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From Domestication Histories to Regional Prehistory: Using Plants to Re-evaluate Early and Mid-Holocene Interaction between New Guinea and Southeast Asia

Abstract

*Emerging records of plant distributions and domestications for three carbohydrate-rich plants indicate highly complex histories of social interaction between New Guinea and Island Southeast Asia during the early and mid-Holocene. Phytogeographic, morphological, molecular and archaeobotanical evidence suggests variable histories of domestication: for *Musa bananas* is complex and involved inter-regional hybridisation between species and subspecies; for taro (*Colocasia esculenta*) suggests regional isolation of wild populations and separate domestications; and, for the greater yam (*Dioscorea alata*) is suggestive of initial domestication of an unknown wild-type in the New Guinea region with subsequent widespread dispersal of sterile clones.*

Keywords

*New Guinea
Island Southeast Asia
Domestication history
Social interaction
Banana (*Musa spp.*)
Taro (*Colocasia
esculenta*)
Greater yam
(*Dioscorea alata*)*

Introduction

Although requiring refinement, existing evidence suggests that agriculture was practiced in the highlands of New Guinea by at least 7000-6500 years ago; while some advocate an earlier date of c. 10,000 years ago.¹ Early agriculture

¹ Tim P. DENHAM, Simon G. HABERLE et al., "Origins of agriculture at Kuk Swamp in the Highlands of New Guinea", *Science*, vol. 301 (2003), pp. 189-193; Tim P. DENHAM, Jack GOLSON, Philip J. HUGHES, "Reading early agriculture at Kuk (Phases 1-3), Wahgi Valley, Papua New Guinea: the wetland archaeological features", *Proceedings of the Prehistoric Society*, vol. 70

in highland New Guinea was, and practices still are, based on the exploitation and cultivation of plants with widely varying degrees of domestication.² For example, some species of tree, shrub and herb are still transplanted or propagated into cultivated plots from wild or feral stock; whereas other species, including some sterile or parthenocarpic varieties, are only propagated from cultivated stock. As well as an enormous range of plants exploited for food and other uses, there are great diversities in crop combinations and practices through which plants are exploited and cultivated across New Guinea today.³

Most food plants in New Guinea have not been subject to intensive botanical, ethnobotanical or genetic, let alone archaeobotanical, study. But even for the exceptions, classifications to species level can be uncertain and contested. For example, relatively extensive research has been undertaken on *Pandanus*, several species of which are exploited for food, building materials, ornaments, among other uses.⁴ Species classifications and domesticatory relationships of different types of highland *Pandanus*, or *karuka* in New Guinea pidgin, are questionable.⁵ The lack of botanical clarity for modern members of the high-altitude *P. julianettii/iwen/brosimos* complex, particularly uncertainties regarding the domesticatory status of its members, hinders any attempt to infer the domestication of *karuka* through time from archaeobotanical assemblages.⁶

Against these backdrops of diversity and uncertainty, some carbohydrate-rich plants that are important staple crops in New Guinea have been subject to intensive botanical, phytogeographic and genetic analysis. These plants

(2004), pp. 259-298; Jack GOLSON, "No room at the top: agricultural intensification in the New Guinea Highlands", in J. ALLEN, J. GOLSON, R. JONES (eds.), *Sunda and Sabul: prehistoric studies in southeast Asia, Melanesia and Australia* (London, 1977), pp. 601-638; Jack GOLSON, Philip J. HUGHES, "The appearance of plant and animal domestication in New Guinea", *Journal de la Société des Océanistes*, vol. 36 (1980), pp. 294-303; Geoffrey S. HOPE, Jack GOLSON, "Late Quaternary change in the mountains of New Guinea", *Antiquity*, vol. 69 (1995), pp. 818-830; see debates in Tim P. DENHAM, Simon G. HABERLE, Carol LENTFER, "New evidence and interpretations for early agriculture in Highland New Guinea", *Antiquity*, vol. 78 (2004), pp. 839-857.

² Javier CABALLERO, *Patterns in human-plant interaction: an evolutionary perspective* (Paper presented at the International Society of Ethnobiology, Ninth International Congress, Canterbury, 2004).

³ Jocelyn M. POWELL, "Vegetation", in K. PAIJMANS (ed.), *New Guinea vegetation* (Canberra, 1976), pp. 23-105; Christin KOCHER SCHMID, *Of people and plants* (Basel, 1991); Jean KENNEDY, William CLARKE, *Cultivated landscapes of the Southwest Pacific, RMAP Working Paper 50* (Canberra, 2004).

⁴ Benjamin C. STONE, 1982, "New Guinea Pandanaceae: first approach to ecology and biogeography" in J.L. GRESSITT (ed.), *Biogeography and ecology of New Guinea* (The Hague, 1982), pp. 401-436.

⁵ Carolyn D. COOK, "Pandanus agroforestry of the Amungme in Irian Jaya, Indonesia", *Forest, Farm, and Community Tree Research Reports*, vol. 4 (1999), pp. 95-103.

⁶ For example Debra DONOGHUE, "Carbonised plant fossils", in W. BECK, A. CLARKE, L. HEAD (eds.), *Plants in Australian Archaeology* (St. Lucia, 1989), pp. 90-100.

tend to be important food or economic plants in other regions, including the Pacific, Southeast Asia and Africa. Staples include bananas (*Musa* spp., especially those of *Eumusa* section), taro (*Colocasia esculenta*) and the greater yam (*Dioscorea alata*). Significantly, traditional claims for the domestication of these plants in Southeast Asia have been supplemented by more recent claims for their domestication in the New Guinea region; these latter claims have received some archaeobotanical corroboration.⁷

In this paper, claims for the domestication of three carbohydrate-rich staple crops in the New Guinea region, and the multi-disciplinary evidence upon which they rest, are reviewed. These emerging plant histories shed light on the long and, in some cases, ongoing processes of domestication for these staples, which in turn reveal complex histories of inter-regional interaction. At present, archaeological traces of inter-regional interaction between New Guinea and Southeast Asia during the early and mid-Holocene are sparse and contested. By contrast, some domestication histories provide more definitive and robust evidence of inter-regional interaction at this time, as well as upon its complex and selective nature.

Chronological frameworks and archaeological deficiencies

Initial colonisation of Australia and New Guinea occurred by sea from Indo-Malaysia at least 45,000 years ago.⁸ At this time of lower sea levels, Australia and New Guinea formed one land mass. Initial colonisation of the Bismarck Archipelago, comprising the major islands of New Britain, New Ireland and New Hanover off the north coast of New Guinea, may also have occurred by approximately 40-39,000 years ago.⁹

A second major colonisation event is thought to have occurred after 3500 years ago with the arrival of Austronesian language-speakers to the region.¹⁰ The ancestry of these colonisers, considered to be agriculturalists with their

⁷ Reviewed by Vincent LEBOT, "Biomolecular evidence for plant domestication in Sahul", *Genetic Resources and Crop Evolution*, vol. 46 (1999), pp. 619-628; Vincent LEBOT, "La domestication des plantes en Océanie et les contraintes de la voie asexuée", *Journal de la Société des Océanistes*, vols. 114-115 (2002), pp. 45-61; corroborated by Tim P. DENHAM, Simon G. HABERLE et al., "Origins of agriculture...", pp. 189-193; Tim P. DENHAM, Jack GOLSON, Philip J. HUGHES, "Reading early...", pp. 259-298; Richard FULLAGAR, Judith FIELD et al., "Early and mid-Holocene processing of taro (*Colocasia esculenta*) and yam (*Dioscorea* sp.) at Kuk Swamp in the Highlands of Papua New Guinea", *Journal of Archaeological Science*, vol. 33 (2006), pp. 595-614.

