*J. Ethnobiol.* 14(2):211–234 Winter 1994

# TRADITIONAL ARROWROOT PRODUCTION AND UTILIZATION IN THE MARSHALL ISLANDS

DIRK H. R. SPENNEMANN
*Johnstone Centre of Parks, Recreation, and Heritage*
*Charles Sturt University*
*P. O. Box 789*
*Albury, NSW 2640*
*Australia*

ABSTRACT.—This paper examines the traditional and modern role of Polynesian arrowroot *(Tacca leontopetaloides)* in the subsistence and market economy of the Republic of the Marshall Islands, a group of atolls in the central equatorial Pacific Ocean. The plant is discussed in its biological and nutritional parameters. Aspects of traditional arrowroot production, starch extraction, and food preparation are examined. In the final section the potential role of the root crop in modern Marshallese society is discussed.

RESUMEN.—Este trabajo examina el papel tradicional y moderno de *Tacca leontopetaloides* en la economía de subsistencia y de mercado en la República de las Islas Marshall, un grupo de islas coralinas en el Océano Pacífico ecuatorial central. Se discuten los parámetros biológicos y nutricionales de esta planta, y se examinan los aspectos de la producción tradicional, la extracción de almidón y la preparación como alimento. En la sección final se discute el papel potencial de este cultivo en la sociedad moderna de las Islas Marshall.

RÉSUMÉ.—Nous examinons les rôles traditionels et modernes de l'arrowroot Polynésien *(Tacca leontopetaloides)* dans la subsistance et l'économie de la République des Ilsles Marshalles, un groupe d'attolls de l'Océan Pacifique Equatorial Central. Les paramètres biologiques et nutritifs de cette plante sont considérés. Nous examinons différents aspects de production traditionelle d'arrowroot, ainsi que l'extraction de la fécule et la préparation des aliments. Enfin, nous discutons le rôle potentiel que cette plante économique joue dans la société Marshalle moderne.

## INTRODUCTION

The Republic of the Marshall Islands is currently undergoing dramatic social and cultural changes. Having been released in 1991 from the trusteeship of the United States of America and accepted as a full member of the United Nations, the young nation strides along the path of modern development. The former subsistence economy, or the remnant thereof that survived the past 40 years of consumer-oriented influences, is waning and imported foods are becoming more prominent. In the course of this change several traditional subsistence items have almost disappeared or are likely to do so in the near future. One of these is Polynesian arrowroot (*Tacca leontopetaloides*, Taccaceae). This paper reviews knowl-

edge on arrowroot production and utilization. It examines the traditional (pre-1900) and pre-World War II production of Polynesian arrowroot, the role it plays in traditional Marshallese horticulture, and planting and harvesting procedures. A discussion of starch extraction techniques is also provided. Pre-World War II food and nonfood uses of arrowroot are presented along with the present-day utilization of the plant and its potential as a source of carbohydrates in the future.

Data for this study were compiled from ethnographic and historic sources covering the period from the beginning of intensified Western contact with the Marshall Islands until today, interviews with Marshallese from various atolls, and my own studies of plant distribution and plant status.

*Geographical background.*—The Marshall Islands comprise 29 atolls and five islands and are located in the northwest equatorial Pacific, about 3,790 km west of Honolulu, 2,700 km north of Fiji, and 1,500 km east of Pohnpei (Ponape) (Fig. 1).[1] The atolls of the Marshall Islands, numbering well over 1,200 islands and islets, are scattered in an ocean area of over 1.1 million km$^2$. The total combined land area of the atolls is only 115 km$^2$. With the exception of the two northwestern atolls, Enewetak and Ujelang, the Marshall Islands are arranged in two island chains, the western Ralik Chain and the eastern Ratak Chain, which run roughly NNW to SSE (Fig. 1). Atolls range from very small, less than 3.5 km$^2$ (Nadikdik [Knox]) to very large (Kwajalein, the world's largest lagoon [2,173 km$^2$ lagoonal area]). The more or less ring-like reef platforms of the atolls support narrow sand cays, very few of which are larger than 2 km$^2$. Traditionally (i.e., without importation of food from outside the Marshall Islands), atolls of the southern Marshalls had a higher carrying capacity than the northern ones, a distribution which coincided with precipitation (Williamson and Sabath 1982).

*The plant.*—The family Taccaceae consists of only one living genus, *Tacca*, which includes several species. In the Marshall Islands only one species, *Tacca leontopetaloides* (L.) Kuntze, occurs.[2] Polynesian arrowroot is a large perennial terrestrial herb that grows as a volunteer plant on every inhabited island in Micronesia (Fig. 2).

The Marshallese distinguish between a "male" and a "female" arrowroot plant, although this is not a botanical distinction. Morphologically, male and female plants can be distinguished by their flowering stalks and leaves. The leaves of the male plant are less deeply serrated, somewhat darker in coloring, and have a coarser surface than those of the female. The female arrowroot is known to bear more and especially larger tubers, with the result that these plants are preferred for harvesting over their male counterparts.

Two varieties of *Tacca leontopetaloides* have been reported from atolls in Micronesia (Sproat 1968:64). On Mile Atoll I observed four varieties or subvarieties recognized by the Marshallese, albeit not separately named. Three varieties have green stems and stalks, while one possesses violet-purple leaf stalks. Tubers of the purple-stemmed variety have a brown skin and a yellow to white interior. Of the three green-stalked varieties, one produces a single large tuber and two produce more than one tuber. One of the latter varieties has purple-red flesh, the other

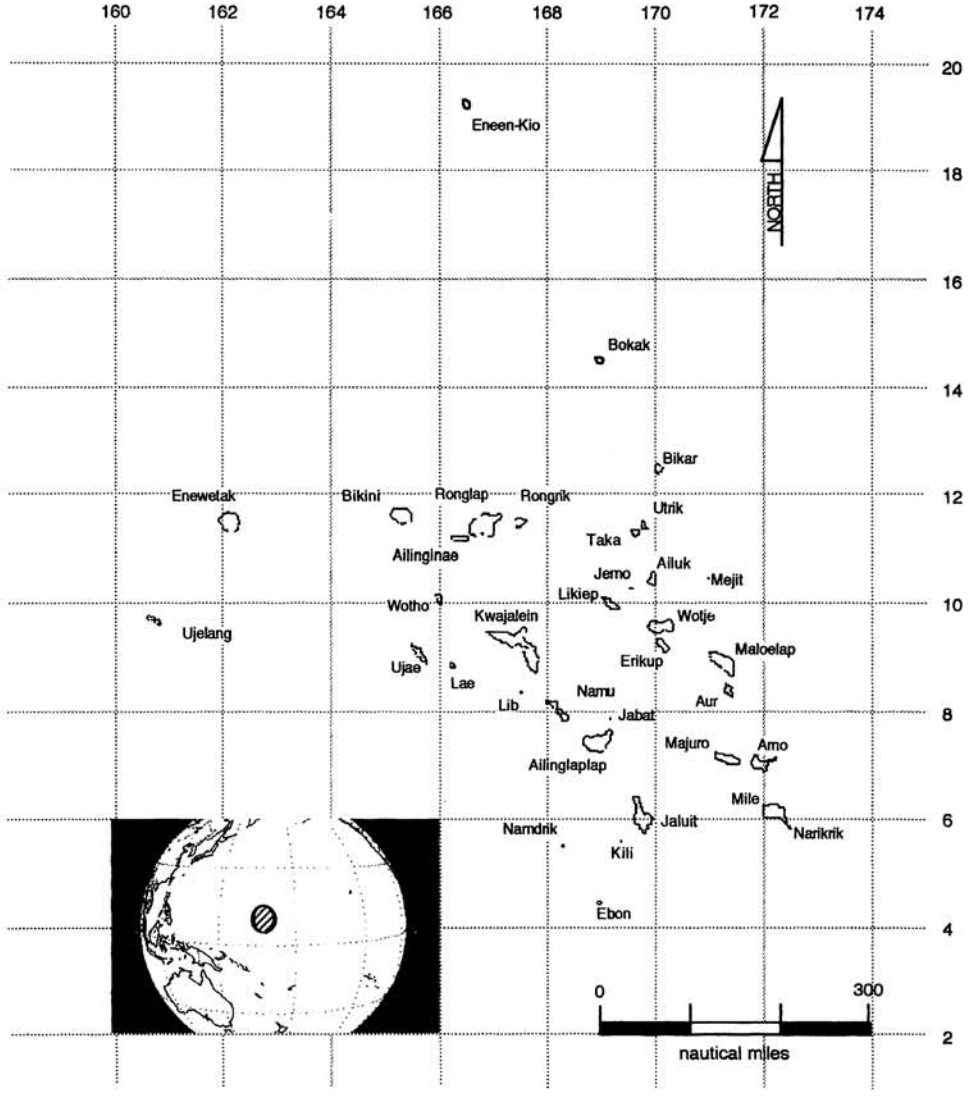


FIG. 1.—Map of the Marshall Islands.

