CRC REVIVALS

CRC Handbook of Nuts

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INTRODUCTION*

Appropriately, one might commence a Handbook of Nuts with a definition of nut. But, if you'll pardon the jargon, that's a "tough nut to crack." To drive home my definition, I'll here recount an anecdote. For several years I was peripherally embroiled in a controversy over that definition. Various people interested in the jojoba (*Simmondsia chinensis*) would call or write, hoping my definition would support their contention that the jojoba was or was not a nut.

Finally, lawyers from the Internal Revenue Service (IRS) called and asked me to send my definition, in writing! I quote my cautious letter to the IRS:

> I understand that the IRS has special treatment for certain farmers raising fruits and nuts.
>
> I quote definitions from my favorite glossary, B. D. Jackson's *A Glossary of Botanic Terms*, 4th ed., Hafner Publishing Company, New York, 1928, reprinted 1953:
>
> *Nut*: a hard indehiscent one-seeded fruit.
>
> *Fruit*: (1) Strictly, the pericarp and its seeds, the fertilized and developed ovary.
>
> I think the jojoba "beans" would qualify just as well as the pecan as both a nut and a fruit, botanically speaking. There are popular concepts of the fruit as fleshy and/or wet, the nut as nonfleshy and/or dry. Relatively speaking, the jojoba is as dry as a pecan and popularly considered a nut. But botanically, a nut is just one kind of fruit. Hence, I conclude the jojoba bean is both a nut and a fruit from a botanical point of view.

Ironically, IRS definitions may make or break a nut species. Vietmeyer[329] shows how an IRS ruling in 1969 withdrew a number of nut species, especially almond, from its list of speculative agricultural investments. "Pistachios, however, remained an allowable tax write-off. Suddenly alone it became a hot investment." Vietmeyer calls this the unexpected source for the real advance into commercialization; e.g., Getty Oil, Superior Oil, and Tenneco West then invested in pistachios. By 1984 we had some 20,000 hectares pistachios and pushed Turkey out of the number 2 production spot. In 1985, Vietmeyer went even farther with his NRC report on jojoba,[233] perhaps giving the jojoba more momentum. Tax advantages to the jojoba may hinge on whether or not it is defined as a nut. Who knows? Perhaps the future of the jojoba as a new crop may hinge on its definition.

In 1985, I received a hasty call from an official of the Jojoba Grower's Association, distressed by the IRS interpretation of my letter quoted previously. The official enticed me to agree that, in common, if not botanical parlance, the words fruit and nut implied edibility.

Here I quote the letter drafted (but never typed) to that official. Following conversations with other jojoba fans in the government, I feared the last half of the letter might jeopardize the future of the jojoba as a "new crop". So few "new crops" break through the economic catch 22 here in the U.S.! The farmer won't grow it until industry provides a guaranteed market, and industry won't generate a market until there's a guaranteed source (the farmer).

> Enclosed is a copy of my letter of July 5, 1983 to the IRS re jojoba. When asked by legal types how to define something, I like to quote published definitions, rather than inventing my own. Trained as a taxonomist, I resorted to Jackson's glossary.[147] Horticulturists might resort to other sources.
>
> It is true that the popular concepts of fruits and nuts with most people may imply edibility. Few, if any, modern Americans eat jojoba "nuts." I would have to agree with you, Dr. M. Faust, of USDA, and J. Janick, of Purdue University, that, if edibility is a prerequisite part of the definition of fruit or nut, jojoba is best not considered a nut.

* Expanded from talks presented at the Agricultural Marketing Workshop for the Caribbean Basin, Miami, Florida, September 24-27, 1984; and New Orleans, Louisiana, September 16-20, 1985.

I realize that paragraph two is what you wanted to hear. Hence, I separate it from the following paragraph which, being something you may not wish to hear, can be extricated from the rest of my letter.

Two books which I procured in preparing a draft *Handbook of Nuts* are Rosengarten's *The Book of Edible Nuts* (Walker and Company, New York, 1984),[283] and Menninger's *Edible Nuts of the World* (Horticultural Books, Inc., Stuart, Florida, 1977).[209] Menninger, who defines nut as "any hardshelled fruit or seed of which the kernel is eaten by mankind", treats the jojoba as an edible nut, noting the Indian consumption and the vulgar names "goat nut" and "deer nut." Rosengarten employs the word "nut" "in the broad and popular sense, covering a wide variety of fruits or seeds, some of which would not be classified as nuts according to strict botanical definition." He groups jojoba among "Thirty Other Edible Nuts", adding as common names "sheep nut" and "pignut". He says "Its fruits and leaves are devoured with avidity by goats, sheep, and deer. Indians of the desert Southwest gathered jojoba nuts and ate them, raw or roasted; their flavor is reminisent of the hazelnut, but more bitter . . . Today the use of jojoba nuts for human consumption is mainly of historic interest." This paragraph of my letter reinforces my reluctance to disqualify jojoba, even in the popular concept "nut." I have tasted them raw, and find them about as unappealing as most acorns I have tried.

Those seeking to exclude jojoba from the staid society of nuts might say that jojoba, an American species, is, with good reason, excluded from Woodruff's *Tree Nuts* (2 vols., AVI Publishing Company, Westport, Connecticut, 1967[341] and Jaynes *Handbook of North American Nut Trees* (NNGA, Knoxville, Tennessee, 1969).[148] My superficial examination of these revealed no definition of nut.

For the record, I did send the following letter and poem that encapsulated my seedy feelings.

Thanks for your letter of April 25, re the jojoba.

While not fully understanding the tax implication of the Jackson (botanical) interpretation of the word "nut" and "fruit", I surely agree with you that in common, rather than botanical parlance, the words fruit and nut imply edibility. Hence, the common parlance for an orchard of nuts would be a cultivated grove of trees or shrubs for their edible nuts. I don't frankly believe that jojoba falls into that common concept.

Hence, the botanical definition of nut is at variance with the popular definition of nut. I think jojoba is a fruit and/or nut according to Jackson's technical definition, but not according to common parlance.

Not a Nut?
(The incredible inedible nut!!!)

The Jojoba Growers' Association
Wishes, to my consternation,
That I'd retract a note,
That long ago I wrote
For IRS edification.

I sent Jackson's definition
To the IRS Commission
I resorted to quote, but,
Jojoba's both fruit and nut,
Which promotes the Growers' dissension.

I find it perfectly credible
To define a "nut" as an edible,
But even that caveat
Won't change the fact that
Its edible uses are negligible.

Poets sometimes get in a rut,
Nonpoetic lines, dry and cut.
No amount of stink
Will lead me to think
The jojoba nut's not a nut.

My interpretation of the facts is
Jojoba's not good for the gut,
And when you tally your taxes,
The jojoba nut's not a nut.

Anonpoet
April 29, 1985

I have included in this book many species which are not true nuts. Unlike a one-seeded peanut, a peanut with two or three seeds in the indehiscent pod is disqualified because it has more than one seed. But I excluded many nuts treated in my *Handbook of Legumes of World Economic Importance.*[83] There are many seeds in the Brazil nut pod, which rules them out (as one-seeded fruits). Similarly, there are many "nuts" in the colas, included in this book, and many "beans" in the cacao pod of the same family. Cacao is no further from the definition of nut than is cola. Cacao will be considered in the volume on Money Crops. As a matter of fact, nearly half the species in this book are *not* nuts in the narrowest sense: "one-seeded indehiscent fruits, the kernels of which are edible."

In 1984, I addressed the Agricultural Marketing Workshop (Miami) on subtropical and tropical nuts. The feedback I got from that first meeting suggested that I may have overdosed the audience with suggestions of nuts that might be grown in the tropics. There are hundreds of species that can be called nuts, by any of several possible definitions. And due to the overall higher species diversity in the tropics, there is a concomitant higher number of nut species available for consideration in the tropical environments with which we were concerned.

During that same year, CRC Press published Martin's *Handbook of Tropical Food Crops*[203] just before I attended the Miami conference that presaged the New Orleans conference of the Agricultural Marketing Workshop. Carl Campbell's[60] excellent chapter on Fruits and Nuts gave a good overview of the cultivation of fruits and nuts, and included short treatises on the cashew, pili nut, brazil nut, breadfruit, coconut, oil palm, and lychee (really a fruit). In a summary table, he listed a few others, the monkey pot (*Lecythis elliptica*), the paradise nut (*Lecythis zabucajo*), the jackfruit (*Artocarpus heterophylla*), the salak (*Salacca edulis*), the peach palm (*Bactris gasipaes*), the macadamia (*Macadamia integrifolia*), and the jujube (*Ziziphus mauritiana*). Certain virtues were suggested for nut trees:

- Dietary diversity
- High oil content
- Luxury long-distance commercial markets
- Important to subsistence farmers
- Everbearing
- Low maintenance
- Intercropping potential
- Wood as byproduct
- Land stabilization

Following my presentations, CRC advised me that they would publish this *Handbook of Nuts.* It was designed to contain information summaries on about 100 nut species, in the same format as my Plenum *Handbook of Legumes of World Economic Importance* (Plenum Press[83]) with succinct paragraphs on Uses, Folk Medicine, Chemistry, Description, Germplasm, Distribution, Ecology, Cultivation, Harvesting, Yields and Economics, Energy, Biotic Factors.

The following recommendations seem germaine to potential nut producers.

1. Understand the crop and its requirements — take the principles of production and do good, replicated, semi-commercial research to adapt the crop to your own situations.
2. Select growing areas where good production of a crop can be concentrated — secure large quantities of nuts to make an impact on the export market.
3. Develop or choose the best varieties and disease-free planting stocks.
4. Concentrate on producing high quality produce to ensure repeat sales.
5. Time production so that it will not overlap competitor production, if any.
6. Practice insect, disease, and pest control — consider quarantine and import regulations for the crop.
7. Develop attractive and protective packaging that is distinctive and makes your product recognizable.
8. Do not plant a tree until you've tentatively contracted a market. Many advanced technological studies concern temperate nuts and oil seeds.

Chemical Business (CB) ran an article on Oleochemicals (Research Sparks Oleochemical Hopes).[320] Oleochemicals are defined as the industrial products based on animal fats and vegetable oils, a $1.2 billion segment of the U.S. chemical industry (cf. nut imports worth ca. $300 million, 200 in brazil nuts, 50 in cashews).

Unlike nuts, oleochemicals find their way into:

1. The personal care product market (20%)
2. Industrial lubricants and related products (14%)
3. Coatings (10%)
4. Detergent intermediates (10%)
5. Plastics, alkyds, urethanes, cellophane, cleaners, detergents (18%)
6. Textiles, emulsion, polymerization, rubber, asphalt, mining, miscellaneous

In this handbook I treat both kinds of nuts, (1) the familiar nuts that we eat and (2) a few oleochemical or chemurgic nuts. Some of the chemurgic nuts of the tropics are tung and its relatives, purging nut, marking nut, jojoba, and some even more obscure species. I suspect more technological advances are emerging with oil palms than with edible nuts.

Lauric acid is now obtained mainly from coconut oil and secondarily from palm kernel oil. Finding an alternative source of lauric acid has sparked much industry interest. Henkel Corporation is betting on palm kernel oil in the short run, "in about 5 years, lauric acid from palm kernel oil will add about 75% to current supplies."[320] We use about 2 billion pounds of oleochemicals, which include fatty acids, surfactants, and other esters, amines, natural glycerins, natural alkanoamides, and primary amides and bisamides, at only $0.60 per pound = 1% of U.S. Chemical Revenues.

Exciting new technologies are being explored in the search for alternative sources of lauric acid. In the continental U.S., the technologies are directed more to temperate annuals than to tropical perennials, but potential is probably greater among tropical perennials which need not contend with winter. Some of the technologies *do* relate to tropical nuts. The kernel of the oil palm is a nut. Britain's Unilever, and others, are propagating high-yielding oil palms and these are showing up in palm plantations. Such palms can produce more than ten times as much oil as the temperate soybean. Elsewhere I have speculated that 2 billion ha oilpalm yielding 25 barrels oil/ha could, with transesterification, support the world's requirements for 50 billion barrels oil.[320]

Meanwhile, back in the temperate zone, Calgene[320] is looking at *Cuphea*, an oilseed with low yields and other agronomic problems, but a crop which produces lauric acid, a short-chain fatty acid. "Most oilseeds, including rapeseed, make long chain fatty acids (C-18 and up) . . . but . . . because the plants do not 'know how' to stop molecule chain growth, no midchain fatty acids, such as lauric acid, are produced by the plants . . . Some oilseed species such as cuphea do know how . . . Calgene scientists plan to isolate the gene or genes responsible and transfer them to rapeseed. Calgene has already overcome difficulties in introducing foreign genes into rapeseed and making the transformed rapeseed plants grow . . . Calgene researchers may be able to modify plants to produce whatever fatty acid is desired."[320] They "expect to have a series of genes cloned and to be able to 'mix-and-match' genes in a low-cost production plant to produce custom-designed plants that produce specialty oils." One potential of this research is the possibility of finding plant sources that can compete with petroleum feedstocks. Some *Cuphea* species synthesize the C-8 and C-10 fatty acids that could potentially replace petroleum based C-7 and C-9 fatty acids.

