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Cover photos: Noni growing in pahoehoe lava field; noni fruits in a processing shed (photos by Scot Nelson).

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Proceedings of the 2002 Hawai‘i Noni Conference

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Diversity of Growth Forms and Uses in the *Morinda citrifolia* L. Complex

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Abstract

Increases in demand for fruit of *Morinda citrifolia* in recent years have led to commercial farming of the trees. Typically as a crop makes the transition from wild-harvested to commercial orchard, there is a concurrent effort to select more desirable varieties and to improve the crop. In order to make these selections and improve the crop, researchers must know about the diversity found within the species and its close relatives. The recognized varietal diversity as well as yet unrecognized (by science) diversity in leaf shape within *M. citrifolia* is discussed. Recommendations for future research are then presented based upon a set of preliminary observations and hypotheses.

Key words: noni; *Morinda citrifolia*; diversity; Pacific crops; traditional medicine

Over the past twenty years, great interest has developed in one of the most important medicinal plants of ancient Pacific Island cultures, *Morinda citrifolia* L. (Dixon et al. 1999, Whistler 1991) commonly known as kura or noni. Much of the commercial interest that has carried the plant into products outside of the Pacific Islands has been fueled by a single publication by Ralph M. Heinicke (Heinicke 1985) and his subsequent efforts to popularize noni. Noni fruit products have become quite popular for a wide range of indications including treatment of cancer, which has encouraged laboratory and clinical research into possible efficacy. Recent reviews of the history of the scientific analysis of noni and its popularization (Dixon et al. 1999, McClatchey 2002) have revealed that there is probably much exaggeration in the claims being made for noni products and that these claims are not always consistent with traditional patterns of usage among Pacific Islanders. Furthermore, little effort has been made to test hypotheses of effectiveness of the actual traditional remedies, with the research instead being conducted on apparently recently developed remedies.

Healers whom I have interviewed in Western Pacific communities in Fiji, Rotuma and the Solomon Islands, often recognize diversity in both the uses and the physical morphology of *M. citrifolia* growing in their areas. Three commonly described “kinds” or “varieties” of *M. citrifolia* from the Western Pacific are: 1) trees with smaller elliptic leaves, having many small fruit arranged at nodes along the branches, and thin stems/branches whose bark and roots are used for dyes, 2) trees with long, strap-like leaves, having larger, lightly scented to non-scented fruit, thicker stems and shorter branches that are used for many indications treated by professional healers, and 3) shorter bushy trees with large elliptic to round leaves and large, strong smelling fruit that may be used medicinally, particularly for topical home remedies.

At least two possible hypotheses can be derived from the healers’ knowledge of the plants. The first hypothesis is that there is only one species of *M. citrifolia* and that it contains distinct genetic populations that can be recognized at the varietal level. Presumably these populations do not interbreed very often and therefore are maintained as relatively distinct units. These populations could be distinguished based upon both morphological and chemical differences. Thus, H_1 = More than one variety of *M. citrifolia* exists in the Western Pacific region.

The second possibility is that the current circumscription of the species, *M. citrifolia* is inclusive of two or more separate species that do not usually interbreed. If this is the case, then there is reason to believe that the different species would have differing medicinal values for people as well as differing rates of growth, disease resistance, fruit production, etc.

Thus, H_2 = More than one species of *Morinda* exists in the Western Pacific region within the plants that are scientifically circumscribed as *M. citrifolia.*

Alternatively, the healers may be recognizing variation between individuals that is not based upon transmittable genetic changes but is rather based upon localized responses to substrate variation or cultural preferences for plants growing in specific locations. If this is the case, then the variation represents intra-specific, non-varietal differences at the level of individuals and not populations. Thus the null hypothesis, H_0 = Only one species of *M. citrifolia* exists with limited variation that cannot accurately be described as more than one variety.

We therefore are left with a basic question: Is there more than one kind of noni? If the answer to this question is yes, then are the fruit that are being used in preparation of commercial products from the same variety or even the same species? If not, then what exactly is being sold?

The balance of this paper is an exploration of the variation that is currently recognized, first in the genus *Morinda* and then within the species *M. citrifolia*. Although compelling evidence exists for there being more than one morphological variety or species within the widely distributed, *M. citrifolia* var. *citrifolia*, no evidence is presented here to support the case for more than one chemical species. This distinction is very important, particularly for those in the herbal products industry seeking an edge over their competitors or simply desiring to grow and market the best product possible. In the conclusion, more questions will be asked than answered, however it is hoped that this paper will serve as a call for more research and provide a bit of direction for such efforts.

