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# THE ORIGIN AND DISTRIBUTION OF KAVA (PIPER METHYSTICUM FORST. F., PIPERACEAE): A PHYTOCHEMICAL APPROACH

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ABSTRACT

After a taxonomic clarification and a review of the ethnobotanical data about kava, an attempt is made to elucidate the origin of this Oceanian plant. For this purpose, an ecogeographical survey of the genetic resources of the plant species *Piper methysticum* Forst. f. and *P. wichmannii* C. DC. was conducted throughout the Pacific. Local cultivars were collected from 42 different islands, planted in germplasm collections, and described. One hundred eighteen different kava cultivars were identified through morphological differentiation. High Performance Liquid Chromatography (HPLC) on more than 200 root samples revealed the existence of various chemotypes. Analysis of quantity variation in kavalactone content was carried out by using cluster analysis and multifactorial analysis. Field trials of various cultivars indicated that the chemotype was not related to environmental factors or ontogeny, but to genotype. The lineage of the chemotypes suggested that *P. wichmannii* was the wild species from which farmers domesticated cultivars of *P. methysticum*.

## I. INTRODUCTION

The remarkable medicinal properties and soothing effects of kava have been part of the wisdom of Pacific islanders for centuries. Melanesian, Polynesian, and Micronesian peoples alike grind the fresh or dry roots and stalks of this plant (*Piper methysticum* Forst. f.) to prepare their traditional beverage, which is the centerpiece for much solemn ritual as well as being the daily social drink for many appreciative Oceanians. The preeminent role kava has long played in Pacific societies is believed to be due to its outstanding pharmacological properties. Indigenous populations unlocked the door to an artificial paradise by consuming an elixir prepared from this plant species, endemic to this vast area of scattered islands and growing nowhere else. Very few other plants with such properties were present in Oceania.

Kava has been classified as a narcotic and hypnotic (Schultes and Hofmann, 1979). When consumed, it has psychoactive properties, but it is neither hallucinogenic nor a stupefacient, and this helps to explain the spirit of sociability felt when drinking kava. By pharmacological standards, kava is not classified as a drug, as its consumption never leads to addiction or dependency.

According to a recent review (Sengupta and Ray, 1987), *Piper methysticum* is the only *Piper* species from which several flavones and chalcones have been isolated. Experimental studies have shown that the active principles of the plant,

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the kavalactones, have diuretic, soporific, antiepileptic, spasmolytic, analgesic, local anesthetic, bactericidal, and antimycotic properties (Hänsel, 1968). Some of these properties have been utilized in the European pharmacopeia for over a hundred years, and there is potential for wider use (Lebot and Cabalion, 1986).

The area of cultivation of kava was much wider before the arrival of the Europeans, at which time the religious taboos of some of the Christian missions were responsible for outlawing its use in all but a handful of islands. Kava was drunk throughout Polynesia (with the exception of New Zealand, Easter Island, Rapa, and the coral atolls where the plant could not grow), in parts of the Melanesian crescent of Fiji, Vanuatú, Solomon Islands, and Papua New Guinea, and in the Micronesian islands of Pohnpei (Ponapé) and Kosrae.

The origin and distribution of such a significant species could be a valuable indicator of population migrations in the Pacific. The information gained from kava distribution is of value when kava is found in areas where it is not indigenous, and especially in view of the fact that the cultivars are solely propagated by cuttings and not by seeds. Several scientists have conducted similar work on Oceanian staples, e.g. sweet potato, *Ipomoea batatas* (Hornell, 1946; Barrau, 1962; Yen, 1974), the fe'i banana, *Musa troglodytarum* (MacDaniels, 1947), the breadfruit, *Artocarpus altilis* (Barrau, 1962; Wilder, 1928), and taro, *Colocasia esculenta* (Kolb, 1953).

In order to study this unexploited crop of great cultural value and promising economic potential, it was decided to clarify the taxonomy before reviewing the ethnobotanical data about kava in an attempt to elucidate the enigma of its origin. The information gained from these first two steps determined the choice of methods used to conduct an ecogeographical survey covering its area of distribution.

It should be borne in mind that the germplasm had never been collected, described, and evaluated. Specific objectives included the assessment of interaction among ecological factors, their effect on the biosynthesis of kavalactones, and the analysis of interspecific and intraspecific polymorphism.

Islands or island groups concerned in this survey were: Papua New Guinea, Solomon Islands, Vanuatu, Fiji, Wallis and Futuna, Western Samoa, American Samoa, Tonga, Cook Islands, Tahiti, the Marquesas, Hawaii, and the Federated States of Micronesia. The results obtained, together with the morphological and chemical descriptions of local kava cultivars and related species, are presented in this paper.

This survey was preceded by more than three years of field study, carried out initially in Vanuatu and subsequently in most of the other Pacific islands or archipelagoes.

## 2. TAXONOMIC CLARIFICATION

The precise date when kava first came to the attention of European explorers is perhaps questionable, although it is stated (Brosses, 1756) that Dutch navigators Le Maire and Schouten observed it in the island of Futuna (from Wallis and Futuna) as early as 1616. It was certainly known to Pacific travelers by the time of the first Cook expedition (Parkinson, 1773), and a drawing (entitled "*Piper*

*inebrians*") by Parkinson, made in the Society Islands in 1769, is preserved at the British Museum (Natural History) and has been reproduced (Beaglehole, 1962). *Piper methysticum* was first validly described, for botanical purposes, by J. G. A. Forster (1786a), who accompanied Cook's second voyage (1772–1775) as a botanist, together with his father, J. R. Forster, and A. Sparrman. Actually, the binomial *Piper methysticum* had previously been used for a different species by the younger Linnaeus in 1781, but that usage was negated by the fact that Linnaeus (in a simultaneously published Emendanda) substituted the binomial *Piper latifolium*. Linnaeus therefore, did not accept his own binomial *Piper methysticum* in the original publication (cf. *International Code of Botanical Nomenclature*, Art. 34.1), and its use by G. Forster in 1786 is nomenclaturally permissible; problems pertaining to the botanical name have been discussed by Moore (1934) and A. C. Smith (1943, 1975, 1981). There are a few botanical synonyms of *P. methysticum*, most of them merely listed without description (and hence of no botanical significance) or later than G. Forster's binomial of 1786. Among truly related species are three endemic to Papua New Guinea, the Solomon Islands, and Vanuatu, namely *P. wichmannii* C. DC., *P. gibbilimbum* C. DC., and *P. plagiophyllum* K. Schum. & Lauterb. In some of the botanical literature the name *Piper methysticum* has been erroneously compared with or confused with species of quite a different genus, *Macropiper*, especially with such species as *M. latifolium* (L. f.) Miq. (Santa Cruz Islands, Vanuatu, and the Cook, Austral, Society, and the Marquesas Islands) and *M. excelsum* (Forst. f.) Miq. (New Zealand, Lord Howe, Norfolk, Kermadec, and the Three Kings Islands) (A. C. Smith, 1975).

Kava is an elegant and attractive shrubby plant measuring from one meter to over four meters in height. It is a hardy, slow-growing perennial, generally resembling other Piperaceae, the main stems being monopodial and the lateral stems being sympodial (Blanc and Andraos, 1983) (FIGURE 1). These lateral branches grow from the young parts of the stem and, as they age, they die and fall away, leaving prominent cicatrices on the nodes. Lateral branches may sprout from the main stem in either a levogyrate or a dextrogyrate arrangement. They are built by a linear succession of monophyllous modules which produce one cataphyll and one terminal spadix (FIGURE 2). When it reaches maturity, the plant takes the form of a bouquet of ligneous stems clustered together at their base. However, cultivars show considerable variation of habit: some are prostrate (very short internodes), while others are normal (many stems), or erect (few stems with very long internodes) (FIGURE 3).

In 1986 and 1987, the major world herbaria were either visited (Paris Museum; Singapore; Lae; Bernice P. Bishop Museum) or invited to list their specimens of *Piper methysticum* and *P. wichmannii* (Royal Botanic Gardens, Kew; British Museum (Natural History); Rijksherbarium; University of Malaya; Bogor; Queensland Herbarium; Royal Botanic Gardens, Sydney; Department of Scientific and Industrial Research, Christchurch; Missouri Botanical Garden; Arnold Arboretum). Data from these specimens were compared with collections from smaller Pacific herbaria located in the Solomons, Vanuatu, Fiji, New Caledonia, Tahiti, and Guam. This gave us an accurate picture of the area of distribution for these two species.

FIGURE 1. *Piper methysticum* Forst. f.; general appearance of the plant (From Lebot and Cabalion, 1986). Bar equals 4 cm.

It is likely that other specimens lie neglected in unknown collections, but we feel that the herbaria contacted have provided a fairly comprehensive list of what has been collected since the first voyages to the Pacific. In general, we found that the plant did not attract a great amount of attention of field botanists, who often feel that they are wasting their time collecting cultivated species.

Nevertheless, more than 240 specimens of *Piper methysticum* have been collected in Oceania (in Micronesia: Pohnpei, Palau, and Guam; in Polynesia: Oahu, Molokai, Kauai, Maui, Hawaii, Nuku Hiva, Fatu Hiva, Uapou, Raiatea, Tahiti, Mangaia, Rarotonga, Aitutaki, Niue, Upolu, Savai'i, Tau, Tutuila, Tongatapu,

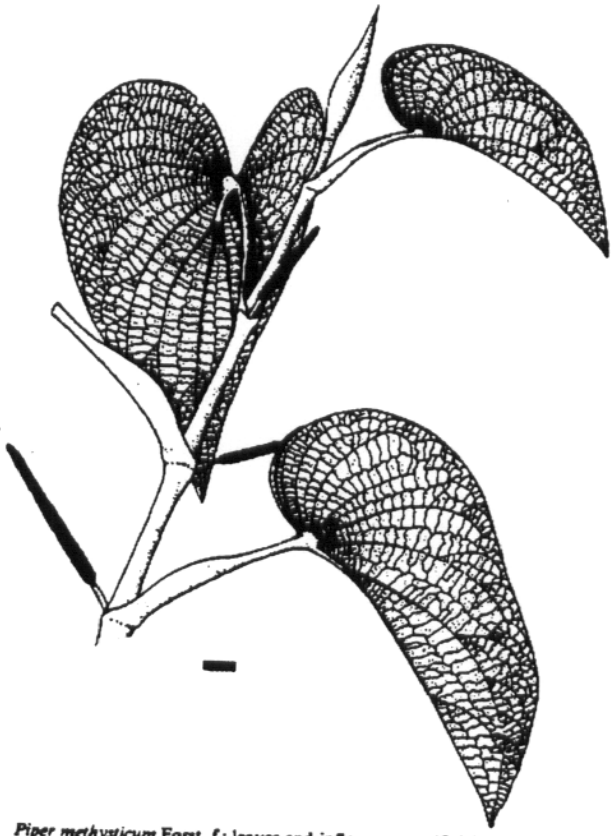


FIGURE 2. *Piper methysticum* Forst. f.; leaves and inflorescences (Original). Bar equals 2 cm.

Vava'u, Eua, Wallis, Futuna, and Alofi; and in Melanesia: Vanua Levu, Viti Levu, Vanua Balavu, Lakeba, Rewa, Tanna, Anatom, and Pentecost).

Only 13 specimens were seen from Papua New Guinea and three from Irian Jaya, on the southern border with Papua New Guinea. These were collected in Western Province, Lake Kutubu, and Madang at the beginning of the century. Miklouche-Maclay (1886) saw kava being prepared at Torendu, Astrolabe Bay in 1872; therefore it was established there before European contact. Strangely, it has not been collected or reported from New Ireland or New Britain, so it arrived in the Madang area by direct introduction, through human interference, rather than through natural diffusion. There are no early records of kava in Western

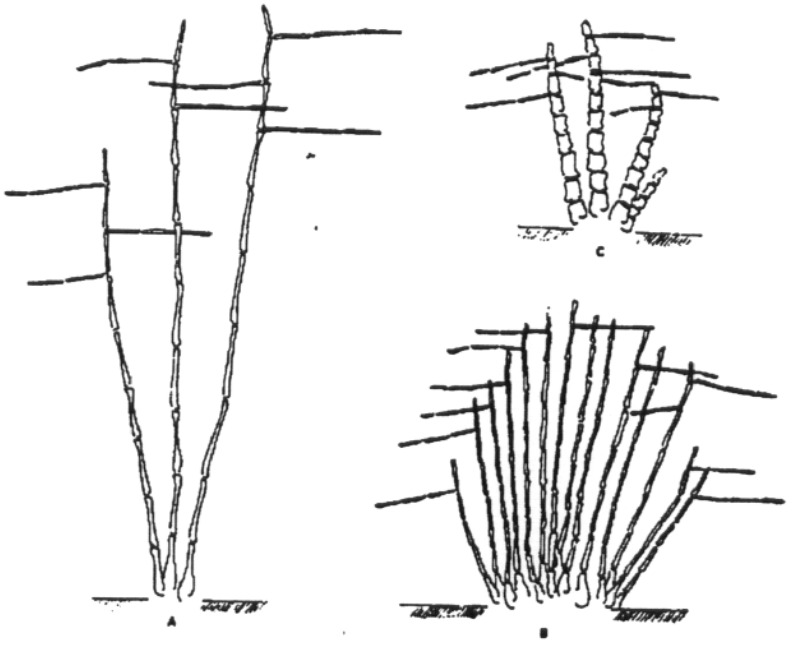



FIGURE 3. Variations of habit of *Piper methysticum*. A, erect; B, normal; C, prostrate.

Province. When missionary work began early this century, catechists, recruited in Tonga and Fiji, were employed. Possibly one of these evangelists spread the root as well as the gospel to Daru or one of the other stations (E. E. Henty, personal communication). No specimens have come to our attention from the Solomons or New Caledonia. Surprisingly, in his first publication, Forster (1786a) noted its occurrence in this territory ("... Piper methysticum verum inter plantas cultas earundem insularum passim reperitur, iis tamen exceptis, quae nigrae gentis sedes sunt, novis Hebridibus et Caledonia nova."). Forster's first statement about kava gives the reader to understand that the first plant collected was a cultivar rather than a wild species. According to A. C. Smith (personal communication), Forster's mention of the new Hebrides and New Caledonia was perhaps intended to exclude those archipelagoes; his observations, in both of his 1786 publications (1786a, 1786b), imply that his remarks were based on material from the Societies, Tonga, and Hawai'i.

A total of 111 specimens of *Piper wichmannii* has been collected, all from Papua New Guinea, the Solomons, and Vanuatu. This species apparently has not been collected anywhere else.

The western edge of the distribution area for *Piper methysticum* is Irian Jaya, while the eastern boundary is the Marquesas. This species has never been collected in Indonesia, the Philippines, or South America.

None of the collected specimens of *Piper methysticum* had seeds, and female plants are uncommon. B. Delessert (1838) depicted male inflorescences without fruit, as did Degener (1940) for Hawaiian material. The latter stated that he had not seen a single female plant in any of the plantations he had visited and pointed out that Hillebrand, an indefatigable collector, had been unable to describe one in his Flora many years earlier because none could be found. In 1968, Hänsel confirmed this information. All these authors stated that they had never seen any female flowers. However, the information on specimens recorded by collectors demonstrates that, although kava has never been collected in undisturbed habitats, female plants, albeit rare, do occur in cultivation. Among the publications dealing with kava, only a few give descriptions of seeds. In two of these (Cuzent, 1860; Barrau, 1957) no herbarium specimen is cited, making the information impossible to verify. In two other references (J. R. and I. Baker, 1936; Guillaumin, 1938), cooperation with the Kew Royal Botanic Gardens (Lebot et al., 1986) has confirmed that the fruits are from *Macropiper latifolium* and not *P. methysticum*.

Local experience confirms the opinions that *Piper methysticum* does not fruit. Growers in Vanuatu are unanimous in stating that, in their country, no fruits or seeds have ever been seen on any kava. *Piper methysticum* does, however, flower; it is dioecious, producing male and female inflorescences on separate plants, but it does not reproduce sexually. When hand-pollinated, female inflorescences fall off before they produce fruit.

Insects and weather are the vectors for natural pollination in Piperaceae (Semple, 1974). When pollination is successful, the small fruits are either dispersed by the wind, by falling to the ground, or are eaten by birds and bats. In the case of *Piper methysticum*, wind-pollination is unlikely because the sticky and glutinous pollen cannot be washed off or blown away easily.

*Piper methysticum* had not been cytologically investigated before our first attempt on root tips (Lebot, 1988, unpublished data). The chromosomes counts have shown that a cultivar of *P. methysticum* originating from Efaté, in Vanuatu, had a somatic complement of $2n = 130$. This decaploid count, based on $x = 13$, is the first recorded in this genus (Samuel, 1986). This high level of ploidy could contribute to the sterility of *P. methysticum*.

Before the distribution of kava can be used as an indicator of Pacific population migrations, it is essential to determine its origin. There is no evidence to suggest that this species is indigenous to Polynesia, as none of the other species of *Piper* in Polynesia are closely related to *P. methysticum*. Botanically, the greatest areal concentration of allied species of the same genus is a good indication of origin. It is clear that the number of *Piper* species is much higher in Papua New Guinea and Melanesia than in Polynesia or Micronesia.

Several botanists have discussed the origin of *Piper methysticum*. Although for Yuncker (1959) ". . . its origin is problematical . . .", according to A. C. Smith (1981), "The nativity of *Piper methysticum* is uncertain, but probably it was indigenous in eastern Malesia or possibly in the New Hebrides; it is now widely cultivated eastward throughout the Pacific and is occasionally naturalized. It is certainly one of the first plants that aboriginal voyagers would have taken with them."

According to a comprehensive revision of the genus in Melanesia made by

FIGURE 4. *Piper wichmannii* C. DC. (Original). Bar equals 2 cm.

Chew Wee-Lek (1972), *Piper wichmannii* (synonyms are *P. erectum* C. DC., *P. schlechteri* C. DC., and *P. arbuscula* Trelease) is the species most closely related to *P. methysticum*. It is also a dioecious shrub, similar to *P. methysticum* in growth patterns and morphological features. The inflorescences are as long as the leaves, with peduncles shorter than the petioles ("... male flowers 2-staminate; stamens 0.5 mm. long; anthers reniform, dehiscing apically; filaments short, broad, and stout. Female flowers sessile; stigmas 3-fid, subsessile; bracts round, peltate, long-pedicillate. Fruits sessile, somewhat obconical, free at maturity." (Chew, 1972)) (FIGURE 4).

One of the aims of this paper is to demonstrate that *Piper wichmannii* is the wild progenitor from which sterile cultivars of *P. methysticum* were derived. Based on their personal field observations, the authors believe that *P. methysticum* is not a different botanical species but rather a group of sterile cultivars selected

from somatic mutants of *P. wichmannii*. This is largely because *P. methysticum* is known only from gardens and should really not be considered as a "species", but as a putative cultivar (Chew, personal communication). The major morphological difference between these two entities is the length of the inflorescence, which for *P. wichmannii* is as long as the lamina (from 15 to 30 cm.). Variability in the inflorescence length for cultivars of *P. methysticum* is also observed (from 6 cm. up to 20 cm.), but it is always shorter than the lamina. For the purpose of this study, we will assume that any particular form, wild or cultivated, belongs to the botanical species *P. wichmannii* when the spadix is as long as the lamina and the plant is erect with few stems. Based on field experience, these are the only characteristics which allow differentiation.

In fact, in Vanuatu, no significant difference in either the male or the female flowers has been found between *Piper wichmannii* and *P. methysticum* specimens (Chew, personal communication). However, *P. methysticum* was described before *P. wichmannii* (Candolle, 1910), and it is such an important economic plant that to consider it as included in *P. wichmannii* would certainly cause conceptual and practical problems for both taxonomy and agro-botany.

Our study of living and preserved material leads us to conclude that morphological differences existing between *Piper wichmannii* and *P. methysticum* (i.e. coloring and pigmentation of stem internodes, leaf coloring, or pubescence on lamina, etc.) are no more significant than those between cultivars of *P. methysticum*. Furthermore, in Vanuatu native farmers who are able to distinguish many cultivars on the basis of morphological features consider that forms of *P. wichmannii* and *P. methysticum* belong to the same species and call both these plants kava. Anatomically, however, although the roots of *P. wichmannii* are similar to those of *P. methysticum*, there are differences. The great hardness of the tissue of *P. wichmannii* is noticeable, and the proportion of lignified tissues is very high. These are scattered around tracheids in contrast to those of the *P. methysticum* root, which is characterized by extraordinarily wide medullary ray segments. For *P. wichmannii*, the parenchymatic tissue occupies a comparatively small area. In contrast with *P. methysticum* cultivars, in which the bark parenchyma contains only nearly separate brachysclereids, *P. wichmannii* possesses large, connected bands of brachysclereids. This feature is very similar to that of the material originating from Papua New Guinea described and analyzed by Saüer and Hänsel (1967), which the authors called "*Piper* sp. Womersley" and from which kavalactones were isolated. This specimen was later identified as *P. wichmannii* (Chew, 1972; specimen *NGF 19746*, Lae Herbarium), and this publication is the only report on kavalactones isolated from a *Piper* species other than *P. methysticum*.

On the island of Baluan, Manus Province (Papua New Guinea), farmers recognize only three *Piper* cultivars, one of which corresponds to the botanical species *P. wichmannii*. In other parts of Melanesia, kava is in rare cases prepared from *P. wichmannii*, which is there considered as representing the primitive wild form (islands of Maewo and Pentecost in Vanuatu) (Lebot et al., 1986).

According to Chew (1972), *Piper wichmannii* ". . . is perhaps the commonest species of *Piper* in New Guinea and the Solomon Islands. . . . Its arborescent habit of growth coupled with the characteristically large cordate leaves with long spikes

makes it the most distinctive species in the genus." However, misidentifications are not uncommon in the genus *Piper*; a specimen collected on the island of Tongoa, in Vanuatu, was sent to two specialists of this geographical area, one of whom identified it as *P. methysticum* and the other as *P. wichmannii*.

This problem is not new. Similar difficulty in determination occurred with samples originating from Astrolabe Bay (Madang Province, Papua New Guinea) (Micklouchо-Maclay, 1886). When Micklouchо-Maclay sent a sample of **kеu**, the plant used by the natives to prepare kava, he ". . . received a short note from Dr. Scheffer, written in haste in the Botanical Garden, with the statement that the bundles of keu contained two different species of *Piper*, both different from the *Piper methysticum*, but that in the absence of flowers and fruits, it was impossible for him to determine the species." Micklouchо-Maclay concluded: ". . . the fact that there are on the Maclay Coast other kinds of *Piper*, allied to *P. methysticum*, remains, I think proved." (p. 688).

This confirms our observation that there is a real difficulty of relying on identifications of *Piper methysticum*, even from experts. Lebot's reexamination of purported specimens of *P. methysticum* in the Museum National d'Histoire Naturelle in Paris has shown that a substantial number of specimens were either *P. wichmannii* or *Macropiper latifolium*. Therefore, reports of *P. methysticum* growing wild have to be treated with extreme suspicion.

Although in the literature and in herbaria misidentifications of *Macropiper latifolium* are not uncommon, in the field confusion is not possible and differentiation is very easy due to the several inflorescences characteristic of the genus *Macropiper* (FIGURE 5). *Macropiper latifolium*, also called in Pidgin English of Vanuatu "wild kava", cannot be considered as the hypothetical ancestor of *Piper methysticum*. It is difficult to establish a relationship between *P. methysticum* and *M. latifolium*, as the gross differences between the two genera are very pronounced (A. C. Smith, 1975). Although it has been indicated that the Tahitians formerly used *M. latifolium* to prepare kava (Cuzent, 1857), this seems doubtful. A chemical analysis conducted on root samples of the latter species showed that kavalactones were not present and that the major constituent was beta-asarone, a depressant of the central nervous system (Lévesque, 1986 and unpublished data).

A comprehensive bibliographical review (Lebot and Cabalion, 1986) and a study of herbarium specimens have allowed us accurately to identify the areas of distribution of *Piper methysticum* and *P. wichmannii*. At this stage, the botanical evidence enables us to specify that the area of origin of *P. methysticum* is within the area of distribution of *P. wichmannii*, which covers Papua New Guinea, the Solomon Islands, and the northern part of Vanuatu (Chew, 1972; Lebot et al., 1986) (FIGURE 6). The available botanical data clearly indicate that *P. methysticum* is sterile. *Piper wichmannii*, although not considered as a botanical synonym in the literature, is considered by native farmers as being morphologically identical, and even botanists not uncommonly confuse the two. Wild forms of *P. wichmannii* were presumably domesticated and characters improved through clonal selection of somatic mutants. As *P. methysticum* is always propagated vegetatively, the identification of its wild ancestor has enabled us to identify its area of origin and hence to use kava as a valid indicator of the migrations of peoples that use it as traditional beverage.