⁸ For example James F. O'CONNELL, Jim ALLEN, "When did humans first arrive in Greater Australia and why is it important to know?", *Evolutionary Anthropology*, vol. 6 (1998), pp. 132-146.

⁹ Matthew G. LEAVESLEY, Michael I. BIRD et al., "Buang Merabak: early evidence for human occupation in the Bismarck Archipelago, Papua New Guinea", *Australian Archaeology*, vol. 54 (2002), pp. 55-57.

¹⁰ Matthew SPRIGGS, *The Island Melanesians* (Oxford, 1997), pp. 67-151.

own distinctive languages, crop assemblages and cultural repertoire, has been traced to Southeast China or Taiwan.¹¹ In the Bismarck Archipelago, these colonisers are often considered to have spawned the Lapita cultural complex marked by a distinctive pottery type.¹²

Apart from highly contested archaeological finds, such as pigs (*Sus scrofa*) and pottery, inter-regional interaction between New Guinea and Southeast Asia before 3500 years ago has primarily been inferred from linguistic and genetic comparisons and *a priori* maritime reconstructions.¹³ Other archaeological evidence for “pre-Austronesian” interaction awaits verification, or has proven erroneous, such as claims for 6800-6400 year-old betel nut (*Areca catechu*) at Dongan, which was redated to modern.¹⁴

Characterisations of the intervening period between initial and “Austronesian” colonisations, i.e. pre c.3500 years ago, infer variable degrees and frequencies of contact between New Guinea and islands of the Indo-Malaysian archipelago to the west.¹⁵ By contrast, intra-regional connectivity and interaction certainly occurred during the Pleistocene between New Guinea and islands off its north coast, as well as among those islands - including Manus, the Bismarck Archipelago and the Solomon Islands. These contacts are variably witnessed through archaeological evidence of trade in obsidian, translocation of marsupials, and movement of plants.¹⁶ Similar regional connectivity continued into the Holocene.¹⁷

¹¹ Peter BELLWOOD, *Prehistory of the Indo-Malaysian Archipelago* (Honolulu, 1997), pp. 201-254; Peter BELLWOOD, *First farmers* (Oxford, 2005), pp. 128-145; see Mark DONOHUE, Tim DENHAM, “Farming and language in Island Southeast Asia: Reframing Austronesian history”, *Current Anthropology*, (in press).

¹² For example Patrick V. KIRCH, *The Lapita peoples* (Oxford, 1997).

¹³ Roger C. GREEN, “Comment” in “Foregone conclusions? In search of ‘Papuaans’ and ‘Austronesians’” by J.E. TERRELL, K.M. KELLY, P. RAINBIRD, *Current Anthropology*, vol. 42 (2001), pp. 97-124; Geoff J. IRWIN, *The prehistoric exploration and colonisation of the Pacific* (Cambridge, 1992).

¹⁴ Pamela SWADLING, Nick ARAHO, Baiva IVUYO, “Settlements associated with the inland Sepik-Ramu Sea”, *Bulletin of the Indo-Pacific Prehistory Association*, vol. 11 (1991), pp. 92-110; Andrew FAIRBAIRN, Pamela SWADLING, “Re-dating mid-Holocene betelnut (*Areca catechu* L.) and other plant use at Dongan, Papua New Guinea”, *Radiocarbon*, vol. 47 (2005), pp. 377-382.

¹⁵ See Jack GOLSON, “Introduction to the chapters on archaeology and ethnology”, in A. PAWLEY, R. ATTENBOROUGH et al. (eds.), *Papuan pasts: Cultural, linguistic and biological histories of Papuan-speaking peoples* (Canberra, 2005), pp. 221-224; and references therein for a recent review.

¹⁶ Glenn R. SUMMERHAYES, Jim ALLEN, “The transport of Mopir obsidian to late Pleistocene New Ireland”, *Archaeology in Oceania*, vol. 28 (1993), pp. 144-148; Glenn R. SUMMERHAYES, “The rocky road: the selection and transport of Admiralties obsidian to Lapita communities”, *Australian Archaeology*, vol. 57 (2003), pp. 135-142; Matthew SPRIGGS, *The Island Melanesians*, pp. 53-54; Douglas E. YEN, “Subsistence to commerce in Pacific agriculture: some four thousand years of plant exchange” in H.D.V. PENDERGAST, N.L. ETKIN et al. (eds.), *Plants for food and medicine* (Kew, 1998), pp. 161-183.

¹⁷ For example Nick ARAHO, Robin TORRENCE, J. Peter WHITE, “Valuable and useful: mid-Holocene stemmed obsidian artefacts from West New Britain, Papua New Guinea”, *Proceedings of the Prehistoric Society*, vol. 68 (2002), pp. 61-81; Pamela SWADLING, Robin

Given the lack of definitive archaeological evidence, the New Guinea region has been considered relatively isolated from Southeast Asia until c. 3500 years ago. However, domestication histories for major staples show that the absence of evidence is an archaeological deficiency and does not necessarily represent an absence of interaction.¹⁸

Plant domestication and early agriculture in New Guinea

Traditional views

Agriculture in New Guinea was traditionally considered to have diffused from a centre of domestication, or hearth, in Southeast Asia.¹⁹ New Guinea is absent from Hawkes' consideration of crop plant origins and half of the island is excluded from Zhukovsky's gene megacenters of cultivated plants, which cover most of the non-polar globe.²⁰ In such studies, phytogeographic methods were applied to elicit the originating locus of crop plants, domestication and agriculture:

“... to know where each crop originated and where to find the geographical centres, whether a given crop is associated with wild species, and when the innumerable types arose that eventually produced cultivated crops.”²¹

Crop plants and agricultural technology were considered to have diffused away from these primary centres or hearths, ie, from Southeast Asia to New Guinea.²²

Formerly, most of the principal staple crops of present-day New Guinean agronomic systems were considered introductions. Sweet potato (*Ipomoea batatas*) and cassava/manioc (*Manihot esculenta*) are post-Colombian introductions from South America. Taro (*C. esculenta*), greater yam (*Dioscorea alata*) and Eumusa bananas (*Musa* spp.) were presumed to be

HIDE, “Changing landscape and social interaction: looking at agricultural history from a Sepik-Ramu perspective” in A. PAWLEY, R. ATTENBOROUGH et al. (eds.), *Papuan pasts: Cultural, linguistic and biological histories of Papuan-speaking peoples* (Canberra, 2005), pp. 289-328; Robin TORRENCE, Pamela SWADLING, “Social networks and the spread of Lapita”, *Antiquity* vol. 82 (2008), pp. 600-616.

¹⁸ Chris GOSDEN, “Production systems and the colonisation of the Western Pacific”, *World Archaeology*, vol. 24 (1992), pp. 55-69; Jean KENNEDY, William CLARKE, *Cultivated landscapes...*, pp. 8-10, 22-27.

¹⁹ Carl O. SAUER, *Agricultural origins and their dispersals* (New York, 1952), p. 24; Nikolai I. VAVILOV (D. LÖVE (ed.)), *Origin and geography of cultivated plants* (Cambridge, 1992), pp. 127, 430.

²⁰ John G. HAWKES, *The diversity of crop plants* (Cambridge, Massachusetts, 1983); Pyotr M. ZHUKOVSKY, *Cultivated plants and their wild relatives* (Farnham Royal, 1962).

²¹ Nikolai I. VAVILOV (D. LÖVE (ed.)), *Origin and geography...*, p. 14.