Intra-generic variation

The genus *Morinda* is pantropical in its distribution with about 80 species (Smith 1988). In the Indo-Pacific region, species diversity is highest in Near Oceania with attenuation into Remote Oceania. The genus *Morinda* includes trees, shrubs, and vines. In the Western Pacific region, vines are most common while the few trees, including *M. citrifolia* typically have "vine-like" characteristics to their branches and stems. Morphological features that unite the species into one genus include syncarps or capitula (aggregated fruits) forming from ovaries and parts of conate caylces, and tricolporate pollen grains with sexine usually finely reticulate (Johansson 1994). The syncarps may be fleshy, as with *M. citrifolia* or may be dry as with many other species. Each syncarp is probably derived from condensation of umbels of separate flowers with further condensation within some species of *Morinda* to form a range of flower/fruit configurations. Figure 1 illustrates probable relationships among species with varying degrees of condensation of the reproductive branching structures. Morphological characteristics that are variable between species include: leaf size, shape, and detail; umbel aggregation position and flower pedicel length; and odor, size, and shape of fruit (see Figures 1 and 2).

Johansson (1994) conducted a cladistic analysis of the *Morinda* species found in New Caledonia. When the natural distributions of the species used in his study are added to his resulting phylogeny (Figure 3), it appears that the fleshy fruited species in the study, including *M. citrifolia* appear to be most closely related to species restricted to Australia and Borneo. This may mean that *M. citrifolia* evolved in Australia, Borneo or intermediate Indonesia and New Guinea and subsequently was distributed by ocean current (Guppy 1917) or by birds, bats, or people to other parts of the Indian and Pacific Oceans (Figure 4).

One of the distinctive adaptations or niches of *M. citrifolia* seems to be its ability to colonize new islands and new terrain. It is frequently identified as a part of primary forests or shrub vegetation on small atolls, new lava flows, and other newly emergent surfaces near the ocean. The trees are not uncommon in both dry and wet coastal forests and are often early succession members of more complex tropical Pacific rain forests. Species of *Morinda* with vine habits are more commonly found within lowland forests and less so in the coastal strand. In some cases, these are very high climbing lianas that spread out in the canopy of rainforests. The genetic relationships between the species of *Morinda* are yet to be explored, but it is likely that a pattern will emerge that is similar to that seen with other oceanic species: a few widely distributed, floating or bird dispersed species, that have given rise to multiple endemic species within different island archipelagos.

No studies of the pollination biology of *Morinda* have been reported, but it seems likely that the plants are able to self-pollinate as part of their adaptation for colonizing new terrain. This therefore leads to a third possible hypothesis about the diversity of *M. citrifolia* reported by traditional healers. *M. citrifolia* plants may be largely self-pollinating and therefore represent long lineages of individuals each accumulating mutational changes over time as they move from island to island and are selected for a wide range of environments. Thus H_3 = The survival strategy of *M. citrifolia* trees includes self pollination so variation within the species represents individual variation rather than varietal or specific differences.

Figure 1. Probable relationships among species with varying degrees of condensation of the reproductive branching structures. A. Probable ancestral state with all axes elongated. B. State with reduced floral pedicels resulting in a compound fruit. C. State with reduced peduncle resulting compound fruit in a leaf axil. D. State with vestigial leaves resulting in cauliflorous fruit.

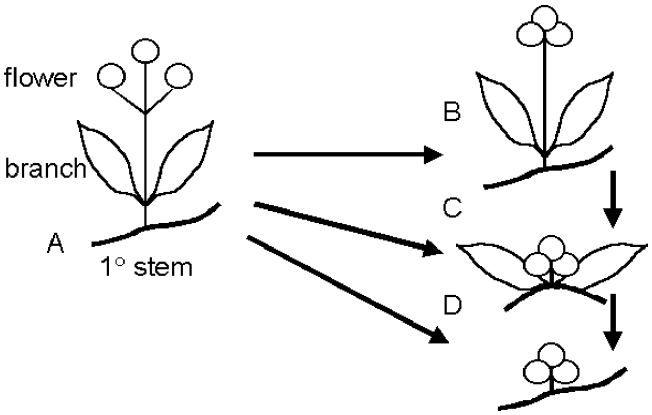


Figure 2. Variation in leaf size, shape, and detail among species of *Morinda*. A. needle-like, B. small myrtle-like, C. prominently veined, D. ovoid, E. elliptical

