Specialty Crops for Pacific Island Agroforestry (http://agroforestry.net/scps)

Farm and Forestry Production and Marketing profile for

Moringa

(*Moringa oleifera*)

By Ted Radovich

PAR

USES AND PRODUCTS

Almost all parts of the moringa tree are used for food, oil, fiber, and/or medicine. In the Pacific, the most important products are pods and leaves. Young pods are consumed as a vegetable. Very young pods are fiberless, and can be cooked like string beans. Because the weight is low on very young pods, most commercial production involves larger, more fibrous pods that are used in soups, stews, and curries. The nutritious leaves are eaten in many dishes including soups, stews, and stir fries. Sauteed young leaves and flowers are also eaten. The demand for home consumption of pods and leaves can generally be met by one or two backyard trees.

Commercial production of mature seeds for oil occurs in India, Africa, and elsewhere. The press cake left over after extracting seed oil is utilized as a fertilizer and as a flocculent for water clarification. The seed cake contains positively charged compounds that are effective in settling suspended solids out of water (flocculation) because most particles have a net negative surface charge while suspended in aqueous solution. There is international interest in using moringa-based flocculants as a locally produced, biodegradable substitute for aluminum sulfate, which is commonly used to clarify water. The seed cake is normally not used as livestock feed because of the presence of antinutritional compounds in the mature seeds.

Leaves are readily eaten by cattle, sheep, goats, pigs, chickens and rabbits and can also be used as food for fish. Several studies demonstrate that significant proportions of traditional fodder can be replaced with moringa leaf. A study in Fiji reports significant weight gain over traditional fodder when 50% of fodder contained moringa (Aregheore, 2002). In Nicaragua, cattle feed consisting of 40–50% moringa leaves is mixed with molasses, sugar cane, and grass. Moringa leaf meal can be used to substitute up to 10% of dietary protein in Nile tilapia without significant reduction in growth. However, excessive feeding with moringa can reduce weight gain in livestock. Animals given fodder with 80% moringa in the Fijian study above showed lower weight gain than animals on 50% moringa fodder. Adverse effects resulting from high rates of moringa in feed are due to ex-

Left: Very young pods contain little fiber and can be cooked like string beans. Right: Commercial production of moringa leaf in Kunia, Oʻahu, primarily for export to the U.S. mainland (West Coast) and Canada.

cessive protein levels, and potentially anti-nutritional compounds in the leaves such as nitrate, oxalate, saponin, phytate and isothiocyanates. Raffinose and stachyose may cause flatulence in monogastrics (Foidl and Paull, 2008). Moringa biomass is reportedly low in lignin and may be valuable for ethanol production (Foidl and Paull 2008).

Bwana-Simba (2006) lists these other traditional and contemporary uses for moringa:

- wood yields a blue dye used in Jamaica and Senegal
- live fence posts
- crop plant growth promotion from leaf extracts (mechanism unknown)
- wood pulp is suitable for making newsprint and writing paper
- bark may be beaten for fiber (for paper).

Most parts of the plant are used as a medicine. The greatest contribution of moringa to health is its high nutritional value (see "Nutrition" below). The most common direct medical use of the plant is as poultice of the leaves and bark applied directly to wounds as an anti-microbial and to promote healing. The anti-fungal and anti-bacterial properties of moringa extracts are well documented and are thought to be derived at least in part from 4-(α-L-rhamnopy-ranosyloxy) benzyl isothiocyanate. This compound is particularly effective against *Helicobacter pylori*, a bacterial pathogen of human beings in medically underserved areas and poor populations worldwide (Fahey, 2005).

Isothiocyanates are the source of the mild horseradish smell in moringa roots and bark, which gives the tree one of its common names, "horseradish tree." Moringa is in the same order as horseradish and other cabbage family members (Capparales). Isothiocyanates and related products from the cabbage family have been shown to have anti-tumor and anti-carcinogenic effects. Work at Johns Hopkins University and elsewhere is supporting traditional use of moringa to treat cancer (Fahey, 2005).