²² Carl O. SAUER, *Agricultural origins...*, p. 3.

introduced Southeast Asian or Indo-Malaysian domesticates.²³ Other significant staples were presumed to originate or have been domesticated in New Guinea, including Australimusa bananas (*Musa* spp.), sago (*Metroxylon sagu*), sugarcane (*Saccharum officinarum*) and, potentially, coconut (*Cocos nucifera*).²⁴

Interpretations of origin and domestication were largely based on phylogeographic identifications of the centres of greatest genetic diversity, away from which diffusion was inferred to have occurred, and the presence of ancestral wild forms from which domesticated forms arose.²⁵ However, and following De Candolle, the greatest abundance of diversity alone is no proof of antiquity; the determination of origin requires the elimination from consideration of all artificial forms.²⁶

A new perspective

During the 1970s, multi-disciplinary research in New Guinea was beginning to document several lines of evidence suggestive of independent plant domestication, landscape modification concomitant with agricultural practices, and archaeological evidence of early and mid-Holocene agriculture.²⁷ Initially, early agricultural activities were thought to be of ultimate Southeast Asian origin and to be based, in part, on an introduced Southeast Asian suite of staple crops, including taro, the greater yam and *Eumusa* bananas, supplemented by indigenous New Guinea domesticates.²⁸

²³ Isaac H. BURKILL, *A dictionary of the economic products of the Malay Peninsula* (2 vols., London, 1935); Donald G. COURSEY, "The civilizations of the yam: interrelationships of man and yams in Africa and the Indo-Pacific region", *Archaeology and Physical Anthropology in Oceania*, vol. 7 (1972), pp. 215-233; Robert H. STOVER, Norman W. SIMMONDS (eds.), *Bananas* (3rd ed., Harlow, 1987).

²⁴ Norman W. SIMMONDS, "Bananas: *Musa* (Musaceae)" in N.W. SIMMONDS (ed.), *Evolution of crop plants* (London, 1976), pp. 211-215; Jacques BARRAU, *Subsistence agriculture in Melanesia* (New Caledonia, 1955), p. 46; Norman W. SIMMONDS, "Sugarcanes: *Saccharum* (Gramineae-Andropogoneae)" in N.W. SIMMONDS (ed.), *Evolution of crop plants* (London, 1976a), pp. 104-108; Hugh C. HARRIES, "Malesian origin for a domestic *Cocos nucifera*", in P. BAAS, K. KALKMAN, R. GEESINK (eds.), *The plant diversity of Malesia: Proceedings of the Flora Malesiana Symposium commemorating Prof. Dr. C.G.G.J. van Steenis, Leiden, August 1989* (Dordrecht, 1990), pp. 351-357.

²⁵ For reviews see Douglas E. YEN, "Wild plants and domestication in Pacific islands" in V.N. MISRA, P. BELLWOOD (eds.), *Recent advances in Indo-Pacific prehistory* (New Delhi, 1985), pp. 315-326; Douglas E. YEN, "Domestication: the lessons from New Guinea" in A. PAWLEY (ed.), *Man and a half: Essays in Pacific anthropology and ethnobiology in honour of Ralph Bulmer* (Auckland, 1991), pp. 558-569.

²⁶ Alphonse De CANDOLLE, *Origin of cultivated plants* (London, 1884), p. 13.

²⁷ Douglas E. YEN, "The origins of Oceanic agriculture", *Archaeology and Physical Anthropology in Oceania*, vol. 8 (1973), pp. 68-85; Jocelyn M. POWELL, *The impact of man on the vegetation of the Mount Hagen region, New Guinea* (Ph.D. thesis, Australian National University, 1970); Jack GOLSON, "No room at...".

²⁸ Jack GOLSON, Philip J. HUGHES, "The appearance of...".

By the early 1990s, arguments had changed; New Guinea was proposed as an early and independent centre of agricultural development.²⁹ These revisions were based on three principal lines of evidence: the antiquity and archaeology of the earliest agricultural practices in the highlands of New Guinea, new crop plant histories, and palaeoenvironmental records of landscape transformation.³⁰

From the late 1990s, and in part triggered by critiques, I undertook new multi-disciplinary research to assess and augment the archaeological, archaeobotanical and palaeoecological records of early agriculture in highland New Guinea.³¹ Earlier claims were confirmed: agriculture was practiced in the highlands by at least 7000-6500 years ago and New Guinea was a centre of early and independent agricultural development.³² At the same time, advances in plant genetics began to identify New Guinea as a centre of origin and domestication for a number of domesticates important in Pacific agriculture, as well as in Southeast Asia and beyond.³³

More recently, I have questioned the idea of “independent agricultural development” in New Guinea because it is predicated on regional isolation during the Pleistocene and early and mid-Holocene.³⁴ My questioning does not negate claims for early agriculture or plant domestication in New Guinea, but interrogates what the term “independent” means in a world of interaction with Southeast Asia. This re-evaluation has been inspired by the domestication histories for several major staple crops.

²⁹ Jack GOLSON, “The New Guinea Highlands on the eve of agriculture”, *Bulletin of the Indo-Pacific Prehistory Association* vol. 11 (1991), pp. 82-91.

³⁰ Simon G. HABERLE, “Anthropogenic indicators in pollen diagrams: problems and prospects for late Quaternary palynology in New Guinea”, in J.G. HATHER (ed.), *Tropical archaeobotany: Applications and new developments* (London, 1994), pp. 172-201; Geoffrey S. HOPE, Jack GOLSON, “Late Quaternary...”; Douglas E. YEN, “The development of Sahul agriculture with Australia as bystander”, *Antiquity*, vol. 69 (1995), pp. 831-847.

³¹ Tim BAYLISS-SMITH, “People-plant interactions in the New Guinea highlands: agricultural hearthland or horticultural backwater?” in D.R. HARRIS (ed.), *The origins and spread of agriculture and pastoralism in Eurasia* (London, 1996), pp. 499-552; Matthew SPRIGGS, “Early agriculture and what went before in Island Melanesia: continuity or intrusion?” in D.R. HARRIS (ed.), *The origins and spread of agriculture and pastoralism in Eurasia* (London, 1996), pp. 524-537; Tim P. DENHAM, *The Kuk morass: multi-disciplinary investigations of early to mid-Holocene plant exploitation at Kuk Swamp, Wahgi Valley, Papua New Guinea* (Ph.D. Thesis, Australian National University, Canberra, 2003).

³² Tim P. DENHAM, Simon G. HABERLE et al., “Origins of agriculture...”, pp.189-193; Tim P. DENHAM, Jack GOLSON, Philip J. HUGHES, “Reading early...”, pp. 259-298; Katharina NEUMANN, “New Guinea: a cradle of agriculture”, *Science*, vol. 301 (2003), pp. 180-181.

³³ See reviews in Vincent LEBOT, “Biomolecular evidence...”, pp. 619-628; Vincent LEBOT, “La domestication des...”, pp. 45-61; Jean KENNEDY, William CLARKE, *Cultivated landscapes...*, pp. 8-10, 22-27.

³⁴ Tim P. DENHAM, “The roots of agriculture and arboriculture in New Guinea: looking beyond Austronesian expansion, Neolithic packages and Indigenous origins”, *World Archaeology*, vol. 36 (2004), pp. 610-620.

Domestication histories

“We need to focus research on the evolutionary history of individual crops and regional crop associations, and to adopt a more rigorous approach to the identification and dating of archaeologically-recovered plant remains.”³⁵

Over the last decade, numerous archaeological, archaeobotanical, phytogeographic and molecular studies have prompted a review of traditional interpretations regarding plant domestication in Southeast Asia and New Guinea. However, the situation is more complex than stating that those staples that were formerly considered to be introduced Southeast Asian domesticates can now be considered to be indigenous New Guinean domesticates. If the multi-disciplinary evidence of individual crop histories is examined, more complex and variable scenarios emerge. The domestication histories for some crops seem to require interaction between New Guinea and Southeast Asia during the early-and-mid Holocene, whereas those for other crops are suggestive of independent domestication with or without subsequent dispersal between regions. Below the domestication histories for three of the most important staple crops of Southeast Asia and New Guinea are considered.