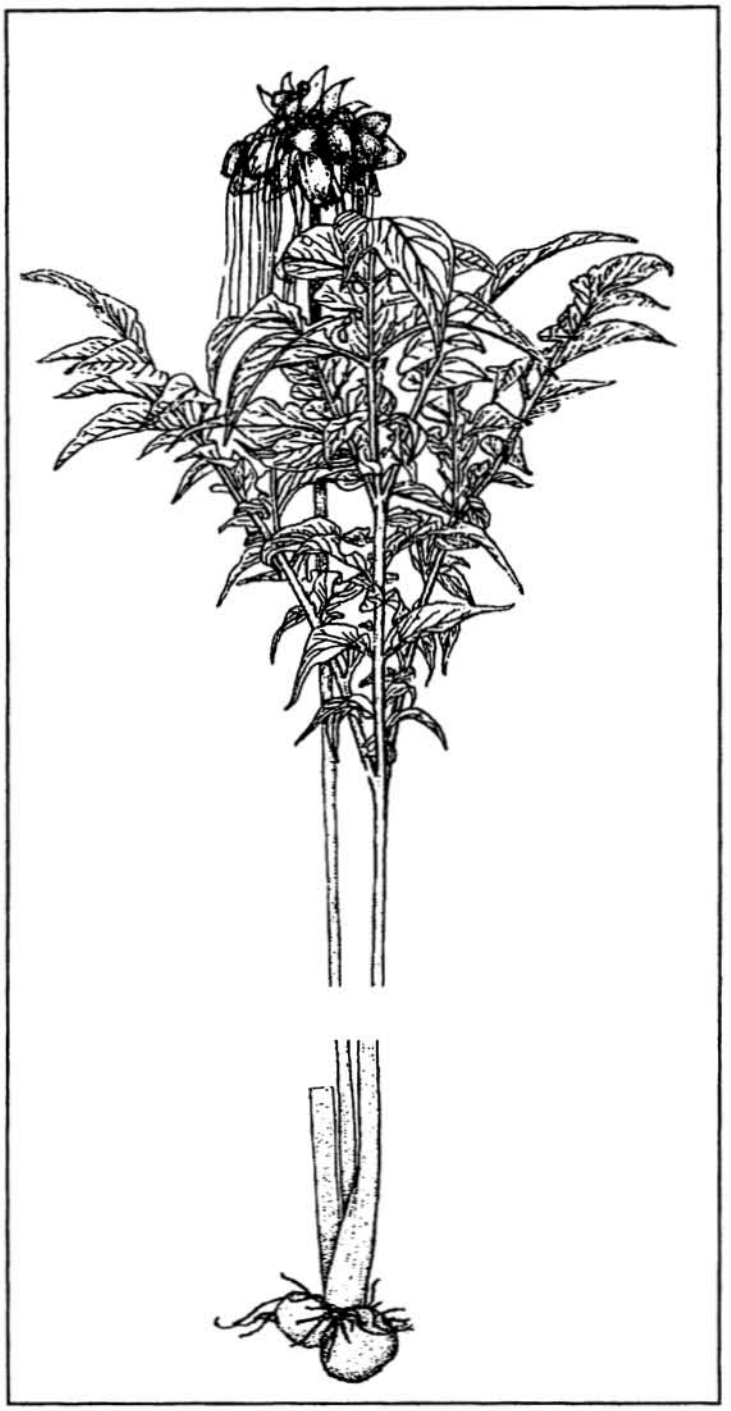

FIG. 2.—Arrowroot (*Tacca leontopetaloides* L. Kuntze) (after Lisowksi et al. 1976).

TABLE 1.—Nutritional value of arrowroot flour (per 100 g edible portion).

| | | |
|---|---|---|
| Water | 12.1 | % |
| Calories | 346 | |
| Protein | 0.18 | g |
| Fat | 0.05 | g |
| Carbohydrate (Total) | 85.74 | g |
| Carbohydrate (Fibre) | 0.0 | |
| Ash | 1.89 | g |
| Calcium | 58.0 | mg |
| Phosphorus | 7.2 | mg |
| Iron | 0.55 | mg |
| Riboflavin | 0.0 | |
| Niacin | 0.0 | |

Source: Murai et al. 1958:104.

yellow-white flesh. According to an informant, the purple variety was introduced from Pohnpei by the Japanese sometime in the 1930s.

*Tacca* thrives well in areas protected from salt-spray that are only slightly shaded and well drained. Such conditions are found in breadfruit and coconut groves without substantial understory, for example (Stone 1951:24).

Arrowroot starch is the richest natural starch (Murai et al. 1958; Wohltmann 1905). Starch content of tubers varies according to growing conditions and soil substrate. It ranges from 10% to 25% of tuber weight (Table 1).

*Distribution of arrowroot.—Tacca leontopetaloides* is a pan-Pacific cultigen that is believed to have originated in Southeast Asia (Herklots 1972:473; Purseglove 1972:517). Its distribution includes Africa, the Indian subcontinent including Sri Lanka, islands in the Indian Ocean, and Australia (Brown 1954:383–384; Fosberg 1957:15; Lisowki et al. 1976; Masefield 1948:45). The plant is believed to be of aboriginal (Austronesian) introduction into Oceania as a whole, and to all inhabited islands groups in particular (Kirch 1979:290; Doty 1973:12; Fosberg 1990:24; Spennemann 1991). Once established, arrowroot readily self-propagates.

In the region surrounding the Marshall Islands arrowroot has been reported from the following areas: Kiribati, Tuvalu, Pohnpei, Kosrae, Eastern Carolines (outer islands of Pohnpei), Yap, Western Carolines (outer islands of Yap), Chuuk, Mortlock Islands (outer islands of Chuuk), Belau, southwestern Carolines (outer islands of Belau), atolls north of Belau, Guam, and the northern Marianas (for details on distribution see Spennemann 1991). Arrowroot distribution in the western Pacific is illustrated in part in Fig. 3.

Apart from coconut (*Cocos nucifera* L.) and screwpine (*Pandanus tectorius* L.) arrowroot is the most widely distributed cultivar in the Marshall Islands. Arrowroot is absent only from Wake (Eneen-Kio), Bokak (Taongi), Bikar, and Lib (Fosberg 1990; personal observation). The absence of arrowroot on Lib is somewhat doubtful, given the fact that no adequate botanical research has been conducted on that island. Its absence on the northern three atolls is likely, however, since these atolls lack reliable rainfall and are not utilized on a regular basis.

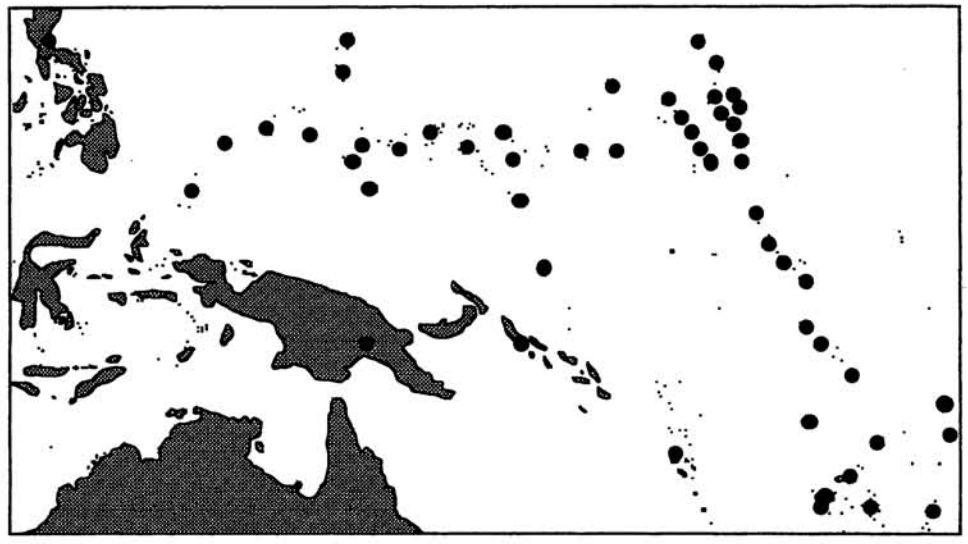

FIG. 3.—Distribution of *Tacca leontopetaloides* in Micronesia and the western Pacific. Distribution in Melanesia is greater than shown.

## TRADITIONAL PRODUCTION OF ARROWROOT

A number of plant species were utilized in traditional Marshallese horticulture. Among these are giant taro (*Alocasia maccrorhiza* L.), swamp taro (*Cyrtosperma chamissionis* Schott), breadfruit (*Artocarpus altilis* Parkinson and *A. mariannensis* Trec.), *ti*-root (*Cordyline fruticosa* L.) coconut, banana (*Musa sapientum* L.), spider lily (*Crinum bakeri* K. Schum.), and *Pandanus*. All were most likely introduced by the Marshallese, either at the initial settlement of the region or in later times of contact. In addition, the following pan-Pacific cultivars introduced by Europeans in the last century are today found in the Marshall Islands: *Dioscorea alata* L. (yam); *D. bulbifera* L. (bitter yam); *Ipomoea batatas* (sweet potato); *Carica papaya* L. (papaya) (Erdland 1906, 1914; Fosberg 1990; Hager 1886; Hathaway 1953; Hernsheim 1887; Krämer 1906; Krämer and Nevermann 1938; Wendler 1911).