An Ohio subsidiary of Lubrizol has developed a high-oleic acid sunflower with 80% oleic acid, up from the traditional 40%. They put in a 20,000 hectare crop of high-oleic acid sunflowers. Perhaps those interested in tropical nuts should look more to the pataua, *Jessenia bataua*, a tropical perennial producing perhaps 3 to 6 MT of oil with 80% oleic acid according to some authors. This oil has been favorably compared with olive oil, at a much lower price.[32]

So much for the annual cupheas, brassicas, and sunflower, the latter treated as a nut by both Menninger[209] and Rosengarten.[283] None of the biotechnologies mentioned are unique to annuals; they can apply just as well to perennials. But it is easier to keep an annual proprietary. Perennials, once given to the world, can usually be clonally reproduced ad infinitum. Hence, I speculate that the world at large, especially the tropical world, would fare better if the new technologies were developed for perennial species, while the seed salesmen and gene-grabbers might fare better with annuals.

Whether annual or perennial, plant sources of oleochemicals, or proteins, or pesticides, or drugs, always seem to suffer from one valid criticism. As Tokay (1985) notes, " . . . the use of natural raw materials that are often inconsistent in composition from batch to batch causes processing headaches. In addition, most fractionation processes produce many by-products and co-products, which are often difficult to sell."[320] Contrastingly, we read in *Science*, September 13, 1985, "Whole plant utilization—extracting medicines, leaf proteins, vitamins, polyphenols, essential oils, and chemurgics, and using the residues for alcohol production for energy—could move us from the petrochemical to the phytochemical era, with the possible fringe benefits of slowing the 'greenhouse effect' and making us more self-sufficient."[88]

Balandrin and Klocke[28] indicate that much evidence shows that natural product research is still potentially less expensive and more fruitful (in terms of new prototype compounds discovered) than are large chemical synthesis programs.

New technologies for better extraction of main products and co-products and by-products are rapidly coming on line. Work goes on with the transesterification of palm oil, which could effectively fuel the diesel needs of the world. In "A Green World Instead of the Greenhouse",[87] one finds scores (yields in barrels oil equivalent per hectare) for several energy plants.

Babassu 5-60	Peachpalm 35—105
Cassava 6,11,15—45	Peanut 4,5,13
Castor 13	Purging nut 18
Coconut 11,25	Rape 4,5
Cottonseed 1	Sesame 8

Date palm 10—20	Soybean 2,2,6
Eucalypt 76	Sugarcane 13,15
Melaleuca 76	Sunflower 4,6
Nypa 30—90	Sweet potato 30—90
Oilpalm 24—58	Tung 17

Coconut is just one of the hundreds of palms which can be termed a nut. Oil-palms are also considered nuts, even by Menninger,[209] if their seeds are edible. Botanically, many familiar palms might better be classified as drupes, but their energetic potential is noteworthy. In his survey of "Amazonian Oil Palms of Promise", Balick[29] notes that most oil palms have a high yield and produce one or both of the basic types of oil (kernel and pulp). These two types usually differ chemically. More importantly, "Most of the palms would seem to be well adapted to underused agricultural lands in tropical areas, where climate or other factors preclude the cultivation of the more common oleaginous plants."[29]

The palms on people's minds today include, besides the conventional coconut and oil palm, both sources of lauric acid, the babassu and the pataua. And then there's another tree, the inche, not even a palm, attracting the attention of the oil-palm people.

The jojoba, with which I opened my talk in 1984, is not even an oilseed, but a "waxseed". Since it is so important to my introduction, I have left it in this CRC Handbook of Nuts.

Menninger, in his *Edible Nuts of the World*[209] after noting that "A thousand kinds of nuts in this world are hunted and eaten by hungry people" defines nut as "any hard shelled fruit or seed of which the kernel is eaten by man-kind." He purports to exclude those nuts that never see the interior of the human stomach in his chapter, "Not Nuts."

Rosengarten, in *The Book of Edible Nuts*,[283] is more cautious, like me, mostly quoting other definitions. Then he selects twelve important edible nuts and discusses their relation to the various definitions. That discussion bears repeating:

> Few botanical terms are used more loosely than the word 'nut'. Technically, according to Funk & Wagnalls Standard Encyclopedic College Dictionary (1968), a nut is '1. A dry fruit consisting of a kernel or seed enclosed in a woody shell; the kernel of such fruit, especially when edible, as of the peanut, walnut, or chestnut; *Bot.* A hard, indehiscent, one-seeded pericarp generally resulting from a compound ovary, as the chestnut or acorn.' (Indehiscent means that the seedcase does not split open spontaneously when ripe.) The nut has also been described as a one-celled, one-seeded, dry fruit with a hard pericarp (shell); and, more simply, as the type of fruit that consists of one edible, hard seed covered with a dry, woody shell that does not split open at maturity. Only a fraction of so-called nuts—for example, chestnuts, filberts, and acorns—answer this description. The peanut is not really a nut; it is a legume or pod, like the split pea, lentil, or bean—but an indehiscent one because the pod does not split open upon maturing. The shelled peanut is a seed or bean. The edible seeds of almonds, walnuts, pecans, pistachios, hickory nuts, and macadamia nuts are enclosed in the hard stones of a drupe—like the stones of peaches, cherries, or plums. A drupe is a soft, fleshy fruit with a spongy or fibrous husk, which may or may not split free from the inner hard-shelled stone containing the seed. In plums and peaches, we eat the fleshy parts and throw away the stones; but the fleshy part of the walnut, for example, is removed and discarded, while the kernel of the stone—the nut —is eaten. The shell of a drupe nut, like the walnut, corresponds to the hard, outer layer of the peach stone. The coconut is the seed of a fibrous drupe. The Brazil nut is a seed with a hard seed coat, as is the pinon nut. Another dry, indehiscent fruit type is the achene—a small, thin shell containing one seed, attached to the outer layer at one point only—as in the dandelion and buttercup. The sunflower seed is an achene. A true nut resembles an achene, but it develops from more than one carpel (female reproductive structure), is usually larger and has a harder, woody wall; e.g., the difference between the filbert nut and the sunflower achene.[283]

In 1983/84, the U.S. imported nuts worth \$305 million per year, with \$216 million in brazil nuts, and \$55 million in cashews, cf. \$233 with \$159 and \$46, respectively, in 1982/83[119] (Table 1).

Table 1
DATA ON AN IMPORTANT DOZEN NUTS

	U.S. production 1980 (1,000 tons)[a]	Import costs annual 1983—84 (million $)[b]	Per cap. consumption (shelled) 1960—1979 (lbs)[a]	Price per pound ($)[a]	Oil percentage (APB) (%)[a]
Almonds	260		0.45	1.75	54.2
Brazil nuts		216		1.65	66.9
Cashew		55		2.15	45.7
Chestnut				1.65	1.5
Coconut			0.50	.65	35.3
Filbert	15		0.08	1.40	62.4
Macadamia	15		0.033	5.50	71.6
Peanut			7.1	.65	47.5
Pecan	92		0.30	2.75	71.2
Pistachio	14			3.30	53.7
Sunflower				.55	47.3
Walnut (Persian)	197		0.50	2.00	64.0

[a] Rosengarten.[283]
[b] Gyawa.[119]

In 1980, the U.S. produced on an in-shell basis, ca.260,000 tons almonds, 197,000 tons walnuts, 92,000 tons pecans, 15,000 tons filberts, 15,000 tons macadamia, and 14 tons pistachios, for a total approximating 600,000 MT nuts production. Of these, it might be noted that only 92,000 (the pecans) were from a native American species.

Here we see a parallel with the other major groups of crops; North America has not contributed much to America's foodbasket. "Of all the horticultural products given by our continent to civilization, none are of more importance than the pecan, nor destined to play a more vital role in our pomological future." Moreover, a great slave, Antoine, of the Oak Valley Plantation, in Louisiana, is accredited with our most important contribution to the nut basket. "The slave Antoine had thus laid the foundation upon which was to be erected a great industry . . . "[341]

Mostly maturing in fall, the temperate zone nuts are extremely rich in calories. Rosengarten notes that one pound of nut kernels (assuming 3,000 calories of fuel value per pound) is equivalent in energy value to about 2.4 lbs breads, 3.2 lbs steak, 8 lbs potato, or 10.4 lbs apple.[283] Oils of the temperate zone are higher in unsaturated fatty acids in general, than oils from the tropics like the palm oils, brazil nut, cashew, etc. It is rather well known that the unsaturated fats are more healthy than the saturated. It is not so well known that you could clone a pecan, grow it in a cold and a hot locale, and have a higher unsaturated profile at the colder locale. In other words, the oils from the tropics will, in general, be less healthy than those from the temperate zone. Perhaps we should raise our edible oils in the temperate zone and our fuel oils in the tropics. But save the pilis, cashews, and brazil nuts for the palates they please so well.

Rosengarten adds that "Most nuts are an excellent source of calcium, phosphorus, iron, potassium, and the B vitamins."[283] This is true on an as-purchased basis, because nuts contain so little water. On a zero-moisture basis (Table 2), the nuts do not seem particularly outstanding with these nutrients. Some of the more familiar nuts are compared in Table 3.

Table 2
AVERAGES OF PROXIMATE ANALYSIS (OF CONVENTIONAL FOODS)

Per 100 g

FOOD		(No.)	H_2O (g)	Cal (g)	Prot (g)	Fat (g)	Total carb (g)	Fiber (g)	Ash (g)	Ca (mg)	P (mg)	Fe (mg)	Na (mg)	K (mg)	B-Car (µg)	Thia (mg)	Rib (mg)	Nia (mg)	Vit ((mg
Aerial	(APB)	(5)	92.4	25	1.4	.2	5.4	.9	.6	31	31	.6	4	224	271	.08	.09	.8	4[illegible]
veg.	(ZMB)		0	331	18.5	2.6	71.4	11.9	7.9	410	410	7.9	53	2,963	3,585	1.06	1.19	10.6	55[illegible]
Tame	(APB)	(5)	90.5	27	2.7	.4	5.0	1.0	1.5	106	46	2.4	89	440	3,568	.08	.16	.5	5[illegible]
greens	(ZMB)			289	28.4	4.0	54.7	10.5	15.8	1,116	484	25.3	937	4,633	37,571	.84	1.68	4.7	60[illegible]
Shoots	(APB)	(5)	89.9	31	3.5	.5	5.2	.6	.9	31	59	1.1	4	345	1,166	.15	.19	1.0	4
	(ZMB)		0	307	34.6	5.0	51.5	5.9	8.9	307	584	10.9	40	3,416	11,543	1.48	1.88	9.9	40[illegible]
Wild	(APB)	(5)	88	35	2.8	.5	6.5	1.3	2.1	186	57	2.7	40	382	5,652	.11	.24	.9	6[illegible]
greens	(ZMB)			292	23.7	4.5	54.0	11.2	17.5	1,553	475	22.2	337	3,183	47,433	.9	2.0	7.5	56[illegible]
Fruits	(APB)	(10)	84.9	54	.8	.4	13.4	1.1	.5	19	17	.6	1	178	280	.04	.04	.4	2[illegible]
	(ZMB)		0	361	5.2	2.6	88.7	7.3	3.3	128	117	4.0	8	1,181	1,854	.28	.28	2.7	15[illegible]
Subter.	(APB)	(5)	84.1	55	2.3	.2	12.5	.9	1.0	28	68	.9	31	337	1,328	.08	.05	.4	1[illegible]
veg.	(ZMB)		0	346	14.5	1.0	78.6	5.7	6.0	176	428	5.5	194	2,119	8,352	.50	.31	2.5	8[illegible]
Roots	(APB)	(10)	79.7	74	1.8	.3	17.3	1.0	.9	32	54	1.0	14	399	568	.09	.05	.8	1[illegible]
	(ZMB)		0	365	8.9	1.5	85.2	4.9	4.4	158	266	4.9	69	1,966	2,798	.44	.25	3.9	8[illegible]
Cereals	(APB)	(10)	11.1	342	11.0	2.3	74.0	2.6	1.6	35	305	3.4	4	339	0	.45	.20	3.8	[illegible]
	(ZMB)		0	385	12.4	2.6	83.2	2.9	1.8	39	343	3.8	4	381	0	.51	.22	4.3	[illegible]
Pulses	(APB)	(10)	10.3	372	24.4	8.0	54.0	4.5	3.3	106	395	6.5	17	1,056	34	.66	.22	3.8	[illegible]
	(ZMB)		0	415	27.2	8.9	60.2	5.0	3.7	118	440	7.2	19	1,177	37	.73	.25	4.2	[illegible]
Nuts	(APB)	(10)	4.2	639	14.4	62.3	16.6	1.7	2.5	86	461	4.1	4	592	55	.65	.24	1.8	Trac
	(ZMB)		0	667	15.0	65.0	17.3	1.8	2.6	90	481	4.3	4	618	57	.68	.25	1.9	Trac
Overall	(APB)	(75)	63.5	165	6.5	7.5	21.0	1.6	1.5	66	149	2.3	21	429	1,292	.24	.15	1.4	2[illegible]
average	(ZMB)		0	376	18.8	9.8	64.4	6.7	7.2	410	403	9.6	166	2,164	11,323	.74	.83	5.2	24[illegible]

From Duke, J. A. and Atchley, A. A., *Proximate Analysis Tables of Higher Plants*, CRC Press, Boca Raton, 1986.

