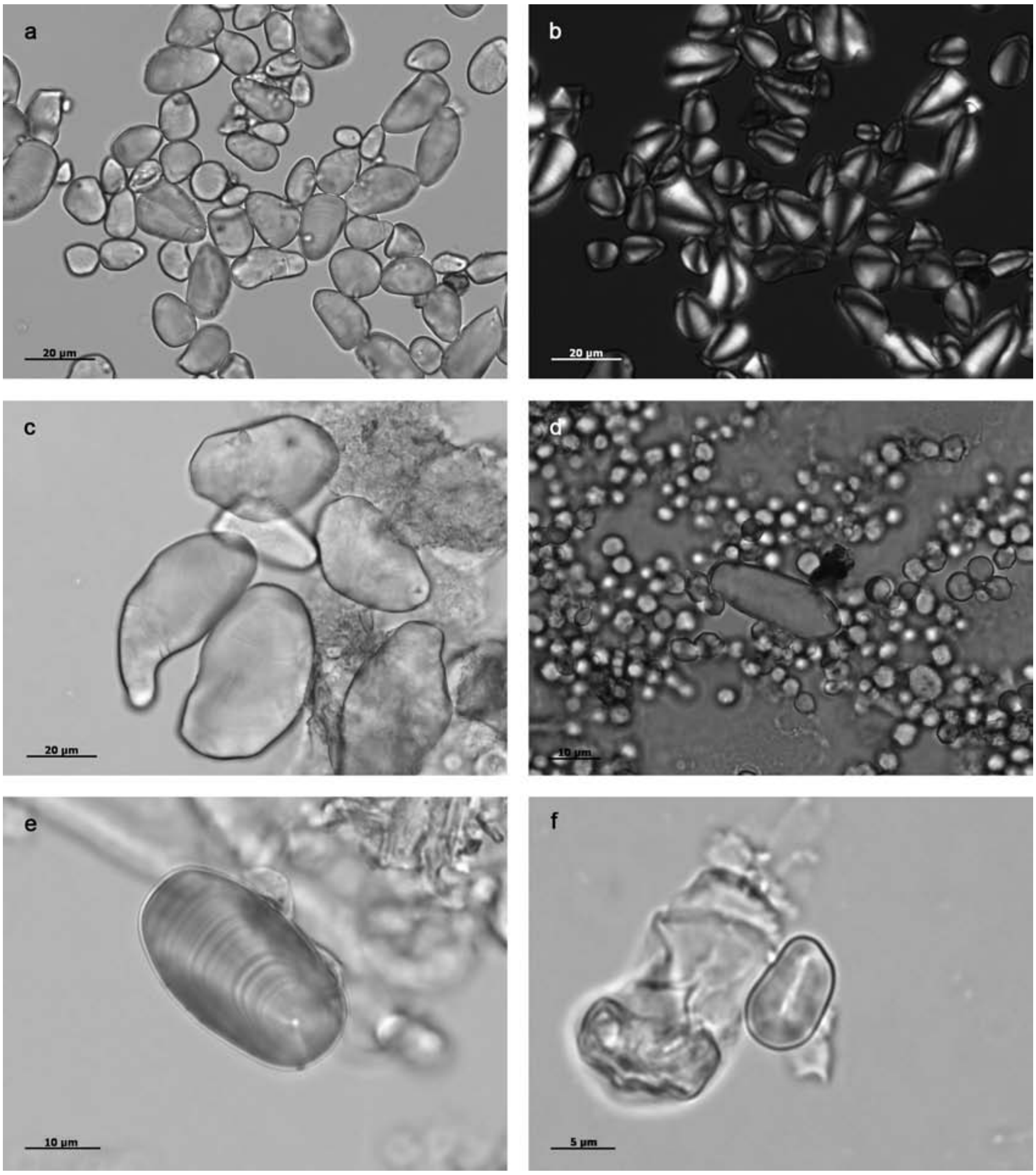

Figure 9. (a and b) *Musa banksii* (WNB10fruit). (c) *Musa acuminata x schizocarpa* (ES10fruit). (d) *Musa acuminata* var. *cerifera* (CL05190fruit) produces two distinctive starch granule forms in the fruit; a larger, ovate to elongate ovate, eccentric type and a comparatively much smaller spherical to sub-spherical, centric type. (e and f) Two starch types present in *Musa acuminata* (CL_F/03/96leaf); cf. *Heliconia dasyantha* seed (Figure 8c-d). (Scale bars in a, b and c = 20 µm; d and e = 10 µm; f = 5 µm).