Taro (*Colocasia esculenta*)

Taro is a root-crop primarily cultivated for its starch-rich corm, and its leaves are also cooked as a leafy vegetable. Taro is an important food plant in the Pacific, Melanesia and in parts of Southeast Asia, South Asia and West Africa, as well as grown for food across a vast region.

The natural range of wild type taro (*Colocasia esculenta* var. *aquatilis*), which is considered the precursor to cultivated taro (*C. esculenta*), extends from northeastern India to mainland Southeast Asia, Indonesia, New Guinea and northern Australia.³⁶ It is uncertain whether this wild type distribution, particularly in northern Australia, represents ancient biogeographic distributions, dispersal by birds, or human dispersal without cultivation.³⁷

³⁵ David R. HARRIS, “Vavilov’s concept of centres of origin of cultivated plants: its genesis and its influence on the study of agricultural origins”, *Biological Journal of the Linnean Society*, vol. 39 (1990), p. 15.

³⁶ Peter J. MATTHEWS, “Aroids and Austronesians”, *Tropics*, vol. 4 (1995), pp. 108-114.

³⁷ Rhys JONES, Betty MEEHAN, 1989, “Plant foods of the Gidjinal: ethnographic and archaeological perspectives from northern Australia on tuber and seed exploitation” in D. R. HARRIS, G. C. HILLMAN (eds.), *Foraging and farming: The evolution of plant exploitation* (London, 1989), pp. 120-135; Peter J. MATTHEWS, “A possible wild type taro: *Colocasia esculenta* var. *aquatilis*”, *Indo-Pacific Prehistory Association Bulletin*, vol. 11 (1991), pp. 69-81; Peter J. MATTHEWS, Ryohei TERAUCHI, “The genetics of agriculture: DNA variation in taro and yam” in J.G. HATHER (ed.),

Regions, such as New Guinea, with endemic species-specific, and hence co-evolved, pollinators (*Drosophilella* sp.) and pests (*Tarophagus* spp.) are likely to have had endemic wild type taro long before the arrival of modern humans.³⁸

Initial cytological and isozyme studies suggested domesticated taro arose in Southeast Asia, or northeastern India, although the greatest genetic diversity occurs in eastern Indonesia.³⁹ Taking a broader view, Matthews interpreted rDNA (ribosomal DNA) results to suggest domestication of taro over a wide region.⁴⁰ Several studies, however, point towards independent domestications of taro in Southeast Asia and New Guinea: a preliminary study of karyotypic data; RAPD (random amplified polymorphic DNA) analysis; a review of isozyme and DNA markers; and a comprehensive analysis of isozyme, morphological, ploidy, AFLP (amplified fragment length polymorphism) and physico-chemical characteristics.⁴¹ These studies clearly show that the gene pools of diploid cultivars in Southeast Asia and New Guinea, as well as potentially other regions where taro occurs naturally, are distinct, with relatively low genetic diversity within each gene pool.⁴² For example, Polynesian cultivars have a narrow genetic base derived from New Guinea and the Solomon Islands.⁴³

Other distinctions occur in ploidy levels of cultivars. Diploid cultivars are common in New Guinea and the Pacific, while diploids and triploids are common in Asia.⁴⁴ Sterile triploids enable taro populations to survive in unfavourable environments, and have been important for the human dispersal of

Tropical archaeobotany: Applications and new developments (London, 1994), pp. 251-262.

³⁸ Peter J. MATTHEWS, "Aroids and Austronesians", pp. 110-111; Peter J. MATTHEWS, "Taro planthoppers (*Tarophagus* spp.) in Australia and the origins of taro (*Colocasia esculenta*) in Oceania", *Archaeology in Oceania*, vol. 38 (2003), pp. 159-176.

³⁹ Douglas E. YEN, Jocelyn M. WHEELER, "Introduction of taro into the Pacific: the indications of chromosome numbers", *Ethnology*, vol. 7 (1968), pp. 259-267; K. M. KURVILLA, Avtar SINGH, 1981, "Karyotypic and electrophoretic studies on taro and its origin", *Euphytica*, vol. 30 (1981), pp. 405-413; Vincent LEBOT, Mallikarjuna K. ARADHYA, "Isozyme variation in taro (*Colocasia esculenta* (L.) Schott) from Asia and Oceania", *Euphytica*, vol. 56 (1991), pp. 55-66.

⁴⁰ Peter J. MATTHEWS, *The origins, dispersal and domestication of taro* (Ph.D. thesis, Australian National University, 1990).

⁴¹ David J. COATES, Douglas E. YEN, P.M. GAFFEY, "Chromosome variation in taro, *Colocasia esculenta*: implications for origin in the Pacific", *Cytologia*, vol. 53 (1988), pp. 551-560; Sally V. IRWIN, Pakieli KAUFUSI et al., "Molecular characterisation of taro (*Colocasia esculenta*) using RAPD markers", *Euphytica*, vol. 99 (1998), pp. 183-189; Vincent LEBOT, "Biomolecular evidence...", p. 624; Vincent LEBOT, Made S. PRANA et al., "Characterisation of taro (*Colocasia esculenta* (L.) Schott) genetic resources in Southeast Asia and Oceania", *Genetic Resources and Crop Evolution*, vol. 51 (2004), pp. 381-392.

⁴² Peter J. MATTHEWS, "Genetic diversity in taro, and the preservation of culinary knowledge", *Ethnobotany Research and Applications*, vol. 2 (2004), pp. 56-58; Vincent LEBOT, Made S. PRANA et al., "Characterisation of taro...", pp. 381-392.

⁴³ Vincent LEBOT, "Biomolecular evidence...", p. 624.

⁴⁴ Peter J. MATTHEWS, "Genetic diversity...", p. 58.

cultivars to regions beyond the natural range, especially to higher altitudes and latitudes. Matthews considers triploid cultivars in New Guinea to be recent introductions.⁴⁵

Although Matthews concurs with the idea of multiple domestications of taro, he does not rule out the possibility that other domestication scenarios could account for the observed phenomena.⁴⁶ He cautions that the results of molecular studies are based on cultivars, with wild type taros often being under-represented, thereby failing to fully account for the complex role of people in the dispersal of taro cultivars through history.

Archaeobotanical corroboration of these phytogeographic and molecular insights is limited for Southeast Asia and Melanesia. Claims for starch grains and raphides of taro on stone tools dating to 28-20,000 years and the early Holocene at Kilu cave in the Solomon Islands are tentative.⁴⁷ Similarly, a charred rhizome fragment dated to 24,000-22,600 years has been tentatively identified as cf. *Colocasia* elim. *esculenta* at Niah Cave on Borneo.⁴⁸ These finds suggest the exploitation of, presumably, wild type taro in the Pleistocene, which is significant given the toxicity of the plant and the need for considerable processing prior to consumption. Taro pollen grains from Lake Wanum, a lowland wetland in eastern New Guinea, confirm the presence of the plant on the island 10,000 years ago.⁴⁹ Relatively robust claims for the processing of taro have been derived from an examination of stone tools from early and mid-Holocene contexts at Kuk Swamp, an archaeological site containing evidence of early agricultural practices in highland New Guinea.⁵⁰

Although microfossil analysis, principally through starch grains, pollen, raphides and charred plant cells, can now be used to identify taro with some security, it is not possible to differentiate between wild type and domesticated, or, perhaps more correctly, cultivated taro varieties. This is not surprising given that the domestication of taro is an ongoing process.⁵¹ Despite these reservations, archaeobotanical finds contribute to an understanding of taro

⁴⁵ Ibid., p. 58.