The strong tradition of medical uses of moringa combined with recent scientific work supporting these traditions has resulted in increased marketing of supplements and so-called "superfoods" based on moringa.

BOTANICAL DESCRIPTION

Preferred scientific name

Moringa oleifera Lam.

Family

Moringaceae (Horseradish-tree family)

Non-preferred scientific names

Moringa pterygosperma (synonym), *M. moringa* Small (synonym, occasional)

Common names

The most frequently used common names in the Pacific are variants of *marrunggai*, *malunggai*, or *kalamunggai*. Other common names used in the Pacific are *katdes* (Guam), *sajina* (Fiji), and *bèn ailé* (French Polynesia). English common names include drumstick, horseradish, and ben oil tree, or moringa, as in this publication.

Brief botanical description

Moringa is a slender softwood tree that branches freely, and can be extremely fast growing. Although it can reach heights in excess of 10 m (33 ft), it is generally considered a small- to medium-size tree. Tripinnate compound leaves are feathery with green to dark green elliptical leaflets 1–2 cm (0.4–0.8 in) long. The tree is often mistaken for a legume because of its leaves. Conspicuous, lightly fragrant flowers are borne on inflorescences 10–25 cm (4–10 in) long, and are generally white to cream colored, although they can be tinged with pink in some varieties. The fruits are tri-lobed capsules, and are frequently referred to as "pods." Immature pods are green and in some varieties have some reddish color. Pods are brown and dry at maturity and contain 15–20 seeds. Seeds are large with three papery wings. Seed hulls are generally brown to black, but can be white if kernels are of low viability. Viable seeds germinate within 2 weeks.

DISTRIBUTION

Moringa is native to the Himalayan foothills (India/Bangladesh). As a commercial crop, it is cultivated extensively in India and parts of Africa. It would be challenging to find a region in the tropics or subtropics where moringa is not grown as a backyard tree for leaf and pod consumption, medicinally, and for fiber. Moringa is most commonly found in areas with South and Southeast Asian (particularly Filipino) populations.

ENVIRONMENTAL PREFERENCES AND TOLERANCES

Climate

Moringa is widely adapted to the tropics and subtropics. Optimum leaf and pod production requires high average daily temperatures of 25–30°C (77–86°F), well distributed annual rainfall of 1000–2000 mm (40–80 in), high solar radiation and well-drained soils. Growth slows significantly under temperatures below 20°C (68°F). Ideal elevation is less than 600 m (1,970 ft). Moringa is relatively tolerant of

Left: Moringa flowers. Right: dried, mature pod broken open to expose seeds.

drought and poor soils, and responds well to irrigation and fertilization.

Soils

Moringa tolerates a wide range of soil types and pH (4.5–9), but prefers well-drained soils in the neutral pH range. It can grow well in heavy (clay) soils provided that they do not become saturated for prolonged periods of time. Light (sandy) soils are preferred for rooting branch cuttings directly in the ground.

GROWTH AND DEVELOPMENT

Plants from seed can grow very rapidly under ideal conditions. Selected early flowering varieties are sometimes called "annual types" because they produce vegetable pods for market within a year and may be removed and new plantings established. Examples of early flowering types include 'PKM-1' and 'PKM-2' developed primarily for vegetable pod production by Tamil Nadu University in India. Early flowering types can produce market-mature pods in 6 months compared to over a year for other types. Moringa varieties generally tolerate the same climatic conditions. After coppicing, branches grow quickly and immature pods are harvested in 6 months.

Flowering and fruiting

Moringa is free flowering. Flowering generally occurs 4–12 months after planting, depending on the type (see above). Some selections flower 4–5 months after planting.

Scale of commercial production

Commercial production of immature pods for processing is a large industry in India with about 1.2 million MT (metric tons) (1.1 million T) produced annually on 38,000 ha (94,000 ac).

In Hawai'i, there is some export of leaves to North America and other markets. Data on quantity shipped is not available. Commercial plantings in Hawai'i seldom exceed 0.25 ha (0.6 ac). Data from other Pacific islands is also not available.