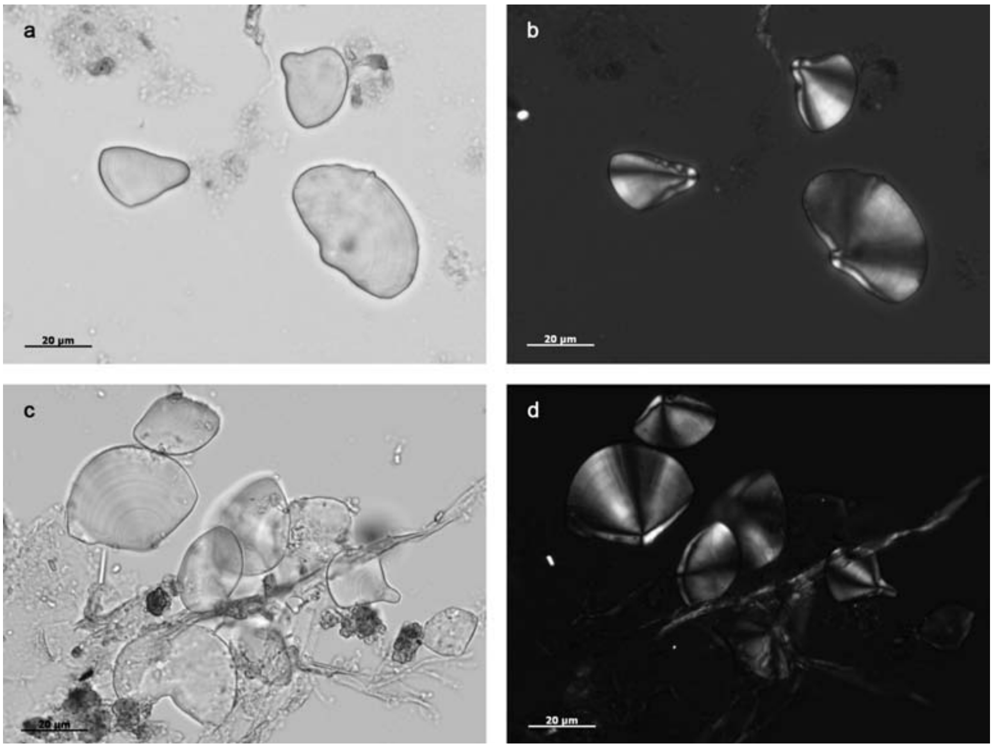

Figure 10. (a and b) *Musa halabanensis* (CL05194corm) and (c and d) *Musa sanguinea* both produce similar types of very distinctive, 'conical-bivalve' granules which may be diagnostic (scale bars = 20 µm).