Table 3
PROXIMATE ANALYSES OF TEN IMPORTANT NUTS
(per 100g)

Nuts

Food item	H_2O (g)	Cal	Prot (g)	Fat (g)	Total carb (g)	Fiber (g)	Ash (g)	Ca (mg)	P (mg)	Fe (mg)	Na (mg)	K (mg)	β-Car (μg)	Thia (mg)	Rib (mg)	Nia (mg)	Vit C (mg)
mond	4.7	598	18.6	54.2	19.5	2.6	3.0	234	504	4.7	4	773	0	.24	.92	3.5	Tr
azil nut	4.6	654	14.3	66.9	10.9	3.1	3.3	186	693	3.4	1	715	Tr	.96	.12	1.6	—
shew	5.2	561	17.2	45.7	29.3	1.4	2.6	38	373	3.8	15	464	60	.43	.25	1.8	—
ckory	3.3	673	13.2	68.7	12.8	1.9	2.0	Tr	360	2.4	—	—	—	—	—	—	—
acadamia	3.0	691	7.8	71.6	15.9	2.5	1.7	48	161	2.0	—	264	0	.34	.11	1.3	0
can	3.4	687	9.2	71.2	14.6	2.3	1.6	73	289	2.4	Tr	603	78	.86	.13	.9	2
linut	6.3	669	11.4	71.1	8.4	2.7	2.8	140	554	3.4	3	489	24	.88	.09	.5	Tr
non	3.1	635	13.0	60.5	20.5	1.1	2.9	12	604	5.2	—	—	18	1.28	.23	4.5	Tr
stachio	5.3	594	19.3	53.7	19.0	1.9	2.7	131	500	7.3	—	972	138	.67	—	1.4	0
alnut	3.1	628	20.5	59.3	14.8	1.7	2.3	Tr	570	6.0	3	460	180	.22	.11	.7	—
v. (APB)	4.2	639	14.4	62.3	16.6	1.7	2.5	86	461	4.1	4	592	55	.65	.24	1.8	Tr
v. (ZMB)	0	667	15.0	65.0	17.3	1.8	2.6	90	481	4.3	4	618	57	.68	.25	1.9	Tr

te: APB, Average on an "as-purchased basis"; ZMB, Average on a zero-moisture basis; tr, Trace.

om Duke, J. A., *CRC Handbook of Medicinal Herbs,* CRC Press, Boca Raton, Fla., 1985.

THE EDITOR

Born in Birmingham, Alabama in 1929, James A. (''Jim'') Duke is a Phi Beta Kappa graduate of the University of North Carolina, where he took his AB (1952) and MS (1955) in Botany. Following a 2 1/2 year tour of military duty at Fort Dietrick, Maryland, Duke took his PhD in Botany in 1961 at the University of North Carolina. Then he undertook postdoctoral activities at Washington University and the Missouri Botanical Garden in St. Louis, Missouri, where he began studies of neotropical ethnobotany, his overriding interest to this day. From 1963 to 1965, Duke served with the USDA at Beltsville, Maryland, devoting much of his time to neotropical ecology, especially seedling ecology. In 1965, he joined Battelle Columbus Laboratories, for ecological and ethnological studies in Panama and Colombia to determine the ethnological feasibility of a Sea Level Canal. He spent long weeks in the forests with the various ethnic groups there, learning which plants they used as food, fiber, fuel, and medicine. Duke counts these years in Panama and Colombia as the most interesting in his career. He rejoined the USDA in 1971 for crop diversification and medicinal plant studies in developing countries. He has taped dozens of TV and radio shows on various aspects of economic botany. He is a popular lecturer on the subjects of ethnobotany, herbs, medicinal plants, and new crops, and their ecology. He grows dozens of interesting plants on his six acre farmette (Herbal Vineyard) with his wife and illustrator, Peggy. Fluent in Spanish, Duke has studied and/or lectured in Argentina, Belize, Bolivia, Brazil, Burma, Chile, China, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, England, France, Guatemala, Honduras, India, Iran, Italy, Jamaica, Korea, Laos, Mexico, Panama, Peru, Puerto Rico, Singapore, Syria, Thailand, and Vietnam. Considered a key figure in the ''Herbal Renaissance'', Duke received the Cutty Sark Science Award in 1981. Currently, he is with the Germplasm Introduction and Evaluation Laboratory, USDA, Beltsville, Maryland, working on an encyclopedia of economic plants.

Dr. Duke is an active member in the American Herb Association (Life), American Society of Pharmacognosy, Association for Tropical Biology, Council for Agricultural Science and Technology (Cornerstone Life), Friends of the National Arboretum, Herb Research Foundation, International Association of Plant Taxonomists (Life), International Platform Association, International Society for Tropical Ecology, International Society for Tropical Root Crops (Life), International Weed Science Society (Life), Organization for Tropical Studies (Life), Oriental Healing Arts Society, Programa Interciencia de Recursos Biologicos (Advisory Council), Sigma Xi (Life), Society for Economic Botany (Life), Southern Appalachian Botanical Club (Life), Tri-State Bluegrass Association (Life), and Weed Science Society of America.

Having published several scientific papers and book chapters, Duke is sole or senior author of several books, including *Isthmian Ethnobotanical Dictionary*, Harrod and Company, Baltimore, 1972 (being reissued with illustrations by Scientific Publishers, Jodphur, India, 1986); *Handbook of Legumes of World Economic Importance*, Plenum Press, New York, 1981 (Japanese translation, 1986); *Medicinal Plants of the Bible*, Trado-Medic Books, Buffalo, New York, 1983; with E. S. Ayensu, *Medicinal Plants of China*, 2 volumes, Reference Publications, Algonac, Michigan, 1985; *Culinary Herbs: A Potpourri*, Trado-Medic Books, Buffalo, New York, 1985; *CRC Handbook of Medicinal Herbs*, CRC Press, Boca Raton, Florida, 1986; *Handbook of Northeastern Amerindian Medicinal Plants*, Quarterman Press, Lincoln, Massachusetts, 1986; with A. A. Atchley, *CRC Handbook of Proximate Analysis Tables of Higher Plants*, CRC Press, Boca Raton, Florida, 1986; and with A. A. Atchley, K. T. Ackerson, and P. K. Duke, *CRC Handbook of Agricultural Energy Potential of Developing Countries*, CRC Press, Boca Raton, Florida, 1987. Duke is a contributing editor to the following periodicals: *Bu$iness of Herbs, Coltsfoot, Herbalgram*, and the *International Permaculture Species Yearbook*; and he frequently writes for *American*

Health, Economic Botany, and *Organic Gardening*. In 1985, he published the *Herbalbum: an Anthology of Varicose Verse*, parts of which were recorded in 1986 as an LP album (bluegrass), the *Herbalbum*, by a studio band in Nashville, Tennessee. In 1987, Quarterman Press published *Living Liqueurs*.

ACKNOWLEDGMENTS (Conceptualization)

Herb Strum, Agricultural Marketing Specialist, USDA, triggered all this when he called and asked if I knew anyone who could address his Agricultural Marketing Workshops on tropical nuts. The next thing you know, I became the speaker without portfolio. Since these nuts are high-priced, light-weight, often labor-intensive crops, it was only natural that I should view the nuts as possible alternative crops for narcotics. For their support in my alternative crops program, I am indebted to the USDA's Dr. T. J. Army, Deputy Administrator, National Program Staff, Beltsville, Maryland; Dr. W. A. Gentner, Research Leader, Weed Science Laboratory, ARS, BARC, Beltsville, Maryland, and Quentin Jones, Assistant to Deputy Administrator for Germplasm (now retired), National Program Staff, Beltsville, Maryland.

In the preparation for these talks, I called on those more knowledgeable to help me decide what should be discussed in papers on Tropical Nuts. I sent these fine correspondents the crude check list, as follows:

TROPICAL NUTS

Anacardium occidentale	Cashew
Artocarpus altilis (A. communis)	Breadfruit
Bauhinia esculenta (Tylosema esculentum)	Marama nut or bean
Bertholettia excelsa	Brazil nut
Buchanania latifolia (lanza)	Cudapah almond or cuddapaha almond or Chironji nut
Canarium indicum	Java almond
Caryocar nuciferum	Suari nut
Caryodendron	Inchi nut
Cordeauxia edulis	Jeheb nut, ye-eb nut
Irvingia gabonensis	Dika nut
Lecythis ollaria	Sapucaja nut
Lecythis minor	—
Lecythis zabucajo	Paradise nut
Licania rigida	Oiticica
Macadamia spp.	Macadamia nut
Omphalea megacarpa	Hunter's nut
Ongokea klaineana	Isano nut
Palaquium burukii	Siak illipe nut
Pangium edule	Pangi nut
Poga oleosa	Oboga nut
Ricinodendron heudelotii	Essang nut
Sclerocarya caffra	Marula nut
Sterculia chicha	Maranhao nut
Terminalia catappa	Indian almond
Terminalia okara	Okari nut
Telfairia pedata	Oyster nut

Omit:

Jojoba
Coconut
Chestnut, water
Cola nut
Chufa or Tiger nut
Peanut
Groundnut
Litchi nut

Frank Martin added the jackfruit (*Artocarpus integer*) and the champedak (*Artocarpus heterophylla*), emphasizing that they were distinct species. He also added *Aleurites triloba* Forst, one of the many candle nuts, stating that it is edible when roasted. Further, he added

the palmyra palm (*Borassus flabellifer* L.), *Gnetum gnemon* (adding that it is excellent), and *Telfairia occidentalis*, another oysternut. He challenged my exclusion of the coconut, and cautioned that *Sterculia chicha* contains a poisonous cyclopropenoid fatty acid.

Gerardo Budowski, of CATIE, added *Salacca edulis*, which is very important in Indonesia, often served at receptions. After he consulted Menninger, he queried how worthwhile are some of the nuts. If you listen to Menninger, all kinds of things are nuts, and may be delicious — to some, such as a large group of palms.

So I wrote to palm specialist Dennis Johnson, and sent him the list of the more than 50 genera of palms that Menninger had included in this books. Dennis seemed comfortable with leaving these in a talk on nuts and added *Areca*, which Menninger excluded because it was not ingested, and the Pacific ivory nut, *Coelococcus*.

Harold Winters, retired USDA author of Kennard and Winters, *Some Fruits and Nuts for the Tropics*,[160] also added several species to my list.

Bob Knight, of the USDA Station at Miami, reminded me of the double meaning of breadnut (1) as the nut of *Brosimum alicastrum*, also known as Maya Breadnut, and (2) as a seeded breadfruit. Bob also added *Aleurites moluccana* as a chemurgic nut, and *Castanopsis* as an edible. He reminded me of the unfortunate consequences of overeating seleniferous species of the Lecithidaceae.

Carl Campbell, also of Florida, added *Brosimum* too, with the Pili Nut (*Canarium ovatum*) and the Malabar chestnut (*Pachira macrocarpa*). He reminded me, as did Julia Morton and Bob Knight, that the pangi nut and the oiticica were "toxic(?)" and "hardly edible", respectively. They are right.