⁴⁶ Ibid., p. 58.

⁴⁷ Thomas LOY, Matthew SPRIGGS, Stephen WICKLER, "Direct evidence for human use of plants 28,000 years ago: starch residues on stone artefacts from northern Solomon Islands", *Antiquity*, vol. 66 (1992), pp. 898-912.

⁴⁸ Huw BARTON, Victor PAZ, "Subterranean diets in the tropical rain forests of Sarawak, Malaysia", in T.P. DENHAM, J. TRIARTE, L. VRYDAGHS (eds.), *Rethinking agriculture: Archaeological and ethnoarchaeological perspectives* (Walnut Creek, 2007), pp. 50-77.

⁴⁹ Simon G. HABERLE, "Identification of cultivated *Pandanus* and *Colocasia* in pollen records and the implications for the study of early agriculture in New Guinea", *Vegetation History and Archaeobotany*, vol. 4 (1995), pp. 195-210.

⁵⁰ Richard FULLAGAR, Judith FIELD et al., "Early and mid-Holocene...", pp. 595-614; Richard FULLAGAR, Judith FIELD et al., "Stone tools and early agriculture at Kuk Swamp, Papua New Guinea" in L. LONGO, N. SKAKUN (eds.), with M. SARACINO, M. DALLA RIVA, 'Prehistoric Technology' 40 years later: *Functional studies and the Russian legacy* (Oxford, 2008), pp. 395-398.

⁵¹ Peter J. MATTHEWS, "Genetic diversity...", p. 58.

domestication for they clarify plant distributions in the distant past and show how people in different places and at different times were using and, in some sense, had begun to domesticate the plant.

In assessing how the multi-disciplinary data contribute to an understanding of the independent processes of taro domestication in Southeast Asia and New Guinea, Lebot concluded:

“The variability of cultivated taro is probably the result of some degree of genetic differentiation among wild taros due to geographical and cultural isolation of human populations at that time [i.e., the time of domestication].”⁵²

Without reproductive isolation, whether geographically or culturally determined, diploid taro populations in Southeast Asia and New Guinea would have inter-bred and inter-mixed. Similarly distinctive genepools and dual domestications are inferred for other crop plants, eg, aerial yam (*Dioscorea bulbifera*).⁵³ Thus the molecular data for taro and some other plants seem to support a scenario of geographical isolation between people living in Southeast Asia and New Guinea prior to the putative dispersal of Austronesian language-speakers c. 3500 years ago.

Greater yam (*Dioscorea alata*)

The greater yam, or water yam, is cultivated throughout the tropics, primarily for its large underground tuber. Domesticated yam species (*D. alata* and *D. esculenta*) were originally concluded to be Southeast Asian introductions to Australia and New Guinea.⁵⁴ Minor yam species were considered to be indigenous to Sahul, or the continental plate comprising Australia and New Guinea, as well as potentially other locales, including *D. bulbifera*, *D. nummularia*, *D. pentaphylla*, *D. transversa* and *D. hispida*.

The greater yam (*D. alata*) is the most widely dispersed yam species globally, although the “original geographic and wild sources are still unidentified” and only cultivars are known.⁵⁵ However, Lebot et al. concluded that morphological, enzymatic and physico-chemical characteristics were not solely the result of somatic mutation and asexual reproduction; they also reflected sexual

⁵² Vincent LEBOT, “Biomolecular evidence...”, p. 624.

⁵³ Ibid., p. 625.

⁵⁴ JOHN ALEXANDER, Donald G. COURSEY, “The origins of yam cultivation” in P. J. UCKO, G. W. DIMBLEDY (eds.), *The domestication and exploitation of plants and animals* (London, 1969), p. 417.

⁵⁵ Hodeba D. MIGNOUNA, Alexandre DANSI, “Yam (*Dioscorea* spp.) domestication by the Nago and Fon ethnic groups in Benin”, *Genetic Resources and Crop Evolution*, vol. 50 (2003), pp. 519-528; Vincent LEBOT, B. TRILLES et al., “Genetic relationships between *Dioscorea alata* L. cultivars”, *Genetic Resources and Crop Evolution*, vol. 45 (1998), p. 508.

reproduction.⁵⁶ The area within which original sexual reproduction occurred, and hence where the plant originated, is not known since molecular studies have only been undertaken on accessions of widely dispersed cultivar clones.

From the plurality of forms, Coursey proposed New Guinea as a centre of *D. alata* diversity, but a secondary centre of dispersal.⁵⁷ Intraspecific differentiation of *D. alata* cultivars on the basis of geography, morphology, isozymes or physico-chemical characteristics is limited, and, furthermore, there are few correlations among attributes.⁵⁸ For example, although *D. alata* exhibits a phenomenal degree of morphological variation, this does not have a genetic correlate.⁵⁹ Thus, the intra-specific classification of *D. alata* is problematic; the lack of clear intra-specific groupings indicates that widely dispersed cultivars are clones with a narrow genetic base.⁶⁰ This situation could change through the greater inclusion of *D. alata* accessions in genetic studies from its putative area of origin, New Guinea, the Solomon Islands and possibly Indonesia.

In the absence of clear genetic evidence, several lines of inference, or a triangulation method, can be used to assess where *D. alata* originated, which is likely to be the place of initial domestication. Firstly, AFLP-fingerprinting profiles show that *D. alata*, *D. nummularia* and *D. transversa* are closely related and that “*D. alata* may belong, together with *D. nummularia* and *D. transversa*, to a Southeast Asian-Oceanian gene pool which is rather confined to the former Sahulian and Wallacean regions”, namely, Eastern Indonesia, New Guinea and Australia.⁶¹ Secondly, several authors have proposed New Guinea as the place of origin because it is the centre of greatest genetic diversity.⁶² Thirdly, Martin and Rhodes noted that primitive cultivar types, “most bizarre and least improved types”, and most types found elsewhere occur in New Guinea.⁶³ Fourthly, “[b]ecause it [*D. alata*] flowers naturally in Melanesia, it might be assumed that its area of greatest diversity is also its area of origin”.⁶⁴ Although circumstantial, these multiple lines of evidence suggest the New Guinea region to be the place of *D. alata* origin and domestication, from which cultivar clones have dispersed widely across the globe.

⁵⁶ Vincent LEBOT, B. TRILLES et al., “Genetic relationships...”, pp. 499-509.

⁵⁷ Donald G. COURSEY, “The civilizations of...”, p. 226; Donald G. COURSEY, 1976, “Yams: *Dioscorea* spp. (Dioscoreaceae)”, in N.W. Simmonds (ed.), *Evolution of crop plants* (London, 1976), p. 71.

⁵⁸ Vincent LEBOT, B. TRILLES et al., “Genetic relationships...”, pp. 499-509; Vincent LEBOT, “Biomolecular evidence...”, pp. 624-625; Roger MALAPA, Gemma ARNAU et al., “Genetic diversity of the greater yam (*Dioscorea alata* L.) and relatedness to *D. nummularia* Lam. and *D. transversa* Br. as revealed with AFLP markers”, *Genetic Resources and Crop Evolution*, vol. 52 (2005), pp. 919-929.

⁵⁹ Roger MALAPA, Gemma ARNAU et al., “Genetic diversity...”, pp. 919-929.

⁶⁰ Vincent LEBOT, “Biomolecular evidence...”, p. 625.