Elevation, rainfall, and temperature

Elevation range	**lower:** sea level **upper:** about 1,500 m (4,921 ft)
Mean annual rainfall	**lower:** 250 mm (10 in) **upper:** 4,000 mm (160 in)
Rainfall pattern	Moringa is adapted to monsoon rainfall patterns.
Dry season duration (consecutive months with <40 mm [1.6 in] rainfall)	Well-established trees can tolerate long periods of drought, but leaf production suffers.
Mean annual temperature	**lower:** 15°C (68°F) **upper:** 30°C (86°F)
Minimum temperature tolerated	Succulent growth is frost sensitive and established trees can survive low temperatures of 0°C (32°F) for short periods with the loss of new growth.

AGROFORESTRY AND ENVIRONMENTAL SERVICES

Agroforestry/interplanting practices

In small subsistence holdings, moringa trees are often interplanted with cassava, pumpkin and other vegetables. In commercial production, moringa is most often grown as a single crop (monocrop).

Environmental services provided

Moringa may be used in windbreaks, living fences, and as a trellis or shade tree. If using as a windbreak, it is recommended that trees be propagated from seeds rather than cuttings so that they develop a strong taproot, and that the apical stem be pinched off at 1 m [3.3 ft] tall to encourage lateral branching and thereby improve wind resistance.

PROPAGATION AND PLANTING

Trees are easily grown from seed, and direct seeding is the most common method used for commercial production in India. Cuttings for propagation should be from at least 1-year-old wood, 4–16 cm (1.6–6.3 in) in diameter and up to 1.5 m (5 ft) long. Cuttings should be rooted in loose, well-drained media or sandy soil.

Top: Moringa trees growing as living fence posts with barbed wire strung between them. Bottom: Large taproot of moringa seedlings (approx. 3 months old).

If direct seeding is not used, 1–2 month old seedlings (about 30 cm [12 in] tall, 0.75 cm [0.3 in] in diameter) or well-rooted cuttings are transplanted into well-cultivated soil. The size of transplants generated by cuttings is not important, but the root system should be well developed. If grown in heavy soils, raised beds may be used to improve drainage.

CULTIVATION

Variability of species and known varieties

Worldwide, there is considerable variability in moringa growth rate, branching habit, time to flowering, leaflet size and shape, pod length, and other characteristics. For leaf production, varieties with large, dark green leaves are preferred. Pods should be long, tender, and not bitter. Early flowering types 'PKM-1' and 'PKM-2' are are perhaps the most well known varieties. Other named varieties recorded include 'Bombay,' 'Chavakacheri,' 'Chemmurungai,' and 'Jaffna.'

Moringa cross-pollinates readily (highly out-crossing) and variability within seedling populations can be high if multiple types are planted together. Cuttings should be used to propagate preferred individuals when other moringa trees are nearby.

Basic crop management

Spacing for leaf production is 0.75 m (30 in) within rows and 1 m (3.3 ft) between rows. For pod production, recommended spacing is 2.5 m × 2.5 m (8.2 ft × 8.2 ft). Fertilizer and irrigation are recommended for maximum productivity. Addition of 300 g (10.5 oz) of complete fertilizer or 0.5–2 kg (1.1–4.4 lb) of manure per tree is recommended at planting. Positive yield response has been reported at N fertilization rates as high as 350 kg N per ha (312 lb N/ac). Trees have been reported to benefit from integrated (organic + synthetic) fertilization. Seedlings should be pinched at 1 m (3.3 ft) tall or 2 months after planting to stimulate side branching. Irrigation should be supplied during dry periods to maxi-

Nursery grown moringa seedlings.

Left: Moringa variety trials, Poamoho, Oʻahu. Right: Mature green and dry pods from short- and long-fruited varieties of moringa.

mize vegetative growth. Subsequent fertilizer applications after coppicing are also recommended.

Special horticultural techniques

Moringa leaf may be produced intensively in beds with seeds spaced 10 cm × 10 cm (4 in × 4 in). Seeds are used for this method. When harvesting leaves from mature trees, it is recommended that branches be cut frequently to stimulate new leafy growth.