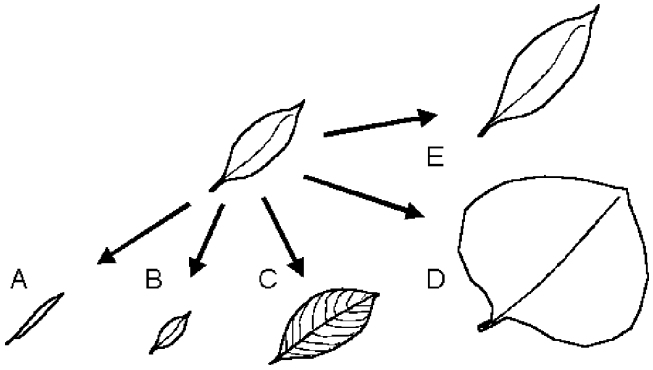


Figure 3. Phylogeny of the *Morinda* species found in New Caledonia (after Johansson 1994) with added distributional data. *M. citrifolia* is nested within a branch of species found in Australia and New Guinea even though *M. citrifolia* is widespread.

Intra-specific variation

In addition to the wide spread variety or kind of *M. citrifolia*, two unusual varieties are recognized by scientists. The first, *M. citrifolia* var. *bracteata* is found in Indonesia and other parts of the margin between the Indian and Pacific Oceans. Because of the assignment of the first variety, there is an implied typical variety, *M. citrifolia* var. *citrifolia*. The third, *M. citrifolia* cultivar 'Potteri', is distributed as an ornamental in the Pacific Islands. Each of these is discussed later. The typical variety of *M. citrifolia* is currently recognized by botanists (Smith 1988) as being a morphologically diverse species with no clear sub-populations bearing unique characteristics.

Traditional healers and other members of Pacific Island cultures distinguish different kinds of *M. citrifolia*

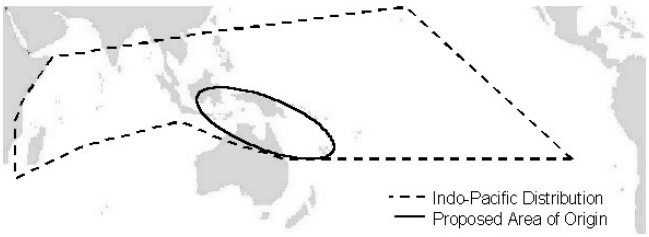
based upon two primary characteristics: leaf size/shape and fruit odor. The latter is likely to relate to fruit chemistry/pharmacology. Other characteristics that are secondarily used include wood strength and root/bark dye color properties. In one case, roots of one kind of *M. citrifolia* were reportedly selected for their usage as a toxin for killing fish. Without visiting each population of plants and communities of people, it is difficult to evaluate these kinds of variation. However, one kind of variation, leaf size/shape, can be readily observed from dried voucher specimens collected over the years by botanical explorers and placed around the world in herbaria.

One of the more extensive collections of samples of the species of *Morinda* is located in the collections of the Bernice P. Bishop Museum, Herbarium in Honolulu, Hawai'i. Measurements of leaf size/shape were conducted by the author with the simple objective of tentatively testing the first hypothesis. My goal was to see if there was any pattern of variation across the range of specimens available and if this might imply that there could be distinct populations of *M. citrifolia* either on different or the same islands. 256 herbarium specimens were observed from collections made on Pacific Islands. A simplified measure was used to classify the leaves of each specimen into one of three categories based upon the cultural observations described above: 1) leaves elliptic, 2) leaves long and strap-like, and 3) leaves ovate or rounded. Elliptic leaves were those that were more than twice as long as wide but less than four times as long as wide. Strap-like leaves were those that were more than four times as long as wide. Ovate or rounded leaves were those that were less than twice as long as wide (and in many cases about as long as wide). No leaves were observed in the herbarium having strap-like characteristics, however I have observed such leaves in Samoa and Rotuma. Distribution of elliptic and ovate leaves from the collections is shown in Table 1. Those with elliptic leaves are found throughout the Pacific, however there is a much smaller distribution of those with ovate leaves. The fact that leaves do seem to vary implies that the healers and other traditional observers of plants, are indeed recognizing a phenomenon that scientists can also see. This is the first step in the research process. The next step is described later under conclusions.