⁶¹ Roger MALAPA, Gemma ARNAU et al., “Genetic diversity...”, p. 928.

⁶² Vincent LEBOT, “Biomolecular evidence...”, p. 625.

⁶³ Franklin W. MARTIN, Ann M. RHODES, “Intra-specific classification of *Dioscorea alata*”, *Tropical Agriculture (Trinidad)*, vol. 54 (1977), pp. 2, 5.

⁶⁴ Vincent LEBOT, “Biomolecular evidence...”, p. 625.

As with taro, archaeobotanical evidence is limited. Yam (*Dioscorea* spp.) residues have been identified on stone tools in Melanesia: *D. bulbifera* or *D. nummularia* from c. 10,400 year-old contexts at Balof 2 in lowland New Ireland; and, *D. alata* or *D. pentaphylla* from early Holocene contexts at Kuk Swamp in highland New Guinea.⁶⁵ In Southeast Asia, greater yam has been reported as “*Dioscorea* sp., possibly *D. alata*” from pre-40,000 year old contexts at Niah Cave on Borneo.⁶⁶ Currently *D. alata* identifications from microfossils of pre-3500 year antiquity are all tentative and await further corroboration.

Given the archaeobotanical record is largely silent regarding the origin and domestication of *D. alata*, the limited multi-disciplinary evidence suggests that cultivated *D. alata* originated in the New Guinea region, from where cloned cultivars dispersed to Southeast Asia, Africa, the Pacific and beyond.⁶⁷

Bananas (*Musa* spp.)

Bananas (*Musa* spp.) are one of the most diverse and important food plants grown in wet tropical and subtropical regions of the world, both as a commercial crop and as a subsistence staple. Bananas of genus *Musa* are primarily grown for edible fruit, whether eaten raw or cooked, although a variety of plant parts can be consumed in some varieties, including the pseudostem and starch accumulation at the base of the pseudostem. Additionally, bananas are cultivated for a variety of other uses, including fibre and fodder.⁶⁸ *Musa* spp. have been reclassified based on chromosome numbers into three sections, although the original classification into five sections is followed here, namely Eumusa, Rhodochlamys, Callimusa, Australimusa and Ingentimusa.⁶⁹ Of these sections, the most important food plants are derived from Eumusa and the following discussion is limited to them.

The domestication of bananas of section Eumusa, which is the focus here, is extremely complex and underpinned the development of nearly all banana cultivars, including such diverse cultivar groups as the African plantains and the yellow Cavendish bananas, the latter being the yellow sweet bananas

⁶⁵ Huw BARTON, Peter J. WHITE, “Use of stone and shell artefacts at Balof 2, New Ireland, Papua New Guinea”, *Asian Perspectives*, vol. 32 (1993), pp. 169-181; Richard FULLAGAR, Judith FIELD et al., “Early and mid-Holocene...”, pp. 595-614; Richard FULLAGAR, Judith FIELD et al., “Stone tools and...”, pp. 395-398.

⁶⁶ Huw BARTON, “The case for rainforest foragers: the starch record at Niah cave, Sarawak”, *Asian Perspectives*, vol. 44 (2005), p. 66.

⁶⁷ After Vincent LEBOT, “Biomolecular evidence...”, p. 625.

⁶⁸ Jean KENNEDY, “Bananas and people in the homeland of the genus *Musa*: not just a pretty fruit”, *Ethnobotany Research and Applications*, vol. 7 (in press a).

⁶⁹ Carol WONG, Ruth KIEW et al., “Assessment of the validity of the sections in *Musa* (Musaceae) using AFLP”, *Annals of Botany*, vol. 90 (2002), pp. 231-238.

that are so widely grown and consumed across the world today. Formerly, *Eumusa* bananas were presumed to be Southeast Asian domesticates, whereas *Australimusa* and *Ingentimusa* bananas were considered indigenous to the New Guinea region.⁷⁰ Phytogeographic and genetic research has revised this interpretation to suggest that the initial stage of *Eumusa* domestication occurred in the New Guinea-Philippines regions with subsequent dispersal to Southeast Asia where hybridisation with local varieties occurred.⁷¹

The exact mechanisms implicated in *Eumusa* section domestication are complex and varied:

“In the section *Eumusa*, the hundreds of banana cultivars form a very heterogeneous group and their phenotypes are the reflection of a ramified pattern of domestication more or less coupled with genome combinations, polyploidization and somatic mutations.”⁷²

According to several sources, the initial phase of the domestication process occurred in two subspecies of *Musa acuminata* (genome A): ssp. *banksii* which grows wild in New Guinea, Manus, northern Australia and possibly some islands of northeastern Indonesia; and, ssp. *errans* which grows wild in the Philippines.⁷³ These two subspecies are fundamental to *Musa* domestication because most cultivars are descended from one of them, and the implication is that they were associated with the development of parthenocarp.⁷⁴ Confusingly some authors include ssp. *errans* within ssp. *banksii*, whereas others distinguish the two subspecies.⁷⁵

⁷⁰ Douglas E. YEN, “The origins of...”, pp. 69-70; Norman W. SIMMONDS, “Bananas...”, p. 213; Robert H. STOVER, Norman W. SIMMONDS (eds.), *Bananas...*

⁷¹ Françoise CARREEL, Diego GONZÁLEZ de LEÓN et al., “Ascertaining maternal and paternal lineage within *Musa* chloroplast and mitochondrial DNA RFLP analyses”, *Genome*, vol. 45 (2002), pp. 679-692; Edmond De LANGHE, Pierre De MARET, “Tracking the banana: its significance in early agriculture” in C. GOSDEN, J. HATHER (eds.), *The prehistory of food: Appetites for change* (London & New York, 1999), pp. 377-396; Jean KENNEDY, “Bananas: towards a revised prehistory”, in A. FAIRBAIRN, E. WEISS (eds.), *Ethnobotanist of distant pasts: Essays in honour of Gordon Hillman* (Oxford, in press b); Jean KENNEDY, William CLARKE, *Cultivated landscapes...*, pp. 22-27; Vincent LEBOT, “Biomolecular evidence...”, pp.621-622; Xavier PERRIER, Frédéric BAKRY et al., “Combining biological approaches to shed light on the evolution of edible bananas”. *Ethnobotany Research and Applications*, vol. 7 (2009).

⁷² Edmond De LANGHE, Pierre De MARET, “Tracking the banana...”, p. 378.

⁷³ Edmond De LANGHE, Pierre De MARET, “Tracking the banana...”, pp. 377-396; Vincent LEBOT, “Biomolecular evidence...”, pp. 619-628; Françoise CARREEL, Diego GONZÁLEZ de LEÓN et al., “Ascertaining maternal...”, pp. 679-692; Jean KENNEDY, “Pacific bananas: complex origins, multiple dispersals?” *Asian Perspectives*, vol. 47 (2008), pp. 75-94; Jean KENNEDY, “Bananas...”; Xavier PERRIER, Frédéric BAKRY et al., “Combining biological approaches...”