The main food plants at the turn of the twentieth century were taro, breadfruit, and *Pandanus*, while arrowroot, *ti*-root, spider lily, and other plants, such as *Triumfetta procumbens* Forst. and *Wedelia (Wollastonia) biflora* L., were famine foods (Anonymous 1895; Stone 1951:25). There is some seasonality in the food supply because of rainfall. Seasonal resources include breadfruit, *Pandanus*, and, to a lesser extent, arrowroot. In assessing the horticulture of the Marshall Islands as a whole, Krämer (1906:420) gives arrowroot the status of the second most important food after *Pandanus*. This assessment is largely based on the geographical distribution, and thus the availability, of the plant throughout the Marshalls.

To evaluate the contemporary relative importance of arrowroot in Micronesia, I analyzed the frequency of occurrence of words relating to arrowroot in dictionaries for Micronesian and northwestern Polynesian languages. Table 2 shows the overall importance that contemporary peoples (here considered as post-World War II) in greater Micronesia attach to arrowroot. The Marshallese

TABLE 2.—Comparison of arrowroot terms in modern dictionaries in Micronesia and northwestern Polynesia.

| Language | Terms for Plant | Food | Use | Total terms | Total entries[1] | Index[2] (‰) | Rank |
|---|---|---|---|---|---|---|---|
| Marshallese | **3** | **4** | **10** | **17** | **8,500** | **2.00** | **1** |
| Tuvaluan | 3 | – | – | 3 | 4,000 | 0.75 | 2 |
| Chamorro | 2 | – | – | 2 | 8,400 | 0.23 | 3 |
| Mokilese | 1 | – | – | 1 | 4,500 | 0.22 | 4 |
| Kiribati | 1 | – | – | 1 | 5,000 | 0.20 | 5 |
| Yapese | 1 | – | – | 1 | 5,000 | 0.20 | 5 |
| Kapinga | 1 | – | – | 1 | 6,000 | 0.17 | 7 |
| Palauan | 1 | 1 | – | 2 | 12,000 | 0.17 | 7 |
| Woleaian | 1 | – | – | 1 | 6,200 | 0.16 | 9 |
| Pohnpeian | 1 | – | – | 1 | 6,750 | 0.15 | 10 |
| Kosraean | 1 | – | – | 1 | 7,650 | 0.13 | 11 |
| Nukuoro | 1 | – | – | 1 | 14,500 | 0.07 | 12 |

[1] The number of entries in a dictionary was computed by multiplying the total number of pages with the average entry count derived from a count of five sample pages.
[2] The index has been computed as follows: number of entries under arrowroot X 1000 / number of local language words contained in the dictionary. That this is valid measure becomes evident if one compares the representation of other food plants or names for fish in the dictionaries. See for example, the names for yams in Pohnpeian (87 entries in the English section; Rehg and Sohl 1979:253).

have by far the greatest number of words for arrowroot and its uses as well as the greatest range of terms in their vocabulary. This finding serves to support older ethnographic observations that arrowroot was only really important as a food crop in the Marshall Islands (Wendler 1911).

Arrowroot was a welcomed addition to the other cultivated plants of the Marshall Islands, especially since it did not compete with taro or breadfruit for prime gardening space. In the traditional way of setting out land, a household would own a land allotment *(wato)* running from the lagoonal to the ocean shore, thus having access to a variety of resources and vegetation zones. The vegetation on the ocean-side commonly consisted of a mixed littoral forest growing on a boulder ridge and on gravelly land. Inland, the soil gradually becomes finer, and humus content increases. An abundance of breadfruit trees are planted in this zone. In the very center of the island, where the underlying ground water lens (Ghyben-Herzberg lens) is the thickest, artificial depressions in the ground allow the cultivation of swamp taro (Krämer and Nevermann 1938; Spennemann 1991). Towards the lagoonal shore vegetation zonation is again breadfruit trees giving way to utility and ornamental shrubs along the rear side of the household units. House sites and yards are located along a sand-covered road or track running parallel to the lagoon shore. Coconut palms are distributed only along the immediate lagoon area, such as the zone of the houses and their backyards. Uninhabited and uncleared stretches of lagoon shore are covered by coconut scrubland with an abundance of *Scaevola taccada* Vahl and *Tournefortia argentea* L. shrubs.

The typical arrowroot planting zone was located between the houses and the

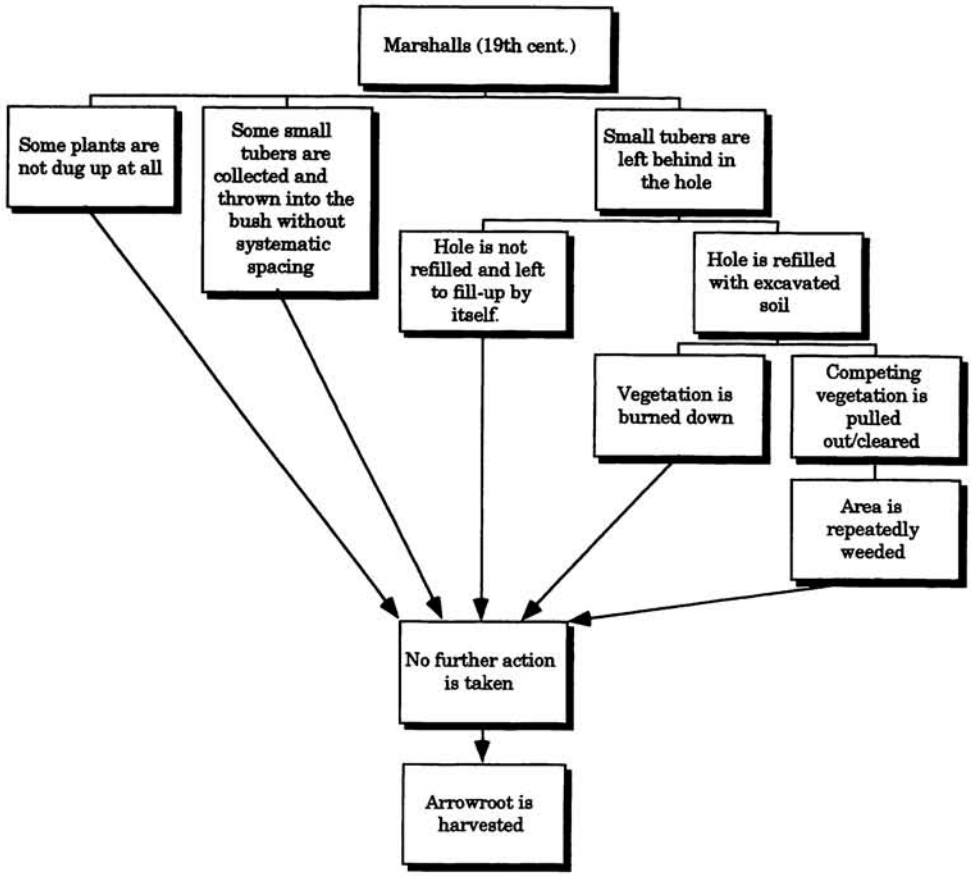


FIG. 4.—Organizational flowchart of traditional (nineteenth century) arrowroot horticulture in the Marshall Islands.

lagoon, as well as between the houses and the onset of the breadfruit forest. Arrowroot could also be grown on the smaller islands of an atoll where breadfruit would not thrive because of the absence of a (reliable) fresh water lens, and where permanent human habitation would have been impossible.

Because the influence of European economy on Marshallese agroforestry led to the systematic replacement of breadfruit forests by coconut plantations for copra production, the habitat for arrowroot has changed. When island centers were cleared of breadfruit to make way for wide-spaced copra plantations, an ideal, semi-shaded habitat for *Tacca* was produced in areas where soils were not too humid. Thus *Tacca*, a plant preferring open spaces traditionally only found in the nearshore areas, came to be an inland plant as well.

*Arrowroot planting and tending.*—At the beginning of the planting cycle, the tuber crop from the previous year was harvested (Fig. 4). Only the large tubers of "female" plants were taken; small tubers, as well as tubers of "male" plants, were not. Small tubers, even if numerous, were not dug up or were thrown back into

the hole. These were called *lep in mākmōk* or "eggs of arrowroot" (Erdland 1914:38; Wendler 1911) since they acted as seedlings for next year's crop. The harvesting hole was then commonly refilled with loose soil (Hiyane 1967), although there are some reports that the hole was left to be filled in naturally (Kiste 1968:37; Taylor 1950:17). Apparently no systematic, spaced planting of small tubers occurred in the Marshall Islands.

More attention to arrowroot tending was given in areas surrounding the Marshall Islands, which is surprising in view of its relatively low importance in these areas. In Chuuk, for example, arrowroot was intentionally planted at new moon or full moon. Land was carefully cleared before planting and the cleared weeds collected in a pile and burnt. One or two small tubers less than 25 mm in diameter were placed in a small hole, on average 50 mm deep. The hole was filled with loose soil. No fertilizer was used. Planting occurred in a rough grid, every plant spaced some 75 cm apart (Paul 1965). In Hawaii *Tacca* was either left to grow "wild" or was intentionally planted along the ridges of taro patches (Handy 1940:299). On Namoluk Atoll, Western Carolines, *Tacca* had been "partially cultivated," and "now grows wild in relatively open coconut groves near the beach" (Marshall and Fosberg 1975:31).