Advantages and disadvantages of growing in polycultures

The relatively open canopy of moringa lends itself well to intercropping. Wider spacing (i.e., 2 m × 2 m or 6.6 ft × 6.6 ft) is desirable for intercropping and may benefit pod production, but will reduce production of moringa leaf per unit area. Wider spacing promotes pod production through greater branching and flowering.

PESTS AND DISEASES

Susceptibility to pests/pathogens

Moringa has few disease problems and the tree's vigorous growth allows it to tolerate occasional pest outbreaks, making intervention with pesticide usually unnecessary. In Hawaiʻi, mites are the biggest economic problem because of the potential for rejection of shipments to North America. Aphids and imported cabbageworm have been observed on moringa in Hawaiʻi, but are not generally considered a problem. Occasionally, heavy damage to tree trunks from borers has been observed. In east Oʻahu, damping-off-like symptoms have been observed in moringa seedlings. In India, several insects (weevils, scales, caterpillars, etc.) can cause damage to trees and fruit. A fungal disease has also been reported to cause fruit rot.

Pest and disease prevention

Moderate use of nitrogen fertilization and avoiding waterlogged clay soils prevent most problems. Neem oil, horticultural soap, and sulfur are low impact pesticides that can control mites, aphids, and other pests. Although there are few reports on variability in pest tolerance within moringa germplasm, local varieties are most likely to be best adapted for local conditions and should be included in new plantings.

DISADVANTAGES

Moringa does not grow well in cool temperatures, low sunlight, or wet soil conditions. Although tolerant of drought and infertile soils, it will not produce well under these conditions. The tree can be susceptible to high winds. The soft wood makes it unsuitable for timber or fuel.

Left: Commercial trees are coppiced at 50–100 cm (20–40 in) tall, and the leaves are harvested from regrowth. Right: Mite damage on moringa leaves.

Potential for invasiveness

Researchers at the University of Hawai'i have assessed moringa's risk of invasiveness to be low (Daehler, 2009).

COMMERCIAL PRODUCTION

Postharvest handling and processing

Fresh moringa products are generally consumed within 2 days of harvest and oftentimes within a day. Leaves are particularly perishable and should be stored under cool temperatures and high humidity to avoid excessive wilting and leaflet abscission. This is most often done by bagging in plastic and refrigerating at approximately 10°C (50°F). Fruit may be canned to preserve it for later consumption.

Leaves and flowers may be dried in the shade or dehydrated and then pounded or ground and used as a food additive to improve protein content of foods (see "Nutrition" below). Leaves and flowers are also used for tea.

An example of a commercial health food drink (Zija™) contains 30 g (1 oz) of moringa leaf, seed, and pod. This is reportedly the first commercially available drink formulated from moringa. Retailing such a commercial product to the average consumer may be challenging because of high costs. However, local, prepared drink and tea products may offer value-added opportunity for sale at farmers markets or health food stores.

Moringa seed kernels contain oil that is valued for culinary and cosmetic use. The oil contains 60–75% oleic acid and is comparable to olive oil in taste and value in cooking characteristics. The oil has a high antioxidant content, which makes it slow to go rancid. Low-tech extraction methods (e.g., grinding and boiling toasted seed) may be used but are relatively slow and inefficient. One low-tech method involves dehulling and grinding the kernels, then boiling them for 5 minutes in water. After boiling, the mixture is strained and allowed to sit overnight, during which time the oil separates from the water.

Low-tech oil expellers have been successfully used for extracting moringa oil. One such press (the "Komet press") is reported to produce 6.5 liters (7.2 qt) in 8 hours, with a 12% yield of oil. The same report said that 10 kg (22 lb) of seed yielded 1.2 kg (2.64 lb), or 1.3L (1.4 qt) of oil. Ram and screw presses have also been used for moringa oil extraction, with yields of 5–6%. Dehulling can improve oil yield, but the increase is small and may not justify the extra effort (Mbeza et al., 2002). Yields using a screw press can be improved to 20% if the seed is first crushed, 10% by volume of water is added, followed by gentle heating over low heat for 10–15 minutes, taking care not to burn the seed (Folkard and Sutherland, 2005).