⁷⁴ Françoise CARREEL, Diego GONZÁLEZ de LEÓN et al., “Ascertaining maternal...”, pp. 679-692

⁷⁵ Edmond De LANGHE, Pierre De MARET, “Tracking the banana...”, pp. 393-394; Vincent LEBOT, “Biomolecular evidence...”, p. 622; Ramon V. VALMAYOR, “Classification and characterization of *Musa exotica*, *M. alinsanaya* and *M. acuminata* ssp. *errans*”, *InfoMusa*, vol. 10

The initial domestication phase probably required “several thousand years for the progressive increase in parthenocarpy and of seed sterility” and for the generation of edible “AA” diploids.⁷⁶ The subsequent cultivation of AA diploids in the vicinity of other wild *M. acuminata* subspecies created inter-subspecific AA hybrids and AAA triploids.⁷⁷ Subsequent cultivation of AA diploids in the vicinity of wild *M. balbisiana* (genome B) populations created interspecific AB cultivars and more robust AAB and ABB triploids. These genomic combinations represent the main five groupings of *Musa* cultivars.⁷⁸

The wild distribution of *M. balbisiana* is uncertain; some restrict its distribution to mainland Southeast Asia, whereas others argue for a range from Sri Lanka to eastern New Guinea.⁷⁹ It is unclear where interspecific hybridisation of *M. acuminata* and *M. balbisiana* occurred. The spatial distributions of wild *M. acuminata* and *M. balbisiana* all overlap in the New Guinea region, and potentially interspecific hybridisation could have occurred there. However, the dispersal of edible AA diploids to Southeast Asia and/or a concomitant dispersal of *M. balbisiana* cultivars to the New Guinea region is equally plausible.⁸⁰ Similar scenarios of initial domestication in New Guinea with subsequent dispersal and interspecific hybridisation in Southeast Asia have been invoked for sugar cane (*Saccharum officinarum*).⁸¹

Against this backdrop of complexity, the influence of New Guinea on domestication of bananas of section Eumusa is profound. The hundreds of known cultivars today represent diverse processes occurring at different times, including: multiple domestications, progressive parthenocarpy and seed suppression, the creation of diploids and triploids, interspecific and inter-subspecific hybridisation, and somatic mutation. Interpretations suggesting initial domestication in the Philippines-New Guinea region, that are based on isozyme and DNA analyses, have received some archaeobotanical corroboration from New Guinea. Seed phytoliths of *Musa acuminata* ssp.

(2001), p.39; Xavier PERRIER, Frédéric BAKRY et al., “Combining biological approaches...”

⁷⁶ Edmond De LANGHE, Pierre De MARET, “Tracking the banana...”, p. 380.

⁷⁷ Ibid., p. 380.

⁷⁸ Françoise CARREEL, Diego GONZÁLEZ de LEÓN et al., “Ascertaining maternal...”, p. 679.

⁷⁹ Edmond De LANGHE, Pierre De MARET, “Tracking the banana...”, pp. 377-396; Mukund D. KAJALE, “Mesolithic exploitation of wild plants in Sri Lanka: archaeobotanical study at the cave site of Beli-Lana” in D. R. HARRIS, G. C. HILLMAN (eds.), *Foraging and farming: The evolution of plant exploitation* (London, 1989), pp. 272-275; Jean KENNEDY, “Pacific bananas...”, pp. 75-94; Jean KENNEDY, “Bananas...”

⁸⁰ Edmond De LANGHE, Pierre De MARET, “Tracking the banana...”, pp. 377-396.

⁸¹ Laurent GRIVET, Charles DANIELS et al., “A review of recent molecular genetics evidence for sugarcane evolution and domestication”, *Ethnobotany Research and Applications*, vol. 2 (2004), pp. 9-17.

banksii type date to c. 10,000 years at Kuk Swamp in the highlands, with subsequent banana cultivation inferred from high Musaceae phytolith levels at 7000-6500 years ago.⁸²

Bananas are unusual genetically for chloroplast DNA (cpDNA) and mitochondrial DNA (mtDNA) can be traced through maternal and paternal lines, respectively.⁸³ Consequently, lineages and contributions of subspecies and species to cultivar groups can be traced to shed greater detail on the history of domestication. For example, several different groups of bananas, including some of the Pacific plantains, Western and Central African plantains (AAB) and an East African AAA group of cultivars, trace part of their ancestry to the New Guinean *Musa acuminata* ssp. *banksii*.⁸⁴ Of significance, the two groups of African bananas show different temporal-geographic domestication pathways. Triploid AAB plantain cultivars originated as AA diploids in New Guinea with subsequent hybridisation with *M. balbisiana* populations, before dispersal via vegetative propagation to West Africa and cultivation there by at least 2500 years ago.⁸⁵ Strikingly, “The [African] Plantains studied have exactly the same cytotype pattern as some *Musa acuminata* ssp. *banksii* accessions still present in New Guinea”.⁸⁶ By contrast, the distinctive East African Highland AAA cooking and beer-making bananas are a hybrid of *M. acuminata* ssp. *banksii* (New Guinea) and *M. acuminata* ssp. *zebrina* (Indonesia) indicating hybridisation of New Guinea and Indonesian subspecies, respectively, before dispersal to Africa.⁸⁷

In these cases, bananas tracing an ancestry to New Guinea hybridised with Southeast Asian species or subspecies before subsequent dispersal to Africa. Although these trajectories are different and potentially occurred at different times, they clearly indicate an early westward dispersal of bananas with New Guinea stock. These dispersals could have been facilitated by Austronesian

⁸² Vincent LEBOT, Brien A. MEILLEUR et al., “Genetic diversity in Eastern Polynesian Eumusa Bananas”, *Pacific Science*, vol. 48 (1994), pp. 16-31; Françoise CARREEL, Diego GONZÁLEZ de LEÓN et al., “Ascertaining maternal...”, pp. 679-692; Tim P. DENHAM, Simon G. HABERLE et al., “Origins of agriculture...”, pp.189-193; Tim P. DENHAM, Jack GOLSON, Philip J. HUGHES, “Reading early...”, pp. 259-298.

⁸³ Françoise CARREEL, Diego GONZÁLEZ de LEÓN et al., “Ascertaining maternal...”, p. 680.

⁸⁴ Vincent LEBOT, “Biomolecular evidence...”, p. 621; Françoise CARREEL, Diego GONZÁLEZ de LEÓN et al., “Ascertaining maternal...”, pp. 679-692; Xavier PERRIER, Frédéric BAKRY et al., “Combining biological approaches...”.

⁸⁵ Françoise CARREEL, Diego GONZÁLEZ de LEÓN et al., “Ascertaining maternal...”, p. 690; Christophe MBIDA MINDZIE, Hughes DOUTRELPONT et al., “First archaeological evidence of banana cultivation in central Africa during the third millennium before present”, *Vegetation History and Archaeobotany*, vol. 10 (2001), pp. 1-6; Xavier PERRIER, Frédéric BAKRY et al., “Combining biological approaches...”.

⁸⁶ Françoise CARREEL, Diego GONZÁLEZ de LEÓN et al., “Ascertaining maternal...”, p. 689.

⁸⁷ Françoise CARREEL, Diego GONZÁLEZ de LEÓN et al., “Ascertaining maternal...”, p. 689; Jean KENNEDY, “Pacific bananas...”, pp. 75-94.

language-speakers, but the antiquity of presumably cultivated bananas in areas beyond their natural range is suggesting an earlier temporal framework for domestication and dispersal. *Musa* phytoliths have been found in the Cameroon dating to 2500 years ago and, more controversially, in Uganda potentially dating to 5000 years ago, whereas those in Pakistan at 4000 years ago may only be significant if interspecific hybrid cultivars.⁸⁸

Early and mid-Holocene interaction

Phytogeographic, morphological, molecular and archaeobotanical evidence indicates variable histories of domestication for three major staples: the domestication bananas of section *Eumusa* was complex, variable and involved hybridisation between species and subspecies in New Guinea and Southeast Asia; the existing genetic evidence for taro (*Colocasia esculenta*) suggests regional isolation of wild populations and separate domestications in both regions; whereas the limited molecular data for the greater yam (*Dioscorea alata*) is suggestive of initial domestication of an unknown wild-type in the New Guinea region with subsequent widespread dispersal of sterile clones. Similarly variable histories can be reconstructed for other staples, including sugar cane (*Saccharum officinarum*) and the aerial yam (*D. bulbifera*). Multi-disciplinary botanical evidence is beginning to show that New Guinea was a primary centre of plant domestication.