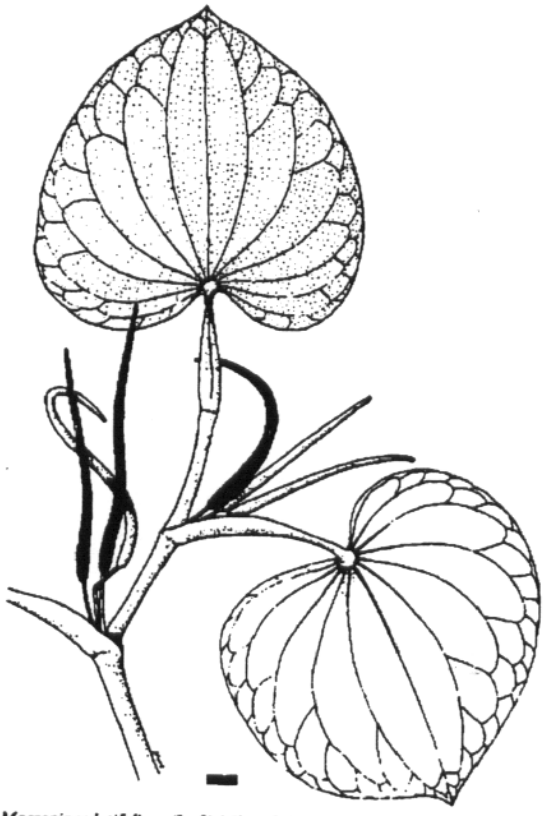


FIGURE 5. *Macropiper latifolium* (L. f.) Miq. (Original). Bar equals 2 cm.

## 3. ETHNOBOTANY OF KAVA

### 3.1 TRADITIONAL USES

The origin of kava is one of the oldest riddles of Pacific ethnobotany, of which the practitioners have attempted to demystify the issue by studying the vernacular names of the plant. The most frequent name, **Kava**, most certainly derives from the Polynesian word **Ava**, traditionally used by the Tahitians at the arrival of the Europeans to designate *Piper methysticum* (Cuzent, 1857). Certain authors, such as Thompson (1859), Seemann (1868), and Steinmetz (1960), think that **Kava** is a deformation of the Sanskrit word **Kashya**, which is also thought to mean "intoxicating" drink. The first hypothesis seems more logical, as it is generally accepted that the species was distributed by man in Polynesia, and this is how

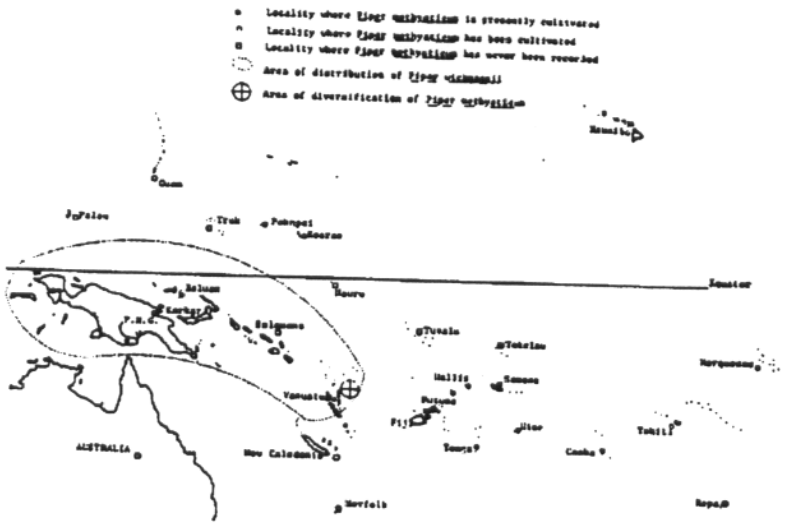



FIGURE 6. Areas of distribution of *Piper wichmannii* C. DC. and *P. methysticum* Forst. f.

Degener (1940) explains its introduction to Hawaii. Throughout that part of the Pacific where the present occurrence of kava seems to be linked to a Polynesian introduction, the plant is known by various terms of Polynesian affinity. Insofar as the presence of kava always seems to result from human activity, the linguistic approach makes it possible to define two main zones, one where the plant is called **Kava**, in Polynesia and southern Vanuatu, and another where it has Melanesian generic names, in northern Vanuatu, Papua New Guinea, and Micronesia. A complete list of these vernacular generic names has been published (Lebot and Cabalion, 1986), showing an evident affinity of names within Melanesia.

The distribution of kava cultivation is puzzling. Rivers (1914) suggested that the consumption of betel nut would lead to the disappearance of kava consumption when both were present. However, in some parts of Papua New Guinea, kava and betel nut are both happily used by the same consumers. This was the case in Tikopia as well (Firth, 1957). The surprisingly patchy pattern of distribution of *Piper methysticum* within Melanesia (FIGURE 6) is unusual for a *Piper* species, as these tend to be either very localized or very widespread. For kava, dispersal of vegetative propagules by wind or birds is impossible, and the plant therefore owes its survival entirely to human distribution of stem cuttings. As a relic of cultivation, kava can survive in well-protected rain forest where vegetative propagation occurs from living stems falling to the ground (Lebot's personal observation in Hawaii and Tahiti). However, in some cases the plant is unsuited and perishes if left untended. Morrisson (1966) mentioned that kava was formerly plentiful in Tubuai, but it failed to survive nonetheless. Without human attention, kava often

declines and disappears from the environment within a few decades. If kava is not present on an island or has never been recorded there in the past, this probably means that the plant was never introduced by man or else disappeared as a result of man's action (i.e. Christian Missions taboos) or lack of attention (Lebot and Cabalion, 1986).

The distribution of kava, once Pacific-wide, is no longer so extensive. Information gained from early publications indicates that kava has been left to die out in many valleys of the Society Islands, the Marquesas, Tubuai, the Cook Islands, Niue, and Hawaii. Neglect and the devastation caused by wild pigs were the major factors in its almost total extinction in the Marquesas, while contributing causes include competition from weeds, especially climbing vines.

In Vanuatu, oral tradition concerning kava's origin seems to indicate that the ancestors of the present inhabitants used *Piper wichmannii* to prepare the beverage, and that this plant is the ancestor of *P. methysticum* (Lebot et al., 1986). On the island of Pentecost, roots of the two species are mixed when there is not enough of the best cultivars of *P. methysticum* for a feast. In the northern part of Vanuatu, kava is of local origin, according to legends, but in the southern islands of this archipelago, especially on the island of Tanna, kava could have been introduced from Samoa or Tonga via the small island of Futuna, along with its Polynesian generic name and rituals. This may be the explanation why the local name for kava in the vernacular language of Tanna is **Kava**, the same word as used in Tonga (Bonnemaison, 1985). Of all the Pacific countries where kava is cultivated, Vanuatu has certainly preserved the richest tradition (Lebot and Cabalion, 1986). Kava has long been important in Vanuatuan culture. As in other Pacific islands, during the colonial period the religious authorities tried to stamp out kava drinking on grounds of hygiene or because of its heathen connotations. Presbyterians and Seventh Day Adventists were far more hostile than Catholics and, in all islands where kava was prepared by grinding, opposition tended to be less marked than in places where it was chewed (Lebot and Brunton, 1985). But, unlike the situation in many other Pacific islands, in most parts of Vanuatu attempts to eradicate kava met with only limited success. Today, kava is cultivated in all the inhabited islands of the archipelago (Lebot and Cabalion, 1986).

Ferdon (1981) suggested that kava may have been the last plant introduced to the Society Islands before European contact and that it was ". . . certainly the last introduced into Tahiti. . . . The active diffusion eastward to Tahiti was still going on as late as 1774–1775." Ferdon referred to the chief of one district of Tahiti as not having a single plant, whereas two years later large kava fields had been planted. This is confirmed by the following statement made by Lieutenant King and published in Cook's Voyages (Cook, 1784): "There is something very singular in the history of this pernicious drug. When Captain Cook first visited the Society Islands, it was very little known among them. On his second voyage, he found the use of it prevalent on Ulitea; but it had still gained very little ground on Otaheite. when we were last there, the dreadful havock it had made was beyond belief, insomuch that the Captain scarce knew many of his old acquaintances".

According to Gatty (1956), oral tradition in Hawaii has it that kava was introduced from Tahiti and first planted on Oahu. However, Titcomb (1948) reported

many points of introduction in the archipelago. In very early Hawaiian history, **Awa** was drunk by chiefs or people of high social rank and never by commoners, probably because the plant was hard to find. Royalty drank for pleasure, the lower class for relaxation after work, and the **Kahuna** (priest) for religious and ceremonial reasons (Titcomb, 1948). However, by the beginning of the 19th century, there was enough for everyone, and **Awa** was drunk by all social classes. It was consumed by the commoners in a much less formal way and did not appear to be ceremonial in its use (Titcomb, 1948).

There is no definite information concerning when or from where kava came to Pohnpei, but it is obvious that it came from either Polynesia or Melanesia (Glassman, 1952). **Sakau** was traditionally a drink reserved for the elite, but its use is now widespread amongst all levels of people. It is the focal point of almost all ceremonies and is also consumed nightly in private gatherings. It is prepared by pounding the roots and then squeezing the material through a filter made of the inner layers of *Hibiscus tiliaceus* bark into half a coconut shell. This is a procedure also reported in various Polynesian islands but no longer practiced today. When prepared this way, kava takes on a very slimy consistency due to the mucilage existing in the bark of *H. tiliaceus*. The kava is passed round in order of rank, both men and women drinking from the same bowl. As Pohnpei and Baluan (Manus Province) are the only islands in the Pacific where kava is prepared by pounding the fresh roots on a large, flat basalt slab, and because in Pohnpei the word **Sakau** sounds like the word **Kau** used by the people of Baluan for kava, it is possible that kava was introduced to Micronesia from Melanesia. In Kosrae, before the drink was banned by the missionaries in 1828, kava was called **Seka** (Glassman, 1952), and this name also seems to be of Melanesian origin as kava is called **Sika** and **Saka** in parts of the Western Province of Papua New Guinea. This theory's plausibility is confirmed by the great distances the central and eastern Pacific navigators would have had to sail with cuttings on board between Polynesia and Kosrae or Pohnpei in Micronesia. Furthermore, most of the islands situated on the route between the kava-cultivating areas of Polynesia and Micronesia are atolls unsuitable for kava cultivation. Importation from New Guinea seems more feasible. Although one specimen was gathered on Palau in 1929 (*Kanehira 453*) and on Guam in 1818, Safford (1905) observed that kava was unknown to the local people in the early 20th century (the reported sighting could have been an early misidentification of *Macropiper guahamense* C. DC.) (A. C. Smith, 1975).

The Admiralty Islands were probably the area of greatest kava consumption in Papua New Guinea. Kava was used on Lou, Baluan, Pam, the Fedarb Islands, and Rambutyo. All were said or known to have had large, flat stones that were used to pound the kava. On Lou, the last remaining plants were destroyed by the native farmers because the population was converted to the Seventh Day Adventist Church (H. MacEldowney, Anthropology Dept., Australian National University, Canberra, personal communication). Baluan is the only area of Manus Province where kava is still sporadically used.

According to Lawrence (1984), who since 1949 has engaged in anthropological research among the Garia in the mountains just north of Usino in Madang Province, kava is prepared for funerals, and the person's relatives consume about half

a coconut shell before bearing the body to the grave. Informants claimed that it had a toxic effect, and this seems to be borne out by the fact that, after the funeral, those who drank it immediately fell asleep. The Garia refer to kava in Pidgin English as **Koniak** and in their own language as **Isa**.

In the Western Province kava consumption is widespread. Crawford (1981) explained that a **Sika** cult existed in Isago village, not far from Balimo, in defiance of the Mission, which tried to discourage its consumption. The Gogodola prepare the drink by masticating the roots and spitting the contents of the mouth into a coconut shell. When all shells are full, their contents are strained through a coconut stipule into a common bowl from which each man's shell is refilled. The drinkers quickly swallow the kava before having a meal of sago and fish. Shaw (1981) reported the use of kava among the Samo of the Nomad River area where it is called **Oyo**. He made a very interesting statement on the preparation: ". . . the brew is made by mixing palm leaf ash with the masticated *Piper methysticum*. Nowhere else has the mixing of ash been reported in conjunction with the preparation of kava. But throughout the Nomad area this practice is necessary as people maintain that by itself the root is too strong, bitter and unpalatable."

According to Whitmore (1966), no sample of *Piper methysticum* has been collected in the Solomon Islands. However, the presence of kava has been reported a number of times in the southerly islands near Vanuatu, such as Tikopia (Firth, 1957) and Vanikoro (Rivers, 1914), which are Polynesian outliers. When Kirch and Yen (1982) visited Tikopia, they observed: "Kava has now become extinct, with only a wild form **Kavakava atua** (kava-diminutive-spirit) remaining that cannot, according to informants, be used for preparation (although it has been identified as *P. methysticum* by Solomon Islands and Bishop Museum botanists. . . .)." Brown (1935) mentioned that the vernacular name for *Macropiper latifolium* in the Marquesas is also **Kava kava atua**.

According to a dictionary of the Are language of Malaita, the word **Kakawa** is used for a tree whose roots are sucked to produce intoxication, and L. Brass recorded that the local name for *Piper wichmannii* in the southeastern part of Santa Isabel was **Kava qwua** (R. Brunton, personal communication).

Although no distinction can be made between the ethnic groups of Oceania regarding methods of preparation, the effect sought does, however, differ from one group of islands to another. In Polynesia and Fiji, traditional consumption followed a highly hierarchical and strictly ceremonial form, whereas in Melanesia in general the purpose of daily consumption of fresh kava is to attain a state of intoxication. In all cases, the most frequent use is as an essentially ritualistic and social drink taken for its soporific and anxiety-relieving properties. There are two different methods of preparation, depending on whether fresh or dried roots are used. The principle applied is very simple and efficient in allowing extraction of the chemical constituents by either chewing or grinding followed by maceration. Today, mastication of the fresh roots is still practiced only in the central and southern parts of Vanuatu and in Papua New Guinea. In other parts of these two countries and in Pohnpei, Wallis, and Futuna, kava is always prepared by grinding the fresh roots. In Fiji, Samoa, and Tonga the most common present-day technique is maceration of a powder of dried roots.

In folk medicine, kava is a panacea. In all the islands where it is still used, kava is known as an efficient treatment for common pains. A historical review of its medicinal uses in the Pacific has shown that kava was used to treat inflammations of the urogenital system, gonorrhea and cystitis, feminine puberty syndrome and menstrual problems, painful migraine headache, chills, and rheumatism (Lebot and Cabalion, 1986). However, in each case it was mentioned that the particular cultivar chosen was an important factor in the treatment.

### 3.2. Traditional Classification

In terms of its cultural role, kava is to the Pacific what wine is to southern Europe. The well known existence of what can accurately be equated to "vintages" confirms this. The plant is represented by numerous cultivars that all have their specific uses in each island or within island groups. The gross morphological variations observed amongst these cultivars do not, according to the botanists, warrant their classification as distinct varieties. On the other hand, the differences observed are of great ethnobotanical interest in terms of their significance and use for the societies that recognize them.

The results of ethnobotanical studies (Lebot and Cabalion, 1986) show that there is a considerable degree of specialization in the use of particular cultivars. Some are used only for customary ceremonies, others for medicinal purposes, with particular cultivars being used to treat specific complaints. Other cultivars are used only for drinking, and the most frequently planted cultivars are, of course, those used for daily drinking (Lebot and Brunton, 1985).

This traditional classification is essentially based on the physiological effect of the kava. Farmers continually engage in the selection process each time they uproot a plant and, if the physiological effect is not interesting, they do not replant that particular clone. The procedure is usually identical in all the islands where kava is consumed fresh by the farmers themselves: they first uproot the plant and leave the stems in the hole produced by the removal of the stock. They drink the kava prepared from this plant with friends the same day and judge the physiological effect. If it is pleasant they go back to their garden a few days later and collect the stem cuttings, which are then used for clone propagation. If the effect is not desirable, they will leave the cuttings in their hole, where they will soon collapse. If, however, they observe that a plant is outstanding in some way, they distribute the planting material and, if its new characteristics are particularly distinguishing, name a new cultivar.

In the case of propagation of kava by cuttings, the problem faced by the growers is the judicious choice of the initial individuals, by eliminating unsuitable mutations, if necessary, or by using favorable mutations as the starting point for new clones. In this connection, ethnobotanical surveys can provide information on the factors which the farmers consider when selecting new kava starts.

Very few other species are subjected to such selection pressure on individual plants. This attention comes to bear first on the chemical composition, which is directly responsible for the physiological effect felt by the drinker, rather than on morphological characters.

In Vanuatu, ceremonies, methods of cultivation, and cultivar classification systems vary from island to island. Folk classification of kava cultivars results from detailed observations, both of interclonal variability and, where it occurs, intraclonal variability. Such classifications sometimes reveal the existence of fully fledged "sciences of kava" known only to elders. Many of these cultivars have remained in the same place for a long time, are the result of local selection carried out by the farmers, and are known by a precise name in the vernacular language. Usually each name consists of a first word or "head term", equivalent to the generic name, followed by a second which acts as a semantic "modifier" or "qualifier", these words together forming a double name as in the Linnaean system. This rule is found in other Pacific countries and is not specific to kava or Vanuatu. Usually, the semantic qualifier marks the cultivar's main feature, a legend, the name of the first person to select the clone, or its color. A complete inventory of the vernacular names applied in Vanuatu to *Piper methysticum* cultivars with their cultural significance, has been published (Lebot and Cabalion, 1986).

Seemann (1868), Parham (1935), and Steinmetz (1960) discussed the traditional system of cultivar classification used in the Fiji Islands. According to these authors, about fifteen cultivars were known in Fiji at the beginning of the century. There, farmers have developed a very efficient morphologically-based "key" which makes it easy for them to differentiate among their cultivars. It is based first on the color and second on the shape of the internode. Today, the vernacular names given by the farmers to their cultivars correspond to the morphological description of the plant. For example, **Vula kasa balavu** means "white with long internodes" (**vula** = white; **kasa** = internode; **balavu** = long). All traditional Fijian cultivars have a name related to their phenotype (**damu** = red; **loa** = black; **leka** = short; **dokobana** = planting stick, i.e. the internodes are as long and thick as a stick; **matakaro** = spotted; Qila is a famous village in Taveuni where this cultivar probably originated). But cultivars named **Honolulu** and **Business** are most probably cultivars recently introduced from an unknown source.

Unlike those of Vanuatu, Fijian farmers differentiate among the organs of the plant. The portions of the plant of commercial value are, in order of decreasing price: **Waka** (lateral roots and rootlets), **Lewena** (the thickened underground portion of stem and stump), **Kasa** (the first three nodes and internodes). This is directly related to the decreasing kavalactone content in these different parts (R. M. Smith, 1983; Lebot, 1987).

Cuzent (1860) recorded 14 cultivars in Tahiti, providing vernacular names, uses, and morphological descriptions for each. Interestingly, he claimed that the strength or weakness of the beverage obtained from the cultivars were the main characteristics used by the Tahitians to classify them. He observed that these chemical characteristics were far more important than morphological features for the users. Brown (1935) observed that in the Marquesas "The species was intensively cultivated by the natives, who had selected 21 varieties differing in height, the length and color of the internodes, the size of the leaf, or in chemical composition."

In 1933, the *Honolulu Star Bulletin* published an article entitled "Awa plant

once in demand here", in which names of seven local cultivars were listed. Handy (1940) recorded 15 cultivars of Awa, but his descriptions show that the characteristics were by no means fixed. The situation in Hawaii is the same as in Tahiti: many vernacular names have been lost, and it appears from the reference material that cultivars were much more numerous in the past. Alternatively, the number of names may have been artificially inflated by synonymy.

## 4. MATERIALS AND METHODS

### 4.1. Background and Rationale

For the consumer, kava can be weak or strong; it can be soothing and induce sleep or, on the contrary, it can fail to produce relaxation and can provoke nausea. Drinkers are well aware of these variations and usually want to know which kava is being prepared or where it comes from. Farmers confirm that the physiological effect varies according to which cultivar is chosen. This is thought to be due to differences in their chemical composition.

When Keller and Klohs (1963) published their review of the chemistry and pharmacology of kava, they observed that "... no systematic scientific survey appears to have been made as to the relative potency of extracts from the various forms of *Piper methysticum*. The published studies generally have been carried out upon samples of plant material identified only as being the dried root of *Piper methysticum* and, since all of the growth forms would most likely not be thought worthy of recognition as separate taxa by plant taxonomists, this area remains one for possible future study and clarification." In 1966, Young et al. stated that the taxonomic value of morphological and chemical relationships in kava needed to be shown through subsequent work in this area. In 1970, Jössang and Molho confirmed that the variation in composition of kava extracts from Fiji was an important point which needed clarification. Duve and Prasad (1981) concluded their quality evaluation by stating that such factors as variation in the active constituents of *P. methysticum* with age, variety, and environmental parameters needed to be studied before chemical standards for kava could be formulated.

Kava's active principles, the kavalactones (19 have been isolated and identified), are a group of very similar organic compounds. The skeleton of these lactonic molecules consists of 13 carbon atoms, six of which form a benzene ring attached by a double bond to a saturated lactone (Figure 7). Many authors have undertaken chemical and pharmacological studies and have produced a wealth of publications, which were reviewed by Lebot and Cabalion (1986). However, not much is known about the chemistry of the various kava cultivars. After Hänsel (1968), Jössang and Molho (1970) tried to explain the biosynthesis of kavalactones by two different processes, one starting from cinnamic acid and ending up with styrylpyrones like demethoxyyangonin, and another from the corresponding alcohol to end up with styryldihydropyrones such as kavain. They explained the absence of the latter in the leaves by the immediate reduction of their double bond 7,8 by ascorbic acid. R. M. Smith (1983; R. M. Smith et al., 1984) showed that the biogenetic activity is essentially the same in the various parts of the vegetative system, and that this leads to different compositions in the rhizome and roots.

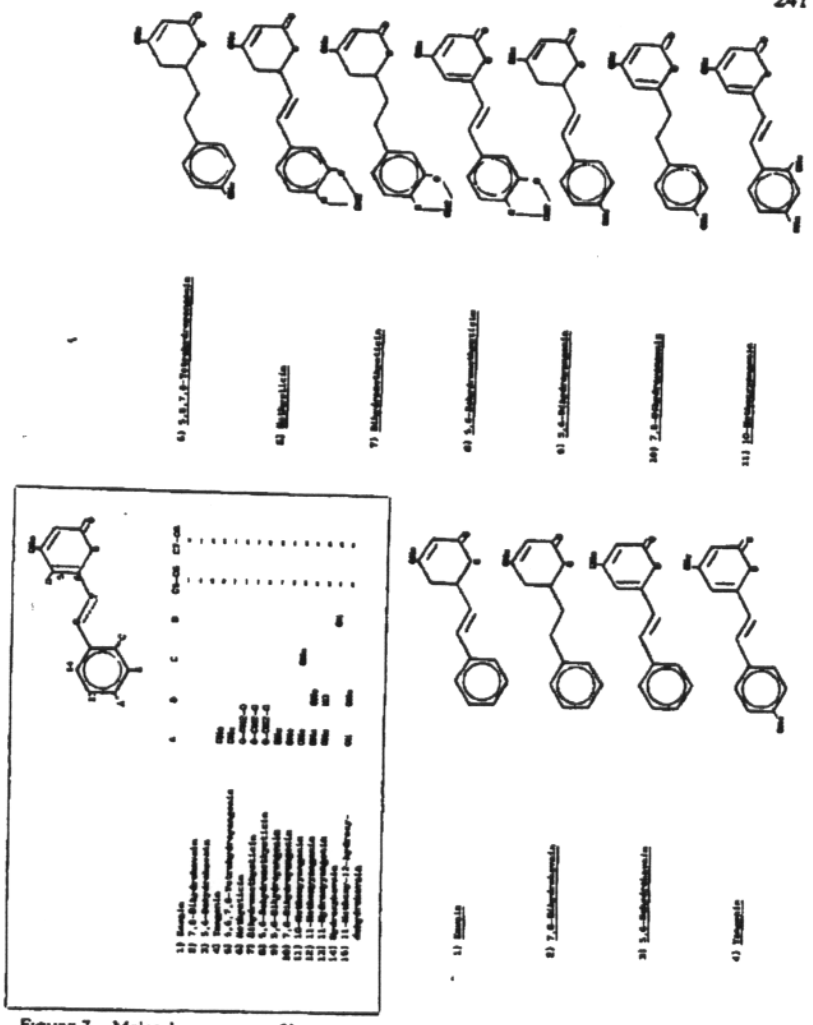


FIGURE 7. Molecular structure of kavalactones (From Lebot and Cabalion, 1986).

It is essential to study the variability in kava to provide a basis for individual selection through cloning. What is needed is a quick and reliable way of evaluating the relevant plant features. The variability study consists of four steps: collecting stem cuttings from cultivars identified by their vernacular names; establishing a

living collection; recording a morphological description of each cultivar; and carrying out a chemical analysis of the roots.

For *Piper methysticum*, perhaps more than for other cultivated species, a study of polymorphism is fundamental. To improve the original genetic material using conventional techniques, such as cross-pollination, seems not to be possible. What should be considered, therefore, are the characteristics and potential of the existing genetic material.

A survey of the genetic resources of the plant species *Piper methysticum* and *P. wichmannii* was conducted over the whole of Oceania. Preliminary screening of the locations to be surveyed was done by studying the information existing on herbarium specimens and by gathering information from scientists with a first-hand knowledge of the species, as well as from anthropologists with field experience.