Immature pods harvested for market.

Producing moringa oil on a small scale might be economically feasible if it were marketed to restaurants, hotels and other high-end venues as a locally produced alternative to imported olive oil. If oil is extracted through pressing, costs may be further reduced if press cake is used to replace purchased fertilizer.

Product quality standards

There are no known formal quality standards for moringa products, including oil.

Product storage requirements and shelf life

Moringa oil possesses exceptional oxidative stability and can be stored for years while maintaining quality. Leaf and pods may be stored at 10°C (50°F) for 5–14 days. Intact pods are less perishable than peeled or cut pods. Shelf life of seed cake has not been determined.

Recommended labeling for products

Food safety certification may be required by some wholesale and retail venues for fresh leaf and pod sales.

SMALL-SCALE PRODUCTION

Intensive leaf production using beds with 10 cm × 10 cm (4 in × 4 in) spacing may be the most feasible commercial application for the home gardener. For urban lots or small fields, leaf production from trees at 0.75 m × 1 m (2.5 ft × 3.3 ft) spacing is perhaps the best option. Intensive bed production produces very high yield of leaf in a small area, but is not feasible over larger areas because of the high amount of seed needed. Wider spacing at 0.75 m × 1 m (2.5 ft × 3.3 ft) is more feasible for leaf production in lots approaching 0.5 hectare (1.2 ac) and will also provide some pod production.

Value-added processing

If a market is available, leaves and flowers may be dried for use as food additives and tea. Oil may also add value to a

small family farm if extraction can be optimized and if it were marketed to high-end venues as a locally produced alternative to imported olive oil. Local and Internet sales of oil for cosmetic use may also add value. The oil has long been valued as cosmetic oil because of its extraordinarily long shelf life and its ability to hold the scent of added fragrances. Infusions of moringa oil with essential oils (jasmine, lavender, etc) may therefore also enhance value.

Use in Pacific households

Currently this tree is vastly underutilized in the Pacific, where its use is limited to a vegetable (leaf and pod) almost exclusively by South and Southeast Asian families. Expanding awareness and appreciation of this tree beyond existing cultural boundaries as a sustainable, local food source will enhance the nutrition and food security of island communities. Optimizing moringa oil production also has the potential to improve grower profitability and enhance community self-sufficiency (as cooking oil and possibly bio-diesel). Improving its use as fodder may also help reduce reliance on expensive, imported animal feed.

Nutrition

Moringa has long been considered a panacea for improving the nutrition of poor communities in the tropics and subtropics. Protein content of leaves is high (20–35% on a dry weight basis). Most important is that the protein is of high quality having significant quantities of all the essential amino acids. This amino acid balance is very unusual in plant foods. Moringa leaves also contain high quantities of nutrients (per 100 g fresh weight): vitamin A (7564 IU), vitamin C (51.7 mg), calcium (185 mg) and potassium (337 mg) (Foidl and Paull, 2008).

Moringa powder is utilized heavily in Africa and other parts of the world as a food supplement, where 1–2 tablespoons of dried powder are added to soups and stews daily to enhance the protein content and nutritional value of food. In Africa, 25 g of moringa powder is administered to pregnant women daily to improve prenatal nutrition (Diatta, 2001).

Import replacement

Potential to replace imported products can be found in several areas.

Leafy vegetables—Moringa leaves can replace some store bought greens.

Animal feed—Cut leaves are used as high protein animal forage.

Fertilizer—Seed cake is used as a fertilizer.

Medicine—It has a wide range of medicinal uses (see "Uses and Products" above)

An example of a moringa-based "superfood" commercially available drink.

Fence posts—Moringa trees can replace lumber or steel as living posts in fence lines and trellis systems.

YIELDS

Actual yields vary widely, depending on season, variety, fertilization, and irrigation regime. Moringa yields best under warm, dry conditions, with some supplemental fertilizer and irrigation.