Ernie Imle, retired USDA cacao specialist, sent literature ranking the pili nut, *Canarium ovatum*, up with the macadam and cashew. He mentioned that several lines of pili were established at La Zamorana, Honduras.

Julia Morton added the jackfruit *Artocarpus heterophylla*, the breadnut, *Brosimum alicastrum*, the quandong, *Fusanus acuminatus*, the Tahiti chestnut, *Inocarpus edulis*, and the Saba nut, or *Pachira aquatica*, and included data on these and other nut species which I have incorporated in my write-ups on these species. She also added her acuminate capsular reviews of Menninger's and Rosengarten's books and equally acuminate warnings on other of our nut species.

I also acknowledge the help of Jayne Maclean, National Agricultural Library, who went through a list of tropical nuts to check how many citations there were in her computerized search. The tabulation which follows, with the number of "hits", might suggest the relative importance of the tropical nuts in the literature:

162 *Anacardium occidentale*	0 *Omphalea megacarpa*
22 *Artocarpus altilis* or *communis*	0 *Ongokea klaineana* (= *O. gore*)
2 *Bauhinia esculenta*	1 *Palaquium*
24 *Bertholettia excelsa*	0 *Pangium edule*
2 *Buchanania latifolia*	0 *Pogo oleosa*
0 *Canarium indicum*	2 *Licania rigida*
0 *Caryocar nuciferum*	0 *Ricinodendron* sp.
0 *Caryodendron* sp.	0 *Sclerocarya caffra*
1 *Irvingia gabonensis*	1 *Sterculia chicha*
3 *Cordeauxia edulis*	8 *Terminalia catappa*
0 *Lecithis ollaria*	0 *Telfairia pedata*
0 *Lecithis zabucajo*	

My wife, Peggy, has helped in gathering and touching up illustrations, some in the public domain, some being redrawn and reproduced here with the permission of the artist and/or publishers. She has gone to the libraries and herbaria around Washington to seek out illustrations, or specimens with which to improve on the quality of the illustrations herein. She

is responsible for those drawings bearing her name. Last and most, my thanks go to my program assistant, Judy duCellier, who helped compile information into format from several disparate sources. Not only has she learned to read my handwritten annotations and seek out data from obscure sources, she has been good enough to type the manuscript as well. In the civil service system, the very fact that she types the data she helped gather may jeopardize her promotion potential. Take this as my letter of recommendation.

ACKNOWLEDGMENTS (Procedure and format)

For conventional nut species, I was immensely aided by a USDA contract with Dr. C. F. Reed,[278] who prepared rough drafts on description, uses, varieties, distribution, ecology, cultivation, economics, yields, and biotic factors of 1000 economic species. I was responsible for the drafts of the nonconventional species reviewed herein as nuts, and Judy duCellier and I edited, updated, and augmented the Reed drafts on the conventional species. Certain major sources constituted the major documentation for Dr. Reed's early drafts and my final drafts.

For the Use paragraph, the major references were Bailey,[25] Bogdan,[43] Brown,[51] Brown and Merrill,[52] Burkill,[55] C.S.I.R.,[70] Dalziel,[71] Duke,[81,86] *Hortus III,*[139] MacMillan,[196] Martin and Ruberte,[202] Uphof,[324] and many others. Often in this or other paragraphs I have internally cited the Chemical Marketing Reporter,[351] a weekly tabloid with much useful information.

For the Folk Medicine paragraphs, primary resources were Boulos,[45] C.S.I.R.,[70] Duke,[80] Duke and Ayensu,[90] Duke and Wain,[93] Hartwell,[126] Kirtikar and Basu,[165] List and Horhammer,[187] Morton,[224] Perry,[249] and Watt and Breyer-Brandwijk.[332]

For the Chemistry paragraph, the major references were C.S.I.R.,[70] Duke,[86] Duke and Atchley,[89] Gibbs,[109] Gohl,[110] Leung et al.,[181] List and Horhammer,[187] and Morton.[224]

For the Description paragraph, various floras were consulted in addition to the prime references, Kirtikar and Basu,[165] Little,[188] Ochse,[238] Radford, Ahles, and Bell,[276] and Reed.[278]

For the Germplasm paragraph, the major references were Duke,[82] Reed,[278] and Zeven and Zhukhovsky;[350] for the Distribution paragraph, various floras, Holm et al.,[134] Little,[188] and NAS;[231,231] for the Ecology paragraph, C.S.I.R.,[70] Duke,[82] Holm et al.,[135] Little,[188] and NAS.[231,232] (While ecological amplitudes were available for many of these nuts from Duke,[821] in other cases I amplified the Duke data from other sources. For yet other species with no hard data, I estimated ecological magnitudes.)

For the Cultivation and Harvesting paragraphs, C.S.I.R.,[70] NAS,[231,232] Purseglove,[272] Reed[70] were consulted; for the Yields and Economics paragraph, Bogdan,[43] Duke,[82] FAO,[98] and Reed;[70] for the Energy paragraph, Channel,[61] Duke,[87] NAS,[232] and Westlake;[334] for the Biotic Factors paragraph, Browne,[53] and Agriculture Handbook No. 165,[4] were the primary references. Dr. C. F. Reed went through some USDA mycology files[186] for those on which he cooperated. These names have not all been verified. In the Biotic Factor or Cultivation paragraph, there may be bibliographic mention of pesticides. In no way do I imply acceptance or rejection of a pesticide by inclusion or omission. I have merely recited items that may be of interest to those seeking information on pesticides.

I have omitted several ''nuts'' included in my *Handbook of Legumes of World Economic Importance.*[83] I have added other legumes, e.g., the groundnut, *Apios* (not really a nut, but a root), and the yeheb, the tallownut, which were not covered in the handbook. I rank *Apios* with the promising, yet still undeveloped, new crops of the New World.[40]

Warning — Although I have compiled from the literature folk medicinal applications for some of these nut species, neither I nor my publishers endorse or even suggest self diagnosis or herbal medication. The folk medicinal information was compiled from open literature, and I cannot vouch for its safety nor efficacy. As a matter of fact, I suspect some folk medicinal applications are both dangerous and inefficacious.

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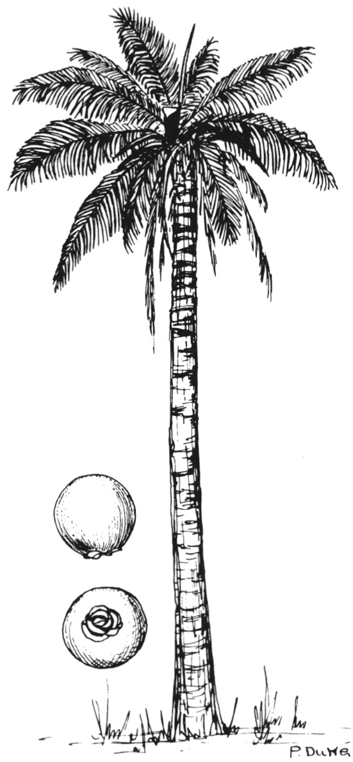
ACROCOMIA SCLEROCARPA Mart. (ARCEACEAE) — Gru-Gru Nut, Coco de Catarro, Macauba, Mucaja

Syn.: ***Acrocomia aculeata*** **(Jacq.) Lodd.**



Uses — The slimy, soft external tissue (mesocarp) and the seed yield oil. The mesocarp oil can be used as cooking oil, without refining, if extracted from fresh or properly stored fruits. The mesocarp oil is also used for soaps. The kernel oil, with a sweet taste like coconut oil, is used as an edible oil, e.g., in the preparation of margarine.[29,152]

Folk medicine — Sometimes used as a purgative and vermifuge.

Chemistry — Seed contains 60% fat with 17% saturated fatty acids (74.6% oleic acid and 8% linoleic acid). Fruit contains 4.58 mg carotene per 100 g fresh weight. Flowers contain 2.1% gallic acid and tannin.[187] According to Balick,[29] air-dried kernels yield 53 to 65 (to 69.4%), pulp up to 63.7% fat. The yellow pulp oil is softer and has a higher iodine value than palm oil, but, unfortunately, hydrolyzes rapidly after harvested, especially if damaged, like the oil palm. Johnson[152] says that fresh fruits contain 35% moisture; dry fruit mesocarp yields 33% oil, the kernel 53.75%.

Description — Armed palm to 11 m tall. Leaves pinnate, armed, like the trunk. Inflorescence with very sharp fine spines. Fruit a reddish-yellow edible drupe surrounded by a tough woody kernel. Dry fruits weigh about 18 g, with 19.8% outer shell, 41.1% mesocarp pulp, 29.0% inner shell, and 10.1% kernel.

Germplasm — Reported from the South American Center of Diversity, gru-gru is reported to tolerate drought.

Distribution — Widely dispersed in Brazil, especially in Minas Gerais, where it grows in dense groves. Ranging into Paraguay.

Ecology — Estimated to range from Tropical Wet to Dry through Subtropical Wet to Dry Forest Life Zones, gru-gru nut is estimated to tolerate annual precipitation of 10 to 40 dm, annual temperature of 22 to 28°C, and pH of 6 to 8. Sometimes gregarious in dense groves. In Johnson,[152] Balick notes this palm occurs in drier regions than most palms, and therefore might be a useful economic plant in the dry areas.

Cultivation — Usually not cultivated.

Harvesting — Balick[29] notes the following, for oil palms in general, not necessarily for this species. "In commercial production, palm fruits first are harvested and removed from the panicles upon which they are formed. Sterilization is next, to inactivate the enzymes present in the mesocarp. These enzymes can cause deterioration of the oil through lipolysis, an increase of the free fatty acid content known commercially as rancidity. A so-called "hard oil", with up to 94.5% free fatty acids, is made by fermenting rather than sterilizing the ripe palm fruits. Sterilization also stops oxidation, which lowers the bleachability of the oil and makes it less valuable for commercial use. The fruits are then macerated to separate the oily pulp from the kernels. In small-scale, local production, natives may pound the fruits with a log or stone to release the pulp. On a large plantation, special machinery is used. To release the oil, this pulpy mass is pressed with a hand press, if primitively processed, or with heavy mechanical presses if on an industrial scale. Clarification follows: in a small operation, the oil is allowed to rise through a layer of boiling water and is then skimmed off. Large processing factories use a settling and centrifuge process. For commercial use, the oil is usually bleached, removing certain natural red or green pigments. These colors may lower the monetary value of the oil.

Kernels of some species of palms are often saved for their oil as a by-product of primitive fruit processing. These are then shipped to mills located in central areas, where heavier equipment is used for extraction. Natives in the past and today extract palm kernel oil by baking the kernels in an oven and pounding them in hollow logs. The resulting mash is boiled in pots with water, and the oil is collected as it rises to the top. Palm kernel cake, a product of the extraction, is a good protein source and may be used for either human consumption or as an animal feed.[29]

Yields and economics — Small local Brazilian establishments develop the oils, which are little known in the world market. Brazil produced small quantities of the oil before and during World War II. In 1980, Brazilian production was limited to three States: Maranhao, Ceara, and Minas Gerais, producing only 190 tons.[152]

Energy — The oil could be used like that of other oil palms for energy, the press-cake for alcohol production or animal feed. An 18 g fruit would yield ca. 2.4 g mesocarp oil and 1 g kernel oil.[152]

Biotic factors — No data available.

ACROCOMIA TOTAI Mart. (ARECACEAE) — Gru-Gru Nut, Paraguay Coco-Palm, Mbocaya

Uses — Since pre-Colombian times, this palm has, with *Copernicia australis* (most abundant palm in Paraguay), supplied food, shelter, and the raw material for fabrication of soaps, hats, ropes, baskets, bags, hammocks, and mats. In Argentina, it is regarded as an ornamental palm with edible nuts. Leaves are sometimes lopped for fodder in the dry season. The "cabbage" and base of the involucral leaves are eaten in salads. Ripe fruits are edible and tasty. Five industrially useful products are obtainable: pulp oil, kernel oil, kernel meal, kernel cake, and extracted pulp. The kernel oil is most valuable and abundant, usable for soap and food.[29]

Folk medicine — No data available.

Chemistry — Per 100 g, the mesocarp is reported to contain 4.3 g H_2O, 4.2 g protein, 27.9 g fat, 4.8 g total sugars, 8.8 g fiber, 10.32 g ash, 90 mg Ca, 120 mg P, and 2,180 mg K. Other data are tabulated in Markley.[199] (See Tables 1 and 2).