Informants I interviewed mentioned that Marshallese children are sometimes asked to spread out small tubers in the bush if an abundance of small ones were recovered from a bunch. *Tacca* can also be propagated by seeds, but this was apparently never practiced in traditional Marshallese horticulture. This is in keeping with the pan-Pacific horticultural tradition, in which tuber- or shoot-propagated plants dominate, while seed-propagated plants are almost absent. One of the reasons advanced by my informants for the decline of *Tacca* in the Marshalls was the fact that children no longer use the leaf stalks as spears. It is possible that childrens' play added to the dissemination of *Tacca* seeds.

Since *Tacca* plants tend to spread like weeds, no care needs to be taken to prepare a planting bed or to provide mulch or fertilizer. According to Wendler (1911), it is not possible to make out where the previous year's arrowroot harvest was obtained. However, he noted that the arrowroot area was weeded regularly, and competing vegetation pulled out. *Tacca* was "spared when other vegetation was slashed in the [coconut] groves, and it clearly benefit[ted] from this weeding" (Stone 1951:24; see also Sproat 1968:66). Polynesian arrowroot is a very hardy plant that can withstand droughts relatively well. In case of a severe drought, the top leafy part of the plant may die off, but the tubers survive and send up new shoots with the return of moisture (Soucie 1983:197).

Since the end of the nineteenth and beginning of the twentieth centuries, when coconut plantations became more common, arrowroot has been "traditionally" grown in coconut groves, often intercropped with papaya, banana, breadfruit, and *Pandanus*. Mixed stands of coconut, *Tacca*, and wild vegetation are very common, especially on the smaller, not generally inhabited islands of atolls.

Burning the underbrush seems to be a new *Tacca* horticultural practice, possibly introduced as late as the post-World War II period (Fig. 5). Burning damages coconut palms and breadfruit trees (Hiyane 1967), but, more thoroughly than any weeding can achieve, destroys the shallow roots of competing plants, leaving the

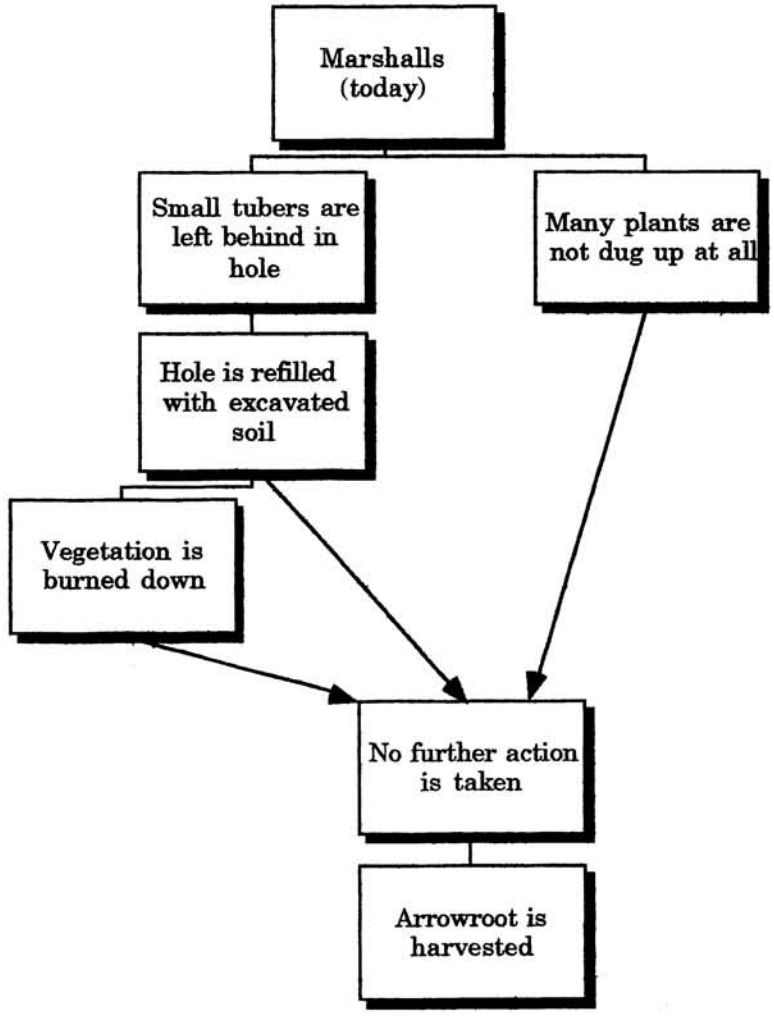


FIG. 5.—Organizational flowchart of modern arrowroot horticulture in the Marshall Islands.

deeper resting tubers of the arrowroot intact. Thus arrowroot can regrow without any competition. Sproat (1968), conducting research on local subsistence agriculture in Micronesia, notes that "in the atolls of the Marshall islands arrowroot is considered as a 'volunteer', subsistence crop, which is allowed to grow under coconuts, breadfruit, and *Pandanus* trees. It grows with other plants such as banana and papaya. Often times large areas of underbrush are burnt out under the coconut groves in the dry season. The bush plants are killed and the *Tacca* plants immediately re-sprout and predominate" (Sproat 1968:64–66).

*Harvesting.*—By the time the arrowroot plant matures, its leaves have turned yellow and the plant dies back. This commonly occurs between the end of

November and the beginning of December in the northern atolls, and between January and February in the southern (Poyer 1990; Spennemann 1991). These changes indicate it is time to harvest the crop.

The Marshallese I interviewed could easily decide which plants would bear many tubers, for every leaf stem corresponds to one root, and at the end of each root is a tuber. In times of relative affluence, only "female" plants are dug up, while "male" plants and plants located on stony ground are spared. The digging up of the tubers traditionally was done with sharpened sticks *(kübwij)* (Abo et al. 1976:170). Since the turn of the twentieth century, spades, shovels, crowbars, and pick axes have become the sole means for excavation, both in soft sands and in gravelly and rubble ground. Before 1900 the collected tubers were placed in a flat coconut leaf basket with two handles *(banonoor)* for transport to the processing site (Abo et al. 1976; Krämer 1906; Krämer and Nevermann 1938; Wendler 1911), while today a discarded sugar bag ("copra-bag") suffices.

## EXTRACTION OF STARCH

Traditionally (i.e., pre-World War II) there were a number of slightly different techniques to make starch (described in Krämer 1906:428–429; Krämer and Nevermann 1938:110; Mural et al. 1958:102; Wendler 1911). Extraction techniques have varied over time, especially as modern appliances have become available. However, the extraction of starch always followed the same general principles (Fig. 6). This description follows Wendler (1911) with additions from other sources (Abo et al. 1976; Curtis 1986; Erdland 1906, 1914; Feeney 1952; Fosberg 1990; Grosser 1902; Hiyane 1967; Krämer 1905, 1906; Krämer and Nevermann 1938).

The collected arrowroot tubers are brought to the processing site and poured into a wide-meshed sack made of plaited coconut (sennit) that resembles a fishing net *(mädo, do)*. The sack is tied on the top with string and carried into the lagoon where the tubers are cleaned of earth and sand by pushing the sack around with the feet. After this cleaning process, the sack is pulled out of the water and carried to the location where the grating takes place. Every single tuber is grated with a rough but soft coral *(pukor)* until it is reduced to a reddish mass *(üne rup)* not dissimilar in consistency and appearance to grated potatoes. In modern times a grater made of a tin plate punched by many nail holes may substitute for the grating stone. In the Ralik Chain, the skin of the tuber is commonly removed after the washing and before the grating process, either with a paring knife or a shell, which results in a cleaner and whiter flour. Washed tubers were also grated with their skins intact in the Ratak Chain, however. The *üne rup* was traditionally collected in large leaves or on old mats *(goid in liklik)* and placed into the processing unit (see below). Today copra bags serve the same purpose.

The men who perform the task of processing arrowroot usually sit in a circle around a pit measuring 1–2 m in diameter and 50–70 cm deep (Fig. 7). The sides and bottom of the pit are lined with leaves or coconut fronds (today: copra bags). A large, strongly woven mat (today: copra bags sown together) is placed on top of these leaves, and its edges protrude a good distance over the edge of the pit. This mat serves as a trough for catching the strained arrowroot flour.


FIG. 6.—Processural flowchart showing the arrowroot preparation process.