### 4.2 Morphological Description

Morphological descriptions of the cultivars recorded for plants at their places of origin may not be applicable for identifying them elsewhere, because the ecological factors are not the same. It is therefore important to study morphological parameters in a single, homogeneous environment. Fortunately, the establishment of a germplasm collection became a reality in 1984 at the Tagabé Agricultural Station, near Port Vila in Vanuatu (altitude: 14 m.; average annual precipitation: 2200 mm.; average minimum temperature: 19.3°C. in August; average maximum temperature: 30.2°C. in February).

The plants were described during their second year of growth. A detailed list of descriptors applicable to kava was developed (Lebot and Cabalion, 1986), but the number of characteristics used for this study was restricted to seven because of the sheer size of the germplasm collection. The characters selected for the description of the accessions were those used by the farmers to distinguish cultivars. These are:

A—general appearance of the plant: 3 = Erect, 5 = Normal, 7 = Prostrate;
C—stem coloring: 1 = Pale green, 2 = Dark green, 3 = Green with purple shading, 4 = Purple, 5 = Black;
I—internode configuration: 1 = Uniform, 2 = Mottled, 3 = Speckled, 4 = Striated and mottled (Figure 8);
L—leaf coloring: 1 = Pale green, 2 = Dark green, 3 = Purple;
E—lamina edges: 1 = Undulate, 2 = Raised, 3 = Drooping, 4 = Regular (Figure 9);
P—leaf pubescence: 1 = Present, 0 = Absent;
S—internode shape: 1 = Short and thick, 2 = Long and thin, 3 = Long and thick (Figure 8).

Each morphological feature was coded. When accessions had an identical coded description of their phenotype, they were given the same cultivar number.

Fiji, Wallis and Futuna, Western Samoa, American Samoa, Tonga, Tahiti, the Marquesas, Hawaii, Micronesia, Papua New Guinea, and the Solomons were surveyed in 1987. The first results gleaned from the Vanuatu collection and the

FIGURE 8. Morphological descriptors: internode shape and configuration. A, uniform; B, mottled; C, speckled; D, striated and speckled (From Lebot and Cabalion, 1986). Bar equals 2 cm.

methods tested were used for these countries. Although country collections from these islands were established, it was not possible to carry out trials in the same environment due to the limited time available for this survey. However, as in most cases the number of cultivars present was rather small, the descriptors used (A–C–I–L–E–P–S) permitted a quick and easy differentiation.

### 4.3 CHEMICAL DESCRIPTION

The chemical composition of each cultivar was elucidated and also described. While collecting roots for analysis, great care was taken systematically to select the same type of roots, excluding any part of the rhizome, because recent research (R. M. Smith, 1983; R. M. Smith et al., 1984) has shown variability in composition and total kavalactone content among the different organs of the plant. Several tests conducted by the authors on samples of roots, rhizomes, and basal stems confirmed these results (Lebot, 1987).

The active ingredients can be divided into two main groups: major kavalactones and minor kavalactones. Extraction of these substances showed that the former account for approximately 96% of the whole extract (Lévesque, 1985). Thus, the major kavalactones were used to determine the chemotype. Root samples gathered in the field from living plants were dried in an oven at 60–80°C. for eight hours. Extraction was performed on powdered dry roots which were placed in a Soxhlet apparatus for six hours with chloroform. The extract was then dried with a rotary evaporator.

The chemical composition of the chloroform extract was analyzed by using

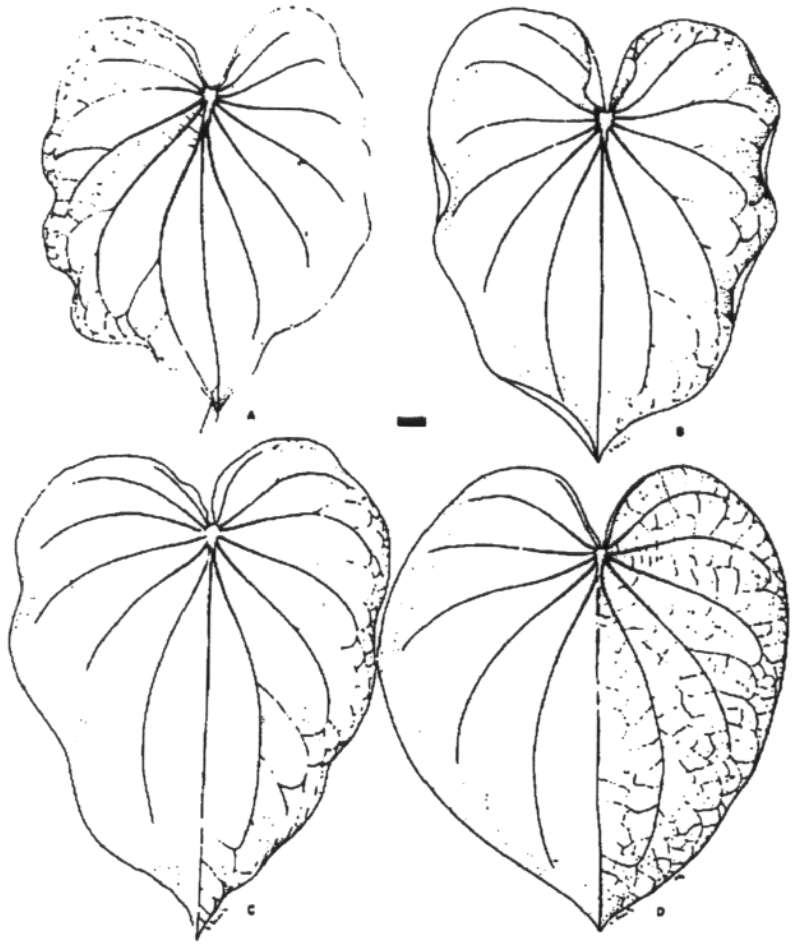


FIGURE 9. Morphological descriptors: lamina edges. A, undulate; B, raised; C, drooping; D, regular (From Lebot and Cabalion, 1986). Bar equals 2 cm.

High Performance Liquid Chromatography (HPLC) following the method developed by Lévesque (1986).

Separations were carried out using a Merck silica column (60 5$\mu$, 125 mm. × 4 mm.) and a pre-column (35 mm. × 4 mm.), a Waters Wisp 710 B, a LDC Milton Roy Constametric III metering pump, a Perkin Elmer LC 95-visible Spec-

trophotometer detector with a Gilson recorder, and a Hitachi 833 integrator. The eluent used was a mixture (85/15) of hexane and dioxan at a flow rate of 1 ml./mn. and a pressure of 60 bars. The detection wave length was 240 nm.

Each extract's composition was coded in decreasing order of the proportion of each lactone present. The chromatogram obtained presents the retention times of the different compounds:

| | |
|---|---|
| Solvent: | 1.9–2.1 mn. |
| 1 = Demethoxyyangonin (DMY): | 12–13 mn. |
| 2 = Dihydrokavain (DHK): | 14–15 mn. |
| 3 = Yangonin (Y): | 18–19 mn. |
| 4 = Kavain (K): | 19–20 mn. |
| 5 = Dihydromethysticin (DHM): | 23–26 mn. |
| 6 = Methysticin (M): | 32–37 mn. |

Coding varied according to the composition of the extracts, and code differences allowed rapid recognition of the different chemotypes. Retention times and the data given by the integrator were combined to quantify the six major kavalactones in percentages.

In Vanuatu, the chemical compositions of 67 cultivars originating from the germplasm collection were analyzed to determine the chemotypes, and the method's reliability was tested in various ways. Because these plants were not planted the same day, neither were root samples collected the same day; this operation was spread over a year, each time the cultivar concerned reached the age of two years.

Several specimens of the same cultivar were harvested after growing in different soils and under different climatic regimes, while different cultivars of varying origins were planted in a common garden and harvested together. Different plants of the same clone grown under the same conditions were harvested at different ages in order to study variation with ontogeny.

In the other countries surveyed, root samples were gathered from living plants at the place of origin of the local cultivar.

The data obtained from HPLC of the root samples were statistically appraised using cluster analysis based on the coefficient of association among several cultivars. This was calculated using Euclidean distance and a hierarchical agglomerative classifying algorithm. Several treatments of the data were conducted using three statistical distances (Euclidean, Jaccard, and Nei). The results obtained confirmed the suitability of the Euclidean distance, and this was due to the quantitative nature of the data. Multifactorial analysis was also used to cast new light on the data and to confirm by space projection the groups defined by cluster analysis. Multivariate statistical analysis was done with a micro computer and a STAT-ITCF software package.

## 5. RESULTS AND DISCUSSION

The results are divided into four main geographical areas: 1) Vanuatu; 2) Fiji; 3) Polynesia; 4) Papua New Guinea, Solomon Islands, and Pohnpei. This geo-

graphical subdivision for study purposes was arrived at as a result of observations made while collecting in the field and indicates morphological affinities among cultivars of various locations, suggesting exchange of planting material within these areas.

### 5.1 Vanuatu

In Vanuatu, kava is widely intercropped in food gardens as well as being grown on a single crop basis. In 1985, kava cultivation covered 3300 ha. and was present in all the inhabited islands of the archipelago (Lebot and Brunton, 1985).

Cuttings were gathered from 21 different islands throughout the Vanuatu archipelago, and a total of 247 accessions were planted at Tagabé Agriculture Station on Efaté. Because gathering cuttings in the field is time-consuming, establishment of the collection was spread over almost a year. Morphological descriptions were made of the 247 accessions in the germplasm collection. Although these accessions originated from different islands, it soon became obvious that some were duplicates. The use of seven descriptors (A—C—I—L—E—P—S) allowed 82 coded phenotypes to be differentiated. These coded transcriptions of a particular phenotype using morphological descriptors are called morphotypes. Such a method is commonly used for this type of germplasm work (Jackson and Breen, 1985). The morphological descriptions of the germplasm collection at Tagabé are presented in Table 1.

These 247 different accessions of kava from Vanuatu were grown in common garden plots and described morphologically, yielding 82 different morphotypes. If it is agreed that each different morphotype should correspond to a different cultivar, then kava in Vanuatu is represented by 82 cultivars. It is obvious that mixing of planting material has taken place along the traditional trade routes. From the data in Table 1, it appears that certain local cultivars originating on different islands and with different vernacular names present the same morphotype when planted in the same environment at Tagabé. Although islands represent very isolated areas, these cultivars travel readily as part of the traditional exchange system. However, a biogeographical boundary does prevail south of Efaté. Traditional exchanges also occur within the southern or northern parts but less easily between north and south. In several islands, the variability observed and the number of cultivars used is greater than in other islands (i.e. Pentecost and Tanna). The great number of accessions was partly due to the difficult identification of these cultivars in different islands, and also to the great number of vernacular languages spoken in Vanuatu (111 according to Tryon, 1976), which increases the chances of having different local names for identical cultivars, the number of names being obviously inflated by synonymy.

All of these cultivars are currently under cultivation by the Vanuatuans. Although it would be premature to say whether or not all are genotypically distinct plant materials, they are most probably the results of naturally occurring mutations while under cultivation. These morphotypes can be called cultivars because, although they are not definitely fixed, they are important for the social groups that cultivate them and have a true cultural importance.

TABLE 1. MORPHOLOGICAL DESCRIPTION OF THE GERMPLASM COLLECTION AT TAGARÉ AGRICULTURAL STATION

| Cultivar | Origin | Use[1] | Morphotype | | | | | | | No.[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | C | I | L | E | P | S | |
| Hin | Torres | M | 5 | 3 | 2 | 3 | 2 | 1 | 1 | 1 |
| Wisabana | Vanualava | T | 5 | 3 | 2 | 3 | 2 | 1 | 1 | 1 |
| Hig | Merelava | Q | 5 | 3 | 2 | 3 | 2 | 1 | 1 | 1 |
| Gumaito | Maewo/N | C | 5 | 3 | 2 | 3 | 2 | 1 | 1 | 1 |
| Mologomavute | Ambae/E | T | 5 | 3 | 2 | 3 | 2 | 1 | 1 | 1 |
| Ahe yoke | Santo/SW | T | 5 | 3 | 2 | 3 | 2 | 1 | 1 | 1 |
| Ngako | Ureparapara | Q | 3 | 3 | 2 | 2 | 1 | 0 | 2 | 2 |
| Hinyanyie | Ureparapara | T | 5 | 3 | 3 | 1 | 2 | 0 | 1 | 3 |
| Mologubanga | Maewo/S | Q | 5 | 3 | 3 | 1 | 2 | 0 | 1 | 3 |
| Tarivoravora | Ambae/E | C | 5 | 3 | 3 | 1 | 2 | 0 | 1 | 3 |
| Pirimerei | Santo/W | Q | 5 | 3 | 3 | 1 | 2 | 0 | 1 | 3 |
| Nol | Ureparapara | Q | 5 | 2 | 3 | 1 | 1 | 0 | 2 | 4 |
| Ngasien | Ureparapara | T | 5 | 3 | 2 | 2 | 1 | 0 | 1 | 5 |
| Ngawo | Ureparapara | Q | 5 | 2 | 2 | 3 | 2 | 1 | 2 | 6 |
| Lab | Motalava | T | 5 | 2 | 2 | 3 | 2 | 1 | 2 | 6 |
| Namtemlao | Motalava | C | 5 | 2 | 2 | 3 | 2 | 1 | 2 | 6 |
| Nambalao | Vanualava | Q | 5 | 2 | 2 | 3 | 2 | 1 | 2 | 6 |
| Hawerara | Maewo/N | M | 5 | 2 | 2 | 3 | 2 | 1 | 2 | 6 |
| Tolu | Ambae/W | T | 5 | 2 | 2 | 3 | 2 | 1 | 2 | 6 |
| Small hand | Vate | Q | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Ngame | Ureparapara | Q | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Nagame | Motalava | Q | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Gemime | Vanualava | Q | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Borogoru | Maewo/N | Q | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Borogu | Maewo/S | Q | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Melmelo | Maewo/S | Q | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Borogu memea | Pentecost/N | Q | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Borogu tememe | Pentecost/C | Q | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Gorogoro entemet | Pentecost/S | Q | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Memea | Ambae/W | C | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Turitamaewo | Ambae/E | T | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Memea | Ambae/W | C | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Kar | Santo/C | Q | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Poua | Malekula/NW | C | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Tarivarus | Ureparapara | T | 5 | 2 | 2 | 4 | 2 | 1 | 2 | 8 |
| Tarivarus | Motalava | T | 5 | 2 | 2 | 4 | 2 | 1 | 2 | 8 |
| Tarvarus | Vanualava | T | 5 | 2 | 2 | 4 | 2 | 1 | 2 | 8 |
| Tariparaus | Maewo/N | T | 5 | 2 | 2 | 4 | 2 | 1 | 2 | 8 |
| Vabu | Maewo/S | T | 5 | 2 | 2 | 4 | 2 | 1 | 2 | 8 |
| Tarivarusi | Maewo/S | T | 5 | 2 | 2 | 4 | 2 | 1 | 2 | 8 |
| Fabukhai | Pentecost/N | Q | 5 | 2 | 2 | 4 | 2 | 1 | 2 | 8 |
| Tarivarus | Pentecost/N | T | 5 | 2 | 2 | 4 | 2 | 1 | 2 | 8 |
| Abogne | Pentecost/C | T | 5 | 2 | 2 | 4 | 2 | 1 | 2 | 8 |
| Tarivarusi | Pentecost/S | T | 5 | 2 | 2 | 4 | 2 | 1 | 2 | 8 |
| Tari | Ambae/W | T | 5 | 2 | 2 | 4 | 2 | 1 | 2 | 8 |
| Wari | Epi | T | 5 | 2 | 2 | 4 | 2 | 1 | 2 | 8 |
| Nipunstaban | Motalava | T | 5 | 1 | 1 | 2 | 1 | 0 | 2 | 9 |
| Rairairegi | Maewo/N | T | 5 | 1 | 1 | 2 | 1 | 0 | 2 | 9 |
| Mavute | Ambae/W | Q | 5 | 1 | 1 | 2 | 1 | 0 | 2 | 9 |
| Tariporo | Ambae/W | T | 5 | 1 | 1 | 2 | 1 | 0 | 2 | 9 |
| Bisuiboe | Ambae/W | Q | 5 | 1 | 1 | 2 | 1 | 0 | 2 | 9 |
| Vasa | Malo | C | 5 | 1 | 1 | 2 | 1 | 0 | 2 | 9 |
| Pakaewa | Epi | Q | 5 | 1 | 1 | 2 | 1 | 0 | 2 | 9 |
| Lulu | Tongoariki | T | 5 | 1 | 1 | 2 | 1 | 0 | 2 | 9 |
| Nakasara | Emae | T | 5 | 1 | 1 | 2 | 1 | 0 | 2 | 9 |

TABLE 1 (continued)

| Cultivar | Origin | Use[1] | Morphotype | | | | | | | No.[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | C | I | L | E | P | S | |
| Malakesa | Nguna | Q | 5 | 1 | 1 | 2 | 1 | 0 | 2 | 9 |
| Kalawas | Tanna/C | C | 5 | 1 | 1 | 2 | 1 | 0 | 2 | 9 |
| Nagamiwok | Motalava | Q | 5 | 2 | 1 | 3 | 2 | 0 | 3 | 10 |
| Take | Pentecost | C | 5 | 2 | 1 | 3 | 2 | 0 | 3 | 10 |
| Merei | Santo/C | C | 5 | 2 | 1 | 3 | 2 | 0 | 3 | 10 |
| Ranranre | Vanualava | Q | 5 | 3 | 1 | 1 | 2 | 1 | 2 | 11 |
| Sese jarakara | Pentecost/N | T | 5 | 3 | 1 | 1 | 2 | 1 | 2 | 11 |
| Gelava | Vanualava | C | 5 | 2 | 2 | 2 | 1 | 0 | 3 | 12 |
| Tumpuinakapmato | Maewo/N | T | 5 | 2 | 2 | 2 | 1 | 0 | 3 | 12 |
| Giemoniagakris | Vanualava | S | 3 | 1 | 2 | 1 | 2 | 0 | 2 | 13 |
| Vambu | Vanualava | S | 3 | 2 | 2 | 1 | 2 | 1 | 3 | 14 |
| Buara | Maewo/N | S | 3 | 2 | 2 | 1 | 2 | 1 | 3 | 14 |
| Tangurlava | Maewo/N | S | 3 | 2 | 2 | 1 | 2 | 1 | 3 | 14 |
| Bamboo | Maewo/N | S | 3 | 2 | 2 | 1 | 2 | 1 | 3 | 14 |
| Bo | Pentecost/C | S | 3 | 2 | 2 | 1 | 2 | 1 | 3 | 14 |
| Mele liap | Pentecost/C | S | 3 | 2 | 2 | 1 | 2 | 1 | 3 | 14 |
| Vambu | Ambae/E | S | 3 | 2 | 2 | 1 | 2 | 1 | 3 | 14 |
| Kau | Tongoa | S | 3 | 2 | 2 | 1 | 2 | 1 | 3 | 14 |
| Daumangas | Maewo/N | T | 3 | 2 | 2 | 1 | 2 | 1 | 3 | 14 |
| Borogoru | Pentecost/N | M | 3 | 2 | 2 | 3 | 2 | 0 | 3 | 15 |
| Borogu | Pentecost/C | Q | 3 | 2 | 2 | 3 | 2 | 0 | 3 | 15 |
| Gorogoro | Pentecost/S | Q | 3 | 2 | 2 | 3 | 2 | 0 | 3 | 15 |
| Melomelo | Ambae/W | Q | 3 | 2 | 2 | 3 | 2 | 0 | 3 | 15 |
| Borogoru | Ambae/W | M | 3 | 2 | 2 | 3 | 2 | 0 | 3 | 15 |
| Borogu | Ambae/E | Q | 3 | 2 | 2 | 3 | 2 | 0 | 3 | 15 |
| Melomelo | Ambae/E | Q | 3 | 2 | 2 | 3 | 2 | 0 | 3 | 15 |
| Gorgor | Ambrym/N | Q | 3 | 2 | 2 | 3 | 2 | 0 | 3 | 15 |
| Paama | Tanna/C | Q | 3 | 2 | 2 | 3 | 2 | 0 | 3 | 15 |
| Paama | Tanna/SE | Q | 3 | 2 | 2 | 3 | 2 | 0 | 3 | 15 |
| Bumalotu | Maewo/N | Q | 3 | 2 | 2 | 3 | 2 | 0 | 3 | 15 |
| Malmalbo | Pentecost/C | M | 5 | 1 | 3 | 2 | 1 | 1 | 2 | 16 |
| Kavik | Pentecost/N | C | 5 | 1 | 3 | 2 | 1 | 1 | 2 | 16 |
| Ganono | Ambae/E | T | 5 | 1 | 3 | 2 | 1 | 1 | 2 | 16 |
| Malokai | Maewo/N | Q | 5 | 1 | 3 | 2 | 1 | 1 | 2 | 16 |
| Ngwangaru | Ambae/E | Q | 5 | 3 | 4 | 1 | 1 | 0 | 2 | 17 |
| Maet | Tongoariki | C | 5 | 3 | 4 | 1 | 1 | 0 | 2 | 17 |
| Kelai | Epi | Q | 5 | 3 | 4 | 1 | 1 | 0 | 2 | 17 |
| Keleiai | Tongoariki | Q | 5 | 3 | 4 | 1 | 1 | 0 | 2 | 17 |
| Resres | Maewo/N | Q | 5 | 3 | 4 | 1 | 1 | 0 | 2 | 17 |
| Sese | Pentecost/N | Q | 7 | 1 | 1 | 4 | 1 | 0 | 2 | 18 |
| Melmel | Pentecost/N | C | 7 | 1 | 1 | 4 | 1 | 0 | 2 | 18 |
| Melmel | Pentecost/C | C | 7 | 1 | 1 | 4 | 1 | 0 | 2 | 18 |
| Sese | Pentecost/S | C | 7 | 1 | 1 | 4 | 1 | 0 | 2 | 18 |
| Fock | Santo/C | T | 7 | 1 | 1 | 4 | 1 | 0 | 2 | 18 |
| Tapoka | Malo | Q | 7 | 1 | 1 | 4 | 1 | 0 | 2 | 18 |
| Mitiptip | Epi | T | 7 | 1 | 1 | 4 | 1 | 0 | 2 | 18 |
| Raimelmelo | Maewo/N | Q | 7 | 1 | 1 | 4 | 1 | 0 | 2 | 18 |
| Tarihani | Maewo/N | T | 5 | 1 | 3 | 1 | 1 | 0 | 2 | 19 |
| Kerakra | Pentecost/S | Q | 5 | 1 | 3 | 1 | 1 | 0 | 2 | 19 |
| Baan | Malekula/NW | Q | 5 | 2 | 2 | 1 | 1 | 0 | 3 | 20 |
| Tufagi | Maewo/N | T | 5 | 2 | 2 | 1 | 1 | 0 | 3 | 20 |
| Nakasara | Tongoa | T | 5 | 2 | 3 | 2 | 2 | 0 | 2 | 21 |
| Ronronvula | Maewo/S | C | 5 | 2 | 3 | 2 | 2 | 0 | 2 | 21 |
| Rongrongvula | Pentecost/N | C | 7 | 4 | 4 | 2 | 3 | 0 | 2 | 22 |
| Rongrongwul | Pentecost/C | M | 7 | 4 | 4 | 2 | 3 | 0 | 2 | 22 |
| Rogorogopula | Ambae/W | C | 7 | 4 | 4 | 2 | 3 | 0 | 2 | 22 |