Description — Monoecious palm to 15 (to 20) m tall, the stipe provided with stout spines, some 7.5 to 12.5 (to 17) cm long. Leaves pinnate, 2 to 3 m long, individual leaflets 50 to 70 cm long; petiole with spines on the dorsal surface. Spadix interfoliar, 1 m long, like the inner spathe densely spinose. Fruits yellow, rounded, ca. 3 to 4 cm diam. with dark orange oily pulp, rich in carotene.

Germplasm — Reported from the South American (Paraguayan) Center of Diversity, mbocaya, or cvs thereof, is reported to tolerate savannas. Some trees are almost devoid of spines, except just below the crown.

Distribution — Higher altitude savannas in Argentina and Paraguay.

Ecology — Estimated to range from Tropical Very Dry to Wet through Subtropical Wet to Dry Forest Life Zones, mbocaya is estimated to tolerate annual precipitation of 8 to 35 dm, annual temperature of 22 to 28°C, and pH of 6 to 8.

Cultivation — Markley[199] calculates yield, at 10 × 4 m spacing (250 trees/ha) at 640 kg oil/ha, at 10 × 6 (166 trees) at 424 kg/ha, at 10 × 8 (125 trees) at 320 kg/ha, and at 10 × 10 (100 trees/ha) at 256 kg oil/ha. Markley's information suggests that the seeds might be as recalcitrant as those of oil palms.[199]

Harvesting — Humans usually eat only the pulp of freshly fallen fruits owing to the difficulty of extracting the kernels. Nature (decay and/or defecation, followed by rains) often leaves clean nuts lying on the ground, to be harvested by humans. Leaves are sometimes lopped to leave only two in the dry season.

Yields and Economics — The mbocaya palm is of greater economic importance to Paraguay than any other indigenous palm. Between 1940 and 1951, Paraguay produced 883 to 2,849 MT of kernel oil annually, exporting 13 to 2,588, and 170 to 1,125 MT pulp oil, exporting 109 to 2,074 MT. In 1971, Paraguay exported 7,400 MT, up from 2300 tons in 1964.[152] Commenting on comparative yields of oil per ha, Markley[199] shows only 96 to 640 kg/ha for this species, compared to 2,790 for oil palm, 818 for coconut, 420 for sesame, 392 for rapeseed, 308 for sunflower, 230 for peanuts, 193 for flaxseeds, and 190 for soybeans.

Energy — The oil could be used like that of other oil palms for energy, the press-cake for alcohol production or animal feed. Brazil is now studying this plant as a renewable source of fuel oil.[152]

Biotic factors — A highly destructive stem borer or snout beetle (*Rhyna barbirostris*) attacks the palm. Larvae may devour the whole interior, except for the long cellulose fiber. A fungus, probably *Phaecophora acrocomiac*, may cause yellow blotches with black centers on the leaves. Ruminants may eat the whole fruit, regurgitating or even defecating entire kernels ("nuts"). Seedlings may be devoured by insects, birds, or other animals, as well as attacked by microorganisms.

Table 1
COMPOSITION (%) OF COMMERCIAL SAMPLES OF *A. TOTAI* PRODUCTS[199]

Constituent	Outer hull (epicarp)	Pulp (mesocarp)	Pulp, expeller cake	Shell (endocarp)	Kernel	Kernel, expeller cake
Moisture (H_2O)	6.65	4.31	5.26	6.84	3.17	7.44
Lipides (oil)	3.88	27.94	6.26	2.46	66.75	7.22
Nitrogen	0.74	0.67	0.98	0.31	2.02	5.50
Protein ($N \times 6.25$)	4.62	4.18	6.12	1.94	12.62	34.38
Crude fiber	36.00	8.82	6.83	49.69	8.60	11.65
Sugars (total)	—	4.85	5.16	—	1.28	2.80
Ash	5.82	10.32	9.16	3.26	1.98	5.37
Potassium	2.18	2.18	2.75	1.02	1.36	1.55
Phosphorus	0.10	0.12	0.16	0.04	0.42	1.14
Calcium	0.07	0.09	0.10	0.04	0.08	0.27

Table 2
CHARACTERISTICS AND COMPOSITION OF THE PULP OILS OF *A. TOTAI* AND *E. GUINEENSIS*[199]

Characteristic	*A. totai*[14]	*A. totai*[13]	*E. guineensis*
Specific gravity (40°C)	—	0.9240	0.898—0.901
Refractive index (40°C)	1.4615	1.4582—1.4607	1.453—1.456
Titer value (°C)	—	26.1—33.2	40—47
Iodine value	68.4	54.5—66.7	44—58
Unsaponifiable matter (%)	0.81	0.27—0.55	<0.8
Saponification value	197.0	200—209	195—205
Free fatty acids (% palmitic)	41.2	1—?	
Total fatty acids			
Iodine value	69.7	—	—
Thiocyanogen value	66.6	—	—
Saturated (%)	20.0	—	39—50
Oleic (%)	80.0	—	38—52
Linoleic (%)	0.0	—	6—10

ADHATODA VASICA (L.) Nees (ACANTHACEAE) — Malabar Nut, Adotodai, Pavettia, Wanepala, Basak
Syn.: ***Justicia adhatoda*** L.

Uses — Plants grown for reclaiming waste lands. Because of its fetid scent, it is not eaten by cattle and goats. Leaves and twigs commonly used in Sri Lanka as green manure for field crops, and elsewhere in rice fields. Leaves, on boiling in water, give durable yellow dye used for coarse cloth and skins; in combination with indigo, cloth takes a greenish-blue to dark green color. Also used to impart black color to pottery. Stems and twigs used as supports for mud-walls. Wood makes good charcoal for gunpowder, and used as fuel for brick-making. Ashes used in place of crude carbonate of soda for washing clothes. In Bengal, statue heads are carved from the wood. Leaves also used in agriculture as a weedicide, insecticide, and fungicide, as they contain the alkaloid, vasicine. As a weedicide, it is used against aquatic weeds in rice-fields; as insecticide, used in same way tobacco leaves; as fungicide, they prevent growth of fungi on fruits which are covered with vasica leaves. Market gardeners place layers of leaves over fruit, like mangoes, plantains, and custard-apples, which have been picked in immature state to hasten ripening and to ensure development of natural color in these fruits without spoilage.[86]

Folk medicine — Plant has many medicinal uses. Whole plant used in Sri Lanka for treatment of excessive phlegm, and in menorrhagia. Leaves are source of an expectorant drug used to relieve coughs. Plants are used in folk remedies for glandular tumors in India. Leaf used for asthma, bronchitis, consumption, cough, fever, jaundice, tuberculosis; smoked for asthma; prescribed as a mucolytic, antitussive, antispasmodic, expectorant. Ayurvedics[165] use the root for hematuria, leucorrhea, parturition, and strangury, the plant for asthma, blood impurities, bronchitis, consumption, fever, heart disease, jaundice, leucoderma, loss of memory (amnesia), stomatosis, thirst, tumors, and vomiting. Yunani use the fruit for bronchitis, the flowers for jaundice, poor circulation, and strangury; the emmenagogue leaves in gonorrhea, and the diuretic root in asthma, bilious nausea, bronchitis, fever, gonorrhea, and sore eyes.[86]

Chemistry — Used in Indian medicine for more than 2000 years, adhatoda now has a whole book dedicated to only one of its active alkaloids.[22] In addition to antiseptic and insecticidal properties, vasicine produces a slight fall of blood pressure, followed by rise to the original level, and an increase in the amplitude of heart beats and a slowing of the rhythm. It has a slight but persistent bronchodilator effect. With a long history as an expectorant in India, vasicine has recently been modified to form the derivative bromhexine, a mucolytic inhalant agent, which increases respiratory fluid volume, diluting the mucus, and reduces its viscosity. Fluid extract of leaves liquifies sputum, relieving coughs and bronchial spasms. The plant also contains an unidentified principle agent active against the tubercular bacillus. Adhatodine, anisotinine, betaine, vasakin, vasicine, vasicinine, vasicinol, vasicinone, vasicoline, vasicolinone, are reported. Deoxyvasicine is a highly effective antifeedant followed by vasicinol and vasicine. These plant products as antifeedants could be safely used for controlling pests on vegetable crops.''[14,86] Atal[22] devoted a whole book to the chemistry and pharmacology of Vasicine-A. At the Regional Research Laboratory (RRL), in Jammu, vasicine showed a definite bronchodilatory effect, comparable to that of theophylline, as well as hypotensive, respiratory stimulant, and uterotonic activities.[13] The total alkaloid content is up to 0.4%, of which 85 to 90% is vasicine.

Toxicity — Vasicine is toxic to cold-blooded creatures (including fish) but not to mammals. Although it is not listed in many poisonous plant books, the fact that it is not grazed suggests that it could well be poisonous.[22] Vasicine and vasicinol exhibit potential to reduce fertility in insects. ''Vasicine is also likely to replace the abortifacient drugs in current use as its abortifacient activity is comparable to prostaglandins.''[22] In large doses the leaves cause diarrhea and nausea.[86]

Description — A gregarious, evergreen, densely branched shrub 1.5 to 3 (to 6) m tall; bark smooth, ash-colored; branches softly hairy, internodes short; leaves opposite, elliptic, ovate or elliptic-lanceolate, pointed at both ends, acuminate, entire, minutely pubescent, 12.5 to 20 cm. long, 8 cm. broad; flowers white with red, pink, or white spots or streaks, in dense axillary, stalked, bracteate spikes 2.5 to 7.5 cm long; bracts conspicuously leafy, 1-flowered; calyx deeply divided into 5 lobes, pubescent; corolla 2-lipped, pubescent outside; upper lip notched, curved, lower lip 3-lobed; capsules 2.5 cm or more long, 0.8 cm broad, clavate, pubescent, 4-seeded; seeds suborbicular, rugose. Flowers and fruit December to April; in some areas flowers May—June also.[278]

Germplasm — Reported from the Indochina-Indonesia Centers of Diversity, Malabar Nut or cvs thereof is reported to tolerate fungus, insects, mycobacteria, and weeds.[82]

Distribution — Common to tropical India from Punjab to southern India, Sri Lanka, N. Burma, Pakistan (Karachi, Sind, Khyber, Wazir, Kurram, Dir); Hong Kong, China, Yunnan, where common.[278]

Ecology — Abundant and gregarious in many areas of China and India, growing in full sun, at edges of forests, in hilly regions often as the co-dominant shrub with *Capparis sepiaria* L. Also grows in full sun on flood plains and in meadows. In Curacao, it grows well on weathered diabase, in south Florida on oolitic limestone. In Sub-Himalayan region ascends to 1,300 m altitude, more frequent at altitudes about 200 to 300 m. Requires a subtropical to tropical climate with moderate precipitation. Though killed to the ground by brief frosts, it recovers rapidly. Ranging from Warm Temperate Dry through Tropical Very Dry Forest Life Zones, Malabar nut is reported to tolerate annual precipitation of 5 to 42 dm (mean of 5 cases = 22), annual temperature of 15 to 27°C (mean of 5 cases = 24), and pH of 4.5 to 7.5 (mean of 4 cases = 6.1).[82,278]

Cultivation — As plants are quite common, often abundant, and gregarious in regions of adaptation and where people use the plant, the plant is cultivated mainly in areas of habitation, as hedges, wind-breaks, and for reclaiming soil. Propagation is by seeds broadcast in areas of need, or in waste areas about areas of cultivation. Any forest edge is a likely place to seed, so that the leaves or branches will be handy for use on other cultivated plants. No particular care is taken, as the plants thrive on any tropical soil that is well-drained and has sufficient precipitation. The plants, also propagated readily from cuttings, are said to coppice well.[278]

Harvesting — Harvesting leaves and branches varies according to the needs of the local farmer, for green manure, covering fruits or protection, etc. As plants are evergreen, leaves are available year-round.[278]

Yields and economics — No data available. However, plants are plentiful, and supply all the leaves and twigs needed by those who use them. An important plant for reclaiming waste land in areas of adaptation, as in India and Sri Lanka. Also used as weedicide, insecticide, and fungicide in tropical areas. Mainly used in tropical Southeast Asia, S. China, India, and Sri Lanka. One ton of leaves can yield 2 kg vasicine equivalent to 2 million human doses.[13]

Energy — I was surprised to see this listed in a book on firewood trees.[232] They note that it has a particularly desirable wood for quick, intense, long-lasting cooking fires, with little or no odor, smoke or sparks. The moderately hard wood has been used to manufacture gunpowder charcoal.[232] If vasicine becomes commercialized, the biomass residues (>99%) following vasicine extraction could conceivably serve as a pesticidal mulch or for conversion to alcohol. Perhaps this should be viewed like the neem tree in the third world, stripping the leaves as a pesticidal mulch, using the woody "skeleton" for firewood.