Leaf

Leaf fresh weight yield is 1–5 kg (2.2–11 lb) per tree/year. This is the equivalent of 10,000–50,000 kg/ha (8,900–44,534 lb/ac) per year at 1 m × 1 m (3.3 ft × 3.3 ft) spacing. Commercial leaf yield of moringa during November–March reportedly declines to 50–100% of summer yields on the west coast of Oʻahu, Hawaiʻi. This reduction in productivity is thought to be a function of lower solar radiation during the winter months.

At 10 cm × 10 cm (4 in × 4 in) spacing, leaf yields are 7–8 kg/m^2 (1.4–1.6 lb/ft^2) at the first cutting in well irrigated, drained and fertilized beds, with up to seven cuttings a year.

Pod

Pod yields in India are reported at 19 kg (42 lb) pods/tree/year. This is the equivalent of 31,000 kg/ha (27,600 lb/ac) per year at 2.5 m × 2.5 m (8.2 ft × 8.2 ft) spacing. At 230 pods per tree, pods average 80–90 g (2.8–3.2 oz) each.

In Hawaiʻi, the Indian variety 'PKM-2' yielded 3–8 times more immature pods than local accessions 6 months after transplanting seedlings (Radovich and Paull, 2008).

Oil

Moringa trees in Hawaiʻi produce about 3 g (0.1 oz) of kernel per dry pod. Oil yield per hectare per year may be estimated based on the numbers above. Assuming a relatively high 20% oil yield by weight from kernels and a 0.90 specific

gravity for the oil, trees might be expected to produce 250 liters of oil per hectare (107 qt/ac).

In polycultures

Generally, crop yields are lower for any single crop in a polyculture, although total production of the system can be significantly higher than in monocultures. In moringa, lower leaf yields may be expected as tree spacing increases to allow for companion crops, although wider spacing (2.5 m × 2.5 m, [8.2 ft × 8.2 ft]) can increase pod yields relative to dense plantings.

Recommended planting density

Spacing for leaf production is 0.75 m (2.5 ft) within rows and 1 m (3 ft) between rows. For pod production, recommended spacing is 2.5 m × 2.5 m (8.2 ft × 8.2 ft).

Moringa leaf may be produced intensively in beds with seeds spaced 10 cm × 10 cm (4 in × 4 in) like an annual leaf vegetable.

Spacings of at least 2 m × 3 m (6.6 ft × 10 ft) are recommended for perennial polycultures, depending on pruning frequency of the trees, the shade tolerance and other requirements of the companion crops, as well as space required for equipment access. Spacing of 5 m × 5 m (16.4 ft × 16.4 ft) may be considered generally appropriate for most situations.

MARKETS

Local markets

Pods and leaves are suited for local markets where South and Southeast Asian foods are sold. Current markets in Hawai'i and other American-affiliated Pacific islands are relatively small and generally met by current production.

Important new potential markets include ethnic groups not traditionally using the crop, restaurants, and health food stores.

Export markets

Leaves, medicinal, and value-added products have potential for shipment to North America and Asia. Data are not available. Fruits are not shipped to the continental U.S. because of pest concerns.

Specialty markets

Given the increased awareness of the high nutritional value of Moringa, health food stores may be the most receptive new market in the short term. Moringa is relatively easy to grow organically and organic certification may increase consumer appeal.

Based on superfood trends, producers of processed juices and smoothies may also be a potential high-value market for moringa growers.

Branding possibilities

As for almost any versatile crop, new product markets can be developed. Here are some ideas for moringa products.

- "Hawaiian Drumstick" brand moringa powder
- Organic Hawaiian Cooking oil: "Better than olive the others"
- "Tropic Passion" scented massage oil
- "Malunggai Energy" smoothies and drinks.

Potential for Internet sales

Strong potential for Internet sales exists, particularly for oil and supplements because of product stability and established or emerging markets. "Organic, Hawaiian grown" would be expected to have additional strong appeal.

EXAMPLE SUCCESSES

Domingo/Edra Farms, Waianae, O'ahu.

