Origin of Horticulture in Southeast Asia and the Dispersal of Domesticated Plants to the Pacific Islands by Polynesian Voyagers: The Hawaiian Islands Case Study

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In the islands of Southeast Asia, following the Pleistocene or Ice ages, the ancestors of the Polynesians began voyages of exploration into the Pacific Ocean (Fig. 1) that resulted in the settlement of the Hawaiian Islands in A.D. 300 (Bellwood, 1987; Finney, 1979; Irwin, 1992; Jennings, 1979; Kirch, 1985). These skilled mariners were also expert horticulturists, who carried aboard their canoes many domesticated plants that would have a dramatic impact on the natural environment of the Hawaiian Islands and other areas of the world.

The exploration and colonization of the Hawaiian Islands by Polynesian voyagers was one of the most remarkable episodes of human prehistory (Irwin, 1992). These seafarers had no writing systems to record their route, no metal, no devices for measuring time, no navigational instruments, and no prior knowledge of island geography (Irwin, 1992). Yet, their trans-Pacific voyage of discovery was accomplished at least 1000 years before the trans-Atlantic voyages of Christopher Columbus that began in A.D. 1492. Research by archaeologists (Bellwood, 1987; Jennings, 1979; Kirch, 1985) and botanists (Abbott, 1992; Fosberg, 1991; Whistler, 1991;) indicates one of the Polynesians most enduring achievements was the dispersal of an assemblage of horticultural plants that transformed the natural environment of both the Hawaiian Islands and much of the world's tropical regions.

ORIGIN OF HORTICULTURE IN SOUTHEAST ASIA

The prevailing view among modern horticulturists is that the discipline originated among the early civilizations of the "fertile crescent"—

the valleys of the Euphrates, Tigris, and Nile rivers—and that the first horticultural crops were figs, dates, grapes, olives, lettuce, onions, cucumbers, and melons (Halfacre and Barden, 1979; Janick, 1979). The Greek, Roman, and European civilizations refined plant cultivation until it evolved into the discipline we recognize as horticulture today (Halfacre and Barden, 1979; Janick, 1979).

An opposing view associates the beginning of horticulture with early Chinese civilization in Asia (Solheim, 1972). Chang (1976) identifies two centers of plant domestication in eastern Asia: North China, the origin of cereal crops such as millet [*Pennisetum americanum* (L.) Lecke] and other sexually reproduced plants, and Southeast Asia, an earlier center for vegetatively propagated root,

tuber, and fruit crops, such as taro, yams, banana, and breadfruit.

Chang (1976) speculates that the first horticulturists were fishers and gatherers who inhabited estuaries in tropical Southeast Asia. They lived sedentary lives and had mastered the use of canoes. The surrounding terrestrial environment contained a diverse flora that enabled the fishers to become intimately familiar with a wide range of plant resources. The first plants to be domesticated were not only food crops, but also plants used as containers, such as bottle gourd [*Lagenaria siceraria* (Molina) Standl.] and bamboo [*Schizostachyum glaucifolium* (Rupr.) Munro]; caulking for canoes; or cordage for nets and fishing lines. Gradually the list of domesticated plants expanded into a horticultural as-

Fig. 1. The introduction of horticulture to the Hawaiian Islands by Polynesian voyagers in A.D. 300 represents the culmination of eastward voyages of discovery by navigators whose origins were in Southeast Asia and who dispersed an important assemblage of horticultural crops throughout the Pacific Islands. [Map adapted from Lindo and Mower (1980).]

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semblage that contained plants grown for food, clothing, housing, medicine, beauty, and fish poison.

DISPERSAL OF HORTICULTURAL PLANTS TO THE PACIFIC ISLANDS

The fishers evolved into skilled navigators, who embarked on eastward migrations (Fig. 1) that would transport their collection of tropical and subtropical plants to distant lands (Kirch, 1985). Their eastward expansion began as island hopping through insular Southeast Asia but gradually developed into long-distance voyaging. They became the ancestors of the Polynesians, brown-skinned islanders who would settle a vast triangle in the Pacific Ocean formed by the islands of Hawaii, New Zealand, and Easter Island (Fig. 1). The triangle covers an area twice that of the continental United States and contains groups of widely separated islands, such as Tonga, Samoa, Tahiti, and the Marquesas.