Biotic factors — Fungi reported attacking this plant include the following species: *Aecidium adhatodae, Alternaria tenuissima, Cercospora adhatodar, Chnoospora butleri, Phomopsis acanthi (Phoma acanthi).*[186] Plants are parasitized by *Cuscuta reflexa*. Not browsed by goats or other animals. One source states that this plant "is never attacked by any insect . . . even the voracious eater, Bihar Hairy Catterpillar (sic) (*Dicresia obliqua*) avoids this plant."[14]

ALEURITES FORDII Hemsl. (EUPHORBIACEAE) — Tung-Oil Tree

Uses — Tung trees are cultivated for their seeds, the endosperm of which supplies a superior quick-drying oil, utilized in the manufacture of lacquers, varnishes, paints, linoleum, oilcloth, resins, artificial leather, felt-base floor coverings, and greases, brake-linings and in clearing and polishing compounds. Tung oil products are used to coat containers for food, beverages, and medicines; for insulating wires and other metallic surfaces, as in radios, radar, telephone, and telegraph instruments.[111,260]

Folk medicine — Reported to be emetic, hemostat, and poisonous, tung-oil tree is a folk remedy for burns, edema, ejaculation, masturbation, scabies, swelling, and trauma.[91]

Chemistry — The fruit contains 14 to 20%; the kernel, 53 to 60%; and the nut, 30 to 40% oil. The oil contains 75 to 80% alpha-elaeo stearic-, 15% oleic-, ca 4% palmitic-, and ca. 1% stearic acids. Tannins, phytosterols, and a poisonous saponin are also reported.[187]

Description — Trees up to 12 m tall and wide, bark smooth, wood soft; leaves dark green, up to 15 cm wide, heart-shaped, sometimes lobed, appearing usually just after, but sometimes just before flowering; flowers in clusters, whitish, rose-throated, produced in early spring from terminal buds of shoots of the previous season; monoecious, male and female flowers in same inflorescence, usually with the pistillate flowers surrounded by several staminate flowers; fruits spherical, pear-shaped or top shaped, green to purple at maturity, with 4 to 5 carpels each with one seed; seeds usually 4 to 5, but may vary from 1 to 15, 2 to 3.2 cm long, 1.3 to 2.5 cm wide, consisting of a hard outer shell and a kernel from which the oil is obtained. Flowers February to March; fruits late September to early November.[278]

Germplasm — Reported from the China-Japan and North American Centers of Diversity, tung-oil tree, or cvs thereof, is reported to tolerate bacteria, disease, frost, insects, poor soil, and slope.[82] High-yielding cultivars continue to be developed. Some of the best cvs released by the USDA for growing in the southern U.S. are the following:

- 'Folsom': low-heading, high productivity; fruits large, late maturing, turning purplish when mature, containing 21% oil; highest resistance to low temperature in fall.
- 'Gahl': low-heading, productive; fruits large, 20% oil content; matures early, somewhat resistant to cold in fall.
- 'Isabel': low-heading, highly productive; fruits large, maturing early, 22% oil content.
- 'La Crosse': High-heading, exceptional productivity; fruits small, late maturing, tending to break segments if not harvested promptly, 21 to 14% oil content; a very popular cv.
- 'Lampton': out-yields all other varieties; very low-heading; fruits large, early maturing; 22% oil content.

Several other species of *Aleurites* are used to produce tung-oil, usually of low quality: *Aleurites cordata*, Japanese wood-oil tree; *A. moluccana*, Candlenut or lumbang tree; *A. trisperma*, Soft Lumbang tree; none of which can be grown commercially in the U.S. *Aleurites montana*, Mu-tree, is the prevailing commercial species in South China and could be grown in Florida.[82,259,278] (zn = zz.)

Distribution — Native to central and western China, where seedlings have been planted for thousands of years; planted in the southern U.S. from Florida to eastern Texas.[278]

Ecology — Ranging from Warm Temperate Dry to Wet through Tropical Very Dry to Moist Forest Life Zones, tung-oil tree is reported to tolerate annual precipitation of 6.4 to 21.0 dm (mean of 22 cases = 14.0), temperature of 18.7 to 27.0°C (mean of 21 cases = 24.0°C), pH of 5.4 to 7.1 (mean of 5 cases = 6.2).[82] Tung trees are very exacting in climatic and soil requirements. They require long, hot summers with abundant moisture, with usually at least 112 cm of rainfall rather evenly distributed through the year. Trees require 350 to 400 hr in winter with temperatures 7.2°C or lower; without this cold requirement, trees tend to produce suckers from the main branches. Vigorous but not succulent growth is most cold-resistant; trees are susceptible to cold injury when in active growth. Production of tung is best where day and night temperatures are uniformly warm. Much variation reduces tree growth and fruit size. Trees grow best if planted on hilltops or slopes, as good air-drainage reduces losses from spring frosts. Contour-planting on high rolling land escapes frost damage. Tung makes its best growth on virgin land. Soils must be well-drained, deep aerated, and have a high moisture-holding capacity to be easily penetrated by the roots. Green manure crops and fertilizers may be needed. Dolomitic lime may be used to correct excessive acidity; pH 6.0 to 6.5 is best; liming is beneficial to most soils in the Tung Belt, the more acid soils requiring greater amounts of lime.[82,278]

Cultivation — Tung trees may be propagated by seed or by budding. Seedlings generally vary considerably from parent plants in growth and fruiting characters. Seedlings which have been self-pollinated for several generations give rather uniform plants. Only 1 out of 100 selected "mother" tung trees will produce seedlings sufficiently uniform for commercial planting. However, a "mother" tree proven worthy by progeny testing may be propagated by budding. The budded trees, which are genetically identical with the original tree, will provide an adequate supply of seed satisfactory for planting. Seedlings are used for the root system for budded trees. Buds from "mother" trees are inserted in stems of 1-year old seedlings, 5 to 7.5 cm above the surface of the soil. Later, the original seedling top is cut off and a new top grown for the transplanted bud, making the tops of budded trees parts of the parent tree. Usually seedling trees outgrow budded trees, but budded trees produce larger crops and are more uniform in production, oil content, and date of fruit maturity. Tung seed are normally short-lived and must be planted during the season following harvest. Seeds are best hulled before planting, as hulls retard germination. Hulled seed may be planted dry, but soaking in water for 5 to 7 days hastens germination. Stratification, cold treatment or chemical treatment of seeds brings about more rapid and uniform germination. Dry-stored seed should be planted no later than February; stratified seed by mid-March; cold-treated and chemical treated seed by early April. Seed may be planted either by hand or with a modified corn-planter, the seed spaced 15 to 20 cm apart, about 5 cm, in rows 1.6 m apart, depending on the equipment to be used for cultivation and for digging the trees. Seeds germinate in 60 days or more; hence weed and grass control may be a serious problem. As soon as seedlings emerge, a side-dressing of fertilizer (5-10-5) with commercial zinc sulfate should be applied. Fertilizer is applied at rate of 600 kg/ha, in bands along each side of row, 20 cm from seedlings and 5 to 7.5 cm deep. Other fertilizers may be needed, depending on the soil. Most successful budding is done in late August, by the simple shield method, requiring a piece of budstock bark, including a bud, that will fit into a cut in the rootstock bar; a T-shaped cut is made in the bark of the rootstock at a point 5 to 7.5 cm above ground level, the flaps of bark loosened, shield-bud slipped inside flaps, and the flaps tied tightly over the transplanted bud with rubber budding stripe, 12 cm long, 0.6 cm wide, 0.002 thick. After about 7 days, the rubber stripe is cut to prevent binding. As newly set buds are susceptible to cold injury, soil is mounded over them for winter. When growth starts in spring, soil is pulled back and each stock cut back to within 3.5 cm of the dormant bud. Later, care consists of keeping all suckers removed and the trees well-cultivated. Trees are transplanted to the orchard late the following winter. Spring budding is done only as a last resort. Trees may be planted at 125 to 750/ha. When trees are small, close planting in rows greatly increases the bearing surface, but at maturity the bearing surface of a crowded row is about the same as that of a row with trees farther apart. However, it is well to leave enough space between row for orchard operations. In contour-planting, distances between rows and total number of trees per hectare vary; rows 10 to 12 m apart, trees spaced 3.3 to 4 m apart in rows, 250 to 350 trees/ha. Tops of nursery trees must be pruned back to 20 to

25 cm at planting. As growth starts, all buds are rubbed off except the one strongest growing and best placed on the tree. A bud 5 cm or more below the top of the stump is preferred over one closer to top.[278]

Harvesting — Tung trees usually begin bearing fruit the third year after planting, and are usually in commercial production by the fourth or fifth year, attaining maximum production in 10 to 12 years. Average life of trees in the U.S. is 30 years. Fruits mature and drop to ground in late September to early November. At this time they contain about 60% moisture. Fruits must be dried to 15% moisture before processing. Fruits should be left on the ground 3 to 4 weeks until hulls are dead and dry, and the moisture content has dropped below 30%. Fruits are gathered by hand into baskets or sacks. Fruits do not deteriorate on the ground until they germinate in spring.[74,278]

Yields and economics — Trees yield 4.5 to 5 tons/ha. An average picker can gather 60 to 80 bushels of fruits per day, depending on conditions of the orchard. Fruits may be gathered all through the winter season when other crops do not need care. Because all fruits do not fall at the same time, 2 or more harvestings may be desirable to get the maximum yield. Fruits are usually sacked, placed in the crotch of the tree and allowed to dry 2 to 3 weeks before delivery to the mill. Additional drying may be done at the mill, but wet fruits contain less oil percentage-wise and prices will be lower. Prices for tung oil depend on price supports, domestic production, imports, and industrial demands. World production in 1969 was 107,000 MT of tung nuts; in 1970, 143,000; and projected for 1980, 199,000. Wholesale prices were about $0.276/kg; European import prices, $0.335/kg. Growers received about $51.10/ton of fruit of 18.5% oil content to about $63.10/ton for fruits of 22% oil content. Major producing countries are mainland China and South America (Argentina and Paraguay); the U.S. and Africa produce much less. U.S. Bureau of Census figures 1,587,000 pounds of tung oil were consumed during February of 1982, representing a 1,307,000 pound drop from January. The largest application for the oil is paint and varnish, which accounted for 566,000 pounds of total consumption in February.[82,278,351] Dealers in tung oil include:[351]

Alnore Oil Co., Inc.
P.O. Box 699
Valley Stream, NY 11582

Pacific Anchor Chemical Corp.
6055 E. Washington Boulevard
Los Angeles, CA 90040

Industrial Oil Products Corp.
375 N. Broadway
Jericho, NY 11753

Welch, Holme, & Clark Co., Inc.
1000 S. 4th Street
Harrison, NJ 07029

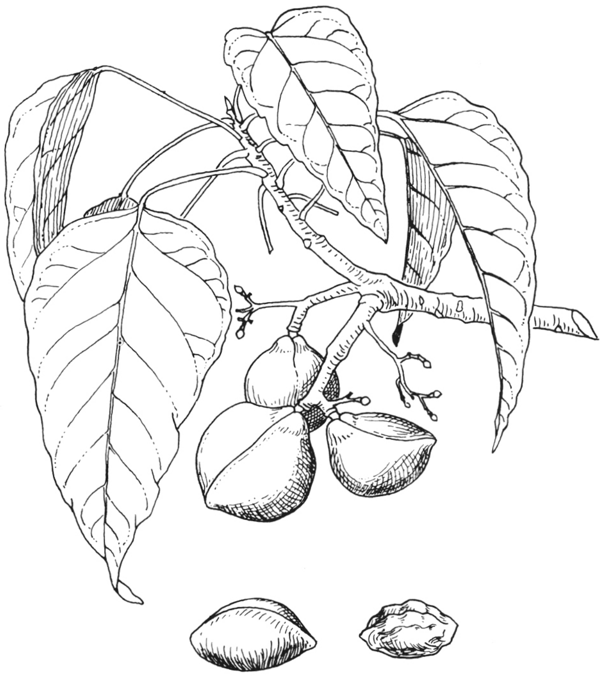
Kraft Chemical Co.
1975 N. Hawthorene Avenue
Melrose Park, IL 60160

Energy — During World War II, the Chinese used tung oil for motor fuel. It tended to gum up the engines, so they processed it to make it compatible with gasoline. The mixture worked fine,[243] Gaydou et al.[107] reported yields of 4 to 6 MT/ha, converting to 1,800 to 2,700 ℓ oil per ha, equivalent to 17,000 to 25,500 kWh/ha.