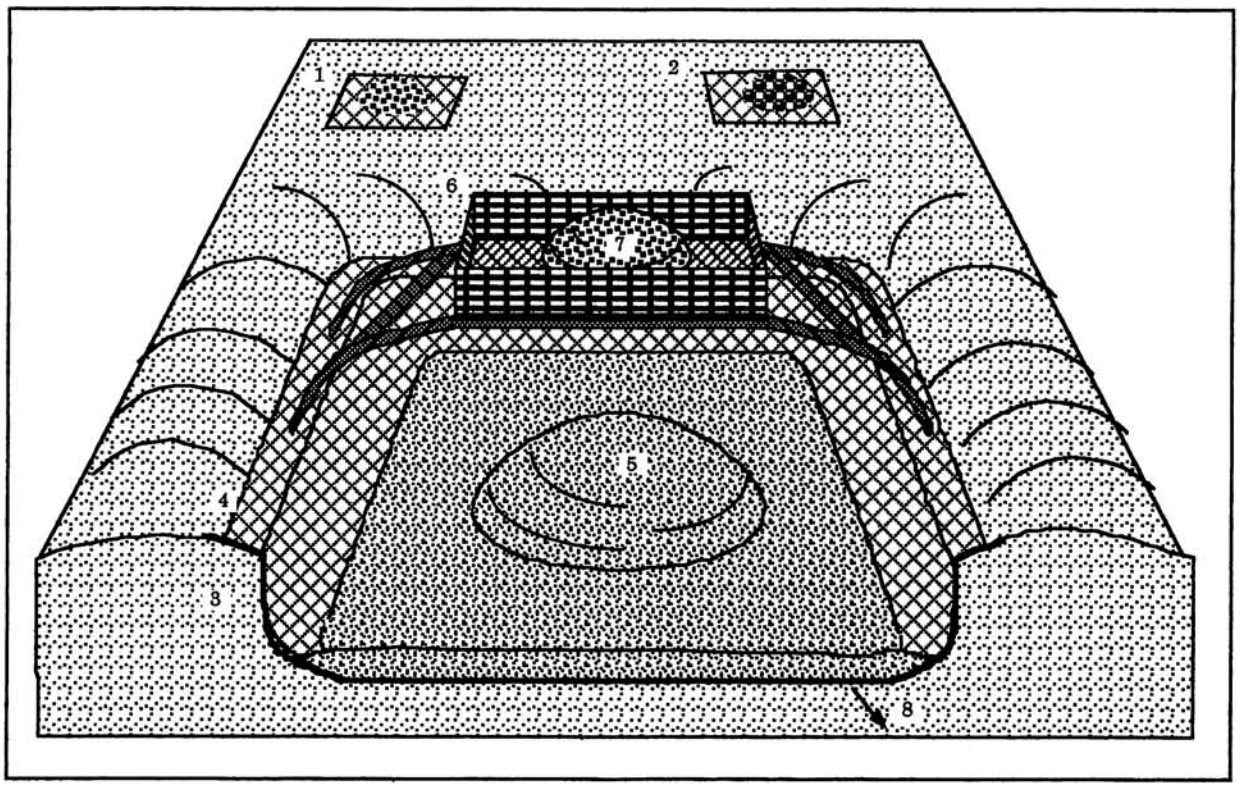


FIG. 7.—Schematic view of the arrowroot sifting process. (1) mat with ground arrowroot tubers; (2) mat with cleaned arrowroot tubers; (3) pit excavated into sand; (4) coarse mat used as lining of the pit, placed above a layer of coconut leaves (not shown); (5) heap of sifted arrowroot starch in the pit; (6) arrowroot strainer *(waliklik)*; (7) ground arrowroot ready for washing with sea water; (8) excess water dissipates into the ground.

Resting on the orifice of the pit and supported by four legs is a rectangular container woven from *Pandanus* roots or from young shoots of the mangrove *Bruguiera gymnorrhiza* L. In order to prevent any large pieces of the *üne rup* or any foreign material from falling into the mat, the coconut mesh is covered with a sticky flexible creeping root (*kil-in-kaönön;* species unknown). In more recent time this has been replaced by a wooden box *(waliklik)* that acts as a strainer, and whose lower part is open and only covered with a mesh made from coconut coir *(ekkwal).* An alternative setup dispenses with the need for a pit altogether and suspends the mat catching the water and washed-out starch on four sturdy stakes. This arrangement permits placing the entire sifting unit at the beach, within easy access to seawater.

The *üne rup* is then enclosed in a net-like wrapper of young coconut leaves (today: bed sheet) that acts as a filtering cloth. This is placed in the box and watered with seawater and continuously kneaded with the hands. While one man kneads, the other from time to time sprinkles the mass with seawater from a canoe bailer *(lem)* or tin can. The water runs off, carrying with it the dissolved arrowroot starch into the trough-like mat underneath. This mixture of water and arrowroot stays in the mat for one to two hours and the starch gradually settles to the bottom. Then water that has not yet escaped through the mat and leaves is skimmed off. The material left over from the kneading *(bwe)* has been leached of its starch content and is thrown away.

Two or three hours later the starch is sifted again in the same manner *(epta),* and if there is large amount of flour processed, even for a third time. Commonly, but apparently not as a rule, the last washing is with fresh water. During this pounding and leaching process, the arrowroot is said to loose its bitterness.

When all water is skimmed off or has dissipated, a small hole is excavated and lined with leaves. The starch lump wrapped in young coconut leaves is placed into the hole in which the excess water will run off *(likatöttöt).* Another way of getting the starch lump to dry is to scrape together the flour and hang it up in a wrapper made from a young coconut leaf (or bed sheet), thus allowing the water to run off and drip out of the starch *(bobo en Ujlan).* In order to expedite the process, some people beat the suspended starch ball with a stick, although most are satisfied to let gravity do the work. The latter is the preferred method in the rest of the Marshall Islands, especially in Likiep and Utirik. As soon as the water has dripped out, the hardened, rounded lump of arrowroot starch *(jibwil)* is placed in a shady place, usually a hut, so that it can dry and harden still more. After two or three days the *jibwil* is crushed on a mat and placed in the sun to dry further. This process, in which the flour is frequently turned and broken into grains, takes about two to four days.

The dry, snow-white flour is then wrapped in *Pandanus* leaves or stored in mat bags *(böjo).* It will last for well over a year. About seven baskets of unprocessed tubers result in one basket of processed, dried flour (Wendler 1911). Krämer (1905) also mentions that a thoroughly dried *jibwil* may be kept as such and not broken up. In this case the drying process creates an hourglass-shaped object from which arrowroot flour is broken off as needed.

*Time expenditure.*—The process of arrowroot starch production as outlined above is time consuming. I estimated time expenditure costs based on interviews with numerous Marshallese who had actively made arrowroot starch at one point in their lives. All time estimates are based on processing two copra bags of tubers estimated to hold a total of about 125 lb. of arrowroot tubers. This quantity is said to produce between 25 and 30 lb of pure starch. Harvesting tubers to fill two bags is said to have taken about two days. Over half a day is spent cleaning tubers in the lagoon and grating them into a mash. The first sifting usually occurs before the day is over, and the starch is allowed to settle overnight. The second and third sifting of the starch takes another day, after which the starch ball is suspended to dry. Over the next three days the predried starch ball is broken up and sun-dried.

*Storage and trade of arrowroot.*—There are two options for storing arrowroot. One is to store it in processed form, the other to store it unprocessed in a cool dark place, such as in pits along the beach. Unprocessed tubers can be stored for up to six months, after which they begin to sprout (Hiyane 1967; Stone 1951:24). Provided the processed starch is kept dry and away from weevils, ants, cockroaches, and the like, it will keep indefinitely, making it a suitable trade item (Kotzebue 1821: I126).

Trade in arrowroot starch in the Pacific developed at the end of the nineteenth century when European traders added it to their list of desirable trade items (Fiji: Safford 1905:380; Philippines: Brown 1954:383). Before World War I, a finely woven *Pandanus* bag was used to package arrowroot traded to Jaluit, the German trading port of the Marshall Islands (Hernsheim 1887; Krämer and Nevermann 1938:138). When starch became an export commodity to the European and Asian markets, it had to be prepared more carefully. This brought about changes in local production techniques. In the Philippines, for example, grating of arrowroot tubers was done underwater to prevent them from turning brown and discoloring the starch (Brown 1954:388). In Fiji a "grater of mushroom coral *(Fungia)* was used and the colour of the arrowroot was grey since the tubers were not properly washed" (Safford 1905:380).

## TRADITIONAL AND MODERN USAGE OF ARROWROOT

In traditional Marshallese culture arrowroot was mainly utilized as a food item. Tubers and other parts of the plant were used in a variety of ways, however. Food and nonfood uses are discussed below.

*Foods prepared from arrowroot.*—Traditionally, as well as today, flour (starch) is the most common form in which arrowroot is used as a food. A number of Marshallese dishes are prepared solely from or with the addition of arrowroot starch (flour). The addition of arrowroot starch gives many dishes a gelatinous, brain-like appearance; for this reason these dishes are called in Marshallese *kömälij.* (Krämer 1906:429; Abo et al. 1976:162). All Marshallese dishes are solids, unlike in the Tuamotus, where *Tacca* starch is also used to make (alcoholic ?) beverages (Doty 1954:34). Commonly arrowroot flour was mixed with water to form a thin paste, *lagalba* (Wendler 1911), which was then mixed with other ingredients (see

Table 3). In addition to the dishes described in Table 3, arrowroot flour was sometimes added to dried and preserved *mogan* (made from the pulp of cooked or raw *Pandanus* keys) during the production process, thus increasing the volume of the *mogan* preserve and adding further starch to it.

For post-World War II times it is mentioned that arrowroot tubers are "cooked like a potato and eaten at meals with other foods" (MacKenzie 1961:60). Stone (1951:24–25), in his treatment of the agriculture of Arno Atoll, notes that "it is possible to eat them [arrowroot tubers] baked." Both cooking methods may be recent developments. According to Merrill (1945:185) the bitter taste attributed to arrowroot will disappear when it is cooked. Raw tubers, however, not only have a bitter taste, but are also credited with being mildly poisonous (Murai et al. 1958:100). In Hawaii fresh *Tacca* was mixed with coconut milk, wrapped in *ti* leaves and baked in an earth-oven (Handy 1940:299; Ihara 1971). Another modern development in the Marshall Islands is the practice of grating arrowroot and boiling it in water to form a spongy ball, which then is covered with freshly grated coconut meat (MacKenzie 1961:60). Today arrowroot starch is mainly used as a thickener in numerous dishes (Poyer 1990:64).