The exploration and colonization of the Pacific Islands by these prehistoric mariners has been reconstructed with archaeological, botanical, and linguistic evidence (Bellwood, 1987; Irwin, 1992; Jennings, 1979; Kirch, 1985). In Polynesia, the voyagers first settled Samoa and Tonga and then moved on to the Marquesas Islands, from which they set out on some of their longest and most daring voyages of discovery, such as to the Hawaiian Islands, Easter Island, and possibly the mainland of South America.

Around the fourth century (Kirch, 1985), a double-hulled voyaging canoe set course north from the Marquesas Islands (Fig. 2). Powered by wind in woven-mat sails, the vessel carried with it all the materials necessary to establish a permanent colony in a new land. On board were 20 to 30 people; 27 horticultural plants (Table 1); three domestic animals [the pig (*Sus scrofa* L.), dog (*Canis familiaris* L.), and chicken (*Gallus gallus* L.)]; and a stowaway, the Pacific rat (*Rattus exulans* L.).

The Hawaiian Islands are geographically one of the most remote places on our planet. The northward voyage covered 4000 km and probably required 4 to 8 weeks. The area traversed is an empty ocean with no islands, poor fishing, and the threat of being becalmed in the doldrums. The discovery and settlement of Hawaii ranks as one of the epic feats in the history of humanity.

The ancient Polynesian navigators used a technique based on stars and natural signs that recently has been termed "wayfinding" (D.L. Travers, personal communication). They preferred double-hulled canoes for long-distance voyaging because of their greater stability and carrying capacity (Finney, 1979). The broad central platform between the hulls provided a large and dry area to shelter people, plants, animals, and food supplies. Water was carried in gourds and sections of bamboo. Although the construction methods for the canoes used stone-age technology, the hull designs were very sophisticated—akin to the design of a modern airplane wing (D.L. Travers, personal communication).

Fig. 2. Polynesian navigators, using a double-hull sailing canoe, such as the replica Hokule'a, transported 27 horticultural plants with them in their voyage of discovery of the Hawaiian Islands. [Photograph reproduced from Lindo and Mower (1980).]

Table 1. Plants introduced to the Hawaiian Islands by Polynesian voyagers.

Names			
Common	Hawaiian ²	Scientific ³	Primary use
Candle nut	Kukui	<i>Aleurites moluccana</i> (L.) Willd.	Illumination, wood
Elephant ear	'Ape	<i>Alocasia macrorrhiza</i> (L.) G. Don	Famine food
Breadfruit	'Ulu	<i>Artocarpus altilis</i> (Parkinson) Fosberg	Food/wood
Paper mulberry	Wauke	<i>Broussonetia papyrifera</i> (L.) Vent.	Clothing, cordage
Alexandrian laurel	Kamani	<i>Calophyllum inophyllum</i> L.	Wood
Coconut	Niu	<i>Cocos nucifera</i> L.	Food, cordage, thatch
Taro	Kalo	<i>Colocasia esculenta</i> (L.) Schott	Staple food
---	Kou	<i>Cordia subcordata</i> Lam.	Wood
Ti	Ki	<i>Cordyline fruticosa</i> (L.) Chev	Container, clothing
Turmeric	'Olena	<i>Curcuma longa</i> L.	Dye, medicine
Greater yam	Uhi	<i>Dioscorea alata</i> L.	Food
Bitter yam	Hoi	<i>Dioscorea bulbifera</i> L.	Famine food
Five-leaved yam	Pi'a	<i>Dioscorea pentaphylla</i> L.	Famine food
Tiare	---	<i>Gardenia taitensis</i> DC.	Adornment, medicine
Sweetpotato	'Uala	<i>Ipomea batatas</i> L.	Staple food
Bottle gourd	Ipu	<i>Lagenaria siceraria</i> (Molina) Standl.	Container
Indian mulberry	Noni	<i>Morinda citrifolia</i> L.	Medicine, famine food
Banana	Mai'a	<i>Musa</i> spp. L.	Food, container
Kawa	'Awa	<i>Piper methysticum</i> Forst. f.	Mild narcotic drink
Sugar cane	Ko	<i>Saccharum officinarum</i> L.	Food, thatch
Polynesian bamboo	'Ohe	<i>Schizostachyum glaucifolium</i> (Rupr.) Munro	Container, wood
---	---	<i>Solanum viride</i> Forst. f. ex Spreng	Adornment
Mountain apple	Ohia'a 'ai	<i>Syzygium malaccense</i> (L.) Merr. & Perry	Food, wood
Arrowroot	Pia	<i>Tacca leontopetaloides</i> (L.) Kuntze	Famine food
Fish poison tree	'Auhuhu	<i>Tephrosia purpurea</i> (L.) Pers.	Fish poison
Pacific rose wood	Milo	<i>Thespesia populnea</i> (L.) Sol. ex Correa	Wood
Wild ginger	Awapuhi	<i>Zingiber zerumbet</i> (L.) J.E. Smith	Adornment, medicine