At present, and unlike other parts of the world, the domestication histories for crop plants cannot be charted in the archaeobotanical record. The threadbare record is due to several factors: poor macrobotanical preservation of relevant plant parts in tropical environments; limited application of nascent microfossil techniques, especially starch grain and phytolith analyses; and, in some cases, the complex histories and ongoing processes of domestication militating against clear differentiation of cultivated and wild plants.⁸⁹ Despite these archaeobotanical problems, which are likely to be overcome by the broader application of microfossil techniques, the timings of plant domestication and dispersal can be interpreted with respect to multi-disciplinary findings, including broader archaeological evidence and linguistic

⁸⁸ Christophe MBIDA MINDZIE, Hughes DOUTRELPONT et al., "First archaeological evidence...", pp. 1-6; B. Julius LEJJU, Peter ROBERSHAW, David TAYLOR, "Africa's earliest bananas?", *Journal of Archaeological Science*, vol. 33 (2006), pp. 102-113; although consider the critique of both these claims in Katharina NEUMANN, Elisabeth HIDLEBRAND, "Early bananas in Africa: the state of the art", *Ethnobotany Research and Applications* 7 (in press); Dorian Q. FULLER, Marco MADELLA, "Issues in Harappan archaeobotany: retrospect and prospect" in S. SETTER, P. KORISSETAR (eds.), *Indian archaeology in retrospect* (vol. 2, New Delhi, 2001).

⁸⁹ Jack GOLSON, Peter UCKO, "Foreword" in J.G. HATHER (ed.), *Tropical archaeobotany: Applications and new developments* (London, 1994), pp. xiv-xix; Douglas E. YEN, "Wild plants and...", pp. 315-326.

reconstructions of the crop assemblage which is presumed to have dispersed with Austronesian language-speakers out of Southeast Asia.⁹⁰

Recent multi-disciplinary findings indicate considerable maritime interaction within Island Southeast Asia and Melanesia, as well as between the two regions, during the early and mid-Holocene, namely, before Austronesian language expansion.⁹¹ These interactions are marked by faunal translocations such as: the Sulawesi warty pig (*Sus celebensis*) to Flores and the domesticated pig (*Sus scrofa*) to eastern Indonesia, marsupial introductions from New Guinea to Island Melanesia, and the cuscus (*Phalanger orientalis*) from New Guinea to Timor.⁹² Furthermore, coherent archaeological signals are beginning to emerge of technology transfers within and between these regions, most prominently concerning shell ornaments and adzes.⁹³ These findings show that the maritime boundaries between New Guinea and regions to the west, as well as within these regions, were porous long before Austronesian language speaking mariners arrived.

Scenarios regarding Proto-Austronesian and Proto-Malayo-Polynesian language-speakers indicate that a whole range of plants of probable New Guinea origin, including the greater yam, *Musa* bananas and sugarcane, were already in Island Southeast Asia by at least 4000 years ago.⁹⁴ Given the phytogeographic and molecular evidence, the presence of these plants in Southeast Asia at this time is predicated on earlier dispersals from New Guinea, whether through demic or cultural diffusion during the early and mid-Holocene.

There is good agreement among archaeological, linguistic and plant data for social interactions between New Guinea and regions to the west before Austronesian language dispersal. People in New Guinea were in, at least intermittently, spheres of attenuated connectivity manifest as local exchange

⁹⁰ For a review see Mark DONOHUE, Tim DENHAM, "Farming and language..."

⁹¹ Lee Anthony M. NERI, "Philippine obsidian and its archaeological implications", *Bulletin of the Indo-Pacific Prehistory Association*, vol. 27 (2007), pp. 154-162; Robin TORRENCE, Pamela SWADLING, "Social networks and...", pp. 600-616; David BULBECK, "An integrated perspective on the Austronesian diaspora", *Australian Archaeology* vol. 67 (2008), pp. 31-51.

⁹² Keith DOBNEY, Thomas CUCCHI, Greger LARSON, "The pigs of Island Southeast Asia and the Pacific: new evidence for taxonomic status and human-mediated dispersal", *Asian Perspectives*, vol. 47 (2008), pp. 59-74; Matthew SPRIGGS, *The Island Melanesians*; J. Peter WHITE, "Where the wild things are: prehistoric animal translocations in the Circum New Guinea Archipelago" in S. FITZPATRICK (ed.), *Voyages of discovery: The archaeology of islands* (Westport, CT, 2004), pp. 147-164.

⁹³ David BULBECK, "An integrated perspective...", pp. 31-51; Katherine A. SZABÓ, *Technique and practice: Shell-working in the Western Pacific and Island Southwest Asia* (Ph.D. thesis, Australian National University, 2004).

⁹⁴ Matthew SPRIGGS, *The Island Melanesians*, p. 94; Peter BELLWOOD, "Reply", *Cambridge Archaeological Journal*, vol. 17 (2007), p. 104.

networks with regions to the west during the early and mid-Holocene.⁹⁵ The evidence suggests that plants were not exchanged as part of a package, for taro domesticated in New Guinea does not seem to have diffused to Southeast Asia, while other plants, including greater yam, *Musa* and sugarcane, did. The lack of accord in the nature of diffusion for plants and other cultural traits indicates considerable socio-spatial and chronological complexity.

Concluding comment

The multi-disciplinary botanical evidence for *Musa*, taro, the greater yam, as well as other plants, clearly shows the fundamental contribution of domesticatory relationships between people and plants in New Guinea to the historical development of several staple crops.⁹⁶ At present, botany hints at plant domestications and regional interactions during the early and mid-Holocene that are also beginning to emerge from the archaeological record. Not only are researchers left trying to explain how vegetatively cultivated plantains dispersed to West Africa by at least 2500 years ago; they are also left trying to understand why the roots of Pacific agriculture are more firmly planted in New Guinea than in any region of Southeast Asia.

Arguments for a Southeast Asian inheritance for Pacific cultivars of banana, taro and yam cultivation are misplaced - as they are for other cultivars, eg, *D. bulbifera*.⁹⁷ Many crop plants of Pacific agriculture exhibit a greater genetic inheritance from genepools in the New Guinea region than from Southeast Asia, contrary to popular assumption.⁹⁸ This is a fundamental insight to understanding the contribution of the New Guinea region to agriculture in the Pacific, Southeast Asia, Africa and beyond. Admittedly botanical studies are incomplete; there are gaps and the interpretations reviewed here are liable to modification. However, these emerging histories of plant domestication open up new vistas of pan-regional interaction, the implications of which are only just beginning to be understood.

⁹⁵ David BULBECK, "An integrated perspective...", pp. 31-51; Tim P. DENHAM, Mark DONOHUE, "Pre-Austronesian dispersal of banana cultivars west from New Guinea: linguistic relics from Eastern Indonesia," *Archaeology in Oceania*, vol. 44 (2009), pp. 18-28; Mark DONOHUE, Tim DENHAM, "Farming and language..."

⁹⁶ For reviews see Douglas E. YEN, "The development of Sahul...", pp. 831-847; Vincent LEBOT, "Biomolecular evidence...", pp. 619-628.

⁹⁷ Vincent LEBOT, "Biomolecular evidence...", p. 625.

⁹⁸ *Ibid.*, pp. 619-628; Vincent LEBOT, "La domestication des...", pp. 45-61; Peter BELLWOOD, *First farmers...*, pp. 144-145.

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