Biotic factors — Bees are needed to transfer pollen from anthers to pistil. When staminate and pistillate flowers are on separate trees, 1 staminate tree for 20 pistillate trees should be planted in the orchard. Pollination can occur over several days. Tung trees are relatively free of insects and diseases, only a few causing losses serious enough to justify control measures: e.g., *Botroyosphaeria ribis*, *Clitocybe tabescens*, *Mycosphaerella aleuritidis*, *Pellicularia koleroga*, *Physalospora rhodina* and the bacterium, *Pseudomonas aleuritidis*. Other bacteria and fungi reported on tung trees are *Armillaria mellea*, *Botryodiplodia theo-*

bromae, *Cephaleures virescens*, *Cercospora aleuritidis*, *Colletotrichum gloeosporioides*, *Corticium koleroga*, *Fomes lamaoensis*, *F. lignosus*, *Fusarium heterosporum* forma *aleuritidis*, *F. oxysporum*, *F. scirpi*, *F. solani*, *Ganoderma pseudoferreum*, *Coleosporium aleuriticum*, *Glomerella cingulata*, *Pestalotia dichaeta*, *Phyllosticta microspora*, *Phytomonas syringae*, *Phytophthora omnivora*, *Ph. cinnamomi*, *Poria hypolateritia*, *Pythium aphanidermatum*, *Rhizoctonia solani*, *Septobasidium aleuritidis*, *S. pseudopedicellatum*, *Sphaerostilbe repens*, *Uncinula miyabei* var. *aleuritis*, *Ustilina maxima*, *U. zonata*. Insect pests are not a serious problem, since fruit and leaves of tung trees are toxic to most animal life. Nematodes *Meloidogyne* spp. have been reported.[186,257,278]

ALEURITES MOLUCCANA (L.) Willd. (EUPHORBIACEAE) — Candlenut Oil Tree, Candleberry, Varnish Tree, Indian or Belgium Walnut, Lumbang Oil
Syn.: ***Aleurites triloba*** **Forst.,** ***Croton moluccanus*** L.



Uses — Seed yields 57 to 80% of inedible, semi-drying oil, liquid at ordinary temperatures, solidifying at −15°C, and containing oleostearic acid. The oil is quicker drying than linseed oil, and is used as a wood preservative, for varnishes and paint oil, also as an illuminant, for soap-making, waterproofing paper, in India rubber substitutes and insulating masses. Fruits said to be used as a fish poison. Seeds are moderately poisonous and press cake is used as fertilizer. Kernels, when roasted and cooked are considered edible; may be strung as candlenuts. Oil is painted on bottoms of small craft to protect against marine borers. Tung oil, applied to cotton bolls, stops boll weevils from eating them; also prevents feeding by striped cucumber beetle.[86]

Folk medicine — Bark used on tumors in Japan. Reported to be aperient, aphrodisiac, laxative, poison, purgative, stimulant, sudorific, candlenut oil tree is a folk remedy for asthma, debility, sores, swelling, tumors, unconsciousness, womb ailments, and wounds.[82] The oil is purgative and sometimes used like castor oil. In China, it is applied to sciatica. Kernels are laxative, stimulant, and sudorific. The irritant oil is rubbed on scalp as a hair stimulant. In Sumatra, pounded seeds, burned with charcoal, are applied round the navel for costiveness. Leaves are applied for rheumatism in the Philippines. In Malaya, the pulped kernel enters poultices for headche, fevers, ulcers, and swollen joints. Boiled leaves are applied to headache, scrofula, swollen joints, and ulcers. In Java, the bark is used for bloody diarrhea or dysentery. Bark juice with coconut milk is used for sprue and thrush. Malayans apply boiled leaves to the temples for headache, and to the pubes for gonnorhea.[56] In Yunani medicine, the oil is considered anodyne, aphrodisiac, and cardiotonic, and the fruit is recommended for the brain, bronchitis, bruises, heart, hydrophobia, liver, piles, ringworm, and watery eyes. In Ayurvedic medicine, the fruit is considered apertif, aphrodisiac, antibilious, cardiac, depurative, and refrigerant.[86,165]

Chemistry — The oil cake, containing ca. 46.2% protein, 4.4% P_2O_5, and 2.0% K_2O, is said to be poisonous. A toxalbumin and HCN have been suggested. Bark contains ca. 4 to 6% tannin. Oil also contains glycerides of linolenic, oleic and various linoleic acids. Per 100 g, the seed is reported to contain 626 calories, 7.0 g H_2O, 19.0 g protein, 63.0 g fat, 8.0 g total carbohydrate, 3.0 g ash, 80 mg Ca, 200 mg P, 2.0 mg Fe, 0 mg beta-carotene equivalent, 0.06 mg thiamine, and 0 mg ascorbic acid.[86]

Description — Medium-sized tree, up to 20 m tall, ornamental, with spreading or pendulous branches; leaves simple, variable in shape, young leaves large, up to 30 cm long, palmate, with 3 to 7 acuminate lobes, shining, while leaves on mature trees are ovate, entire, and acuminate, long-petioled, whitish above when young, becoming green with age, with rusty stellate pubescence beneath when young, and persisting on veins and petiole; flowers in rusty-pubescent panicled cymes 10 to 15 cm long; petals 5, dingy white or creamy, oblong, up to 1.3 cm long; ovary 2-celled; fruit an indehiscent drupe, roundish, 5 cm or more in diameter, with thick rough hard shell making up 64 to 68% of fruit, difficult to separate from kernels; containing 1 or 2 seeds. Flowers April to May (Sri Lanka).[196,278]

Germplasm — Reported from the Indochina-Indonesia Center of Diversity, *Aleurites moluccana*, or cvs thereof, is reported to tolerate high pH, low pH, poor soil, and slope.[82] (2n = 44,22).

Distribution — Native to Malaysia, Polynesia, Malay Peninsula, Philippines, and South Seas Islands; now widely distributed in tropics. Naturalized or cultivated in Malagasy, Sri Lanka, southern India, Bangladesh, Brazil, West Indies, and the Gulf Coast of the U.S.[278]

Ecology — Candlenut trees thrive in moist tropical regions, up to 1,200 m altitude. Ranging from Subtropical Dry to Wet through Tropical Very Dry to Wet Forest Life Zones, Aleurites moluccana is reported to tolerate annual precipitation of 6.4 to 42.9 dm (mean of 14 cases = 19.4) annual temperature of 18.7 to 27.4°C (mean of 14 cases = 24.6) and pH of 5.0 to 8.0 (mean of 7 cases = 6.4).[82]

Cultivation — Usually propagated from seed, requiring 3 to 4 months to germinate. Seedlings planted 300/ha. Once established, trees require little to no attention.[196,278]

Harvesting — Bear two heavy crops each year. After harvesting mature fruits, it is difficult to separate kernels from shell, as the kernels adhere to sides of shell.[278]

Yields and economics — As a plantation crop, tree yields are estimated at 5 to 20 tons/ha of nuts, each tree producing 30 to 80 kg. Oil production varies from 15 to 20% of nut weight. Most oil produced in India, Sri Lanka, and other tropical regions is used locally and does not figure into international trade. In the past, oil has sold for 12 to 14 pounds per ton in England. According to the Chemical Marketing Reporter,[351] tung oil prices (then ca. $.65/lb) are likely to rise in the near future if demand remains adequate and Argentinean and Paraguayan suppliers pressure the U.S. market by charging high prices for replacement oil. U.S. imports for the first quarter of 1981 were 58% higher than 1980, despite the absence of Chinese tung from the market.

Energy — Nut yields are estimated at 80 kg/tree, which, spaced at 200 trees per hectare, would suggest 16 MT/ha/yr, about 20% of which (3 MT) would be oil, suitable, with modification, for diesel uses, the residues for conversion to alcohol or pyrolysis. Fruit yields may range from 4 to 20 MT/ha/yr. Commercial production of oil yields 12 to 18% of the weight of the dry unhulled fruits, the fruits being air-dried to ca. 12 to 15% moisture before pressing. The pomace contains 4.5 to 5% oil. This suggests that the "chaff factor" might be ca 0.8. Oil yields as high as 3,100 kg/ha have been reported. As of June 15, 1981, tung oil was $0.65/lb, compared to $0.38 for peanut oil, $1.39 for poppyseed oil, $0.33 for linseed oil, $0.275 for coconut oil, $0.265 for cottonseed oil, $0.232 for corn oil, and $0.21 for soybean oil.[351] At $2.00 per gallon, gasoline is roughly $0.25/lb.

Biotic factors — Following fungi are known to attack candlenut-oil tree: *Cephalosporium* sp., *Clitocybe tabescens*, *Fomes hawaiensis*, *Gloeosporium aleuriticum*, *Phasalospora rhodina*, *Polyporus gilvus*, *Pythium ultimum*, *Sclerotium rolfsii*, *Sphaeronaema reinkingii*, *Trametes corrugata*, *Xylaria curta*, *Ustulina deusta*.[186]

ALEURITES MONTANA (Lour.) Wils. (ANACARDIACEAE) — Wood-Oil Tree, Mu-Oil Tree

Uses — Kernels yield a valuable drying oil, largely used in paints, varnishes, and linoleums. Also used locally for illumination and lacquer-work. Varnish made from this plant possess a high degree of water-resistance, gloss, and durability. There are only slight differences between the oils of *A. montana* and *A. fordii*.[278]

Folk medicine — The oil is applied to furuncles and ulcers.

Chemistry — The oil content of the seed is ca. 50 to 60%. Oil consists chiefly of glycerides of beta-elaeostearic and oleic acids, and probably a little linoleic acid. Oil cake residue is poisonous and is only fit for manuring.

Description — A small tree about 5 m tall, much-branched, partially deciduous, dioecious. Leaves simple, ovate or more or less cordate, apex cuspidate, about 12 cm long, 10 cm broad, sometimes larger and 3-lobed; leaf-blade with 2 large, conspicuous glands at base, petiole up to 24 cm long. Flowers monoecious, petals large, white, up to 3 cm long. Fruits egg-shaped, 3-lobed, wrinkled, about 5 cm in diameter, pointed at summit, flattened at base, generally with 3 or 4 one-seeded segments, the outer surface with wavy transverse ridges, the pericarp thick, hard, and weedy. Flowers and fruits March.[278]

Germplasm — Reported from the China-Japan Center of Diversity, mu-oil tree, or cvs thereof, is reported to tolerate high pH, poor soil, and slope. (2n = 22.)[82]

Distribution — Native to South China and some of the S. Shan States (Burma). Introduced and cultivated successfully in Indochina (where it has replaced *A. fordii*), Malawi, and in cooler parts of Florida, and other tropical regions.[278]

Ecology — Ranging from Warm Temperate Moist through Tropical Dry to Moist Forest Life Zones, mu-oil tree is reported to tolerate annual precipitation of 6.7 to 20.2 dm (mean of 8 cases = 13.6), annual temperature of 14.8 to 26.5°C (mean of 8 cases = 21.9°C), and pH of 5.5 to 8.0 (mean of 6 cases = 6.2).[82] Adapted to subtropical regions and high elevations with moderate rainfall. Mainly a hillside species, it can thrive in warmer climates and will withstand heavier rainfall than *A. fordii*, provided the area is well-drained. Maximum temperature 35.5°C, minimum temperature 6°C. It is frost-tender, and does not require a low temperature (below 3°C) as tung-oil trees (*A. fordii*) do, so can be grown in warmer regions. In Assam, grown where rainfall is 175 to 275 cm annually; in Mysore at elevations of 800 to 1,000 m with annual rainfall of 150 cm. Grows well in alluvial soils and is not very exacting in its soil requirements. In richer soils, the growth is more vigorous. A slightly acid soil is preferable.[278]