Vicky Domingo has been growing moringa for many years and has selected her own variety for long pods and superior leaf production. She has been successful in selling pods and leaf at traditional local markets, and has in recent years worked tirelessly to increase awareness of moringa among non-traditional consumers. She has appeared on television and the Internet promoting moringa as a healthful, local product.

Vicky Domingo of Domingo/Edra Farms shows off the long pods of her improved moringa variety.

Fat Law Farms, Kunia, O'ahu.

This family of Laotian immigrants began farming in Hawai'i in 1986. They grow moringa leaf primarily for export by the container load to Canada, and also buy moringa from other Hawai'i growers to meet international demand for moringa leaf.

Tim Law of Fat Law Farms examines moringa leaf for export.

ECONOMIC ANALYSIS

Costs vary with location, and would be expected to be comparable or lower to other crops for vegetable production in the first year of establishment, depending on intensity of management. This cost is estimated at less than $12,250/ha ($5,000/ac), not including operating overhead. For examples of production costs for a wide range of crops, see <http://www.ctahr.hawaii.edu/ocs/CoP_spreadsheets.html>.

Costs are expected to be somewhat lower in subsequent years because of the perennial nature of the crop, i.e., costs associated with planting and establishment are not reoccurring. Costs may be further reduced by direct seeding, eliminating the need for a nursery, containers, and media.

For oil production, costs can be quite high because of the relatively low yield of oil per acre (See "Yields" above). At an estimated yield of 250 liters/ha (106 qt/ac), costs of production may be as high as $49/liter ($46/qt). A commercial project in Malawi estimated cost to extract oil to be US$2.60–6.00/kg ($1.20–2.70/lb) oil (de Saint Sauveur, 2001). As with all other crops, labor costs put Hawai'i at a disadvantage compared to most other tropical locations. Internet retail prices for moringa oil range $30–$120/liter, depending on quantity purchased. In order for oil production to be viable, the highest pod yielding varieties must be used. Planting of seed and harvesting should be mechanized to reduce labor costs, pressing procedures should be optimized to increase oil yield from kernels and marketing must be done at higher end markets such as restaurants, health food stores, etc.

Expected income per plant

At current market prices on O'ahu, the maximum gross income per year for fresh product in Hawai'i is estimated to be $41 per tree:

- $19/tree/year for pod production assuming a price of $1 for 12 pods, and 230 pods/tree/year.
- $22/tree/year for fresh leaf production assuming $4.50/kg ($2.00/lb) and 5 kg (2.3 lb) of fresh leaf/tree/year.
- Oil production would gross a maximum of $18/tree/year assuming 150 ml of oil per tree per year and $120/L ($114/qt). Oil production excludes pod and leaf production.

Moringa products, particularly the pods, may be retailed at higher prices if marketed in certain venues as exotic, nutrient dense vegetables.

FURTHER RESEARCH

Potential for crop improvement

There are good opportunities for further genetic improvement through continued selection and hybridization. Particular traits of interest include cluster bearing habit (5–6 pods per inflorescence), dwarf plant stature, and improved tolerance to adverse conditions.

Improving potential for family or community farming

Community education about moringa's valuable products should be carried out, especially for import replacement (e.g., leafy greens and oil).

Genetic resources where collections exist

Collections exist around the world, including:

- The World Vegetable Research and Development Center (Taiwan)
- Tamil Nadu Agricultural University (India)
- ECHO (North Fort Meyers, Florida)

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OTHER RESOURCES

Internet

The MoringaNews Network, a rich source of informaton. http://www.moringanews.org/moringa_en.html

Trees for Life promotes moringa and other useful trees. http://www.treesforlife.org

Sundhara and Komet oil expellers: http://www.jatropha.de/expellers

The National Sustainable Agriculture Information Service (ATTRA) provides a useful guide on small-scale oil production: http://attra.ncat.org/attra-pub/oilseed.html

Specialty Crops for Pacific Island Agroforestry (http://agroforestry.net/scps)

Farm and Forestry Production and Marketing profile for Moringa (*Moringa oleifera*)

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