²Pukui and Elbert (1986).

³Whistler (1991).

Present archaeological interpretation (Finney, 1979; Kirch, 1985) suggests that this initial voyage to Hawaii may have been the only northward migration from the Marquesas and that Hawaiian society then developed in isolation until contacted in A.D. 1778 by the noted English navigator and explorer Captain James Cook. There is some evidence, arising from oral traditions among the Hawaiians, that, around the 12th century, there was a period of two-way voyaging between Hawaii and Tahiti. This assertion is not well documented.

PLANTS IN THE HORTICULTURAL ASSEMBLAGE

Among the wide range of plant types on board the canoe (Table 1), the most prevalent

were herbaceous species with edible roots or tubers and trees that yielded fruit or nuts. The assemblage contained five important staples of the Pacific islanders: taro (Fig. 3.), sweetpotato, yam, breadfruit, and banana. Also present was the tree referred to in the Pacific as the "staff of life"—the coconut palm (Abbott, 1992). As discussed earlier, most of the assemblage originated in Southeast Asia, either the mainland or associated islands. There was one important exception—the sweetpotato, whose origin lies in South America. Yen (1971) suggests that the navigators, before their departure from the Marquesas north to Hawaii, completed a two-way voyage to the mainland of South America, during which they acquired the sweetpotato. Interestingly, the assemblage contained no cereal crops. Although rice (*Oryza sativa* L.) and millet were grown in Southeast

Asia, they were not cultivated in Polynesia. This is an intriguing point because rice can be produced with practices similar to those used for taro (Fig. 3), which became widely established in Polynesia.

Most of the horticultural assemblage (Table 1) was transported as vegetative propagules, such as cuttings, tubers, slips, or suckers. These were first swathed in freshwater-moistened moss, then swaddled in dry leaves, *kapa*, or bark cloth, or skin from the banana tree (Holmes, 1981). Finally, these bundles were put in a casing of woven mats and hung from the roof of the canoe's hut where they would be protected from saltwater spray.

During a voyage from Hawaii to Tahiti (Fig. 2), Hokule'a, a modern replica of a Polynesian voyaging canoe (Lindo and Mower, 1980), attempted to transport the same plant assemblage the Polynesians originally brought to Hawaii (Holmes, 1981). The effort was partially successful. Some plants died, while others survived and were planted upon arrival in Tahiti (Holmes, 1981). These mixed results underscore the difficulty of transporting planting material over vast distances and under extreme environmental conditions.

IMPACT OF HORTICULTURE ON ISLAND ENVIRONMENT

The Polynesian discoverers found the Hawaiian Islands to be volcanic, surrounded by coral reefs, with a subtropical climate and a natural ecosystem that had evolved over several million years in the absence of people (Fosberg, 1991). Prevailing northeastern tradewinds shaped windward and leeward sides of the islands. The former were characterized by high rainfall, permanent streams, and rain forests; while the latter were arid with dryland forests. The indigenous flora of the islands consisted of few edible plant species (Fosberg, 1991). Edible bird and marine species, however, were abundant.