*Nonfood uses of arrowroot.*—Apart from the predominant use of the plant as a source of carbohydrates, arrowroot was also used for other purposes. When the stems, especially those of the flower stalks, are broken up, they provide thin fibers that can be woven into hats. Because of the great amount of labor involved in manufacturing these hats, they were the property only of chiefs (Wendler 1911). In Tahiti "straw" hats were made by splitting the flower stalks and the petioles of arrowroot into narrow strips, then curing and drying them. The material was woven into white, glossy hats of little weight (Safford 1905:380).

Mason, in his study of the economic organization of the Marshall Islands, states that arrowroot flour is used as a medicine, but does not elaborate (Mason 1947:71). On Namoluk Atoll, Caroline Islands, the seeds (fruits) are collected and used in leis, the leaves are considered to be essential in the treatment of persons bitten by a sea ghost, and the stem has medicinal uses (Marshall and Fosberg 1975:31).

A common use for arrowroot starch developed with the advent of Christianity in the islands and the increased use of European clothes, especially white dresses worn for Sunday church services: use as laundry starch. *Tacca* starch was widely used in the Marshall Islands for that purpose (MacKenzie 1956; Pollock 1970:162).

The long green stalks (up to 2 m) supporting the flower and the seeds of the plants *(aetöktök)* served village children as spear-like projectiles (Abo et al. 1976:6; Wendler 1911). In the modern Marshall Islands, *Tacca* stems are also used as cigarette holders, mainly during the frequent times when there is little tobacco on the islands. A medium-sized *Tacca* stem is chosen, pulled out, and cut to a length of about 15 cm. A cut piece of a cigarette or a cigarette stub is inserted in the end and smoked. In this way the cigarette can be smoked until virtually no tobacco is left. These arrowroot cigarette holders, when no longer usable, are carefully kept and dried. When the tobacco shortage becomes so severe that there are no stubs left to smoke, the nicotine-drenched tips of the dried arrowroot cigarette holders are chopped up and smoked in fresh holders (see also Pollock 1970:250).

TABLE 3.—Traditional Marshallese dishes prepared with arrowroot.

| Name of dish | Ingredients and preparation of dish |
|---|---|
| *Aikiu* | Soup made from *iu* (spongy coconut/coconut embryo) and arrowroot flour. |
| *Auiik* | Arrowroot flour boiled with (rolled in?) grated coconut. |
| *Benben in mokmok* | The most common use. Arrowroot flour boiled in water with coconut sap *(jekaro)* added until it attained a thick, jelly-like consistency. Shaped into small balls or patties and rolled in grated coconut. |
| *Beru* | Soft pulp from the ends of boiled *Pandanus* keys *(mokwan)* combined with arrowroot flour, poured into a cone-shaped or triangular receptacle made of two fresh breadfruit leaves; cooked together as a dessert. Coconut cream *(el)* may be added for taste. Commonly cooked in the earth oven *(um).* |
| *Bobo* | Arrowroot flour mixed with coconut water and cooked in coconut shells (with some sugar added). When jelled and cooled down, the jelly is cut into squares and rolled in grated coconut. This food is mainly used for sick and old people (and infants?). |
| *Buiabui* | Starvation food made by pounding the internal part of a driftwood tree (or old coconut palm) to pulp and mixing it with arrowroot flour and water. |
| *Bwiro iiök* | Preserved breadfruit *(bwiro)* mixed with arrowroot flour and *jekaro* wrapped in breadfruit leaves and baked. |
| *Iek* | *Bwiro* mixed with arrowroot flour, kneaded, and shaped into a ball. It is then sun-dried and can be stored for a limited period of time. When it is to be eaten, it is soaked for an hour in water. At meal time the water is poured out and the ball is mashed with a *Tridacna* pounder. Grated coconut is added to the mixture when pounded. |
| *Jaboen* | Arrowroot starch boiled in water with coconut sap *(jekaro)* added. Allowed to cool, formed into a ball, and rolled in grated coconut. |
| *Jamok(ok)* | Arrowroot flour mixed with grated coconut meat from semi-ripe coconuts and baked. |
| *Jinkap* | Arrowroot flour mixed with coconut water and cooked in coconut shells. Solely used for postpartum women. |
| *Jokwob* | Boiled arrowroot flour with fish added. A soup-like dish. |
| *Jup in mokmok* | Arrowroot flour, *iu,* fish, and coconut milk. |
| *Kärek* | *Bwiro* mixed with arrowroot flour. |
| *Kebieltak* | Arrowroot flour, crackers, and *jekaro.* |
| *Likbbla* | Arrowroot starch is first mixed with water, sugared water, or *jekaro* into a watery consistency (at a ratio of three to one). Then the mixture is slowly poured into a pot of boiling water and stirred until a soft, sticky substance is obtained. |
| *Managedien* | Same as *lek,* but not rolled in grated coconut. |
| *Peaut Iu* | Cooked with water or coconut milk and arrowroot flour. |
| *Wagakgak* | Meal prepared from arrowroot flour boiled with grated coconut. |

TABLE 3.—Traditional Marshallese dishes prepared with arrowroot. (continued)

| Name of dish | Ingredients and preparation of dish |
|---|---|
| no name | An innovative dish, apparently introduced by the UNDP Integrated Atoll Project, was reported for Taroa, Maloelap Atoll. Papaya and arrowroot are mixed with water, apparently to make a *poi*-like dish. |

Data compiled from Abo et al. 1976:297; Erdland 1906:165, 177; 1914:221; Hiyane 1967, 1971b:14; Kotzebue 1821:1126; Krämer 1905:144; Krämer and Nevermann 1938:139–141; MacKenzie 1961:60; Mason 1947:71; Murai 1954:2; Murai et al. 1958:102–103; Pollock 1970:319; Poyer 1990:64; Wendler 1911).

*Contemporary role of arrowroot.*—At the end of World War II arrowroot starch still played a major role in the subsistence economy of the Marshallese, especially of the more northern atolls. A nutrition survey undertaken during the early 1950s in the northern Marshall Islands showed that "arrowroot flour was used extensively where imported goods were not available and before the breadfruit season began (Murai 1954:102).

Previous botanical and agricultural studies (e.g., Hatheway 1953) had shown that arrowroot does well planted under coconut, provided that competing vegetation is cleared. This finding was applied in the recommendations of an agriculture survey of Kili Island and islands in Jaluit Atoll. In order to maximize production for feeding the dislocated Bikini people, it was proposed that all coconut scrubland on the islets be cleared, with the exception of Jabwor, and that *Tacca* be interplanted as a starch source (MacKenzie 1956:3, 4, 8, 20).

From June to August, 1967, the subsistence patterns of some families on Laura, Majuro Atoll, were investigated (Domnick and Seeleye 1967). At the time, some 700 people lived on Laura and it was not as urbanized as it is today (in 1988, population was 1,575; OPS 1989; Kabua and Pollock 1967). The 1967 assessment found that none of the nine households analyzed utilized arrowroot starch. This finding may be a result of the time of year when the study was conducted, but the omission of arrowroot from the introduction to the study and the discussion of food items suggests that it had lost its importance altogether.

These data from Laura contrast to some degree with findings on the outer islands, where arrowroot production was still practiced, although gradually declining, through the 1960s. In a 1968 assessment of nutrition on Namu Atoll, Pollock states that in "November when arrowroot corms should have been ready to dig up, there were only barely enough to make starch for clothes, let alone for food." (Pollock 1970:162–163). At the time, arrowroot cultivation—like taro cultivation—had almost died out since seed corms were no longer planted to ensure a supply for the following year. According to Namu informants it was easier to gather coconuts for copra to sell to buy rice than to grow taro and arrowroot as staple foods. The sequence in which the use of arrowroot starch is mentioned, first as starch for clothes, then as a food, indicates that the starch has lost its position as a major food source.

The role of arrowroot starch in the contemporary (i.e., 1990s) Marshall Islands economy is hard to ascertain. The starch is virtually impossible to obtain in the urban atolls Majuro and Kwajalein, and is also very rare in the outer islands. Based on my interviews, arrowroot starch is still produced, although not in very large quantities. When the starch is available, it is almost invariably quickly exhausted for daily consumption, rather than stored and used over a longer period of time. Quantitative data, however, cannot be provided.

It appears that the decline of arrowroot in the Marshall Islands is a result of a simultaneous demise in importance of all traditional food items. With lack of weeding, arrowroot quickly becomes crowded by competitors and is eventually overgrown. The fact that the plants have to put all their energies into leaf growth, in order to keep up with weedy competitors, rather than producing a seed stalk and a large tuber, results in the recovery of very small tubers from modern arrowroot plants.