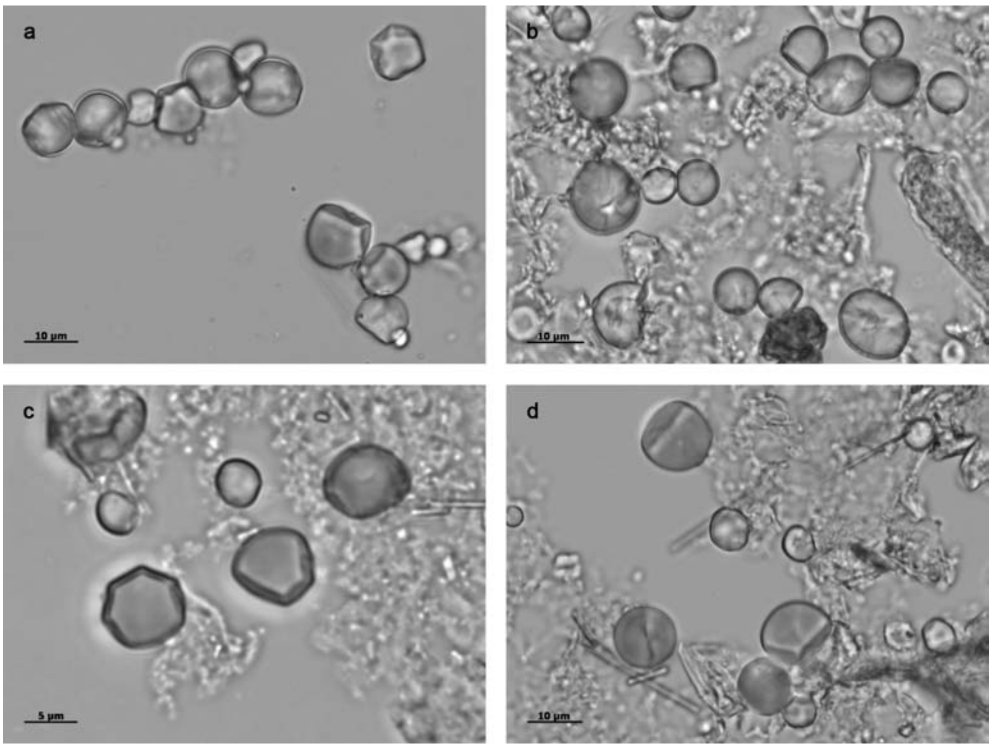

Figure 11. (a) *Pandanus dubius* (CL05341wood). (b) *Pandanus* sp. maluka (CL05140wood). (c and d). *Pandanus furcatus* (CL05131wood) (scale bars in a, b and d = 10 µm; c = 5 µm).

Table 3. Plants and plant parts that have been examined in the first stage of the analysis

Accession No.	Species	Plant Part
Araceae		
7075	*Acorus calamus*	lf,st,rz,rt
5016	*Aglaonema marantaifolia*	pet,lf,st,rt
5038	*Aglaonema novoguineense*	pet,lf,st,rt
5013	*Aglaonema oblanceotam*	pet,lf,st,rt
5014	*Aglaonema pictum*	pet,lf,st,rt
5015	*Aglaonema simplex*	pet,lf,st,rt
NC	*Aglaonema sp.*	lf,cm,rt
5022	*Alocasia alba*	lf,st,rt
48	*Alocasia culcullata*	st
18	*Alocasia denudata*	st,cm
5020	*Alocasia gigantea*	lf,cm,sd
5021	*Alocasia macrorrhizos* var. *diversifolia*	lf
5023	*Alocasia macrorrhizos* var. *diversifolia*	pet,st,fl
NC	*Alocasia macrorrhizos*	lf,st,cm,rt
58	*Alocasia princeps*	cm
NC	*Alocasia* sp. ‘elephant ear’	st,rt
5019	*Amorphophallus blumei*	pet,lf,st,rt,cm,sd
6915	*Amorphophallus campunulatus*	cm
5018	*Amorphophallus variabilis*	lf,st,rt,cm,sd
5027	*Anchomanes hookeri*	pet,lf,cm,rt
NC	*Anthurium* sp.	lf,st,rt
91	Unknown	cm
5029	*Colocasia esculenta*	pet,lf,cm,rt
PM1	*Colocasia esculenta*	cm
53	*Colocasia esculenta*	cm
92	*Colocasia esculenta*	cm
6990	*Colocasia esculenta*	cm
NC	*Colocasia esculenta*	cm
5042	*Culcasia manii*	pet,lf,st,rt
694	*Cyrtosperma chamissonis*	cm
5089	*Cyrtosperma johnstonii*	pet,lf,rt,fl
5011	*Dieffenbachia amoena*	pet,lf,st,rt
5012	*Dieffenbachia arvida*	pet,lf,st,rt
NC	*Dieffenbachia exotica*	lf,st,cm,rt
5010	*Dieffenbachia howmanii*	pet,lf,st,rt
5009	*Dieffenbachia splendens*	pet,lf,st,rt
5028	*Dracontium gigas*	pet,cm,rt
5032	*Homalomena cordata*	pet,rt
5033	*Homalomena cordata*	pet,lf,st,rt
NC	*Homalomena* sp.	lf,st
5037	*Homalomona humilis*	pet,lf,st,rt,fl
5039	*Homalomona pendula*	pet,st,rt
NC	*Monstera deliciosa*	lf,rt
5030	*Philodendron gloriosum*	pet,lf,st,rt
NC	*Philodendron selloum*	lf,cm,rt
NC	*Raphidophora* sp.	lf,st,rt
5031	*Rhodospathia latifolia*	pet,lf,st
5034	*Schismatoglottis lancifolia*	pet,lf,st,rt,fr,
5035	*Schismatoglottis neoguineensis*	pet,st,rt
5036	*Schismatoglottis pumila*	pet,lf,st,rt
5040	*Schismatoglottis rupestrius*	pet,lf,st,rt,fl
5045	*Scindapsus pictus*	pet,lf,st,rt
5043	*Spathiphyllum commulatum*	pet,lf,st,rt,fl