The first colonists settled at the mouths of windward valleys, such as Kahana Bay on Oahu. This high-rainfall environment most resembled their former homes in the Marquesas and would be most likely to accommodate the plants they transported. After their plants were established, the settlers began to emphasize taro cultivation for food production. A taro plant (Fig. 3) produces 10 shoots or suckers during a typical crop cycle of 12 to 15 months (C. Reppun, personal communication). The shoots can be separated from the mother plant to start new plants. By my calculation, taro production would have been sufficient to support the colony 3 years after the initial planting of propagules transported by the voyagers. During the first 3 years, the settlers must have relied on the marine environment for a diet of fish, shellfish, seaweed, and marine mammals. Birds were also an important source of food. Thereafter, the yield of horticultural crops, such as taro and sweetpotato, increasingly formed the basis of the Hawaiian diet.

The introduction of the Polynesians' horticultural assemblage had a dramatic impact on the island environment (Fosberg, 1991). The

Fig. 3. The staple food of traditional Hawaiian society was taro or kalo (*Colocasia esculenta*). The corm or underground portion was mashed and eaten as a paste called "poi." Large, irrigated, terrace systems were developed for taro production. [Figure adapted from Abbott (1992).]

ecological balance that had been achieved during several million years of isolation was severely disrupted. The settlers used fire as a tool in clearing land for planting. Much of the lowland vegetation was replaced by introduced flora. Native forests were converted to tree gardens on the windward sides and grasslands on the leeward sides. Windward valleys were transformed first into shifting gardens, then into irrigated field systems for taro culture.

Beggerly (1990) reconstructed the introduction of horticulture by Polynesian voyagers to Kahana Valley on windward Oahu. Before settlement, the vegetation was a stable forest. The early colonists used slash-and-burn techniques to establish their crops. This technology deforested the slopes of the lower valley and began the conversion of forest to grassland. The denuded slopes were exposed to erosion and the virgin soils were carried into the bay, which was transformed into an alluvial plain. This action damaged the marine habitats that had provided shellfish and other

marine foods to the colonists. Beggerly (1990) believes that repeated burning eventually resulted in a massive ecosystem disturbance. Confronted with an environmental disaster, the settlers abandoned the valley and relocated to another windward valley. Not all archaeologists share Beggerly's interpretation that the environmental impact of horticulture resulted in the abandonment of a windward valley, but there is general agreement that the impact was dramatic and damaging.

The fossil evidence showing the extinction of numerous endemic birds is the most enduring evidence for the theory that environmental disturbance followed the arrival of the Polynesians (Kirch, 1985). Likely, well over half of the species of endemic land birds that were present in the archipelago before the arrival of the Polynesians became extinct as the Hawaiian civilization became established (Olson and James, 1982).

For unknown reasons, the Hawaiians abandoned the Polynesian tradition of long-distance voyaging (Finney, 1979). Captain Cook

reported seeing only coastal craft in his initial accounts of European contact with the Hawaiians. However, the Hawaiians did strengthen and expand the horticultural base of their society. Their population grew to 300,000 and spread over the islands' lowlands. They adapted and developed their horticultural techniques and intensified their crop production. At the time of European contact, numerous varieties of the major crops were observed. For example, there were 300 named varieties of taro (C. Reppun, personal communication). Handy and Handy (1972) suggest that this is evidence the Hawaiians had mastered techniques for plant improvement. It is certain that the Hawaiians achieved a level of agricultural production unrivaled elsewhere in Oceania (Kirch, 1985). The irrigated field systems for taro production, in particular, demonstrated high levels of social organization and engineering skills.

The ancient Polynesians have long been recognized as explorers and colonists of the Pacific Islands, but they also deserve recognition as horticulturists for developing a complex civilization in the Hawaiian Islands based on the production of horticultural crops.

I hope that when future historians of our discipline chronicle the development of horticulture, they will look to Southeast Asia and the Pacific Islands and include the prehistoric

exploits of fishers who domesticated an important assemblage of tropical plants, the daring Polynesian navigators who dispersed them over a sizeable portion of the globe (long before Europeans were sailing out of sight of land), and the ancient Hawaiians who developed irrigated field systems for the intensive production of horticultural crops.

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