## THE FUTURE OF ARROWROOT PRODUCTION

One major issue remains to be discussed: whether there is a future for arrowroot production in the Marshall Islands. From the previous discussion, it is apparent that arrowroot has lost its importance. In fact, throughout the Pacific region the role of arrowroot in the local subsistence economy has seen a major downturn. Colonial interference with traditional food production was limited during the first half of this century, and the small amount of money circulating in the islands made subsistence agriculture a necessity on the atolls. In the immediate post-World War II period, many traditional subsistence systems still existed, although in a phase of transition to a consumer society. Arrowroot was still a staple crop on some atolls, although it had become restricted to a source to rely on in times of food scarcity. Over time arrowroot starch was produced as a laundry starch, rather than as a food. Finally, the advent of washing powder—as opposed to bar soap—and the general decline of the habit of wearing starched clothes brought about the decline of arrowroot starch altogether. This is true for the Tuamotus (Doty 1954:12–13) and Belau (Otobed 1977:8) as well as for the Marshall Islands.

The cash economy brought upon the islanders by the burgeoning Pacific trade and the high return for copra, the staple export crop for most atolls, changed food production to food purchases. It became easier to produce copra and to purchase staple foods from the proceeds. This was even more compelling since modern introduced foods could be cooked with less preparation time than traditional foods. This has pointedly been called the "copra-tin can economy" and has been observed on numerous atoll groups (Doty 1954:13). While this made economic sense in the heyday of copra production and high copra prices of the 1970s and 1980s, this makes little economic sense in the days of low copra profits in the 1990s.

The modern economy of the Republic of the Marshall Islands is heavily supported by outside funding. Available balance of payment figures show a trend towards increasing imports, while exports stagnate or at best increase negligibly. The balance of trade is highly negative: exports would have to be raised 1500% to level out the balance (OPS 1989a:138). For most outer islanders, copra is still the

sole means of a cash income, apart from handicraft production, but it has become less and less lucrative. Other income-generating schemes do not always work, and in order to increase the standard of living, the lowering of expenditure by import substitution is a feasible option.

Previous botanical and agricultural studies have shown that arrowroot does very well under coconut, provided that competing vegetation is kept in check. Thus arrowroot would be a very suitable intercrop in copra plantations. Based on the analysis of arrowroot tending, production, and starch extraction described above, a comparison of the costs of producing arrowroot and copra can be made. I have used a household comprising two able-bodied males (15–64 years of age) and two male minors for purposes of this comparison. Female labor input, which would speed up the process, was not taken into account since this is not "traditional."

As shown elsewhere (Spennemann 1992) daily income from copra production is $3.00 per person (male) *on very productive atolls*. Thus the seven days of labor invested in the production of 25 lb. arrowroot starch (refer to previous discussion) are equivalent to at most $21.00 of copra production. Processing arrowroot instead of copra, therefore, costs the producer and self-consumer $0.84 per pound of arrowroot. In view of the fact that both copra income figures and arrowroot labor investment figures have been rather conservatively calculated, the actual per pound cost of arrowroot starch is very likely substantially less than $0.84. For example, if weeding of plots and drying of the extracted starch were done by children, who are not involved in copra-making, the labor investment for men is reduced to four days, resulting in a cost of $0.48 per pound of arrowroot starch. Alternatively, the cost per pound of starch is reduced to $0.37 if copra income *averaged for all copra-producing atolls* is used in the calculation, and then to $0.21 per lb when a 4-day labor investment figure is used.

This cost of $0.84 or less per pound of arrowroot starch can be compared with the cost of corn starch in Majuro ($1.15 or more) and in outer island retail stores ($1.50 or more). Because of the remote location of the Republic of the Marshall Islands, all imported foods are expensive due to transportation costs and mark-ups. Substitution of locally produced products therefore is feasible and, in view of the economic situation of the outer atolls, also desirable.

## CONCLUSIONS

The goal of this study was to review the state of knowledge on arrowroot production and utilization in the Marshall Islands and to assess its potential as a future source of carbohydrate. In many Pacific Island nations the former subsistence economy is waning in view of consumer-oriented influences, and imported foods are becoming more prominent. In the course of this change several traditional subsistence sources, such as Polynesian arrowroot, have almost disappeared. A review of arrowroot and its role in Marshallese horticulture has shown that the plant was a common staple before World War II, but that in the 1960s its role changed from a food source to a provider of laundry starch. Where arrowroot is still produced in small quantities, it is a sought after food item. A brief economic assessment demonstrates that arrowroot starch is a cheap alternative to

imported starch. Because it thrives well intercropped under coconut, arrowroot is an ideal plant for import substitution.

## NOTES

[1]It should be noted that the Republic of the Marshall Islands, in its internationally recognized boundaries, comprises 28 atolls and five coral islands. The geographical term "Marshall Islands," however, also includes Eneen-Kio (Wake Atoll), currently under the jurisdiction of the United States of America. The Republic of the Marshall Islands has repeatedly made clear its position that Eneen-Kio forms an integral part of the Republic of the Marshall Islands.

[2]In Western literature on Pacific plants, *Tacca leontopetaloides* (L). Kuntze is known as arrowroot, Tacca, East Indian arrowroot, Island arrowroot, Polynesian arrowroot, Tahiti arrowroot, or Fiji arrowroot. African arrowroot is the common name synonym for *Tacca involucrata* Schumacher and Thonn (1827), which in turn is a synonym for *T. leontopetaloides*. The German ethnographic literature on the Marshall Islands, the main source for nineteenth century data, describes arrowroot as *Pfeilwurz*. For comparison, Indian arrowroot *(Curcuma angustiofolia)* and Queensland arrowroot *(Canna edulis)* have similar vernacular names, but belong to totally different plant families. The name East Indian Arrowroot is also used to contrast *Tacca* with West Indian Arrowroot *(Maranta arundinacea)*, which was discovered first by Europeans and received its name from the fact that the plant was used by West Indian natives to treat wounds inflicted by poisoned arrows (Masefield 1948:44–45).

Apart from the official Marshallese spelling *mäkmök* as shown in the current edition of the Marshallese-English Dictionary (Abo et al. 1976:212), there is an abundance of phonetic variations by which the Marshallese name has been spelled, such as *makemok* (Bryan 1972:132); *mogumok* (Kotzebue 1821:1126); or *mok mok* (Fosberg and Sachet 1962:13)

## LITERATURE CITED

ABO, TAKEO, BRYON W. BENDER, ALFRED CAPELLE, and TONY DEBRUM. 1976. Marshallese-English Dictionary. Pacific-Asian Language Institute Language Texts, Micronesia. University of Hawaii Press, Honolulu.

ANONYMOUS. 1895. Denkschriften betreffend (Jahresberichte über) das Schutzgebiet der Marschall-Inseln (1893–1894). Stenographische Berichte über die Verhandlungen des Reichstages, 1895.

BROWN, WILLIAM H. 1954. Useful Plants of the Philippines. Technical Bulletin No 10, Department of Agriculture and Natural Resources, Republic of the Philippines. Agricultural Information Division, Department of Agriculture and Natural Resources, Manila.

BRYAN, EDWIN H. 1972. Life in the Marshall Islands. Pacific Scientific Information Center, Honolulu.

CHAMISSO, ADALBERT VON. 1986. A Voyage Around the World with the Romanzov Exploring Expedition in the Years 1815–1818 in the Brig Rurick, Captain Otto von Kotzebue. H. Kratz (trans.) University of Hawaii Press, Honolulu.

CURTIS, CAROL. 1986. Handcrafts of the Marshall Islands. Manuscript on file, National Archives of the Republic of the Marshall Islands, Alele Museum, Majuro Atoll.

DOMNICK, CHARLES and MICHAEL SEELEYE. 1967. Subsistence patterns among selected Marshallese villagers. Pp. 1–45 *in* The Laura Report. A Field Report of Training and Research in Majuro Atoll, Marshall Islands. Leonard Mason (editor). University of Hawaii, Honolulu.

DOTY, MAXWELL S. 1954. Floristics and Plant Ecology of Rairoa Atoll, Tuamotus. Part 1: Floristics and Ecological Notes on Rairoa. Atoll Research Bulletin 33:1–41. Pacific Science Board, Washington, D.C.

ERDLAND, AUGUSTIN. 1906. Wörterbuch und Grammatik der Marshallsprache nebst ethnographischen Erläuterungen und kurzen Sprachübungen. Archiv Deutscher Kolonialsprachen, Vol. IV. Georg Reimer, Berlin.

———. 1914. Die Marshall Insulaner. Leben und Sitte, Sinn und Religion eines Südsee-volkes. Anthropos Bibliothek. Internationale Sammlung Ethnologischer Monographien, Vol. 2(1). Aschendorffsche Verlagsbuchhandlung, Münster.

FEENEY, THOMAS J. 1952. Letters from Likiep. Pandick Press, New York.

FOSBERG, F. RAYMOND. 1957. The Maldives Islands, Indian Ocean. Atoll Research Bulletin 58. Pacific Science Board, Washington, D.C.

———. 1990. A Review of the Natural History of the Marshall Islands. Atoll Research Bulletin 330. Smithsonian Institution, Washington, D.C.

——— and MARIE-HELENE SACHET. 1962. Vascular Plants Recorded from Jaluit Atoll. Atoll Research Bulletin 92. Pacific Science Board, Washington, D.C.

GRÖSSER, HERBERT. 1902. Wörterbuch der Marschall-Sprache nach hinterlassenen Papieren des verstorbenen Stabsarztes Dr. Erwin Steinbach. Hamburg.

HAGER, CARL. 1886. Die Marschall-Inseln. Georg Limcke Verlag, Leipzig.