TABLE 1 (continued)

| Cultivar | Origin | Use[1] | Morphotype | | | | | | | No.[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | C | I | L | E | P | S | |
| Mologubanano | Maewo/S | Q | 3 | 1 | 4 | 3 | 2 | 0 | 2 | 23 |
| Rara | Pentecost/N | Q | 3 | 1 | 4 | 3 | 2 | 0 | 2 | 23 |
| Small leaf | Vate | Q | 3 | 1 | 4 | 3 | 2 | 0 | 2 | 23 |
| Avia | Erromango | C | 3 | 1 | 4 | 3 | 2 | 0 | 2 | 23 |
| Pia | Tanna/C | Q | 3 | 1 | 4 | 3 | 2 | 0 | 2 | 23 |
| Biya | Anatom | Q | 3 | 1 | 4 | 3 | 2 | 0 | 2 | 23 |
| Borogu maita | Pentecost/N | Q | 3 | 1 | 1 | 3 | 1 | 0 | 3 | 24 |
| Borogu temit | Pentecost/C | Q | 3 | 1 | 1 | 3 | 1 | 0 | 3 | 24 |
| Gorogoro entepal | Pentecost/S | C | 3 | 1 | 1 | 3 | 1 | 0 | 3 | 24 |
| Gawoboe | Ambae/E | T | 3 | 1 | 1 | 3 | 1 | 0 | 3 | 24 |
| Tarimavute | Ambae/E | Q | 3 | 1 | 1 | 3 | 1 | 0 | 3 | 24 |
| Mologugei | Ambae/E | T | 3 | 1 | 1 | 3 | 1 | 0 | 3 | 24 |
| Palimet | Emae | Q | 3 | 1 | 1 | 3 | 1 | 0 | 3 | 24 |
| Mita | Tanna/C | T | 5 | 2 | 2 | 2 | 2 | 1 | 2 | 25 |
| Fabulakalaka | Pentecost/C | T | 5 | 2 | 2 | 2 | 2 | 1 | 2 | 25 |
| Lalahk | Pentecost/S | T | 5 | 2 | 2 | 2 | 2 | 1 | 2 | 25 |
| Laklak | Ambrym/N | T | 5 | 2 | 2 | 2 | 2 | 1 | 2 | 25 |
| Bukelita | Pentecost/N | M | 5 | 1 | 2 | 4 | 2 | 0 | 2 | 26 |
| Bukulit | Pentecost/C | M | 5 | 1 | 2 | 4 | 2 | 0 | 2 | 26 |
| Palisi | Santo/W | T | 5 | 1 | 2 | 4 | 2 | 0 | 2 | 26 |
| Pentecost | Tanna/C | T | 5 | 1 | 2 | 4 | 2 | 0 | 2 | 26 |
| Pentecost | Tanna/SE | T | 5 | 1 | 2 | 4 | 2 | 0 | 2 | 26 |
| Bogongo | Pentecost/N | S | 3 | 1 | 1 | 4 | 1 | 0 | 2 | 27 |
| Bogong | Pentecost/C | S | 3 | 1 | 1 | 4 | 1 | 0 | 2 | 27 |
| Jabualeva | Pentecost/N | C | 5 | 1 | 4 | 2 | 2 | 0 | 2 | 28 |
| Purumbue | Epi | Q | 5 | 1 | 4 | 2 | 2 | 0 | 2 | 28 |
| Boraeto | Pentecost/N | C | 3 | 3 | 3 | 1 | 2 | 0 | 2 | 29 |
| Mcoler | Epi | Q | 3 | 3 | 3 | 1 | 2 | 0 | 2 | 29 |
| Rara | Pentecost/N | C | 3 | 1 | 3 | 3 | 3 | 2 | 2 | 30 |
| Maga | Pentecost/N | C | 3 | 2 | 1 | 4 | 2 | 0 | 2 | 31 |
| Renkaru | Pentecost/C | T | 7 | 1 | 3 | 1 | 1 | 1 | 2 | 32 |
| Garaeto | Ambae/E | T | 7 | 1 | 3 | 1 | 1 | 1 | 2 | 32 |
| Makaru | Ambae/E | T | 7 | 1 | 3 | 1 | 1 | 1 | 2 | 32 |
| Palavoke | Santo/SW | Q | 7 | 1 | 3 | 1 | 1 | 1 | 2 | 32 |
| Vip | Epi | T | 7 | 1 | 3 | 1 | 1 | 1 | 2 | 32 |
| Raro | Tongoa | C | 7 | 1 | 3 | 1 | 1 | 1 | 2 | 32 |
| Takere | Pentecost/S | C | 5 | 2 | 1 | 2 | 3 | 1 | 2 | 33 |
| Tamaevo | Pentecost/S | Q | 5 | 2 | 4 | 2 | 1 | 0 | 3 | 34 |
| Mindo | Ambae/W | C | 5 | 1 | 1 | 3 | 2 | 0 | 2 | 35 |
| Meihang | Paama | Q | 5 | 1 | 1 | 3 | 2 | 0 | 2 | 35 |
| Rhowen | Tanna/C | T | 5 | 1 | 1 | 3 | 2 | 0 | 2 | 35 |
| Ring | Tanna/SE | C | 5 | 1 | 1 | 3 | 2 | 0 | 2 | 35 |
| Qoro | Ambae/E | M | 5 | 2 | 3 | 4 | 2 | 0 | 2 | 36 |
| Nemleu | Malekula/NE | Q | 5 | 2 | 3 | 4 | 2 | 0 | 2 | 36 |
| Bagavia.1 | Epi | Q | 5 | 2 | 3 | 4 | 2 | 0 | 2 | 36 |
| Bagavia.2 | Epi | Q | 5 | 2 | 3 | 4 | 2 | 0 | 2 | 36 |
| Milake | Tongoariki | Q | 5 | 2 | 3 | 4 | 2 | 0 | 2 | 36 |
| Nisginekrai | Anatom | C | 5 | 2 | 3 | 4 | 2 | 0 | 2 | 36 |
| Ranriki | Ambae/E | C | 5 | 1 | 3 | 1 | 2 | 0 | 3 | 37 |
| Puariki | Tongoa | Q | 5 | 1 | 3 | 1 | 2 | 0 | 3 | 37 |
| Buarik | Tongoariki | Q | 5 | 1 | 3 | 1 | 2 | 0 | 3 | 37 |
| Puariki | Emae | Q | 5 | 1 | 3 | 1 | 2 | 0 | 3 | 37 |
| Liki | Erromango | Q | 5 | 1 | 3 | 1 | 2 | 0 | 3 | 37 |
| Kowariki | Tanna/SE | Q | 5 | 1 | 3 | 1 | 2 | 0 | 3 | 37 |
| Riki | Anatom | Q | 5 | 1 | 3 | 1 | 2 | 0 | 3 | 37 |

TABLE 1 (continued)

| Cultivar | Origin | Use[1] | Morphotype | | | | | | | No.[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | C | I | L | E | P | S | |
| Big hand | Vate | Q | 5 | 1 | 3 | 1 | 2 | 0 | 3 | 37 |
| Sulusulu | Ambae/E | M | 7 | 1 | 4 | 3 | 2 | 0 | 2 | 38 |
| Valeiboe | Ambae/E | C | 3 | 1 | 3 | 2 | 1 | 0 | 2 | 39 |
| Visul | Santo/C | Q | 5 | 1 | 4 | 3 | 1 | 0 | 2 | 40 |
| Palarasul | Santo/SW | Q | 5 | 1 | 4 | 3 | 1 | 0 | 2 | 40 |
| Bualap | Tongoariki | Q | 5 | 1 | 4 | 3 | 1 | 0 | 2 | 40 |
| Pualapa | Emae | Q | 5 | 1 | 4 | 3 | 1 | 0 | 2 | 40 |
| Tuan | Tanna/C | C | 5 | 1 | 4 | 3 | 1 | 0 | 2 | 40 |
| Tapuga | Tanna/SE | C | 5 | 1 | 4 | 3 | 1 | 0 | 2 | 40 |
| Yevoet | Santo/C | Q | 5 | 2 | 4 | 2 | 2 | 0 | 2 | 41 |
| Marino | Santo/C | C | 3 | 1 | 2 | 4 | 1 | 1 | 2 | 42 |
| Urukara | Santo/SW | Q | 3 | 1 | 2 | 4 | 1 | 1 | 2 | 42 |
| Urukara | Santo/W | Q | 3 | 1 | 2 | 4 | 1 | 1 | 2 | 42 |
| Vila | Epi | T | 3 | 1 | 2 | 4 | 1 | 1 | 2 | 42 |
| Vila | Erromango | T | 3 | 1 | 2 | 4 | 1 | 1 | 2 | 42 |
| Vila | Tanna/C | T | 3 | 1 | 2 | 4 | 1 | 1 | 2 | 42 |
| Vila | Tanna/SE | T | 3 | 1 | 2 | 4 | 1 | 1 | 2 | 42 |
| Thyei | Santo/C | T | 7 | 2 | 4 | 4 | 2 | 0 | 1 | 43 |
| Malogro | Santo/C | T | 3 | 1 | 2 | 4 | 2 | 0 | 2 | 44 |
| Tudey | Santo/C | T | 5 | 2 | 4 | 4 | 2 | 1 | 2 | 45 |
| Tudey | Tanna/C | T | 5 | 2 | 4 | 4 | 2 | 1 | 2 | 45 |
| Tudey | Tanna/SE | T | 5 | 2 | 4 | 4 | 2 | 1 | 2 | 45 |
| Woko | Santo/W | T | 3 | 1 | 2 | 2 | 2 | 0 | 2 | 46 |
| Tabal | Pentecost/C | C | 3 | 4 | 1 | 4 | 2 | 1 | 3 | 47 |
| Roge | Malo | T | 3 | 4 | 1 | 4 | 2 | 1 | 3 | 47 |
| Daou | Malekula/NW | Q | 7 | 2 | 1 | 4 | 1 | 0 | 2 | 48 |
| Pade | Malekula/NW | Q | 7 | 2 | 4 | 3 | 2 | 0 | 2 | 49 |
| Silese | Malekula/NW | Y | 5 | 2 | 4 | 3 | 1 | 0 | 2 | 50 |
| Pilake | Nguna | Q | 5 | 2 | 4 | 3 | 1 | 0 | 2 | 50 |
| Tafandai | Malekula/NW | T | 5 | 3 | 2 | 4 | 1 | 0 | 3 | 51 |
| Toh | Paama | Q | 5 | 1 | 1 | 5 | 1 | 0 | 2 | 52 |
| Teiha | Paama | Q | 5 | 2 | 1 | 2 | 2 | 0 | 2 | 53 |
| Meawmelo | Epi | C | 5 | 2 | 1 | 2 | 2 | 0 | 2 | 53 |
| Mage | Epi | M | 5 | 2 | 1 | 4 | 1 | 0 | 2 | 54 |
| Meawmeia | Epi/S | C | 5 | 2 | 1 | 4 | 1 | 0 | 2 | 54 |
| Meawlake | Epi/E | M | 5 | 2 | 1 | 4 | 1 | 0 | 2 | 54 |
| Lo | Epi | Q | 3 | 5 | 4 | 1 | 1 | 0 | 1 | 56 |
| Tinbokai | Epi | Q | 3 | 5 | 4 | 1 | 1 | 0 | 1 | 56 |
| Ulutao | Emae | T | 5 | 2 | 1 | 1 | 2 | 0 | 2 | 57 |
| Kaviui | Epi | T | 5 | 2 | 1 | 1 | 2 | 0 | 2 | 57 |
| Elot | Tongoariki | Q | 3 | 2 | 1 | 3 | 1 | 0 | 2 | 58 |
| Metolei | Tongoa | Q | 5 | 1 | 4 | 3 | 2 | 0 | 1 | 59 |
| Tau | Tongoa | C | 5 | 4 | 4 | 1 | 1 | 0 | 2 | 60 |
| Oleikaro | Tongoa | Q | 5 | 4 | 4 | 1 | 1 | 0 | 2 | 60 |
| Oleikaro | Emae | Q | 5 | 4 | 4 | 1 | 1 | 0 | 2 | 60 |
| Black hand | Vate | Q | 5 | 3 | 1 | 3 | 1 | 0 | 2 | 61 |
| Ewo | Tongoa | T | 5 | 3 | 1 | 3 | 1 | 0 | 2 | 61 |
| Fiji | Tanna/C | Q | 3 | 3 | 1 | 3 | 1 | 0 | 2 | 62 |
| Nimau | Tongoa | Q | 3 | 3 | 4 | 1 | 1 | 0 | 3 | 63 |
| Miela | Emae | Q | 3 | 1 | 3 | 2 | 2 | 0 | 2 | 64 |
| Loa | Nguna | Q | 5 | 2 | 3 | 1 | 2 | 0 | 2 | 65 |
| Pore | Erromango | Q | 5 | 2 | 3 | 1 | 2 | 0 | 2 | 65 |
| Pic | Erromango | Q | 5 | 3 | 1 | 4 | 1 | 0 | 2 | 66 |
| Amon | Tanna/C | Q | 5 | 1 | 2 | 2 | 2 | 0 | 2 | 67 |
| Mokom | Anatom | | | | | | | | | |
| Ahouia | Tanna/C | | | | | | | | | |

TABLE 1 (continued)

| Cultivar | Origin | Use[1] | Morphotype | | | | | | | No.[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | C | I | L | E | P | S | |
| Pualiu | Tongoa | Q | 5 | 1 | 2 | 2 | 2 | 0 | 2 | 67 |
| Aigen | Tanna/C | Q | 3 | 1 | 3 | 1 | 1 | 0 | 2 | 68 |
| Nidinolai | Anatom | M | 3 | 1 | 3 | 1 | 1 | 0 | 2 | 68 |
| Apin | Tanna/C | M | 3 | 5 | 1 | 3 | 3 | 0 | 3 | 69 |
| Apol | Tanna/SE | C | 2 | 5 | 1 | 3 | 3 | 0 | 3 | 69 |
| Apeg | Anatom | C | 3 | 5 | 1 | 3 | 3 | 0 | 3 | 69 |
| Pare | Tanna/C | C | 3 | 1 | 2 | 3 | 1 | 0 | 2 | 70 |
| Leay | Tanna/C | Q | 7 | 1 | 2 | 3 | 1 | 0 | 2 | 71 |
| Kiskisnian | Tanna/C | C | 7 | 1 | 4 | 3 | 1 | 0 | 2 | 72 |
| Malamala | Tanna/SE | Q | 3 | 2 | 1 | 2 | 2 | 0 | 3 | 73 |
| Malamala | Anatom | Q | 3 | 2 | 1 | 2 | 2 | 0 | 3 | 73 |
| Tchai | Tanna/C | S | 3 | 2 | 1 | 2 | 2 | 0 | 3 | 73 |
| Tikiskis | Tanna/C | C | 7 | 1 | 2 | 3 | 2 | 0 | 2 | 74 |
| Wapil | Anatom | Q | 5 | 1 | 1 | 2 | 1 | 0 | 1 | 75 |
| Asyaij | Tanna/C | Q | 5 | 1 | 1 | 3 | 1 | 0 | 1 | 75 |
| Gnare | Anatom | M | 5 | 2 | 1 | 4 | 2 | 0 | 3 | 76 |
| Tchap | Tanna/C | C | 5 | 2 | 1 | 4 | 2 | 0 | 3 | 76 |
| Awor | Tanna/C | Q | 3 | 2 | 4 | 2 | 2 | 0 | 2 | 77 |
| Awke | Tanna/C | C | 3 | 2 | 3 | 1 | 1 | 0 | 2 | 78 |
| Kowarwar | Tanna/SE | C | 3 | 3 | 1 | 1 | 2 | 0 | 2 | 79 |
| Kokoffe | Tanna/SE | Q | 5 | 1 | 4 | 1 | 1 | 0 | 2 | 80 |
| Ketche | Anatom | Q | 5 | 1 | 4 | 1 | 1 | 0 | 2 | 80 |
| Yag | Anatom | C | 5 | 1 | 2 | 1 | 1 | 0 | 1 | 81 |
| Metche | Anatom | C | 5 | 3 | 3 | 4 | 1 | 0 | 2 | 82 |

[1]Use column refers to traditional use of the cultivar: daily (Q), medicinal (M), custon purposes (C), 'two-day' kava (T), and never-drunk (S) (from Lebot and Brunton, 1985).

[2]No. column in this and subsequent tables refers to cultivar identification numbers based on morphological description of germplasm collection. Where same cultivar name appears more than once, it denotes samples from different localities (see APPENDIX 1). See text for morphotype and kavalactone abbreviations in this and subsequent tables.

Cultivars 14 and 47 are thought to belong to the species *Piper wichmannii* because of their extremely long inflorescences (as long as the central vein of the lamina). When collected in the field, however, farmers argued that they had been planted, and this is why they are called cultivars locally.

This method is, however, not well suited to medicinal plants for which morphological characters are less important than chemical ones. Selection of cultivars based on morphological characters would therefore be of very limited use as there is no relationship between chemistry and morphology. Furthermore, the use of numerical taxonomic techniques (multivariate analysis and agglomerative clustering) to treat these morphological data did not help to identify distinct groups of morphotypes.

The results of the chemical analysis work conducted using HPLC are presented in TABLE 2. The data are expressed as percentages representing the proportion of kavalactones in each extract. Several samples of the same extract injected repeatedly through the column have shown that the figures obtained are reliable, since variation between samples was close to nil (Lévesque, 1985, unpublished data); this confirmed the accuracy of the method and allowed interpretation of the results.

TABLE 2. RESULTS OF THE CHEMICAL ANALYSES CONDUCTED ON 67 CULTIVARS FROM THE GERMPLASM COLLECTION OF TAGABÉ AGRICULTURAL STATION

| Cultivar | No. | DMY 1 | DHK 2 | Y 3 | K 4 | DHM 5 | M 6 | KL% | Chemotype[1] |
|---|---|---|---|---|---|---|---|---|---|
| Metolei | 58 | 6.11 | 33.24 | 19.93 | 19.36 | 9.81 | 11.55 | 10.73 | 234651 |
| Tau | 59 | 6.38 | 39.03 | 12.90 | 19.13 | 12.47 | 10.08 | 10.76 | 243561 |
| Poua | 7 | 9.25 | 27.33 | 12.44 | 23.32 | 14.56 | 11.11 | 8.71 | 245361 |
| Borogoru | 7 | 9.20 | 35.80 | 8.15 | 20.87 | 15.83 | 10.15 | 9.80 | 245613 |
| Pualiu | 67 | 6.09 | 42.83 | 7.87 | 21.20 | 11.07 | 10.93 | 6.80 | 245631 |
| Ewo | 61 | 4.97 | 44.39 | 9.25 | 16.57 | 14.02 | 10.81 | 6.24 | 245631 |
| Riki | 37 | 4.71 | 42.02 | 5.11 | 27.13 | 10.88 | 10.15 | 6.35 | 245631 |
| Bumalotu | 16 | 5.40 | 39.29 | 8.36 | 24.45 | 14.63 | 7.87 | 9.11 | 245631 |
| Paama | 15 | 8.35 | 35.48 | 5.72 | 28.77 | 8.16 | 13.50 | 6.30 | 246153 |
| Rongrongwul | 22 | 10.54 | 28.82 | 13.36 | 21.80 | 9.83 | 15.64 | 8.66 | 246315 |
| Leay | 71 | 6.89 | 29.25 | 9.81 | 26.46 | 9.11 | 18.49 | 14.00 | 246351 |
| Palarasul | 40 | 7.55 | 28.59 | 15.34 | 22.56 | 10.42 | 15.44 | 13.69 | 246351 |
| Mita | 24 | 7.48 | 32.29 | 9.52 | 26.01 | 9.04 | 15.65 | 14.55 | 246351 |
| Black hand | 60 | 6.72 | 33.97 | 8.56 | 26.90 | 8.44 | 15.40 | 12.20 | 246351 |
| Malamala | 73 | 7.88 | 33.15 | 0.99 | 31.24 | 8.70 | 18.04 | 15.13 | 246513 |
| Kar | 7 | 8.25 | 34.10 | 8.11 | 22.30 | 10.89 | 16.36 | 9.44 | 246513 |
| Kiskisnian | 72 | 7.21 | 36.30 | 6.99 | 27.05 | 8.18 | 14.27 | 13.47 | 246513 |
| Nimau | 62 | 5.96 | 36.24 | 8.48 | 21.51 | 13.16 | 14.65 | 7.61 | 246531 |
| Big hand | 37 | 6.55 | 36.83 | 6.70 | 27.81 | 8.08 | 14.04 | 8.72 | 246531 |
| Tuan | 40 | 7.44 | 30.46 | 9.63 | 25.21 | 9.63 | 17.02 | 7.77 | 246531 |
| Tikiskis | 74 | 4.16 | 38.01 | 4.57 | 23.85 | 13.40 | 15.92 | 8.86 | 246531 |
| Aigen | 68 | 6.14 | 36.35 | 7.31 | 23.92 | 10.35 | 15.93 | 13.76 | 246531 |
| Ahouia | 67 | 6.43 | 29.55 | 7.96 | 26.74 | 9.36 | 19.96 | 13.13 | 246531 |
| Visul | 40 | 5.44 | 38.28 | 10.00 | 21.11 | 11.64 | 13.53 | 7.96 | 246531 |
| Amon | 65 | 7.16 | 33.84 | 9.12 | 20.73 | 12.59 | 16.56 | 13.33 | 246531 |
| Oleikaro | 60 | 6.17 | 34.39 | 7.26 | 18.56 | 16.50 | 17.12 | 9.84 | 246531 |
| Puariki | 37 | 7.47 | 40.33 | 7.84 | 23.81 | 9.71 | 10.83 | 6.33 | 246531 |
| Biya | 23 | 6.36 | 35.09 | 6.72 | 29.64 | 10.28 | 11.91 | 7.09 | 246531 |
| Nidinolaï | 68 | 6.34 | 38.99 | 8.20 | 26.11 | 10.14 | 10.22 | 11.81 | 246531 |
| Borogu | 15 | 7.04 | 31.18 | 10.26 | 26.71 | 11.37 | 13.43 | 6.59 | 246531 |
| Yag | 81 | 5.86 | 36.97 | 6.53 | 25.63 | 11.05 | 13.95 | 10.70 | 246531 |
| Asyaij | 75 | 7.40 | 34.29 | 8.80 | 30.43 | 8.36 | 10.72 | 7.75 | 246531 |
| Tariparaus | 8 | 5.98 | 27.61 | 6.67 | 19.86 | 20.79 | 19.09 | 11.14 | 254631 |
| Pirimerei | 3 | 5.84 | 28.33 | 6.11 | 20.48 | 20.62 | 18.62 | 13.65 | 254631 |
| Aheyoke | 1 | 4.64 | 49.02 | 6.54 | 9.48 | 17.65 | 12.66 | 11.86 | 256431 |
| Malogro | 44 | 4.07 | 35.10 | 6.75 | 11.15 | 23.71 | 19.23 | 8.10 | 256431 |
| Thyei | 43 | 4.90 | 37.20 | 10.75 | 11.25 | 20.02 | 15.87 | 17.16 | 256431 |
| Vila | 42 | 4.62 | 31.54 | 10.43 | 11.09 | 21.57 | 20.71 | 16.50 | 256431 |
| Merei | 10 | 5.24 | 38.85 | 9.80 | 11.83 | 18.07 | 16.21 | 13.21 | 256431 |
| Malmalbo | 16 | 4.03 | 44.43 | 7.38 | 7.75 | 23.87 | 12.53 | 16.33 | 256431 |
| Tudey | 45 | 4.66 | 31.87 | 10.89 | 13.07 | 21.36 | 18.15 | 10.40 | 256431 |
| Apeg | 69 | 5.76 | 29.59 | 12.16 | 13.08 | 22.16 | 17.25 | 11.17 | 256431 |
| Yevoet | 41 | 9.26 | 26.82 | 8.34 | 22.05 | 10.59 | 22.94 | 7.65 | 264531 |
| Woko | 46 | 5.90 | 29.36 | 10.54 | 19.28 | 15.11 | 19.81 | 15.29 | 264531 |
| Small hand | 6 | 5.07 | 32.67 | 8.18 | 12.48 | 18.99 | 22.61 | 12.07 | 265431 |
| Fock | 18 | 5.62 | 30.03 | 12.17 | 15.10 | 15.74 | 21.33 | 18.70 | 265431 |
| Abogae | 8 | 4.51 | 28.00 | 9.82 | 11.75 | 20.84 | 25.09 | 13.00 | 265431 |
| Lalahk | 25 | 5.72 | 27.79 | 9.33 | 14.71 | 15.83 | 26.61 | 11.54 | 265431 |
| Marino | 42 | 5.93 | 30.81 | 9.71 | 11.67 | 18.09 | 23.79 | 11.22 | 265431 |
| Palavoke | 32 | 5.56 | 43.99 | 7.77 | 13.63 | 14.16 | 14.88 | 15.75 | 265431 |
| Nakasara | 21 | 4.56 | 30.17 | 9.33 | 11.03 | 21.93 | 22.98 | 14.72 | 265431 |
| Palisi | 26 | 5.74 | 34.30 | 11.46 | 11.09 | 17.93 | 19.47 | 13.70 | 265431 |
| Small leaf | 23 | 8.06 | 22.16 | 15.09 | 35.20 | 6.36 | 13.13 | 14.80 | 423615 |
| Kelaï | 17 | 9.25 | 30.22 | 7.64 | 37.41 | 5.95 | 9.52 | 11.28 | 426135 |
| Pia | 23 | 7.19 | 30.63 | 6.70 | 30.74 | 7.11 | 17.62 | 13.25 | 426153 |
| Tchap | 76 | 10.00 | 24.29 | 10.66 | 30.58 | 9.68 | 14.80 | 8.02 | 426315 |

TABLE 2 (continued)

| Cultivar | No. | DMY 1 | DHK 2 | Y 3 | K 4 | DHM 5 | M 6 | KL% | Chemotype[1] |
|---|---|---|---|---|---|---|---|---|---|
| Miela | 63 | 7.59 | 24.93 | 12.92 | 30.56 | 9.78 | 14.22 | 11.25 | 426351 |
| Palimet | 24 | 7.45 | 25.21 | 8.27 | 33.68 | 8.17 | 17.72 | 12.34 | 426351 |
| Urukara | 42 | 6.39 | 22.68 | 9.07 | 35.46 | 8.85 | 17.54 | 9.00 | 426351 |
| Ulutao | 56 | 11.90 | 18.30 | 14.53 | 29.91 | 8.10 | 17.26 | 10.05 | 426351 |
| Kau | 14 | 15.16 | 22.20 | 9.33 | 2.79 | 42.37 | 8.14 | 6.60 | 521364 |
| Vambu | 14 | 10.09 | 16.49 | 3.88 | 1.80 | 58.21 | 9.53 | 4.43 | 521634 |
| Buara | 14 | 10.48 | 19.07 | 4.32 | 1.70 | 56.80 | 7.63 | 7.10 | 521634 |
| Bo | 14 | 11.47 | 34.19 | 4.21 | 3.06 | 38.89 | 8.19 | 7.31 | 521634 |
| Tabal | 47 | 7.91 | 21.26 | 14.35 | 13.86 | 24.55 | 18.08 | 17.60 | 526341 |
| Tangurlava | 14 | 4.60 | 24.12 | 9.93 | 13.76 | 25.27 | 22.30 | 10.28 | 526431 |
| Apin | 69 | 4.89 | 23.48 | 12.11 | 11.02 | 21.69 | 27.31 | 14.60 | 625341 |

[1]Numbers in 'Chemotype' column indicate the extract composition. The composition is coded in decreasing order of the proportion of each lactone present in the extract.