NC	*Spathiphyllum* sp.	lf,cm,rt
NC	*Spathiphyllum* sp.	lf,tb,rt
NC	*Syngonium* sp.	lf,rt,st
5026	*Xanthosoma hastifolium*	pet,lf,st,cm,rt
5024	*Xanthosoma nigrum*	st,cm
5025	*Xanthosoma sagittifolium*	lf,st,pet
692	*Xanthosoma sagittifolium*	cm
Dioscoreaceae		
698	*Dioscorea alata*	tb
5088	*Dioscorea alata*	lf,st,pet,tb
7062	*Dioscorea alata*	lf
5086	*Dioscorea bulbifera*	pet,lf,st,blbl,tb,rt
6914	*Dioscorea bulbifera*	tb
697	*Dioscorea esculenta*	lf,st,pet,tb
6918	*Dioscorea esculenta*	tb
696	*Dioscorea esculenta*	tb
5087	*Dioscorea hispida*	pet,tb,rt
7060	*Dioscorea hispida*	pet,tb,sk
6913	*Dioscorea nummularia*	st
6912	*Dioscorea pentaphylla*	st
6910	*Dioscorea rotundata*	st
F/03/22	*Dioscorea* sp.	lf,st,tb
F/03/17	*Dioscorea* sp.	lf,st,tb
F/03/04	*Dioscorea* sp.	lf,tb
NC	*Dioscorea* sp.?	tb
6911	*Dioscorea trifida*	st
Heliconiaceae		
5197	*Heliconia caribea*	lf,psst,rt,fl
5196	*Heliconia collinsiana*	lf,psst,cm,rt
5288	*Heliconia dasyantha*	lf,psst,cm,fl,fr,sd
5287	*Heliconia indica*	lf,cm,rt,fl,fr
Musaceae		
MB1	*Ensete glaucum*	fr,sd
F/03/13	*Musa* AAA	psst,cm,rt,fr
F/03/96	*Musa acuminata*	lf,st
ES6	*Musa acuminata* ssp. *banksii*	fr
M7	*Musa acuminata* ssp. *banksii*	lf,psst,cm,fl,fr,sk,sd
ES11	*Musa acuminata* ssp. *banksii*	lf,psst,cm,fr,sk,sd
M8	*Musa acuminata* ssp. *banksii x schizocarpa*	lf,br,fl,fr,sk,sd
5190	*Musa acuminata* var. *cerifera*	lf,psst,cm,rt,fl,fr
ES10	*Musa acuminata* var. *schizocarpa*	fr,sd
ES10	*Musa acuminata x schizocarpa*	br,psst,fr,sk,sd
WNB10	*Musa banksii*	fr,sk,sd
5195	*Musa borneensis*	lf,psst,cm
NI14	*Musa* Fe'i	fr,sd
ES5	*Musa* Fe'i	fr
5194	*Musa halabanensis*	lf,psst,cm
WH1	*Musa ingens*	lf,rs,psst,rt,fl,fr
WH2	*Musa ingens*	psst,fl,fr,sk,sd
WH3	*Musa ingens*	sd
MB3	*Musa maclayi*	lf,psst,fr,sd
MB5	*Musa maclayi*	lf,br,psst,fl,fr,sk
5193	*Musa ornata*	lf,rt,cm
M5	*Musa peekeli*	lf,br,psst,sk,sd
M5	*Musa peekelii* ssp. *angustigemma*	fr
5192	*Musa salaccensis*	lf,psst,cm,rt
5191	*Musa sanguinea*	lf,psst,cm,rt,fl,fr
M4	*Musa schizocarpa*	lf,psst,fl,sd