HANDY, E. S. C. 1940. The Hawaiian Planter. Bernice P. Bishop Museum Bulletin 161. Bernice P. Bishop Museum, Honolulu.

HATHEWAY, WILLIAM H. 1953. The Land Vegetation of Arno Atoll, Marshall Islands. Atoll Research Bulletin 16. Pacific Science Board, National Research Council, Washington D.C.

HERKLOTS, G. A. C. 1972. Vegetables in South-East Asia. Hafner Press, New York.

HERNSHEIM, FRANZ. 1887. Die Marshall-Inseln. Mittheilungen der geographischen Gesellschaft in Hamburg 1885–1886 (1887):297–308.

IHARA, VIOLET K. 1971. Life in Ancient Hawaii—Foods. A Supplement. Research Materials, Bulletin 15. State of Hawaii, Department of Education, Honolulu.

KABUA, PHILLIP and NANCY POLLOCK. 1967. The ecological bases of political power in Laura Community Pp. 1–83 *in* The Laura Report. A Field Report of Training and Research in Majuro Atoll, Marshall Islands. L. Mason (editor). University of Hawaii, Honolulu.

KIRCH, PATRICK V. 1979. Subsistence and Ecology. Pp. 286–307 *in* The Prehistory of Polynesia. J. D. Jennings (editor). Harvard University Press, Cambridge, MA.

KISTE, ROBERT C. 1968. Kili Island: A Study of the Relocation of the Ex-Bikini Marshallese. Unpublished Ph. D. Dissertation, Department of Anthropology, University of Oregon, Eugene.

KOTZEBUE, OTTO VON. 1821. A Voyage of Discovery into the South Sea and Beering's Straits for the Purpose of Exploring a North-east Passage Undertaken in the Years 1815–1818, at the Expense of His Highness the Chancellor of the Empire, Count Romanzoff in the Ship Rurick, under the Command of the Lieutenant in the Russian Imperial Navy, Otto von Kotzebue. 3 Vols. Longman, Hurst, Rees, Orme and Brown, London.

KRÄMER, AUGUSTIN. 1905. Die Gewinning und Zubereitung der Nahrung auf den Ralik-Ratak Inseln. Globus 88:140–146.

———. 1906. Hawaii, Ost-Mikronesien und Samoa. Schweizerbartsche Veriagsbuchhandlung, Stuttgart.

——— and HANS NEVERMANN. 1938. Ralik-Ratak (Marschall Inseln). *in* Ergebnisse der Südsee-Expedition 1908–1910. II. Ethnographie, B: Mikronesien. Vol. II. G. Thilenius (editor). Friedrichsen and de Gruyter, Hamburg.

LISOWSKI, S., F. MALAISSE, and J. J. SYMOENS. 1976. Flore d' Afrique Centrale (Zaire-Rwanda-Burundi). Spermathophytes. Taccaceae. Jardin Botanique National de Belgique, Brussels.

MACKENZIE, J. B. 1956. Agriculture Survey of Jebet, Jar Bokalap, Jebwor, and

Kili Islands. Manuscript on file, National Archives of the Republic of the Marshall Islands, Alele Museum, Majuro Atoll.

———. 1961. X: Population and economy of Jaluit. Pp. 81–87 *in* A Report on Typhoon Effects upon Jaluit Atoll. D. I. Blumenstock (editor). Atoll Research Bulletin 75. Pacific Science Board, Washington, D.C.

MARSHALL, MAC. and F. RAYMOND FOSBERG. 1975. The natural history of Namoluk Atoll, Eastern Caroline Islands with identifications of vascular flora. Atoll Research Bulletin 12:67–80.

MASEFIELD, G. B. 1948. A Handbook of Tropical Agriculture. Clarendon Press, Oxford.

MASON, LEONARD. 1947. The economic organisation of the Marshall Islands. U. S. Commercial Company Economic Survey. Manuscript on file, University of Hawaii Library.

MERRILL, ELMER D. 1945. Plant Life of the Pacific World. 1981 Facsimile reprint by Charles E. Tuttle Co., Rutland, VT.

MURAI, MARY. 1954. Nutrition Study in Micronesia. Atoll Research Bulletin 27. Pacific Science Board, Washington D.C.

———, F. PEN, and C. D. MILLER. 1958. Some Tropical South Pacific Island Foods. Description, History, Use, Composition, and Nutritional Value. University of Hawaii Press, Honolulu.

OFFICE OF PLANNING AND STATISTICS. 1989. Census of Population and Housing, 1988. Final Report. Office of Planning and Statistics, Majuro, Marshall Islands.

OTOBED, D. O. 1977. Guide list of plants of the Palau Islands. Manuscript on file, Entomology Section, Biology Laboratory, Trust Territory of the Pacific Islands, Koror, Palau.

PAUL, T. 1965. Arrowroot and sweet potato in Truk. *in* Field Training and Interchange in Root Crops, Koror, Palau Islands. September 25 - October 15, 1965. Microfilm No. 219 on file, Archives of the Trust Territory of the Pacific Islands, Palau.

POLLOCK, NANCY. 1970. Breadfruit and Breadwinning on Namu Atoll, Marshall Islands. Unpublished Ph. D. Dissertation, Department of Anthropology, University of Hawaii, Honolulu. University Microfilms (MF 71-12211), Ann Arbor, MI.

POYER, LIN. 1990. Ethnology component. Micronesian resource study, Taroa Island, Maloelap Atoll, Republic of the Marshall Islands. Micronesian Endowment for Historic Preservation. Report on file, Historic Preservation Office, Republic of the Marshall Islands.

PURSEGLOVE, J. W. 1972. Tropical Crops. Monocotyledons. Longmans, London.

REHG, KENNETH L. and DAMIEN G. SOHL. 1979. Ponapean-English Dictionary. Pacific-Asian Language Institute Language Texts, Micronesia. University of Hawaii Press, Honolulu.

SAFFORD, W. E. 1905. The Useful Plants of the Island of Guam. Contributions from the U. S. National Herbarium 9. Smithsonian Institution, Washington D.C.

SOUCIE, EDWARD A. 1983. Atoll Agriculture for Secondary Schools. Soils and Major Agricultural Crops of Micronesia. Ponape Agriculture and Trade School, Pohnpei.

SPENNEMANN, DIRK H. R. 1991. Notes on the Occurrence, Utilisation, and Importance of Polynesian Arrowroot *(Tacca leontopetaloides)* in the Marshall Islands. Independent Nationwide Radiological Survey Background Study No. 39. Majuro, Marshall Islands.

———. 1992. Copra revenues as a parameter of male income in the Outer Islands of the Republic of the Marshall Islands. Journal of the Pacific Society (Tokyo) 15:43–54.

SPROAT, M. N. 1968. A Guide to Subsistence Agriculture in Micronesia. Agricultural Extension Bulletin 9. Publications Office, Saipan, Commonwealth of the Northern Marianas.

STONE, EARL L. 1951. The Agriculture of Arno Atoll, Marshall Islands. Atoll Research Bulletin 6. Pacific Science Board, National Research Council, Washington D.C.

TAYLOR, WILLIAM RANDOLPH. 1950. Plants of Bikini and other Northern

Marshall Islands. University of Michigan Press, Ann Arbor.
WENDLER, PATER JOACHIM. 1911. Zur Feuer-und Nahrungsbereitung der Marschall-Insulaner (Südsee). Baessler-Archiv 1:269–276.
WILLIAMSON, L. and M. D. SABATH. 1982. Island population, land area, and climate: A case study of the Marshall Islands. Human Ecology 10:71–84.
WOHLTMANN, F. 1905. Pfeilwurzmehl. Der Tropenpflanzer March 1905. Cited in Krämer, Augustin. 1905. Die Gewinning und Zubereitung der Nahrung auf den Ralik-Ratak Inseln. Globus 88:140–146.

## BOOK REVIEW

**Barley: Chemistry and Technology.** Alexander W. MacGregor and Rattan S. Bhatty (Editors). St. Paul, Minnesota: American Association of Cereal Chemists, Inc., 1993. Pp. viii; 486. $145.00 (in United States), $169 (outside of United States) (add $2.00 postage). BEF 5575.

One of the oldest of cultivated plants, barley, is treated in this valuable book by seventeen contributors from six countries, an extraordinary collection of outstanding experts who in ten chapters present the most up-to-date data on the chemistry and technology of *Hordeum*. As stated in the preface, "The intention of the editors was to produce a volume that was broad in scope yet covered each topic in depth." Their intention has indeed been fulfilled. The book must be considered a major contribution to economic botany.

The ten chapters present a mass of information organized in a most orderly sequence: (1) The taxonomy, origin, distribution, production, genetics, and breeding of barley; (2) Formation of the barley grain—morphology, physiology, and biochemistry; (3) Carbohydrates of the barley grain; (4) Barley seed proteins; (5) Barley lipids; (6) Physiology and biochemistry of barley germination; (7) Malting technology and uses of malt; (8) Non-malting uses of barley; (9) Potential improvement of quality through genetic engineering; and (10) Whole crop utilization of barley, including potential new uses.

Each chapter naturally has its own extensive bibliography. The index, which occupies eleven and a half pages, is extremely detailed.

Richard Evans Schultes
Botanical Museum of Harvard University
Cambridge, Massachusetts 02138