Statistical analysis conducted on data obtained from the germplasm collection indicates several well-differentiated groups (FIGURE 10). In terms of selection processes, this clustering technique allows identification of convars, or groups of different cultivars (different morphotypes), with similar chemotypes (chemical compositions). The results of this study suggest that kava in Vanuatu is represented by six main chemotypes (FIGURE 10). Within each group, cultivars are not significantly different. When these results were compared with those obtained from ethnobotanical studies (TABLE 1), a definite correlation was observed between the traditional uses and chemotypes of the cultivars. Chemotypes 521634 and 526341 represent cultivars that are rarely consumed. The latter is used for ritual purposes and belongs to the species *Piper methysticum* (**Tangurlava, Tabal**, cultivars no. 14 and 47), and the former is *P. wichmannii* (**Kau, Bo, Buara, Vambu**; cultivar no. 14). Farmers observe that the physiological effect of these two chemotypes is too severe to allow daily consumption. When imbibed, an unpleasant sensation of nausea is felt. This is certainly due to the very high proportion of DHK (2) and DHM (5), which are the most active kavalactones (Hänsel, 1968; Lebot and Cabalion, 1986). This observation is also true for chemotype 256431, which is a group of cultivars famous for their very pronounced physiological effect and known in Pidjin English as **Tudey** for "Two days", the drinker being affected for two days.

Chemotype 265431 is a group of cultivars traditionally used for medicinal and custom purposes. Chemotype 246531, which is the biggest group, is a group of cultivars used for daily drinking, and chemotype 426135 (cultivar **Kelaï** from Epi) is famous throughout Vanuatu for its very pleasant effect. It is known from physiological studies that each kavalactone has its characteristic properties (Hänsel, 1968), and each chemotype comprises a distinctive natural mixture of active ingredients with different properties. The physiological effect of a chemotype is governed by its dominant kavalactone concentration, of which the first three often represent over 70% of the total. Correlation with information gained from ethnobotanical studies shows that drinkers do not appreciate a high percentage of DHK (2) and DHM (5). On the other hand, it seems that chemotypes with a high

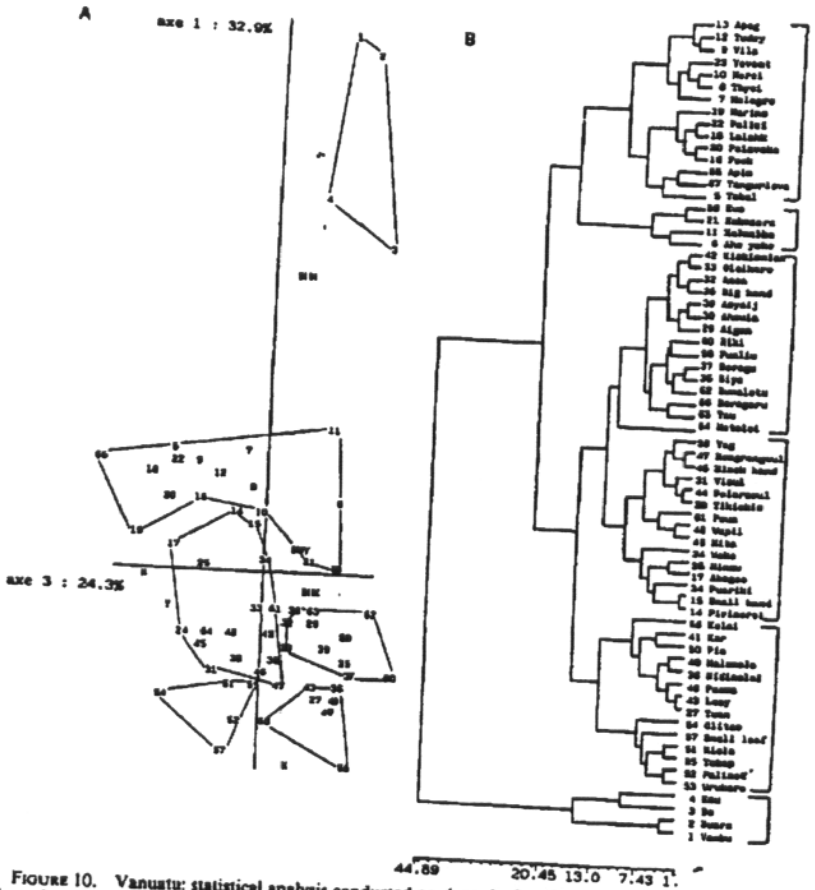



FIGURE 10. Vanuatu: statistical analysis conducted on data obtained from HPLC of root samples from the germplasm collection. A, multifactorial analysis on data obtained from the chemical analysis of 67 cultivars; B, dendrogram of 67 cultivars based on their coefficient of association (Euclidean distance). The horizontal lines indicate the level of association at which cultivars are linked. The vertical lines represent cultivars showing closest coefficient of association.

percentage of K (4) and a low percentage of DHM (5) produce a pleasant and desirable effect. This observation is not surprising as, according to Kretzschmar (1970), the excellent psychopharmacological activities of kavain are emotional and muscular relaxation, stabilization of the feelings, and stimulation of the ability to think and act.

Chemotype variability is not due to the origin of the cultivars, as the variability

TABLE 3. CHEMICAL ANALYSES CONDUCTED ON CLONES OF CULTIVARS VILA AND SMALL LEAF. COMPARISON WITH MOTHER PLANT (*), FROM THE GERMPLASM COLLECTION

| Cultivar | DMY 1 | DHK 2 | Y 3 | K 4 | DHM 5 | M 6 | KL% | Chemotype |
|---|---|---|---|---|---|---|---|---|
| Vila (*) | 4.62 | 31.54 | 10.43 | 11.09 | 21.57 | 20.71 | 16.50 | 256431 |
| Vila 1 | 5.18 | 35.10 | 9.90 | 12.94 | 20.61 | 16.27 | 23.58 | 256431 |
| Vila 2 | 4.93 | 38.39 | 10.28 | 11.15 | 22.40 | 12.84 | 23.63 | 256431 |
| Vila 3 | 5.26 | 36.59 | 9.25 | 12.33 | 20.72 | 15.85 | 24.77 | 256431 |
| Vila 4 | 7.54 | 30.69 | 12.74 | 14.91 | 15.30 | 18.82 | 22.92 | 265431 |
| Vila 5 | 7.15 | 29.79 | 13.32 | 18.32 | 13.92 | 17.51 | 23.64 | 246531 |
| Vila 6 | 7.24 | 34.45 | 12.38 | 15.90 | 14.76 | 15.27 | 24.11 | 246531 |
| Vila 7 | 7.18 | 31.83 | 13.32 | 16.48 | 14.77 | 16.42 | 21.20 | 246531 |
| Vila 8 | 7.04 | 34.93 | 13.33 | 14.46 | 15.26 | 14.99 | 25.27 | 256431 |
| Mean | 6.23 | 33.70 | 11.66 | 14.17 | 17.70 | 16.52 | 22.84 | 256431 |
| C.V.% | 6.39 | 2.85 | 4.77 | 5.86 | 6.58 | 4.61 | 3.85 | – |
| Small leaf (*) | 8.06 | 22.16 | 15.09 | 35.20 | 6.36 | 13.13 | 14.88 | 423615 |
| Small leaf 1 | 7.77 | 26.65 | 12.99 | 32.18 | 7.09 | 13.31 | 16.90 | 426315 |
| Small leaf 2 | 8.52 | 27.23 | 13.42 | 33.03 | 6.14 | 11.65 | 19.20 | 423615 |
| Small leaf 3 | 7.87 | 25.48 | 16.69 | 32.57 | 7.14 | 13.25 | 19.86 | 423615 |
| Small leaf 4 | 7.81 | 26.58 | 13.48 | 32.49 | 6.74 | 12.90 | 17.00 | 423615 |
| Small leaf 5 | 8.11 | 24.09 | 13.04 | 34.18 | 6.24 | 14.35 | 18.96 | 426315 |
| Small leaf 6 | 7.91 | 25.86 | 13.41 | 33.01 | 6.86 | 12.95 | 15.72 | 423615 |
| Small leaf 7 | 7.68 | 26.14 | 13.78 | 32.92 | 7.11 | 12.37 | 17.24 | 423615 |
| Mean | 7.96 | 25.52 | 13.98 | 33.19 | 6.71 | 12.98 | 17.47 | 423615 |
| C.V.% | 1.17 | 2.28 | 3.21 | 1.06 | 2.16 | 2.17 | 3.53 | – |

among all the cultivars from Pentecost Island is as great as that among those of other islands. Furthermore, it is difficult to correlate morphological and chemical characteristics. In some cases, plants that show a similar morphotype also show a similar chemotype (i.e. cultivars no. 14 and 40), but exceptions are numerous. This calls into question the accuracy and value of utilizing morphology in the selection process, as no conclusion can be formulated on the basis of morphological differences.

The results obtained from cultivars planted in a homogeneous environment (soil and climate) indicate that the variability in chemical composition and total kavalactone content is controlled by genotype rather than by external factors. Ethnobotanical studies already suggested this (Lebot and Cabalion, 1986), with farmers asserting that different cultivars uprooted from the same garden produced different effects. This theory, however, remained to be substantiated by chemical data, and the information gained from this first experiment needed to be confirmed by additional trials.

Trials were conducted in order to evaluate variations due to environmental factors. The results of these trials are presented in TABLES 3 and 4.

Cultivars **Vila** and **Small leaf** were analyzed when harvested from the germplasm collection. Clones of these two plants were planted on the same day and harvested exactly two years later.

These results show that kavalactone content is very homogeneous within the clone and that chemotype is consistent, although some variation was observed. The coefficients of variation obtained indicate that farmers have a high probability of preserving the same physiological effect by cloning the mother plant.

TABLE 4. VARIATION OF CHEMICAL COMPOSITION WITH ONTOGENY AND ENVIRONMENT. COMPARISON BETWEEN RESULTS OBTAINED FROM THE GERMPLASM COLLECTION OF TAGABE AGRICULTURAL STATION ON EFATE (*), A LOCAL CONTROL FROM SANTO (SAN), AND PLANTS HARVESTED AT 13, 18, 23, AND 28 MONTHS

| Cultivar | DMY 1 | DHK 2 | Y 3 | K 4 | DHM 5 | M 6 | KL% | Chemotype |
|---|---|---|---|---|---|---|---|---|
| Malogro (*) | 4.07 | 35.10 | 6.75 | 11.15 | 23.71 | 19.23 | 8.06 | 256431 |
| Malogro 13 | 7.14 | 26.62 | 11.90 | 17.49 | 16.68 | 20.16 | 16.41 | 256431 |
| Malogro 18 | 6.53 | 31.65 | 12.94 | 13.91 | 18.11 | 16.87 | 17.53 | 256431 |
| Malogro 23 | 8.67 | 32.06 | 9.39 | 13.40 | 20.40 | 16.07 | 16.89 | 256431 |
| Malogro 28 | 9.64 | 26.58 | 10.86 | 14.00 | 21.71 | 17.21 | 16.57 | 256431 |
| Mean | 7.21 | 30.40 | 10.37 | 13.99 | 20.12 | 7.90 | 15.09 | 256431 |
| C.V.% | 13.28 | 5.46 | 10.40 | 7.26 | 6.22 | 4.27 | 11.71 | |
| Marino (*) | 5.93 | 30.81 | 9.71 | 11.67 | 18.09 | 23.79 | 11.22 | 265431 |
| Marino (San) | 6.15 | 26.78 | 12.55 | 14.25 | 17.95 | 22.32 | 15.71 | 265431 |
| Marino 13 | 7.28 | 26.24 | 10.93 | 15.91 | 17.31 | 22.34 | 14.47 | 265431 |
| Marino 18 | 8.55 | 28.94 | 11.56 | 14.58 | 17.63 | 18.73 | 14.92 | 265431 |
| Marino 23 | 9.67 | 26.83 | 10.10 | 14.15 | 19.26 | 19.99 | 15.13 | 265431 |
| Marino 28 | 7.53 | 30.19 | 11.28 | 13.18 | 18.70 | 19.11 | 15.28 | 265431 |
| Mean | 7.51 | 28.29 | 11.02 | 13.95 | 18.15 | 21.04 | 14.45 | 265431 |
| C.V.% | 7.72 | 2.81 | 3.80 | 4.17 | 1.60 | 3.98 | 4.62 | |
| Tudey (*) | 4.66 | 31.87 | 10.89 | 13.07 | 21.36 | 18.15 | 10.40 | 256431 |
| Tudey (San) | 6.63 | 38.63 | 14.11 | 20.17 | 11.96 | 8.51 | 11.53 | 243561 |
| Tudey 13 | 11.47 | 24.74 | 8.27 | 38.20 | 5.53 | 11.79 | 9.68 | 426135 |
| Tudey 18 | 11.37 | 23.63 | 9.71 | 39.57 | 4.98 | 10.74 | 10.32 | 421635 |
| Tudey 23 | 7.63 | 38.03 | 9.58 | 11.00 | 21.70 | 12.07 | 10.77 | 256431 |
| Tudey 28 | 9.33 | 24.09 | 11.91 | 39.88 | 5.12 | 9.66 | 10.11 | 423615 |
| Mean | 8.51 | 30.16 | 10.74 | 26.98 | 11.77 | 11.82 | 10.46 | 246531 |
| C.V.% | 12.99 | 9.48 | 7.83 | 20.79 | 27.69 | 11.65 | 2.46 | |
| Merei (*) | 5.24 | 38.85 | 9.80 | 11.83 | 18.07 | 16.21 | 13.21 | 256431 |
| Merei 13 | 6.28 | 35.01 | 12.54 | 14.24 | 16.66 | 15.27 | 22.25 | 256431 |
| Merei 18 | 8.09 | 35.82 | 11.51 | 13.32 | 18.45 | 12.82 | 20.80 | 254631 |
| Merei 23 | 5.84 | 28.33 | 6.11 | 20.48 | 20.62 | 18.62 | 13.65 | 254631 |
| Merei 28 | 6.62 | 35.19 | 10.78 | 13.24 | 20.47 | 13.70 | 13.43 | 256431 |
| Mean | 6.41 | 34.64 | 10.14 | 14.62 | 18.85 | 15.32 | 16.66 | 256431 |
| C.V.% | 7.45 | 4.97 | 10.83 | 10.35 | 3.98 | 6.61 | 11.98 | |
| Fock (*) | 5.62 | 30.03 | 12.17 | 15.10 | 15.74 | 21.33 | 18.70 | 265431 |
| Fock 13 | 7.06 | 32.11 | 11.54 | 15.72 | 18.29 | 15.28 | 16.60 | 254631 |
| Fock 18 | 8.51 | 33.01 | 11.31 | 16.19 | 16.31 | 14.66 | 17.40 | 254631 |
| Fock 23 | 7.38 | 31.12 | 11.63 | 15.33 | 20.44 | 14.10 | 20.84 | 254631 |
| Fock 28 | 9.39 | 30.31 | 12.25 | 14.79 | 17.69 | 15.57 | 19.21 | 256431 |
| Mean | 7.59 | 31.31 | 11.78 | 15.42 | 17.69 | 16.18 | 18.55 | 256431 |
| C.V.% | 8.46 | 1.77 | 1.55 | 1.57 | 4.66 | 8.09 | 3.96 | |
| Kar (*) | 8.25 | 34.10 | 8.11 | 22.30 | 10.89 | 16.36 | 9.40 | 246513 |
| Kar 13 | 7.24 | 26.43 | 14.26 | 26.16 | 10.68 | 15.22 | 11.50 | 246351 |
| Kar 18 | 7.16 | 28.47 | 11.22 | 24.43 | 13.42 | 15.30 | 10.16 | 246351 |
| Kar 23 | 8.21 | 30.04 | 9.78 | 27.16 | 10.68 | 14.13 | 11.27 | 246531 |
| Kar 28 | 8.53 | 30.39 | 12.19 | 22.61 | 14.63 | 11.65 | 9.96 | 245361 |
| Mean | 7.87 | 29.88 | 11.11 | 24.53 | 12.06 | 14.53 | 10.45 | 246531 |
| C.V.% | 3.58 | 4.21 | 9.36 | 3.89 | 6.84 | 5.51 | 3.82 | |
| Thyei (*) | 4.90 | 37.20 | 10.75 | 11.25 | 20.02 | 15.87 | 17.16 | 256431 |
| Thyei 13 | 8.70 | 38.45 | 10.55 | 10.35 | 18.16 | 13.79 | 16.10 | 256341 |
| Thyei 18 | 9.41 | 32.73 | 10.05 | 22.29 | 13.53 | 11.98 | 16.63 | 245631 |
| Thyei 23 | 7.26 | 41.83 | 10.70 | 11.40 | 16.69 | 12.13 | 15.72 | 256431 |
| Mean | 6.88 | 38.07 | 12.38 | 13.77 | 17.32 | 13.55 | 16.10 | 254631 |
| C.V.% | 14.97 | 4.04 | 15.10 | 15.90 | 6.25 | 5.24 | 2.37 | |

TABLE 4 (continued)

| Cultivar | DMY 1 | DHK 2 | Y 3 | K 4 | DHM 5 | M 6 | KL% | Chemotype |
|---|---|---|---|---|---|---|---|---|
| Visul (*) | 5.44 | 38.28 | 10.00 | 21.11 | 11.64 | 13.53 | 7.96 | 246531 |
| Visul 13 | 10.48 | 26.08 | 9.27 | 31.84 | 8.57 | 13.76 | 8.18 | 426135 |
| Visul 18 | 10.74 | 25.07 | 11.69 | 31.89 | 8.20 | 12.41 | 9.91 | 426315 |
| Visul 23 | 8.20 | 24.90 | 10.16 | 32.23 | 11.12 | 13.39 | 8.76 | 426531 |
| Visul 28 | 9.00 | 22.55 | 10.41 | 33.61 | 11.91 | 12.52 | 10.14 | 426531 |
| Mean | 8.77 | 27.37 | 10.30 | 30.13 | 10.28 | 13.12 | 8.99 | 426351 |
| C.V.% | 10.88 | 10.15 | 3.83 | 7.53 | 7.67 | 2.09 | 4.92 | |
| Yevoet (*) | 9.26 | 26.82 | 9.34 | 22.05 | 10.59 | 22.94 | 7.65 | 264531 |
| Yevoet 13 | 9.11 | 20.01 | 10.66 | 32.85 | 6.20 | 21.17 | 12.66 | 462315 |
| Yevoet 18 | 10.60 | 18.18 | 9.55 | 31.58 | 7.21 | 22.88 | 14.63 | 462135 |
| Yevoet 23 | 9.63 | 19.23 | 10.22 | 33.12 | 7.05 | 20.75 | 14.08 | 462315 |
| Yevoet 28 | 11.13 | 18.07 | 11.87 | 31.44 | 6.62 | 20.87 | 13.78 | 462315 |
| Mean | 9.94 | 20.46 | 10.32 | 30.20 | 7.53 | 21.72 | 12.56 | 462315 |
| C.V.% | 3.95 | 7.96 | 4.36 | 6.84 | 10.40 | 2.25 | 10.09 | |

Clones from different cultivars were planted in a row on the same day, and one plant from each was harvested every five months. Results obtained from this trial set up on the IRCC (Institut de Recherches sur le Café et le Cacao) station at Valeteruru, Santo Island (altitude: 140 m.; average annual precipitation: 3200 mm.), were compared with a local control, when available, and also with the same cultivar from the germplasm collection on Efaté.

The results given in TABLE 4 show that kavalactone content does not seem to be related to ontogeny but rather to genotype. Some cultivars present very consistent chemotypes (**Marino** and **Malogro**), although cultivar **Tudey** seems to be subject to great variations.

These results (TABLES 3 and 4), compared with those obtained from the germplasm collection (TABLE 2), suggest that chemotype is not related to ontogeny or environment. However, clones seem to produce not only replicants of the initial chemotype but also variants.

A simple linear correlation analysis conducted on various kavalactones and total kavalactone content indicates the following significant correlations (calculated using data from TABLE 2). Demethoxyyangonin (DMY) is negatively correlated with dihydrokavain (DHK), methysticin (M), and total kavalactone content (KL%). Dihydromethysticin (DHM) is negatively correlated with dihydrokavain (DHK) and kavain (K), while the total kavalactone content is positively correlated with yangonin (Y) and methysticin (M). These results are presented in TABLE 5.

On the basis of data obtained from these trials and the statements made by farmers, it may be inferred that Vanuatu possesses *in situ* collections of the different clones produced from the domestication process of *Piper wichmannii*. Among these clones, some are replicants and others variants of given chemotypes. By selecting the appropriate variants, farmers have "developed" *P. methysticum*. The process of domestication could be portrayed as a process of clone selection. FIGURE 11 proposes a lineage of chemotypes, from the wild species, *P. wichmannii*.

TABLE 5. SIMPLE LINEAR CORRELATION ANALYSIS BETWEEN KAVALACTONES

| Parameter | | | | |
|---|---|---|---|---|
| X | Y | Sample Size | Correlation Coefficient | Significance |
| DMY | DHK | 67 | −0.5528 | ** |
| | Y | 67 | −0.0021 | ns |
| | K | 67 | 0.0003 | ns |
| | DHM | 67 | 0.1287 | ns |
| | M | 67 | −0.3966 | ** |
| | KL% | 67 | −0.2893 | * |
| DHK | Y | 67 | −0.2493 | * |
| | K | 67 | 0.0061 | ns |
| | DHM | 67 | −0.2813 | ** |
| | M | 67 | −0.2028 | ns |
| | KL% | 67 | −0.1234 | ns |
| Y | K | 67 | 0.0086 | ns |
| | DHM | 67 | −0.2108 | ns |
| | M | 67 | 0.1855 | ns |
| | KL% | 67 | 0.3053 | * |
| K | DHM | 67 | −0.9222 | ** |
| | M | 67 | −0.0007 | ns |
| | KL% | 67 | 0.0091 | ns |
| DHM | M | 67 | −0.1383 | ns |
| | KL% | 67 | −0.1662 | ns |
| M | KL% | 67 | 0.4558 | ** |

**Significant at 1% level, tabular value: 0.325; *Significant at 5% level, tabular value: 0.250; ns Not Significant.

to the cultivated species, *P. methysticum*. From the information yielded by this study, it is possible to suggest that the center of origin and diversification of *P. methysticum* was the northern part of Vanuatu (Lebot and Lévesque, 1988). From there, Polynesian travellers could have spread clones to other Pacific islands. If this hypothesis could be verified, it would explain why *P. methysticum* is not present in the Solomon Islands.

On the basis of the results obtained from Vanuatu, which show that kava is represented by various chemotypes, it was decided to use the same techniques to survey the whole distribution area. Root samples of local cultivars were collected in their area and their chemical composition analyzed. However, so many islands and cultivars had to be covered in such a short time (six months, from April to September 1987), that it was not possible to establish trials to confirm the data obtained. Nevertheless, germplasm collections were established in each island group surveyed, and in the near future it will be possible to conduct such trials.

### 5.2. Fiji

Local cultivars were collected from Viti Levu, Vanua Levu, and Taveuni. Due to the "Yaqona disease complex", kava cultivation on Viti Levu is becoming very difficult, especially in the Suva/Rewa Districts. On the other hand, the rich volcanic soils of Taveuni are well suited for kava cultivation, and the crop is very important in this area.

Kava cultivation represents 2400 ha. and an income of $US 20 million for the

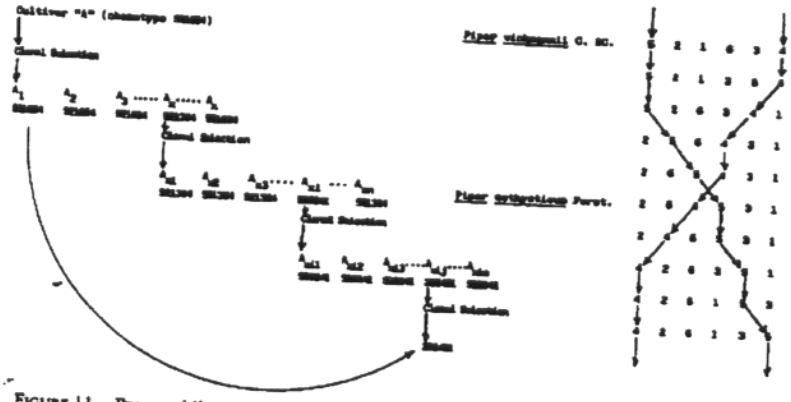


FIGURE 11. Proposed lineage of chemotypes, from *Piper wichmannii* to *P. methysticum*.

growers (Duve and Prasad, 1983). With the development of kava cultivation as a cash crop, farmers now use only two or three cultivars known for their hardiness or their resistance to disease, although they are not the most palatable ones. This is true for cultivars **Loa kasa leka** and **Loa kasa balavu**, which are certainly the most widely cultivated. According to Fijian farmers, there seems little doubt that the "white" (green) cultivars are the source of the best **Yaqona**, but they take longer to reach maturity and are more susceptible to diseases. The "black" (purple) cultivars are not favored by the Fijians and are said to produce a poorer beverage.