MB2	*Musa schizocarpa*	lf,br,psst,fl,fr,sk
ES3	*Musa schizocarpa*	fr,sk
ES5	*Musa schizocarpa*	sd
ES4	*Musa schizocarpa*	fr,sk,sd
7106	*Musa* sp.	pet,lf,psst,rt
NC	*Musa* sp. 'halevudi'	lf,psst
5175	*Musa velutina*	lf,rt,fr,sk,sd
F/03/90	*Musa velutina?*	rt,fl,fr
NC	*Strelitzia reginae*	fr
Palmae		
7010	*Areca catechu*	fr
5162	*Arenga brevipes*	lf,wd,rt
5149	*Arenga obtusifolia*	rs
5156	*Arenga pinnata*	wd,rt
7013	*Arenga pinnata*	fr,sd
F/03/24	*Arenga pinnata?*	wd
5154	*Arenga tremula*	lf,rs,wd
5155	*Arenga undulatifolia*	lf,wd,rt
5187	*Borassus flabellifer*	wd,rt,sd
F/02/38	*Calamus javensis*	st
5158	*Caryota cummungli*	rs,wd,ped,fr,rt
5179	*Caryota intis*	rs,rt,sd
5160	*Caryota rumphiana*	wd
5177	*Cocos nucifera*	rs,wd
7097	*Corypha utan*	wd
5157	*Cyrtostachys microcarpa*	lf,rs,wd,rt
5184	*Cyrtostachys renda*	wd
5178	*Elaesis guineensis*	fr
5150	*Eugeissona utilis*	lf,rs,wd,rt,fr
5161	*Licuala rumphii*	rt
5183	*Licuala spinosa*	rs,wd,rt
5148	*Livistonia hasseltii*	sd,st
5176	*Metroxylon sagu*	pet,lf,wd,rt
5186	*Nypa fruticans*	lf,rs,fr
5159	*Oncosperma tigillarium*	rs,rt
5151	*Phoenix* sp.	rs,wd
5145	*Pinanga coronata*	wd,rt,fr
7102	*Pinanga coronata*	pet,lf,ped,wd,bk
5146	*Ptychosperma macarthii*	lf,wd,rt,fl
5153	*Ptychosperma propinquum*	wd
5182	*Salacca affinis*	lf,rs,wd,rt
5168	*Salacca zalacca*	sd
5181	*Salacca zalacca*	rs,wd,fr
5147	*Verschaffeltia splendida*	wd
Pandanaceae		
7084	*Freycinetia insignis*	lf,wd,fr
F/02/54	*Freycinetia* sp.	lf
5136	*Pandanus affinis*	lf,wd,rt
5341	*Pandanus dubius*	lf,wd
5131	*Pandanus furcatus*	lf,pet,wd,rt
5143	*Pandanus kurzii*	rt
5135	*Pandanus multifurcatus*	pet,lf,st,wd
5123	*Pandanus nitidus*	pet,lf,st,rt
5124	*Pandanus papilio*	pet,lf,st,rt
5142	*Pandanus polycephalus*	pet,lf,wd,fr,sd
5139	*Pandanus pygmaeus*	lf,wd,rt
5145	*Pandanus* sp.	lf,wd,rt,fr,sd
5140	*Pandanus* sp.	lf,wd,rt