Cultivation — Trees are propagated from seeds or by budding. In Malawi, propagation is by budding from high-yielding clones. Seeds are usually planted in a nursery and may take from 2 to 3 months to germinate. When seedlings are about 1 year old, they are planted out, spaced 6.6 × 6.6 m or more. Cultural practices are similar to those for *A. fordii*. As soon as the seedlings emerge, a side-dressing of fertilizer (5-10-5) of nitrogen and phosphorus, along with commercial zinc sulfate, should be applied. Fertilizer is applied at rate of 600 kg/ha, in bands along each side of row, 20 cm from seedlings and 5 to 7.5 cm deep. Other fertilizers may be needed, depending on the soil. According to Spurling and Spurling,[312] N is the most important nutrient for tung in Malawi, irrespective of climate or soil. Most successful budding is done in late August, by the simple shield method, requiring a piece of budstick bark, including a bud, that will fit into a cut in the rootstock bark. A T-shaped cut is made in bark of rootstock at a point 5 to 7.5 cm above ground level, the flaps of bark loosened, shield-bud slipped inside flaps, and the flaps tied tightly over the transplanted bud with rubber budding strip 12 cm long and 0.6 cm wide. After about 7 days, the rubber strip is cut to prevent binding. As newly set buds are susceptible to cold injury, soil is mounded over them for winter. When growth starts in spring, soil is pulled back and each stock cut back to within 3.5 cm of the dormant bud. Later care consists of keeping all suckers removed and the trees well-cultivated. Trees may be planted 125 to 750/ha. When trees are small, close planting in rows greatly increases the bearing surface, but at maturity the bearing surface of a crowded row is about the same as for a row with trees further apart. However, it is well to leave enough space between rows for orchard operations. In contour-planting, distances between rows and total number of trees per hectare vary; rows 10 to 12 m apart, trees spaced 3.3 to 4 m apart in rows, 250 to 350 trees/ha. Tops of trees must be pruned back to 20 to 25 cm at planting. As growth starts, all buds are rubbed off except the one strongest growing and best placed on the tree. A bud 5 cm or more below the top of stump is preferred over one closer to the top.[278,312]

Harvesting — Trees begin bearing 2 to 5 years after transplanting with maximum production reached in 8 years and continuing for 40 years. In northern Burma, it has been observed to be more vigorous and disease-resistant than *A. fordii*. In Indochina, it has been successfully planted and its oil is now being produced on a commercial scale, replacing that of *A. fordii*. Fruits mature and drop to ground in late September to early November. They are gathered and dried to 15% moisture before processing. Fruits should be left on the ground 3 to 4 weeks until hulls are dead and dry, and the moisture content has dropped below 30%; fresh they are about 60% moisture. Fruits are gathered by hand into baskets or sacks.[278]

Yields and economics — *A. montana* is reported to give much higher yields of fruits than *A. fordii*. The percentage of kernels in the seeds is about 56%, and of oil in the kernels, about 59.3%. Major producers of the oil from *A. montana* are Burma, Indochina (Vietnam, Cambodia, Laos), Malawi, Congo, East Africa, South Africa, Malagasy Republic, India, and U.S.S.R. It has been considered for introduction in Florida.[278]

Energy — Yields of oil per tree in China is figured to be about 3.2 kg; in Florida, 4.5 to 9 kg. Trees yield about 45 to 68 kg nuts per year, these yielding about 35 to 40% oil. In one Malawi trial, N treatments gave an increase of 519 kg/ha dry seed over a trial mean of 1070 kg/ha. With tung cake and ammonium sulphate, air dry tung seed yields of 12 to 17 year old trees was 2013 to 2367 kg/ha, of 6 to 9 year olds 766 to 1546 kg/ha.[278,312]

Biotic factors — Fungi reported on *A. montana* include the following: *Armillaria mellea, Botryodiplodia theobromae, Botryosphaeria ribis, Cephaleuros mycoidea, C. virescens, Cercospora aleuritidis, Colletotrichum gloeosporioides* var. *aleuritidis, Corticium koleroga, C. solani (Rhizoctonia solani), Corynespora cassiicola, Diplodia theobromae, Fusarium arthrosporioides, F. lateritium, Glomerella cingulata, Haplosporella aleurites, Mycosphaerella aleuritidis, Periconia byssoides, Pestalotiopsis disseminata, P. glandicola, P. japonica, P. versicolor, Pestalotia dichaeta, Phyllosticta microspora, Pseudocampton fasciculatum, Rhizoctonia lanellifera, Schizophyllum commune, Thyronectria pseudotrichia, Trametes occidentalis, Ustulina zonata.*[186]

AMPHICARPAEA BRACTEATA (L.) Fernald (FABACEAE) — Hog Peanut, Wild Peanut

Uses — Ojibwa Indians were said to eat both roots and seeds cooked. (There's not much to the roots.) Meskwaki (Fox) Indians learned that mice gathered the underground nuts and laid them up in stores, which stores the Indians gathered for themselves (Dakota Indians were said to leave corn or other food in exchange). The subterranean seeds are more important as food. They have been likened to garden-bean in flavor, the aerial seeds to soybeans. As late as November in Maryland, the subterranean seeds may be tracked from the dying yellow/brown tops. If eaten raw, seeds might be soaked in warm water or water with hardwood ashes. In October, when both *Amphicarpaea* and *Apios* seeds are available, I find both the aerial and subterranean seeds of the *Amphicarpaea* seeds much more pleasing to the palate raw than the *Apios* seeds. Gallaher and Buhr[405] speculate that the subterranean seeds may "have survival-potential under conditions of intense grazing." I suggest that the subterranean seeds might not set in tightly packed sod. Both aerial and subterranean seeds are eaten by bear, chipmunk, deer, grouse, mice, pheasant, prairie chicken, quail, and wild turkey. Vines are browsed by livestock and probably deer. Once cultivated in southern U.S., hog peanuts have been suggested for planting in poultry forage systems and for intercropping with corn and perhaps ginseng. All members of the genus can be important in soil improvement, as soil cover, and in erosion control.[8,400,401]

Folk medicine — Chippewa drank the root with other roots as a general physic, while, conversely, the Cherokee used it for diarrhea. Cherokee also blew the root tea onto snakebite wounds.[400]

Chemistry — Marshall[402] notes that the aerial seeds, with flavor similar to soybeans, contain ca. 30% protein, 7 to 16% oil. The oil contains 10.3 to 10.4% palmitic-, 1.3 to 1.6% stearic-, 24.9 to 26.7% oleic-, 54.8 to 58.5% linoleic-, and 6.5 to 7.6% linolenic-acids. The cleistogamous, underground seeds, weighing as much as 1 g each, may contain 50% water. Their oil content is lower, and the protein content may be only 14.3%, perhaps[404] reflecting the higher water content.[402] Lectins are also reported. Gallaher and Buhr[405] analyzed Tennessee fodder during early pod-fill stage, reporting for the whole plant ca. 89% organic matter, 26.5 g/kg N, 2.4 g/kg P, 14.2 g/kg K, 17.3 g/kg Ca, 4.1 g/kg Mg, 20 ppm Cu, 40 ppm Zn, 120 ppm Mn, and 360 ppm Fe, averaging slightly lower than pegging peanut forage, but higher in P, Ca, Mn, and Fe. Crude protein in the hog peanut forage was over 16%, slightly below the peanut forage.

Description — Weak, twining, climbing annual (though often cited as perennial) to 2 m long, the stems sparsely appressed short-pubescent to densely villous. Leaves 3-foliolate; leaflets entire, ovate to rhombic-ovate, the laterals often asymmetrical, 2 to 10 cm long, petiolulate, stipellate; usually pubescent. Axillary racemes of 1 to 17 petaliferous flowers, on peduncles 1 to 6 cm long, the ovate bracts 2 to 5 mm long; pedicels 1.5 to 5 mm long; racemes from lower axils slender, elongate, with cleistogamous, apetalous, inconspicuous flowers. Calyx of petaliferous flowers narrowly campanulate; tube 4 to 6 mm long, ca. 2 mm in diameter; upper 2 lobes united, or nearly so, glabrous to densely appressed-pubescent; petals pale purple or lilac to white, 9 to 16 mm long; stamens of the petaliferous flowers diadelphous, 9 and 1; ovary stipitate, style not bearded. Legume from petaliferous flowers flattened, oblong-linear, 1.5 to 4 cm long, 7-10 mm broad, often 3-seeded, valves laterally twisting in dehiscence; fruit from cleistogamous flowers fleshy, often subterranean, usually 1-seeded, indehiscent, cryptocotylar.[276] Duke[403] recognizes four different flower/fruit combinations:

1. Subterranean seed, whose cleistogamous flowers never left the soil (usually one or two); the biggest, juiciest, softest, and most edible (15% protein). For propagation *in situ*.
2. Geotropic seed from cleistogamous flowers at the tip of branches originating in the axils of the first simple aerial leaves. Usually solitary, soft, plump. For propagation nearby.
3. Aerial cleistogamous flowers, whose pods, and usually single hard seeds, develop strictly above ground. For dispersal.
4. Aerial chasmogamous flowers followed by pods with usually three small hard seeds (the smallest, driest, hardest, and least edible, yet 30% protein). For longer distance dispersal. The type 4 flower/fruits are said to occur mostly in sunny situations. If the forest is cleared, the increased sunlight would trigger more dispersal seed, enhancing the chances to move the plant back into the forest.

Germplasm — Reported from the North American Center of Diversity, hog peanut, or cvs thereof, is reported to tolerate alluvium, muck, mulch, sand, shade, slope, and brief waterlogging. *A. bracteata* is said to merge imperceptibly with var. *comosa*, which grows on richer, often calcareous or alluvial soil. Turner and Fearing[406] concluded the genus contained only three species, *A. africana* in the cool high mountains of Africa, *A. edgeworthii* in the Himalayas and eastern Asia, and the American *A. bracteata*, the latter two nearly indistinguishable. ($2n = 20,40$.)

Distribution — Native to damp shaded woodlands from Quebec to Manitoba and Montana, south to Florida, Louisiana, and Texas.

Ecology — Estimated to range from Warm Temperate Moist to Wet through Cool Temperate Dry to Wet Forest Life Zones, hog peanut is estimated to tolerate annual precipitation of 8 to 20 dm, annual temperature of 8 to 14°C, and pH of 5.5 to 7.5. Although native to damp shaded forest, the plant can be cultivated in sandy, sunny situations. The underground seed must have very different chemistry, ecology, and physiology, destined for immediate survival and not dispersal, as contrasted to the aerial seed, destined for long-term dispersal.

Cultivation — Said to have been cultivated in the South, but few details are available. W. G. Dore[407] sterilizes his soil, plants in the fall, and mulches with such things as sawdust, peat moss, vermiculite, and/or organic muck. Gas-sterilization is all but imperative to control weeds since the clambering habit of the vine precludes cultivation. In fertile soils in full sun, the one-seeded beans grow large and succulent, comparable to peanuts, or even lima beans. Frey[401] suggests intercropping the hog peanut with corn.

Harvesting — The large seeds appear beneath the dead leaves, generally just under the surface of the ground. In weed-free culture, the tangled vines can be raked off preparatory to harvest in fall. In loose sandy soil, the seeds separate out easily with a quarter inch screen. Harvested seed tend to germinate in the refrigerator, if not frozen.

Yields and economics — Unpublished research by W. G. Dore[407] reported yields as high as 1 kg seed per 10 m row. His seed were fall-planted about 10 cm apart in gas-sterilized sandy loam.

Energy — Both biomass (ca. 5 g per plant) and oil yields are low. The biomass raked up before harvesting could conceivably be converted to energy. The nitrogen fixed by the plant could be energetically important, in pastures, forests, and in intercropping scenarios.

Biotic factors — Agriculture Handbook No. 165[4] lists the following as affecting *Amphicarpaea bracteata*: *Cercospora monoica* (leaf spot), and *Erysiphe polygoni* (powdery mildew). Agriculture Handbook No. 165,[4] without reference to a specific species, also lists: *Colletotrichum* sp. (leaf spot), *Parodiella perisporioides* (black mildew), *Puccinia andropogonis* var. *onobrychidis* (rust), and *Synchytrium aecidioides* (false rust, leaf gall). Allen and Allen[8] report that earlier studies showed a relative inability of the hog peanut *Rhizobium* to nodulate legumes from 21 diverse genera. Later plant-infection studies discounted this exclusiveness by showing plant-infection kinships within the cowpea miscellany. Larvae of *Rivella pallida* Lowe, a common and widely distributed species of the dipteran family Platystomatidae (and a potential pest of soybean), attack the N_2-fixing root nodules of *Amphicarpaea*. The nodular contents are completely destroyed, thus eliminating the nodule's ability to fix N_2. Up to 25% of an individual's nodules are damaged in northeastern Ohio. There is one and perhaps a partial second generation per year in northern Ohio, with overwintering occurring as mature larvae in diapause. Eight species of neartic *Rivellia* (including *R. flavimana* Loew and *R. metallica* (Walp)) occur on *Amphicarpaea bracteata* (L.).[408] Chasmogamous flowers are pollinated primarily by *Bombus affinis*.[409]