A total of 16 accessions have been planted at Koronivia Research Station, near Nausori on Viti Levu. Kava in Fiji is represented by twelve cultivars (twelve morphotypes) in the surveyed area, but it was not possible to survey the Lau group or Rotuma.

Although it is hazardous to compare these cultivars with those described in the Vanuatu germplasm collection because they were not described in a homogeneous environment, cultivar numbers were given according to the same procedure, based on the coded phenotype, in order to identify them in the germplasm collection planted at Koronivia Research Station. However, it is interesting to observe that cultivars **Honolulu and Business**, which are identical, have the same morphotype as cultivar 52 from Vanuatu and are doubtless recently introduced cultivars. The morphological descriptions compiled in the field of origin are presented in TABLE 9.

Because the various root samples used for the chemical analysis originated from different types of soil, the total kavalactone content is not indicated in this table, as it cannot be used for comparison (see APPENDIX 1 for details on the origin of samples). Owing to its abnormal chemical composition, it was decided not to include the data on **Qila leka**.

It is interesting to note that these results confirm data from the experiments

TABLE 6. RESULTS OF CHEMICAL ANALYSES CONDUCTED ON SAMPLES COLLECTED IN FIJI

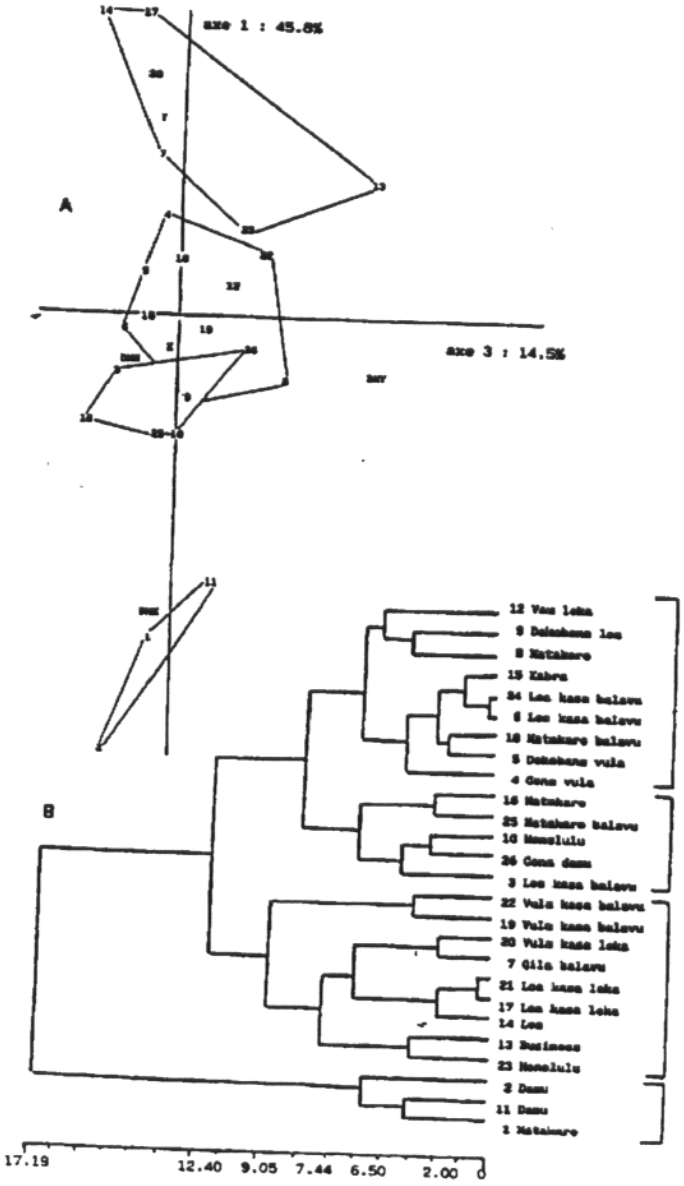
| Cultivar | No. | DMY 1 | DHK 2 | Y 3 | K 4 | DHM 5 | M 6 | Chemotype |
|---|---|---|---|---|---|---|---|---|
| Matakaro | 1 | 9.33 | 29.98 | 10.03 | 23.71 | 9.83 | 18.12 | 246351 |
| Damu | 2 | 8.47 | 31.66 | 7.85 | 26.12 | 12.00 | 13.89 | 246513 |
| Loa kasa balavu | 3 | 7.91 | 21.80 | 11.66 | 23.18 | 10.17 | 25.29 | 642351 |
| Qila leka | | 3.55 | 6.78 | 5.87 | 7.97 | 5.00 | 70.84 | 642351 |
| Gona vula | 4 | 8.88 | 15.65 | 19.12 | 20.38 | 12.81 | 23.16 | 643251 |
| Dokobana vula | 5 | 8.83 | 18.35 | 17.20 | 18.48 | 13.68 | 23.47 | 642351 |
| Loa kasa balavu | 6 | 10.74 | 19.04 | 13.56 | 15.11 | 15.57 | 25.98 | 625431 |
| Qila balavu | 7 | 7.44 | 13.19 | 16.41 | 26.16 | 9.79 | 27.01 | 643251 |
| Matakaro | 8 | 12.39 | 19.27 | 16.55 | 20.67 | 12.93 | 18.19 | 426351 |
| Dokobana loa | 9 | 9.49 | 20.40 | 13.58 | 24.22 | 11.77 | 20.55 | 462351 |
| Honolulu | 10 | 9.80 | 22.34 | 11.58 | 20.91 | 12.97 | 22.40 | 624531 |
| Damu | 11 | 10.84 | 26.00 | 10.70 | 23.53 | 12.20 | 16.73 | 246513 |
| Vau leka | 12 | 9.92 | 19.12 | 16.97 | 23.04 | 7.57 | 23.38 | 642315 |
| Business | 13 | 13.93 | 12.80 | 13.44 | 19.40 | 11.91 | 28.82 | 641325 |
| Loa | 14 | 6.10 | 10.94 | 17.29 | 21.02 | 11.02 | 33.64 | 643251 |
| Kabra | 15 | 8.84 | 18.04 | 14.09 | 20.27 | 15.36 | 23.41 | 642351 |
| Matakaro | 16 | 8.15 | 22.73 | 11.23 | 17.31 | 16.41 | 24.17 | 624531 |
| Loa kasa leka | 17 | 10.29 | 11.11 | 14.66 | 16.83 | 12.05 | 33.05 | 643251 |
| Matakaro balavu | 18 | 9.54 | 17.44 | 15.27 | 18.35 | 13.70 | 25.71 | 642351 |
| Vula kasa balavu | 19 | 8.92 | 17.61 | 11.50 | 28.87 | 8.75 | 24.32 | 462315 |
| Vula kasa leka | 20 | 6.82 | 11.83 | 17.91 | 26.08 | 8.20 | 29.16 | 643251 |
| Loa kasa leka | 21 | 7.43 | 11.25 | 19.38 | 20.36 | 10.96 | 31.63 | 643521 |
| Vula kasa balavu | 22 | 10.66 | 15.88 | 14.62 | 26.09 | 9.02 | 24.74 | 462315 |
| Honolulu | 23 | 10.62 | 15.32 | 11.83 | 20.91 | 12.52 | 28.79 | 642351 |
| Loa kasa balavu | 24 | 8.45 | 18.92 | 14.58 | 21.20 | 13.59 | 23.26 | 642351 |
| Matakaro balavu | 25 | 9.62 | 23.14 | 13.35 | 18.15 | 14.08 | 21.66 | 264531 |
| Gona damu | 26 | 11.43 | 19.33 | 12.59 | 19.51 | 12.67 | 24.47 | 642531 |

conducted in Vanuatu. Two different samples of the same cultivar that were gathered from different islands (see APPENDIX 1) gave very similar chemotypes. This is the case with **Loa kasa balavu** (no. 6 is from Vanua Levu, and no. 24 from Viti Levu), for **Vula kasa balavu** (no. 19 is from Taveuni, and no. 20 from Viti Levu), and for **Loa kasa leka** (no. 14 and 17 are from southern Taveuni at-sea level, and no. 21 is from northern Taveuni at 400 m. alt.).

Chemotypes from Fiji show a very high rate of methysticin (6) compared with those from Vanuatu. Results of the analysis conducted on data from TABLE 6 are presented in FIGURE 12. It is concluded that kava in Fiji is represented by five chemotypes. It is important to note that "white" cultivars (**Vula** . . .) produce chemotypes based on 462, which is also a much appreciated chemotype in Vanuatu, and "black" cultivars (**Loa** . . .) produce chemotypes based on 643. Here again it is possible to correlate the appraisal made by farmers with chemotypes. Although cultivars **Honolulu** and **Business** present similar morphotypes to cultivar 52 from Vanuatu, their chemotypes are clearly different from this cultivar.

**Matakaro** and **Matakaro balavu** are probably the same cultivar because they present similar morphotypes and chemotypes (TABLE 9).

FIGURE 12. Fiji: statistical analysis conducted on data obtained from HPLC of root samples. A, multifactorial analysis; B, dendrogram. For explanation of horizontal and vertical lines, see FIGURE 9.


A
axe 1 : 45.8%
axe 3 : 14.5%
B
12 Vau loka
9 Dakeibau lau
8 Natakaro
15 Kabra
24 Lau kasa balavu
6 Lau kasa balavu
18 Natakaro balavu
5 Dakeibau vula
4 Gona vula
16 Natakaro
25 Natakaro balavu
10 Honolulu
26 Gona dama
3 Lau kasa balavu
22 Vula kasa balavu
19 Vula kasa balavu
20 Vula kasa loka
7 Gila balavu
21 Lau kasa loka
17 Lau kasa loka
14 Lau
13 Business
23 Honolulu
2 Dama
11 Dama
1 Natakaro
17.19
12.40
9.05
7.44
6.50
2.00
0

= black (purple); **hina** = white (light green); **akau** = long internodes; **leka** = short internodes; **fulufulu** = hairy; **valu** = eight). The traditional classification system is similar to the one used in Fiji and is based on a dichotomous choice between characters, first the color and then the shape of the internode.

*Western Samoa and American Samoa:* In Western Samoa, the islands of Upolu and Savai'i were comprehensively surveyed and six accessions planted in the collection of the College of Agriculture, on the Alafua Campus of the University of the South Pacific.

Farmers stated that kava grew best in a cool and wet location on well-drained soils. The steady rains and sloping land of Fagaloa Bay are very suitable, and this is the major producing area on Upolu. Much kava is also grown on Savai'i at medium elevations, where it is also cool and moist. Because most of the Samoan soils are volcanic, with lava and tuff taking a rather long time to decompose, water retention is poor. As kava is especially sensitive to drought, planting always takes place at the beginning of the rainy season (i.e. Nov., Dec.).

**Ava lea** and **Ava la'au** are by far the two most frequently planted cultivars and are equally popular. Only five cultivars are known to farmers, three of them being extremely uncommon (**talo**, **mumu** and **sa**, cultivated on Savai'i and not Upolu (see APPENDIX 1). The local names refer to the main character (**talo**, because the rhizome becomes tuberous and very compact, like a tuber of *Colocasia esculenta*, called **talo** in Polynesian; **mumu** = red internodes). **Ava sa** is a variant of **Ava la'au** but used for ceremonies only. On Upolu it turned out that farmers were using a variant of **Ava lea** but did not give it a proper name, identifying it as **Ava lea 2**.

In American Samoa the island of Tuitula was surveyed. The word **ulu** designates the breadfruit and is used for this cultivar, which flowers quite often, producing spadices similar to the male inflorescences of *Artocarpus altilis*.

*Wallis and Futuna:* These two islands were surveyed, and only three cultivars were found to be used by growers on each island. Here again the cultivar names refer to major morphological characters (**hina** = white; **huli** = black; **leka** = short; **loa** = long; **kata** = internode). The language spoken in Wallis is of Tongan origin, dating from the colonization of this island before the European era, while the language spoken in Futuna is of Samoan origin for the same reason.

*The Cook Islands:* The Cook Islands were not visited, but a root sample was obtained from the island of Mangaia, courtesy of Mr. B. Hosking, Secretary of Agriculture.

*Tahiti and the Marquesas:* Cuzent (1856, 1857) listed the vernacular names of 14 cultivars traditionally used by the Tahitians and by the Marquesans; in 1935, Brown recorded the names of 19 cultivars still used by the Marquesans at that time. Today, cultivation of this plant is another part of the lost history of these islands.

In Tahiti, a survey of the Papenoo and Fataua Valleys located a very few isolated plants (10–20), which had probably escaped from cultivation, growing in the thick, wet forests still covering the valleys. In the Marquesas, the islands of Nuku Hiva, Ua Huka, Hiva Oa, and Fatu Hiva were surveyed. Kava is not cultivated and, as in Tahiti, a few fugitives from cultivation were found surviving in the forests of Fatu Hiva. Four accessions were planted in the Papeete Botanical Garden.

TABLE 7. RESULTS OF CHEMICAL ANALYSES CONDUCTED ON SAMPLES GATHERED IN POLYNESIA

| Cultivar | No. | DMY 1 | DHK 2 | Y 3 | K 4 | DHM 5 | M 6 | Chemotype |
|---|---|---|---|---|---|---|---|---|
| **Tonga** | | | | | | | | |
| Fulufulu | 1 | 9.56 | 28.25 | 9.82 | 20.11 | 13.93 | 18.32 | 246531 |
| Huli | 2 | 11.12 | 23.21 | 12.95 | 18.54 | 12.98 | 21.21 | 264531 |
| Akau | 3 | 7.79 | 26.31 | 10.31 | 21.03 | 13.84 | 20.71 | 246531 |
| Huli leka | 4 | 9.76 | 17.01 | 13.70 | 20.80 | 17.75 | 20.98 | 645231 |
| Valu | 5 | 7.60 | 25.23 | 11.06 | 16.60 | 17.36 | 22.15 | 265431 |
| Akau | 6 | 8.95 | 24.29 | 10.26 | 22.23 | 14.02 | 20.26 | 246531 |
| Huli | 7 | 9.04 | 24.34 | 11.61 | 16.33 | 15.00 | 23.69 | 264531 |
| Leka huli | 8 | 10.46 | 20.24 | 11.21 | 17.96 | 15.86 | 24.30 | 624531 |
| Akau huli | 9 | 6.26 | 27.70 | 10.63 | 19.24 | 12.79 | 23.38 | 264531 |
| Akau hina | 10 | 9.80 | 25.26 | 8.80 | 22.77 | 12.38 | 21.00 | 246513 |
| Fulufulu | 11 | 8.55 | 25.77 | 9.84 | 20.30 | 15.23 | 20.32 | 264531 |
| Leka hina | 12 | 8.71 | 23.73 | 8.91 | 23.08 | 15.39 | 20.18 | 264531 |
| **Western Samoa** | | | | | | | | |
| Ava la'au | 13 | 7.14 | 16.87 | 12.46 | 28.68 | 8.62 | 26.23 | 462351 |
| Ava la'au | 14 | 5.36 | 28.77 | 5.16 | 29.58 | 10.26 | 20.59 | 426513 |
| Ava la'au | 15 | 10.68 | 22.52 | 11.27 | 21.66 | 13.98 | 19.90 | 246531 |
| Ava lea | 16 | 5.73 | 29.02 | 5.03 | 26.28 | 11.54 | 22.40 | 426531 |
| Ava lea | 17 | 5.18 | 19.24 | 14.47 | 22.90 | 12.38 | 25.84 | 642531 |
| Ava sa | 18 | 17.79 | 10.11 | 16.45 | 21.11 | 7.70 | 26.84 | 641325 |
| Ava mumu | 19 | 6.70 | 15.41 | 19.81 | 24.82 | 9.10 | 24.16 | 463251 |
| Ava talo | 20 | 18.18 | 33.15 | 4.88 | 18.75 | 9.16 | 15.88 | 241653 |
| **American Samoa** | | | | | | | | |
| Ava lea | 21 | 4.60 | 21.74 | 8.36 | 39.43 | 8.74 | 17.14 | 246513 |
| Ava samoa | 22 | 7.61 | 28.30 | 8.15 | 33.76 | 5.65 | 16.54 | 426315 |
| Ava la'au | 23 | 9.45 | 26.09 | 8.21 | 23.56 | 12.18 | 20.52 | 246513 |
| Ava ulu | 24 | 8.82 | 30.28 | 11.22 | 19.02 | 14.38 | 16.27 | 246531 |
| Ava talo | 25 | 7.67 | 33.67 | 4.83 | 22.40 | 15.31 | 16.13 | 246513 |
| **Wallis** | | | | | | | | |
| Hina kata loa | 26 | 10.85 | 22.64 | 13.30 | 15.29 | 20.13 | 17.79 | 256431 |
| Huli kata loa | 27 | 8.84 | 24.39 | 12.32 | 16.93 | 22.10 | 15.41 | 254631 |
| Hina leka | 28 | 9.59 | 24.80 | 14.66 | 15.72 | 17.80 | 17.44 | 256431 |
| **Cook Islands** | | | | | | | | |
| Mangaia | 29 | 8.68 | 25.12 | 6.67 | 21.04 | 10.18 | 28.30 | 624513 |
| **Tahiti and the Marquesas** | | | | | | | | |
| Fatsua | 30 | 8.20 | 21.19 | 13.47 | 16.18 | 17.41 | 23.55 | 625431 |
| Papenoo | 31 | 12.70 | 22.51 | 9.12 | 20.74 | 13.07 | 21.86 | 264513 |
| Omoa | 32 | 9.74 | 24.45 | 12.26 | 16.51 | 18.15 | 18.90 | 265431 |
| **Hawaii** | | | | | | | | |
| Oahu 236 | 33 | 7.58 | 26.73 | 12.34 | 15.02 | 15.78 | 22.55 | 265431 |
| Oahu 237 | 34 | 6.61 | 19.15 | 15.14 | 21.55 | 14.32 | 23.23 | 642351 |
| Oahu 238 | 35 | 11.65 | 35.88 | 8.42 | 12.33 | 18.03 | 13.69 | 256143 |
| Oahu 239 | 36 | 7.04 | 26.07 | 10.14 | 16.38 | 19.89 | 20.48 | 265431 |
| Oahu 240 | 37 | 15.73 | 32.38 | 10.09 | 13.98 | 13.86 | 13.96 | 214653 |
| Oahu 241 | 38 | 13.17 | 29.11 | 9.63 | 12.32 | 18.10 | 17.66 | 256143 |
| Oahu 242 | 39 | 13.58 | 32.36 | 10.07 | 6.22 | 21.48 | 16.30 | 256134 |

5.3 POLYNESIA

*Tonga:* The islands of Tongatapu and Vava'u were surveyed and seven cultivars planted in the collection of Vainii Research Station, near Nuku'alofa. Local names used by the farmers to identify their cultivars concern the major character (**huli**

*Hawaii:* The islands of Oahu and Hawaii were surveyed and eleven accessions planted in the collection of the Harold L. Lyon Arboretum in Manoa Valley, Honolulu. No vernacular names could be recorded, since this plant, as in Tahiti, is no longer cultivated.

One of Hawaii's earliest export commodities items was **Awa** root. The industry declined after 14 years, having exported an estimated 8000 kg. (Kepler, 1983). Today, **Awa** is a relic of Hawâii's history, an attractive and very rare plant that can be found for sale as an ornamental in commercial nurseries. However, in a few steep-sided, shady valleys it is still possible to find abandoned groves (e.g. Halawa Valley on Oahu). On the island of Hawaii itself, the district of Puna was famous for its **Awa**, but very few specimens survive today.

In the Hawaiian Islands, kava shows little evidence of being indigenous but thrives and competes with the native vegetation in some localities.

The affinities observed between both local names and morphological descriptions, although the latter were not from common garden trials, suggests that some exchange of planting material has taken place between the different islands of this geographical area, Fiji, and central Polynesia, but this is not borne out by the chemical data. Statistical analysis of the data obtained from the chemical analysis of 39 root samples (Table 7) is presented in FIGURE 13 and indicates that kava comprises five main chemotypes in this area. Some of these are related to those existing in Fiji and, as in Fiji, no seeded (or cultivated) forms of *Piper wichmannii* were collected.

### 5.4 PAPUA NEW GUINEA, SOLOMON ISLANDS, AND MICRONESIA

*Papua New Guinea and Solomon Islands:* The following areas were surveyed: Daru and the mainland opposite that island, Balimo, and Isago in Western Province; Lae, Wau, Bulolo, and Bundun in Morobe Province; Karkar Island, Astrolabe Bay, Maclay Coast, and Usino in Madang Province; Manus Island, Lou Island, and Baluan Island in Manus Province. In the Solomon Islands, only the island of Guadalcanal was surveyed. Six cultivars were gathered plus three wild forms.

In Western Province, kava is widely cultivated and sold to the market in several locations. Only one cultivar is used, and plants are cultivated in raised beds under sago palm leaves (*Metroxylon sagu* Rottb.). According to the farmers, plants never survive more than two years. During the survey it was impossible to find a single lignified plant; all appeared to be very young, confirming the farmers' statements. Rhizomes produced in such conditions are rather small. In this area kava has all the attributes of an introduced plant, as the environment is unsuitable for this species (swamps with alkaline soils called halaquepts, characterized by very high exchangeable $Na^+$ levels, and mangrove vegetation with *Rhizophora* sp., *Eucalyptus* sp., *Acacia* sp., *Asplenium* sp., *Melaleuca* sp., and *Pandanus* sp.). The area has a monsoon type climate, with about 80% of the annual rainfall (2060 mm.) being recorded between December and April. Such ecological conditions are not favorable to kava cultivation, which requires rainfalls fairly evenly spread over the year.

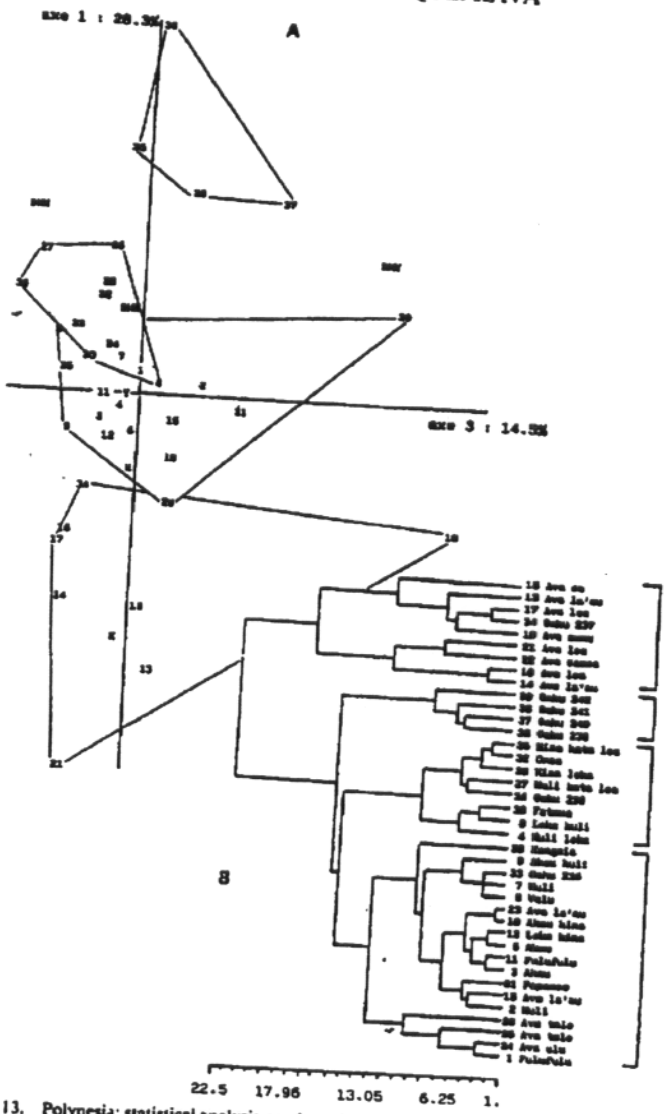



FIGURE 13. Polynesia: statistical analysis conducted on data obtained from HPLC of root samples. A, multifactorial analysis; B, dendrogram.