5137	*Pandanus* sp.	pet,lf,wd,rz,fr
5120	*Pandanus* sp.	pet,lf,st
5134	*Pandanus* sp.	pet,lf,wd,rt,fr,sd
5121	*Pandanus* sp.	pet,lf,st,rt,rt
5144	*Pandanus* sp.	pet,lf,st,wd
F/03/92	*Pandanus* sp.	rt
F/03/067	*Pandanus* sp.	st
5333	*Pandanus* sp.	pet,lf,st,rt,fr,sd
7099	*Pandanus* sp.	lf,st,wd,rt
5122	*Pandanus* sp.	pet,lf,st,rt
5132	*Pandanus* sp.	pet,lf,wd,rt
5138	*Pandanus tectorius*	lf,wd,rz,rt
7004	*Pandanus tectorius*	lf
F/03/02	*Pandanus* sp.	rt
Zingiberaceae		
5063	*Alpinia katsumadai*	pet,st,rz,fr,sd
5063	*Alpinia katsumadai*	lf
5059	*Alpinia romburghiana*	pet,lf,st,rz,rt
5052	*Alpinia schumannia*	pet,lf,st,rz,fl
5052	*Alpinia schumannia*	ped
5060	*Alpinia speciosa/zerumbet*	st,rz
5057	*Amomum aculeatum* var. *sulianum*	pet,st,rz,rt,fl
5211	*Amomum compactum*	st
5066	*Amomum compactum*	pet,rz,rt
5053	*Amomum lappaceum*	pet,lf,rz
5050	*Amomum meglalochellos*	pet,lf,st,rz,fl
5065	*Amomum truncatum*	st,rz
5062	*Catimbium malaccensis*	st,rz
5064	*Catimbium speciosum*	lf,st,rz
5075	*Costus afer*	lf,st,rz,rt
5079	*Costus discolor*	st,rz
5051	*Costus lucanusianus*	pet,st,rz,rt,fl
5077	*Costus malortianus*	pet,lf,st,rz,rt,fl
5080	*Costus megalobrachtea*	rt
5048	*Costus mexicanus*	pet
5073	*Costus niveus*	rz
5073	*Costus niveus*	pet,st
5074	*Costus rumphianus*	st,rz
5078	*Costus speciosus*	rz,rt
5076	*Costus spiralis*	fl
5079	*Costus villosissimus*	pet,lf,st,rz,rt
F/03/96	*Cucurma* sp.	lf,st,rz,rt
7063	*Cucurma viridiflora*	pet,st,rz,rt
7073	*Cucurma zedoaria*	lf,rz,rt
5055	*Curcuma aeroginosa*	pet,lf,rz,rt
5061	*Curcuma longa*	pet,sr,rz,rt
5056	*Curcuma longa*	st,rz,rt
5083	*Curcuma roscoeana*	lf,st
5205	*Curcuma zedoaria*	pet,rt
5069	*Etlingera elattior*	st,rz
7074	*Globba marantina*	lf,st,rz,rt
5047	*Hedychium coronarium* var. *flavescens*	pet,rz,rt
5084	*Hedychium elatum*	pet,st,rz,fl
581	*Hedychium poccineum*	lf,st
5082	*Hedychium poccinium*	pet,rz,rt
5046	*Hedychium roxburghii*	pet,lf,st,rz,rt
5046	*Hedychium roxburghii*	pet,lf,st,rz,rt
5067	*Hornstedtia minor*	pet,lf,st,rz,rt
7059	*Kaempferia galanga*	lf,st,rz

5058	*Languas galanga*	pet,lf,st,rz,rt
7057	*Languas galanga*	lf,st,rz,rt
5071	*Tapeinocheilos ananassae*	lf,st,rz,fl,sd
5070	*Tapeinocheilos punglus*	pt,st,rz
5070	*Tapeinocheilos purgus*	pet,lf,rz,rt
5200	*Zingiber aromaticum*	pet,lf,st,rz,rt
5054	*Zingiber gramineum*	pet,rz
5054	*Zingiber gramineum* var. *robustum*	pet,lf,st,rz,rt
7049	*Zingiber oderatum*	pet,lf
5049	*Zingiber odoriferum*	pet,lf,st,rz,rt
NC	*Zingiber officinale*	rz
5201	*Zingiber ottensi*	rz,rt
7077	*Zingiber* sp.	lf,rz,rt
F/03/32	Unknown	rz
WNB	Unknown	fl,rz

KEY: br (bract), blbl (bulbil), cm (cm), fl (flower, fr (fruit), lf (leaf), ped (peduncle),pet (petiole), psst (pseudostem), rs (rachis), rt (root), rz (rhizome), sd (seed), sk (skin), st (stem), tb (tuber)

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