Variation in *Morinda* species found in Hawai'i

The diversity of *Morinda* in Hawai'i is limited to one endemic species of tree that grows in dry forests, *M. trimera* Hillebr., and three cultivated varieties of *M. citrifolia* that may or may not be distinct varieties or species, *M. citrifolia* var. *citrifolia*, var. *bracteata* and

Figure 4. Distribution of *M. citrifolia* with its probable area of origin.



cultivar 'Potteri' (Figure 5). The phylogenetic affiliations of *M. trimera* are unknown, but Wagner et al. (1990) speculate that it is related to species of the South Pacific or Malesia rather than to the species of Central and South America. If its closest relative proves to be *M. citrifolia*, it would either bring into question the age of the species (*M. trimera*) or the time of arrival of *M. citrifolia* in Hawai'i (currently assumed to be a Polynesian introduction of only 2000 years ago).

Variation within *M. citrifolia* variety *citrifolia* in Hawai'i is much more limited than elsewhere in the South and Western Pacific based upon observations of the Bishop Museum collections. Although it is found throughout the archipelago and in as extreme of a variety of habitats as anywhere else, the morphological diversity seems to be largely restricted to individuals with ovate or rounded leaves. Variety *bracteata* is represented by a few trees growing in the University of Hawai'i, Lyon Arboretum. These were grown from seeds brought from Indonesia within the last 30 years. Cultivar 'Potteri' is a variegated variety introduced to Hawai'i by Otto Degener in 1949 from Fiji (Smith 1988). Specimens of the original tree are represented in the Bishop Museum collections under *Degener & Ordonez 13663*. The variety has been dispersed, initially from plants grown in Foster Botanical Garden and subsequently through other means. It is now noted on most of the major islands.