TABLE 8. RESULTS OF CHEMICAL ANALYSES ON SAMPLES GATHERED IN PAPUA NEW GUINEA, THE SOLOMON ISLANDS, AND POHNPEI

| Cultivar | No. | DMY 1 | DHK 2 | Y 3 | K 4 | DHM 5 | M 6 | Chemotype |
|---|---|---|---|---|---|---|---|---|
| Kau kupwe | 5 | 34.01 | 8.07 | 7.55 | 6.25 | 21.48 | 22.64 | 165234 |
| Bundun 1 | 4 | 34.41 | 8.38 | 10.90 | 6.77 | 17.35 | 22.19 | 165324 |
| Bundun 2 | 3 | 35.71 | 5.26 | 9.17 | 6.86 | 16.74 | 26.27 | 165342 |
| Borosak | 8 | 25.14 | 27.71 | 7.46 | 5.59 | 22.32 | 11.78 | 215634 |
| Ume 1 | 1 | 11.54 | 40.02 | 8.15 | 8.80 | 21.48 | 10.01 | 251643 |
| Kau pel | 6 | 6.93 | 40.36 | 6.06 | 15.01 | 19.87 | 11.76 | 254613 |
| Kau pwusi | 7 | 7.24 | 39.05 | 6.95 | 16.28 | 16.38 | 14.10 | 254613 |
| Ayou 1 | 9 | 9.55 | 42.30 | 7.51 | 11.92 | 17.29 | 11.43 | 254613 |
| Isa | 11 | 6.84 | 38.39 | 7.28 | 15.03 | 18.03 | 14.43 | 254631 |
| Waeld koniak | 12 | 7.41 | 31.79 | 2.11 | 0.99 | 30.52 | 27.19 | 256134 |
| Sipaia | 13 | 6.97 | 38.21 | 9.57 | 8.86 | 23.72 | 12.66 | 256341 |
| Iwi | 14 | 5.86 | 38.57 | 8.30 | 13.01 | 18.95 | 15.31 | 256431 |
| Ume 2 | 2 | 10.12 | 37.42 | 8.15 | 10.74 | 22.00 | 11.58 | 256413 |
| Ayou 2 | 10 | 6.39 | 42.29 | 5.33 | 10.12 | 24.81 | 11.06 | 256413 |
| Kwakwako 1 | 15 | 30.21 | 12.27 | 9.73 | 6.29 | 22.35 | 19.15 | 156234 |
| Kwakwako 2 | 16 | 29.50 | 17.74 | 8.77 | 6.47 | 18.76 | 18.75 | 156234 |
| Rahmedel | 17 | 10.92 | 21.49 | 10.26 | 29.96 | 5.47 | 21.90 | 462135 |
| Rahmwahnger | 18 | 14.97 | 25.69 | 11.16 | 16.82 | 16.22 | 15.14 | 245613 |

On the northern coast (Madang and Morobe Provinces) *Piper wichmannii* is plentiful, while *P. methysticum* is cultivated in a few isolated areas for consumption and also as a cash crop, in Sipaia Village for example, where it is grown and sold to Fijians living in Lae. In Papua New Guinea, *P. methysticum* shows all the characteristics of an introduced plant.

**Bundun**, **Kau kupwe**, **Borosak**, **Waeld koniak**, and **Kwakwako** represent *Piper wichmannii*. All are seeded forms except **Kau kupwe**, which is cultivated on Baluan Island and is always propagated by cuttings as it never sets seeds. All the plants observed on this island were male. Because the island is rather small and isolated, this sterility may be due to the absence of female plants, *P. wichmannii* being dioecious. In Karkar, Madang, and Morobe *P. wichmannii* is plentiful, and all the forms observed appeared to be morphologically close to those occurring in Vanuatu. In Guadalcanal, *P. wichmannii* is a very common species that grows wild in undisturbed habitats; plants are never found in colonies, however small, but always singly.

*Micronesia:* Pohnpei, Palau, and Guam were surveyed, but only two cultivars were gathered, both on Pohnpei. These are easy to distinguish, one having speckled and the other uniform internodes. There is no trace of kava having been cultivated in the past in Guam, and environmental factors seem unfavorable. In Palau and the other Federated States of Micronesia, kava is not cultivated.

Statistical analysis conducted on data obtained from this geographical area (TABLE 8 and FIGURE 14) clearly indicates the presence of four chemotypes, one of which occurs as both wild and cultivated forms of *Piper wichmannii*. This species was not consumed except in Baluan, where farmers stated that it was used for drinking as commonly as the other two cultivars of *P. methysticum*.

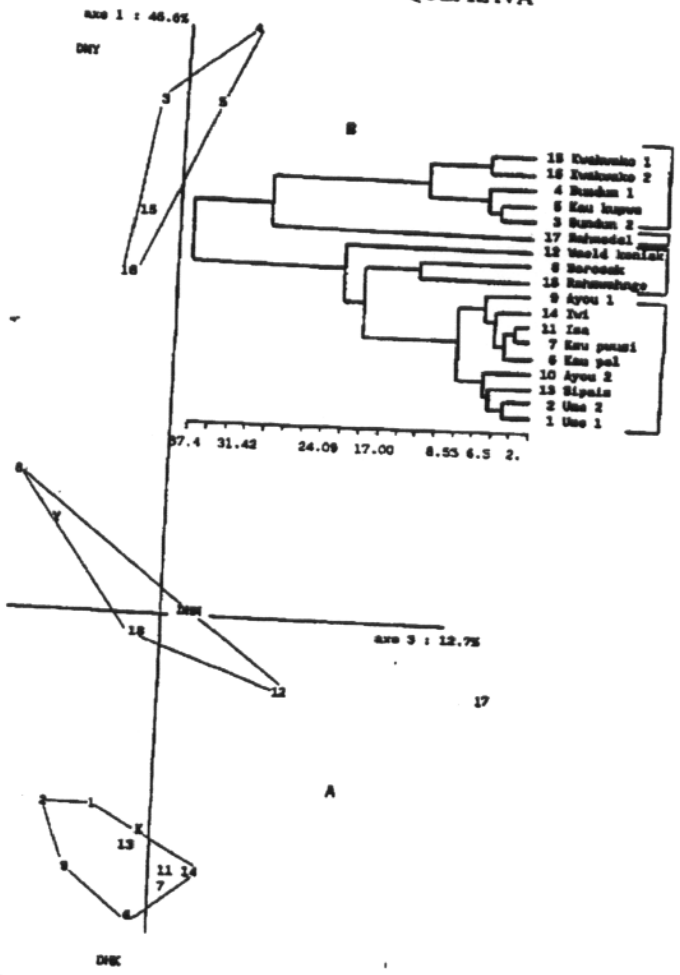



FIGURE 14. Papua New Guinea, the Solomon Islands, and Micronesia: statistical analysis conducted on data obtained from HPLC of root samples. A, multifactorial analysis; B, dendrogram.

## 6. CONCLUSIONS

A fairly thorough exploration of the geographic distribution of kava has been made in this survey. A total of 42 Pacific islands plus Papua New Guinea was visited, more than 110 cultivars described and planted in germplasm collections, and over 220 root samples analyzed.

This fieldwork, coupled with a comprehensive bibliographical review, a study of herbarium specimens, and the required chemical analysis work lead the authors to the following conclusions:

1. *Piper methysticum* Forst. f. is a species whose area of distribution is entirely restricted to the Pacific islands; it is the only cultivated plant of such economic importance for which this can be said.

2. The name kava includes two botanical species: *Piper methysticum* is the botanical name used by botanists to identify sterile cultivars of kava, while *P. wichmannii* C. DC. is the name given to identify seeded wild forms of kava, which are known to have a distribution area limited to Melanesia. These two botanical species are the only ones in the genus *Piper* from which kavalactones have been isolated.

3. Both these species are dioecious, but for *Piper methysticum* only clones are found in cultivation. Pollinations occurring in the wild between different plants of *P. wichmannii* are thought to produce very heterogeneous progeny. Variability can be observed in both morphological and chemical characters.

4. The large number of root samples analyzed has shown that kava (both *Piper wichmannii* and *P. methysticum*) takes the form of a number of different chemotypes. When various cultivars from different origins are planted in a homogeneous environment, they produce a range of chemotypes.

5. When a particular cultivar is cloned, the resultant plants show chemotypes and kavalactone content very similar to the mother plant. Results obtained from the first field experiments conducted with kava indicate that chemotype does not seem related to ontogeny or environmental factors but rather to genotype. Nevertheless, subsequent work in this area is needed.

It is beyond doubt that this species has reached its highest degree of diversification in Vanuatu. In this country, *Piper wichmannii* is seedless and cultivated, although this species does produce seeds in Papua New Guinea and the Solomon Islands. The distribution of seeded forms is important in determining the center of distribution of this asexually propagated plant. Vanuatu is very probably an area of domestication of these wild forms.

The numerous cultivars found may have arisen in a number of different ways, including:

- Variation or mutation of seeded forms.
- Hybridization of two closely related species or seeded variants of one species (intraspecific and interspecific hybrids).
- Somatic mutation with human selection of somatic mutants.
- A combination of these different ways.

The first possibility seems reasonable because of the occurrence and variability of seeded forms of *Piper wichmannii*. It is likely that seeded forms showing valuable chemotype characteristics were cloned by man in order to preserve them, since the dioecious *P. wichmannii* and *P. methysticum* both produce highly heterogeneous progeny. The variability of the existing cultivars could result from the conservation through the years by man of the progeny of ancient fertilizations, although other causes have to be considered.

If kava is a hybrid between two similar species, one being *Piper wichmannii*, then the second species is unknown.

That the various cultivars may have originated by somatic mutation is a real possibility. Such mutations do occur frequently in some horticultural plants. The creation of a new cultivar or clone by bud mutation and its dispersal can be achieved by man. It would appear that selection must have taken place, at least to the extent of preserving new cultivars as they appeared, otherwise it is difficult to account for the preservation of the variants now found. The cultivars were selected for the sole purpose of improving those characteristics that are useful to man. Most of these cultivars, moreover, do not seem to be fixed. During field surveys, farmers often stated that some of their cultivars would "change" their characters when cuttings were planted.

The diverse cultivars of kava may have arisen by a combination of all these processes, but further discussion would be sheer speculation.

None of the analytical techniques described in this study are new (Bohm, 1987), but this is the first time that *Piper* species have been analyzed in detail to determine the variation in active ingredient composition between cultivars.

Quantitative variation between the six major kavalactones is truly phenomenal. These differences were used to characterize more than a hundred cultivars. The effects of environmental factors on kavalactone production should be further studied.

For this study, we considered that an accurate analysis of variation in kavalactone content and composition needed a broad data base. Although some data were difficult to analyze owing to the collection of samples from different environments, the information collected is nevertheless valuable. We believe that even though the chemical data are interesting in their own right, the social importance of kava for Pacific communities makes it essential to correlate these data with information gained from ethnobotanical studies; it was found that this information confirmed the chemical data.

The use of numerical classification on data obtained from the chemical analysis of all the wild and cultivated forms gathered in this ecogeographical survey allowed the differentiation of ten chemotypes, all with particular characteristics (multivariate analysis is represented in FIGURE 15). These chemical data, coupled with the morphological descriptions of these forms, are presented in TABLE 9. The large number of plants studied during this survey has revealed that different chemotypes do exist in kava. In order to facilitate the discussion and analysis of future results we suggest that these chemotypes be identified by letters, which are easier to use than the codes used in this study. These results (TABLE 9) suggest that chemotype is related to genotype in the cultivars existing in the Pacific, but the chemotypes do not correspond to any patterns observed in morphological characters, which are surprisingly variable in this species.

Morphotypes of *Piper wichmannii* scattered between the Admiralty Islands, in Papua New Guinea, and the Sheperds group in Vanuatu are quite close to each other. However, their chemotypes present great variations. Forms from Baluan, Morobe, and Guadalcanal are identical, although the one from Baluan is cultivated, whereas the other two are wild. The wild form originating from Karkar

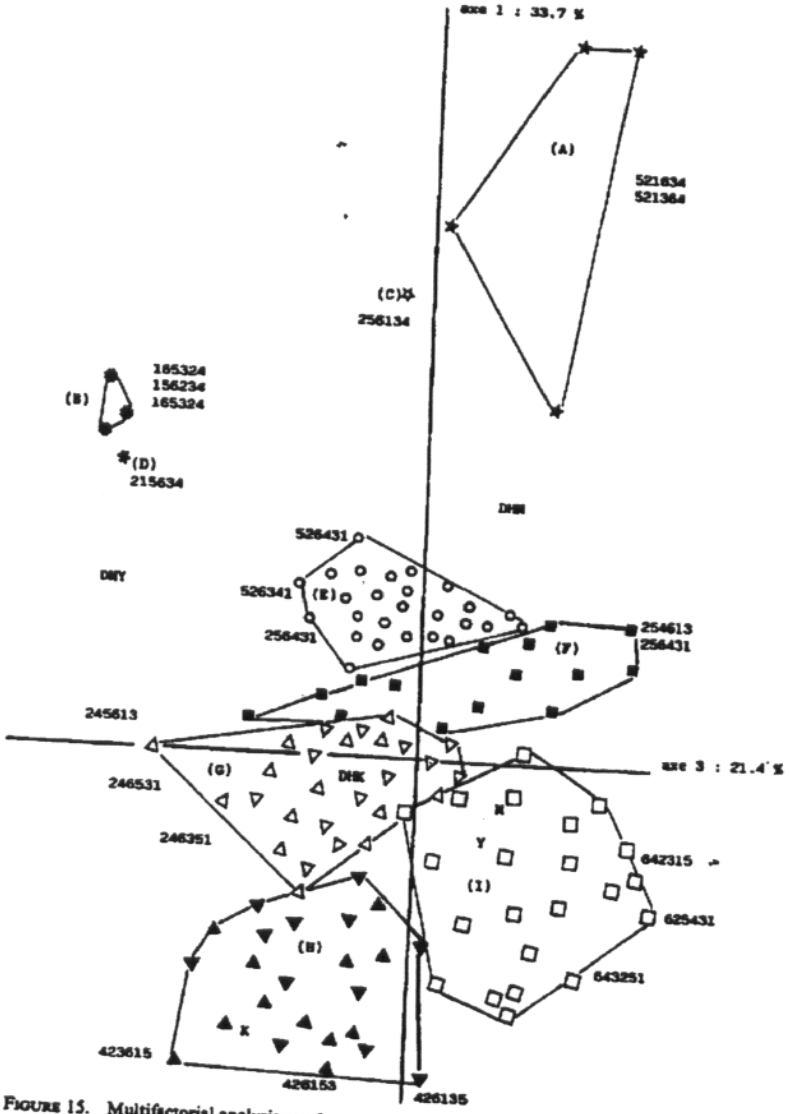



FIGURE 15. Multifactorial analysis conducted on data obtained from HPLC of root samples gathered in the Pacific. For explanation of letters, see textual discussion of chemotypes.

TABLE 9. CLASSIFICATION OF THE WILD AND CULTIVATED FORMS GATHERED IN THIS ECOGEOGRAPHICAL SURVEY, BASED ON THEIR CHEMICAL COMPOSITION (RESULTS OF CLUSTER ANALYSIS USING HIERARCHICAL AGGLOMERATIVE CLUSTERING AND EUCLIDEAN DISTANCE)

| Cultivar | Origin | Chemotype | | | | | | Morphotype | | | | | | | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | A | C | I | L | E | P | S | |
| **A** | | | | | | | | | | | | | | | |
| Vambu* | Vanua Lava | 5 | 2 | 1 | 6 | 3 | 4 | 3 | 2 | 2 | 1 | 2 | 1 | 3 | 14 |
| Buara* | Maewo | 5 | 2 | 1 | 6 | 3 | 4 | 3 | 2 | 2 | 1 | 2 | 1 | 3 | 14 |
| Bo* | Pentecost | 5 | 2 | 1 | 6 | 3 | 4 | 3 | 2 | 2 | 1 | 2 | 1 | 3 | 14 |
| Kau* | Tongoa | 5 | 2 | 1 | 3 | 6 | 4 | 3 | 2 | 2 | 1 | 2 | 1 | 3 | 14 |
| **B** | | | | | | | | | | | | | | | |
| Bundun* | Morobe | 1 | 6 | 5 | 3 | 2 | 4 | 3 | 2 | 3 | 2 | 2 | 1 | 3 | 112 |
| Kwakwako* | Guadalcanal | 1 | 5 | 6 | 2 | 3 | 4 | 3 | 2 | 3 | 2 | 2 | 1 | 3 | 112 |
| Kau Kupwe* | Baluan | 1 | 6 | 5 | 3 | 2 | 4 | 3 | 2 | 3 | 2 | 2 | 0 | 3 | 113 |
| **C** | | | | | | | | | | | | | | | |
| Waeld koniak* | Madang | 2 | 5 | 6 | 1 | 3 | 4 | (1) | | | | | | | – |
| **D** | | | | | | | | | | | | | | | |
| Borosak* | Karkar | 2 | 1 | 5 | 6 | 3 | 4 | 3 | 2 | 3 | 2 | 2 | 0 | 3 | 113 |
| **E** | | | | | | | | | | | | | | | |
| Tabal* | Pentecost | 5 | 2 | 6 | 3 | 4 | 1 | 3 | 4 | 1 | 4 | 2 | 1 | 3 | 47 |
| Tangurlava* | Maewo | 5 | 2 | 6 | 4 | 3 | 1 | 3 | 2 | 2 | 1 | 2 | 1 | 3 | 14 |
| Vila | Tanna | 2 | 5 | 6 | 4 | 3 | 1 | 3 | 1 | 2 | 4 | 1 | 1 | 2 | 42 |
| Marino | Santo | 2 | 6 | 5 | 4 | 3 | 1 | 3 | 1 | 2 | 4 | 1 | 1 | 2 | 42 |
| Palavoke | Santo | 2 | 6 | 5 | 4 | 3 | 1 | 7 | 1 | 3 | 1 | 1 | 1 | 2 | 32 |
| Hina kata loa | Wallis | 2 | 5 | 6 | 4 | 3 | 1 | 3 | 1 | 1 | 5 | 1 | 1 | 2 | 99 |
| Abogae | Pentecost | 2 | 6 | 5 | 4 | 3 | 1 | 5 | 2 | 2 | 4 | 2 | 1 | 2 | 8 |
| Lalahk | Pentecost | 2 | 6 | 5 | 4 | 3 | 1 | 5 | 2 | 2 | 2 | 2 | 1 | 2 | 25 |
| Tudey | Santo | 2 | 5 | 6 | 4 | 3 | 1 | 5 | 2 | 4 | 4 | 2 | 1 | 2 | 45 |
| Hina leka | Wallis | 2 | 5 | 6 | 4 | 3 | 1 | 7 | 1 | 1 | 5 | 1 | 1 | 1 | 94 |
| Fock | Santo | 2 | 6 | 5 | 4 | 3 | 1 | 7 | 1 | 1 | 4 | 1 | 0 | 2 | 18 |
| Oahu 242 | Oahu | 2 | 5 | 6 | 1 | 3 | 4 | 5 | 3 | 4 | 4 | 1 | 0 | 2 | 108 |
| Nimau | Tongoa | 2 | 4 | 6 | 5 | 3 | 1 | 3 | 3 | 1 | 3 | 1 | 0 | 2 | 62 |
| Akau | Tongatapu | 2 | 4 | 6 | 5 | 3 | 1 | 3 | 3 | 3 | 1 | 1 | 0 | 2 | 91 |
| Oahu 236 | Oahu | 2 | 6 | 5 | 4 | 3 | 1 | 3 | 1 | 1 | 1 | 1 | 0 | 2 | 101 |
| Apin | Tanna | 6 | 2 | 5 | 3 | 4 | 1 | 3 | 5 | 1 | 3 | 3 | 0 | 3 | 69 |
| Apeg | Anatom | 2 | 5 | 6 | 4 | 3 | 1 | 3 | 5 | 1 | 3 | 3 | 0 | 3 | 69 |
| Palisi | Santo | 2 | 6 | 5 | 4 | 3 | 1 | 5 | 1 | 2 | 4 | 2 | 0 | 2 | 26 |
| Akau huli | Tongatapu | 2 | 6 | 4 | 5 | 3 | 1 | 3 | 4 | 3 | 4 | 2 | 0 | 2 | 84 |
| Huli kata loa | Wallis | 2 | 5 | 4 | 6 | 3 | 1 | 3 | 4 | 3 | 4 | 2 | 0 | 2 | 84 |
| Oahu 241 | Oahu | 2 | 5 | 6 | 1 | 4 | 3 | 3 | 3 | 1 | 1 | 2 | 0 | 2 | 79 |
| Omoa | Fatu Hiva | 2 | 6 | 5 | 4 | 3 | 1 | 3 | 4 | 3 | 1 | 2 | 0 | 2 | 102 |
| Rahmwahnger | Pohnpei | 2 | 4 | 5 | 6 | 1 | 3 | 3 | 2 | 1 | 2 | 2 | 0 | 2 | 111 |
| Oahu 240 | Oahu | 2 | 1 | 4 | 6 | 5 | 3 | 5 | 3 | 3 | 4 | 2 | 0 | 1 | 104 |
| Oahu 238 | Oahu | 2 | 5 | 6 | 1 | 4 | 3 | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Oahu 239 | Oahu | 2 | 6 | 5 | 4 | 3 | 1 | 3 | 2 | 3 | 3 | 2 | 0 | 3 | 95 |
| **F** | | | | | | | | | | | | | | | |
| Nakasara | Emae | 2 | 6 | 5 | 4 | 3 | 1 | 5 | 1 | 1 | 2 | 1 | 0 | 2 | 21 |
| Kau pei | Baluan | 2 | 5 | 4 | 6 | 1 | 3 | 3 | 4 | 1 | 2 | 1 | 0 | 2 | 114 |
| Kau pwusi | Baluan | 2 | 5 | 4 | 6 | 1 | 3 | 5 | 5 | 1 | 1 | 1 | 0 | 2 | 115 |
| Ewo | Tongoa | 2 | 4 | 5 | 6 | 3 | 1 | 5 | 3 | 1 | 3 | 1 | 0 | 2 | 61 |
| Yevoet | Santo | 2 | 6 | 4 | 5 | 3 | 1 | 5 | 2 | 4 | 2 | 2 | 0 | 2 | 2 |
| Malogro | Santo | 2 | 5 | 6 | 4 | 3 | 1 | 3 | 1 | 2 | 4 | 2 | 0 | 2 | 44 |
| Aheyoke | Santo | 2 | 5 | 6 | 4 | 3 | 1 | 5 | 3 | 2 | 3 | 2 | 1 | 1 | 1 |
| Thyei | Santo | 2 | 5 | 6 | 4 | 3 | 1 | 7 | 2 | 4 | 4 | 2 | 0 | 1 | 43 |
| Merei | Santo | 2 | 5 | 6 | 4 | 3 | 1 | 5 | 2 | 1 | 3 | 2 | 0 | 3 | 10 |

TABLE 9 (continued)

| Cultivar | Origin | Chemotype | | | | | | Morphotype | | | | | | | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | A | C | I | L | E | P | S | |
| Malmalbo | Pentecost | 2 | 5 | 6 | 4 | 3 | 1 | 5 | 1 | 3 | 2 | 1 | 1 | 2 | 16 |
| Ume | Fly | 2 | 5 | 6 | 4 | 1 | 3 | 7 | 1 | 1 | 2 | 1 | 1 | 2 | 111 |
| Isa | Usino | 2 | 5 | 4 | 6 | 3 | 1 | 7 | 2 | 3 | 1 | 2 | 1 | 2 | 117 |
| Sipaia | Morobe | 2 | 5 | 6 | 3 | 4 | 1 | 7 | 2 | 3 | 1 | 2 | 1 | 2 | 117 |
| Iwi | Madang | 2 | 5 | 6 | 4 | 3 | 1 | 7 | 2 | 3 | 1 | 2 | 1 | 2 | 117 |
| Ayou | Karkar | 2 | 5 | 4 | 6 | 1 | 3 | 7 | 2 | 3 | 1 | 2 | 1 | 2 | 117 |
| G | | | | | | | | | | | | | | | |
| Pirimerei | Santo | 2 | 5 | 4 | 6 | 3 | 1 | 5 | 3 | 3 | 1 | 2 | 0 | 1 | 3 |
| Tau | Tongoa | 2 | 4 | 3 | 5 | 6 | 1 | 5 | 1 | 4 | 3 | 2 | 0 | 1 | 59 |
| Asyaij | Anatom | 2 | 4 | 6 | 5 | 3 | 1 | 5 | 1 | 1 | 3 | 1 | 0 | 1 | 75 |
| Woko | Santo | 2 | 6 | 4 | 5 | 3 | 1 | 3 | 1 | 2 | 2 | 2 | 0 | 2 | 46 |
| Ahouia | Tanna | 2 | 4 | 6 | 5 | 3 | 1 | 5 | 1 | 2 | 2 | 2 | 0 | 2 | 67 |
| Pualiu | Tongoa | 2 | 4 | 5 | 6 | 3 | 1 | 5 | 1 | 2 | 2 | 2 | 0 | 2 | 67 |
| Amon | Tanna | 2 | 4 | 6 | 5 | 3 | 1 | 5 | 2 | 3 | 1 | 2 | 0 | 2 | 65 |
| Iliya | Anatom | 2 | 4 | 6 | 5 | 3 | 1 | 3 | 1 | 4 | 3 | 2 | 0 | 2 | 23 |
| Aigen | Tanna | 2 | 4 | 6 | 5 | 3 | 1 | 3 | 1 | 3 | 1 | 1 | 0 | 2 | 68 |
| Ava ulu | Tutuila | 2 | 4 | 6 | 5 | 3 | 1 | 3 | 1 | 3 | 1 | 1 | 0 | 2 | 68 |
| Kiskisnian | Tanna | 2 | 4 | 6 | 5 | 1 | 3 | 7 | 1 | 4 | 3 | 1 | 0 | 2 | 72 |
| Metolei | Tongoa | 2 | 3 | 4 | 6 | 5 | 1 | 3 | 2 | 1 | 3 | 1 | 0 | 2 | 58 |
| Oleikaro | Tongoa | 2 | 4 | 6 | 5 | 3 | 1 | 5 | 4 | 4 | 1 | 1 | 0 | 2 | 60 |
| Borogu | Pentecost | 2 | 4 | 6 | 5 | 3 | 1 | 3 | 2 | 2 | 3 | 2 | 0 | 3 | 15 |
| Borogoru | Macwo | 2 | 4 | 5 | 6 | 1 | 3 | 3 | 2 | 1 | 3 | 2 | 0 | 3 | 15 |
| Poua | Malekula | 2 | 4 | 5 | 3 | 6 | 1 | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Ava talo | Savai'i | 2 | 4 | 1 | 6 | 5 | 3 | 3 | 2 | 3 | 3 | 2 | 0 | 3 | 95 |
| Ava talo | Tutuila | 2 | 4 | 6 | 5 | 1 | 3 | 3 | 2 | 3 | 3 | 2 | 0 | 3 | 95 |
| Riki | Anatom | 2 | 4 | 5 | 6 | 3 | 1 | 5 | 1 | 3 | 1 | 2 | 0 | 3 | 37 |
| Big hand | Efate | 2 | 4 | 6 | 5 | 3 | 1 | 5 | 1 | 3 | 1 | 2 | 0 | 3 | 37 |
| Puariki | Tongoa | 2 | 4 | 6 | 5 | 3 | 1 | 5 | 1 | 3 | 1 | 2 | 0 | 3 | 37 |
| Mita | Tanna | 2 | 4 | 6 | 3 | 5 | 1 | 3 | 1 | 1 | 3 | 1 | 0 | 3 | 24 |
| Bumalotu | Macwo | 2 | 4 | 5 | 6 | 3 | 1 | 5 | 1 | 3 | 2 | 1 | 1 | 2 | 16 |
| Akau hina | Vava'u | 2 | 4 | 6 | 5 | 1 | 3 | 3 | 1 | 3 | 5 | 1 | 1 | 2 | 86 |
| Leka hina | Vava'u | 2 | 6 | 4 | 5 | 3 | 1 | 3 | 1 | 3 | 5 | 1 | 1 | 2 | 85 |
| Small hand | Efate | 2 | 6 | 5 | 4 | 3 | 1 | 5 | 2 | 2 | 3 | 2 | 1 | 2 | 6 |
| Fulufulu | Tongatapu | 2 | 4 | 6 | 5 | 3 | 1 | 5 | 1 | 1 | 5 | 1 | 1 | 1 | 98 |
| H | | | | | | | | | | | | | | | |
| Olitao | Emae | 4 | 2 | 6 | 3 | 5 | 1 | 3 | 5 | 4 | 1 | 1 | 0 | 1 | 56 |
| Yag | Anatom | 2 | 4 | 6 | 5 | 3 | 1 | 5 | 1 | 2 | 1 | 1 | 0 | 1 | 81 |
| Tuan | Tanna | 2 | 4 | 6 | 5 | 3 | 1 | 5 | 1 | 4 | 3 | 1 | 0 | 2 | 40 |
| Visul | Santo | 2 | 4 | 6 | 5 | 3 | 1 | 5 | 1 | 4 | 3 | 1 | 0 | 2 | 40 |
| Palarasul | Santo | 2 | 4 | 6 | 3 | 5 | 1 | 5 | 1 | 4 | 3 | 1 | 0 | 2 | 40 |
| Leay | Tanna | 2 | 4 | 6 | 3 | 5 | 1 | 7 | 1 | 2 | 3 | 1 | 0 | 2 | 71 |
| Nidinolai | Anatom | 2 | 4 | 6 | 5 | 3 | 1 | 3 | 1 | 3 | 1 | 1 | 0 | 2 | 68 |
| Black hand | Efate | 4 | 2 | 6 | 1 | 3 | 5 | 5 | 4 | 4 | 1 | 1 | 0 | 2 | 60 |
| Kelaĭ | Epi | 2 | 4 | 6 | 5 | 3 | 1 | 5 | 3 | 4 | 1 | 1 | 0 | 2 | 17 |
| Tikiskis | Tanna | 4 | 2 | 6 | 1 | 5 | 3 | 7 | 1 | 2 | 3 | 2 | 0 | 2 | 74 |
| Pia | Tanna | 4 | 2 | 3 | 6 | 1 | 5 | 3 | 1 | 4 | 3 | 2 | 0 | 2 | 23 |
| Small leaf | Efate | 2 | 4 | 6 | 3 | 1 | 5 | 3 | 1 | 4 | 3 | 2 | 0 | 2 | 23 |
| Rongrongwul | Pentecost | 2 | 4 | 6 | 5 | 1 | 3 | 7 | 4 | 4 | 2 | 3 | 0 | 2 | 22 |
| Malamala | Tanna | 2 | 4 | 6 | 5 | 1 | 3 | 3 | 2 | 1 | 2 | 2 | 0 | 3 | 73 |
| Kar | Santo | 2 | 4 | 6 | 5 | 1 | 3 | 3 | 4 | 1 | 3 | 2 | 0 | 3 | 7 |
| Tchap | Anatom | 4 | 2 | 6 | 3 | 1 | 5 | 5 | 2 | 1 | 4 | 2 | 0 | 3 | 76 |
| Paama | Tanna | 2 | 4 | 6 | 1 | 5 | 3 | 3 | 2 | 2 | 3 | 2 | 0 | 3 | 15 |
| Miela | Emae | 4 | 2 | 6 | 3 | 5 | 1 | 3 | 3 | 4 | 1 | 1 | 0 | 3 | 63 |
| Palimet | Emae | 4 | 2 | 6 | 3 | 5 | 1 | 3 | 1 | 1 | 3 | 1 | 0 | 3 | 24 |
| Urukara | Santo | 4 | 2 | 6 | 3 | 5 | 1 | 3 | 1 | 2 | 4 | 1 | 1 | 2 | 42 |

TABLE 9 (continued)

| Cultivar | Origin | Chemotype | | | | | | Morphotype | | | | | | | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | A | C | I | L | E | P | S | |
| Ava lea | Upolu | 2 | 4 | 6 | 5 | 1 | 3 | 7 | 1 | 3 | 5 | 1 | 1 | 1 | 85 |
| Ava lea | Tutuila | 2 | 4 | 6 | 5 | 1 | 3 | 7 | 1 | 3 | 5 | 1 | 1 | 1 | 85 |
| Ava lea 2 | Upolu | 6 | 4 | 2 | 5 | 3 | 1 | 7 | 1 | 1 | 5 | 1 | 1 | 1 | 94 |
| Ava samoa | Tutuila | 4 | 2 | 6 | 3 | 1 | 5 | 7 | 1 | 1 | 5 | 1 | 1 | 1 | 94 |
| Oahu 237 | Oahu | 6 | 4 | 2 | 3 | 5 | 1 | 5 | 1 | 1 | 1 | 1 | 0 | 1 | 103 |
| Loa kasa leka | Vanua Levu | 6 | 4 | 3 | 2 | 5 | 1 | 7 | 4 | 3 | 4 | 2 | 0 | 1 | 83 |
| Loa | Taveuni | 6 | 4 | 3 | 2 | 5 | 1 | 7 | 4 | 3 | 4 | 2 | 0 | 1 | 83 |
| Kabra | Taveuni | 6 | 4 | 3 | 2 | 5 | 1 | 7 | 4 | 3 | 4 | 2 | 0 | 1 | 52 |
| Leka huli | Tongatapu | 6 | 2 | 4 | 5 | 3 | 1 | 7 | 4 | 3 | 4 | 2 | 0 | 1 | 83 |
| Dame | Taveuni | 2 | 4 | 6 | 5 | 1 | 3 | 5 | 3 | 1 | 5 | 2 | 0 | 1 | 92 |
| Matakaro | Taveuni | 6 | 2 | 4 | 5 | 3 | 1 | 3 | 3 | 3 | 1 | 1 | 0 | 2 | 91 |
| Matakaro balavu | Viti Levu | 6 | 4 | 2 | 3 | 5 | 1 | 3 | 3 | 3 | 1 | 1 | 0 | 2 | 91 |
| Honolulu | Vanua Levu | 6 | 4 | 2 | 3 | 5 | 1 | 5 | 1 | 1 | 5 | 1 | 0 | 2 | 52 |
| Business | Taveuni | 6 | 4 | 1 | 3 | 2 | 5 | 5 | 1 | 1 | 5 | 1 | 0 | 2 | 52 |
| Loa kasa balavu | Vanua Levu | 6 | 4 | 2 | 3 | 1 | 5 | 3 | 4 | 3 | 4 | 2 | 0 | 2 | 84 |
| Ava mumu | Savai'i | 4 | 6 | 3 | 2 | 5 | 1 | 3 | 4 | 3 | 4 | 2 | 0 | 2 | 84 |
| Fataua | Tahiti | 6 | 2 | 5 | 4 | 3 | 1 | 5 | 3 | 1 | 1 | 2 | 0 | 2 | 100 |
| Papenoo | Tahiti | 2 | 6 | 4 | 5 | 1 | 3 | 3 | 4 | 3 | 1 | 2 | 0 | 2 | 101 |
| Rahdmel | Pohnpei | 4 | 6 | 2 | 1 | 3 | 5 | 3 | 2 | 3 | 2 | 2 | 0 | 2 | 110 |
| Gona vula | Viti Levu | 6 | 4 | 3 | 2 | 5 | 1 | 3 | 1 | 2 | 5 | 2 | 0 | 3 | 87 |
| Dokobana vula | Vanua Levu | 6 | 4 | 2 | 3 | 5 | 1 | 3 | 1 | 2 | 5 | 2 | 0 | 3 | 87 |
| Qila balavu | Taveuni | 6 | 4 | 3 | 2 | 5 | 1 | 3 | 2 | 3 | 3 | 2 | 1 | 2 | 90 |
| Vula kasa balavu | Vanua Levu | 4 | 6 | 2 | 3 | 1 | 5 | 3 | 1 | 3 | 5 | 1 | 1 | 2 | 85 |
| Ava la'au | Upolu | 4 | 6 | 2 | 3 | 5 | 1 | 3 | 1 | 3 | 5 | 1 | 1 | 2 | 86 |
| Vula kasa leka | Vanua Levu | 6 | 4 | 3 | 2 | 5 | 1 | 7 | 1 | 3 | 5 | 1 | 1 | 2 | 85 |
| Ava sa | Savai'i | 6 | 4 | 1 | 3 | 2 | 5 | 3 | 2 | 1 | 5 | 1 | 1 | 2 | 96 |

*indicates that the form belongs to the species *Piper wichmannii*. (1) sample received from Dr. Thredgold, Unitech, Lae; plant not described.

Island presents a chemotype (215634) which is very similar to the one spread between the Banks and Sheperds groups in Vanuatu (521634). In this latter country, *P. wichmannii* presents chemotypes which are closer to those of *P. methysticum* rather than to the wild forms of *P. wichmannii* occurring in other Melanesian islands (526431 for **Tabal** and **Tangurlava**).

*Piper methysticum* is represented by only one cultivar in the northern part of New Guinea (Usino, Morobe, Madang, and Karkar), yet it is not possible to trace this cultivar elsewhere. On the other hand, the only cultivar existing in the western province (Fly River area) seems to be closely related to **Malmalbo**, a cultivar originating from Pentecost, in Vanuatu. The two cultivars of *P. methysticum* grown on Baluan (Admiralty Islands) are also closely related to cultivars originating from the Sheperds group in Vanuatu (e.g. **Nakasara** and **Ewo**).

In Polynesia, it is easier to associate cultivars, even if great distances separate them. For example, cultivar **Omoa** (locality name) collected on Fatu Hiva in the Marquesas seems to be related to **Oahu 241** from Hawaii. The same observations can be made for other cultivars: **Aigen** from the island of Tanna, southern Vanuatu, is identical to **Ava ulu** from the island of Tutuila, American Samoa. In central

Polynesia and between Fiji and Tonga, Wallis, or Samoa it is obvious that an exchange of planting material has taken place.

Chemotypes **A**, **B**, **C**, and **D** are all exclusive to Melanesia and are forms of *Piper wichmannii*; of these, **Vanubu**, **Buara**, **Bo**, **Kau**, and **Kau kupwe** are cultivated.

Chemotypes **A** and **B** have a very high proportion of DHM (38–58%) and DHK, these two kavalactones together accounting for 64–75% of the total; the proportion of K is very low (<-3%) (521634). Chemotypes **C** and **E** have a very high proportion of DMY (25–35%) and a very low proportion of K (165234 or 156234). Chemotype **D** has equivalent proportions of DHK, DHM, and M (31/30/27) and almost no K (0.99%). All are variants of *Piper wichmannii* and are typified by a very low K content. The forms encompassed by these chemotypes possess different phenotypes but are all erect.

Chemotypes **E**, **F**, **G**, **H**, and **I** all include cultivars of *Piper methysticum*.

Chemotype **E** (526431 or 526341) produces a beverage with a very pronounced physiological effect, which is thought to be due to the very high proportions of DHK and DHM. This chemotype is present in Vanuatu, Tonga, Wallis, Fatu Hiva, Oahu, and Pohnpei.

Chemotype **F** (256431 or 254613) is similar to chemotype **E** but gives a very low level of Y. This chemotype is present only in Vanuatu and Papua New Guinea.

Chemotype **G** (246531 or 264531) is known to produce a beverage suitable for daily consumption, especially in the islands where the roots are consumed fresh (Vanuatu and Wallis).

Chemotype **H** (426135 or 426315) is certainly the most palatable. This chemotype is present only in Vanuatu and Western Samoa.

Chemotype **I** (642351 or 643251) seems to be endemic to Fiji, but it is also present in Tonga, Samoa, the Cooks, Tahiti, Hawaii, and Pohnpei.

On the basis of these observations, it may be inferred that in Melanesia and in Vanuatu especially, the whole *in situ* collections of the different clones derived from the domestication process of *Piper wichmannii* are preserved. When Polynesian travellers came to collect their cultivars, they selected the most interesting clones and did not spread those with "wild characters" (e.g. 521634) to other islands of Polynesia.

Active ingredient content is very often closely related to environmental pressures (Bohm, 1987). The production of secondary metabolites in plants can often be linked to their action against herbivores. However, mammalian herbivores were introduced to the Pacific islands by man and, as has been seen, rats and pigs (as well as insects) are not repelled by kavalactones. Because the plant is always a cultivated one, the selection pressure is essentially the result of man's efforts to mold the plants' characteristics to suit him.

For kava, the most important character is the nature of the chemical composition. Farmers have selected their cultivars on this basis. A geneology of chemotypes, from the wild species, *Piper wichmannii*, to the cultivated species, *P. methysticum*, has been suggested for Vanuatu.

When farmers select a cultivated species from a wild source, selection pressure is applied to characters that are important for them. The new plant often bears little or no resemblance to the original one, because the purpose of domestication

is to adapt the features of the wild form to meet the needs of man. For kava, morphological characters are not important to the farmers. It is therefore logical that the cultivated species should have a similar phenotype to the wild species. This situation is due to the fact that selection is based on chemical characteristics appraised each time individual plants are harvested and consumed. Evolutionary changes in plants involve morphological and/or chemical changes according to where the selection pressure is applied.

This study deals with a traditional crop that is widely grown but not improved. Because the plant does not reproduce sexually, traditional genetic improvement, which requires sexual propagation, would be very difficult or impossible. Further use of the germplasm after screening is therefore limited, unless non-traditional methods of creating genetic variability (such as tissue culturing) can be developed. This is why great care has to be taken when choosing selection criteria for the existing germplasm. Completion of such a task could well contribute to our understanding of the genetic dynamics of kava distribution.

Risks of error in the handling and measuring equipment used were small, and the accuracy of the results was confirmed by the large number of samples analyzed. The appropriate size of the sample analyzed made it possible to establish the existence of chemically unique groups of plants therein, i.e. the chemotypes. The most valuable advantage of this method is the possibility of selecting traditionally grown cultivars directly from the farmer's field, according to chemotype, thus allowing selection of appropriate chemical compositions to meet the varying demands of the market. For example, an extraction laboratory might wish to obtain chemotypes with a low proportion of yangonin and methysticin, which are the less soluble kavalactones and affect the quality of the hydro-alcoholic extract. The drinking market, on the other hand, requires chemotypes with a low proportion of dihydromethysticin, which has unpleasant side effects.

This simple technique also helps to monitor *in situ* conservation of kava genetic resources through maintenance of traditional cultivation systems. Because all the cultivated forms are clones identified by their own name in vernacular languages, it is fairly easy to preserve these traditional cultivars in the field once their chemotypes have been identified.

The fact that kava is traditionally grown in the South Pacific makes it a very attractive species for further development. If strains that produce more active ingredients can be selected, then new, more lucrative markets could be opened up with potential benefit for the development of Pacific countries.

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APPENDIX 1. ORIGIN OF ROOT SAMPLES

| No.[1] | Cultivar | Ref. | Locality | Island | KL% |
|---|---|---|---|---|---|
| **Fiji** | | | | | |
| 164 | Matakaro | 1 | Koronivia | Viti Levu | 10.11 |
| 165 | Damu | 2 | Koronivia | Viti Levu | 14.60 |
| 166 | Loa kasa balavu | 3 | Koronivia | Viti Levu | 12.55 |
| 167 | Qila leka | | Waïnigata | Vanua Levu | 14.46 |
| 168 | Gona vula | 4 | Waïnigata | Vanua Levu | 9.18 |
| 169 | Dokobana vula | 5 | Waïnigata | Vanua Levu | 12.02 |
| 170 | Loa kasa balavu | 6 | Waïnigata | Vanua Levu | 11.76 |
| 171 | Qila balavu | 7 | Waïnigata | Vanua Levu | 13.33 |
| 172 | Matakaro | 8 | Waïnigata | Vanua Levu | 9.97 |
| 173 | Dokobana loa | 9 | Waïnigata | Vanua Levu | 13.91 |
| 174 | Honolulu | 10 | Waïnigata | Vanua Levu | 16.81 |
| 175 | Damu | 11 | Waïnigata | Vanua Levu | 13.36 |
| 176 | Vau leka | 12 | Delaïnua | Taveuni | 10.28 |
| 177 | Business | 13 | Delaïnua | Taveuni | 11.21 |
| 178 | Loa | 14 | Delaïnua | Taveuni | 8.70 |
| 179 | Kabra | 15 | Delaïnua | Taveuni | 12.30 |
| 180 | Matakaro | 16 | Delaïnua | Taveuni | 14.90 |
| 181 | Loa kasa leka | 17 | Qali | Taveuni | 9.10 |
| 182 | Matakaro balavu | 18 | Qali | Taveuni | 8.10 |
| 183 | Vula kasa balavu | 19 | Qali | Taveuni | 14.12 |
| 184 | Vula kasa leka | 20 | Qali | Taveuni | 15.30 |
| 185 | Loa kasa leka | 21 | Qali | Taveuni | 11.00 |
| 186 | Vula kasa balavu | 22 | Lami | Viti Levu | 13.15 |
| 187 | Honolulu | 23 | Lami | Viti Levu | 14.25 |
| 188 | Loa kasa balavu | 24 | Lami | Viti Levu | 12.70 |
| 189 | Matakaro balavu | 25 | Lami | Viti Levu | 9.40 |
| 190 | Gona damu | 26 | Qali | Taveuni | 17.30 |
| **Tonga** | | | | | |
| 205 | Fulufulu | 1 | Vaïnii | Tongatapu | 17.00 |
| 206 | Huli | 2 | Vaïnii | Tongatapu | 13.24 |
| 207 | Akau | 3 | Sanft farm | Tongatapu | 12.95 |
| 208 | Huli leka | 4 | Sanft farm | Tongatapu | 12.40 |
| 209 | Valu | 5 | Sanft farm | Tongatapu | 15.78 |
| 210 | Akau | 6 | Fifita farm | Tongatapu | 18.03 |
| 211 | Huli | 7 | Fifita farm | Tongatapu | 17.90 |
| 212 | Leka huli | 8 | Longamapu | Vava'u | 18.12 |
| 213 | Akau huli | 9 | Longamapu | Vava'u | 17.90 |
| 214 | Akau hina | 10 | Longamapu | Vava'u | 18.12 |
| 215 | Akau fulufulu | 11 | Longamapu | Vava'u | 12.37 |
| 216 | Leka hina | 12 | Longamapu | Vava'u | 11.34 |
| **Samoa** | | | | | |
| 192 | Ava la'au | 13 | Fagaloa | Upolu | 9.90 |
| 193 | Ava lea | 16 | Fagaloa | Upolu | 11.50 |
| 194 | Ava la'au | 14 | Fagaloa | Upolu | 9.50 |
| 195 | Ava lea | 17 | Tapatapao | Upolu | 20.60 |
| 196 | Ava la'au | 15 | Tapatapao | Upolu | 21.70 |
| 197 | Ava sa | 18 | Asau | Savai'i | 13.90 |
| 198 | Ava mumu | 19 | Neiafu | Savai'i | 16.06 |
| 199 | Ava talo | 20 | Neiafu | Savai'i | 17.30 |
| 200 | Ava lea | 21 | Pago Pago | Tutuila | 19.70 |
| 201 | Ava samoa | 22 | Aolau | Tutuila | 13.40 |
| 202 | Ava la'au | 23 | Fagali | Tutuila | 11.45 |
| 203 | Ava ulu | 24 | Afono | Tutuila | 11.53 |
| 204 | Ava talo | 25 | Afono | Tutuila | 5.60 |

APPENDIX I (continued)

| No.[1] | Cultivar | Ref. | Locality | Island | KL% |
|---|---|---|---|---|---|
| **Wallis** | | | | | |
| 217 | Hina kata loa | 26 | Wallis | Wallis & Futuna | 16.45 |
| 218 | Huli kata loa | 27 | Wallis | Wallis & Futuna | 15.56 |
| 219 | Hina leka | 28 | Wallis | Wallis & Futuna | 17.89 |
| **Cook Islands** | | | | | |
| 246 | Mangaia | 29 | Mangaia | Mangaia | 9.48 |
| **Tahiti and the Marquesas** | | | | | |
| 231 | Fataua | 30 | Fataua | Tahiti | 11.13 |
| 233 | Papenoo | 31 | Papenoo | Tahiti | 9.92 |
| 235 | Omoa | 32 | Omoa | Fatu Hiva | 18.05 |
| **Hawaii** | | | | | |
| 236 | Oahu 236 | 33 | Lyon Arb. | Oahu | 25.31 |
| 237 | Oahu 237 | 34 | Lyon Arb. | Oahu | 21.84 |
| 238 | Oahu 238 | 35 | Lyon Arb. | Oahu | 23.48 |
| 239 | Oahu 239 | 36 | Lyon Arb. | Oahu | 20.11 |
| 240 | Oahu 240 | 37 | Lau's house | Oahu | 5.88 |
| 241 | Oahu 241 | 38 | Lau's house | Oahu | 14.48 |
| 242 | Oahu 242 | 39 | Lau's house | Oahu | 9.10 |
| **Papua New Guinea, Solomons, and Pohnpei** | | | | | |
| 247 | Ume 1 | 1 | Daru area | Western Prov. | 20.61 |
| 248 | Ume 2 | 2 | Daru area | Western Prov. | 9.48 |
| 249 | Bundun 1 | 3 | Bundun | Morobe Prov. | 16.54 |
| 250 | Bundun 2 | 4 | Bundun | Morobe Prov. | 8.15 |
| 251 | Kau kupwe | 5 | Baluan | Manus | 11.46 |
| 252 | Kau pel | 6 | Baluan | Manus | 9.75 |
| 253 | Kau pwusi | 7 | Baluan | Manus | 9.13 |
| 255 | Borosak | 8 | Karkar | Madang Prov. | 6.54 |
| 256 | Ayou 1 | 9 | Karkar | Madang Prov. | 13.80 |
| 257 | Ayou 2 | 10 | Karkar | Madang Prov. | 17.43 |
| 258 | Isa | 11 | Usino | Madang Prov. | 9.97 |
| 320 | Waeld koniak | 12 | Lae | Morobe Prov. | 8.39 |
| 321 | Sipaia | 13 | Sipaia | Morobe Prov. | 22.60 |
| 322 | Iwi | 14 | Madang | Madang Prov. | 29.62 |
| 259 | Kwakwako 1 | 15 | Honiara | Guadalcanal | 6.54 |
| 260 | Kwakwako 2 | 16 | Honiara | Guadalcanal | 7.65 |
| 243 | Rahmedel | 17 | Kolonia | Pohnpei | 9.10 |
| 244 | Rahwahnger | 18 | Kolonia | Pohnpei | 14.65 |

[1]No. column refers to cultivar identification numbers.

## INDEX

Synonyms are printed in *italics*; an asterisk indicates a figure. Names occurring in abstract, tables, and illustration legends are not indexed.