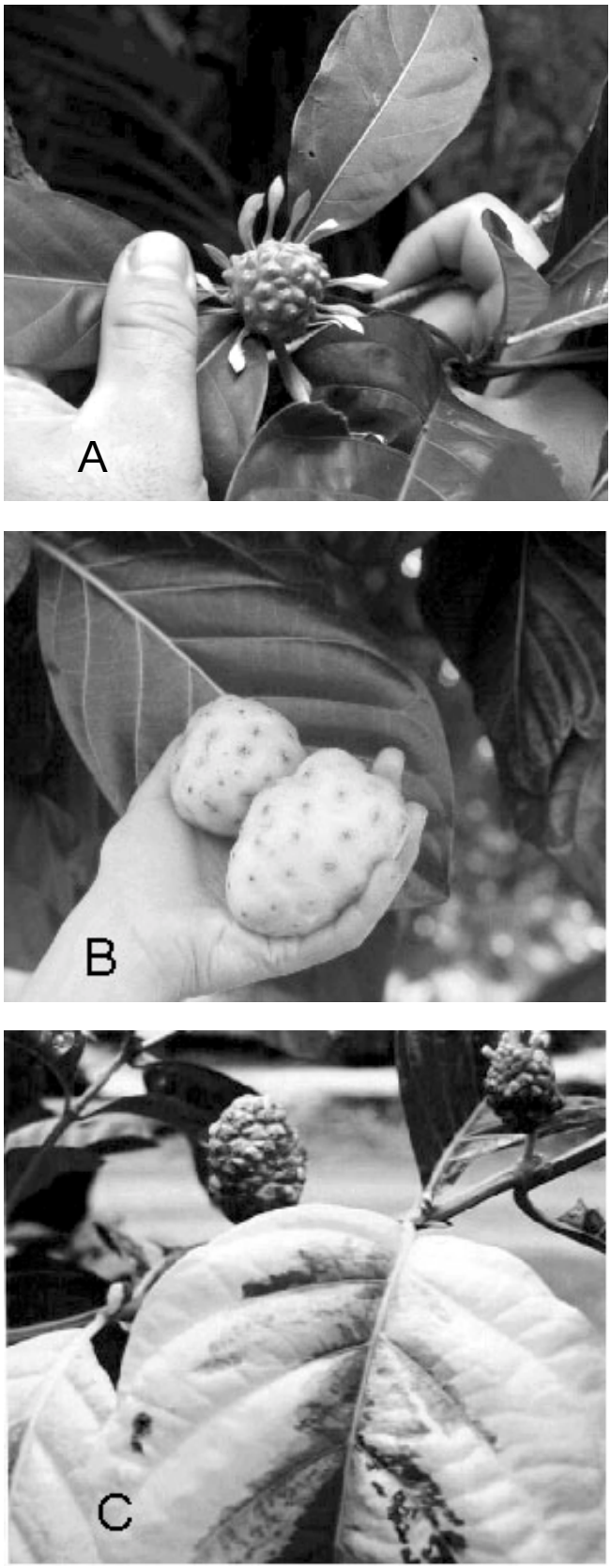
Value of knowing diversity

Crops that become of any importance to society involve selection or improvement. Selections are made based upon a set of desirable characteristics. Selections are possible because of genetic diversity within species including adaptations to deal with specific kinds of stresses such as diseases, drought, salt, etc. Initial clues about the presence of adaptational diversity are found in differences in morphology and productivity on different substrates. Table 2 illustrates possible kinds of crop improvement that could be conducted with *M. citrifolia*

Table 1. Elliptic and ovate leaves of *M. citrifolia* from the collections of the B. P. Bishop Museum, Herbarium, Honolulu, Hawai'i. E = elliptic, O = ovoid, E/O = roughly equal numbers of elliptic and ovoid specimens, E/O = predominantly elliptic, O/E = predominantly ovoid.

Archipelago	Leaf types
Eastern Polynesia	
Hawai'i:	O
Line Islands	O
Marquesas	E/O
Society Islands	E/O
Austral	O
Tuamotu	O/E
Pitcairn	E
Cook Islands	O/E
Melanesia	
Fiji	E/O
Vanuatu	E
New Caledonia	E/O
Solomon Islands	E/O
New Guinea	E
Western Polynesia	
Samoa	O/E
Niue	E
'uvea/Futuna	E/O
Rotuma	E/O
Tuvalu	E/O
Tonga	E/O
Micronesia	
Marshall Islands	E
Pohnpei	E/O
Chuuk	E
Guam	O
Northern Marianas	O
Palau	E

Figure 5. *Morinda citrifolia* previously described varieties: A = var. *bracteata*, B = var. *citrifolia*, C = cultivar 'Potteri'.



through study of its adaptational diversity. One of the most exciting possibilities of such work would be the identification of seedless varieties of trees that could be propagated via cuttings.

Understanding and using the diversity of the species throughout its range may also help to prevent common kinds of disasters. Most plants have natural pests that can devastate genetically uniform plantations. Exploration of the diversity of the species is likely to uncover a range of potential pests as well as pest resistant varieties. Knowing about pests BEFORE they attack could save the industry. Based upon observations of leaf diversity, the few farms that are growing *M. citrifolia* in Hawai'i are likely planted with very closely related trees.

Table 3. Recommended research on *M. citrifolia* variation throughout its distribution.

- Collection of genetic, morphological, and chemical diversity.
- Test hypotheses 1–3 (see text) through specific studies.
- Collection of ethnobotanical information about its usefulness.
- Conduct ethnopharmacological studies addressing original cultural hypotheses rather than modern assumptions.

Table 2. Possible kinds of crop improvement that could be conducted with *M. citrifolia* through study of its adaptational diversity.

- Further drought resistance
- Pest resistance
- Increased fruit production
- Dwarf trees
- Trees with greater fruit to leaf ratios
- Faster growing trees
- Trees with less breakage during harvest or storms
- Increased levels of desirable compounds
- SEEDLESSNESS!

Plantations with more diverse genetic structures would be more resistant to pests and reduce risks associated with other farming threats.

Conclusions

We know very little about the diversity of *M. citrifolia*. However, traditional knowledge and some basic observations of sample diversity in an herbarium lead to the conclusion that there is significant diversity within the species. This diversity needs to be examined for a number of reasons that all relate to increasing the stability of the market through improved products and product reliability. Table 3 illustrates the kinds of research that are recommended in order to improve our understanding of *M. citrifolia*.

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